Public Health Assessment for

Lincoln Park Superfund Site
And Associated Activities at the
Cotter Corporation Uranium Mill
Cañon City, Fremont County, Colorado

EPA FACILITY ID: COD042167858

SEPTEMBER 22, 2014

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. The revised document was released for a 60-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Agency for Toxic Substances & Disease Registry .... Thomas R. Frieden, M.D., M.P.H., Administrator
Robin Ikeda, M.D., M.P.H. Director (Acting)

Division of Community Health Investigations…….. Tina Forrester, Ph.D., Director (Acting)
(Vacant) Deputy Director

Central Branch.………………………………………………………Richard E. Gillig, M.C.P., Chief

Eastern Branch ……………………………………………………...Sharon Williams-Fleetwood, Ph.D., Chief

Western Branch ……………….. Cassandra Smith, B.S., M.S., Chief

Science Support Branch ……….. Susan Moore, M.S., Chief

Additional copies of this report are available from:

Agency for Toxic Substances and Disease Registry
Attn: Records Center
1600 Clifton Road, N.E., MS F-09
Atlanta, Georgia 30333

You May Contact ATSDR Toll Free at
1-800-CDC-INFO
or
Visit our Home Page at: http://www.atsdr.cdc.gov

PUBLIC HEALTH ASSESSMENT

Lincoln Park Superfund Site
And Associated Activities at the
Cotter Corporation Uranium Mill
Cañon City, Fremont County, Colorado

EPA FACILITY ID: COD042167858

Prepared by:

Eastern Branch
Division of Community Health Investigations
Agency for Toxic Substances and Disease Registry

Foreword

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as the Superfund law. This law set up a fund to identify and clean up hazardous waste sites. The Environmental Protection Agency (EPA) and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites proposed for or on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment process allows ATSDR scientists and public health assessment cooperative agreement partners flexibility in document format when presenting findings about the public health impact of hazardous waste sites. The flexible format allows health assessors to convey to affected populations important public health messages in a clear and expeditious way.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high-risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to evaluate possible the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals, and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the public comments that relate to the document are addressed in the final version of the report.

Conclusions: The report presents conclusions about the public health threat posed by a site. Ways to stop or reduce exposure will then be recommended in the public health action plan. ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA or other responsible parties. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also recommend health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Table of Contents

Acronyms and Abbeviations

CCAT	Colorado Citizens Against Toxic Waste
CDPHE	Colorado Department of Public Health and Environment
CREG	cancer risk evaluation guide
CV	comparison value
D	dissolved
EMEG	environmental media evaluation guide
EPA	US Environmental Protection Agency
LOAEL	Lowest observed adverse effect level
LPWUS	Lincoln Park Water Use Survey
LTHA	lifetime health advisory for drinking water
MCL	maximum contaminant level
mg/L	milligrams per liter
MRL	ATSDR Minimal Risk Level
µR/hr	microroentgen per hour
N	not defined in the CDPHE database
NA	not available
ND	not detected
NOAEL	No observed adverse effect level
NPL	National Priorities List
OU	operable units
pCi/g	picocuries per gram
pCi/L	picocuries per liter
ppm	parts per million
RAP	Remedial Action Plan
RBC	risk based concentration
RfD	EPA Reference Dose
RMEG	reference dose media evaluation guide
S	suspended
SCS	Soil Conservation Service
SSL	soil screening level
T	total
UMTRCA	1978 Uranium Mill Tailings Radiation Control Act
USGS	United States Geological Survey

I. SUMMARY

Introduction

ATSDR's top priority is to ensure that the community of Lincoln Park and surrounding communities have the best information possible to safeguard their health.

The purpose of this public health assessment (PHA) is to evaluate available data and information on the release of hazardous substances from the Cotter Uranium Mill and other potential sources to determine if people could be harmed by coming into contact with those substances. This PHA evaluates environmental sampling data collected from air, soil, water, biota (fruits and vegetables), and sediment near the Cotter Uranium Mill and surrounding communities. This PHA lists actions, as needed, to be taken to protect the public's health.

The public comment version of this PHA was released in September 2010. ATSDR received numerous comments from the public and other third parties. Comments are addressed in Appendix E in this document.

Background

The Cotter Uranium Mill (Cotter) is located approximately two miles south of downtown Cañon City in Fremont County, Colorado. The Shadow Hills Golf and Country Club borders the Cotter Mill to the northwest, the community of Lincoln Park borders the facility to the north and the housing developments of Shadow Hills Estates, Dawson Ranch, Wolf Park, and Eagle Heights are located along Cotter's northern and western boundaries. The nearest residence is about 0.25 miles from the mill [Galant et al. 2007] and 0.45 miles from the restricted area [ATSDR, 2011].

The approximately 2,600-acre site includes an inactive mill, ore stockpile areas, a partially reclaimed tailings pond disposal area (i.e., the old ponds area), and a current tailings pond disposal area (i.e., the lined "main impoundment area"). A portion of the site is used to store waste products in the impoundment area. The tailings impoundment area is approximately 140 acres. The mill area is fenced and is known as the "restricted area." The restricted area is the area that is regulated under the radioactive materials license (RML). The restricted area is approximately 880 acres, which includes the 140 acres of the tailings impoundments. The mill and associated facilities occupy an area of approximately 82 acres.

The Cotter Mill began operations in 1958, extracting uranium ore using an alkaline leach process. In 1979, the facility switched to an acid leach process for extracting uranium. Cotter suspended primary operations in

1987, and only limited and intermittent processing occurred until the facility resumed operations in 1999 with a modified alkaline-leaching capability until 2000 [EPA 2002]. Uranium-zirconium (UZr) ore was received, pilot and full scale tested from 2000-2002 then calcium fluoride (CaFI) was processed in 2003-2004 [Cotter 2010]. Cotter refabricated the mill circuits between 2002 and 2005 to operate using an acid process when it went into stand down in March 2006. In June 2010, Cotter announced that it will decommission all current operations [CDPHE 2010].

Wastes containing metals and radionuclides were released from Cotter and entered the nearby environment. People could potentially be exposed to these wastes if they come into contact with them. ATSDR evaluated environmental data collected from drinking water, soil, sediment, biota (fruits and vegetables) and ambient air.

Conclusions

After evaluating the available data, ATSDR reached four important conclusions in this public health assessment:

Conclusion 1

ATSDR concludes that drinking water for many years from a private well that contains elevated levels of molybdenum and uranium could harm people's health. ATSDR concludes that drinking water from a contaminated private well is a past, current and potential future public health hazard.

Basis for Conclusion

Private well sampling data collected from 1984 to 2007 revealed the presence of molybdenum and uranium at levels that could harm people's health. People who drank water from private wells impacted by the highest molybdenum contamination are at increased risk for health effects such as gout-like conditions, particularly individuals who do not take in enough dietary copper or cannot process copper correctly. People who drank water from private wells impacted by the highest uranium contamination are at increased risk for kidney damage.

A water use survey was conducted in the Lincoln Park area in 1989. Survey results revealed that seven residences had private wells on their property that were used for personal consumption. Five of the seven wells contained uranium or molybdenum concentrations above the drinking water standards. Between 1989 and 1993, Cotter connected affected private well users to the municipal water supply, although several residents opted to continue using their private wells.

The 1989 water use survey was updated in 2008. Seven wells were identified as being used for personal consumption. One of the seven wells exceeded the drinking water standard for molybdenum. The owner of the well declined to be connected to the municipal water system. Therefore, a completed exposure pathway currently exists for people drinking water from contaminated private wells. Also, the groundwater is still contaminated and the contaminant plume can migrate to previously uncontaminated wells. Therefore, a future potential pathway also exists for private wells until the contamination in cleaned up and no one is drinking contaminated well water.

In November 2008, a notification procedure was established through the auspices of the Colorado State Engineer's Office. Section 37-92 of the Colorado Revised Statute requires permit approval prior to construction of a well. The notification procedure requires that the State Engineer's Office inform well applicants of potential contamination. In June 2010, the Uranium Processing Accountability Act was signed into law. The law requires Cotter to annually notify nearby residents with wells of the potential for contamination from the site.

Next Steps

ATSDR recommends routine monitoring of private wells used for personal consumption until the groundwater reaches remedial goals. ATSDR recommends a sampling plan that allows comparison of results for each well throughout the sampling period, and that the sampling plan include testing for all site-related constituents. ATSDR recommends that officials take appropriate actions if other private wells in the area are impacted by site-related contaminants.

In October 2010, VOC contamination was discovered in groundwater beneath the Cotter Mill. Cotter is currently investigating the nature and extent of this contamination. The Colorado Department of Public Health and Environment (CDPHE) will follow-up on this investigation and make conclusions and recommendations, as appropriate.

Conclusion 2

ATSDR concludes that accidentally ingesting or touching soil or sediment in the Lincoln Park community will not harm people's health. However, there is not enough information for ATSDR to determine if exposures to lead will harm people's health in residential communities immediately northwest of Cotter Mill.

Basis for Conclusion

Soil and sediment in the residential community of Lincoln Park do not contain contamination at levels high enough to harm people's health. Additionally, ATSDR conducted Exposure Investigations (EIs) that focused assessments on 1) blood lead levels in children/residents living in

	Lincoln Park and 2) lead contaminated dust in homes and soil in Lincoln Park. The results of EIs did not indicate the presence of elevated levels of lead in residential indoor dust samples or soil at the sampled homes, or in the blood of occupants of those homes or in tested school children. Soil on the residential properties north and west of Cotter Mill (adjacent to the Shadow Hills Golf and Country Club) is contaminated with high levels of lead. There is not enough information to evaluate whether lead contamination in this residential area will harm people's health. However, since there is no proven safe level of lead in the blood, ATSDR and CDC recommend reducing lead exposure wherever possible.
Next Steps	ATSDR recommends additional sampling for lead in soil in residential yards north and west of the Cotter facility.
Conclusion 3	ATSDR concludes that a person eating an average amount of homegrown fruits and vegetables (defined as approximately 1½ cups per day) will not experience harmful health effects. However, people who eat a lot of fruits and vegetables (defined as approximately 5 cups per day) from their home garden may be at risk from exposure to arsenic. People who eat approximately 5 cups or more per day of arsenic-contaminated homegrown fruits and vegetables may experience harmful health effects.
Basis for Conclusion	Sampled homegrown fruits and vegetables indicate the presence of arsenic at levels that could cause a low increased risk of developing cancer for those who eat more than typical amounts. The risk is based on arsenic exposure to a person eating more fruits and vegetables (95th percentile) than a typical consumer. The cancer estimate is very conservative because it assumes that a person eats 5 cups or more of arsenic-contaminated homegrown fruits and vegetables every day for 30 years. The amount of arsenic-contaminated fruits and vegetables eaten by the average person is much less. As a precaution with any produce, ATSDR recommends that residents thoroughly wash their fruits and vegetables prior to eating them. ATSDR was unable to determine the source of the arsenic found in the fruits and vegetables; it could originate from natural sources.
Next Steps	Because the source(s) of the arsenic in fruits and vegetables could not be determined, ATSDR recommends that residents who have gardens to wash their homegrown produce thoroughly before eating them. This measure is a precaution to remove contaminated soil adhering to the surface of the crop. ATSDR also recommends that residents who have arsenic

contamination in their groundwater to not irrigate their produce with the contaminated water.

ATSDR recommends that residents who have elevated arsenic levels in their soil or irrigation/well to limit their consumption of homegrown fruits and vegetables to no more than 5 cups per day.

Conclusion 4	ATSDR concludes that ambient air emissions of particle bound radionuclides have not resulted in exposures to the public at levels known to cause adverse health outcomes. Outdoor radon concentrations will not harm people's health.
Basis for Conclusion	With the exception of thorium-230 levels observed in 1981 and 1982 that were associated with excavation of contaminated tailings, every radionuclide monitored has been more than a factor of ten below annual dose-based health limits to the public. The excavation releases appear to have only exposed on-site workers, but still below occupational limits at that time.
For More Information	ATSDR's Colorado Cooperative Program and Region 8 Office will provide appropriate follow-up actions at this site. If you have concerns about your health, you should contact your health care provider. You can also call ATSDR at 1-800-CDC-INFO for more information on the Lincoln Park Superfund Site.

II. BACKGROUND

A. Site description and operational history

The Cotter Mill is located approximately two miles south of downtown Cañon City in Fremont County, Colorado (see Figure 1) [Galant et al. 2007]. The Shadow Hills Golf and Country Club borders the Cotter Mill to the northwest, the community of Lincoln Park borders the facility to the north and the housing developments of Shadow Hills Estates, Dawson Ranch, Wolf Park, and Eagle Heights are located along Cotter's northern and western boundaries. The nearest residence is about 0.25 miles from the mill [Galant et al. 2007] and 0.45 miles from the restricted area [ATSDR, 2011].

The approximately 2,600-acre site includes an inactive mill, ore stockpile areas, a partially reclaimed tailings pond disposal area (i.e., the old ponds area), and a current tailings pond disposal area (i.e., the lined "main impoundment area"). The impoundment area (used to store waste products) covers approximately 140 acres of the site. The mill and associated facilities occupy an area of approximately 82 acres. The mill area is fenced and is known as the "restricted area" [Galant et al. 2007]. The restricted area is regulated under the radioactive materials license (RML). The restricted area is approximately 880 acres, which includes the 140 acres of the tailings impoundments. The mill and associated facilities occupy approximately 82 aces [EPA 2002].

The Cotter Mill began operations in 1958, extracting uranium ore using an alkaline leach process. In 1979, the facility switched to an acid leach process for extracting uranium. Cotter suspended primary operations in 1987 [Weston 1998], and only limited and intermittent processing occurred until the facility resumed operations in 1999 with a modified alkaline-leaching capability until 2000 [EPA 2002]. The mill ran a pilot and then a full scale run of Uranium-zirconium (UZr) ore from 2000-2002, then calcium fluoride (CaFl) was processed in 2003-2004 [Cotter 2010]. Cotter refabricated the mill circuits between 2002 and 2005 to operate using an acid process until it went into stand down in March 2006 [Cotter 2007]. In June 2010, Cotter announced that it is decommissioning all processing operations [CDPHE 2010a].

Additional information about the history and licensing of the Cotter Mill is available on the Colorado Department of Public Health and Environment's (CDPHE) and the US Environmental Protection Agency's (EPA) Web sites at http://www.cdphe.state.co.us/hm/cotter/sitedescript.htm and http://www.epa.gov/region8/superfund/co/lincolnpark/.

B. Remedial and regulatory history

Originally, mill tailings (i.e., solid ore processing waste), raffinate (liquid waste that remains after extraction), and other liquids from the alkaline leach process were stored in ten on-site unlined ponds. In 1978, lined impoundment areas were built on site to store process waste products. The main impoundment contained two cells to segregate acid-leach tailings and liquids in the primary impoundment cell from alkaline-leach tailings in the secondary impoundment cell [EPA 2002]. By 1983, more than 2.5 million cubic yards of waste products from historic operations were transferred from the original unlined ponds to the secondary impoundment [Galant et al. 2007]. From inception of the Remedial Action Plan (RAP) until interim closure commenced in 2009, liquid wastes were stored for evaporation in the Secondary Impoundment [Cotter 2010].

According to a signed Memorandum of Agreement, CDPHE is the lead regulatory agency overseeing cleanup at the Cotter Mill.

Because Cotter Mill operations released radionuclides and metals into the environment, soil around the mill and groundwater in the nearby Lincoln Park community were contaminated, primarily with molybdenum and uranium [CDPHE 2008]. In 1984, the Lincoln Park Site was added to the Superfund National Priorities List (NPL) [EPA 2008]. EPA divided the site into two operable units (OUs)—OU1 consists of the on-site contamination and OU2 is the neighborhood of Lincoln Park (i.e., the off-site impacted area) [CDPHE 2008; EPA 2007]. Together, the Lincoln Park Superfund Site and Cotter Uranium Mill encompass about 7.8 square miles (5,000 acres) [EPA 2004].

In 1988, the Cotter Corporation and CDPHE signed a Consent Decree and RAP [Galant et al. 2007]. The purpose of the court-ordered action was to assess and mitigate human and environmental impacts from the Cotter Mill. As part of the settlement, Cotter agreed to clean up the site at the corporation's expense [EPA 2008]. The cleanup was estimated to take 16 years and cost $11 million [Galant et al. 2007]. EPA and the US Department of Energy have also contributed funds for cleanup [DOE 2003]. Remedial activities have focused on eliminating the sources of contamination at the Cotter Mill and eliminating exposures to Lincoln Park residents [CDPHE 2008]. Many of the activities outlined in the 1988 RAP are completed, including the following:

- Connecting Lincoln Park residents to city water;
- Constructing a groundwater barrier at the Soil Conservation Service (SCS) Flood Control Dam to minimize migration of contaminated groundwater into Lincoln Park;
- Moving tailings and contaminated soils into a lined impoundment to eliminate them as a source of contamination; and
- Excavating contaminated stream sediments in Sand Creek.

The old pond area underwent reclamation in 2008 [CDPHE 2010]. Remaining activities include groundwater remediation and final site cleanup [CDPHE 2008; Galant et al. 2007]. In June 2010, Cotter announced their plan to decommission the facility. Cotter has since been involved in various demolition and disposal activities in accordance with their decommission plan.

Groundwater remediation activities have shown some positive results, although restoring groundwater quality has had some setbacks. Many of the remedial measures specified in the Consent Decree have been discontinued (e.g., barrier wall, dam to ditch flushing, calcium-polysulfide fix/flush, and permeable reactive treatment wall) [CDPHE 2008]. Until a solution is agreed upon, contaminated groundwater is captured at the SCS Dam and pumped back to the on-site impoundments [Cotter 2011].

Volatile organic compounds (VOCs) were discovered in the groundwater beneath the Cotter facility during sampling in October 2010. Cotter is investigating the nature and extent of VOC contamination in groundwater at the Cotter Mill and surrounding areas and is seeking to identify the source area [Cotter 2011].

Table 1 below lists a timeline of some of the process events, remedial activities, and government actions for the Lincoln Park Superfund Site. The list does not include all events, activities and actions at the site. More recent events are not included; the goal is to give the reader a general idea of major historical events regarding the site. For more detailed information about site-related activities, the reader is referred to the CDPHE and EPA Web sites at http://www.cdphe.state.co.us/hm/rpcotter.htm and http://www.epa.gov/region8/superfund/co/lincolnpark/, respectively.

Table 1. Lincoln Park Superfund Site Activity Timeline

Date	Type of Event[1]	Event[2]
July 1958	Process	Cotter Corporation began alkali leach process operations (licensing by the Atomic Energy Commission)
June 1965	Event	Flood that caused the unlined tailings ponds at the Cotter Mill to overflow into Lincoln Park
1971	Remediation	SCS Dam completed; water is pumped back to the main impoundment (groundwater barrier completed at a later date after 1988 RAP)
July 1972	Remediation	Pond 2 lined
June 1976	Remediation	Pond 10 lined
1978–1979	Remediation	A new lined impoundment consisting of two cells (primary and secondary) constructed adjacent to the old ponds area for management of wastes from the new mill (alkali process)
1979	Remediation	The old mill was demolished and new mill construction began
1979–present	Remediation	Impounded water at the SCS Dam pumped back to the main impoundment
1979–1998	Process	Operations switched from an alkali leach process to an acid leach mill; continuing operations intermittently
1980	Remediation	Old upstream method tailings ponds replaced by a full-height compacted earth embankment
1980	Remediation	Construction of Well 333 just north of Cotter; well removes contaminated water flowing from the old ponds area
June 1981	Remediation	Pond 3 lined
1981–1983	Remediation	Tailings from the unlined old ponds area (~2.5 million cubic yards) removed and placed in the new impoundment
September 8, 1983	Government Action	Site proposed to be added to the NPL
December 9, 1983	Government Action	State of Colorado files a complaint against Cotter under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
September 21, 1984	Government Action	Cotter (OU1) and Lincoln Park (OU2) added to the NPL.
1985–1986	Investigation	Remedial Investigation and Feasibility Study [GeoTrans 1986]
April 1986	Government Action	Memorandum of Agreement between EPA and the state of Colorado
April 8, 1988	Government Action	Consent decree signed, including a RAP that required cleanup activities
1988	Remediation	An additional 2 feet of soil was removed from the old ponds area and placed in the lined primary impoundment
1988	Remediation	Lined water distribution/surge pond constructed over Pond 7
1988	Remediation	Installation of a hydrologic clay barrier upgradient from the SCS Dam

Date	Type of Event[1]	Event[2]
1989	Remediation	The secondary impoundment cell was covered with liquid for dust control and to create evaporative capacity; additional contaminated soils were removed from the old ponds area and placed in the primary impoundment cell
1989–2000	Remediation	Installation of two hydraulic barriers (injection/withdrawal systems) to control groundwater flow from the old ponds area; discontinued in 2000 because the system was unproductive
1990–1996	Remediation	SCS Dam to DeWeese ditch flushing project
1990–1998	Remediation	Four pilot tests to evaluate the effectiveness of active flushing of vadose zone and aquifer for contaminant removal in OU1
October 29, 1991	Report	Health Risk Assessment of the Cotter Uranium Mill Site: Phase I [HRAP 1991]
January 7, 1993	Report	RAP final report, Willow Lakes (Cotter)
1993–1999	Remediation	Sand Creek Soil Cleanup Action identified and removed approximately 9,000 cubic yards of tailings, soil, and sediment from Sand Creek [Cotter 2000]
1995	Licensing	Cotter filed a license amendment with the state for alkaline leach processing of uranium ore (approved 2/97)
November 19, 1996	Report	Supplemental Human Health Risk Assessment: Phase II Final Report [Weston 1996]
1996–1998	Remediation	Flush/fixation process using Calcium Polysulfide in surface infiltration cells
February 1997	Government Action	Radioactive materials license amendment became effective
1998	Process	Mill reconverted to an alkaline leach process
September 29, 1998	Report	Ecological Risk Assessment, Lincoln Park Superfund Site [Stoller Corporation and Schafer & Associates]
1998	Report	Supplemental Human Health Risk Assessment, Phase III Final Report [Weston 1998]
1999	Remediation	Old ponds area surface soils (~100,000 cubic yards) were removed and placed in the lined primary impoundment
May 1999	Process	Cotter resumed operations (which had been intermittent since 1979) with modified alkaline-leaching capability
September 30, 1999	Investigation	Final Focused Feasibility Study, Lincoln Park
June 2000	Remediation	Installation of a permeable reactive treatment wall across Sand Creek channel, north of SCS Dam in DeWeese Dye Ditch flush (to fulfill EPA requirement to address contaminated groundwater that was bypassing the SCS Dam barrier)
2000–2005	Process	Cotter proposes modifications to the circuit to process zircon ore. Process was not successful and discontinued by 2005.
January 2002	Government Action	EPA issued a Record of Decision for Lincoln Park requiring “No Further Action” for surface soils within Lincoln Park [EPA 2002]
April 2002	Government Action	The governor of Colorado signed House Bill 1408 requiring an Environmental Assessment be conducted before shipping out-of-state radioactive waste to Cotter

Date	Type of Event[1]	Event[2]
July 9, 2002	Government Action	CDPHE denied Cotter's license amendment request, preventing receipt of shipments for direct disposal
September 13, 2002	Government Action	State of Colorado allowed Cotter to receive limited amounts of waste material as a test of its handling/storage capability
2002/2003	Investigation	Sampling for plutonium, uranium, lead and molybdenum in the Canon City vicinity [CDPHE 2003]
January 3, 2003	Government Action	EPA issued a notice of unacceptability under the Off-Site Rule regarding the five Proposed Units and impoundments previously found acceptable
2003	Remediation	Permeable reactive treatment wall not functioning as designed
2003	Government Action	Governor signed HB 1358 that modified HB 1408 to include additional restrictions on disposal of radioactive waste
September 9, 2004	Investigation	Cotter submits Feasibility Study for Old Ponds Area with six alternatives
December 15, 2004	Government Action	State health officials approved a 5-year extension of Cotter's uranium-processing license but denied requests to become a disposal facility for off-site radioactive materials
February 1, 2005	Government Action	Cotter filed a request for a hearing regarding the conditions of the license renewal
October 2005	Investigation	Survey of lead in indoor dust, soils, and blood in Lincoln Park [ATSDR 2006a, 2006b, 2006c, 2006d]
April 2006	Government Action	A judge recommended in CDPHE's favor and Cotter filed an exception on the direct disposal issue only
2006	Remediation	To replace the permeable reactive treatment wall, water building up behind barrier is pumped back to the impoundments
January 2007	Government Action	CDPHE signed a Final Agency Decision, affirming the judge's Decision on the license. Cotter filed an appeal to be able to dispose of out-of-state soils in its primary impoundment.
2007	Government Action	Cotter goes on stand down due to process failures. Processing is not resumed.
2008	Process	Cotter decides not to take the case to the Court of Appeals, effectively ending the licensing issues from the 2004 renewal.
2008	Remediation	The S.M. Stoller Corp performed further cleanup of the Old Ponds Area; relocated ponds and demolished the kiln and feed building
2008	Investigation	Cotter performed Water Use Survey in Lincoln Park
2009	Investigation	Investigation for extent and path of Golf Course groundwater plume
2009	Remediation	Removal of two ore pad and two old mill buildings
February 2009	Report	Lincoln Park WaterSurvey Report 2008 available
June 2010	Process	Cotter announces that it will decommission
2010	Remediation	Cotter continues demolition and disposal activities

Date	Type of Event[1]	Event[2]
October 2010	Investigation	Cotter discovers TCE in groundwater

[1] Describes the general nature of events/actions relating to the Lincoln Park Superfund Site.

[2] Includes events/actions most pertinent to ATSDR's evaluation of exposures and potential health effects. Not all site-related events and reports are included. Please consult CDPHE's or EPA's website for a comprehensive list of activities and events at the site.

C. Demographics

ATSDR examines demographic data to identify sensitive populations, such as young children, the elderly, and women of childbearing age, to determine whether these sensitive populations are potentially exposed to contaminants at levels that may pose a health risk. Demographics also provide details on population mobility and residential history in a particular area. This information helps ATSDR evaluate how long residents may have been exposed to contaminants. According to the 2010 census, 1,170 people live within one mile of the Cotter Mill property—90 of whom are aged 6 years of age or younger, 190 are women of childbearing age (15–44 years of age), and 243 are 65 years of age or older. Census data also show 6,268 people living within two miles of the Cotter Mill property—463 of whom are aged 6 years or younger, 1,113 are women of childbearing age (15-44 years), and 1,242 are 65 years of age or older. Figure 2 in Appendix B shows the demographics within one and two miles of the mill.

A 2000 survey [Cotter 2007] shows Cañon City as the largest population center in Fremont County with 15,760 residents (see Table 2 below). The Cañon City Metro area includes Cañon City, North Cañon, Lincoln Park, Brookside, Prospect Heights, Four Mile Ranch, Shadow Hills, Dawson Ranch, and the Colorado State Correctional Facilities. Florence is the second largest community in the area with a population of 3,816. The unincorporated portions of Fremont County represent 55% of the population and include Lincoln Park, Prospect Heights, and Shadow Hills [Cotter 2007].

Table 2. Population of communities near the Cotter Mill

Community	2000 Census Population	2010 Population Estimate
Brookside	219	218
Cañon City	15,431	15,760
Coal Creek	303	380
Florence	3,653	3,816
Lincoln Park	3,904	Not available
Rockvale	426	432
Williamsburg	714	700
Fremont County	46,145	47,727

Source: Cotter 2007; Galant et al. 2007 ; ATSDR GRASP 2010 US Census

The unincorporated community of Lincoln Park is located in the greater Cañon City area, south of the Arkansas River and north of the Cotter Mill (see Figure 1). The community consists of single and multi-family homes, mobile home parks, and rural single-family homes. Many of the residents are retired and own their homes. The Lincoln Park area is currently experiencing growth [Galant et al. 2007].

The largest employers in Fremont County are the Colorado Department of Corrections and the Federal Bureau of Prisons. Tourism is the second largest employer in the Cañon City area [Cotter 2007; Galant et al. 2007]. Additional industry and manufacturing employers in Fremont County include Portec, Inc.; Holcim, Inc.; Thermal Ceramics; and Cañon Industrial Ceramics [Cotter

2007]. The health care and school systems also employ a substantial number of people in the county [CCAT, personal communication, August 2008].

D. Land use and natural resources

The Cotter Mill is located in an industrial zone. All abutting lands are zoned for agriculture-forestry. The semi-rural community of Lincoln Park is comprised predominantly of residential developments, agricultural plots and orchards, and small livestock grazing parcels. The Shadow Hills Golf Course is located to the north of the Cotter Mill complex. The land to the south and east of the site is largely undeveloped. Recently, several high-end homes have been built near the golf course and in the Wolf Park and Dawson Ranch areas [Galant et al. 2007]. The distance from Cotter Mill's restricted area boundary to the nearest home is about 0.45 miles [ATSDR, 2011].

Fremont County contains a large amount of public land managed by the US Department of the Interior Bureau of Land Management and the US Department of Agriculture Forest Service. Some of these areas are leased for livestock grazing, aggregate mining, and firewood removal. Visiting the many scenic attractions in Colorado's High Country (e.g., the Royal Gorge Bridge) and rafting in the Arkansas River are popular recreational activities [Cotter 2007].

1. Hydrogeology

In the vicinity of the Cotter Mill, contaminated groundwater primarily migrates along the near surface alluvium and fractured, weathered bedrock immediately underlying the alluvium (<100 feet deep) [USGS 1999a]. Groundwater migration is generally in northerly directions from the mill area, along the Sand Creek drainage area, through a gap in Raton Ridge, and into Lincoln Park. However, groundwater contamination has also been found in the vicinity of the Shadow Hills Golf Course, which is west of the Sand Creek drainage area [EPA 2007]. The hydrogeology of the Lincoln Park Superfund Site can be conceptually divided into two areas: the upgradient area near the mill and the downgradient area to the north-northeast in Lincoln Park [USGS 1999a].

- In the upgradient area near the mill, the rate of groundwater flow is limited by small hydraulic conductivities [USGS 1999a]. However, cracks in the bedrock, fractures, and weathering enhance water transmission and allow groundwater to travel at considerable rates. Monitoring wells in the upgradient area, specifically in the Poison Canyon Formation, yield small amounts of water.

- The downgradient area in Lincoln Park is characterized by an "alluvial aquifer" comprised of alluvium and terrace alluvium, to a depth of 0–60 feet, and the underlying weathered and/or fractured bedrock below the alluvium. In this area, groundwater can be transmitted at substantial rates. The mix of gravel, sand, silt, and clay in this aquifer yields 10 to 400 gallons per minute to wells in Lincoln Park. The aquifer discharges to Sand Creek, as well as to multiple springs and seeps as far downgradient as the Arkansas River, approximately 2.5 miles downgradient from the Cotter site.

2. Geology

The Cotter Mill is located in a topographic depression resulting from an underlying structure called the Chandler syncline. The core of the syncline is the Poison Canyon formation, which is the uppermost bedrock unit beneath the site. Soils near the mill are shallow and well drained. The top layer consists of brown loam. The subsoil is a pale brown loam, grading into a yellowish brown sandy loam. Areas north of the mill are covered with Quaternary alluvium consisting of gravel, cobble, boulders, and sand [EPA 2002].

3. Hydrology

The Cotter Mill lies within the Sand Creek watershed [HRAP 1991]. The main hydrologic feature of the Lincoln Park Superfund Site is Sand Creek, a primarily ephemeral creek [EPA 2007]. The creek originates at Dawson Mountain (south of the Cotter Mill), travels north through the Cotter Mill, intersects the DeWeese Dye Ditch, and runs north-northeast through Lincoln Park. It becomes perennial for the last 0.25–0.5 mile before its confluence with the Arkansas River. The DeWeese Dye Ditch is one irrigation ditch that flows between the Cotter Mill and Lincoln Park.

An ephemeral creek has flowing water only during, and for a short duration after, precipitation. A perennial creek has flowing water year-round.

Alluvial material (sediment deposited by flowing water) associated with Sand Creek is the predominant migration pathway for mill-derived contaminants in groundwater. Sand Creek carved a channel into the Vermejo formation at the Raton outcrop near the SCS Dam, which filled with permeable sediments, creating a preferential pathway for alluvial groundwater into Lincoln Park. The alluvial aquifer in Lincoln Park receives recharge from the DeWeese Dye Ditch, Crooked Ditch, Pump Ditch, ditch laterals, and ponds filled by the DeWeese Dye Ditch [EPA 2007].

4. Prevailing Wind Patterns

Cotter's monitoring network includes an on-site meteorological station that continuously measures a standard set of meteorological parameters (e.g., wind speed, wind direction, temperature, and relative humidity). The wind rose in Figure 3 in Appendix B depicts the statistical distribution of measured wind speeds and wind directions. During 2008, wind patterns at the station were principally westerly (i.e., winds out of the southwest to northwest) and accounted for 55% of the total winds [Cotter 2008b]. Easterly winds (i.e., winds out of the southeast to northeast) accounted for a smaller, but still significant, portion (26%) of the observed wind directions. Southerly and northerly winds were much less common. A nearly identical profile was observed in 2007. Other average parameters measured in 2008 follow: air temperature of 53.4 °F; relative humidity of 41%; and rainfall of 5.18 inches.

The prevailing westerly and easterly wind patterns are reasonably consistent with trends in the observed ambient air concentrations of selected site-related pollutants; they were highest at the perimeter monitoring stations directly east and west of the primary operations. A hilly ridge that straddles the western border of the site, blocks much east/west wind flow. However, it should be noted that prevailing wind patterns measured at Cotter Mill might not be representative of surface winds throughout the area, especially considering the proximity of nearby terrain features.

E. Past ATSDR involvement

ATSDR has been involved with the Lincoln Park site since the 1980's. In October 1983, ATSDR completed a Public Health Assessment for the site. After reviewing available groundwater data, ATSDR concluded in 1983 that the potential long-term health effects from consumption of the contaminated water were:

- cancer[1] and kidney damage, from uranium;
- gout-like symptoms, from molybdenum; and
- possibly a group of physiological and psychological symptoms, from selenium.

Numerous questions and concerns have been voiced by Lincoln Park residents about the historical milling and smelting facilities in the Cañon City area. One of the main concerns was about the residual lead contamination from all of the milling and smelting operations. In response, and after a specific request by the EPA, ATSDR evaluated the health risks associated with area lead contamination. ATSDR focused on two primary issues: 1) the blood lead levels of children living in the area and 2) lead contaminated dust in homes in the Lincoln Park area.

In September and October 2005, ATSDR conducted an Exposure Investigation (EI) to answer the questions presented by the community and EPA. After reviewing hospital and state blood lead level data, ATSDR concluded that lead exposures to children represented an indeterminate health hazard because of a lack of available data. ATSDR conducted the EIs to gather data on blood lead levels in the children, and lead in residential soil and indoor dust.

The activities of the EI included:

- Collecting 44 indoor dust samples from 21 homes in Lincoln Park
- Collecting 80 composite soil samples from 22 properties (sampling conducted by EPA)
- Obtaining 45 blood samples from adults and children in 21 households (42 blood samples were analyzed)

After evaluating the results, ATSDR concluded that blood lead levels in adults and children, lead levels in dust in homes, and lead levels in soil did not represent a public health hazard. ATSDR recommended no further actions related to lead in dust in homes, but did recommend routine monitoring of children's blood lead levels in the Lincoln Park area.

In September 2005, ATSDR conducted a blood lead testing program as a service to the community of Lincoln Park. A total of 115 children from a local school were tested for blood

---

[1] Although older evaluations suggested carcinogenicity of uranium among smokers, the U.S. EPA has withdrawn its classification for carcinogenicity for uranium.

lead. None of the children tested had elevated blood lead levels. Therefore, ATSDR concluded that the children tested did not have unusual exposures to lead at the time of testing. ATSDR recommended that local and state agencies continue routine monitoring of blood lead levels in area children.

To get copies of these reports, contact any of the contacts listed at the end of this report, visit our website at www.atsdr.cdc.gov , or call our toll-free hotline at 800-232-4636.

III. EVALUATION OF EXPOSURE PATHWAYS

A. What is meant by exposure?

ATSDR's public health assessments focus on exposure to, or contact with, environmental contaminants. Contaminants released into the environment have the potential to cause harmful health effects. Nevertheless, *a release does not always result in exposure.* People can only be exposed to a contaminant if they come in contact with that contaminant—if they breathe, eat, drink, or come into skin contact with a substance containing the contaminant. If no one is exposed to a contaminant, no health effects could occur. Often the public does not have access to the source area of contamination or areas where contaminants are moving through the environment. This lack of access to these areas becomes important in determining whether people could be exposed to the contaminants.

An exposure pathway has five elements: (1) a source of contamination, (2) an environmental media, (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population. The *source* is the place where the chemical or radioactive material was released. The *environmental media* (such as groundwater, soil, surface water, or air) transport the contaminants. The *point of exposure* is the place where people come into contact with the contaminated media. The *route of exposure* (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body. The people actually exposed are the *receptor population*.

The route of a contaminant's movement is the *pathway*. ATSDR identifies and evaluates exposure pathways by considering how people might come in contact with a contaminant. An exposure pathway could involve air, surface water, groundwater, soil, dust, or even plants and animals. Exposure can occur by breathing, eating, drinking, or by skin contact with the chemical contaminant. ATSDR identifies an exposure pathway as completed, potentially completed,, or eliminates the pathway from further evaluation.

- *Completed exposure pathways* exist for a past, current, or future exposures if contaminant sources can be linked to a receptor population. All five elements of the exposure pathway must be present. In other words, people contact or are likely to come into contact with site-related contamination at a particular exposure point. As stated above, a release of a chemical or radioactive material into the environment does not always result in human exposure. For an exposure to occur, a completed exposure pathway—contact with the contaminant—must exist.

- *Potential exposure pathways* indicate that exposure to a contaminant might have occurred in the past, might be occurring currently, or might occur in the future. It exists when one or more of the elements are missing but available information indicates possible human exposure. A potential exposure pathway is one that ATSDR cannot rule out, even though not all of the five elements are identifiable.

- An *eliminated exposure pathway* exists when one or more of the elements are missing. Exposure pathways can be ruled out if the site characteristics make past, current, and future human exposures extremely unlikely. If people are not exposed to contaminated areas, the pathway is eliminated from further evaluation. Also, an exposure pathway is eliminated if site monitoring reveals that media in accessible areas are not contaminated.

B. How does ATSDR determine which exposure situations to evaluate?

ATSDR scientists evaluate site conditions to determine if people could have been, are being, or could be exposed in the future (i.e., exposed in a past scenario, a current scenario, or a future scenario) to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, sediment, water, air, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation.

If exposure was, is, or could be possible, ATSDR scientists consider whether contamination is present at levels that might adversely affect public health. ATSDR scientists select contaminants for further evaluation by comparing them to comparison values. These are developed by ATSDR from available scientific literature related to exposure and adverse health effects. Comparison values are derived for each of the different media and reflect an estimated contaminant concentration that is *not likely* to cause non-cancer adverse health effects for a given chemical, assuming a certain exposure rate (e.g., an amount of water or soil consumed or an amount of air breathed) and body weight.

Contact with contamination on the Cotter Mill property is eliminated as an exposure pathway of concern. What about past exposure?

Because the mill site is fenced and access is restricted, public exposure to on-site contamination at the Cotter Mill is eliminated. Further, remediation efforts have removed some of the contaminated on-site soil Efforts to reduce off-site contaminant migration include moving millions of cubic yards of tailings and contaminated soils from unlined ponds to lined impoundments [EPA 2002]. In some areas, contaminated soil was removed down to bedrock. In addition, various other process changes reduced the release of contaminated materials [EPA 2002].

Comparison values are not thresholds for adverse health effects. ATSDR comparison values establish contaminant concentrations many times lower than known levels at which “no” or “lowest” effect were observed in experimental animal or human studies. If contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (for example, duration and frequency of exposure), the toxicology of the contaminant, other epidemiology studies, and the scientific weight of evidence for adverse health effects.

Some of the comparison values used by ATSDR scientists include ATSDR’s environmental media evaluation guides (EMEGs), reference dose media evaluation guides (RMEGs), and cancer risk evaluation guides (CREGs) and EPA’s drinking water maximum contaminant levels (MCLs). EMEGs, RMEGs, RfCs, and CREGs are non-enforceable, comparison values developed by ATSDR for screening environmental contamination data to determine if further evaluation is necessary. MCLs are enforceable EPA drinking water regulations and are to be set as close to the maximum contaminant level goals (MCLGs) (Health Goals) as is feasible and are based upon treatment technologies, costs (affordability) and other feasibility factors, such as availability of analytical methods, treatment technology and costs for achieving various levels of removal. Effective May 2008, Colorado established state groundwater standards for uranium and molybdenum.

You can find out more about the ATSDR evaluation process by calling ATSDR's toll-free telephone number, 1-800-CDC-INFO (1-800-232-4636) or reading ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/PHAManual/.

C. If someone is exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects (if any) a person can experience because of contact with a contaminant depend on the exposure concentration (how much), the frequency (how often) and/or duration of exposure (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the exposure to more than one contaminant. Once exposure occurs, a person's characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status influence how the individual absorbs, distributes, metabolizes, and excretes the contaminant. Together, these factors and characteristics determine if adverse health effects that may occur.

In almost every situation, there is considerable uncertainty about the true level of exposure to environmental contamination. To account for this uncertainty and to be protective of public health, ATSDR scientists typically use worst-case exposure level estimates as the basis for determining whether adverse health effects are possible. These estimates are usually much higher than the levels that people are really exposed to. If the exposure levels indicate that adverse health effects may be possible, ATSDR performs more detailed reviews of exposure and reviews the toxicologic and epidemiologic literature for scientific information about the health effects from exposure to hazardous substances.

D. What exposure situations were evaluated for residents living near the Cotter Mill?

ATSDR obtained information to support the exposure pathway analysis for the Lincoln Park Superfund Site from multiple site investigation reports; state, local, and facility documents; and information from communication with local and state officials. The analysis also draws from available environmental data for groundwater, soil, surface water and sediment, and biota. Throughout this process, ATSDR examined concerns expressed by the community to ensure exposures of special concern have been adequately addressed. ATSDR identified the following exposure pathways for further evaluation:

1. Exposure to site-related contaminants in potable private wells in Lincoln Park,

2. Contact with site-related contaminants in soil adjacent to the Cotter Mill and in Lincoln Park,

3. Contact with site-related contaminants in surface water downstream from the Cotter Mill,

4. Exposure from eating locally-grown produce in Lincoln Park,

5. Exposure to site-related soil contaminants in windborne dust, and

6. Exposure to air emission sources (stacks and uncontrolled fugitive dust).

This exposure pathway analysis focuses on possible past, current, and future contaminant exposures for the residents living near the Cotter Mill, with a focus on the community of Lincoln Park. Some evaluation was made of exposures to users of the Shadow Hills Golf Course and along the county road. Table 3 below provides a summary of exposure pathways evaluated in this public health assessment.

1. *Exposure to contaminants in groundwater in Lincoln Park*

a) 1989 Water Use Survey

In the past, a number of residences used wells[2] on their property [GeoTrans 1986] [IMS 1989]. Based on a 1989 water use survey in Lincoln Park, 60 out of 104 wells, springs, and cisterns were used to obtain water for domestic purposes, including consumption and irrigation IMS 1989 See Table 14 in Appendix A for the reported groundwater uses in the Lincoln Park area. Seven survey respondents indicated that they used groundwater for domestic consumption, accounting for 5 to 100% of their total water consumption. Based on the survey, five residents had private wells that had elevated uranium or molybdemum concentrations; these residents were connected to the municipal water supply between 1989 and 1993 [EPA 2002]. The 1988 RAP requires Cotter to connect eligible affected users with legal water rights for a well to the town water supply [CDPHE 2005]. Cotter checks the State of Colorado's Engineer's Office database for new water permits and reports their findings semiannually and in their annual ALARA reports [Pat Smith, EPA Region 8, personal communication, August 2008].

While the majority of town residents are now connected to the public water supply [Galant et al. 2007], several residences opted to continue using their private wells. A 2005 summary of the RAP status reports that some residents chose not to connect to the public water supply [CDPHE 2005]. Additionally, no formal institutional controls existed at the time to control groundwater use in Lincoln Park [EPA 2007]. The United States Geological Survey (USGS) reports that existing private wells are used primarily for stock watering and irrigation [USGS 1999a]. However, a newspaper article reports that at least one residence, located on Grand Avenue in Lincoln Park, used private well water for consumption as recently as 2002 [Plasket 2002]. Based on a 2007 review of Colorado State well permits for residences in the plume configuration, at least one well is permitted for irrigation and domestic use, but no details of actual use are documented [EA 2007]. On properties that continue to use private wells, new purchasers are offered connection to the town's municipal water system [Galant et al. 2007].

> The past use of private groundwater wells was a completed exposure pathway. Most residences are now connected to the public water supply. The current and future use of private wells is a completed and a potentially exposure pathway, respectively, because some residents continue to use contaminated private wells for personal consumption. Additionally, the recent discovery of VOCs in groundwater is considered a potential exposure pathway via vapor intrusion until the nature and extent to which wells are impacted is known.

b) 2008 Water Use Survey

---

[2] The term "well" is used to represent all groundwater sources, and includes both wells and springs.

In 2008, Cotter Corporation updated the 1989 Lincoln Park Water Use Survey in accordance with the site RAP and the requirements of the *EPA First Five-Year Review for the Lincoln Park Superfund Site Operable Unit, (OU2), Fremont County Colorado, September 2007, U.S. Environmental Protection Agency, Region 8 Denver, Colorado*. Well water samples were also collected and analyzed. ATSDR reviewed the updated water use survey, which was available in February 2009.

The objective of the 2008 water use survey was to identify wells used for personal consumption (e.g., drinking water supply) in the area potentially impacted by the uranium and molybdenum plume. The 2008 study area was larger than the 1989 study area, extending in all directions but particularly one block north of Colorado Avenue (the 1989 boundary) to Sherman Avenue.

For the *2008 Lincoln Park Water Use Survey*, four hundred thirty two (432) residents (out of mailings to 802 physical addresses and 209 absentee owners) responded. The survey identified 82 viable wells and/or springs in the Lincoln Park study area (an additional dry well was also identified). Of these 82 wells, seven are used for personal consumption; the usage of the remaining wells is limited to irrigation and livestock. According to the 2008 survey, one well out of seven being used for personal consumption exceeded the drinking water standard for molybdenum. The resident was provided the sampling result; however, the resident declined connection to the municipal water system, preferring to continue to use the well water for personal consumption.

In November 2008, an institutional control was established through the auspices of the Colorado State Engineer's Office. Section 37-92 of the Colorado Revised Statute requires permit approval prior to construction of a well. The notification procedure requires that the State Engineer's Office inform well applicants of potential contamination. In June 2010, the Uranium Processing Accountability Act was signed into law. The law requires Cotter to annually notify nearby residents with wells of the potential for contamination from the site. The PHA conclusions and recommendations relevant to this information have been revised since the public comment version was released to reflect these new requirements.

c) VOCs in groundwater

In October 2010, Cotter discovered elevated concentrations of trichloroethane (TCE), a volatile organic compound (VOC), in groundwater beneath the property [Cotter, 2011]. The highest TCE concentration was 1,800 ppb, which exceeds EPA's Maximum Contaminant Level (MCL) of 5 ppb. Cotter will be conducting further investigations to determine the nature and extent of VOC contamination in the area. Because TCE is a VOC, it can readily evaporate at room temperature, including out of groundwater and into aboveground living spaces. For this reason, ATSDR has identified VOCs in groundwater as a potential exposure pathway until further information is known.

ATSDR's Colorado Cooperative Program will review the additional groundwater data that is being collected by Cotter for the Hazardous Materials and Waste Management Division of the CDPHE in order to define the extent of TCE on- and off-site. To date, TCE has been detected in four on-site wells. The additional data will be reviewed to evaluate whether there are potential receptors to TCE via the vapor intrusion pathway. When the additional data becomes available, the Colorado Cooperative Program will initiate the appropriate follow-up action(s) from the public health perspective.

2. Contact with contaminated soil adjacent to the Cotter Mill and in Lincoln Park

People (especially children) might accidentally ingest soil or exposed sediment, and dust generated from these materials, during normal activities. Everyone ingests some soil or dust every day. Small children (especially those of preschool age) tend to swallow more soil or dust than any other age group because children of this age tend to have more contact with soil through play activities and have a tendency for more hand-to-mouth activity. Children in elementary school, teenagers, and adults swallow much smaller amounts of soil or dust. The amount of grass, mulch, or vegetation in an area, the amount of time spent outdoors, and weather conditions also influence how much contact people have with soil.

a) Contact with soil near the Cotter Mill

Soils adjacent to the Cotter Mill have been contaminated by wind-blown particulates [CDPHE 2005]. Elevated levels of contaminants are primarily detected in soils directly east and west of the facility [Weston 1998]. This distribution of contaminated soils is consistent with wind patterns in the area, which blow mainly from west to east with occasional flows from east to west. The primarily vacant areas directly east and west of the facility are referred to as a "buffer zone" between the Cotter Mill and residential developments [EPA 2002]. Therefore, limited opportunities for exposure to impacted site-adjacent soils exist—people are not expected to be in this area on a daily basis or for extended periods of time. However, residential properties are located north and west of the mill; the nearest home is approximately 0.45 miles north of the restricted area. Exposure to potentially impacted soil at the Shadow Hills Golf Course, a public golf course located immediately north of the Cotter mill complex, is unlikely due to grass cover. Golfers may contact bare soils in the rough while retrieving balls, but this contact is likely to be short and intermittent.

Contact with contaminated soil near the Cotter Mill (i.e., in the buffer zone) is **a past, current, and future potential exposure pathway**.

For nearly 50 years, Cotter has intermittently hauled materials by truck, possibly losing some materials along the county road leading to the facility and along the access road entering the mill site [MFG 2005]. The public could be exposed to potentially impacted soils along the county road. However, there is limited potential for exposure to contaminants along the access road, since access to the Cotter Mill is restricted and Cotter remediated soil along the access road in 2007 and 2008.

b) Contact with soil and sediment in the community of Lincoln Park

The community of Lincoln Park is located approximately 1.5 miles north-northeast of the restricted area of the Cotter Mill. Contaminated materials from the Cotter Mill may have contributed to soil contamination in Lincoln Park in two ways:

1. Dust from soil or tailings associated with site operations could be transported by wind to Lincoln Park. However, wind patterns in the area suggest that wind-blown contamination is not likely a considerable source of soil contamination in Lincoln Park [Weston 1998]. Additionally, on-site remediation at the Cotter Mill substantially reduced the sources of soil contamination.

2. Potentially impacted groundwater used for irrigation could lead to the accumulation of contaminants in town soils [Weston 1998].

Contact with contaminated sediment in Sand Creek was a past potential exposure pathway. Due to the remediation of Sand Creek, current and future contact is an eliminated exposure pathway.

Further, in the past, contaminated surface water runoff from the Cotter Mill entered Sand Creek, where it was transported downstream toward Lincoln Park [EPA 2002]. However, Sand Creek is not believed to be used for recreational activities—the creek is ephemeral and on private land until it goes under the river walk and enters the Arkansas River [Phil Stoffey, CDPHE, personal communication, June 2007].

Contact with soil in Lincoln Park was a past completed exposure pathway. Cotter has performed all required off-site soil cleanup activities, as outlined in the RAP [EPA 2002]. CDPHE reports that the Cotter Mill poses no risk to the residents of Lincoln Park by exposure to soil [Weston 1998], and EPA and CDPHE have advised “No Further Action” in regards to Lincoln Park soils [EPA 2002]. EPA’s Record of Decision states that surface-soil cleanup activities have eliminated or reduced risks to “acceptable” levels [EPA 2002, 2007]. However, surface soil cannot be eliminated as a potential current or future exposure pathway because 1) remediation has not occurred in residential areas and 2) not all on-site and off-site sources of contamination have been eliminated.

3. Contact with surface water downstream from the Cotter Mill

Contact with contaminated surface water near the Cotter Mill was a past potential exposure pathway. Due to the construction of the SCS Dam and the remediation of Sand Creek, current and future contact is an eliminated exposure pathway.

In the past, people could have come in contact with contamination in surface water during recreational activities. The Arkansas River is used primarily for fishing and boating or rafting, as well as some swimming [Phil Stoffey, CDPHE, personal communication, June 2007]. Sand Creek is on private land until it goes under the river walk and enters the Arkansas River. It is generally not used for recreational activities [Phil Stoffey, CDPHE, personal communication, June 2007].

4. Exposure from eating locally grown produce

Many Lincoln Park residents have orchards and gardens. Water from the DeWeese Dye Ditch, which is not known to be contaminated, is primarily used to irrigate the orchards and gardens. However, some residents use water from their groundwater wells [Galant 2007; IMS 1989]. If fruits and vegetables are grown in contaminated soil and/or irrigated with contaminated water, the people who eat this produce could be exposed to contaminants.

5. Exposure from breathing airborne dust

Many Lincoln Park residents are concerned about the arid environment and the risks of breathing in contaminated dust from the site. The profile of air emission sources at Cotter Mill has changed considerably over the years. These sources include both releases through stacks and uncontrolled (or fugitive) dust emissions. Stack emissions occurred during times of active processing at Cotter Mill; however, the magnitude of these stack emissions has varied, depending on production rates and effectiveness of air pollution controls. The sources of fugitive dust emissions have also changed. In the past, the site had many uncontrolled sources of wind-blown dust, which would cause particulate matter (along with any chemical and radiological constituents) to be emitted into the air. Examples of these sources include ore handling operations, stockpiles, and the previous unlined holding ponds. Many of these sources of wind-blown dust have since been controlled or eliminated, causing facility-wide fugitive dust emissions to decrease considerably over the years, though some fugitive dust emissions (e.g., from unpaved roads) continue to occur.

Table 3. Exposure pathways for residents living near the Cotter Mill

Exposure Pathway	Exposure Pathway Elements					Time Frame	Comments
	Sources of Contamination	Fate and Transport	Point of Exposure	Exposed Population	Route of Exposure		
Groundwater							
Completed Exposure Pathway							
Private groundwater wells	Tailings and other wastes from the Cotter Mill (heavy metals and radionuclides)	Migration of groundwater into the Lincoln Park area	Residential tap water drawn from private wells; crops and livestock irrigated using contaminated well	Residents, including children, who are not connected to the public water supply and rely on private wells;	Ingestion, Dermal contact	Past	Past consumption of groundwater from contaminated private wells has been documented and was, therefore, a completed exposure pathway.
Potential Exposure Pathway							
Private groundwater wells	Tailings and other wastes from the Cotter Mill (heavy metals and radionuclides)	Migration of contaminated groundwater into the Lincoln Park area; migration of vapors (volatile organic compounds) from groundwater to indoor air(subsurface vapor intrusion)	Residential tap water drawn from private wells; indoor air in above-ground structures over the plume	Residents, including children, who are not connected to the public water supply and rely on private wells; residents in homes above the groundwater plume	Ingestion, Dermal contact, Inhalation	Current Future	Most residents are supplied with town water. According to the 2008 water use survey, only one of 7 wells used for personal consumption exceeded the drinking water standard for molybdenum; none exceeded the drinking water standard for uranium. The discovery of VOCs in groundwater beneath the mill presents a potential inhalation exposure pathway via vapor intrusion. Also, current and future use of water from private wells is a potential ingestion and inhalation exposure pathway.

Exposure Pathway	Exposure Pathway Elements					Time Frame	Comments
	Sources of Contamination	Fate and Transport	Point of Exposure	Exposed Population	Route of Exposure		
Soil and Sediment							
Completed Exposure Pathway							
Surface soil and dust in Lincoln Park	Tailings, dusts, and other wastes from the Cotter Mill	Windblown dust; soil irrigated by contaminated groundwater	Residences and public areas	Residents, including children	Dermal contact, Incidental ingestion, Inhalation	Past	Contaminants were detected in soil from residential lawns and gardens. Therefore, contact with contaminated soil in Lincoln Park is a past completed exposure pathway.
Potential Exposure Pathways							
Surface soil and dust in Lincoln Park	Tailings, dusts, and other wastes from the Cotter Mill	Windblown dust; soil irrigated with contaminated groundwater	Residences and public areas	Residents, including children	Dermal contact, Incidental ingestion, Inhalation	Current Future	Contaminants were detected in soil from residential lawns and gardens. Until all source areas are eliminated and site-related work ceases, this remains a current and future potential exposure pathway.
Sediment in Sand Creek	Tailings, dusts, and other wastes from the Cotter Mill	Tailings carried in surface water runoff	Along Sand Creek	Recreational users; children playing along Sand Creek	Dermal contact, Incidental ingestion	Past	There were limited opportunities for exposure since Sand Creek was not used for recreational purposes. Therefore, exposure to sediments prior to the Sand Creek Cleanup project was a past potential exposure pathway.
Eliminated Exposure Pathways							
Surface soil at the Cotter Mill	Tailings, dusts, and other wastes from the Cotter Mill	Windblown dust; surface water runoff	Unauthorized access is not allowed	None	None	Past Current Future	Because the mill site itself is fenced and access is restricted, contact with on-site contamination is an eliminated exposure pathway. Further, remediation efforts have removed some impacted soils.

Exposure Pathway	Exposure Pathway Elements					Time Frame	Comments
	Sources of Contamination	Fate and Transport	Point of Exposure	Exposed Population	Route of Exposure		
Sediment in Sand Creek	Tailings, dusts, and other wastes from the Cotter Mill	Tailings carried in surface water runoff	Contaminated sediment was removed from Sand Creek	None	None	Current Future	Sediment in Sand Creek is no longer a hazard since the completion of the Sand Creek Cleanup project. Therefore, current and future contact with sediment in Sand Creek is an eliminated exposure pathway.
Surface Water							
Potential Exposure Pathway							
Surface water near the Cotter Mill	Tailings and other waste from the Cotter Mill	Surface water runoff; transport from Sand Creek to the Arkansas River	Along Sand Creek between the Cotter Mill and the Arkansas River; the Arkansas River	Recreational users (mostly in the Arkansas River, limited recreational use in Sand Creek	Incidental ingestion, Dermal contact	Past	In the past, surface water in Sand Creek was found to contain elevated levels of metals and radionuclides. Therefore, past contact with contaminated surface water near the Cotter Mill was a potential exposure pathway.
Eliminated Exposure Pathway							
Surface water near the Cotter Mill	Tailings and other waste from the Cotter Mill	Surface-water runoff; transport from Sand Creek to the Arkansas River	Contamination was removed from Sand Creek	None	None	Current Future	Due to the construction of the SCS Dam and the remediation of Sand Creek, current and future contact with contaminated surface water is an eliminated exposure pathway.

<table>
<tr><th rowspan="2">Exposure Pathway</th><th colspan="5">Exposure Pathway Elements</th><th rowspan="2">Time Frame</th><th rowspan="2">Comments</th></tr>
<tr><th>Sources of Contamination</th><th>Fate and Transport</th><th>Point of Exposure</th><th>Exposed Population</th><th>Route of Exposure</th></tr>
<tr><td colspan="8">Locally Grown Produce</td></tr>
<tr><td colspan="8"><i>Potential Exposure Pathway</i></td></tr>
<tr><td>Produce grown in Lincoln Park</td><td>Tailings, dusts, and other wastes from the Cotter Mill</td><td>Produce grown in contaminated soil or irrigated with contaminated water</td><td>Orchards and gardens in Lincoln Park</td><td>People who eat locally grown produce</td><td>Ingestion</td><td>Past
Current
Future</td><td>Because many Lincoln Park residents have orchards and gardens, eating locally grown produce is a past, current, and future potential exposure pathway.</td></tr>
<tr><td colspan="8">Air Emissions</td></tr>
<tr><td colspan="8"><i>Completed Exposure Pathway</i></td></tr>
<tr><td>Ambient air near the Cotter Mill facility</td><td>Ground-level fugitive emissions (e.g., wind-blown dust) and elevated point sources (e.g., stacks)</td><td>Windblown dust; stack emissions into the air and transport to off-site locations</td><td>Off-site or down-wind locations</td><td>People who live in the vicinity of Cotter Mill or downwind of the stacks</td><td>Inhalation</td><td>Past
Future
Present</td><td>Cotter’s air monitoring network monitors air concentrations at off-site locations. With the facility currently in “stand down” status, facility emissions are now predominantly fugitive; air quality impacts should be characterized by perimeter monitoring stations.</td></tr>
</table>

IV. EVALUATION OF ENVIRONMENTAL CONTAMINATION

A. Groundwater

Prior to 1980, Cotter disposed of waste in unlined ponds, which allowed contaminated liquids to leach into the groundwater [EPA 2002]. Groundwater was shown to be contaminated as far away as the Arkansas River, which is approximately 2.5 miles downgradient from the mill [EPA 2002]. Results from the 1984–1985 Remedial Investigation found that despite remediation attempts, the new lined impoundments were leaking and the old ponds area was a continuing source of groundwater contamination [GeoTrans 1986]. This study also found that a gap in the ridge at the SCS Dam, built in 1971 across Sand Creek on the Cotter property, was allowing shallow groundwater to move downgradient towards Lincoln Park. This resulted in concentrations of molybdenum and uranium that were 2,000 times above background levels at that time.

Groundwater concentrations of molybdenum and uranium have decreased in recent years, but concentrations have not yet returned to background levels in some wells [Weston 1998]. Figures 4 and 5 in Appendix B show the extent of the molybdenum and uranium concentrations, respectively, above water quality standards (0.035 milligrams per liter [mg/L] for molybdenum and 0.03 mg/L for uranium)[3]. Historically, the highest levels in Lincoln Park were detected nearest to the Cotter property in the vicinity of the DeWeese Dye Ditch [Weston 1998]. Despite remediation efforts, the physical groundwater data suggest a continuing minor leakage from the primary impoundment at the Cotter site [CDPHE 2007a; EPA 2002; USGS 1999b].

1. Remedial actions for controlling groundwater contamination

Since the early- to mid-1980s, remedial actions have been aimed at controlling groundwater contamination and the spread of the resulting plume. Remediation has targeted the area along the primary groundwater migration pathway, which runs parallel to Sand Creek [USGS 1999a]. Remediation has included the following:

- In the early 1980s, contaminated materials were moved into lined impoundments [EPA 2002].
- In 1988, a hydrologic clay barrier was installed on the Cotter property to help contain the contaminated groundwater plume associated with the Cotter Mill.
- In 1989, a network of injection and withdrawal wells was constructed downgradient of the lined impoundment to reverse the hydraulic gradient and prevent the northward migration of contaminated groundwater. This system was discontinued in 2000; the system had little or no discernable effect on groundwater conditions [CDPHE 2005].
- Dam to ditch flushing began in 1990. However, this effort was discontinued in 1996 due to citizens' concerns about contaminant concentrations rising in groundwater wells as the plume was being flushed [CDPHE 2005].

---

[3] Compliance goals for uranium and molybdenum during the RAP were 35 and 100 ppb, respectively. Prior to June 2008, there were no state groundwater standards for uranium or molybdenum.

- In 2000, a permeable reactive treatment wall was constructed across Sand Creek channel in the DeWeese Dye Ditch flush, downstream of the SCS Dam [EPA 2002]. Although the permeable reactive treatment wall has not performed as anticipated, it is acting as a barrier to additional groundwater flowing into Lincoln Park [Phil Egidi, CDPHE, personal communication, July 2008].

These efforts have reduced groundwater contamination downgradient of the Cotter Mill [CDPHE 2008; EPA 2002; USGS 1999a]. The rate at which groundwater quality is being restored is slower than anticipated [EPA 2007]. Groundwater north and west of the facility, outside the Restricted Area, under the adjacent Shadow Hills Golf Course, is also contaminated [Hydrosolutions 2010]. In October 2010, Cotter discovered elevated concentrations of trichloroethene (TCE), a volatile organic compound (VOC), in groundwater beneath the property [Cotter, 2011].

Cotter and CDPHE continue to explore options for cleaning the groundwater. Until a solution is reached, contaminated groundwater is captured at the SCS Dam and pumped back to the on-site lined impoundments [CDPHE 2008].

2. Nature and extent of groundwater contamination in Lincoln Park

CDPHE maintains a database containing environmental sampling data from various sources dating back to 1961. To evaluate exposures to residents of Lincoln Park, ATSDR identified data within the CDPHE database for the wells reported to be in use during the 1989 water use survey (see Table 14 in Appendix A). After discussions with a CDPHE representative, the following assumptions were made while summarizing the data.

- For chemicals, samples that were designated “Y” in the detect flag column and contained a zero in the result value column, but no value in the reporting detection limit column, were excluded from the summary statistics. For radionuclides, however, these samples were included in the summary statistics since zero is considered a valid result.
- Samples that were designated “N” in the detect flag column and had the same value in the result value column as the reporting detection limit column were included in the summary statistics as ½ the reporting detection limit.
- Negative result values for manganese and iron were assumed to be not detected and were included in the summary statistics as ½ the reporting detection limit.
- Negative values[4] for radionuclides were included in the summary statistics.

a) Wells used for personal consumption

The 1989 *Lincoln Park Water Use Survey* identified seven wells used for personal consumption [~~(~~IMS 1989~~)~~] (see Table 14). Data for six of the wells are available in the CDPHE database. The seventh well had a broken pump at the time of the survey [IMS 1989]; no data for this well

---

[4] Negative values for radionuclides occur when samples are not much different from background, since standard protocol is to subtract background radioactivity from the sample count.

appear to be in the database. The data for wells reportedly used for personal consumption in 1989 are summarized in Table 15. Samples were collected intermittently from 1984 to 2007. The locations of these wells are shown in Figure 6. With the exception of molybdenum and uranium, the data are limited (e.g., only two wells were sampled for the majority of the chemicals and none were sampled for radionuclides). However, all six wells were repeatedly tested for molybdenum and uranium, which were the only chemicals detected above comparison values (see Table 15). Of the personal consumption wells, Well 189 contains the highest molybdenum and uranium concentrations. Well 189 is the only well with levels of uranium consistently detected above the comparison value (see Figure 6).

It is difficult to evaluate the molybdenum and uranium data over time, because of the limited sampling data for these wells and the inconsistency of sampling the same wells. The molybdenum and uranium concentrations in the personal consumption wells over time are graphically shown in Figure 7 and Figure 8 in Appendix B, respectively. Well 168 (house well on Grand Avenue)[5] and Well 189 (house well on Hickory)[6] were sampled the most frequently. No clear pattern of decreasing concentrations from 1984 to 2007 is apparent.

The USGS identified Well 10 (So. 12th St.) and Well 114 (Pine) as representative of background for the Lincoln Park area [Weston 1998]. The data available in the CDPHE database for these two wells are summarized in Table 16.[7] The average concentration of molybdenum in the wells used for personal consumption (0.082 mg/L; see Table 15) is higher than the average concentration found in the background wells (0.023 mg/L; see Table 16). The average uranium concentration in the wells used for personal consumption (0.028 mg/L; see Table 15) is only slightly higher than the average concentration in the background wells (0.021 mg/L; see Table 16).

---

[5] There are five non-detected molybdenum values for Well 168. Four of them are most likely due to the detection limit being too high for the level of molybdenum in that well. The detection limits were 0.01 mg/L for three of the samples and 0.05 mg/L for one of the samples. The concentrations in that well hover around 0.01 mg/L.

[6] One of the non-detected molybdenum concentrations in Well 189 is unexplainable. The detection limit (0.01 mg/L) is low enough to have detected the level of molybdenum typically found in the well. The detection limit (0.5 mg/L) for the other non-detected concentration is too high for the level of molybdenum typically found in the well.

[7] Groundwater samples from the background wells were not tested for radionuclides.

ATSDR reviewed the results of the *2008 Lincoln Park Water Use Survey* after the publication of the public comment document for this site. According to the 2008 survey, one well out of seven being used for personal consumption exceeded the drinking water standard for molybdenum. No tested personal consumption wells exceeded the drinking water standard for uranium

Most of the exposures to contaminated drinking water occurred in the past. Currently, most homes are connected to the municipal water supply. Therefore, our evaluation using data from the 1989 water use survey (using data collected from 1984 to 2007) is still appropriate to define past exposures. Data from the 2008 water use survey can be used to define current and future exposures, but it does not alter conclusions regarding past exposures and health effects. ATSDR will continue to use the results from the 1989 survey when evaluating past exposures.

Currently, one private well exceeds the molybdenum drinking water standard and is being used for personal consumption. ATSDR recommends routine sampling of private wells used for personal consumption to ensure continued compliance with drinking water standards. ATSDR recommends that officials take appropriate actions if other private wells in the area are impacted by site-related contaminants.

The measured concentrations in the 2008 sampling event for all seven personal consumption wells were within the 0.03 mg/L water quality standard for uranium. The measured concentrations in six of the seven wells were within the 0.035 mg/l water quality standard for molybdenum. The seventh well (Well # 198) exceeded the water quality standard for molybdenum. Molybdenum was detected at 0.094 mg/L in Well #198, which is located on Grand Avenue. The resident was provided the sampling result; however, the resident declined connection to the municipal water system, preferring to continue to use the well water for personal consumption.

ATSDR was unable to evaluate private well usage and contaminant concentrations over time because many of the private drinking water wells tested in 1989 were not retested in 2008. One reason for this may be because residents were required to abandon their private drinking water wells as a condition of connecting to the municipal water supply. Of the seven wells identified for personal consumption in 1989, only Well #198 was retested in 2008. This means that six of the seven personal consumption wells in 2008 were not identified in the 1989 survey.

(1) Grand Avenue Well

In a 2002 newspaper article, a resident on Grand Avenue reported drinking water from their well [Plasket 2002]. Limited data (25 samples) are available in the CDPHE database for this location (see Figure 6). Samples were collected and analyzed for most chemicals in 1984, and then from either 2004 or 2005 to 2007. Samples from this well were also tested for molybdenum and uranium from 1988 to1991. The water from this well was tested for several chemicals, but not for radionuclides. None of the samples detected chemicals above comparison values (see Table 17).

b) Wells used to irrigate fruit and vegetable gardens

The 1989 *Lincoln Park Water Use Survey* identified 22 wells used to irrigate fruit and 21 wells used to irrigate vegetable gardens [IMS 1989].[8] Data for 28 of these wells are available in the CDPHE database (see Table 14). Samples were sporadically collected from these wells and analyzed for various chemicals between 1962 and 2007. Samples were collected and analyzed for radionuclides from 1995 to 2000. The data for wells reportedly used to irrigate fruit and vegetable gardens in 1989 are summarized in Table 18 (chemicals) and Table 19 (radionuclides). The locations of these wells are shown in Figure 9. The data for these wells are much more robust than the data available for the wells used for personal consumption, in part due to the increased number of wells. Molybdenum and uranium were sampled in all 28 wells used for irrigation. Five wells were tested for radionuclides.

The maximum contaminant concentrations in the wells used to irrigate fruit and vegetable gardens exceeded the comparison values for molybdenum, selenium, sulfate, total dissolved solids, and uranium. The average concentrations exceeded comparison values only for molybdenum, total dissolved solids, and uranium. Looking at data from 2000 to 2007, only the average molybdenum concentration (0.1 mg/L) continued to exceed the comparison value.

The average concentration of molybdenum in the wells (0.99 mg/L; see Table 18) is higher than the average concentration found in the wells that USGS identified as background for Lincoln Park (0.023 mg/L; see Table 16). Similarly, the average uranium concentration (0.13 mg/L; see Table 13) is higher than the average concentration in the background wells (0.021 mg/L; see Table 16). The average concentration for total dissolved solids (550 mg/L; see Table 18) is also higher than the average concentration found in the background wells (429 mg/L; see Table 16).

c) Wells used to water livestock

The 1989 *Lincoln Park Water Use Survey* identified 22 wells used to water livestock [IMS 1989]. Data for 19 of these wells are available in the CDPHE database (see Table 14). Samples were sporadically collected from these wells and analyzed for various chemicals between 1962 and 2007. Samples were collected and analyzed for radionuclides in 1995 and 1996. The data for wells reportedly used to water livestock in 1989 are summarized in Table 20 (chemicals) and Table 21 (radionuclides). The locations of these wells are shown in Figure 10. Only one to four wells were sampled for the majority of the chemicals, however, molybdenum and uranium were sampled in all 19 wells used to water livestock. Two wells were tested for radionuclides.

The maximum concentrations exceeded the comparison values for molybdenum, sulfate, total dissolved solids, and uranium. The average concentrations only exceeded comparison values for molybdenum and uranium. Looking at data from 2000 to 2007, only the average molybdenum concentration (0.08 mg/L) continued to exceed the comparison value.

The average concentration of molybdenum in the wells used to water livestock (0.212 mg/L; see Table 20) is a factor of ten higher than the average concentration found in the wells that USGS identified as background for Lincoln Park (0.023 mg/L; see Table 16). The average uranium

---

[8] Some wells were used for both purposes.

concentration in the wells used to water livestock (0.034 mg/L; see Table 20) is higher than the average concentration in the background wells (0.021 mg/L; see Table 16).

d) Wells used to water lawns

The 1989 *Lincoln Park Water Use Survey* identified 42 wells used to water lawns [IMS 1989]. Data for all 42 wells are available in the CDPHE database (see Table 14). Samples were sporadically collected from these wells and analyzed for various chemicals between 1962 and 2007. Samples were collected and analyzed for radionuclides from 1995 to 2000. The data for wells reportedly used to water lawns in 1989 are summarized in Table 22 (chemicals) and Table 23 (radionuclides). The locations of these wells are shown in Figure 11. Several wells were sampled for each chemical, and molybdenum and uranium were tested in all 42 wells used to water lawns. Seven wells were sampled for radionuclides.

The maximum concentrations exceeded the comparison values for chloride, molybdenum, selenium, sulfate, total dissolved solids, and uranium. The average concentrations exceeded comparison values for molybdenum, sulfate, total dissolved solids, and uranium. Looking at data from 2000 to 2007, only the average molybdenum concentration (0.1 mg/L) continued to exceed the comparison value from 2000 to 2007, while the average uranium concentration (0.03 mg/L) was at the comparison value.

The average concentration of molybdenum in wells used to water lawns (2.2 mg/L; see Table 22) is two orders of magnitude higher than the average concentration found in the wells that USGS identified as background for Lincoln Park (0.023 mg/L; see Table 16). The average sulfate concentration in wells used to water lawns (351 mg/L; see Table 22) is almost six times higher than the average concentration in the background wells (61 mg/L; see Table 16). The average concentration for total dissolved solids in wells used to water lawns (746 mg/L; see Table 22) is higher than the average concentration found in the background wells (429 mg/L; see Table 16). The average dissolved uranium concentration in wells used to water lawns (0.233 mg/L; see Table 22) is a factor of ten higher than the average concentration in the background wells (0.021 mg/L; see Table 16).

(1) <u>Well 138</u>

Well 138 (field well on Cedar Street; see Figure 11) was identified during the *1998 Supplemental Human Health Risk Assessment* as the maximally impacted off-site well [Weston 1998]. In 1989, Well 138 was used only to water the lawn [IMS 1989]. Adequate data for this well are available in the CDPHE database. Samples were collected from Well 138 and analyzed for various chemicals between 1968 and 2000. Samples were collected and analyzed for radionuclides from 1995 to 2000. The data for Well 138 are summarized in Table 24 (chemicals) and Table 25 (radionuclides).

The maximum concentrations exceeded the comparison values for chloride, molybdenum, selenium, sulfate, total dissolved solids, and uranium. The average concentrations also exceeded comparison values for molybdenum, sulfate, total dissolved solids, and uranium. A clear decrease in concentrations occurred over time for molybdenum (see Figure 12), selenium (see Figure 13), and uranium (see Figure 14).

Well 138 has higher levels of contamination than the wells that USGS identified as background for Lincoln Park. The average concentration of molybdenum in Well 138 (8.0 mg/L; see Table 24) is hundreds of times higher than the average concentration found in the background wells (0.023 mg/L; see Table 16). The average sulfate concentration in Well 138 (1,059 mg/L; see Table 24) is considerably higher than the average concentration in the background wells (61 mg/L; see Table 16). The average concentration for total dissolved solids in Well 138 (1,530 mg/L; see Table 24) is three times higher than the average concentration found in the background wells (429 mg/L; see Table 16). The average dissolved uranium concentration in Well 138 (0.73 mg/L; see Table 24) is more than a factor of ten higher than the average concentration in the background wells (0.021 mg/L; see Table 16).

e) Groundwater trends over time

To evaluate the levels of molybdenum, selenium, and uranium in groundwater over time, ATSDR combined and graphed all the groundwater data for the wells used for personal consumption, irrigating fruit and vegetables, watering livestock, and watering lawns (Figures 15 through 17 in Appendix B). Figure 15 shows a pattern of decreasing concentrations of molybdenum in groundwater over time. The concentrations of selenium seem to hold steady, but do decrease slightly over time (see Figure 16). The concentrations of uranium also decrease over time (see Figure 17).

B. Soil and sediment

1. Background levels

Cotter was required by the 1988 RAP to establish background levels of certain elements in soils and sediments. Twenty soil samples were collected from five sub-basins considered free from mill-related contamination to represent natural background typical of the area near the mill [HRAP 1991]. Table 4 below presents the results of that study, which were further supported by additional sampling [CDPHE 2005].

Table 4. Background soil and sediment levels

	Soil		Sediment	
	Average	95% UCL of the mean	Average	95% UCL of the mean
Molybdenum	2.4 ppm	4.6 ppm	2.3 ppm	4.7 ppm
Uranium	2.1 ppm	2.9 ppm	2.0 ppm	3.4 ppm
Radium-226	1.3 pCi/g	1.9 pCi/g	1.1 pCi/g	1.7 pCi/g
Thorium-230	1.8 pCi/g	3.2 pCi/g	1.5 pCi/g	3.1 pCi/g
Gamma Exposure Rates	9.4 µR/hr	--	--	--

Source: CDPHE 2005; HRAP 1991
pCi/g – picocuries per gram
ppm – parts per million
µR/hr – microroentgen per hour
UCL – upper confidence limit

2. *Off-site soil contamination and remediation*

As part of the 1988 RAP, Cotter was required to survey soils outside the restricted area (the fenced active mill site) and to remediate contaminated soils with levels of radium and molybdenum that are above the established background [CDPHE 2005].

As part of the *1998 Supplemental Human Health Risk Assessment* [Weston 1998], Weston (a contractor for Cotter) collected surface soil samples (0-2 inches) from eight zones around the mill property (see Figure 18 in Appendix B). Each zone was divided into 8 to 12 grids. Four samples were collected near the center of each grid and were composited (i.e., combined and homogenized) to form a single representative sample [Weston 1998]. The results of this sampling are shown in Table 26 (chemicals) and Table 27 (radionuclides). The maximum concentrations exceeded the comparison values for arsenic[9] in all eight zones, for cadmium in all zones except one (D), for lead in three zones (F, G, and H), and for radium-226 in four zones (A, B, C, and E). The average concentrations also exceeded comparison values for arsenic in all eight zones, for cadmium in one zone (F), for lead in one zone (H), and for radium-226 in two zones (A and B). The average radium-226 and thorium-230 concentrations were higher than the established average background levels in all eight zones (see 4 for background).

There is limited potential for exposure to contaminants along the access road since access to the Cotter Mill is restricted and soils along the access road were remediated in 2007 and 2008.

Cotter has occasionally hauled ore and other materials by truck to the site for processing at their facility. To assess the potential that material has been lost alongside the county road leading to the mill and the access road entering the mill site, MFG (a contractor to Cotter) scanned the county road (assuming CR 143) from the road leading to the Shadow Hills Golf Course to the Cotter Mill access road for gamma radiation (see Figure 19). They also collected soil samples to establish a correlation between the gamma exposure rate and the concentration of gamma emitters in the soil. A total of 16 locations were sampled—five along the county road, five along

---

[9] The *1998 Supplemental Human Health Risk Assessment* found no discernible spatial pattern for arsenic around the Cotter Mill, indicating that arsenic levels have not been measurably altered by airborne releases from the mill [Weston 1998].

the mill's access road, and six from background locations. The locations were not chosen to estimate an average concentration, but rather to provide data for a range of gamma exposure rates. Each sample was a composite of 10 aliquots within a 100 x 100 meter area [MFG 2005]. The results of this sampling are shown in Table 28. The maximum and average radium-226 and natural uranium concentrations exceeded the comparison values for samples taken along the mill's access road. The maximum and average radium-226 concentrations also exceeded the comparison value for samples taken along the county road. Average concentrations of all radionuclides sampled were higher along the county road and the mill's access road than from those areas designated as background (see Table 28).

To address public concerns about the impact of the Cotter Mill on the health of Cañon City residents, CDPHE collected 21 soil samples in January 2003 [CDPHE 2003]. Each sample was a composite of 30–40 scrape samples[10] from each location. Seven samples from Lincoln Park were collected, including one sample of suspected flood sediment (Pine Street near Elm Avenue), two samples of dust (one from a barn loft and one from a residential attic), and four samples of surface soil (one from the McKinley Elementary School playground). Seven samples were collected from areas east of the mill, including the Brookside Head Start School. Six samples were collected from areas west of the mill, including a private residence. One sample was collected from the extreme northern part of Cañon City to represent the regional background (corner of Orchard Avenue and High Street). The sampling event was intentionally biased toward finding the highest amounts of contamination possible [CDPHE 2003]. Sample locations are shown in Figure 20. The data from this sampling event are summarized in Table 29 (chemicals) and Table 30 (radionuclides). The maximum concentrations for lead and radium-226 exceeded the comparison values. The average concentration for lead also exceeded the comparison value. The average concentration for radium-226 did not exceed the comparison value.

Since 1994, Cotter has been annually collecting surface soil samples (0–6 inches) at 10 environmental air monitoring stations that are located along the facility's boundary and in residential areas (see Figure 21). From 1979 to 1993, soils were collected every 9 months. The data from this effort are summarized in Table 31. The maximum concentration for radium-226 exceeded the comparison value; however, the average concentration of samples over the timeframe did not.

a) The nearest resident

The nearest resident is located 0.45 mile from the restricted area [ATSDR 2011]. One of the air monitoring stations annually monitored by Cotter was established as "the nearest resident" (AS-212). This location is between the Cotter Mill and an actual residence [Cotter 2007]. The limited data for this location are shown in Table 32 (chemicals) and Table 33 (radionuclides). The maximum concentration for radium-226 exceeded the comparison value; however, the average concentration did not.

b) Lincoln Park

---

[10] Surface soil samples were collected using a method developed specifically to look for airborne contamination that settled to the ground [CDPHE 2003].

EPA determined that sediment and soil contamination in Lincoln Park are no longer an issue since the completion of the Sand Creek Cleanup project in 1998 [EPA 2002, 2007].

As part of the 1988 RAP, Cotter was required to conduct a gamma scintillometer survey in Lincoln Park to evaluate whether soils had been contaminated by windblown and waterborne contaminants from the facility. In December 1988, 127 scintillometer readings were taken near intersections in Lincoln Park. The average external gamma radiation for Lincoln Park was 9.8 microroentgen per hour (µR/hr), which is considered to show “no elevated gamma in Lincoln Park” [CDPHE 2005; HRAP 1991].

As part of the *1996 Supplemental Human Health Risk Assessment* [Weston 1996], Weston compiled data from several past soil studies, including the following:

- Samples collected at the air monitoring location in Lincoln Park in 1987 and 1988
- Samples collected from yards of 10 participants in the Lincoln Park water use survey in 1989
- Samples collected from residential gardens in Lincoln Park in 1990
- Samples collected from lawns and gardens in Lincoln Park in 1996

The data from these studies are summarized in Table 34 (chemicals) and Table 35 (radionuclides). Only the maximum and average concentrations for arsenic exceeded the comparison value.

The soil samples collected from yards of the participants in the 1989 *Lincoln Park water use survey* were also analyzed for molybdenum and uranium. The average molybdenum concentration was 2.0 ppm and the average uranium concentration was 2.8 ppm [HRAP 1991]. The samples collected as part of the 1990 residential garden soil survey were also analyzed for molybdenum. The average concentration was 0.13 ppm [HRAP 1991]. These concentrations are well below the comparison values for molybdenum (300 ppm) and uranium (100 ppm).[11]

As part of the *1998 Supplemental Human Health Risk Assessment* [Weston 1998], 73 surface soil samples were collected from lawns (0–2 inches) and gardens (0–6 inches) in Lincoln Park. For sampling purposes, Lincoln Park was divided into seven areas and 6–16 samples were taken from each area [Weston 1998]. The results of this sampling are shown in Table 26 (chemicals) and Table 27 (radionuclides). Arsenic was the only chemical where the maximum and average concentrations exceeded ATSDR’s comparison value.

The effect of irrigation with contaminated well water on the levels in the soil was also examined during the *1998 Supplemental Human Health Risk Assessment* [Weston 1998]. The soil samples from Lincoln Park were divided into two categories—those irrigated with well water that had been impacted by mill releases and those not believed to have been irrigated with contaminated well water. These data are shown in Table 36 (chemicals) and Table 37 (radionuclides). The

---

[11] The data for molybdenum and uranium are not summarized in Tables 36 because the raw data for these two chemicals are not presented in the *1996 Supplemental Human Health Risk Assessment* [Weston 1996].

concentrations of arsenic, molybdenum, and uranium were statistically higher in soil samples irrigated with impacted well water [Weston 1998].

(1) Lead in Lincoln Park

Residents of Lincoln Park expressed concerns about lead contamination in soil and dust due to historical and current mining and milling operations in the area. Six potential sources of lead are located near the community of Lincoln Park—the Cotter Mill, the Empire Zinc Smelter (also known as New Jersey Zinc and the College of the Cañons), the US Smelter Facility, the Cañon City Copper Smelter, the Ohio Zinc Company, and the Royal Gorge Smelter [EPA 2004]. The Lincoln Park neighborhood is located generally east-southeast of these facilities and the general wind direction is west to east.

To address the residents' concerns, EPA requested that ATSDR assess the health risk associated with lead contamination in Lincoln Park. After a site visit and discussions with the community, ATSDR focused assessments on two primary issues—1) blood lead levels in children living in Lincoln Park and 2) lead contaminated dust in homes in Lincoln Park.

ATSDR reviewed the available data on blood lead levels in children and concluded that the rate of elevated blood lead levels for Fremont County is below the state average. However, it was not possible to evaluate whether area children, including "high risk" children, were being adequately screened for blood lead levels [ATSDR 2006a]. To further assess blood lead levels, ATSDR tested the blood level of 115 "at risk" school children in 2005. None of the children had elevated blood lead levels using CDC's previous blood lead level of 10 μg/dL or greater to designate elevated blood lead levels in children [ATSDR 2006b].[12] CDC's current reference value for designating elevated blood lead levels in children is 5 μg/dL.

ATSDR reviewed the available data on lead levels in household dust and found the data to be sparse and/or lacking. ATSDR conducted a screening level evaluation of the available dust samples and concluded that the data were not sufficient to determine the magnitude or extent of the potential hazard associated with levels of lead in household dust [ATSDR 2006c]. To further assess the health impacts in Lincoln Park, ATSDR, in collaboration with the Colorado Citizens Against Toxic Waste (CCAT) and EPA, collected and analyzed 44 indoor dust samples, 80 surface soil samples (0–2 inches or 0–6 inches) from 22 properties, and 45 blood samples. The results of this exposure investigation did not indicate the presence of unusual levels of lead in residential indoor dust samples, the soil at those homes, or in the blood of occupants of those homes [ATSDR 2006d].

EPA's report documenting the residential soil sampling project can be accessed at the following site: http://www.epa.gov/region8/superfund/co/lincolnpark/.

---

[12] The 2005 Exposure Investigation and findings about blood lead levels in school children were completed when the Centers for Disease Control and Prevention (CDC) considered a blood lead level of 10 μg/dL or greater as elevated in children younger than 6 years of age. In 2012, CDC adopted 5 μg/dL as the reference value for designating elevated blood lead levels in children. Applying the new reference value to the 2005 EI results reveal that only one child had a blood lead level above 5 μg/dL; that child had a blood lead level of 9.3 μg/dL.

c) *Sand Creek*

Sand Creek is primarily an intermittent creek that passes through the Cotter Mill and runs north-northeast through Lincoln Park. It becomes perennial for the last 0.25–0.5 mile before its confluence with the Arkansas River. Prior to the construction of the SCS Dam north of the Cotter Mill in 1971, surface water and sediment from the facility flowed down the Sand Creek drainage into Lincoln Park [CDPHE 2005; GeoTrans 1986]. Mill tailings in the Old Tailings Pond Area are the source of the mill-derived contaminants (primarily radium-226 and thorium-230) in Sand Creek [Cotter 2000].

During the *1986 Remedial Investigation* [GeoTrans 1986], sediment samples were collected from the following locations in Sand Creek to evaluate present (i.e., 1985) and historical loadings from Cotter Mill.

- SD01 – mouth near the Arkansas River
- SD02 – near spring where flow begins (reflects migration of contaminants in the groundwater)
- SD04 – below the SCS Dam in
  (1) an abandoned stock watering pond (formed by diversion of runoff water into a depression adjacent to Sand Creek)
  (2) drainage (reflects historical picture of uncontrolled emissions)
  (3) drainage above #2 (reflects historical picture of uncontrolled emissions)
- SD05 – above the SCS Dam adjacent to the west property edge

The results of this sampling are presented in Table 38 and Table 39. Only the concentrations for arsenic and radium-226 exceeded ATSDR's comparison values.

As part of the 1988 RAP, Cotter was required to evaluate the mill's potential impacts to Sand Creek and remove sediments that exceeded the radium-226 cleanup goal of 4.0 picocuries per gram (pCi/g), which allows unrestricted use of the creek [Cotter 2000]. A total of 721 samples were systematically collected along the 1.25 mile stretch from just north of the Cotter Mill to where Sand Creek becomes perennial (see Figure 22). Surveying and cleanup began in the spring of 1993 and continued until remediation was completed in December 1998. Approximately 9,000 cubic yards of soil were removed from Sand Creek and disposed of on Cotter property [Cotter 2000]. The excavated areas were backfilled with clean soil [CDPHE 2005]. Thirty confirmatory samples established that the average site-wide radium-226 concentration was 1.5 pCi/g (below the cleanup goal of 4.0 pCi/g) and the average site-wide thorium-230 concentration was 3.9 pCi/g after remediation [Cotter 2000]. In addition to the sampling and remediation for radium-226, seven of the confirmation samples were analyzed for 10 chemicals in 1998 [Cotter 2000]. These results are presented in Table 40. Arsenic was the only chemical where the maximum and average concentrations exceeded ATSDR's comparison value.

At the time of mill closure, Cotter was required by the 1988 RAP to survey molybdenum and radium-226 in sediments in the perennial stream segments of Sand Creek and Willow (Plum) Creek to determine whether these areas have been impacted by the mill. The creek was cleaned up only to the stretch where it become perennial (before its confluence with the Arkansas River. If necessary, sediments above background will be removed and properly disposed of [CDPHE 2005].

d) The Fremont Ditch

The Fremont Ditch system is downstream of Sand Creek. It diverts water from near the confluence of Sand Creek and the Arkansas River downgradient toward Florence. The ditch receives substantial amounts of water from Sand Creek during low flows in the Arkansas River. During these periods, any contaminants moving down Sand Creek were potentially transported to Fremont Ditch [GeoTrans 1986].

As part of the 1988 RAP, Cotter was required to conduct a gamma survey of the dry beds of the Fremont Ditch. Cotter sampled sediment in Fremont Ditch from its head gate near Sand Creek to about a quarter mile downstream. The average radium-226 level was 1.86 pCi/g, which was below the cleanup standard of 4 pCi/g. The state agreed with Cotter that the Fremont Ditch did not require remediation because the concentrations of gross alpha (3.8 pCi/g), uranium (6.6 ppm), and molybdenum (2.2 ppm) were also low [CDPHE 2005].

C. Surface waters

1. Nature and extent of contamination

The Cotter Mill is a non-discharge facility, meaning that Cotter does not release wastewater to the surface water system. All remediation water is pumped to on-site impoundments for evaporation or recycling. However, prior to construction of the SCS Dam in 1971, storm events carried contaminated surface water and sediments from the facility down the Sand Creek drainage [CDPHE 2005]. One event in particular, a flood in June 1965, caused the unlined tailings ponds at the Cotter Mill to overflow into Lincoln Park. Sediment in the Lincoln Park portion of Sand Creek was contaminated with tailings that were carried in surface water runoff from the mill [EPA 2007].

CDPHE maintains a database containing surface water monitoring data dating back to 1962. To evaluate exposures to people living near the Cotter Mill, ATSDR extracted surface water data collected from Sand Creek, the DeWeese Dye Ditch, and the Arkansas River. After discussions with a CDPHE representative, the following assumptions were made while summarizing data within the database.

The SCS Dam was built in 1971 to prevent surface water and sediment from flowing into Lincoln Park during storm-generated floods. Since the construction of the dam, Lincoln Park no longer receives runoff from the Cotter Mill. Additionally, since 1979, impounded water collected at the dam has been pumped back to the lined impoundment on site [EPA 2002; GeoTrans 1986; HRAP 1991].

- Samples that were designated “N” in the detect flag column and had the same value in the result value column as the reporting detection limit column were included in the summary statistics as ½ the reporting detection limit.

- Negative result values for manganese and iron were assumed to be not detected and were included in the summary statistics as ½ the reporting detection limit.

- Negative values[13] for radionuclides were included in the summary statistics.

a) Sand Creek

From 1993 to 1998, Cotter conducted the Sand Creek Cleanup project to identify and remove mill tailings that had moved into the creek bed as the result of surface water runoff from the Cotter Mill prior to the construction of the SCS Dam. Sediments above the radium-226 cleanup goal of 4.0 pCi/g were removed, which allows unrestricted use of the creek [Cotter 2000; EPA 2002].

Two locations in Sand Creek—one at Ash Street (008) and one at the confluence with the Arkansas River (506)—are sampled as part of the surface water monitoring program (Cotter 2007). The CDPHE database contains surface water monitoring data from these two locations, which are summarized in Table 41 (chemicals) and Table 42 (radionuclides). The maximum concentrations for manganese, molybdenum, sulfate, and total dissolved solids exceeded the comparison values. However, for all four of these chemicals, only the maximum concentrations exceeded comparison values—the second highest detected concentrations were below comparison values. None of the average concentrations exceeded comparison values.

As part of the *1991 Health Risk Assessment of the Cotter Uranium Mill Site* [HRAP 1991], the Health Risk Assessment Panel (HRAP) reviewed over 18,000 samples collected from 1976–1989, from 55 different surface water locations. More than 95% of the surface water data were collected from 10 main locations. The location in Sand Creek at Ash Street (008, formerly known as 555) was one of these locations. The average molybdenum (0.009 mg/L) and uranium (0.016 mg/L) concentrations from this location were well below the comparison values (molybdenum: 0.035 mg/L; uranium: 0.03 mg/L).[14]

b) DeWeese Dye Ditch

The DeWeese Dye Ditch is an irrigation ditch that flows between the Cotter Mill and Lincoln Park. The ditch diverts water from Grape Creek to irrigate about 1,200 acres during the summer growing period [GeoTrans 1986]. The ditch crosses Sand Creek downstream from the SCS Dam, but does not join it. Seepage from the ditch recharges groundwater within the Sand Creek drainage. This process dilutes and flushes the contaminated groundwater under Lincoln Park [EPA 2002].

The CDPHE database contains surface water monitoring data from two locations in the DeWeese Dye Ditch—one upstream of the confluence with Forked Gulch (520) and one at Cedar Avenue

---

[13] Negative values for radionuclides occur when samples are not much different from background, since standard protocol is to subtract background radioactivity from the sample count.

[14] It was not possible to determine whether these data are included in the CDPHE database.

(526). The location at Cedar Avenue is sampled as part of the surface water monitoring program [Cotter 2007]. The data for both locations are summarized in Table 43 (chemicals) and Table 44 (radionuclides). The maximum concentrations exceeded the comparison values for iron, manganese, total dissolved solids, and dissolved uranium. However, for iron and manganese, only the maximum concentrations exceeded comparison values—the second highest detected concentrations were below comparison values. Only three of the total dissolved solids samples and three of the dissolved uranium samples were detected above comparison values. None of the average concentrations exceeded comparison values.

Molybdenum and uranium data from 1984 to 1989, from the same two locations in the DeWeese Dye Ditch (520 and 526), are summarized in the *1991 Health Risk Assessment of the Cotter Uranium Mill Site* [HRAP 1991]. The average molybdenum and uranium concentrations were well below the comparison values (see Table 5 below).

Table 5. Average molybdenum and uranium concentrations in the DeWeese Dye Ditch

Chemical	**Average concentration at Location 520 (mg/L)**	**Average concentration at Location 526 (mg/L)**	**Comparison Value (mg/L), State Water Quality Standard**
Molybdenum	0.003	0.003	0.035
Uranium	0.002	0.0019	0.03

Source: HRAP 1991

Molybdenum data that were several orders of magnitude greater than any other observed sample (i.e., outliers) were not used to calculate the average concentrations (HRAP 1991).

It was not possible to determine whether these data are included in the CDPHE database.

c) *Arkansas River – Surface water and biota*

From April 1989 to June 1990, Cotter and their consultant, Western Environmental Analysts, conducted sampling in the Arkansas River at the following five locations:

The Arkansas River sampling plan was approved by the CDPHE Water Quality Control Division [CDPHE 2005].

1. Parkdale (background)
2. Grape Creek
3. 1st Street (upstream of where Sand Creek enters the Arkansas River)
4. Mackenzie Avenue Bridge (downstream from where Sand Creek enters the Arkansas River)
5. Where Highway 67 to Florence crosses the river

Water, sediment, autotrophs (algae), primary consumers/detrivores (tadpoles, macroinvertebrates), and carnivores (fish) were collected and tested for molybdenum, uranium, radium-226, and thorium-230. Extremely low concentrations were detected, which indicated no statistical evidence of an increase in contamination downstream on the Arkansas River [CDPHE 2005].

In addition, four sampling events (i.e., sampling of water in-flows) were conducted between Canyon Mouth and Highway 67. The purpose of the sampling was to determine whether tributary flows reflect unusual sources of uranium or molybdenum. The sampling showed that other sources such as Fourmile Creek, as well as Sand Creek and Plum Creek, contribute to increases in the Arkansas River [CDPHE 2005].

Two locations in the Arkansas River—one upstream of Sand Creek at 1st Street (907) and one downstream of Sand Creek at Mackenzie Avenue (904)—are sampled as part of the surface water monitoring program [Cotter 2007]. The CDPHE database contains surface water monitoring data from these two locations, which are summarized in Tables 45 (chemicals) and Table 46 (radionuclides). At both locations, the maximum concentrations exceeded the comparison value for sulfate. The maximum concentration for total dissolved solids exceeded the comparison value for the upstream location, but not the downstream location. In all three instances, these maximum concentrations appear to be outliers and are the only concentrations that exceeded comparison values—the second highest detected concentrations were below comparison values. The maximum concentration for molybdenum also exceeded the Colorado state groundwater standard for the upstream location, but not the downstream location. None of the average concentrations exceeded comparison values.

Data from 1984 to 1989, from two locations in the Arkansas River—one upstream of Sand Creek near Grape Creek (502) and one downstream of Sand Creek near Fourmile Bridge (504)—are summarized in the *1991 Health Risk Assessment of the Cotter Uranium Mill Site* [HRAP 1991]. The average molybdenum and uranium concentrations were below the comparison values (see Table 6 below).

Table 6. Average molybdenum and uranium concentrations in the Arkansas River

Chemical	Average concentration upstream of Sand Creek near Grape Creek (502) (mg/L)	Average concentration downstream of Sand Creek near Fourmile Bridge (504) (mg/L)	Comparison Value (mg/L), State Water Quality Standard
Molybdenum	0.00391	0.0056	0.035
Uranium	0.00532	0.00574	0.03

Source: HRAP 1991

Molybdenum data that were several orders of magnitude greater than any other observed sample (i.e., outliers) were not used to calculate the average concentrations (HRAP 1991).

d) Willow Lakes – Surface water and biota

The Willow Lakes are comprised of several small ponds near the Arkansas River in the Willow Creek watershed, which lie directly to the east of the Sand Creek watershed. The Willow Lakes receive water from shallow groundwater and surface runoff [HRAP 1991].

Cotter was required by the 1988 RAP to evaluate whether the Willow Lakes had been contaminated by the mill. Water, sediment, autotrophs (algae), primary consumers/detrivores (tadpoles, macroinvertebrates), and carnivores (fish) from the Willow Lakes and three comparison lakes were collected and tested for molybdenum, uranium, and radium. The information showed that the Willow Lakes had not been contaminated by the Cotter Mill [CDPHE 2005a].

D. Locally grown foods

1. Nature and extent of contamination

As part of the *1996 Supplemental Human Health Risk Assessment* [Weston 1996], Weston compiled available food data from several past studies. Samples included chicken meat, fruit (apples, cherries, grapes), and vegetables (asparagus, carrots, lettuce, tomatoes, turnips) that were locally raised. The results were compared to food collected from supermarkets. The data are presented in Table 47 and Table 48 in Appendix A. The limited sample data suggest that the chemicals and radionuclides found in the foods are probably natural in origin, however, it was not possible to exclude the possibility that some food types may be influenced by mill-related contaminants [Weston 1996].

To further evaluate exposures to residents who eat locally grown fruits and vegetables, a sampling program was initiated in Lincoln Park during the *1998 Supplemental Human Health Risk Assessment* [Weston 1998]. People were asked to donate locally grown produce samples for analysis. The fruits and vegetables sampled are presented in the table below. The samples were tested for heavy metals and radionuclides. The analytical results of the sampling program are summarized in Table 49 and Table 50 in Appendix A.

Fruits Sampled

Apples
Cantaloupe
Grapes
Honey dew melon
Plums
Watermelon

Vegetables Sampled

Acorn squash
Beets
Carrots
Celery
Corn
Cucumbers
Green Beans
Green Onions
Kohlrabi
Patty pan squash
Peppers
Pumpkin
Rhubarb
Squash
Tomatoes
Turnip Greens
Turnips
Winter squash

The samples were divided into two categories—(1) produce that was grown in soil known to have been irrigated with contaminated well water (fruits n = 16; vegetables n = 43) and (2) produce that was grown in soil not believed to have been irrigated with contaminated well water (fruits n = 1; vegetables n = 6). A statistical comparison of the data for the two categories of vegetables indicated that irrigation with contaminated well water did not cause a significant increase in contaminant levels [Weston 1998]. The following trends were also noted:

- The concentrations of most metals were higher in root vegetables than other types of vegetables and fruit.
- Concentrations were much lower in peeled turnips than in whole turnips, suggesting that most of the contamination was on or in the surface layer.
- There was high variability both within and between the different types of produce.

- Concentration values were below the limit of detection for many of the samples.

E. Ambient Air

ATSDR reviewed ambient air monitoring data and air sampling data collected from the following two sources:

- Cotter Mill has operated an ambient air monitoring program to characterize air quality impacts of radioactive particulates and radon for more than 20 years. ATSDR accessed summaries of the monitoring data from Cotter Mill's annual Environmental and Occupational Performance Reports, which are posted to the CDPHE's web site; and

- The state of Colorado operated three particulate monitoring stations in Fremont County, one each in Lincoln Park, Cañon City, and Florence. The station in Cañon City continues to operate today. ATSDR downloaded measured concentrations of particulate matter, and some chemical constituents of particulate matter, from EPA's Air Quality System (AQS) database—a publicly accessible online clearinghouse of ambient air monitoring data. Some of the measurements collected date back 40 years.

Historically, Cotter Mill had two general types of air emission sources: ground-level fugitive emissions (e.g., wind-blown dust) that are expected to have greatest air quality impacts nearest the source; and point sources (e.g., stacks) that have the potential for having peak ground-level impacts at downwind locations. With the facility currently in "stand down" status, facility emissions are now predominantly fugitive and their air quality impacts should be adequately characterized by the perimeter monitoring stations. Additionally, terrain features arount Cotter channel air flow in the area, blocking flow into some areas. This does not mean the sample locations are inappropriate; it clarifies why some areas have significantly lower concentrations than expected.

1. Nature and extent of air contamination

ATSDR compiled ambient air monitoring data to assess potential air quality impacts from Cotter Mill's past and ongoing operations. As will be discussed later, ambient air concentrations of some substances changed considerably from one year to the next—in some cases, annual average concentrations vary by more than a factor of 250 over the period of record. These substantial changes in measured air contamination levels can sometimes be traced back to site-specific activities.

To provide background information and context for the air quality trends documented later in this report, the following list identifies key milestones over the history of Cotter Mill's operations. The timeline is not a comprehensive listing of site-specific events, but rather focuses on events and activities expected to be *associated with notable changes in the facility's air emissions*.

- 1958: Cotter Corporation begins its uranium milling operations at the Cotter Mill site

- 1979: Continuous operations cease, but intermittent operations continue

- 1981-1983: Cotter excavates 2,500,000 cubic yards of contaminated tailings from unlined holding ponds and places the material in a newly constructed, lined surface impoundment
- 1987: Cotter suspends its primary milling operations and only limited and intermittent ore processing occurs for the next 12 years
- 1993-1999: Cotter excavates 9,000 cubic yards of contaminated tailings, soil, and sediment from 1.25 miles of Sand Creek near the facility
- 1999: Cotter excavates 100,000 cubic yards of contaminated soil in "near surface soils" from the on-site Old Pond Area and places this material into the lined, surface impoundment
- 1999: Milling operations using a different production process begin
- 2006: Cotter ceases its routine operations and enters "stand down" status; site remediation activities continue; stack emissions from most sources continue into 2006, after which the main operational stack is for the laboratory baghouse
- 2008: Cotter excavated approximately 250,000 yards of contaminated soils from Old Pond Area
- 2009: Cotter submits letter to CDPHE announcing its intent to refurbish the mill, rather than decommission it
- 2010: Cotter announces it will decommission

The following sections summarize the data and air quality trends for particulate matter, selected particle-bound radionuclides, radon gas, and gamma radiation.

a) Ambient Air Monitoring for Radioactive Substances

The Cotter Mill monitoring network is operated by Cotter Mill in accordance with guidelines and requirements set forth by the U.S. Nuclear Regulatory Commission [USNRC 1980] and the Radioactive Materials License established between Cotter Mill and the state of Colorado [CDPHE 2009]. The purpose of the network is to characterize the extent to which Cotter Mill's operations affect off-site air quality.

Cotter Mill's ambient air monitoring network has been operating from 1979 to the present, but the number of monitoring stations included in the network has changed over time. In 1979, four stations were operational; this increased to seven by 1981 and to ten by 1999. These ten monitoring stations continue to operate today. Each station is equipped with the same air monitoring equipment: a sampler used to collect particulates for analysis of particle-bound radionuclides; a radon track etch measurement device; and a thermoluminescent dosimeter (TLD) for measuring gamma exposure. The height of the sampling inlet probes was not specified in the reports that ATSDR reviewed to prepare this health assessment. Table 51 in Appendix A identifies the monitoring stations and their periods of operation. Figure 23 in Appendix B shows the approximate locations of the monitoring stations. For purposes of this evaluation, ATSDR has classified the ten monitoring stations as being either “perimeter” or “off-site.” The five “perimeter” monitoring stations are located along or just within Cotter Mill’s property line; and the five “off-site” monitoring stations are located off-site, anywhere from 0.5 mile to 4 miles from the Cotter Mill property line.

(1) Particulate Matter

At each of the 10 monitoring stations described above, Cotter Mill operates a high-volume total suspended particulate (TSP) sampling device. For each sampling period, the devices are loaded with glass fiber filters that collect airborne particulates as ambient air passes through the sampling apparatus. The TSP sampling devices collect 1-week integrated samples; when the sampling period ends, field personnel remove filters, record observations on chain-of-custody forms, and store filters for subsequent laboratory analysis.

Cotter prepares annual summary reports for its environmental monitoring network, and those reports document monthly average TSP concentrations measured at each station. ATSDR had access to the summary reports for 2006, 2007, and 2008. TSP data from earlier years can be accessed through data reports that CDPHE has on compact disk. Over the last three years, annual average TSP concentrations were consistently higher in the more populated areas (Lincoln Park and Cañon City) than at the perimeter monitoring stations. In 2008, for instance, the annual average TSP levels at Lincoln Park and Cañon City were 29.9 $\mu g/m^3$ and 26.5 $\mu g/m^3$, respectively; in contrast, annual average concentrations at the five perimeter monitoring stations ranged from 15.5 $\mu g/m^3$ to 21.4 $\mu g/m^3$.

Although quantitative quality control information was not available when summarizing Cotter’s TSP data, these measurements can be compared to CDPHE’s PM_{10} monitoring results in Cañon City during the same time frame. From 2006 to 2008, the annual average TSP levels measured by Cotter Mill in Cañon City were 26.6 $\mu g/m^3$, 26.3 $\mu g/m^3$, and 26.5 $\mu g/m^3$, respectively; the annual average PM_{10} levels measured by CDPHE in Cañon City during these same years were 16.5 $\mu g/m^3$, 16.4 $\mu g/m^3$, and 15.0 $\mu g/m^3$. The difference between the TSP and PM_{10} annual average concentrations in Cañon City are within the expected range and direction (i.e., TSP levels exceeding PM_{10} levels, as PM_{10} makes up part of the TSP measurements), which gives some assurance in the quality of the underlying data sets.

(2) Particle-Bound Radionuclides

Weekly particulate filters collected at the 10 stations mentioned in the previous section are not only weighed for mass loading but are also analyzed at Cotter Mill’s analytical laboratory for concentrations of five radionuclides, identified below. All laboratory analyses are conducted according to methodologies approved by CDPHE.

Field sampling and laboratory analyses for particle-bound radionuclides are conducted according to specifications outlined in Cotter Mill’s Quality Assurance Program Plan (QAPP). This document is revised periodically and submitted to CDPHE for review. The QAPP outlines many quality control and quality assurance (QA/QC) procedures implemented to ensure that the network's measurements are of a known and high quality. Examples of specific QA/QC procedures followed include: routine collection and analysis of blank samples to ensure sampling media and laboratory equipment are not contaminated; quarterly calibration of flow rates for the "high volume" samplers; and audit of sampler flow rates using special equipment. While these and other quality control procedures give some assurance that samples are collected and analyzed with fine attention to data quality, the reports available to ATSDR during this review generally did not present the actual data quality metrics (e.g., the relative percent difference in duplicate samples or for inter-laboratory audits, contamination levels found in blanks) for the particle-bound radionuclides.

The key findings from the monitoring program for the five radionuclides measured are below. For each substance, a section compares the measured concentrations to regulatory limits or health-based comparison values, comments on temporal and spatial variations, and then presents a brief summary.

- **Natural uranium (^{nat}U).** Table 52 in Appendix A presents the history of annual average ^{nat}U concentrations measured in Cotter Mill's monitoring network. The shaded cells in the table are the highest annual average concentration for the year.
    - *Screening.* Cotter Mill compares measured concentrations of ^{nat}U to an "effluent concentration" (9.0×10^{-14} µCi/ml), which is defined [10 CFR 20, Appendix B] as the radionuclide concentration which, if inhaled continuously over the course of a year, would produce a total effective dose equivalent of 50 mrem. None of the annual average concentrations in Table 52 exceed this derived concentration guide. The highest annual average concentration over the period of record (2.5×10^{-14} µCi/ml at a perimeter monitoring station in 1982) is 3.6 times below this screening value. The highest annual average in 2008 (4.4×10^{-16} µCi/ml at a perimeter monitoring station) was approximately 200 times below the screening value, and larger margins are observed for the off-site monitoring stations.
    - *Spatial and temporal variations.* Generally, the highest annual average concentrations of ^{nat}U were observed at perimeter monitoring stations, with lower levels observed at the off-site stations. During most years, the annual average values did not vary considerably (by more than a factor of ten) across all of the stations. As an exception, the 1982 annual average ^{nat}U concentration observed at the west boundary monitoring station was roughly 50 times greater than the annual averages observed at the other monitoring stations during the same year; this "spike" at one station during one year was most likely caused by air emissions associated with an on-site tailings excavation project. As another exception, in several years between 1998 and 2006, annual average ^{nat}U concentrations at the mill entrance road monitoring station were more than a factor of ten higher than those recorded at all other stations, which most likely reflects contributions from clean-up of the site entry road and delivery of ores (which mostly ended in 2006). As noted above, the highest annual average concentration of ^{nat}U was observed in 1982, and more recent (2004-2008) annual average levels are considerably lower.

  - *Summary.* Every annual average concentration of ^{nat}U recorded to date has been lower than Cotter Mill's health-based regulatory limit. In the last five years, the annual average concentrations at every station have been at least 20 times below this limit. It seems unlikely that air emissions from the mill would lead to an off-site "hot spot" of ^{nat}U concentrations that could be considerably higher than the levels measured by the monitoring network.

- **Thorium-230 (^{230}Th).** Table 53 in Appendix A presents the history of annual average ^{230}Th concentrations measured in Cotter Mill's air monitoring network. The shaded cells in the table are the highest annual average concentration for the year.

  - *Screening.* Cotter Mill compares measured concentrations of ^{230}Th to an "effluent concentration" (2.0 x 10^{-14} µCi/ml), which is defined [10 CFR 20, Appendix B] as the radionuclide concentration which, if inhaled continuously over the course of a year, would produce a total effective dose equivalent of 50 mrem. The annual average concentration at the west boundary monitoring station exceeded this value in 1981 and 1982, as did the annual average concentration in 1981 at the east boundary monitoring station. The highest annual average concentration recorded by this network (9.0 x 10^{-14} µCi/ml at the west boundary in 1982) was 4.5 times higher than the derived concentration guide. Concentrations decreased over the years, and the highest annual average in 2008 (7.2 x 10^{-16} µCi/ml at a perimeter monitoring station) was 28 times lower than the screening value, and larger margins are observed for the off-site monitoring stations.

  - *Spatial and temporal variations.* Without exception, the highest annual average concentrations of ^{230}Th were observed at perimeter monitoring stations, with considerably lower levels observed at the off-site stations—a spatial trend suggesting that Cotter Mill's emissions very likely account for a considerable portion of the measured levels. As with natural uranium, the ^{230}Th concentrations exhibited a notable "spike" in 1981-1982, when 2.5 million cubic yards of on-site tailings were excavated from the unlined ponds. As an illustration of this effect, the highest annual average concentration in 1981 (3.0 x 10^{-14} µCi/ml at a perimeter monitoring station) was nearly 370 times higher than the annual average concentration measured in Cañon City. Moreover, the highest concentrations were observed at the monitoring station closest to, and downwind from, the excavation activity. Average concentrations of ^{230}Th decreased markedly after the 1981-1982 peak: the most recent (2004-2008) annual average concentrations at perimeter stations are all at least 20 times lower than the highest levels from 1981-1982.

  - *Summary.* In 1981 and 1982, annual average concentrations of ^{230}Th at two perimeter monitoring stations exceeded Cotter Mill's health-based regulatory limit; however, for every other calendar year, every station's annual average concentration was lower than this limit. In the last five years, the annual average concentrations at every station were between six and 30 times below this limit.

For the off-site monitoring stations, however, all annual average concentrations during this 5-year time frame were at least a factor of 40 below Cotter Mill's health-based regulatory limit.

- **Thorium-232 (^{232}Th).** Table 54 in Appendix A presents the history of annual average ^{232}Th concentrations measured in Cotter Mill's air monitoring network. Laboratory analyses for this radionuclide first began in 2001. The shaded cells in the table are the highest annual average concentration for the year.

    - *Screening.* Cotter Mill compares measured concentrations of ^{232}Th to an "effluent concentration" (4.0 x 10^{-15} µCi/ml), which is defined [10 CFR 20, Appendix B] as the radionuclide concentration which, if inhaled continuously over the course of a year, would produce a total effective dose equivalent of 50 mrem. None of the annual average concentrations in Table 54 exceed this derived concentration guide. In 2008, the highest annual average concentration (3.1 x 10^{-17} µCi/ml in Lincoln Park) was a factor of 128 lower than the screening value.

    - *Spatial and temporal variations.* Unlike ^{nat}U and ^{230}Th, for which measured concentrations were consistently (if not always) highest at perimeter monitoring stations, the highest annual average concentrations of ^{232}Th have always been observed at off-site monitoring stations, most commonly at the Lincoln Park monitoring station. Moreover, of all the radionuclides measured, annual average concentrations of ^{232}Th exhibited the least variability from station to station. For any given year between 2001 and 2008, annual average concentrations at the ten monitoring stations fell within a factor of three of each other. The annual average concentrations did not exhibit considerable variability from one year to the next.

    - *Summary.* Over the last five years, annual average concentrations of ^{232}Th at every monitoring station were more than 60 times lower than Cotter Mill's health-based regulatory limit. The spatial variations in ^{232}Th concentrations have been limited, suggesting that air emissions from Cotter Mill may be relatively insignificant for this radionuclide.

- **Radium-226 (^{226}Ra).** Table 55 in Appendix A presents the history of annual average ^{226}Ra concentrations measured in Cotter Mill's air monitoring network. The shaded cells in the table are the highest annual average concentration for the year.

    - *Screening.* Cotter Mill compares measured concentrations of ^{226}Ra to an "effluent concentration" (9.0 x 10^{-13} µCi/ml), which is defined [10 CFR 20, Appendix B] as the radionuclide concentration which, if inhaled continuously over the course of a year, would produce a total effective dose equivalent of 50 mrem. None of the annual average concentrations in Table 55 exceed this derived concentration guide. In 2008, the highest annual average concentration (7.9 x 10^{-16} µCi/ml at a perimeter monitoring station) was three orders of magnitude lower than the screening value.

  - *Spatial and temporal variations.* In almost every year between 1979 and 2008, the highest annual average concentrations of ^{226}Ra were measured at perimeter monitoring stations, and primarily at the west boundary and mill entrance road locations. For most years, the highest annual average value at the facility's perimeter was usually between one and two orders of magnitude greater than the lowest annual average concentration at off-site locations—a pattern that points to facility emissions as a likely source for contributing to at least part of the measured concentrations. At the four perimeter stations with the longest period of record, the highest annual average concentrations occurred prior to 1985, and the current (2008) levels at these stations are between 10 and 100 times lower than those peaks.

  - *Summary.* The spatial variations in ^{226}Ra concentrations suggest that Cotter Mill's emissions contribute to the measured levels. However, over the last five years, annual average concentrations of ^{226}Ra at every monitoring station were more than 390 times lower than Cotter Mill's health-based regulatory limit.

- **Lead-210 (^{210}Pb).** Table 56 in Appendix A presents the history of annual average ^{210}Pb concentrations measured in Cotter Mill's air monitoring network. The shaded cells in the table are the highest annual average concentration for the year.

  - *Screening.* Cotter Mill compares measured concentrations of ^{210}Pb to an "effluent concentration" (6.0×10^{-13} µCi/ml), which is defined [10 CFR 20, Appendix B] as the radionuclide concentration which, if inhaled continuously over the course of a year, would produce a total effective dose equivalent of 50 mrem. None of the annual average concentrations in Table 56 exceed this derived concentration guide. In 2008, the highest annual average concentration (1.9×10^{-14} µCi/ml at a perimeter monitoring station) was more than a factor of 30 lower than the screening value.

  - *Spatial and temporal variations.* The main distinguishing feature of the ^{210}Pb monitoring data (when compared to data for the other radionuclides) is the low variability, both spatially and temporally. Since 1983, annual average concentrations across the ten monitoring stations tended to fall within a factor of two; and year-to-year variability was of a comparable magnitude. This lack of variability points to a "background effect" (i.e., the measured concentrations likely are not the result of Cotter Mill's emissions, but reflect typical atmospheric levels for this part of the country). In 1981-1982, annual average concentrations at a perimeter monitoring station were slightly higher than what was routinely measured at all other locations and years; and these slightly elevated levels likely reflected air quality impacts from the excavation of the unlined holding ponds.

  - *Summary.* Of all the radionuclides considered, ^{210}Pb showed the least variability in annual average concentrations, suggesting that the monitoring data characterize background levels and not a site-specific contribution. From 1983 to the present, annual average concentrations during every year and at every station were generally at least 20 times below Cotter Mill's health-based regulatory limit.

With one exception, the five radioactive substances measured by Cotter Mill's air network were below their corresponding health-based regulatory limits at all 10 monitoring stations and for the entire 30 years of record. As the exception, annual average ^{230}Th concentrations exceeded health-based regulatory limits during a tailing pond excavation project, but this was limited to a short time frame (1981-1982) and the immediate proximity of the facility (two fenceline monitoring locations). The spike in measured concentrations during this time was far less pronounced (if not completely imperceptible) at monitoring stations in Lincoln Park or Cañon City. Another spatial variation linked to site activities is the relatively elevated readings (e.g., for ^{nat}U) observed at the "mill entrance road" monitoring station between roughly 1997 and 2006.

Over the last five years, annual average air concentrations of every radionuclide were at least 20 times lower than health-based screening limits at the five off-site monitoring stations. This large margin provides some assurance that the monitoring network has adequate coverage in terms of monitors.It is quite possible that annual average ambient air concentrations of radionuclides at some un-monitored off-site locations exceed what has been measured to date, but it is far less likely that the network is failing to capture a "hot spot" with concentrations more than 20 times higher than the levels that are currently measured.

b) *Radon Gas*

Cotter measures radon gas concentrations at the same ten air monitoring stations where particle-bound radionuclides are sampled. The annual environmental monitoring reports provide very limited information on the sampling methodology, other than noting that the detectors are apparently exposed to ambient air for a calendar quarter and then retrieved for laboratory analysis. Recent data summary reports suggest that a new sampling and analytical method was implemented in the second quarter of 2002. This new method outputs combined ^{220}Rn (from natural thorium) and ^{222}Rn (from natural uranium). However, the report does not describe what the previous sampling and analytical method measured.

According to Cotter's radon sampling procedures [Cotter 2004b], the sampling devices are "Landauer Type DRNF Radon Detectors." The reports provided to ATSDR suggest that various quality control measures have been implemented for this sampling (e.g., collection and analysis of co-located samples to characterize precision), but they do not document quantitative data quality metrics. The method detection limit for the combined ^{220}Rn/^{222}Rn measurement is 70 pCi/m^3 (Cotter 2004b). This appears to offer adequate measurement sensitivity, because most quarterly average concentrations measured since implementing this method are at least a factor of ten greater than the detection limit.

Table 57 presents the annual average ^{220}Rn/^{222}Rn concentrations that Cotter has measured from 2002 to the present. Data are not presented for earlier years (1979 to 2001), as they may not be directly comparable due to the use of different measurement technologies. Cotter has recently concluded that its radon monitoring data "demonstrate slightly elevated readings at boundary locations [when compared to] readings in residential areas at background levels" [Cotter 2008b]. This statement seems to be supported, in a general sense, by the monitoring results, though the difference between the perimeter and the off-site concentrations is much lower in certain years, particularly in 2008.

The approach used for screening the ^{220}Rn/^{222}Rn concentrations differs from that used for other radionuclides. Cotter screens the ^{220}Rn/^{222}Rn using an approach approved by CDPHE. In this approach, Cotter derives an “effective effluent limit” based on a baseline regulatory limit, an equilibration factor for the measurements, and average background concentrations that are calculated semi-annually. The details of this derivation are documented in a letter that CDPHE sent to Cotter in June 2004. The net effect of this calculation approach is that the “effective effluent limit” (i.e., the concentration used for screening purposes) can vary across the monitoring stations and years. To illustrate this point, between 2006 and 2008, the “effective effluent limit” of ^{220}Rn/^{222}Rn concentrations ranged from 1,290 to 1,981 pCi/m^3, depending on the magnitude of the background concentrations at the time. During this time frame, measured concentrations at perimeter monitoring stations reached as high as 85% of the “effective effluent limit,” but did not exceed it.

c) *Gamma Radiation*

Cotter measures gamma radiation levels at the same ten air monitoring stations where particle-bound radionuclides are sampled. Measurements are made using thermoluminescent dosimeters (TLDs) that are exposed for 3-month periods before being sent off-site for analysis. Every calendar quarter, an additional duplicate TLD is deployed to at least one monitoring station to assess measurement precision, and a control TLD is placed in a lead-shielded box at another location to serve as a “blank” sample. However, the site reports provided to ATSDR did not contain any quantitative metrics of data quality (e.g., relative percent difference in co-located samples).

Table 58 presents the annual average gamma radiation exposure rates between 1979 and 2008 by monitoring station. These annual averages were calculated from the quarterly TLD measurements from each calendar year. For every year on record, the highest annual average exposure rate was observed at one of the perimeter monitoring stations. Since Cotter installed the monitoring station at the mill’s entrance road in 1994, this station has recorded the highest annual average exposure rates every year through the present. The relatively high readings at this location are believed to result primarily from past spillage or incoming materials entering the facility [Cotter 2008b]. Under oversight from CDPHE, Cotter removed contamination alongside the entrance road in 2006 and 2007, with exposure rates decreasing thereafter.

Cotter’s monitoring reports do not include health-based screening evaluations for these measurements, but they do acknowledge that the exposure rates near the facility perimeter (and particularly along the entrance road) exceed background levels. Specifically, the reports assume that the Cañon City station’s measurements reflect “background” contributions from all external sources. The report indicates that the reported background level at this station (10.2 µR/hr) is equivalent to a dose of 89 mrem/year. These values do not exceed any health based comparison values. Since no one would reside 24/7 at these locations, a time weighted average dose would be far lower.

d) Ambient Air Monitoring for non-Radioactive Substances

To prepare this summary, ATSDR accessed all ambient air monitoring data that the state of Colorado collected in Fremont County and reported to EPA's Air Quality System (AQS) the AQS is an online clearinghouse of monitoring data that states collect to assess compliance with federal air quality standards. The AQS database included monitoring results for three locations in Fremont County: one in Cañon City, one in Lincoln Park, and one in Florence. This section summarizes only those data collected in Cañon City and in Lincoln Park given their proximity to Cotter Mill. However, the monitoring summarized in this section was not conducted to characterize air quality impacts associated with Cotter Mill's emissions; the measured concentrations at these locations likely reflect contributions from many different local emission sources (e.g., mobile sources, wind-blown dust, wood-burning stoves). The AQS database does not specify quality control parameters for the monitoring results; however, state agencies that submit data to AQS are supposed to thoroughly validate measured concentrations before entering them into the database.

(1) Particulate Matter (TSP, PM_{10}, and $PM_{2.5}$)

The state-operated Cañon City and Lincoln Park monitoring stations measured three different size fractions of particulate matter between 1969 and the present. Following standard practice, all three size fractions were measured in 24-hour average integrated samples that were typically collected once every 6 days, though more frequent monitoring occurred during some years. Measurements were collected using either standard technologies (e.g., high-volume samplers for TSP and PM_{10}) or EPA-approved Federal Reference Method devices. A brief summary of the measurements follows:

- **TSP measurements.** From 1969 through 1987, high-volume sampling devices were used to measure TSP. Table 59 in Appendix A presents the maximum and annual average TSP concentrations measured by the two monitoring stations over the period of record. Annual average TSP in Cañon City did not change considerably from 1969-1987. In Lincoln Park, only two calendar years have complete data sets; the annual average concentration in 1982 was below the range of annual averages observed at Cañon City. The fact that TSP levels were lower in Lincoln Park than in Cañon City suggests that Cotter Mill's emissions are not the primary contribution to TSP levels in the area.

- **PM_{10} measurements.** The state of Colorado began monitoring PM_{10} in Cañon City in 1987 and continues this monitoring today. The monitoring station was originally located at the courthouse in Cañon City, but the state moved the monitoring equipment in 1987 to a less obstructed site at city hall. Annual average PM_{10} concentrations throughout the period of record range from 15 to 23 $\mu g/m^3$, well below EPA's former National Ambient Air Quality Standard for annual average levels (50 $\mu g/m^3$). Between 1987 and 2009, only one measured 24-hour average concentration exceeded EPA's current health-based standard; that occurred in 1988 and likely reflected contributions from many different local sources and should not be attributed solely to Cotter Mill's emissions.

- **$PM_{2.5}$ measurements.** In 1991 and 1992, the state conducted $PM_{2.5}$ monitoring at its Cañon City station. All measured 24-hour average concentrations and both annual average concentrations were lower than the health-based standards that EPA developed later in the 1990s. This monitoring occurred before EPA designated Federal Reference Methods for $PM_{2.5}$ measurement devices.

(2) Constituents of Particulate Matter

Between 1978 and 1987, the state of Colorado analyzed some of the TSP filters collected in Cañon City and Lincoln Park for chemical constituents. This included analyses for metals (iron, lead, manganese, and zinc) and ions (nitrate and sulfate). Table 60 summarizes these measurements by presenting the highest 24-hour average concentration and the highest annual average concentration for the period of record.

V. PUBLIC HEALTH EVALUATION

A. Introduction

This section of the public health assessment evaluates the health effects that could possibly result from exposures to site-related contaminants at or near the Cotter Mill site. For a public health hazard to exist, people must contact contamination at levels high enough and for long enough time to affect their health. The environmental data and conditions at the site revealed five completed exposure pathways:

1. Exposure to site-related contaminants in groundwater in Lincoln Park.
2. Contact with site-related contaminants in soil adjacent to the Cotter Mill and in Lincoln Park.
3. Contact with site-related contaminants in surface water downstream from the Cotter Mill.
4. Exposure from eating produce locally grown in Lincoln Park
5. Exposure to ambient air near the Cotter Mill facility

B. How Health Effects are Evaluated

The potential health effects associated with completed exposure pathways (listed above) will be evaluated in this section. For chemicals found to exceed comparison values, ATSDR calculated exposure doses and estimated non-cancer and cancer risks, where applicable. The calculations estimate the amount of the chemical to which a person may have been exposed. Calculated exposure doses are then compared to the available health guidelines to determine whether the potential exists for adverse non-cancer health effects. In the event that calculated exposure doses exceed established health guidelines (e.g., ATSDR's Minimal Risk Levels or EPA's Reference Doses), an in-depth toxicological evaluation is necessary to determine the likelihood of harmful health effects. ATSDR also may compare the estimated amount of exposure directly to human and animal studies, which are reported in ATSDR's chemical-specific toxicological profiles. Not only do the toxicological profiles provide health information, they also provide information about environmental transport, human exposure, and regulatory status.

ATSDR's **Minimal Risk Level (MRL),** which is derived from human and animal studies, is an estimate of daily exposure to a contaminant below which non-cancer health effects are unlikely to occur.

EPA's **Reference Dose (RfD)** is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. Generally used for assessing noncancer risks.

A detailed explanation of ATSDR's evaluation process for determining cancer and non-cancer health effects is contained in Appendix C of this document. The equations to calculate exposure doses, the exposure scenarios, and the exposure assumptions used to estimate exposures at this site are also in Appendix C.

C. Groundwater Pathway: Private wells used for personal consumption

As discussed above, the data from the 1989 *Lincoln Park Water Use Survey* indicated approximately 7 wells were used for personal consumption; sampling data for 6 of the 7 wells were available to ATSDR for evaluation. Samples were collected intermittently from 1984 to 2007. Data from the *2008 Lincoln Park Water Use Survey* also indicated that 7 wells are used for personal consumption, although these are not the same wells as identified in the 1989 survey.

Although most residents in Lincoln Park currently use municipal water for drinking purposes, the surveys reveal that some residents still use their private wells for drinking purposes. It is not verified whether residents who reported using their well water for personal consumption also use their well water for other household purposes, such as bathing and showering. Some residents report that they and others used their private wells for personal consumption and other household uses in the past (before the installation of the municipal water line). Therefore, it is reasonable to assume that many more people obtained their drinking water from private wells in the past.

Very little quantitative information is known about what levels of contamination residents may have been exposed to in the past. However, ATSDR attempted to address this issue by assuming that the average resident would have been exposed to the average chemical concentration (i.e., temporal average per well) detected in the 6 private wells for which we have sampling data. There is some uncertainty in using this estimate because some people may have been exposed to more, and some to less, than the estimated amount. To capture the resident who may have been more highly exposed (or a worst case scenario), ATSDR used the average chemical concentration from the single private well that consistently contained the highest chemical concentrations (Well 189). ATSDR assumed that adults and children drank the water from this well for 350 days per year for 30 years (adults) and 6 years (children), respectively.

Molybdenum was the only chemical in private wells that had an average detected level (0.082 mg/L) that exceeded its comparison value (0.05 mg/L). The average level of molybdenum in Well 189 (0.16 mg/L) also exceeded the comparison value for molybdenum in drinking water. Therefore, molybdenum was retained as a chemical of concern and evaluated for possible adverse health effects. The maximum detected level of uranium (0.067 mg/L), but not the average detected level (0.028 mg/L), exceeded the comparison value of 0.03 mg/L for uranium. Additionally, the average detected level of uranium in Well 189 (0.048 mg/L) exceeded the comparison value for uranium. Therefore, ATSDR evaluated uranium more closely for potential adverse health effects. Table 7 below summarizes the estimated child and adult doses for molybdenum and uranium that guide the health discussion below. (See Table C1 in Appendix C for a detailed discussion of how these values were derived.)

Table 7. Estimated Child and Adult Doses for Molybdenum and Uranium in Drinking Water

Chemical	Exposure Group	Adult Estimated Dose (mg/kg/day)	Child Estimated Dose (mg/kg/day)	Health Guideline (mg/kg/day)
Molybdenum	Well 189 (high exposures)	0.004	**0.010**	0.005 Chronic Oral RfD
	All wells (average exposures)	0.002	0.005	
Uranium	Well 189 (high exposures)	0.001	**0.003**	0.0002 Intermediate Oral MRL
	All Wells (average exposures)	0.0008	**0.002**	

Note: Bold text exceeds a health guideline.

1. *Molybdenum*

Molybdenum is a naturally occurring element found in various ores. Molybdenum is also considered an essential dietary nutrient in humans and animals. Foods such as legumes, leafy vegetables, nuts and cereals tend to be higher in molybdenum than meats, fruits, and root and stem vegetables [WHO 2003]. The Food and Nutrition Board (FNB) of the Institute of Medicine has determined the Tolerable Upper Intake Level[15] (UL) for molybdenum in children and adults [FNB 2001] as follows:

- children 1 to 3 years of age - 0.3 mg/kg/day;
- children 4 to 8 years of age - 0.6 mg/kg/day;
- children 9 to 13 years of age - 1.1 mg/kg/day;
- adolescents 14 to 18 years of age - 1.7 mg/kg/day; and
- adults - 2.0 mg/kg/day.

a) Health Evaluation of Molybdenum

Drinking water from a private well contaminated with molybdenum would result in an estimated dose of 0.002 mg/kg/day for an average adult and 0.005 mg/kg/day for an average child. The adult dose is lower than the oral RfD of 0.005 mg/kg/day for molybdenum. The estimated child

---

[15] UL = maximum level of daily nutrient intake that is likely to pose no risk of adverse health effects in all individuals. The UL represents the total intake from food, water, and supplements.

dose is equal to the oral RfD (0.005 mg/kg/day) for molybdenum. Therefore, adverse health effects are not expected for the average adult or child who drank from a private well contaminated with molybdenum.

Adults who may have had high exposures, such as those similar to Well 189, have an estimated dose of 0.004 mg/kg/day, and children who may have had high exposures have an estimated dose of 0.010 mg/kg/day. The adult high dose is less than the oral RfD for molybdenum. However, the estimated child high exposure dose is 2 times greater than the oral RfD of 0.005 mg/kg/day for molybdenum. Because the estimated exposure dose for children exceeds the long-term health guidelines for molybdenum, the possibility of health consequences from this exposure was evaluated further.

To further evaluate the possibility of adverse health effects, ATSDR divides the lowest observed adverse effect level (LOAEL) and/or the no observed adverse effect level (NOAEL) by the site-specific exposure doses. Interpretation of the resulting value is subjective and depends on a host of toxicological factors. Further evaluation consists of a careful comparison of site-specific exposure doses and circumstances with the epidemiologic and experimental data on the chemical. The purpose of the comparison is to evaluate how close the estimated exposure doses are to doses that cause health effects in humans or animals.

The oral RfD for molybdenum is based on a human epidemiological study that found a LOAEL of 0.14 mg/kg/day for increased serum uric acid levels and prevalence of gout-like condition in Armenian villagers [Koval'skiy 1961]. A higher incidence (18-31%) of a gout-like disease was associated with high intake of molybdenum (10-15 mg/day) from soil and plants. The gout-like condition was characterized by pain, swelling, inflammation and deformities of the joints, and, in all cases, an increase in the uric acid content of the blood. In a number of cases, illnesses of the GI tract, liver, and kidneys accompanied the condition [EPA IRIS]. In deriving the oral RfD, an uncertainty factor of 3 was used for protection of sensitive human populations and a factor of 10 was used for the use of a LOAEL instead of a NOAEL for a long-term study in a human population. The estimated child high dose (0.010 mg/kg/day) for molybdenum at the Cotter Mill/Lincoln Park site is 14 times lower than the LOAEL from this study. There was no NOAEL determination for molybdenum from this study.

Molybdenum is known to interfere with copper metabolism in ruminant animals (grazing animals that "chew their cud," such as sheep or cows); the resulting copper deficiency is reported to cause the animal's hair/wool to turn white [FNB 2001]. This is a problem with ruminant animals in particular because high dietary molybdenum reacts with moderate to high dietary sulfur in the rumen (the first stomach) to form thiomolybdates. These compounds greatly reduce copper absorption, and certain thiomolybdate species can be absorbed and interfere systemically with copper metabolism [Spear 2003]. This interaction between thiomolybdates and copper is not expected to occur to a significant degree in humans [Turnlund 2002]. Although the exact effect of molybdenum intake on copper status in humans remains to be clearly established, individuals who do not take in enough dietary copper or cannot process it correctly could be at increased risk of molybdenum toxicity [FNB 2001].

In conclusion, children who drink water containing high concentrations of molybdenum could be at a slight increased risk of adverse health effects such as gout-like symptoms. However, molybdenum is not stored at high levels in the body, so it is unlikely that children will suffer long-term health effects once the exposure is stopped [FNB 2001]. In healthy people, excess molybdenum is not associated with adverse health outcomes. However, individuals who do not take in enough dietary copper or cannot process it correctly could be at increased risk for adverse health effects. The actual risk of adverse health effects occurring depends on the concentration of molybdenum in the water and how much water is drunk. Therefore, private wells known to be contaminated with molybdenum are unsuitable for drinking purposes.

b) Additional Comments about Molybdenum in Drinking Water

- ATSDR did not evaluate potential exposures to molybdenum that could occur if well water is used for other household purposes such as showering or bathing. If it is confirmed that residents are using their wells for other potable purposes, then exposure levels would increase, as well as the likelihood of adverse health effects. However, exposure to airborne and/or dermal molybdenum is not likely to be a major exposure pathway because of the physicochemical properties of molybdenum.

- The estimated dose for children and adults at this site did not exceed the Tolerable Upper Intake Level (UL) for molybdenum established by the Institute of Medicine. However, ATSDR's evaluation did not consider molybdenum intake from other sources, including food and supplements, which would increase total intake.

- Molybdenum is often found naturally in the geology of this region. The wells identified and sampled as background for the Lincoln Park area contained an average molybdenum concentration of 0.023 mg/L. This concentration is lower than the average of 0.082 mg/L found in private wells used for personal consumption. The maximum concentration of molybdenum in a background well (0.3 mg/L) was about the same as that in a private well (0.28 mg/L) used for personal consumption.

- Overall molybdenum levels in groundwater decreased over time. Molybdenum levels measured from 1968 to 2000 show a clear pattern of decrease in molybdenum concentrations. Therefore, exposures to molybdenum in groundwater were likely higher in the past, and may continue to decrease in the future.

People who currently own private wells are not prevented from using their private wells for any purpose. Therefore, this exposure pathway will continue to exist as a potential current and future exposure pathway.

2. Uranium

Throughout the world uranium is a natural and common radioactive element. Uranium is a silver-white, extremely dense, and weakly radioactive metal. It is typically extracted from ores containing less than 1% natural uranium. Natural uranium is a mixture of three isotopes: 238U (99.2739%), 235U (0.7204%), and 234U (0.0057%). It usually occurs as an inorganic compound with oxygen, chlorine, or other elements [NHANES 2005]. Rocks, soil, surface and ground water, air, plants, and animals all contain varying amounts of uranium. Colorado ranks third, behind Wyoming and New Mexico, tied with Arizona and Utah, as the state with the most uranium reserves in the United States [EIA 2001].

a) Health Evaluation of Uranium

Natural uranium is radioactive but poses little radioactive danger—it releases only small amounts of radiation that cannot travel far from its source. Moreover, unlike other types of radiation, alpha radiation released by natural uranium cannot pass through solid objects, such as paper or human skin. You have to eat, drink, or breathe natural uranium in order to be exposed to the alpha radiation; however, no adverse effects from natural uranium's radiation properties have been observed in humans. The National Academy of Sciences determined that bone sarcoma is the most likely cancer from oral exposure to uranium; its report noted, however, that this cancer has not been observed in exposed humans and concluded that exposure to natural uranium may have no measurable effect [BEIR IV].

Scientists have seen chemical effects in people who have ingested large amounts of uranium. Kidney disease has been reported in both humans and animals that were exposed to large amounts of uranium; however, the available data on soluble (more bioavailable) and insoluble uranium compounds are sufficient to conclude that uranium has a low order of metallotoxicity in humans [Eisenbud and Quigley 1955].

When uranium is ingested most of it leaves the body through the feces and a small portion (approximately 2% for an adult) will be absorbed into the blood stream through the gastrointestinal (GI) tract. Most of the uranium in the blood is excreted from the body through urine within a few days; however, a small amount will be retained in the kidneys, bone, and soft tissue for as long as several years. The percentage of the uranium retained in the kidneys over time is different for acute and chronic ingestion of uranium (as long as the individual continues to drink the water). When an individual discontinues drinking the uranium contaminated water, the percentage of retention in the kidney decreases similar to an acute exposure. In the case of chronic ingestion of drinking water containing uranium, the kidney retention (or kidney burden) increases rapidly in the first two weeks. After approximately 100 days, the amount present in the kidney is approximately 5% of the daily intake for an infant and approximately 3% for all other ages. After 25 years of chronic ingestion, the uranium kidney burden reaches equilibrium for all age groups at approximately 6.6% of the daily intake [Chen et al 2004].

Nephrotoxicity (kidney toxicity) occurs when the body is exposed to a drug or toxin such as uranium that causes temporary or permanent damage to the kidneys. When kidney damage occurs, blood electrolytes (such as potassium and magnesium) and metabolic by products in the blood (such as creatinine) become elevated indicating either a temporary condition or the development of kidney failure. Creatinine is a chemical waste molecule that is generated from muscle metabolism. Creatinine is a fairly reliable indicator of kidney damage. As the kidneys are impaired, the creatinine level in the blood will rise because of the poor clearance by the kidney. If detected early, permanent kidney problems may be avoided.

Several mechanisms for uranium-induced kidney toxicity have been proposed. In one of these, uranium accumulates in specialized (epithelial) cells that enclose the renal tubule, where it reacts chemically with ion groups on the inner surface of the tubule. This uranium accumulation interferes with ion and chemical transport across the tubular cells, causing cell damage or cell death. Cell division and regeneration occur in response to cell damage and death, resulting in enlargement and decreased kidney function. Heavy metal ions, such as uranyl ions, may also delay or block the cell division process, thereby magnifying the effects of cell damage [Leggett 1989, 1994; ATSDR 1999].

Animal and human studies conducted in 1940s and 1950s provide evidence that humans can tolerate certain levels of uranium, suffering only minor effects on the kidney [Leggett 1989]. Most of these studies involved inhalation exposures to uranium; however, the kidney is the target organ for inhaled as well as ingested uranium. On the basis of this tolerance, the International Council on Radiologic Protection (ICRP) adopted a maximal permissible concentration of 3 µg of uranium per gram of kidney tissue for occupational exposure in 1959 [Spoor and Hursh 1973]. This level has often been interpreted as a threshold for chemical toxicity.

More recent papers have been published on effects of uranium at levels below 3 µg/g of kidney tissue, and those papers have discussed possible mechanisms of uranium toxicity [Diamond 1989; Leggett 1989, 1994; Zhao and Zhao 1990; Morris and Meinhold 1995]. It is thought that the kidney may develop an acquired tolerance to uranium after repeated doses; however, this tolerance involves detectable histological (structural) and biochemical changes in the kidney that may result in chronic damage. Cells of the inner surface of the tubule that are regenerated in response to uranium damage are flattened, with fewer energy-producing organelles (mitochondria). Transport of ions and chemicals across the tubule is also altered in the tubule cells [Leggett 1989, 1994; McDonald-Taylor et al. 1997]. These effects may account for the decreased rate of filtration through the kidney and loss of concentrating capacity by the kidney following uranium exposure. Biochemical changes include diminished activity of important enzymes (such as alkaline phosphatase), which can persist for several months after exposure has ended. Therefore, acquired tolerance to uranium may not prevent chronic damage, because the kidney that has developed tolerance is not normal [Leggett 1989]. Acting on the basis of this information for uranium, researchers have suggested that exposure limits be reduced to protect against these chronic effects on the kidney.

Renal damage appears to be definite at concentrations of uranium per gram of kidney tissue above 3 µg/g for a number of different animal species, but mild kidney injury can occur at uranium concentrations as low as 0.1 to 0.4 µg/g in dogs, rabbits, guinea pigs, and rats after they inhale uranium hexafluoride or uranium tetrachloride over several months [Maynard and Hodge 1949; Hodge 1953; Stokinger et al. 1953; Diamond 1989]. Zhao and Zhao proposed a limit of uranium to the kidney of 0.26 µg/g based on renal effects in a man who was exposed to high concentrations of uranyl tetrafluoride dust for 5 minutes in a closed room [Zhao and Zhao 1990]. The man showed signs of kidney toxicity, including increased protein content in the urine (proteinuria) and nonprotein nitrogen. These signs persisted for 4.6 years, gradually returning to normal values. The kidney content 1 day after the accident was estimated to be 2.6 µg/g.

A study conducted in Finland and published in 2002 observed 325 people that had used their drilled wells for drinking water over a period of 13 years on average (range 1 – 34 years) [Kurttio et. al 2002]. The median uranium concentration in the water was 28 ppb (range 0.001 – 1,920 ppb). The study showed an association between increased uranium exposure through drinking water and tubular function, but not between uranium exposure and indicators of glomerular injury. The primary target is the proximal convoluted tubule of the kidney which is where most of the sodium, water, glucose, and other filtered substances are reabsorbed, secreted, or passively diffused back into the blood stream. The authors of the study indicated that tubular dysfunction may merely represent a manifestation of subclinical toxicity, and it is unclear if it carries a risk of development into kidney failure or overt illness. This study concluded that “The public health implications of these findings remain uncertain, but suggest that the safe concentration of uranium in drinking water may be close to the guideline values proposed by the WHO and the U.S.EPA.” However, this study found that altered tubular function was statistically significant at water uranium concentrations exceeding 300 µg/L [Kurttio et. al 2002], or 0.3 mg/L, which is a factor of ten higher than EPA’s and Colorado’s drinking water standard (0.03 mg/l) and the highest average concentration at the Lincoln Park site (0.048 mg/L). At 300 µg/L and assuming ingestion of two liters of water per day, the kidney burden after 25 years of chronic ingestion would be 39.6 µg of uranium with a uranium concentration per gram of kidney tissue of 0.13 µg/g.

A review of studies of uranium effects on the kidney [Morris and Meinhold 1995] suggests a probability distribution of threshold values for kidney toxicity ranging from 0.1 to 1 µg/g kidney, with a peak at about 0.7 µg/g. The researchers proposed that the severity of effects increases with increasing dose to the kidney with probably no effects below 0.1 to 0.2 µg/g, possible effects on the kidney at 0.5 µg/g, more probable effects at 1 µg/g, and more severe effects at 3 µg/g and above [Morris and Meinhold 1995; Killough et al. 1998b].

If an adult in Lincoln Park drank 2 liters (L) of uranium-contaminated water per day (at the highest average exposure concentration of 0.048 mg/L, or 48 µg/L) for 25 years or longer, then the maximum daily ingestion would be 96 µg of uranium, resulting in a uranium kidney burden of 6.3 µg [96 µg × 0.066 (percentage where adult kidney reaches equilibrium)]. The weight of both kidneys in adults is about 300 g [Madsden et al 2007]. Thus, the estimated uranium concentration per gram of kidney tissue for an adult is 0.02 µg/g. If a child drank 1 L of uranium-contaminated water per day (at the highest average exposure concentration of 0.048 mg/L, or 48 µg/L) for 100 days to 25 years, then the maximum daily ingestion would be 48 µg of uranium, resulting in a uranium kidney burden of 1.4 µg [48 µg x 0.03, percentage where child kidney reaches equilibrium)]. The weight of both kidneys in a child is about 100 g; therefore, the uranium concentration per gram of kidney tissue to be 0.01 µg/g. The calculated kidney uranium concentration for adults and children is above the level found to cause harm in published studies.

ATSDR’s health-based guidelines for ingested (and inhaled) uranium are lower than the lower limit threshold for kidney toxicity proposed by [Morris and Meinhold 1995]. ATSDR’s guidelines are derived by use of levels of toxicity observed in animal studies, and those guidelines incorporate safety factors to account for uncertainty in extrapolating from animals to humans and to protect the most sensitive human individuals [ATSDR 2013].

Note that urinalysis has limitations as a test for kidney toxicity. First, the presence of substances in urine may indicate that kidney damage has occurred, but it cannot be used to determine whether the damage was caused by uranium. Second, most uranium leaves the body within a few days of exposure, so that urine tests can be used only to determine whether exposure has occurred in the past week or two. Finally, the tests may be used to detect mild effects on the kidney, but such effects are generally transient in nature and may not result in permanent damage. More severe effects involve greater damage to the kidney that is likely to be clinically manifest and longer lasting. The kidney has incredible reserve capacity and can recover even after showing pronounced clinical symptoms of damage; however, biochemical and functional changes can persist in a kidney that appears to have recovered structurally [Leggett 1989, 1994; CDC 1998].

The maximum average uranium concentration detected in a private well was 0.048 mg/L, or 48 µg/L. The residence where this concentration was detected is not connected to the municipal water supply and is noted to use a private well for personal consumption. Drinking water from this private well containing uranium would result in an estimated dose of 0.001 mg/kg/day for an adult and 0.003 mg/kg/day for a child. The adult and child doses are greater than the MRL of 0.0002 mg/kg/day for an intermediate-duration oral exposure. The MRL level for intermediate-duration oral exposure is also protective for chronic-duration oral exposure because the renal toxicity of uranium exposure is more dependent on the dose than on the duration of the exposure. The MRL is based on a LOAEL of 0.06 mg U/kg/day for renal effects in rabbits.

Although older evaluations suggested carcinogenicity of uranium among smokers, the U.S. EPA has withdrawn its classification for carcinogenicity for uranium; the International Agency for Research on Cancer (IARC) and the National Toxicology Program (NTP) have no ratings [NHANES 2005].

D. Soil Pathway: Surface Soil near Cotter Mill and in Lincoln Park

As discussed above, surface soil samples were collected from areas around the Cotter Mill property, from property access roads and in the Lincoln Park area. Surface soil sampling data were available from eight designated zoned areas (A-H) around Cotter Mill and in the Lincoln Park community. People who live or recreate in these areas could accidentally ingest some contaminated soil or get it on their skin. ATSDR evaluated these potential exposure scenarios to determine if concentrations of chemicals and radionuclides in soil are high enough to cause adverse health effects.

The vacant area between the Cotter Mill property and the residential areas has been designated as a “buffer zone”. The area east and west of Cotter Mill is referred to as the nonresidential area for purposes of this evaluation. Small children were not assumed to access the soil in this area because these areas are primarily industrial or vacant (zoned areas A-G, excluding H). ATSDR assumed that the average adult or adolescent in these nonresidential areas would accidentally ingest 100 milligrams of soil per day and would also contact the contaminated soil with their skin (dermal).

A residential exposure scenario was used to evaluate potential exposures in Lincoln Park and in Zone H (See Figure 18), which contains a small residential area north and west of the facility, adjacent to the Shadow Hills Golf Club. For Lincoln Park and Zone H, we assumed that a small child would ingest 200 mg of soil per day, and an adult would ingest 100 mg/day, for 350 days per day and would also contact the contaminated soil with their skin (dermal).

Maximum concentrations of arsenic, cadmium and lead exceeded their comparison values in soil taken from the zoned areas (A-G) near Cotter Mill; average concentrations of arsenic and cadmium exceeded their comparison values from the same area. Radium-226 was the only radionuclide to exceed its comparison value in soil near Cotter Mill.

Maximum and average concentrations of arsenic exceeded its comparison value in soil in the community of Lincoln Park. Maximum and average concentrations of lead in Zone H, which is considered residential, exceeded the comparison value for lead.

The highest average concentration of arsenic (Zone A), cadmium (Zone F), and radium-226 (Zone B) was used to estimate exposure doses for soil in nonresidential areas near Cotter Mill. The highest average concentration of arsenic and cadmium in Lincoln Park and Zone H, respectively, was used to estimate exposure doses for soil in a residential setting. If the highest average concentration of a chemical would not result in adverse health effects, it follows that lower concentrations of the chemical would not as well.

1. Soils Near Cotter Mill (Zones A-G, excluding H)

a) Arsenic

Arsenic is a naturally occurring element that is widely distributed throughout the earth's crust and may be found in air, water, and soil [ATSDR 2000]. Arsenic in soil exists as inorganic and organic arsenic. Generally, organic arsenic is less toxic than inorganic arsenic, with some forms of organic arsenic being virtually non-toxic. Inorganic arsenic occurs naturally in soil and in many kinds of rock, especially in minerals and ores that contain copper and lead. Arsenic has also historically been used in a variety of industrial applications, including bronze plating, electronics manufacturing, preserving animal hides, purifying industrial gases, and mining, milling and smelting activities. In the past, arsenic was used as a pesticide, primarily on cotton fields and in orchards. Arsenic concentrations in soil range from about 1 to 40 ppm, with an average of 5 ppm. However, soils in the vicinity of arsenic-rich geological deposits, some mining and smelting sites, or agricultural areas where arsenic pesticides had been applied in the past may contain much higher levels of arsenic. People may be exposed to arsenic in soil by eating soil or by direct skin contact [ATSDR 2007].

The estimated dose of arsenic for adolescents and adults in nonresidential areas near the mill is 0.00002 mg/kg/day. This dose is lower than the chronic Minimal Risk Level (MRL) of 0.0003 mg/kg/day for arsenic; therefore, non-cancer health effects are not likely from being exposed to arsenic in surface soil near Cotter Mill (Zones A through G in Figure 18).

The U.S. Environmental Protection Agency (EPA), the International Agency for Research on Cancer (IARC), and the National Toxicology Program (NTP) classify arsenic as a human carcinogen. The EPA has developed an oral cancer slope factor to estimate the excess lifetime risk for developing cancer. Using EPA's cancer slope factor for arsenic, and based on a 30 year exposure scenario to the average concentration in soil, ATSDR calculated a lifetime estimated cancer risk level of 1×10^{-5} (1 additional cancer per 100,000 people exposed) for exposure to arsenic in soil near Cotter Mill. Qualitatively, we interpret this as a low increased lifetime risk of developing cancer. Stated another way, an adult who lives at their property with arsenic in soil has an estimated cancer risk of 1 in 100,000. It should be pointed out that the cancer risk for adults is higher than for children because adults were assumed to have 30 years of exposure while children were only assumed to have 6 years of exposure.

The U.S. EPA generally considers an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} (1 in 10,000) and 10^{-6} (1 in 1,000,000) as an acceptable range. That means regular exposure to a substance would lead to one additional case of cancer per ten thousand to one additional case of cancer per one million people exposed.

b) Cadmium

Cadmium is a natural element in the earth's crust. All soils and rocks, including coal and mineral fertilizers, contain some cadmium. Most cadmium used in the United States is extracted during the production of other metals like zinc, lead, and copper. Cadmium enters soil, water, and air from mining and smelting operations, application of phosphate fertilizers, fossil fuel combustion, waste incineration and disposal, and burning coal [ATSDR 2008a]. In the United States, for nonsmokers the primary source of cadmium exposure is from the food supply. People who regularly consume shellfish and organ meats will have higher exposures. In general, leafy vegetables such as lettuce and spinach, potatoes and grains, peanuts, soybeans, and sunflower seeds contain high levels of cadmium [ATSDR 2008b].

The estimated dose for adolescents and adults for cadmium is 0.00002 mg/kg/day, which is lower than the MRL of 0.0001 mg/kg/day for cadmium; therefore, non-cancer adverse health effects are not likely. The U.S. Department of Health and Human Services (DHHS), IARC, and EPA have determined that cadmium is probably carcinogenic to humans. Although cadmium can be carcinogenic when inhaled, human or animal studies have not provided sufficient evidence to show that cadmium is a carcinogen by oral routes of exposure [ATSDR 1999b]. Therefore, a cancer evaluation for cadmium was not done as part of this assessment.

c) Radium-226

The average concentrations of radium-226 detected in Zones A and B are higher than allowed by the Uranium Mill Tailing Act (UMTRA). That standard does not apply in this case, since the Cotter Mill is still considered active.

The highest average soil concentration of 9.2 pCi/g in surface soil would result in a dose from radium's decay gammas of 58 mrem per year above background, assuming that residents spend 12 hours per day 365 days per year sitting or lying on the highest measured radium concentration of 9.2 pCi/g on the haul road. Since Zones A and B are buffer areas (actually haul roads), the time spent in these areas would be much lower (less than 2 hours per day) and the resulting dose would be roughly 10 mrem per year above background, to a maximally exposed individual.

2. Soil in Lincoln Park and residential area northwest of Cotter Mill

a) Arsenic

The estimated arsenic dose for an adult in Lincoln Park is 0.00007 mg/kg/day, which is a factor of ten lower than the chronic MRL of 0.0003 mg/kg/day for arsenic. The estimated arsenic dose for a child in Lincoln Park is 0.0005 mg/kg/day, which is slightly greater than the MRL. Children tend to have higher arsenic doses than adults because 1) children are more likely to be exposed to certain media (e.g., soil, surface water, etc.) because they play outdoors; 2) children are shorter than adults, which means they can are closer to the ground; and 3) children are smaller than adults, therefore childhood exposure results in higher doses of chemical per body weight. Adults are not expected to experience adverse health effects from exposure to arsenic in soil in Lincoln Park. Children's arsenic exposures in Lincoln Park require additional evaluation.

To evaluate children's exposures more closely, ATSDR compared the doses to known toxicological values, starting with the No Observable Adverse Effect Levels (NOAEL) and (Lowest Observed Adverse Effect Level) LOAEL used to derive the MRL. If the estimated doses are well below a NOAEL or LOAEL that is based on a human study, the likelihood for an adverse health effect in the exposed population would be low. The chronic oral MRL of 0.0003 mg/kg/day for inorganic arsenic was derived by dividing the identified chronic NOAEL of 0.0008 mg/kg/day (obtained from human epidemiologic studies) by an uncertainty factor of three to account for the lack of data on reproductive toxicity and to account for some uncertainty as to whether the NOAEL accounts for all sensitive individuals [ATSDR 2007]. The LOAEL associated with these epidemiologic studies was 0.014 mg/kg/day, where exposure to arsenic above this level resulted in hyperpigmentation of the skin, keratosis (patches of hardened skin), and possible vascular complications [ATSDR 2007]. The estimated exposure dose for children approaches the NOAEL, but is well below the LOAEL dose which caused adverse health effects.

Studies of background levels of arsenic in soils have revealed that background concentrations range from 1 ppm to 40 ppm, with average values around 5 ppm [ATSDR 2007]. Based upon a data set developed by EPA Region 8, background soil arsenic concentrations in Colorado range from 3 to 19 ppm, with an average of 11 ppm [CDPHE 2010].The average and maximum arsenic concentrations detected in Lincoln Park were 44 ppm and 50 ppm, respectively.These concentrations are the higher than the average background concentration.

Although the arsenic concentrations are higher than background concentrations for the state of Colorado, this fact alone does not definitely point to a man-made or site-related source for the arsenic. Uncertainty exists regarding whether the arsenic levels detected are a natural occurrence or from past milling operations in the area.

Several factors contribute to whether people have contact with contaminated soil, including:

- grass cover, which is likely to reduce contact with contaminated soil when grass cover is thick but increase contact with soil when grass cover is sparse or bare ground is present,
- weather conditions, which is likely to reduce contact with outside soil during cold months because people tend to stay indoors more often,
- the amount of time someone spends outside playing or gardening, and
- people's personal habits when outside, for instance, children whose play activities involve playing in the dirt are likely to have greater exposure than other children

Using EPA's cancer slope factor for arsenic, and based on a 30 year exposure scenario, ATSDR calculated a lifetime estimated cancer risk level of 4 x 10^{-5} (4 additional cancers per 100,000 people exposed) for exposure to arsenic in Lincoln Park. Qualitatively, we interpret this as a low to moderate estimated increased lifetime risk of developing cancer. Stated another way, an adult who lives at their property with arsenic in soil has an estimated cancer risk of 4 in 100,000. It should be pointed out that the cancer risk for adults is higher than for children because adults were assumed to have 30 years of exposure while children were only assumed to have 6 years of exposure.

The U.S. EPA generally considers an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} (1 in 10,000) and 10^{-6} (1 in 1,000,000) as an acceptable range. That means regular exposure to a substance would lead to one additional case of cancer per ten thousand to one additional case of cancer per one million people exposed.

b) Cadmium

The estimate dose for adults for cadmium is 0.00005 mg/kg/day. The estimated dose for children for cadmium is 0.0003 mg/kg/day, which is greater than the chronic MRL of 0.0001 mg/kg/day for cadmium. Therefore, further evalution is required for children exposed to cadmium in soil in residential areas.

The toxic effects of chronic cadmium exposure occur primarily to the bone, lungs and kidneys. Pulmonary effects are associated solely with inhalation exposures, while the kidney effects may occur after either oral or inhalation exposures. Using a number of large-scale environmental exposure studies and an uncertainty factor of 3, ATSDR used 0.0003 mg/kg/day to establish the chronic MRL of 0.0001 mg/kg/day [ATSDR 2008b]. The EPA used a toxicokinetic model to determine the level of chronic human oral exposure that would result in the highest renal cadmium level not associated with significant proteinuria (200 µg/g wet weight). Assuming 2.5% absorption of cadmium from food and 5% from water, the model predicts a NOAEL for chronic cadmium exposure of 0.01 mg/kg/day from food and 0.005 mg/kg/day from water. Based on these NOAELs and an uncertainty factor of 10, the EPA calculated a chronic oral reference dose (RfD) of 0.001 mg/kg/day for food and an equivalent RfD for cadmium in water of 0.0005 mg/kg/day. After comparing the estimated child exposure dose for cadmium to effect levels in critical studies, ATSDR does not expect children in residential areas to experience adverse health effects.

The U.S. Department of Health and Human Services (DHHS), IARC, and EPA have determined that cadmium is probably carcinogenic to humans. Although cadmium can be carcinogenic when inhaled, human or animal studies have not provided sufficient evidence to show that cadmium is a carcinogen by oral routes of exposure [ATSDR 1999b]. Therefore, a cancer evaluation for cadmium was not done as part of this assessment.

c) Lead

Maximum lead concentrations in zones F, G and H are 800 ppm, 450 ppm, and 1,400 ppm,[16] respectively. The highest average concentration of lead detected in any of the zones (Zone H) is 445 ppm.

The *1998 Supplemental Human Health Risk Assessment* provides the only characterization of surface soils adjacent to the Cotter Mill property (See Figure 18, Zones A through H). The soil sample results in this report were generated by collecting four samples from the center of a grid and compositing the samples to form a single representative sample. The size of each sampled grids, however, appears to be larger than 100 x 100 feet, which is the size that triggers additional sampling for lead [EPA 1995]. Although the sampling in the *1998 Supplemental Human Health Risk Assessment* measured contamination in soils at several properties near Cotter Mill, it does not allow ATSDR to evaluate contamination in individual exposure units (yards, playgrounds, etc), as would be required to accurately assess exposures in a residential, commercial or recreational setting. Therefore, ATSDR recommends additional sampling for lead on residential properties located northwest of the mill (in Zone H). Additional sampling for lead should be considered if any of the areas closest to Cotter Mill are expanded for residential use in the future.

In January 2012, the Centers for Disease Control and Prevention (CDC) Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) recommended that CDC adopt the 97.5 percentile for children 1 to 5 years old (currently 5 micrograms per deciliter, µg/dL) as the reference value for designating elevated blood lead levels in children. In the fall 2012, CDC adopted the ACCLPP's recommendation and now uses a reference level of 5 µg/dL to identify children whose blood lead levels are higher than most children's levels and who require follow-up. The reason for the change is that recent scientific research has shown that blood lead levels below 10 µg/dL cause serious harmful effects in young children, including neurological, behavioral, immunological, and development effects. In children, there is *sufficient* evidence that blood Pb levels less than 5 µg/dL are associated with increased diagnosis of attention-related behavioral problems. Specifically, lead causes or is associated with decreases in intelligent quotient (IQ), attention deficit hyperactivity disorder (ADHD), deficits in reaction time, visual-motor integration, fine motor skills, withdrawn behavior, lack of concentration, sociability, deceased height, and delays in puberty, such as breast and pubic hair development, and delays in menarche [ACCLPP 2012]. ***Since there is no known safe level of lead in the blood, ATSDR and CDC recommend reducing lead exposure wherever possible.***

E. Surface Water: Sand Creek, DeWeese Dye Ditch, and the Arkansas River

People who swim or wade in the surface waters of Sand Creek, the DeWeese Dye Ditch, or the Arkansas River will get surface water on their skin and they might also accidentally swallow some of the surface water. To estimate exposures to adults and children who may have come into contact with contaminated surface water, ATSDR assumed that adults and children will swallow 50 mL of water per hour while swimming or wading, for 104 days per year for 30 and 6 years, respectively. Molybdenum exceeded its comparison value in Sand Creek and the Arkansas River.

---

[16] An EPA soil default value of 400 ppm was commonly used in the past to determine if lead should be evaluated further. However, ATSDR no longer uses this value to evaluate lead in soil in residential properties. ATSDR recommends reducing lead exposure whenever possible.

Manganese exceeded its comparison value in Sand Creek and the DeWeese Dye Ditch. ATSDR conservatively selected the maximum concentration for each chemical to estimate exposures.

1. Manganese

The estimated exposure dose for manganese is 0.0007 mg/kg/day for adults and 0.0006 mg/kg/day for children. Both adult and child doses are considerably lower than the EPA oral reference dose (RfD) of 0.05 mg/kg/day for manganese. Therefore, no adverse health effects are expected to occur as a result of exposure to manganese in surface waters.

2. Molybdenum

The estimated exposure dose for molybdenum is 0.00002 mg/kg/day for adults and 0.00006 mg/kg/day for children. Both adult and child doses are below the oral RfD of 0.005 mg/kg/day for molybdenum. Therefore, no adverse health effects are expected to occur as a result of exposure to molybdenum in surface waters.

F. Homegrown Fruits and Vegetables

Ingestion of contaminated foods is a potential exposure pathway for this site. Residents may have been exposed to contaminants when they ate homegrown fruits and vegetables after using contaminated groundwater (either surface water or private well water) to irrigate their crops, or after growing their crops in contaminated soil. The soil may become contaminated from contaminated water or from tailings, dusts and other wastes deposited in the soil in the past.

Eating fruits, vegetables, herbs, or other produce grown in gardens with contaminated soil can result in exposure. Some plants slowly absorb small amounts of the chemicals found in soil into their tissue. Also, contaminated soil can adhere to the exterior surface of produce, particularly low-growing leafy produce or produce where the underground portion is eaten. Some of the absorbed chemicals are essential nutrients and are actually good for humans to eat, but other chemicals can present health hazards if they are found at high enough levels and are consumed on a regular basis.

Generally, there is not a strong relationship between levels of heavy metals in soils and plants [Vousta, et.al. 1996]. The uptake of heavy metal concentration depends on speciation of metal, soil characteristics, the type of plant species and other characteristics [Laizu 2007]. Table 8 below developed by Sauerbeck (1988) provides a qualitative guide for assessing heavy metal uptake into a number of plants.

Table 8. Plant Uptake of Heavy Metals

High	Moderate	Low	Very Low
Lettuce	Onion	Corn	Beans
Spinach	Mustard	Cauliflower	Peas
Carrot	Potato	Asparagus	Melons
Endive	Radish	Celery	Tomatoes
Crest		Berries	Fruit
Beet			
Beet leaves			

Source: USEPA (1991), Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors."

To address the concern regarding contaminated crops, residents contributed locally grown produce for sampling analysis. ATSDR used the sampling results to estimate an exposure dose for each contaminant using typical consumption rates for the average and above-average (95th percentile) consumer in the Western United States. Child and infant consumption rates were also used to assess exposures to these vulnerable populations. Table 9 below provides the consumption rates used by ATSDR for homegrown fruits and vegetables.

Table 9. Homegrown Fruit and Vegetable Consumption Rates for the Western United States

Food	Consumer Type†	Intake Rate (g/kg/day)	Standard Error
Homegrown fruits	Average consumer**	2.62	0.3
	Above-average consumer**	10.9	
	Child	4.1	NA
	Infant (1 to 2 years)	8.7	
Homegrown vegetables	Average consumer**	1.81	0.1
	Above-average consumer**	6.21	
	Child	2.5	NA
	Infant (1 to 2 years)	5.2	

Sources: EPA Exposure Factors Handbook, Volume II, 2011; Child-Specific Exposure Factors Handbook, 2008
g/kg/day = grams per kilogram per day
NA = not applicable

†An average consumer is represented here as a person who eats fruits and vegetables in the typical range (mean intake); defined as eating approximately 1 ½ cups of fruits and vegetables per day. An above-average consumer is a person who eats more fruits and vegetables than is average, represented by the 95th percentile intake, defined here as eating approximately 5 or more cups of fruits and vegetables per day. A percentile rank of 95 indicates that only 5% of the population eats more fruits and vegetables than this person.

** EPA's 2011 Exposure Factors Handbook was published in September 2011 after the release of the public comment version of this document. The 2011 intake rates for the average and above-average consumer are the same as the previously reported 1997 rates.

All of the estimated fruit and vegetable doses were below health guideline values except for those for arsenic (See Table C5 in Appendix C). The estimated doses for fruits for the above-average consumer (95th percentile intake rate) and for infants exceed the chronic health guideline 0.0003 mg/kg/day for arsenic. The above-average consumer and infant doses for fruit are 0.0006 mg/kg/day and 0.0004 mg/kg/day, respectively. Also, the estimated doses for vegetables for the above-average consumer (95th percentile intake rate) and for infants exceed the chronic health guideline for arsenic. The vegetable doses are 0.0005 mg/kg/day for an above-average consumer and 0.0004 mg/kg/day for an infant. These doses exceed the chronic oral MRL of 0.0003 mg/kg/day for arsenic.

Next, ATSDR assumed that a person will eat both fruits and vegetables daily. To do this, we added the calculated doses for fruits and vegetables to derive a single dose. The estimated fruit and vegetable doses for the above-average consumer, child and infant exceed the health guideline of 0.0003 mg/kg/day for arsenic. The above-average consumer dose is 0.001 mg/kg/day; the child dose is 0.0004 mg/kg/day; and the infant dose is 0.0008 mg/day/day.

The chronic oral MRL of 0.0003 mg/kg/day for inorganic arsenic was derived by dividing the chronic No Observable Adverse Effect Level (NOAEL) of 0.0008 mg/kg/day (obtained from human epidemiologic studies) by an uncertainty factor of 3 to account for the lack of data on reproductive toxicity and to account for some uncertainty as to whether the NOAEL accounts for all sensitive individuals [ATSDR 2007]. The Lowest Observed Adverse Effect Level (LOAEL) associated with these epidemiologic studies was 0.014 mg/kg/day, where exposure to arsenic above this level resulted in hyperpigmentation of the skin, keratosis (patches of hardened skin), and possible vascular complications [ATSDR 2007]. The child and infant doses are below or equal to the NOAEL, and the above-average consumer dose is 14 times lower than the dose that caused adverse health effects in epidemiologic studies. Therefore, non-cancer adverse health effects are not expected in infants, children or the above-average consumer.

Using EPA’s cancer slope factor for arsenic and the average and the above-average consumer exposure doses, ATSDR calculated a estimated lifetime cancer risk of 1 x 10^{-4} (1 additional cancers per 10,000 people exposed) and 6 x 10^{-4} (6 additional cancers per 10,000 people exposed), respectively, for exposure to arsenic in fruits and vegetables. Qualitatively, we interpret this as a moderate increased risk of developing cancer over a lifetime. Stated another way, an adult who eats a lot of homegrown fruits and vegetables contaminated with arsenic has an estimated cancer risk of 6 in 10,000. The U.S. EPA generally considers an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} (1 in 10,000) and 10^{-6} (1 in 1,000,000) as an acceptable range. That means regular exposure to a substance would lead to one additional case of cancer per ten thousand people exposed to one additional case of cancer per one million people exposed.

ATSDR noted that the highest arsenic level detected in lawns and gardens in Lincoln Park was 50 ppm. This level is near what is typically observed as background arsenic levels (1 ppm to 40 ppm) in soil. This suggests that the contaminated well water used to irrigate crops may not be contributing significantly to arsenic soil levels, or that other soil additives may have been added that dilute soil contamination [ODEQ 2003]. The highest arsenic level detected in soil at the site was 86 ppm. There were no sampling data for arsenic in drinking or irrigation water. Therefore, ATSDR is unsure if the arsenic found in soil at this site is a natural occurrence or from an anthropogenic (man-made) source.

Plants vary in the amount of arsenic they absorb from the soil and where they store arsenic. Some plants move arsenic from the roots to the leaves, while others absorb and store it in the roots only [Peryea 1999]. The best method of reducing exposure to external arsenic from home-grown vegetables is to soak and wash residual soil from produce before bringing it into the home and washing the produce again thoroughly indoors before eating [ATSDR 2007]. It is always a good health practice to wash all fruits and vegetables thoroughly before eating, whether they are store-bought or homegrown.

Molybdenum was the only other contaminant to approach a health guideline when calculating a single dose for fruits and vegetables. The above-average consumer and infant doses are 0.005mg/kg/day, which is equal to the chronic health guideline of 0.005mg/kg/day for molybdenum. Therefore, molybdenum in fruits and vegetables is not likely to cause noncancer health effects.

G. Air Pathway

ATSDR looked at all the air data collected from 1979 to present. Concentrations of radionuclides in air from direct release or re-suspension of radioactive contaminants in soil were less than a tenth of ATSDR's health based comparison value (100 millirem per year) at all off-site sampling locations (CC-1/2, LP-2, AS-210, AS-212, OV-3). ATSDR evaluated doses to all age groups and found that adults would have received the highest doses, because of their higher breathing rate. Infants only received one quarter the dose of an adult.

Table 10 below breaks down the dose estimates by age group and by the highest annual concentration measured for each radionuclide and by the highest location. The two highest doses were both in 1982, during the excavation of the unlined settling ponds and were measured at the on-site sampling location AS-204, that was directly adjacent to the dewatered ponds. Neither of those doses would have been to the public. The combined dose to a worker near AS-204 would have been less than a third of the sum in the table since the worker was there less than 8 hours per day for 5 days a week, or 70 mrem of inhalation dose for the year 1982, while the numbers in Table 10 reflect 24/7 exposure through the year. Doses listed in Table 10 did not result in any elevated exposures to the public.

Table 10. Annual Effective Doses by Highest Concentration, Location and Age Group

Radionuclide	Highest Year	Highest Location	Concentration (µCi/ml)	Dose to Infant (mrem/yr)	Dose to Adult (mrem/yr)	Notes
Natural Uranium (µCi/ml)	1979	AS-204	2.48E-14	2.72	5.97	
Thorium-230 (µCi/ml)	1982	AS-204	8.95E-14	71.57	272.68	
Thorium-232 (µCi/ml)	2001	CC#2	8.33E-17	0.07	0.27	
Radium-226 (µCi/ml)	1985	AS-202	9.63E-15	1.25	2.75	

Lead-210 (µCi/ml)	1982	AS-204	9.95E-14	7.01	16.77	Dose from Radon Progeny
Radon-220/222 (pCi/l)	2004	AS-202	1.50E+00	NA	NA	No dose from Radon

µCi/ml is one millionth of a Curie of activity per one thousandth liter of air.
mrem/yr is one thousandth of a rem of wholebody effective radiation dose in a year.

Most of the calculated inhalation dose was from the isotope Thorium-230 (Th-230). Table 11 below lists just the dose from Th-230 for the highest annual average concentration at each sampling station. Again, it can be seen that the on-site concentrations are consistently orders of magnitude higher than at off-site locations in Cañon City, Lincoln Park and west of the site boundary.

Outdoor concentrations of radon contributed zero dose to the public, because it is a noble gas and does not stay in the lungs long enough to radioactively decay. On the other hand, the dose from radon decay products (e.g., lead-210) attached to respirable dust held constant year over year and accounted for an annual inhalation dose of four to seven millirem. Radon decay product concentration off-site did not appear to be related to releases from the site. Radon and its decay products appear to be from natural background and do not represent any health threat at the 66 reported concentrations.

Table 11. Annual Doses from Thorium-230 by Location and Year

Year	Highest Location	Concentration (µCi/ml)	Annual Dose to Infant (mrem/yr)	Annual Dose to Adult (mrem/yr)
1982	AS-204	8.95E-14	71.57	272.68
1982	AS-202	2.12E-14	16.95	64.59
1983	AS-203	9.79E-15	7.83	29.83
1982	AS-206	1.26E-14	10.08	38.39
2000	AS-209	4.16E-15	3.33	12.67
2005	AS-210	4.85E-16	0.39	1.48
2000	AS-212	6.69E-16	0.53	2.04
1982	LP-1/2	7.49E-16	0.60	2.28
1982	CC-1/2	9.18E-16	0.73	2.80
1982	OV-3	3.15E-15	2.52	9.60

µCi/ml is one millionth of a Curie of activity per one thousandth liter of air.
mrem/yr is one thousandth of a rem of wholebody effective radiation dose in a year.

VI. COMMUNITY HEALTH CONCERNS

Responding to community health concerns is an essential part of ATSDR's commitment to public health. The community associated with a site is both an important resource for and a key audience in the public health assessment process. Community members can often provide information that will contribute to the quality of the health assessment. Therefore, during site visits and telephone conversations with community members, ATSDR obtained information from the community regarding their specific health concerns related to the site. The community health concerns addressed here are different from the comments received during the public comment period for this document. Public comments are addressed in the Response To Comments section in Appendix E.

In some cases, ATSDR was unable to address a community health concern because 1) adequate scientific information on the particular health effect is not available or is limited, or 2) the available scientific data are insufficient to assess whether the specific health effect is related to exposure to a particular chemical. Where feasible, ATSDR addressed the health concerns identified by the community. Below is a summary of the community concerns and ATSDR's response to those concerns.

1. How did the 1965 flood event affect my health?

In June 1965, a flood caused the unlined tailings ponds at the Cotter Mill to overflow into Lincoln Park. This occurred prior to the construction of the SCS Dam in 1971. According to the residents, water flowed north through the gap in the ridge, down Pine Street, and ultimately down 12th Street (Sharyn Cunningham, CCAT, personal communication, February 2008). There is concern that this flood event contaminated groundwater wells and that dust from soil or tailings may have been resuspended by wind and distributed in Lincoln Park. Community members are very concerned that current illnesses may be a result of this tailings pond flood event.

There is documentation that ponds at the Cotter Mill historically overflowed, which led to the construction of the SCS Dam. Aerial photography from October 1970 indicates that one of the evaporation ponds overflowed into an alluvial channel tributary to Sand Creek [Wilder et al. 1983]. A chronology compiled by CDPHE states that in October 1970 and January 1971, an evaporation pond overflowed with high levels of total dissolved solids, sodium, molybdenum, sulfate, and high radiation [CDPHE 1975].However, since the construction of the SCS Dam, there are no recorded surface water discharges past the dam [GeoTrans 1986].

ATSDR tried to locate data to evaluate the potential health effects resulting from this flood event. No data from 1965 or 1966 exist in the CDPHE database. The *1986 Remedial Investigation* [GeoTrans 1986] states that off-site groundwater contamination in the Lincoln Park areas was first identified in 1968; therefore, any data prior to 1968 are unlikely to exist. The only data ATSDR found related to this flood event were from a sediment sample collected in January 2003 [CDPHE 2003]. To address community concerns, CDPHE collected a sample of suspected flood sediment from Pine Street near Elm Avenue. This area was identified by a property owner who was present during the flood. The sample was collected from two locations. About 250 grams of soil were collected from each location to a depth of approximately 18 inches. No obvious soil horizons were identified, and no significant differences in gamma radiation were noted between shallow and deep soils. The results are presented in Table 12, below. Where a comparison value is available, all concentrations are below the comparison value. Additionally, if this one sample was representative of the material moved by the floodwaters, it would not cause any adverse health effects.

Table 12. Concentrations found in a suspected flood sediment sample, January 2003

Chemical	**Concentration (ppm)**	**Comparison Value (ppm)**	**CV Source**
Lead	87	Not available	
Molybdenum	Not detected	300	RMEG, child
Uranium	1.6	100	iEMEG, child
Radionuclide	**Concentration (pCi/g)**	**Comparison Value (pCi/g)**	
Cesium-137	0.12	Not available	
Lead-210	2.2	Not available	
Plutonium-239, 240	Not detected	Not available	
Potassium-40	22.5	Not available	
Radium-226	2.2	15	UMTRCA
Radium-228	1.3	15	UMTRCA

ppm is one gram of contaminant in a million grams of soil.
pCi/g is one millionth of one millionth of a Curie of activity in a gram of soil.
RMEG – reference dose media evaluation guide
iEMEG – intermediate environmental media evaluation guide
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Source: CDPHE 2003

2. Were an adequate number of soil samples collected during the *1998 Supplemental Human Health Risk Assessment*?

The community expressed concern that not enough samples were collected during the *1998 Supplemental Human Health Risk Assessment*. Weston, a contractor for Cotter, collected surface soil samples (0-2 inches) from eight zones around the mill property (see Figure 18). Each zone was divided into 8 to 12 grids. Four samples were collected near the center of each grid and were composited (i.e., combined and mixed) to form a single representative sample [Weston 1998]. The dates the samples were collected were not specified in the report; however, it is assumed to be in the 1994–1996 timeframe. In 1995, EPA released guidance for obtaining representative soil samples at Superfund sites [EPA 1995]. The systematic grid sampling approach used by Weston conforms to EPA's guidance for delineating the extent of contamination. The number of samples taken from each grid for compositing, however, is not entirely consistent with EPA's guidance. For grids larger than 100 x 100 feet, which it appears that the grids established by Weston are, EPA recommends collecting nine aliquots from each grid. Compositing four aliquots from each grid is recommended for grids smaller than 100 x 100 feet [EPA 1995]. Because the timeframe of the sampling is unclear, it is not known whether EPA's 1995 guidance was available during Weston's sampling effort, but appear to be adequate.

3. Are there high levels of thorium near the Black Bridge?

The community expressed concern that high thorium levels were detected in surface water near the Black Bridge. This bridge is located where a railroad spur crosses the Arkansas River between the 4th Street and 9th Street bridges. The closest sampling location in the Arkansas River is upstream at 1st Street (907). Thorium-230 was sampled at this location as part of the surface water monitoring program between 1995 and 2007. These data are summarized below in Table 13. The highest thorium-230 concentration detected was 2.5 picocuries per liter (pCi/L) (suspended sediment) in August 2007. This concentration is below levels known to cause adverse health effects. It should also be noted that the Black Bridge is located upstream of the confluence with Sand Creek.

Table 13. Thorium-230 data upstream of the Black Bridge

Chemical	Frequency of Detection	Minimum (pCi/L)	Average (pCi/L)	Maximum (pCi/L)
Thorium-230 (D)	121/127	-0.1	0.1	1
Thorium-230 (S)	115/120	0	0.2	2.5
Thorium-230 (T)	7/7	0.1	0.3	0.7

Source: CDPHE 2007b
Averages were calculated using ½ the reporting detection limit for non-detects.
Negative and zero result values were included in the summary statistics.
Thorium-230 “D” and “S” samples were collected between 1995 and 2007. Thorium-230 “T” samples were only collected in 1995.

D – dissolved
pCi/L – picocuries per liter
S – suspended
T – total

4. I grew up near the Cotter plant. Does this increase my risk of getting cancer?

Soil sampling data from the nearest residence to the Cotter plant did not indicate the presence of chemicals at levels above established guidelines. Soil sampling data from the Lincoln Park community did not reveal the presence of contaminants at levels associated with adverse health effects, including cancer. Air data do not indicate the presence of chemicals at levels associated with adverse health effects, including cancer.

However, if you drank water from a contaminated private well, you might be at increased risk for gout-like conditions, such as pain, swelling, inflammation and deformities of the joints. However, once exposure is stopped, the risk of this adverse health effect goes down. Also, people who eat a lot of fruits and vegetables from their garden may be at risk from exposure to arsenic. People who eat 5 cups or more per day of arsenic-contaminated homegrown fruits and vegetables may experience harmful effects.

5. I used water from my private well or surface water to irrigate my crops and garden vegetables. Am I going to get sick?

According to our very conservative evaluation, people who ate average amounts (defined as approximately 1 ½ cups per day) of homegrown fruits or vegetables that were irrigated with contaminated well water are not at increased risk for non-cancer health effects. However, people who eat more than the average amount of fruits and vegetables (95th percentile consumers, defined as eating approximately 5 cups or more per day) might be at increased risk for developing cancer over a lifetime. This conclusion is based on a person eating more fruits and vegetables than an average person every day for 30 years.

People who grew fruits and vegetables at their home and used their well water to irrigate their crops submitted crop samples for analysis. The analysis revealed that vegetables irrigated with well water did not cause a significant increase in contaminant levels [Weston 1998]. As a precaution, however, we recommend thoroughly washing all homegrown fruits and vegetables before eating them.

6. **I have lived in Lincoln Park since the 1960s. I know of many neighbors and family members who are sick. Is uranium from the mill making us sick?**

Uranium primarily acts as a heavy metal toxin. Renal toxicity is the main effect of uranium exposure, specifically to the proximal tubules of the kidney. We looked at CDC's Compressed Mortality Database "WONDER" looking specifically at specific modes of kidney failure that could be associated with uranium toxicity. Fremont County in Colorado had an age adjusted rate for renal failure as the cause of death of 7.1 per 100,000, for the years 1999-2006. The state average during that same period was 12.1 per 100,000[17]. Census track or zipcode level health outcome data is not readily available to ATSDR. From the available health outcome data, it does not appear that residents in the area have elevated rates of kidney disease, which could be associated with uranium exposure.

7. **My husband worked at the plant. Was I possibly exposed when he brought his dirty work clothes home?**

Workers in industrial settings have the potential to expose their household members to work-related chemicals if residues attach to the worker's clothing, skin, shoes, or in their vehicles and is inadvertently brought into the home. Whether and to what magnitude these take-home exposures actually occur depends on a number of factors, including the nature of the job held by the worker, the occupational practices of the industrial facility (e.g., providing workers with disposable gowns and gloves), and the precautions/practices of the worker and other family members. ATSDR did not evaluate potential exposures to workers' families because the data needed to quantitatively or qualitatively make a determination on potential health effects are not available.

8. **I used contaminated water from my private well water for many years as a potable (drinking water) source of water for my family. Are we now at risk for adverse health effects?**

The levels of molybdenum were high enough in some wells to potentially cause adverse health effects in individuals who were exposed for many years. Once exposure stops, the risk of adverse health effects goes down. Residents, particularly individuals who do not take in enough dietary

---

[17] Centers for Disease Control and Prevention, National Center for Health Statistics. Compressed Mortality File 1999-2006. CDC WONDER On-line Database, compiled from Compressed Mortality File 1999-2006 Series 20 No. 2L, 2009. Accessed at http://wonder.cdc.gov/cmf-icd10.html on Sep 30, 2009 10:42:05 AM

copper or cannot process copper correctly, might be at increased risk for gout-like conditions. The levels of other contaminants are too low to cause adverse health effects.

9. **Colorado Citizens Against Toxic Waste (CCAT) conducted a health survey and submitted it to ATSDR. Why didn't ATSDR use the results of this survey to determine if people are experiencing adverse health effects in the community?**

The community organization CCAT conducted a health survey in 2004–2005. The survey included responses from 239 individuals in the Lincoln Park area. Volunteers went door-to-door in Lincoln Park and the surrounding areas to administer the health surveys. Each person filled out a survey and submitted it to a volunteer. A tabulation of self-reported illnesses reported by respondents included: occurrences of cancer; lung, skin, central nervous system, kidney, and thyroid problems; reproductive issues (including chromosomal and congenital defects); autoimmune disease; psychological disorders; and gout. Although ATSDR could not use the survey to make conclusions about disease associations, we did use the survey results to focus our attention and pursue a more in-depth scientific analysis of the health conditions identified by the community.

While the CCAT health survey was a good effort by the community to examine the frequency of their various health concerns, there are many issues that make it of limited use in determining the health problems present in the entire community and their potential associations with exposure to environmental contaminants. Some of these issues include: 1) the use of a relatively small number of people surveyed which impacts our ability to see if the number of people with a disease is different than in other locations, 2) the people who completed the survey might not be representative of the population (people without health problems may have declined the survey), 3) the lack of medical verification of self-reported health outcomes, and 4) the need for individual-level exposure data. Also, many of the self-reported health outcomes measured in the survey are present in most populations and are related to several different potential causes beyond environmental exposures, such as lifestyle or genetics. Therefore, without any assessment of exposure, it is not possible to link the occurrence of disease to environmental concerns.

10. **CDPHE previously ordered Cotter to have all environmental samples analyzed by an external laboratory until Cotter could demonstrate that its laboratory had addressed various deficiencies. Why was this done and how did it affect the data used by ATSDR?**

Cotter's license requires the company to collect and report a wide range of environmental measurements. Cotter's own analytical laboratory conducted most of the measurements between the late 1970s and the present. The main exception is that an external analytical laboratory measured contamination levels in most of the samples collected in 2005 and 2006.

For many years, Cotter has participated in so-called "round robin" inter-laboratory performance evaluations. As part of these evaluations, selected environmental samples are split every calendar quarter and simultaneously sent to Cotter's laboratory and to three external analytical laboratories for analysis. The measurement results are then compared to assess the performance of Cotter's laboratory. CDPHE's website (http://www.colorado.gov/cs/Satellite/CDPHE-

HM/CBON/1251635122495) presents data from these inter-laboratory comparisons from 2007 to the present. Earlier comparisons are not readily available, mostly because Cotter's laboratory was not analyzing samples throughout much of 2005 and 2006 and data from earlier years have since been archived from CDPHE's website.

In September 2008, Cotter submitted a letter to CDPHE documenting five quarters of inter-laboratory comparisons for groundwater samples [Cotter 2008a]. These comparisons presented "round robin" data for more than two dozen substances or indicators, including uranium, molybdenum, selenium, nitrate, and selected radionuclides. In some cases, Cotter's laboratory tended to measure higher concentrations than the other participating laboratories; but in other cases, the opposite was observed. With one exception, the differences between the measurements made by the various laboratories fell within the acceptable variation range typically within the analytical method.

The exception is for molybdenum, for which Cotter's laboratory did not meet pre-established comparability limits for the "round robin" sampling. Specifically, in two out of the five quarters of samples that were collected, Cotter's laboratory did not meet the acceptable limits.[18] In contrast, the three external laboratories' molybdenum measurements met the pre-established comparability limits for all five quarters considered in this report. The table below presents the specific concentration measurements for the two quarters of interest, and these measurements show that (in these two instances) the molybdenum levels measured by Cotter were less than 50 percent of the average concentrations calculated from the three external laboratories' measurements.

After CDPHE requested that Cotter investigate the issue further, Cotter prepared a written response to the issue [Cotter 2009]. The response suggests that the poor performance on these samples resulted from the analytical method used. Cotter uses atomic adsorption to measure molybdenum levels in groundwater samples, and the external laboratories used a different method (inductively coupled plasma with mass spectrometry). When molybdenum concentrations are below roughly 0.5 mg/L, Cotter measures molybdenum by atomic adsorption *graphite furnace* analysis; but at higher concentrations, analysis is by atomic adsorption *flame* analysis. The two quarters with the poor comparisons both had concentration levels below 0.5 mg/L, leading Cotter to infer that the underreporting was associated with the graphite furnace analyses. In January 2009, Cotter proposed several measures that were believed to cause the graphite furnace analyses to perform better, and CDPHE approved of the proposed remedy.

Overall, the "round robin" studies have demonstrated that Cotter's analytical laboratory met pre-specified performance criteria for almost every one of the substances considered. Only for molybdenum was a performance issue noted, and it appears that Cotter's laboratory previously used a method that would understate molybdenum concentrations, but typically only when those concentrations were less than approximately 0.5 mg/L. This issue was observed for samples collected between January 2007 and March 2008, but it likely also affected earlier samples that Cotter's laboratory analyzed; and this negative bias should be considered in any uses of these

---

[18] CDPHE actually voiced concern about three quarters of Cotter's molybdenum data, even though only two of these three quarters did not meet the pre-established comparability limits.

data. Measurements collected since this timeframe likely do not exhibit the same negative bias, given the changes that Cotter proposed to its analytical methods.

Inter-Laboratory Comparison Results for Molybdenum (Groundwater): First Quarter 2007 & First Quarter 2008

Parameter	Analytical Laboratory			
	Cotter	**Laboratory #1**	**Laboratory #2**	**Laboratory #3**
Inter-Laboratory Comparison for First Quarter 2007				
Measurement 1 (mg/L)	0.012	0.0263	0.027	0.024
Measurement 2 (mg/L)	0.012	0.025	0.027	0.0232
Average (mg/L)	0.012	0.0257	0.027	0.0236
Avg across three comparison laboratories (mg/L)		0.025		
Inter-Laboratory Comparison for First Quarter 2008				
Measurement 1 (mg/L)	0.01	0.0281	0.029	0.0267
Measurement 2 (mg/L)	0.011	0.0274	0.029	0.0274
Average (mg/L)	0.011	0.0278	0.029	0.0271
Avg across three comparison laboratories (mg/L)		0.028		

Note: A mg/L is one milligram per liter or a part per million (ppm).
Every laboratory was supposed to analyze each sample twice, thus providing data allowing for intra-laboratory and inter-laboratory comparisons.

VII. CONCLUSIONS

ATSDR reached four important conclusions in this public health assessment:

1. Drinking water for many years from a private well that contains elevated levels of molybdenum and uranium could harm people's health. ATSDR concludes that drinking water from a contaminated private well is a past, current and potential future public health hazard.

   Private well sampling data collected from 1984 to 2007 revealed the presence of molybdenum at levels that could harm people's health. People who drank water from private wells impacted by the highest molybdenum contamination are at increased risk for health effects such as gout-like conditions, particularly individuals who do not take in enough dietary copper or cannot process copper correctly. People who drank water from private wells impacted by the highest uranium contamination are at increased risk for kidney damage.

   A water use survey was conducted in the Lincoln Park area in 1989. Survey results revealed that seven residences had private wells on their property for personal consumption. Five of the seven wells contained uranium or molybdenum concentrations above the drinking water standards. Between 1989 and 1993, Cotter connected affected private well users to the municipal water supply, although several residents opted to continue using their private wells.

   The 1989 water use survey was updated in 2008. Seven wells were identified as being used for personal consumption. One of the seven wells exceeded the drinking water standard for molybdenum. The owner of the well declined to be connected to the municipal water system. Therefore, a completed exposure pathway currently exists for people drinking water from contaminated private wells. Also, the groundwater is still contaminated and the contaminant plume can migrate to previously uncontaminated wells. Therefore, a future potential pathway also exists for private wells until the contamination in cleaned up and no one is drinking contaminated well water.

   In November 2008, an institutional control was established through the auspices of the Colorado State Engineer's Office. Section 37-92 of the Colorado Revised Statute requires permit approval prior to construction of a well. The notification procedure requires that the State Engineer's Office inform well applicants of potential contamination. In June 2010, the Uranium Processing Accountability Act was signed into law. The law requires Cotter to annually notify nearby residents with wells of the potential for contamination from the site.

2. Accidentally ingesting or touching soil or sediment in the community of Lincoln Park will not harm people's health.

   Soil and sediment in the residential community of Lincoln Park do not contain contamination at levels high enough to harm people's health. Additionally, ATSDR conducted Exposure Investigations (EIs) that focused assessments on 1) blood lead levels in children/residents living in Lincoln Park and 2) lead contaminated dust in homes and soil in Lincoln Park. The results of EIs did not indicate the presence of elevated levels of lead in residential indoor dust samples or soil at the sampled homes, or in the blood of occupants of those homes or in tested school children.

Soil on the residential properties north and west of Cotter Mill (adjacent to the Shadow Hills Golf and Country Club) is contaminated with high levels of lead. There is not enough information to evaluate whether lead contamination in this residential area will harm people's health. However, since there is no proven safe level of lead in the blood, ATSDR and CDC recommend reducing lead exposure wherever possible.

3. People eating an average amount of homegrown fruits and vegetables (defined as approximately 1½ cups per day) will not experience harmful health effects. However, people who eat a lot of fruits and vegetables (defined as approximately 5 cups per day) from their home garden may be at risk from exposure to arsenic. People who eat approximately 5 cups or more per day of arsenic-contaminated homegrown fruits and vegetables may experience harmful health effects. We cannot determine if the arsenic found in the fruits and vegetables is from site-related sources.

   Sampled homegrown fruits and vegetables indicate the presence of arsenic at levels that could cause a low increased cancer risk. The increased cancer risk is based on arsenic exposure to a person consuming more fruits and vegetables (95th percentile) than a typical consumer. The cancer estimate is very conservative because it assumes a person eats 5 cups or more of arsenic-contaminated homegrown fruits and vegetables every day for 30 years. The amount of arsenic-contaminated fruits and vegetables eaten by the average person is much less.

4. Ambient air emissions of particle-bound radionuclides have not resulted in exposures to the public at levels known to cause adverse health outcomes. With the exception of thorium-230 levels observed in 1981 and 1982, associated with excavation of contaminated tailings, every radionuclide monitored has been more than a factor of ten below annual dose-based health limits. The excavation releases appear to have only exposed on-site workers, but at levels below occupational limits at that time.

VIII. RECOMMENDATIONS

Based upon ATSDR's review of the environmental data and the concerns expressed by community members, the following recommendations are appropriate and protective of the health of residents in and around the Lincoln Park area.

- Continue to inform residents about the health risks associated with contaminated private wells and advise them to connect to the public water supply if possible. Inform residents who choose to continue to use their contaminated private wells of how to reduce their health risks and provide assistance with free/low-cost remedial measures available to reduce their exposures.

- Discontinue any household use of private wells containing levels of contaminants above drinking water standards. Landowners who are considering using the groundwater for livestock need to consult the state veterinarian before use.

- Wash crops from fruit and vegetable gardens thoroughly before eating them. This measure is a precaution to remove soil adhering to the surface of the produce. Do not irrigate crops with contaminated groundwater. Limit consumption of homegrown fruits to no more than 5 cups per day if you have elevated arsenic levels in your soil or irrigation/home well.

- Continue to investigate the nature and extent of groundwater contamination at the site.

- Continue monitoring the groundwater plume to assess whether additional private wells become impacted in the future. The 2008 water use survey revealed only one private well that exceeded a drinking water standard. However, consider monitoring all private wells that are used for personal consumption to ensure continued compliance with drinking water standards. Consider a sampling plan that allows comparison of results from one sampling event to the next (i.e., routinely sampling the same well for the same contaminants over time), and that includes testing for all site-related constituents, including VOCs.

- Make residential well data available to the public and to public health officials. This information would assist public health officials in evaluating current and future exposures.

- Consider testing for all chemical constituents, including VOCs, SVOCs, metals, and chlorinated hydrocarbons, in environmental media.

- Test for lead in soil in residential yards north and west of the Cotter facility. Take appropriate steps to prevent exposures, if necessary.

IX. PUBLIC HEALTH ACTION PLAN

The public health action plan for the site contains a description of actions that have been taken or will be taken by ATSDR or other government agencies at the site. The purpose of the public health action plan is to ensure that this document both identifies public health hazards and provides a plan of action designed to mitigate and prevent harmful human health effects resulting from exposure to the hazardous substances at this site.

Public health actions COMPLETED:

- ATSDR conducted site visits to gather community health concerns, to communicate to identified stakeholders, and to gather relevant site-related data;
- ATSDR performed two Exposure Investigations to 1) evaluate blood lead levels in children living in the Lincoln Park area, and 2) evaluate lead in dust in homes in the Lincoln Park area. These documents are available on our website at www.atsdr.cdc.gov.
- ATSDR conducted health-related educational activities in the community.

Public health actions PLANNED:

- ATSDR's Colorado Cooperative Program and Office of Regional Operations will initiate and implement appropriate follow-up activities at this site.

X. SITE TEAM

Teresa Foster, MPH
Environmental Health Scientist
Division of Community Health Investigations
Eastern Branch

Michael Brooks, CHP
Health Physicist
Division of Community Health Investigations
Eastern Branch, Regional Office

Debra Joseph, MHA
Community Involvement Specialist
Division of Community Health Investigations

Carla Galindo,* MPH
Health Education Specialist
Division of Health Assessment and Consultation
Health Promotion and Community Involvement Branch

Dawn Arlotta,* MPH, CHES
Health Education Specialist
Division of Health Assessment and Consultation
Health Promotion and Community Involvement Branch

ATSDR Regional Representative:

David Dorian
Regional Representative
Region 8

Epidemiological Review:

Candis Mayweather Hunter, MSPH
Epidemiologist
Division of Toxicology and Human Health Sciences

*Carla Galindo provided health education input until 2009; Dawn Arlotta provided health education input from 2009 to 2011. Carla and Dawn are no longer employed at ATSDR.

XI. REFERENCES

[ACCLPP] Advisory Committee on Childhood Lead Poisoning Prevention of the Centers for Disease Control and Prevention. 2012. Low Lead Level Exposure Harms Children: A Renewed Call for Primary Prevention.

[ATSDR 2004] Agency for Toxic Substances and Disease Registry, 2004. Interaction Profile for: arsenic, cadmium, chromium, and lead. Atlanta: US Department of Health and Human Services. May 2004.

[ATSDR 2006a] Agency for Toxic Substances and Disease Registry. 2006a. Health Consultation, Blood Lead Levels in Children in the Lincoln Park Neighborhood, Cañon City, Fremont County, Colorado. November 16, 2006. Available at: http://www.atsdr.cdc.gov/HAC/pha/LincolnParkBloodLeadLevels/LincolnPark-BloodLeadLevelsChildrenHC11.16.06.pdf.

[ATSDR 2006b] Agency for Toxic Substances and Disease Registry. 2006b. Health Consultation, Blood Levels in the Cañon City Vicinity, Fremont County, Colorado. November 16, 2006. Available at: http://www.atsdr.cdc.gov/HAC/pha/CanonCityBloodLevels/BloodLevels-CanonCityEI11.16.06.pdf.

[ATSDR 2006c] Agency for Toxic Substances and Disease Registry. 2006c. Health Consultation, Lead in Dust in Homes in the Lincoln Park Neighborhood, Cañon City, Fremont County, Colorado. November 16, 2006. Available at: http://www.atsdr.cdc.gov/HAC/pha/LincolnParkDustinLeadinHomes/LincolnPark-LeadinDustHC11.16.06.pdf.

[ATSDR 2006d] Agency for Toxic Substances and Disease Registry. 2006d. Health Consultation, Exposure Investigation Report: Lead in Indoor Dust, Outdoor Soil, and Blood of Lincoln Park Neighborhood Residents. November 16, 2006. Available at: http://www.atsdr.cdc.gov/HAC/pha/LincolnParkLeadinIndoo%20Dust/LincolnPark-LeadEI11.16.06.pdf.

[ATSDR 2006e] Agency for Toxic Substances and Disease Registry, 2006e. ToxFACTS Chemical Agent Briefing Sheet - Arsenic. Atlanta: US Department of Health and Human Services. January 2006.

[ATSDR 2007] Agency for Toxic Substances and Disease Registry, 2007. Toxicological profile for arsenic (update). Atlanta: US Department of Health and Human Services. 2007.

[ATSDR 2008a] Agency for Toxic Substances and Disease Registry, 2008a. ToxFACTS Chemical Agent Briefing Sheet - Cadmium. Atlanta: US Department of Health and Human Services. September 2008.

[ATSDR 2008b] Agency for Toxic Substances and Disease Registry, 2008b. Toxicological profile for cadmium. Atlanta: US Department of Health and Human Services. 2008.

[ATSDR 2011] Agency for Toxic Substances and Disease Registry, Geospatial Research, Analysis, and Services Program (GRASP). Mapping Showing Cotter Mill and Surrounding Area. May 2011.

[ATSDR 2013] Agency for Toxic Substances and Disease Registry, 2013. Toxicological profile for uranium (update). Atlanta: US Department of Health and Human Services. February 2013.

[BEIR IV]. Committee on the Biological Effects of Ionizing Radiations, National Research Council. 1988. Health risks of radon and other internally deposited alpha-emitters. Washington DC: National Academy Press.

[Braun, et.al.] Braun JM, Kahn RS, Froehlich T, Auinger P, Lanphear BP. 2006. Exposure to environmental Toxicants and attention deficit hyperactivity disorder in US children. Environ Health Perspectives 114(12);1904-1909.

[CCAT 2005] Colorado Citizens Against Toxic Waste. 2004-2005 Lincoln Park Health Survey, Cañon City, Colorado 81212.

[CDC 1998] Centers for Disease Control and Prevention. 1998. Estimation of the impact of the former Feed Materials Production Center (FMPC) on lung cancer mortality in the surrounding community. Atlanta: US Department of Health and Human Services Public Health Service; December 1998.

[CDPHE 1975] Colorado Department of Public Health and Environment. 1975. Letter to Fred Matter, Cotter Corporation, from Joe Virgona, CDPHE, concerning the chronological report on Cotter Corporation. July 1975.

[CDPHE 2001] Colorado Department of Public Health and the Environment. 2001. 6 CCR 1007-1, Part 18, State Board of Health Licensing Requirements for Uranium and Thorium Processing. Hazardous Materials and Waste Management Division, Radiation Control, November 2001.

[CDPHE 2003] Colorado Department of Public Health and Environment, Laboratory Services Division. 2003. Results of Sampling for Plutonium, Uranium, Lead and Molybdenum in the Cañon City Vicinity. July 2003.

[CDPHE 2005a] Colorado Department of Public Health and Environment. 2005a. Cotter Cañon City Uranium Mill 1988 Remedial Action Plan, Summary and Status – August 2005. Available at: http://www.cdphe.state.co.us/hm/cotter/rapsummary050826.pdf.

[CDPHE 2005b] Colorado Department of Public Health and the Environment. 2005. Cotter Cañon City Uranium Mill 1988 Remedial Action Plan Summary and Status – August 2005b.

[CDPHE 2005c] Colorado Department of Public Health and the Environment. 2005. 6 CCR 1007-1, Part 3, Licensing of Radioactive Material. Hazardous Materials and Waste Management Division, State Board of Health Rules and Regulations Pertaining to Radiation Control, July 2005.

[CDPHE 2007a] Colorado Department of Public Health and Environment. 2007a. Letter to Mr. John Hamrick, Cotter Corporation, from Steve Tarlton, CDPHE, concerning the Cotter Corporation Cañon City Mill Impoundments evaluation. June 14, 2007.

[CDPHE 2007b] Colorado Department of Public Health and Environment. 2007b. Cotter Mill Site Monitoring Database: data through September 25, 2007.

[CDPHE 2008] Colorado Department of Public Health and Environment. 2008. Cotter Corporation Uranium Mill Site Description. Available at: http://www.cdphe.state.co.us/hm/cotter/sitedescript.htm.

[CDPHE 2009] Colorado Department of Public Health and the Environment. 2009. Radioactive Materials License 369-01, Amendment 50, February 2009.

[CDPHE 2010a] Colorado Department of Public Health and the Environment. 2010. Letter to ATSDR Records Center from Steve Tarlton,. Re: Lincoln Park Cotter Uranium Mill Site, November 5, 2010.

[CDPHE 2010b] Colorado Department of Public Health and the Environment. 2010. Risk Management Guidance for Evaluating Arsenic Concentrations in Soil. Hazardous Materials and Waste Management Division, First Edition, June 2010.

[Chen, et.al. 2004] Chen J, Meyerhof DP, Tracy BL. 2004. Model results of kidney burdens from uranium intakes. Health Phys 86(1):3-11 (2004).

[Cotter 2000] Sand Creek Project Cleanup Report. June 2000.

[Cotter 2007] Environmental and occupational performance report, ALARA review and annual report on remedial action plan activities. Calendar year 2006. Cañon City Milling Facility. June 29, 2007. Available at: http://www.cdphe.state.co.us/hm/cotter/LetterFromCotter/2006perfrpt/.

[Cotter 2004a] Cotter Corporation, Cañon City Milling Facility. 2004. Procedure: Environmental Air Particulate Sampling, #EV-020, Revision 5. July 2004.

[Cotter 2004b] Cotter Corporation, Cañon City Milling Facility. 2004. Procedure: Radon-222/220 Air Surveys, #EV-030, Revision 2. July 2004.

[Cotter 2008a] Operational unit 2 (OU2) Lincoln Park water use survey. April 7, 2008. Available at: http://www.cdphe.state.co.us/hm/cotter/08cotterdocs.htm.

[Cotter 2008b] Cotter Corporation, Cañon City Milling Facility. 2008. Environmental and Occupational Performance Report, ALARA Review, and Annual Report on Remedial Action Plan Activities for Calendar Year 2008.

[Cotter 2009b] Cotter Corporation, Cañon City Milling Facility. 2009. Quality Assurance Program Plan for Environmental and Occupational Sampling and Monitoring Studies for the Cotter Corporation, Cañon City Milling Facility and Lincoln Park, Colorado Superfund Site. Prepared by Environmental Alternatives, Inc., May 2009.

[Cotter 2011] Cotter Corporation, Cañon City Milling Facility. 2011. Nature and Extent Investigation for Volatile Organic Compounds, Cotter Corporation, Cañon City Milling Facility April 2011.

[Diamond 1989] Diamond GL. 1989. Biological consequences of exposure to soluble forms of natural uranium. Rad Protect Dosim 26: 23-33.

[DOE 1993] U.S. Department of Energy. 1993. Order 5400.5 Change 2. Radiation Protection of the Public and the Environment. Office of Environment, Safety, and Health, January, 1993.

[DOE 2003] United States Department of Energy. 2003. Fiscal year 2003 status report, Reimbursements to licensees of active uranium and thorium processing sites. Title X of the Energy Policy Act of 1992. September 2003.

[EA 2007] Environmental Alternatives, Inc. 2007. Report on Semi-Annual Review of Well Permits. March 20, 2007. Available at: http://www.cdphe.state.co.us/hm/cotter/LetterFromCotter/wellpermitreview070329.pdf.

[EIA 2001] Energy Information Administration, 2001, Web site: U.S. Department of Energy, http://www.eia.doe.gov/.

Eisenbud M, Quigley JA. 1955. Industrial hygiene of uranium processing. AMA Archives of Industrial Health. p. 12–22.

[EPA 1995] Environmental Protection Agency, Environmental Response Team. 1995. Superfund Program, Representative Sampling Guidance, Volume 1: Soil. Interim Final. Available at: http://www.clu-in.org/download/char/SF_Rep_Samp_Guid_soil.pdf.

[EPA 2002] Environmental Protection Agency. 2002. Record of Decision: Lincoln Park Study Area Surface Soils, Lincoln Park Superfund Site, Cañon City, Colorado. Available at: http://www.epa.gov/region08/superfund/co/lincolnpark/LincolnPkROD.pdf.

[EPA 2004] Environmental Protection Agency, Superfund Technical Assessment and Response Team 2 - Region 8. 2004. Cañon City Lead Data Compilation Report, Cañon City, Fremont County, Colorado. March 24, 2004. Available at: http://www.epa.gov/region8/superfund/co/lincolnpark/.

[EPA 2007] Environmental Protection Agency, Region 8. 2007. Final First 5-year review report for Lincoln Park Superfund site, Operable Unit 2. September 2007. Available at: http://www.epa.gov/region08/superfund/co/lincolnpark/LincolnPark5YrRvw07.pdf.

[EPA 2008] Environmental Protection Agency, Region 8. 2008. Superfund Program: Lincoln Park. Available at: http://www.epa.gov/region8/superfund/co/lincolnpark/.

[EPA 2009] Environmental Protection Agency, Integrated Risk Information System (IRIS). Cincinnati, OH: Office of Health and Environmental Assessment, Environmental Criteria and Assessment. Accessed June 16, 2009 at http://www.epa.gov/ncea/iris/subst/0425.htm.

[EPA 2011] Environmental Protection Agency. 2011. Exposure Factors Handbook: 2011 Edition. National Center for Environmental Assessment, Office of Research and Development. Washington, DC. Available at http://www.epa.gov/ncea/efh/pdfs/efh-complete.pdf.

[FNB 2001] Food and Nutrition Board, Institute of Medicine. 2001. Molybdenum. In: Dietary reference intakes for vitamin A, vitamin K, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington, D.C.: National Academy Press. p. 420–41.

[FDA 2008] US Food and Drug Administration. 2008. Total Diet Study - Summary of Toxic and Nutritional Elements Found in TDS Foods. Accessed August 4, 2009 at . http://www.fda.gov/downloads/Food/FoodSafety/FoodContaminantsAdulteration/TotalDietStudy/UCM184301.pdf.

[Galant, et.al. 2007] Galant, M.M., Linnert, T., and J. Dalton. 2007. Community involvement plan: Lincoln Park Superfund site and associated activities at the Cotter Corporation uranium mill. March 2007. Available at: http://www.cdphe.state.co.us/hm/cotter/lincolnparkcottercip.pdf.

[GeoTrans 1986] GeoTrans, Inc. 1986. Remedial Investigation: Cotter Corporation Uranium Mill Site. February 1986. Gump BB, Stewart P, Reihman et al. 2007. Low-level prenatal and postnatal blood lead (Pb) exposure and adrenocortical responses to acute stress in children. Environ Health Perspectives 116(2): 249-55.

[Gump, et.al. 2007]Gump BB, Stewart P, Reihman et al. 2007. Low-level prenatal and postnatal blood lead (Pb) exposure and adrenocortical responses to acute stress in children. Environ Health Perspectives 116(2): 249-55.

[HRAP 1991] Health Risk Assessment Panel, Cotter Uranium Mill Site. 1991. Health Risk Assessment of the Cotter Uranium Mill Site, Cañon City, Colorado. Prepared with the assistance of ENVIRON Corporation, Radiation Surveillance Associates, Radiant Energy Management, and Western Radiation Consultants. October 29, 1991.

[Hodge 1953] Hodge HC. 1953. Resume of chapters 18 to 28. In: Voegtlin C and Hodge HC, eds. Pharmacology and toxicology of uranium compounds. National Nuclear Energy Series, Division VI, Vol 1, Part IV. New York: McGraw-Hill.

[Hydrosolutions 2010]. Hydrosolutions and TetraTech. Groundwater Investigation North and West of the Cotter Corporation, Cañon City Milling Facility, Colorado, Prepared for Cotter Corporation, PO Box 1750, Cañon City, CO. May 17, 2010.

[IMS 1989] IMS Inc. 1989. Lincoln Park Water Use Survey. Submitted to Cotter Corporation, Lakewood, Colorado. June 28, 1989.

[IPCS 2001] International Programme on Chemical Safety. 2001.Environmental Health Criteria for Arsenic and Arsenic compounds. EHC 224, Chapter 1: Summary, section 4.

[Juhasz, et.al. 2008] Juhasz, Albert L., Euan Smith, John Weber, Matthew Rees, Allan Rofe, Tim Kuchel, Lloyd Sansom, Ravi Naidu, Application of an In Vivo Swine Model for the

Determination of Arsenic Bioavailability in Contaminated Vegetables. Chemosphere. Feb 7, 2008.

[Jusko, et.al. 2007] Jusko TA, Henderson CR, Lanphear BP, Cory-Slechta DA, Parsons PJ, Canfield RL. 2007. Blood lead concentrations less than 10 micrograms per deciliter and child intelligence at 6 years of age. Environ Health Perspectives 116(2): 243-248.

[Killough, et.al. 1998] Killough GG, Case MJ, Meyer KR, et al. 1998. Fernald Dosimetry Reconstruction Project, Task 6 radiation doses and risk to residents from FMPC Operations from 1951-1988. Vol I and II (final report). Radiological Assessments Corporation Report No. CDC-1. Neeses, SC: 1998 Sep

[Koval'skiy, et.al. 1961] Koval'skiy, V.V., G.A. Yarovaya and D.M. Shmavonyan. 1961. Changes of purine metabolism in man and animals under conditions of molybdenum biogeochemical provinces. Zh. Obshch. Biol. 22: 179-191.

[Kurttio**,**et.al. 2002] Päivi Kurttio, Anssi Auvinen, Laina Salonen, Heikki Saha, Juha Pekkanen, Ilona Mäkeläinen, Sari B. Väisänen, Ilkka M. Penttilä, and Hannu Komulainen. Renal Effects of Uranium in Drinking Water. Environmental Health Perspectives Volume 110, Number 4, April 2002.

[Laizu 2007] Laizu Jahanara. 2007. Speciation of arsenic in vegetables and their correlation with inorganic phosphate level. Bangladesh J Pharmacol 2007; 2:88-94.

[Leggett 1989] Leggett RW. 1989. The behavior and chemical toxicity of U in the kidney: a reassessment. Health Phys 57(3): 365-383.

[Leggett 1994] Leggett RW. 1994. Basis for ICRP's age-specific biokinetic model for uranium. Health Phys 67: 589-601.

[MFG 2005] MFG, Inc. 2005. Assessment of potential dose to members of the public from materials along roads near the Cotter Corporation, Cañon City Milling Facility. May 2005. Available at: http://www.cdphe.state.co.us/hm/cotter/potentialdoseassessment.pdf.

[Madsden, et.al. 2007] Madsden KM, Nielsen S, Tisher CC. 2007. Chapter 2 – Anatomy of the Kidney from Brenner: Brenner and Rector's The Kidney, 8th ed. Oxford: Elsevier Science Ltd.

[Maynard and Hodge 1949] Maynard EA, Hodge HC. 1949. Studies of the toxicity of various uranium compounds when fed to experimental animals. In: Voegtlin IC, Hodge HC, eds. Pharmacology and toxicology of uranium compounds. National Nuclear Energy Series (VI). New York: McGraw-Hill; 309-376.

[McDonald-Taylor et al. 1997] McDonald-Taylor CK, Singh A, Gilman A. 1997. Uranyl nitrate-induced tubule alterations in rabbits: a quantitative analysis. Toxicol Pathol 25(4): 381-389.

[Morris and Meinhold 1995] Morris SC, Meinhold AF. 1995. Probabilistic risk assessment of nephrotoxic effect of uranium in drinking water. Health Phys 69: 897-908.

[ODEQ 2003] State of Oregon Department of Environmental Quality. 2003. Memorandum, Red Rock Road Project File, Evaluation Potential for Arsenic and Mercury Uptake into Garden Vegetables. September 22, 2003.

[NHANES 2005] National Health and Nutrition Examination Survey. Third National Report on Human Exposure to Environmental Chemicals, Dept of Health and Human Services, Centers for Disease Control and Prevention. Atlanta, GA. July 2005.

[Plasket 2002] Plasket, BJ. 2002. Cotter at the Crossroads: On the Hot Seat. The Daily Record News Group. Available at: http://www.timescall.com/cotter/cotter24.htm.

[Spear 2003] Spear JW. Trace mineral bioavailability in ruminants. J. Nutr. 2003; 133: 1506S—1509S.

[Spoor and Hursh 1973] Spoor NL, Hursh JB. 1973. Protection criteria. In: Hodge HC, Stannard JN, Hursh JB, eds. Handbook of experimental pharmacology. Berlin: Springer-Verlag; 241-270.

[Stokinger, et.al. 1953] Stokinger HE, Baxter RC, Dygent HP, et al. 1953. In: Voegtlin C, Hodge HC, eds. Toxicity following inhalation for 1 and 2 years. National Nuclear Energy Series: Manhattan Project Technical Section, Div VI, Vol 1. New York: McGraw-Hill.

[Turnlund 2002] Turnlund JR. Molybdenum metabolism and requirements in humans. Met. Ions Bio. Syst. 2002; 39:727—739.

[USGS 1999a] United States Geological Survey. 1999a. Migration and Geochemical Evolution of Ground Water Affected by Uranium-Mill Effluent near Cañon City, Colorado. Water-Resources Investigations Report 98-4228. DT Chafin and ER Banta.

[USGS 1999b] United States Geological Survey. 1999b. Ground-Water Hydrology and Simulation of Five Remediation Alternatives for an Area Affected by Uranium-Mill Effluent near Cañon City, Colorado. ER Banta and DT Chafin.

[USNRC 1980] U.S. Nuclear Regulatory Commission. 1980. Regulatory Guide 4.14 Radiological Effluent and Environmental Monitoring at Uranium Mills, Revision 1. Office of Standards Development, April 1980.

[USNRC 1996] U.S. Nuclear Regulatory Commission. 1996. Regulatory Guide 4.20 Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees other than Power Reactors. Office of Nuclear Regulatory Research, December 1996.

[Vousta, et.al. 1996] Vousta D, Grimanis A, Samara C. 1996. Trace elements in vegetables grown in an industrial area in relation to soil and air particulate matter. Environ Pollution 94(3):325–35.

[Weston 1996] Roy F. Weston, Inc. 1996. Supplemental Human Health Risk Assessment. Lincoln Park Superfund Site. Cañon City, Colorado. Phase II Evaluation. Baseline Human Health Risks in 1988. Final Report. Prepared for CDPHE. November 19, 1996.

[Weston 1998] Roy F. Weston, Inc. 1998. Supplemental Human Health Risk Assessment, Lincoln Park Superfund Site, Cañon City, Colorado: Phase III Evaluation, Baseline Human Health Risks in 1994-1996. January 1998.

[Wilder, et.al. 1983] Wilder, RJ, DJ Goode, P Huidobro, MO Kozik, DR Cogley, NH Krusell, ME Connolly, EJ Limberakis, and AW Levin. 1983. Assessment of data concerning ground water contamination in the Lincoln Park section of Cañon City, Colorado. Final report prepared for EPA by GCA Corporation. May 1983.

[WHO 2003] World Health Organization. 2003. Molydbenum in Drinking water: Background document for development of WHO *Guidelines for Drinking-water Quality*.

[Zhao and Zhao 1990] Zhao LS, Zhao SF. 1990. Nephrotoxic limit and annual limit on intake for natural U. Health Phys 58: 619-623.

Appendix A - Tables

Table 14. Well Use in Lincoln Park, 1989

Well Number	Description	Reported Well Use				
		Personal Consumption	Irrigating Fruit	Irrigating Vegetable Gardens	Watering Livestock	Watering Lawns
117	Logan (LPWUS)		✓			✓
119	Birch (LPWUS)			✓		✓
122	Elm (LPWUS)					✓
123	Cedar (LPWUS)					✓
124	Elm (LPWUS)			✓		✓
129	Elm (LPWUS)		✓	✓		✓
130	Poplar (LPWUS)		✓			✓
138	Field well, Cedar (LPWUS)					✓
139	House well, Cedar (LPWUS)					✓
140	C. R. Ransom house well, Cedar (LPWUS)		✓	✓		✓
144	Cedar (LPWUS)		✓	✓	✓	✓
165	Spring, Elm (LPWUS)	✓		✓		✓
166	Willow (LPWUS)				✓	✓
168	Grand (house well) (LPWUS)	✓			✓	✓
173	Beulah (LPWUS)		✓			✓
174	Chestnut (LPWUS)		✓		✓	✓
189	Hickory (LPWUS)	✓				
198	Grand (LPWUS)	✓	✓	✓	✓	✓
206	Grand (field well) (LPWUS)				✓	
212	Cedar (LPWUS)		✓	✓		✓
219	Locust (LPWUS)	✓				
221	Elm (LPWUS)					✓
222	Elm (LPWUS)					✓

Well Number	Description	Reported Well Use				
		Personal Consumption	Irrigating Fruit	Irrigating Vegetable Gardens	Watering Livestock	Watering Lawns
223	Elm (LPWUS)				✓	
224	Elm (LPWUS)		✓			✓
226	Chestnut (LPWUS)					✓
229	Grand (LPWUS)				✓	✓
230	Birch (LPWUS)		✓			✓
231	Birch (LPWUS)		✓	✓		
235	Elm (LPWUS)				✓	
237	Elm (LPWUS)				✓	
239	Grand (LPWUS)		✓	✓	✓	✓
241	Grand (LPWUS)				✓	
243	Chestnut (LPWUS)					✓
245	Elm (LPWUS)				✓	
246	Elm (LPWUS)		✓			✓
252	Poplar (cistern* in barn) (LPWUS)					✓
255	Riley Dr. (LPWUS)	✓	✓			✓
261	Elm (LPWUS)		✓	✓		✓
262	Cedar (LPWUS)		✓	✓		✓
263	Willow (LPWUS)					✓
264	Chestnut (LPWUS)		✓	✓		✓
266	Willow (LPWUS)		✓	✓		✓
267	Willow (spring) (LPWUS)		✓	✓	✓	✓
269	Birch			✓		✓
273	Willow (cistern #1) (LPWUS)			✓		✓
274	Grand (LPWUS)		✓	✓		✓
278	Cedar (LPWUS)					✓

Well Number	Description	Reported Well Use				
		Personal Consumption	Irrigating Fruit	Irrigating Vegetable Gardens	Watering Livestock	Watering Lawns
280	Grand (LPWUS)				✓	
284	Spring - Grand St. (LPWUS)				✓	
285	Grand (LPWUS)				✓	
286	Willow (cistern #2) (LPWUS)				✓	
287	Willow (LPWUS)			✓		✓
288	Poplar (cistern* on porch)					✓
293	Cedar (LPWUS)		✓	✓	✓	✓
	Totals	**6**	**22**	**20**	**19**	**42**

Source: IMS 1989

*Modified from the original spelling: “cystern”
Street numbers have been excluded for privacy reasons.

LPWUS – Lincoln Park Water Use Survey

Table 15. Groundwater sampling data (chemicals) from wells used for personal consumption

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Location of Maximum	Date of Maximum	CV (mg/L)	Wells Sampled	Years Sampled
Chloride	N/T*	11/11	4.5	8.8	14	Spring, Elm [165]	13-Mar-84	250 (Secondary MCL)	165, 168	1984, 2005–2007
Iron	D	2/12	0.04	0.06	0.1	Grand (house well) [168]	19-Aug-05	26 (RBC)	165, 168	1984, 2004–2007
Manganese	D	2/12	0.002	0.008	0.01	Grand (house well) [168]	13-Dec-04	0.5 (RMEG, child)	165, 168	1984, 2004–2007
Molybdenum	D	52/59	0.007	**0.082**	**0.28**	Hickory [189]	19-Jan-89	0.035 (SS); 0.05 (RMEG, child)	165, 168, 189, 198, 219, 255	1984, 1988–1991, 1995, 2000–2007
Nitrate	T	8/8	0.5	2.9	7.7	Grand (house well) [168]	19-Mar-07	10 (MCL)	168	2005–2007
Selenium	D	0/2	ND	ND	ND	--	--	0.05 (c-EMEG, child)	165, 168	1984
Sulfate	N/T*	11/11	15	62	214	Grand (house well) [168]	19-Aug-05	250 (Secondary MCL)	165, 168	1984, 2005–2007
Total Dissolved Solids	N/T*	11/11	240	330	410	Spring, Elm [165]	13-Mar-84	500 (Secondary MCL)	165, 168	1984, 2005–2007
Uranium	D	56/57	0.001	0.028	**0.067**	Hickory [189]	15-Dec-06	0.03 (MCL)	165, 168, 189, 198, 219, 255	1984, 1988–1991, 1995, 2001–2007

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
The source of water used for personal consumption at 1935 Elm [165] was a spring.

* For chloride, sulfate, and total dissolved solids, 1984 data were designated “N” and 2005–2007 data were designated “T”.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
LTHA – lifetime health advisory for drinking water
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
SS – Colorado state groundwater standard
T – total

Table 16. Groundwater sampling data (chemicals) from background wells

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Date of Maximum	CV (mg/L)	Years Sampled
Aluminum	D	0/25	ND	ND	ND	--	10 (c-EMEG, child)	1981, 1988–1994
Ammonia	N	3/45	0.02	0.4	4.2	26-Jan-90	30 (LTHA)	1988–1994
Ammonium	T	0/3	ND	ND	ND	--	NA	1995
Chloride	N/T*	168/168	3	12	110.3	07-Jan-80	250 (Secondary MCL)	1975, 1976, 1978–2007
Iron	D	24/79	0.02	0.03	0.3	16-May-89	26 (RBC)	1981–2007
Manganese	D	13/79	0.005	0.007	0.05	16-Mar-99	0.5 (RMEG, child)	1981–2007
Molybdenum	D	116/193	0.005	0.023	**0.3**	09-Nov-82, 09-Jun-76	0.035 (SS); 0.05 (RMEG, child)	1975, 1976, 1979–2007
Nitrate	N/T*	70/79	0.4	2.5	**50.4****	10-Feb-89	10 (MCL)	1988–2007
Selenium	D	10/103	0.001	0.003	0.015	15-Apr-80	0.05 (c-EMEG, child)	1975, 1977–1988, 1996–2000
Sulfate	N/T*	171/171	10	61	**434§**	18-Aug-80	250 (Secondary MCL)	1975–2007
Total Dissolved Solids	N/T*	171/171	286	429	**1,580†**	18-Aug-80	500 (Secondary MCL)	1980–2007
Uranium	D	155/193	0.004	0.021	**0.29**	07-Aug-79	0.03 (MCL)	1975–1977, 1979–2007

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
The USGS identified Well 10 (1220 So. 12th St.) and Well 114 (1408 Pine) as representative of background for the Lincoln Park area [Weston 1998].

* For chloride, nitrate, sulfate, and total dissolved solids, pre-1995 data were designated "N" and post-1995 data were designated "T".
** Only two of 79 samples were above the CV.

[§] Only one of 171 samples was above the CV.

[†] The maximum concentration appears to be an outlier. The next highest concentration is 590 mg/L.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
LTHA – lifetime health advisory for drinking water
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
NA – not available
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
SS – Colorado state groundwater standard
T – total

Table 17. Groundwater sampling data (chemicals) from the Grand Avenue Well

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Date of Maximum	CV (mg/L)	Years Sampled
Chloride	N/T*	10/10	4.5	8.250	11	20-Jun-84, 20-Jun-05	250 (Secondary MCL)	1984, 2005–2007
Iron	D	2/11	0.04	0.06	0.1	19-Aug-05	26 (RBC)	1984, 2004–2007
Manganese	D	2/11	0.002	0.009	0.01	13-Dec-04	0.5 (RMEG, child)	1984, 2004–2007
Molybdenum	D	15/20	0.008	0.01	0.015	21-Jun-04	0.035 (SS); 0.05 (RMEG, child)	1984, 1988–1991, 2004–2007
Nitrate	T	8/8	0.5	2.9	7.7	19-Mar-07	10 (MCL)	2005–2007
Selenium	D	0/1	ND	ND	ND	--	0.05 (c-EMEG, child)	1984
Sulfate	N/T*	10/10	15	58	214	19-Aug-05	250 (Secondary MCL)	1984, 2005–2007
Total Dissolved Solids	N/T*	10/10	240	322	402	19-Mar-07	500 (Secondary MCL)	1984, 2005–2007
Uranium	D	20/20	0.001	0.013	0.0218	28-Mar-05	0.03 (MCL)	1984, 1988–1991, 2004–2007

Source: CDPHE 2007b

Averages were calculated using ½ the reporting detection limit for non-detects.
* For chloride, sulfate, and total dissolved solids, 1984 data were designated "N" and 2005–2007 data were designated "T".

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
SS – Colorado state groundwater standard
T – total

Table 18. Groundwater sampling data (chemicals) from wells used to irrigate fruit and vegetable gardens

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Location of Maximum	Date of Maximum	CV (mg/L)	Wells Sampled	Years Sampled
Aluminum	D	3/120	0.01	0.186*	0.02	Elm [124] & Elm [129]	15-Mar-95	10 (c-EMEG, child)	117, 119, 124, 129, 130, 140, 144	1981, 1988–1995
Ammonia	N	10/53	0.01	0.3	0.6	house well, Cedar [140]	23-Aug-88	30 (LTHA)	119, 124, 129, 130, 140, 144	1988–1995
Ammonium	T	0/3	ND	ND	ND	--	--	NA	119, 140, 144	1995
Cadmium	D	0/3	ND	ND	ND	--	--	0.002 (c-EMEG, child)	119, 140, 144	1995
Chloride	N/T**	784/793	2.5	19.6	232	house well, Cedar [140]	05-Apr-79	250 (Secondary MCL)	117, 119, 124, 129, 130, 140, 144, 165, 174, 224	1970, 1975, 1976, 1978–2007
Copper	D	0/3	ND	ND	ND	--	--	0.1 (i-EMEG, child)	119, 140, 144	1995
Iron	D	114/398	0.011	0.029	0.31	Elm [129]	21-Apr-03	26 (RBC)	117, 119, 124, 129, 130, 140, 144, 165, 174, 224	1970, 1981–2007
Manganese	D	69/397	0.0007	0.008	0.13	house well, Cedar [140]	09-Sep-94	0.5 (RMEG, child)	117, 119, 124, 129, 130, 140, 144, 165, 174, 224	1981–2007
Molybdenum	D	1,052/1,077	0.004	**0.99**	**42**	house well, Cedar [140]	12-May-73	0.035 (SS); 0.05 (RMEG, child)	All 28 wells (see Table 14)	1968–2007
Nickel	D	0/3	ND	ND	ND	--	--	0.2 (RMEG, child)	119, 140, 144	1995

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Location of Maximum	Date of Maximum	CV (mg/L)	Wells Sampled	Years Sampled
Nitrate	N/T**	159/185	0.1	1.7	9.8	Cedar [144]	14-May-70	10 (MCL)	119, 124, 129, 130, 140, 144, 174, 224	1970, 1988–2007
Selenium	D	115/626	0.001	0.003	**0.082**[†]	house well, Cedar [140]	21-Apr-78	0.05 (c-EMEG, child)	117, 119, 124, 129, 130, 140, 144, 165, 174, 224, 264	1974–1988, 1995–2000
Sulfate	N/T**	798/800	8	214	**25,460**[‡]	house well, Cedar [140]	07-May-79	250 (Secondary MCL)	117, 119, 124, 129, 130, 140, 144, 165, 174, 224	1970, 1975–2007
Total Dissolved Solids	N/T**	767/767	31	**550**	**3,438**	house well, Cedar [140]	20-Apr-81	500 (Secondary MCL)	117, 119, 124, 129, 130, 140, 144, 165, 174, 224	1970, 1980–2007
Uranium	D	1,048/1,088	0.0003	**0.13**	**2.54**	house well, Cedar [140]	05-Jan-79	0.03 (MCL)	All 28 wells (see Table 14)	1962–1964, 1967, 1968, 1971, 1974–2007
	S	1/20	0.081	0.005[§]	**0.081**	house well, Cedar [140]	27-May-97		140, 174, 224	1995–2000
Vanadium	D	0/3	ND	ND	ND	--	--	0.03 (i-EMEG, child)	119, 140, 144	1995
Zinc	D	2/3	0.005	0.01	0.022	Birch [119]	25-Aug-95	3 (c-EMEG, child)	119, 140, 144	1995

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
The source of water used to water fruits and vegetable gardens at 1935 Elm [165] was a spring.

* The calculated average is higher than the maximum detected concentration due to including ½ the detection limit in the calculation.
** For chloride, nitrate, sulfate, and total dissolved solids, pre-1995 data were designated “N” and post-1995 data were designated “T”.
[†] Only two of 626 samples were above the CV.
[‡] The maximum concentration appears to be an outlier. The next highest concentration is 1,948 mg/L from the same well [140] in 1981.
[§] The calculated average is lower than the minimum detected concentration due to including ½ the detection limit in the calculation.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
i-EMEG – intermediate environmental media evaluation guide
LTHA – lifetime health advisory for drinking water
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
NA – not available
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
S – suspended
SS – Colorado state groundwater standard
T – total

Table 19. Groundwater sampling data (radionuclides) from wells used to irrigate fruit and vegetable gardens

Radionuclide	Type	Frequency of Detection	Minimum (pCi/L)	Average (pCi/L)	Maximum (pCi/L)	Location of Maximum	Date of Maximum	CV (pCi/L)	Wells Sampled	Years Sampled
Lead-210	D	29/29	-0.2	0.22	1.5	Birch [119]	21-Jun-95	NA	119, 140, 144, 174, 224	1995–2000
	S	20/20	-0.1	0.15	0.6	house well, Cedar [140]	22-Feb-96, 05-May-99		140, 174, 224	1995–2000
Polonium-210	D	29/29	-0.1	0.13	0.6	Cedar [144]	08-Mar-95, 21-Jun-95,	NA	119, 140, 144, 174, 224	1995–2000
	S	20/20	0	0.12	0.6	house well, Cedar [140]	22-Feb-96, 05-Dec-96		140, 174, 224	1995–2000
Radium-226	D	29/29	0	0.12	0.5	house well, Cedar [140]	12-May-95	5 (MCL radium-226/228)	119, 140, 144, 174, 224	1995–2000
	S	19/19*	0	0	0	--	--		140, 174, 224	1995–2000
Thorium-230	D	28/28	-0.1	0.08	0.3	Birch [119] house well, Cedar [140]	25-Aug-95 21-Feb-95	NA	119, 140, 144, 174, 224	1995–2000
	S	17/17	0	0.08	0.3	house well, Cedar [140]	05-May-99		140, 174, 224	1995–2000

Source: CDPHE 2007b

Averages were calculated using ½ the reporting detection limit for non-detects.
Negative and zero result values were included in the summary statistics.
*The detect flag is "Y" for all 19 samples, however, the result value is zero for all 19 samples.

CV – comparison value
D – dissolved
MCL – maximum contaminant level
NA – not available
pCi/L – picocuries per liter
S – suspended

Table 20. Groundwater sampling data (chemicals) from wells used to water livestock

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Location of Maximum	Date of Maximum	CV (mg/L)	Wells Sampled	Years Sampled
Aluminum	D	0/19	ND	ND	ND	--	--	10 (c-EMEG, child)	144	1981, 1988–1995
Ammonia	N	0/10	ND	ND	ND	--	--	30 (LTHA)	144	1988–1995
Ammonium	T	0/1	ND	ND	ND	--	--	NA	144	1995
Cadmium	D	0/1	ND	ND	ND	--	--	0.002 (c-EMEG, child)	144	1995
Chloride	N/T*	160/160	2.5	14	185	Cedar [144]	24-Aug-83	250 (Secondary MCL)	144, 166, 168, 174	1970, 1975, 1976, 1979–1989, 1991–2007
Copper	D	0/1	ND	ND	ND	--	--	0.1 (i-EMEG, child)	144	1995
Iron	D	27/97	0.03	0.04	0.19	Cedar [144]	18-Oct-01	26 (RBC)	144, 166, 168, 174	1970, 1981–2007
Manganese	D	14/96	0.0007	0.007	0.02	Cedar [144]	13-Jul-81, 13-Sep-83, 17-May-01, 06-Jun-02, 23-Oct-03	0.5 (RMEG, child)	144, 166, 168, 174	1981–2007
Molybdenum	D	271/286	0.006	**0.212**	**1**	Cedar [144]	12-May-71	0.035 (SS); 0.05 (RMEG, child)	All 19 wells (see Table 14)	1968–1971, 1975–1977, 1979–2007
Nickel	D	0/1	ND	ND	ND	--	--	0.2 (RMEG, child)	144	1995

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Location of Maximum	Date of Maximum	CV (mg/L)	Wells Sampled	Years Sampled
Nitrate	N/T*	55/58	0.1	1.8	9.8	Cedar [144]	14-May-70	10 (MCL)	144, 168, 174	1970, 1988–2007
Selenium	D	10/119	0.001	0.003	0.011	Cedar [144]	19-Mar-80	0.05 (c-EMEG, child)	144, 166, 168, 174	1975–1977, 1979–1988, 1995–2000
Sulfate	N/T*	162/162	10	95	**1,650****	Cedar [144]	18-Aug-80	250 (Secondary MCL)	144, 166, 168, 174	1970, 1975–1977, 1979–1989, 1991–2007
Total Dissolved Solids	N/T*	162/162	195	465	**860**	Cedar [144]	18-Aug-80	500 (Secondary MCL)	144, 166, 168, 174	1970, 1980–2007
Uranium	D	283/302	0.001	**0.034**	**0.46**	Cedar [144]	28-Jun-68	0.03 (MCL)	All 19 wells (see Table 14)	1962–1964, 1967, 1968, 1971, 1975–1977, 1979–2007
	S	0/1	ND	ND	ND	--	--		174	1996
Vanadium	D	0/1	ND	ND	ND	--	--	0.03 (i-EMEG, child)	144	1995
Zinc	D	0/1	ND	ND	ND	--	--	3 (c-EMEG, child)	144	1995

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
* For chloride, nitrate, sulfate, and total dissolved solids, pre-1995 data were designated “N” and post-1995 data were designated “T”.
** The maximum concentration appears to be an outlier. The next highest concentration is 340 mg/L from the same well [144] in 1984.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
i-EMEG – intermediate environmental media evaluation guide
LTHA – lifetime health advisory for drinking water
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
S – suspended
SS – Colorado state groundwater standard
T – total

Table 21. Groundwater sampling data (radionuclides) from wells used to water livestock

Radionuclide	Type	Frequency of Detection	Minimum (pCi/L)	Average (pCi/L)	Maximum (pCi/L)	Location of Maximum	Date of Maximum	CV (pCi/L)	Wells Sampled	Years Sampled
Lead-210	D	4/4	-0.1	0.1	0.3	Cedar [144]	08-Mar-95	NA	144, 174	1995, 1996
	S	1/1	0.2	0.2	0.2	Chestnut [174]	19-Sep-96		174	1996
Polonium-210	D	4/4	-0.1	0.3	0.6	Cedar [144]	08-Mar-95, 21-Jun-95	NA	144, 174	1995, 1996
	S	1/1*	0	0	0	Chestnut [174]	19-Sep-96		174	1996
Radium-226	D	4/4	0.1	0.1	0.1	--**	--**	5 (MCL radium-226/228)	144, 174	1995, 1996
	S	1/1*	0	0	0	Chestnut [174]	19-Sep-96		174	1996
Thorium-230	D	4/4	0	0.05	0.1	Cedar [144] Chestnut [174]	20-Sep-95 19-Sep-96	NA	144, 174	1995, 1996
	S	1/1*	0	0	0	Chestnut [174]	19-Sep-96		174	1996

Source: CDPHE 2007b

Averages were calculated using ½ the reporting detection limit for non-detects.
Negative and zero result values were included in the summary statistics.
* The detect flag is “Y” for the one sample, however, the result value is zero.
** All four result values were 0.1 pCi/L.

CV – comparison value
D – dissolved
MCL – maximum contaminant level

NA – not available
pCi/L – picocuries per liter
S – suspended

Table 22. Groundwater sampling data (chemicals) from wells used to water lawns

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Location of Maximum	Date of Maximum	CV (mg/L)	Wells Sampled	Years Sampled
Aluminum	D	11/239	0.01	0.19*	0.13	Field well, Cedar [138]	18-Dec-90	10 (c-EMEG, child)	117, 119, 122, 123, 124, 129, 130, 138, 139, 140, 144	1981, 1988–1995
Ammonia	N	21/112	0.01	0.3	0.9	Field well, Cedar [138]	23-Aug-88	30 (LTHA)	119, 122, 123, 124, 129, 130, 138, 139, 140, 144	1988–1995
Ammonium	T	0/5	ND	ND	ND	--	--	NA	119, 138, 139, 140, 144	1995
Cadmium	D	0/5	ND	ND	ND	--	--	0.002 (c-EMEG, child)	119, 138, 139, 140, 144	1995
Chloride	N/T**	1,362/1,372	2.5	30	**450**	Field well, Cedar [138]	12-Aug-80	250 (Secondary MCL)	117, 119, 122, 123, 124, 129, 130, 138, 139, 140, 144, 165, 166, 168, 174, 224	1970, 1975, 1976, 1978–2007
Copper	D	0/5	ND	ND	ND	--	--	0.1 (i-EMEG, child)	119, 138, 139, 140, 144	1995
Iron	D	205/683	0.005	0.031	0.31	Field well, Cedar [138] Elm [129]	09-Mar-95 21-Apr-03	26 (RBC)	117, 119, 122, 123, 124, 129, 130, 138, 139, 140, 144, 165, 166, 168, 174, 224	1970, 1981–2007

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Location of Maximum	Date of Maximum	CV (mg/L)	Wells Sampled	Years Sampled
Manganese	D	134/683	0.0005	0.008	0.13	house well, Cedar [140]	09-Sep-94	0.5 (RMEG, child)	117, 119, 122, 123, 124, 129, 130, 138, 139, 140, 144, 165, 166, 168, 174, 224	1979, 1981–2007
Molybdenum	D	1,755/1,790	0.004	**2.2**	**56.7**	Field well, Cedar [138]	11-Aug-72	0.035 (SS); 0.05 (RMEG, child)	All 42 wells (see Table 14)	1968–2007
Nickel	D	0/5	ND	ND	ND	--	--	0.2 (RMEG, child)	119, 138, 139, 140, 144	1995
Nitrate	N/T**	277/314	0.1	1.8	9.8	Cedar [144]	14-May-70	10 (MCL)	119, 122, 123, 124, 129, 130, 138, 139, 140, 144, 168, 174, 224	1970, 1988–2007
Selenium	D	320/1,105	0.001	0.005	**0.134**	Field well, Cedar [138]	13-Jul-81	0.05 (c-EMEG, child)	117, 119, 122, 123, 124, 129, 130, 138, 139, 140, 144, 165, 166, 168, 174, 224, 264	1974–1976, 1978–1988, 1995–2000
Sulfate	N/T**	1,382/1,384	8	**351**	**25,460**†	house well, Cedar [140]	07-May-79	250 (Secondary MCL)	117, 119, 122, 123, 124, 129, 130, 138, 139, 140, 144, 165, 166, 168, 174, 224	1970, 1975–2007

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Location of Maximum	Date of Maximum	CV (mg/L)	Wells Sampled	Years Sampled
Total Dissolved Solids	N/T**	1,311/1,311	31	**746**	**4,373**	Field well, Cedar [138]	06-Mar-81	500 (Secondary MCL)	117, 119, 122, 123, 124, 129, 130, 138, 139, 140, 144, 165, 166, 168, 174, 224	1970, 1980–2007
Uranium	D	1,733/1,789	0.0003	**0.233**	**5.161**	Field well, Cedar [138]	01-Aug-68	0.03 (MCL)	All 42 wells (see Table 14)	1962–1964, 1967, 1968, 1971, 1974–2007
	S	4/38	0.0067	0.010	**0.26**	Field well, Cedar [138]	27-May-97		138, 140, 174, 224	1995–2000
Vanadium	D	0/5	ND	ND	ND	--	--	0.03 (i-EMEG, child)	119, 138, 139, 140, 144	1995
Zinc	D	3/5	0.005	0.007	0.022	Birch [119]	25-Aug-95	3 (c-EMEG, child)	119, 138, 139, 140, 144	1995

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
* The calculated average is higher than the maximum detected concentration due to including ½ the detection limit in the calculation.
** For chloride, nitrate, sulfate, and total dissolved solids, pre-1995 data were designated “N” and post-1995 data were designated “T”.
[†] The maximum concentration and the second highest concentration (23,200 mg/L from Well 138 in 1978) appear to be outliers. The third highest concentration is 3,360 mg/L from Well 138 in 1979.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
i-EMEG – intermediate environmental media evaluation guide
LTHA – lifetime health advisory for drinking water
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
S – suspended
SS – Colorado state groundwater standard
T – total

Table 23. Groundwater sampling data (radionuclides) from wells used to water lawns

Radionuclide	Type	Frequency of Detection	Minimum (pCi/L)	Average (pCi/L)	Maximum (pCi/L)	Location of Maximum	Date of Maximum	CV (pCi/L)	Wells Sampled	Years Sampled
Lead-210	D	53/53	-0.2	0.2	1.5	Birch [119]	21-Jun-95	NA	119, 138, 139, 140, 144, 174, 224	1995–2000
	S	38/38	-0.1	0.1	0.6	house well, Cedar [140]	22-Feb-96, 05-May-99		138, 140, 174, 224	1995–2000
	T	1/1*	0	0	0	Field well, Cedar [138]	06-Sep-96		138	1996
Polonium-210	D	53/53	-0.1	0.2	0.9	Field well, Cedar [138]	04-May-99	NA	119, 138, 139, 140, 144, 174, 224	1995–2000
	S	38/38	0	0.1	0.6	house well, Cedar [140]	22-Feb-96, 05-Dec-96		138, 140, 174, 224	1995–2000
	T	1/1	0.5	0.5	0.5	Field well, Cedar [138]	06-Sep-96		138	1996
Radium-226	D	51/51	0	0.1	0.5	house well, Cedar [140]	12-May-95	5 (MCL radium-226/228)	119, 138, 139, 140, 144, 174, 224	1995–2000
	S	37/37**	0	0.003	0.1	Field well, Cedar [138]	30-Oct-95		138, 140, 174, 224	1995–2000
	T	2/2	0	0.05	0.1	Field well, Cedar [138]	06-Sep-96		138	1995–1996
Thorium-230	D	51/51	-0.1	0.08	0.4	Field well, Cedar [138]	06-Aug-98	NA	119, 138, 139, 140, 144, 174, 224	1995–2000
	S	34/34	0	0.06	0.3	house well, Cedar [140]	05-May-99		138, 140, 174, 224	1995–2000
	T	1/1	0.1	0.1	0.1	Field well, Cedar [138]	06-Sep-96		138	1996

Source: CDPHE 2007b
Averages were calculated using ½ the reporting detection limit for non-detects.
Negative and zero result values were included in the summary statistics.
* The detect flag is "Y" for the one sample, however, the result value is zero.
** For all but one sample, the result value is zero.

CV – comparison value
D – dissolved
MCL – maximum contaminant level
NA – not available
pCi/L – picocuries per liter
S – suspended
T – total

Table 24. Groundwater sampling data (chemicals) from Well 138

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Date of Maximum	CV (mg/L)	Years Sampled
Aluminum	D	8/57	0.05	0.23*	0.13	18-Dec-90	10 (c-EMEG, child)	1981, 1988–1995
Ammonia	N	10/42	0.02	0.29	0.9	23-Aug-88	30 (LTHA)	1988–1995
Ammonium	T	0/1	ND	ND	ND	--	NA	1995
Cadmium	D	0/1	ND	ND	ND	--	0.002 (c-EMEG, child)	1995
Chloride	N/T**	199/199	5.5	70	**450**	12-Aug-80	250 (Secondary MCL)	1975, 1976, 1978–2000
Copper	D	0/1	ND	ND	ND	--	0.1 (i-EMEG, child)	1995
Iron	D	21/106	0.01	0.025	0.31	09-Mar-95	26 (RBC)	1981–2000
Manganese	D	21/107	0.01	0.008§	0.06	11-Jun-91	0.5 (RMEG, child)	1979, 1981–2000
Molybdenum	D	253/253	**1.1**	**8.0**	**56.7**	11-Aug-72	0.035 (SS); 0.05 (RMEG, child)	1968–1973, 1975, 1976, 1978–2000
Nickel	D	0/1	ND	ND	ND	--	0.2 (RMEG, child)	1995
Nitrate	N/T**	59/62	0.7	2.3	4.1	11-Jun-91	10 (MCL)	1988–2000
Selenium	D	102/151	0.001	0.011	**0.134**†	13-Jul-81	0.05 (c-EMEG, child)	1974–1976, 1978–1988, 1995–2000
Sulfate	N/T**	200/200	71	**1,059**	**23,200**‡	01-Nov-78	250 (Secondary MCL)	1975, 1976, 1978–2000
Total Dissolved Solids	N/T**	202/202	290	**1,530**	**4,373**	06-Mar-81	500 (Secondary MCL)	1980–2000

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Date of Maximum	CV (mg/L)	Years Sampled
Uranium	D	253/253	0.0005	**0.73**	**5.161**	01-Aug-68	0.03 (MCL)	1968, 1974–1976, 1978–2000
	S	3/18	0.007	0.016	**0.26**	27-May-97		1995–2000
Vanadium	D	0/1	ND	ND	ND	--	0.03 (i-EMEG, child)	1995
Zinc	D	0/1	ND	ND	ND	--	3 (c-EMEG, child)	1995

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
* The calculated average is higher than the maximum detected concentration due to including ½ the detection limit in the calculation.
** For chloride, nitrate, sulfate, and total dissolved solids, pre-1995 data were designated “N” and post-1995 data were designated “T”.
§ The calculated average is lower than the minimum detected concentration due to including ½ the detection limit in the calculation.
† Only three of 151 samples were above the CV.
‡ The maximum concentration appears to be an outlier. The next highest concentration is 3,360 mg/L in 1979.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
i-EMEG – intermediate environmental media evaluation guide
LTHA – lifetime health advisory for drinking water
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
S – suspended
SS – Colorado state groundwater standard
T – total

Table 25. Groundwater sampling data (radionuclides) from Well 138

Radionuclide	Type	Frequency of Detection	Minimum (pCi/L)	Average (pCi/L)	Maximum (pCi/L)	Date of Maximum	CV (pCi/L)	Years Sampled
Lead-210	D	21/21	-0.2	0.22	1.1	03-Aug-95	NA	1995–2000
	S	18/18	0	0.08	0.2	27-May-97, 06-Feb-98, 29-Jul-99, 19-Oct-99		1995–2000
	T	1/1*	0	0	0	06-Sep-96		1996
Polonium-210	D	21/21	0	0.28	0.9	04-May-99	NA	1995–2000
	S	18/18	0	0.11	0.4	28-Aug-00		1995–2000
	T	1/1	0.5	0.5	0.5	06-Sep-96		1996
Radium-226	D	19/19	0	0.13	0.4	21-Mar-96	5 (MCL radium-226/228)	1995–2000
	S	18/18	0	0.006	0.1	30-Oct-95		1995–2000
	T	2/2	0	0.05	0.1	06-Sep-96		1995, 1996
Thorium-230	D	20/20	0	0.07	0.4	06-Aug-98	NA	1995–2000
	S	17/17	0	0.04	0.2	04-May-99, 29-Jul-99		1995–2000
	T	1/1	0.1	0.1	0.1	06-Sep-96		1996

Source: CDPHE 2007b

Averages were calculated using ½ the reporting detection limit for non-detects.
Negative and zero result values were included in the summary statistics.
*The detect flag is “Y” even though the result value is zero.

CV – comparison value
D – dissolved
MCL – maximum contaminant level
NA – not available
pCi/L – picocuries per liter
S – suspended
T – total

Table 26. Surface soil sampling data (chemicals) from eight zones around the Cotter Mill and from Lincoln Park

Chemical		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Zone H	Lincoln Park	CV (ppm)
Arsenic	Range (ppm)	33–**69**	19–**39**	14–**42**	10–**40**	16–**38**	17–**60**	17–**33**	19–**86**	13–**50**	0.5 (CREG), 20 (c-EMEG, child)
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	73/73	
	Average (ppm)	**45**	**30**	**25**	**26**	**28**	**35**	**26**	**42**	**31**	
Beryllium	Range (ppm)	0.5–1.6	0.5–0.9	0.6–1	0.5–1.2	0.6–1.7	0.5–0.7	0.6–0.7	0.5–0.9	0.5–1.7	100 (c-EMEG, child)
	Frequency of Detection	9/10	11/12	9/12	10/10	6/8	8/8	4/4	7/8	72/73	
	Average (ppm)	0.8	0.7	0.7	0.6	0.7	0.6	0.7	0.6	0.7	
Cadmium	Range (ppm)	1.2–**15**	2.1–**13**	2.2–**16**	2.5–6.8	5.3–**18**	8.9–**110**	1.6–**20**	4.4–**51**	0.5–5	10 (c-EMEG, child)
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	68/73	
	Average (ppm)	6.9	6.4	6.4	4.1	9.8	**36.5**	7.9	**21.1**	1.4	
Lead	Range (ppm)	43–270	45–240	46–260	47–130	100–280	68–800	37–450	61–1,400	17–270	NA
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	73/73	
	Average (ppm)	132	104	113	74	173	380	201	445	120	
Manganese	Range (ppm)	180–480	320–630	200–500	110–750	150–420	140–400	200–370	210–770	290–640	3,000 (RMEG , child)
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	73/73	
	Average (ppm)	336	422	356	391	298	268	290	439	424	
Selenium	Range (ppm)	5–7	39	7–16	5	ND	ND	ND	7	5–44	300 (c-EMEG, child)
	Frequency of Detection	5/10	1/12	2/12	1/10	0/8	0/8	0/4	1/8	7/73	
	Average (ppm)	4.2*	5.5*	4*	2.8*	ND	ND	ND	3.1*	3.5*	

Source: Weston 1998

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.

Each sample is a composite of four subsamples collected from the corners of a 10x10 square established near the center of the grid.
The dates the samples were collected were not specified in the report. It is assumed to be in the 1994–1996 timeframe.
See Figure 18 for a map of the sampling zones.

* The calculated averages are lower than the minimum detected concentrations due to including ½ the detection limit in the calculation.

c-EMEG – chronic environmental media evaluation guide
CREG – cancer risk evaluation guide
CV – comparison value
ND – not detected
NA – not available
ppm – parts per million
RMEG – reference dose media evaluation guide

Table 27. Surface soil sampling data (radionuclides) from eight zones around the Cotter Mill and from Lincoln Park

Radionuclide		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Zone H	Lincoln Park	CV (pCi/g)
Lead-210	Range (pCi/g)	1.6–9.7	3.0–14.4	2.5–6.0	2.3–4.5	2.6–6.1	2.7–4.9	1.2–4.4	1.5–4.7	0.7–4.2	NA
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	58/58	
	Average (pCi/g)	6.3	8.2	4.1	3.4	4.4	3.9	2.9	2.6	2.1	
Radium-226	Range (pCi/g)	2.4–**10.7**	3.6–**16.5**	1.3–**5.7**	1.4–2.3	2.5–**5.6**	1.9–3.0	1.4–1.9	1.2–2.2	1.1–2.2	5 (UMTRCA, surface)
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	58/58	
	Average (pCi/g)	**6.6**	**9.2**	2.6	1.8	3.9	2.5	1.7	1.5	1.5	
Thorium-230	Range (pCi/g)	3.6–35.3	5.8–40.1	1.6–21.7	1.8–4.4	4.3–12.1	3.6–8.3	1.7–2.8	1.6–11.9	1.0–4.2	NA
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	58/58	
	Average (pCi/g)	17.7	20.9	5.9	2.5	7.7	5.2	2.4	3.3	1.7	
Uranium, natural	Range (pCi/g)	0.871–4.288	1.541–5.427	0.737–5.628	0.737–1.64	1.005–2.412	0.6432–1.943	0.5561–1.005	0.536–1.206	0.6566–3.417	NA
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	73/73	
	Average (pCi/g)	2.45	3.29	1.98	1.17	1.52	1.21	0.83	0.73	1.215	
Uranium-234	Range (pCi/g)	0.436–2.14	0.771–2.71	0.369–2.81	0.369–0.82	0.503–1.21	0.322–0.972	0.278–0.503	0.268–0.603	0.328–1.709	NA
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	73/73	
	Average (pCi/g)	1.23	1.65	0.991	0.584	0.758	0.606	0.413	0.366	0.607	

Radionuclide		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Zone H	Lincoln Park	CV (pCi/g)
Uranium-238	Range (pCi/g)	0.436–2.14	0.771–2.71	0.369–2.81	0.369–0.82	0.503–1.21	0.322–0.972	0.278–0.503	0.268–0.603	0.328–1.709	NA
	Frequency of Detection	10/10	12/12	12/12	10/10	8/8	8/8	4/4	8/8	73/73	
	Average (pCi/g)	1.23	1.65	0.991	0.584	0.758	0.606	0.413	0.366	0.607	

Source: Weston 1998

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that radionuclide.
The dates the samples were collected were not specified in the report. It is assumed to be in the 1994–1996 timeframe.
Each sample is a composite of four subsamples collected from the corners of a 10x10 square established near the center of the grid.
See Figure for a map of the sampling zones.

CV – comparison value
NA – not available
pCi/g – picocuries per gram
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Table 28. Surface soil sampling data (radionuclides) from the county road and the Cotter Uranium Mill access road

Radionuclide		Samples from background areas	Samples along the county road	Samples along the access road*	CV
Radium-226	Range (pCi/g)	0.8–2.1	3.8–**14**	2.7–**351**	5 pCi/g (UMTRCA, surface)
	Frequency of Detection	5/5	5/5	6/6	
	Average (pCi/g)	1.42	**7.7**	**65**	
Thorium-230	Range (pCi/g)	0.2–2.4	9.7–25	10–395	NA
	Frequency of Detection	3/5	5/5	6/6	
	Average (pCi/g)	1.53	20	87	
Uranium, natural	Range (ppm)	1.18–3.05	5.28–29.2	4.31–**922**	100 ppm (i-EMEG, child for highly soluble salts)
	Frequency of Detection	5/5	5/5	6/6	
	Average (ppm)	1.87	13.6	**161**	
Uranium-238**	Range (pCi/g)	0.39–1.01	1.74–9.64	1.42–304	NA
	Frequency of Detection	5/5	5/5	6/6	
	Average (pCi/g)	0.62	4.5	53	
Gamma Exposure Rates	Range (µR/hr)	NA	13.8–55.3	18.6–893	NA
	Frequency of Detection	NA	NA	NA	
	Average (µR/hr)	15.7	25.8	73.7	

Source: MFG 2005

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value.
Each sample consists of 10 aliquots taken from 0–6 inches within a 100 m^2 area.
See Figure for a map of the sampling locations.

*There is limited potential for exposure to contaminants along the access road since access to the Cotter Mill is restricted and soils along the access road were remediated in 2007 and 2008.
**Uranium-238 concentrations were calculated by multiplying the natural uranium concentrations by 0.33.

CV – comparison value
i-EMEG – intermediate environmental media evaluation guide
µR/hr – microroentgen per hour
NA – not available
pCi/g – picocuries per gram
ppm – parts per million
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Table 29. Soil data (chemicals) from samples taken by CDPHE, January 2003

Chemical	Frequency of Detection	Minimum (ppm)	Average (ppm)	Maximum (ppm)	Location of Maximum	CV (ppm)
Lead	20/20	23	410	3,651*	Private barn in Lincoln Park (dust sample)	NA
Molybdenum	0/20	ND**	ND**	ND**	--	300 (RMEG , child)
Uranium	20/20	1.2	6.0	31	Mill Entrance Road	100 (i-EMEG, child for highly soluble salts)

Source: CDPHE 2003, 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
See Figure for a map of the sampling locations.
The sampling event was intentionally biased toward finding the highest amounts of contamination possible [CDPHE 2003].

*The second highest lead concentration is 908 ppm from a location northwest of the Cotter Mill.
**The molybdenum detection limit was 25 ppm.
§ Concentrations from the background location on the corner of Orchard Avenue and High Street were not included in the table.

CV – comparison value
i-EMEG – intermediate environmental media evaluation guide
ND – not detected
NA – not available
ppm – parts per million
RMEG – reference dose media evaluation guide

Concentrations from the Background Location§

Lead	36 ppm
Molybdenum	ND
Uranium	1.3 ppm

Table 30. Soil data (radionuclides) from samples taken by CDPHE, January 2003

Radionuclide	Frequency of Detection	Minimum (pCi/g)	Average (pCi/g)	Maximum (pCi/g)	Location of Maximum	CV (pCi/g)
Cesium-137	20/20	0	0.64	1.33	Private residence in Lincoln Park (dust sample)	NA
Lead-210	20/20	1.9	9.7	22.8	East of the Cotter Mill	NA
Plutonium-239, 240	9/20	0.03	0.03*	0.06	East of the Cotter Mill & a private residence in Lincoln Park (dust sample)	NA
Potassium-40	20/20	17.6	22.6	31.9	East of the Cotter Mill	NA
Radium-226	20/20	1.4	7.8	**21.2**	East of the Cotter Mill	15 (UMTRCA, subsurface)
Radium-228	20/20	0.6	1.0	1.3	Private barn in Lincoln Park (dust sample), private residence in Lincoln Park (dust sample), Pine St near Elm Ave in Lincoln Park (sediment sample), Northwest of the Cotter Mill	15 (UMTRCA, subsurface)

Source: CDPHE 2003, 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that radionuclide.
Averages were calculated using ½ the reporting detection limit for non-detects.
See Figure for a map of the sampling locations.
The sampling event was intentionally biased toward finding the highest amounts of contamination possible [CDPHE 2003].

* The calculated average is the same as the minimum detected concentration due to including ½ the detection limit in the calculation.
** Concentrations from the background location on the corner of Orchard Avenue and High Street were not included in the table.

CV – comparison value
NA – not available
pCi/g – picocuries per gram
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Concentrations from the Background Location**

Cesium-137	0.2 pCi/g
Lead-210	3.2 pCi/g
Plutonium-239, 240	ND
Potassium-40	19.5 pCi/g
Radium-226	1.9 pCi/g
Radium-228	1.0 pCi/g

Table 31. Surface soil sampling data from 10 air monitoring locations

Chemical	Frequency of Detection	Minimum (ppm)	Average (ppm)	Maximum (ppm)	Location of Maximum	Date of Maximum	Years Sampled	CV (ppm)
Molybdenum	106/134	0.6	15.1	251.3	AS-204 (West Boundary)	2002	1992–2006*	300 (RMEG, child)
Radionuclide	**Frequency of Detection**	**Minimum (pCi/g)**	**Average (pCi/g)**	**Maximum (pCi/g)**	**Location of Maximum**	**Date of Maximum**	**Years Sampled**	**CV (pCi/g)**
Radium-224**	10/10	-5.7	-2.9	0.3	Lincoln Park	2006	2006	5 (UMTRCA, surface)
Radium-226	246/251	<0.5	3.9	**53.5**	AS-209 (Mill Entrance Road)	2002	1979–2006[†]	5 (UMTRCA, surface)
Thorium-230	107/107	0.4	22.2	354	AS-209 (Mill Entrance Road)	2002	1996–2006	NA
Thorium-232	60/60	0.5	1.4	7.9	AS-209 (Mill Entrance Road)	2002	2001–2006	NA
Uranium	258/262	<0.001	4.6	73.6	AS-209 (Mill Entrance Road)	2002	1979–2006	NA

Source: Cotter 2007; GeoTrans 1986

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value.
Uranium and radium-226 were also tested in soil from two additional off-site locations (Oro Verde #1 and Oro Verde #2) in 1983 and 1984.
See Figure for a map of the air monitoring locations.

*Data from 2006 are unavailable.
**Data are blank corrected.
[†] Results from 2005 were not reported based on quality assurance analysis (Cotter 2007).

CV – comparison value
NA – not available
pCi/g – picocuries per gram
ppm – parts per million
RMEG – reference dose media evaluation guide
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Table 32. Soil sampling data (chemicals) from location AS-212 (the Nearest Resident)

Chemical	Frequency of Detection	Minimum (ppm)	Average (ppm)	Maximum (ppm)	Date of Maximum	Years Sampled	CV (ppm)
Lead	1/1	199	199	199	15-Jan-03	2003	NA
Molybdenum	7/8	1.6	11.3	42.4	2005	1999–2005	300 (RMEG , child)
Uranium	1/1	4.9	4.9	4.9	15-Jan-03	2003	100 (i-EMEG, child for highly soluble salts)

Source: CDPHE 2007b, Cotter 2007

Averages were calculated using ½ the reporting detection limit for non-detects.
See Figure for the location of AS-212, the nearest resident.

CV – comparison value
i-EMEG – intermediate environmental media evaluation guide
ppm – parts per million
NA – not available
RMEG – reference dose media evaluation guide

Table 33. Soil sampling data (radionuclides) from location AS-212 (the Nearest Resident)

Radionuclide	Frequency of Detection	Minimum (pCi/g)	Average (pCi/g)	Maximum (pCi/g)	Date of Maximum	Years Sampled	CV (pCi/g)
Cesium-137	1/1	0.61	0.61	0.61	15-Jan-03	2003	NA
Lead-210	1/1	8	8	8	15-Jan-03	2003	NA
Plutonium-239, 240	1/1	0.03	0.03	0.03	15-Jan-03	2003	NA
Potassium-40	1/1	17.7	17.7	17.7	15-Jan-03	2003	NA
Radium-224*	1/1	-3.6	-3.6	-3.6	2006	2006	5 (UMTRCA, surface)
Radium-226	8/8	1.4	3.3	**7.5**	2004	1999–2004, 2006	5 (UMTRCA, surface)
Radium-228	1/1	0.9	0.9	0.9	15-Jan-03	2003	5 (UMTRCA, surface)
Thorium-230	8/8	3.3	10.1	20	2004	1999–2006	NA
Thorium-232	6/6	0.7	1.0	1.1	2001, 2002	2001–2006	NA
Uranium	8/8	2.0	5.2	13	2004	1999–2006	NA

Source: CDPHE 2007b, Cotter 2007

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that radionuclide.
See Figure for the location of AS-212, the nearest resident.

*Data are blank corrected.

CV – comparison value
NA – not available
pCi/g – picocuries per gram
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Table 34. Surface soil sampling data (chemicals) from lawns and gardens in Lincoln Park

Chemical	Frequency of Detection	Minimum (ppm)	Average (ppm)	Maximum (ppm)	Location of Maximum	Years Sampled	CV (ppm)
Arsenic	15/15	31	**44**	**50**	garden soil	1996	0.5 (CREG), 20 (c-EMEG, child)
Beryllium	14/15	0.5	0.7	1.1	lawn soil	1996	100 (c-EMEG, child)
Cadmium	14/15	0.5	1.2	1.9	lawn soil	1996	10 (c-EMEG, child)
Manganese	15/15	290	428	640	lawn soil	1996	3,000 (RMEG , child)
Selenium	1/32	18	1.7*	18	garden soil	1990, 1996	300 (c-EMEG, child)

Source: Weston 1996 (some or all of these data may also be included in Table)

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.

* The calculated average is lower than the minimum detected concentration due to including ½ the detection limit in the calculation.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
ppm – parts per million
RMEG – reference dose media evaluation guide

Table 35. Surface soil sampling data (radionuclides) from yards, gardens, and air monitoring locations in Lincoln Park

Radionuclide	Frequency of Detection	Minimum (pCi/g)	Average (pCi/g)	Maximum (pCi/g)	Source of Maximum	Years Sampled	CV (pCi/g)
Lead-210	17/17	0.4	1.6	2.5	0–2” garden sample	1990	NA
Polonium-210	17/17	1.1	1.7	2.6	0–2” garden sample	1990	NA
Radium-226	19/19	0.8	1.5	2.0	0–2” garden sample	1987, 1988, 1990	5 (UMTRCA, surface)
Thorium-228	17/17	1.0	1.4	1.8	0–2” garden sample	1990	NA
Thorium-230	17/17	1.0	1.5	2.3	0–2” garden sample	1990	NA
Uranium-234	29/29	0.355	1.23	1.95	Soil from the yard of a participant in the LPWUS	1987–1990	NA
Uranium-235	0/17	ND*	ND*	ND*	--	1990	NA
Uranium-238	29/29	0.355	1.21	1.95	Soil from the yard of a participant in the LPWUS	1987–1990	NA

Source: Weston 1996

*The uranium-235 detection limit was 0.2 pCi/g.

CV – comparison value
LPWUS – Lincoln Park Water Use Survey
NA – not available
ND – not detected
pCi/g – picocuries per gram
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Table 36. Surface soil data (chemicals) from lawns and gardens in Lincoln Park

Chemical		Samples from locations irrigated with contaminated well water	Samples from locations not irrigated with contaminated well water	CV (ppm)
Arsenic	Range (ppm)	14–**50**	13–**38**	0.5 (CREG), 20 (c-EMEG, child)
	Frequency of Detection	26/26	47/47	
	Average (ppm)	**36***	**28***	
Beryllium	Range (ppm)	0.5–1.1	0.6–1.7	100 (c-EMEG, child)
	Frequency of Detection	25/26	47/47	
	Average (ppm)	0.7	0.8	
Cadmium	Range (ppm)	0.6–1.9	0.5–5	10 (c-EMEG, child)
	Frequency of Detection	23/26	45/47	
	Average (ppm)	1.2	1.5**	
Lead	Range (ppm)	17–270[†]		None
	Frequency of Detection	73/73[†]		
	Average (ppm)	122	121	
Manganese	Range (ppm)	290–640	320–580	3,000 (RMEG , child)
	Frequency of Detection	26/26	47/47	
	Average (ppm)	430	421**	
Molybdenum	Range (ppm)	*Data not available*[§]	*Data not available*[§]	300 (RMEG , child)
	Frequency of Detection	*Data not available*[§]	*Data not available*[§]	
	Average (ppm)	1.7*	0.5*	
Selenium	Range (ppm)	18	5–44	300 (c-EMEG, child)
	Frequency of Detection	1/26	6/47	
	Average (ppm)	3.1	3.8	
Uranium	Range (ppm)	*Data not available*[§]	*Data not available*[§]	100 (i-EMEG, child for highly soluble salts)
	Frequency of Detection	*Data not available*[§]	*Data not available*[§]	
	Average (ppm)	2.3*	1.6*	

Source: Weston 1998

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
The dates the samples were collected were not specified in the report. It is assumed to be in the 1994–1996 timeframe.

*The concentrations were statistically higher in irrigated soil samples.
**The calculated averages for cadmium and manganese differ slightly from the reported mean concentrations in Table 3-3.
[†] The raw data for lead are not presented by whether the samples were taken from locations irrigated with contaminated well water. However, Table 3-3 presents the mean concentrations by manner of irrigation.
[§] The raw data for molybdenum and uranium are not presented in the report. Therefore, the range and frequency of detection could not be determined. Table 3-3 presents the mean concentrations.

c-EMEG – chronic environmental media evaluation guide
CREG – cancer risk evaluation guide
CV – comparison value
i-EMEG – intermediate environmental media evaluation guide
ppm – parts per million
RMEG – reference dose media evaluation guide

Table 37. Surface soil data (radionuclides) from lawns and gardens in Lincoln Park

Radionuclide		Samples from locations irrigated with contaminated well water	Samples from locations not irrigated with contaminated well water	CV (pCi/g)
Lead-210	Range (pCi/g)	0.8–3.0	0.7–4.2	NA
	Frequency of Detection	11/11	47/47	
	Average (pCi/g)	2.2	2.1*	
Radium-226	Range (pCi/g)	1.3–1.7	1.1–2.2	5 (UMTRCA, surface)
	Frequency of Detection	11/11	47/47	
	Average (pCi/g)	1.4	1.5	
Thorium-230	Range (pCi/g)	1.1–2.2	1.0–4.2	NA
	Frequency of Detection	11/11	47/47	
	Average (pCi/g)	1.6*	1.7	
Uranium, natural	Range (pCi/g)	0.871–3.417	0.6566–2.077	NA
	Frequency of Detection	26/26	47/47	
	Average (pCi/g)	1.514	1.05	
Uranium-234	Range (pCi/g)	0.436–1.709	0.328–1.039	NA
	Frequency of Detection	26/26	47/47	
	Average (pCi/g)	0.755	0.525	
Uranium-238	Range (pCi/g)	0.436–1.709	0.328–1.039	NA
	Frequency of Detection	26/26	47/47	
	Average (pCi/g)	0.755	0.525	

Source: Weston 1998

The dates the samples were collected were not specified in the report. It is assumed to be in the 1994–1996 timeframe.

*The calculated averages for lead-210 and thorium-230 differ slightly from the reported mean concentrations in Table 3-3.

CV – comparison value
NA – not available
pCi/g – picocuries per gram
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Table 38. Sediment sampling data (chemicals) from Sand Creek

Chemical	Location Concentration (ppm)						CV (ppm)
	SD01	SD02*	SD04			SD05	
			1	2	3		
Arsenic	NA	13.7	13	NA	17	<5	20 (c-EMEG, child)
Cadmium	NA	3.9	7.2	NA	7.6	1.5	10 (c-EMEG, child)
Cobalt	NA	11.3	43	NA	21	10	500 (i-EMEG, child)
Copper	19	52.3	46	NA	38	19	500 (i-EMEG, child)
Lead	27	106	93	NA	130	22	None
Molybdenum	4.4	2.6	8	NA	7.9	9.4	300 (RMEG , child)
Nickel	NA	17	63	NA	28	18	1,000 (RMEG, child)
Zinc	NA	343	540	NA	580	106	20,000 (c-EMEG, child)

Source: GeoTrans 1986

SD01 – mouth near the Arkansas River
SD02 – near spring where flow begins (reflects migration of contaminants in the groundwater)
SD04 – below the SCS Dam in
  (1) an abandoned stock watering pond (formed by diversion of runoff water into a depression adjacent to Sand Creek)
  (2) in drainage (reflects historical picture of uncontrolled emissions)
  (3) in drainage above #2 (reflects historical picture of uncontrolled emissions)
SD05 – above the SCS Dam adjacent to the west property edge

Bolded text indicates that the concentration exceeded the comparison value for that chemical.
Samples were collected July 10–20, 1985.

*Values are the mean of three field replicates.

c-EMEG – chronic environmental media evaluation guide
CREG – cancer risk evaluation guide
CV – comparison value
i-EMEG – intermediate environmental media evaluation guide
ppm – parts per million
RMEG – reference dose media evaluation guide

Table 39. Sediment sampling data (radionuclides) from Sand Creek

Radionuclide	Location Average (pCi/g)						CV
	SD01	SD02	SD04			SD05	
			1	2	3		
Gross Alpha	22±3	47±9	240±40	74±9	39±7	22±5	NA
Gross Beta	29±6	43±8	90±20	34±7	32±7	32±6	NA
Radium-226	1.21±0.06	1.7±1	**12.8±0.6**	3.5±0.2	3.4±0.2	2.3±1	5 (UMTRCA, surface)
Throium-230	4.6±0.3	34±2	82±4	32±2	15.5±0.8	5.2±0.3	NA
Total Uranium	2.4	4.3	11.7	3.4	3.4	3.9	NA

Source: GeoTrans 1986

SD01 – mouth near the Arkansas River
SD02 – near spring where flow begins (reflects migration of contaminants in the groundwater)
SD04 – below the SCS Dam in
    (1) an abandoned stock watering pond (formed by diversion of runoff water into a depression adjacent to Sand Creek)
    (2) in drainage (reflects historical picture of uncontrolled emissions)
    (3) in drainage above #2 (reflects historical picture of uncontrolled emissions)
SD05 – above the SCS Dam adjacent to the west property edge

Bolded text indicates that the concentration exceeded the comparison value for that radionuclide.
Samples were collected July 10–20, 1985.

CV – comparison value
NA – not available
pCi/g – picocuries per gram
UMTRCA – 1978 Uranium Mill Tailings Radiation Control Act

Table 40. Chemical sampling for the Sand Creek Cleanup Project

Chemical	Frequency of Detection	Minimum (ppm)	Average (ppm)	Maximum (ppm)	CV (ppm)
Arsenic	7/7	2.7	3.9	6.9	20 (c-EMEG, child)
Barium	7/7	69	106	160	10,000 (c-EMEG, child)
Beryllium	7/7	0.2	0.3	0.6	100 (c-EMEG, child)
Chromium	7/7	7.4	9.5	12.8	200 (RMEG, child for hexavalent chromium)
Lead	7/7	17	35	75	None
Manganese	7/7	258	343	502	3,000 (RMEG , child)
Molybdenum	7/7	2.1	2.8	3.5	300 (RMEG , child)
Nickel	7/7	8	10.9	16	1,000 (RMEG , child)
Selenium	0/7	ND*	ND*	ND*	300 (c-EMEG, child)
Vanadium	7/7	16.1	20.3	26.1	200 (i-EMEG, child)

Source: Cotter 2000

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Samples were collected in April and May 1998.

*The selenium detection limit was 5 ppm.

c-EMEG – chronic environmental media evaluation guide
CREG – cancer risk evaluation guide
CV – comparison value
i-EMEG – intermediate environmental media evaluation guide
ND – not detected
ppm – parts per million
RMEG – reference dose media evaluation guide

Table 41. Surface water sampling data (chemicals) from Sand Creek

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Date of Maximum	CV (mg/L)	Years Sampled
Aluminum	D	0/2	ND	ND	ND	--	10 (c-EMEG, child)	1988
Ammonia	N	2/35	0.5	0.43*	0.8	10-Nov-88	30 (LTHA)	1988–1994
Ammonium	T	0/3	ND	ND	ND	--	NA	1995
Chloride	N/T**	92/92	3	8	14	13-May-04	250 (Secondary MCL)	1986–2007
Iron	D	21/55	0.03	0.04	0.26	07-Nov-02	26 (RBC)	1986–1988, 1995–2007
Manganese	D	36/55	0.0084	0.04	**1.3**[†]	19-Nov-01	0.5 (RMEG, child)	1986–1988, 1995–2007
Molybdenum	D	98/104	0.005	0.02	**0.051**[†]	01-Dec-87	0.035 (SS); 0.05 (RMEG, child)	1986–2007
Nitrate	N/T**	75/87	0.5	1.1	4.7	03-May-06	10 (MCL)	1988–2007
Selenium	D	0/8	ND	ND	ND	--	0.05 (c-EMEG, child)	1986–1988
Sulfate	N/T**	94/94	12	65	**310**[†]	11-Oct-96	250 (Secondary MCL)	1986–2007
Total Dissolved Solids	N/T**	99/99	10.7	369	**1,372**[‡]	22-Aug-91	500 (Secondary MCL)	1986–2007
Uranium	D	101/101	0.006	0.012	0.0267	01-Aug-95	0.03 (MCL)	1986–2007
	S	8/48	0.000098	0.001	0.0031	10-Jan-00		1995–2007

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
* The calculated average is lower than the minimum detected concentration due to including ½ the detection limit in the calculation.
** For chloride, nitrate, sulfate, and total dissolved solids, pre-1995 data were designated "N" and post-1995 data were designated "T".
[†] Only the maximum concentration was above the CV.
[‡] This appears to be an outlier. The next highest concentration is 460 mg/L. Only the maximum concentration was above the CV.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
LTHA – lifetime health advisory for drinking water
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
NA – not available
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
S – suspended
SS – Colorado state groundwater standard
T – total

Table 42. Surface water sampling data (radionuclides) from Sand Creek

Radionuclide	Type	Frequency of Detection	Minimum (pCi/L)	Average (pCi/L)	Maximum (pCi/L)	Date of Maximum	CV (pCi/L)	Years Sampled
Lead-210	D	40/49	-0.2	0.39	3.7	06-Aug-07	NA	1995–2007
	S	40/49	-0.1	0.40	4.6	06-Aug-07		1995–2007
Polonium-210	D	41/49	-0.1	0.15	0.6	28-Nov-06	NA	1995–2007
	S	40/49	0	0.13	1.6	09-Nov-99		1995–2007
Radium-226	D	45/49	0	0.12	0.6	03-May-06	5 (MCL radium-226/228)	1995–2007
	S	42/47	0	0.06	0.4	09-Nov-99, 28-Nov-06		1995–2007
Thorium-230	D	44/49	-0.1	0.13	0.8	28-Nov-06	NA	1995–2007
	S	41/46	0	0.16	0.9	06-Aug-07		1995–2007

Source: CDPHE 2007b

Averages were calculated using ½ the reporting detection limit for non-detects.
Negative and zero result values were included in the summary statistics.

CV – comparison value
D – dissolved
MCL – maximum contaminant level
NA – not available
pCi/L – picocuries per liter
S – suspended

Table 43. Surface water sampling data (chemicals) from the DeWeese Dye Ditch

Chemical	Type	Frequency of Detection	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Date of Maximum	CV (mg/L)	Years Sampled
Aluminum	D	1/4	0.02	0.06*	0.02	14-Jun-95	10 (c-EMEG, child)	1981, 1995
Ammonia	N	0/2	ND	ND	ND	--	30 (LTHA)	1989, 1995
Chloride	N/T**	95/102	2	7	18	08-May-01	250 (Secondary MCL)	1981–1989, 1995–2007
Iron	D	22/50	0.029	0.9	**43**[†]	09-Jun-99	26 (RBC)	1981–1987, 1995–2007
Manganese	D	28/50	0.004	0.05	**1.9**[‡]	09-Jun-99	0.5 (RMEG, child)	1981–1987, 1995–2007
Molybdenum	D	10/120	0.001	0.013[§]	0.013	06-Aug-03	0.035 (SS); 0.05 (RMEG, child)	1981–2007
Nitrate	N/T**	7/26	0.1	0.3	0.8	10-May-00, 02-Aug-06	10 (MCL)	1989, 1995–2007
Selenium	D	4/76	0.005	0.003[††]	0.011	22-Jun-87, 25-Apr-88	0.05 (c-EMEG, child)	1981–1988, 1995
Sulfate	N/T**	102/102	6	31	95	28-Apr-82	250 (Secondary MCL)	1981–1989, 1995–2007
Total Dissolved Solids	N/T**	119/119	12.9	231	**1,647**[‡‡]	10-Sep-90	500 (Secondary MCL)	1981–2007
Uranium	D	86/116	0.0004	0.01	**0.11**[§§]	05-May-83	0.03 (MCL)	1981–2007
	S	0/8	ND	ND	ND	--		1996–1999

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.

* The calculated average is higher than the maximum detected concentration due to including ½ the detection limit in the calculation.
** For chloride, nitrate, sulfate, and total dissolved solids, pre-1995 data were designated “N” and post-1995 data were designated “T”.
[†] This appears to be an outlier. The next highest concentration is 0.24 mg/L from the same location in 2003. Only the maximum concentration was above the CV.
[‡] Only the maximum concentration was above the CV.
[§] The calculated average is the same as the maximum detected concentration due to including ½ the detection limit in the calculation.

[††] The calculated average is the lower than the minimum detected concentration due to including ½ the detection limit in the calculation.
[‡‡] This appears to be an outlier. The next highest concentration is 870 mg/L. Only three of the 119 samples were above the CV.
[§§] Only three of the samples were above the CV.

c-EMEG – chronic environmental media evaluation guide
CV – comparison value
D – dissolved
LTHA – lifetime health advisory for drinking water
MCL – maximum contaminant level
mg/L – milligrams per liter
N – not defined in the CDPHE database
ND – not detected
RBC – risk based concentration for drinking water
RMEG – reference dose media evaluation guide
S – suspended
SS – Colorado state groundwater standard
T – total

Table 44. Surface water sampling data (radionuclides) from the DeWeese Dye Ditch

Radionuclide	Type	Frequency of Detection	Minimum (pCi/L)	Average (pCi/L)	Maximum (pCi/L)	Date of Maximum	CV (pCi/L)	Years Sampled
Lead-210	D	8/8	0	0.3	1.2	09-May-96	NA	1996–1999
	S	8/8	0	0.09	0.2	12-May-97		1996–1999
Polonium-210	D	8/8	0	0.1	0.2	09-Jun-99, 02-Sep-99	NA	1996–1999
	S	8/8	0	0.05	0.2	09-Jun-99		1996–1999
Radium-226	D	8/8	0	0.04	0.1	09-May-96, 16-Jul-96, 02-Sep-99	5 (MCL radium-226/228)	1996–1999
	S	7/7	0	0.01	0.1	02-Sep-99		1996–1999
Thorium-230	D	8/8	0	0.025	0.2	12-May-97	NA	1996–1999
	S	7/7	0	0.07	0.2	09-Sep-98		1996–1999

Source: CDPHE 2007b

Averages were calculated using ½ the reporting detection limit for non-detects.
Negative and zero result values were included in the summary statistics.

CV – comparison value
D – dissolved
MCL – maximum contaminant level
NA – not available
pCi/L – picocuries per liter
S – suspended

Table 45. Surface water sampling data (chemicals) from the Arkansas River

Chemical	Type		Upstream of Sand Creek at 1st Street (907)	Downstream of Sand Creek at Mackenzie Ave (904)	CV (mg/L)
Chloride	T	Range (mg/L)	3–60	3–14	250 (Secondary MCL)
		Frequency of Detection	127/130	127/130	
		Average (mg/L)	8	8	
Molybdenum	D	Range (mg/L)	0.0029–**0.046**	0.003–0.029	0.035 (SS); 0.05 (RMEG, child)
		Frequency of Detection	32/142	46/142	
		Average (mg/L)	0.025	0.025	
Molybdenum	S	Range (mg/L)	0.0019–0.022	0.0017–0.016	0.035 (SS); 0.05 (RMEG, child)
		Frequency of Detection	8/135	6/135	
		Average (mg/L)	0.025	0.025	
Molybdenum	T	Range (mg/L)	0.006	0.005	0.035 (SS); 0.05 (RMEG, child)
		Frequency of Detection	1/7	1/7	
		Average (mg/L)	0.003*	0.003*	
Sulfate	T	Range (mg/L)	10–**1,300** **	5–**4,200** **	250 (Secondary MCL)
		Frequency of Detection	130/130	130/130	
		Average (mg/L)	41	84	
Total Dissolved Solids	T	Range (mg/L)	45–**2,880**[†]	62–337	500 (Secondary MCL)
		Frequency of Detection	130/130	130/130	
		Average (mg/L)	172	192	
Uranium	D	Range (mg/L)	0.0003– 0.0135	0.0002–0.0155	0.03 (MCL)
		Frequency of Detection	129/130	130/130	
		Average (mg/L)	0.004	0.005	
Uranium	S	Range (mg/L)	0.0002– 0.014	0.0002–0.0043	0.03 (MCL)
		Frequency of Detection	16/121	14/121	
		Average (mg/L)	0.001	0.001	
Uranium	T	Range (mg/L)	0.0033–0.0056	0.0029–0.0054	0.03 (MCL)
		Frequency of Detection	7/7	7/7	
		Average (mg/L)	0.004	0.004	

Source: CDPHE 2007b

Bolded text indicates that the average and/or maximum concentration exceeded the comparison value for that chemical.
Averages were calculated using ½ the reporting detection limit for non-detects.
All samples were collected between 1995 and 2007. The "T" samples for uranium were only collected in 1995.
* The calculated average is lower than the minimum detected concentration due to including ½ the detection limit in the calculation.
** This appears to be an outlier. The next highest concentration is 200 mg/L. Only the maximum concentration was above the CV.
[†] This appears to be an outlier. The next highest concentration is 405 mg/L. Only the maximum concentration was above the CV.

CV – comparison value
D – dissolved
MCL – maximum contaminant level
mg/L – milligrams per liter
RMEG – reference dose media evaluation guide
S – suspended
SS – Colorado state groundwater standard
T – total

Table 46. Surface water sampling data (radionuclides) from the Arkansas River

Radionuclide	Type		Upstream of Sand Creek at 1st Street (907)	Downstream of Sand Creek at Mackenzie Ave (904)	CV (pCi/L)
Lead-210	D	Range (pCi/L)	ND	3.7	NA
		Frequency of Detection	0/1	1/1	
		Average (pCi/L)	ND	3.7	
Lead-210	S	Range (pCi/L)	ND	0	NA
		Frequency of Detection	0/1	1/2	
		Average (pCi/L)	ND	0.25*	
Polonium-210	D	Range (pCi/L)	ND	ND	NA
		Frequency of Detection	0/1	0/1	
		Average (pCi/L)	ND	ND	
Polonium-210	S	Range (pCi/L)	ND	0.26–3.3	NA
		Frequency of Detection	0/1	2/2	
		Average (pCi/L)	ND	1.8	
Radium-226	D	Range (pCi/L)	0–0.6	0–0.4	5 (MCL radium-226/228)
		Frequency of Detection	119/128	116/127	
		Average (pCi/L)	0.13	0.07	
Radium-226	S	Range (pCi/L)	0–0.8	0–2.3	5 (MCL radium-226/228)
		Frequency of Detection	114/120	112/119	
		Average (pCi/L)	0.08	0.09	
Radium-226	T	Range (pCi/L)	0.1–0.7	0.1–0.7	5 (MCL radium-226/228)
		Frequency of Detection	7/7	7/7	
		Average (pCi/L)	0.3	0.3	
Thorium-230	D	Range (pCi/L)	-0.1–1	-0.1–1.2	NA
		Frequency of Detection	121/127	116/127	
		Average (pCi/L)	0.1	0.1	
Thorium-230	S	Range (pCi/L)	0–2.5	0–2.4	NA
		Frequency of Detection	115/120	113/119	
		Average (pCi/L)	0.2	0.2	
Thorium-230	T	Range (pCi/L)	0.1–0.7	0–0.6	NA
		Frequency of Detection	7/7	7/7	
		Average (pCi/L)	0.3	0.2	

Source: CDPHE 2007b

Averages were calculated using ½ the reporting detection limit for non-detects.
Negative and zero result values were included in the summary statistics.
Radium-226 and thorium-230 "D" and "S" samples were collected between 1995 and 2007. The radium-226 and thorium-230 "T" samples were only collected in 1995. Lead-210 and polonium-210 were sampled upstream (907) in 2005 ("D" and "S") and downstream (904) in 2005 ("D") and 2006 ("D" and "S").

* The calculated average is higher than the detected concentration due to including ½ the detection limit in the calculation.

CV – comparison value
D – dissolved
MCL – maximum contaminant level
NA – not available
ND – not detected
pCi/L – picocuries per liter
S – suspended
T – total

Table 47. Sampling data (chemicals) for local and supermarket foods

Chemical	Food Type	Average (mg/kg)	
		Local	Supermarket
Barium*	Vegetables	4.75	NA
Cadmium*	Vegetables	0.215	NA
Chromium*	Vegetables	0.095	NA
Manganese*	Vegetables	11.25	NA
Molybdenum	Chicken	0.19	0.72
	Fruits	0.079	0.017
	Vegetables	0.667	0.023
Selenium	Chicken	0.31	0.18
	Fruits	0.024	0.017
	Vegetables	0.061	0.020
Strontium*	Vegetables	22	NA
Uranium	Chicken	0.061	0.001
	Fruits	0.0056	0.0013
	Vegetables	0.0043	0.0013
Vanadium*	Vegetables	0.105	NA
Zinc*	Vegetables	7.5	NA

Source: Weston 1996

Averages were calculated using ½ the reporting detection limit for non-detects.
Concentrations are reported on a wet weight basis.
Vegetables were also tested for arsenic, beryllium, cobalt, lead, mercury, nickel, and silver, but none of these chemicals were detected.

*Chicken and fruits were not analyzed for these chemicals.

NA – not available
mg/kg – milligrams per kilogram

Table 48. Sampling data (radionuclides) for local and supermarket foods

Radionuclide	Food Type	Average (pCi/kg)	
		Local	Supermarket
Lead-210	Chicken	1.26	1.70
	Fruits	1.48	1.18
	Vegetables	0.58	0.60
Polonium-210	Chicken	3.79	21.75
	Fruits	2.26	1.30
	Vegetables	1.13	1.56
Radium-226	Chicken	0.64	2.60
	Fruits	1.34	0.05
	Vegetables	1.37	0.07
Thorium-228	Chicken	0.39	ND
	Fruits	0.33	ND
	Vegetables	0.41	1.42
Thorium-230	Chicken	1.01	0.53
	Fruits	1.85	ND
	Vegetables	0.27	0.29
Uranium-234	Chicken	1.10	1.05
	Fruits	1.53	0.34
	Vegetables	0.55	0.76
Uranium-235	Chicken	ND	0.36
	Fruits	0.13	0.13
	Vegetables	0.13	0.14
Uranium-238	Chicken	1.59	0.53
	Fruits	1.41	0.23
	Vegetables	0.44	0.25

Source: Weston 1996

Averages were calculated using ½ the reporting detection limit for non-detects.
Concentrations are reported on a wet weight basis.

ND – not detected
pCi/kg – picocuries per kilogram

Table 49. Sampling data (chemicals) for local produce irrigated with contaminated well water

Chemical		Fruits	Vegetables
Arsenic	Frequency of Detection	2/16	14/43
	Average (mg/kg)	0.051	0.077
	Maximum (mg/kg)	0.2	0.4
Barium	Frequency of Detection	7/16	33/43
	Average (mg/kg)	0.44	1.6
	Maximum (mg/kg)	0.9	15
Cadmium	Frequency of Detection	2/16	18/43
	Average (mg/kg)	0.041	0.034
	Maximum (mg/kg)	0.23	0.14
Chromium	Frequency of Detection	12/16	39/43
	Average (mg/kg)	0.052	0.056
	Maximum (mg/kg)	0.1	0.19
Cobalt	Frequency of Detection	0/16	6/43
	Average (mg/kg)	ND	0.02
	Maximum (mg/kg)	ND	0.07
Lead	Frequency of Detection	3/16	26/43
	Average (mg/kg)	0.13	0.2
	Maximum (mg/kg)	1.2	1.9
Manganese	Frequency of Detection	16/16	43/43
	Average (mg/kg)	0.87	2.4
	Maximum (mg/kg)	1.8	11
Molybdenum	Frequency of Detection	6/16	41/43
	Average (mg/kg)	0.11	0.68
	Maximum (mg/kg)	0.3	9.8
Nickel	Frequency of Detection	0/16	2/43
	Average (mg/kg)	ND	0.075
	Maximum (mg/kg)	ND	0.2
Strontium	Frequency of Detection	16/16	43/43
	Average (mg/kg)	1.6	4.9
	Maximum (mg/kg)	8.5	33
Uranium	Frequency of Detection	3/16	14/43
	Average (mg/kg)	0.0074	0.0071
	Maximum (mg/kg)	0.035	0.041
Vanadium	Frequency of Detection	0/16	16/43
	Average (mg/kg)	ND	0.046
	Maximum (mg/kg)	ND	0.21

Chemical		Fruits	Vegetables
Zinc	Frequency of Detection	16/16	43/43
	Average (mg/kg)	1.4	3.1
	Maximum (mg/kg)	4.0	10

Source: Weston 1998

Averages were calculated using ½ the reporting detection limit for non-detects.
Concentrations are reported on a wet weight basis.
The dates the samples were collected were not specified in the report. It is assumed to be in the 1994–1996 timeframe.

ND – not detected
mg/kg – milligrams per kilogram

Table 50. Sampling data (radionuclides) for local produce irrigated with contaminated well water

Radionuclide		Fruits	Vegetables
Lead-210	Frequency of Detection	3/16	8/43
	Average (pCi/kg)	12	21
	Maximum (pCi/kg)	21	51
Radium-226	Frequency of Detection	1/16	15/43
	Average (pCi/kg)	5.7	6.2
	Maximum (pCi/kg)	18	41
Thorium-230	Frequency of Detection	1/16	8/43
	Average (pCi/kg)	3.9	5.1
	Maximum (pCi/kg)	10	20
Uranium (natural)	Frequency of Detection	3/16	14/43
	Average (pCi/kg)	5.0	4.8
	Maximum (pCi/kg)	23	27

Source: Weston 1998

Averages were calculated using ½ the reporting detection limit for non-detects.
Concentrations are reported on a wet weight basis.
The dates the samples were collected were not specified in the report. It is assumed to be in the 1994–1996 timeframe.
pCi/kg – picocuries per kilogram

Table 51. Characteristics of Cotter Mill's Ambient Air Monitoring Stations

Monitor Code	*Monitor Location*	*Years of Operation*	*Monitor Type*	*Area Description*
AS-202	East Boundary	1979 – present	Perimeter	Eastern perimeter of Cotter Mill facility
AS-203	South Boundary	1979 – present	Perimeter	Southern perimeter of Cotter Mill facility
AS-204	West Boundary	1979 – present	Perimeter	Western perimeter of Cotter Mill facility
AS-206	North Boundary	1981 – present	Perimeter	Northern perimeter of Cotter Mill facility
AS-209	Mill entrance road	1994 – present	Perimeter	Entrance road to Cotter Mill
AS-210	Shadow Hills Estates	1997 – present	Off-site	Near Shadow Hills Golf Club
AS-212	Nearest resident	1999 – present	Off-site	Residential
LP-1/LP-2	Lincoln Park	1980 – present	Off-site	Residential
CC-1/CC-2	Cañon City	1979 – present	Off-site	Residential
OV-3	Oro Verde	1981 – present	Off-site	Remote (1 mile west of AS-204)

Notes: Both the Lincoln Park and Cañon City monitoring stations moved locations in the 1991-1992 time frame. The original station in Lincoln Park (LP-1) operated from 1980 to 1992, and the new station (LP-2) operated from 1991 to the present. The original station in Cañon City (CC-1) operated from 1979 to 1992, and the new station (CC-2) operated from 1991 to the present.

Table 52. Average Annual ^{nat}U Concentrations 1979-2008 (µCi/ml)

Year	Perimeter Monitoring Stations					Off-Site Monitoring Stations				
	AS-202	**AS-203**	**AS-204**	**AS-206**	**AS-209**	**AS-210**	**AS-212**	**LP-1/2**	**CC-1/2**	**OV-3**
1979	6.19E-15	1.50E-15	2.26E-15	--	--	--	--	--	1.00E-15	--
1980	3.71E-15	1.55E-15	2.82E-15	--	--	--	--	8.36E-16	1.40E-15	--
1981	4.07E-15	1.54E-15	5.28E-15	8.30E-15	--	--	--	1.03E-15	1.02E-15	1.37E-15
1982	2.31E-15	1.26E-15	2.48E-14	2.79E-15	--	--	--	5.28E-16	4.79E-16	5.96E-16
1983	1.26E-15	1.43E-15	1.32E-15	1.63E-15	--	--	--	4.77E-16	6.86E-16	5.03E-16
1984	5.50E-16	7.64E-16	8.36E-16	1.52E-15	--	--	--	2.78E-16	3.27E-16	4.01E-16
1985	1.42E-15	1.22E-15	8.96E-16	1.92E-15	--	--	--	4.56E-16	5.77E-16	6.66E-16
1986	6.71E-16	6.56E-16	4.05E-16	9.36E-16	--	--	--	2.95E-16	2.93E-16	4.84E-16
1987	8.08E-16	1.03E-15	1.09E-15	1.05E-15	--	--	--	4.66E-16	5.12E-16	4.60E-16
1988	6.73E-16	6.96E-16	9.03E-16	5.51E-16	--	--	--	1.85E-16	1.95E-16	1.89E-16
1989	9.58E-17	9.95E-17	2.86E-16	3.62E-17	--	--	--	8.37E-17	9.38E-17	6.38E-17
1990	5.59E-17	3.14E-17	1.06E-16	3.10E-17	--	--	--	6.18E-17	1.26E-16	9.09E-17
1991	1.12E-16	9.18E-17	2.65E-16	1.24E-16	--	--	--	1.70E-16	1.73E-16	2.60E-16
1992	6.55E-17	7.84E-17	1.12E-16	6.48E-17	--	--	--	9.71E-17	9.40E-17	8.23E-17
1993	7.13E-17	9.08E-17	1.61E-16	6.30E-17	--	--	--	8.26E-17	1.20E-16	2.55E-16
1994	1.25E-16	4.68E-17	1.00E-16	3.68E-17	1.55E-16	--	--	9.68E-17	8.12E-17	2.54E-16
1995	2.99E-16	5.86E-17	1.53E-16	5.23E-17	2.11E-16	--	--	9.34E-17	1.26E-16	4.83E-16
1996	2.25E-16	1.43E-16	2.26E-16	8.62E-17	2.44E-16	7.89E-17	--	9.73E-17	1.25E-16	5.93E-17
1997	1.23E-16	1.18E-16	2.20E-16	1.19E-16	1.51E-16	1.75E-16	--	1.27E-16	2.00E-16	9.48E-17
1998	1.32E-16	1.02E-16	3.29E-16	1.06E-16	2.27E-15	2.32E-16	--	8.13E-17	7.50E-17	2.43E-16
1999	4.06E-16	1.49E-16	2.91E-16	3.23E-16	1.46E-15	2.82E-16	4.59E-16	1.16E-16	9.41E-17	7.97E-17
2000	4.33E-16	2.04E-16	2.61E-16	1.63E-16	1.49E-15	1.89E-16	4.82E-16	5.39E-17	5.33E-17	5.39E-17
2001	4.96E-16	6.19E-16	4.96E-16	5.29E-16	1.32E-15	2.06E-16	2.88E-16	4.96E-17	3.80E-17	5.18E-17
2002	6.50E-16	4.93E-16	6.21E-16	3.24E-16	9.91E-16	3.69E-16	4.05E-16	2.46E-16	1.59E-16	2.05E-16
2003	3.55E-16	2.19E-16	2.55E-16	2.01E-16	4.91E-16	2.21E-16	2.20E-16	2.11E-16	2.07E-16	2.62E-16
2004	2.51E-16	1.95E-16	2.40E-16	1.99E-16	6.27E-16	1.40E-16	2.30E-16	9.69E-17	9.68E-17	8.61E-17
2005	4.54E-16	2.77E-16	2.87E-16	1.58E-16	3.97E-15	4.85E-16	5.25E-16	1.68E-16	1.29E-16	1.23E-16
2006	5.14E-16	2.68E-16	3.24E-16	2.12E-16	1.72E-15	6.62E-16	3.40E-16	2.20E-16	1.75E-16	1.87E-16
2007	3.56E-16	1.51E-16	2.03E-16	1.39E-16	3.13E-16	1.46E-16	1.33E-16	1.41E-16	1.43E-16	1.27E-16
2008	4.36E-16	8.61E-17	1.72E-16	8.44E-17	2.17E-16	9.77E-17	9.78E-17	9.02E-17	8.97E-17	6.43E-17

Notes: For station LP-1/2, data from 1980-1992 were collected at LP-1, and data from 1993-2008 were collected at LP-2.

For station CC-1/2, data from 1979-1992 were collected at CC-1, and data from 1993-2008 were collected at CC-2.

Shaded cells are the highest annual averages for the calendar year; "--" indicates that no data are available because the station was not yet operating.

Table 53. Average Annual ^{230}Th Concentrations 1979-2008 (µCi/ml)

Year	Perimeter Monitoring Stations					Off-Site Monitoring Stations				
	AS-202	AS-203	AS-204	AS-206	AS-209	AS-210	AS-212	LP-1/2	CC-1/2	OV-3
1979	2.33E-15	1.05E-15	8.08E-15	--	--	--	--	--	3.07E-16	--
1980	2.50E-16	8.76E-16	2.81E-16	--	--	--	--	8.17E-17	1.30E-16	--
1981	2.60E-15	3.50E-15	**3.00E-14**	6.93E-15	--	--	--	1.42E-16	8.17E-17	3.92E-16
1982	**2.12E-14**	1.94E-14	**8.95E-14**	1.26E-14	--	--	--	7.49E-16	9.18E-16	3.15E-15
1983	5.86E-15	9.79E-15	5.64E-15	8.26E-15	--	--	--	3.74E-16	3.12E-16	1.07E-15
1984	1.64E-15	2.98E-15	3.82E-15	6.35E-15	--	--	--	2.69E-16	2.00E-16	2.89E-16
1985	1.84E-15	2.15E-15	4.86E-15	3.73E-15	--	--	--	2.60E-16	2.64E-16	2.84E-16
1986	3.70E-15	5.55E-15	3.13E-15	4.68E-15	--	--	--	3.70E-16	3.08E-16	2.41E-16
1987	1.21E-15	1.29E-15	2.28E-15	1.08E-15	--	--	--	2.06E-16	1.77E-16	9.90E-17
1988	2.58E-15	3.51E-15	5.85E-15	2.05E-15	--	--	--	1.41E-16	1.72E-16	1.70E-16
1989	6.33E-16	3.85E-16	9.17E-16	1.08E-16	--	--	--	8.93E-17	9.03E-17	9.24E-17
1990	7.63E-16	4.00E-16	5.86E-16	1.09E-16	--	--	--	7.40E-17	7.04E-17	7.20E-17
1991	7.25E-16	4.59E-16	8.75E-16	2.83E-16	--	--	--	1.91E-16	1.25E-16	1.33E-16
1992	4.57E-16	2.20E-16	4.71E-16	9.46E-17	--	--	--	6.58E-17	5.98E-17	9.56E-17
1993	4.45E-16	3.03E-16	6.42E-16	9.32E-17	--	--	--	1.06E-16	9.17E-17	2.33E-16
1994	1.18E-15	2.96E-16	1.08E-15	1.24E-16	9.20E-16	--	--	1.54E-16	1.16E-16	2.83E-16
1995	1.65E-15	5.33E-16	1.24E-15	1.18E-16	8.88E-16	--	--	9.80E-17	1.12E-16	3.30E-16
1996	2.21E-15	2.95E-16	8.13E-16	8.85E-17	7.67E-16	2.33E-16	--	7.11E-17	5.08E-17	6.39E-17
1997	7.64E-16	1.31E-16	6.17E-16	6.49E-17	1.99E-15	3.82E-16	--	8.37E-17	7.86E-17	3.24E-17
1998	2.88E-15	2.02E-16	9.34E-16	1.15E-16	2.17E-15	3.32E-16	--	7.70E-17	7.99E-17	7.82E-17
1999	3.76E-15	3.24E-16	1.09E-15	1.84E-16	2.19E-15	4.15E-16	3.02E-16	7.37E-17	9.51E-17	1.11E-16
2000	1.22E-15	2.48E-16	1.01E-15	2.02E-16	4.16E-15	4.71E-16	6.69E-16	1.47E-16	1.57E-16	1.27E-16
2001	8.20E-16	5.19E-16	9.67E-16	2.61E-16	4.15E-15	4.04E-16	4.61E-16	1.56E-16	9.95E-17	1.13E-16
2002	5.84E-16	2.76E-16	5.95E-16	2.57E-16	1.25E-15	2.38E-16	3.13E-16	8.15E-17	8.54E-17	8.55E-17
2003	5.19E-16	2.62E-16	4.90E-16	9.73E-17	1.40E-15	4.11E-16	1.77E-16	8.27E-17	8.91E-17	5.30E-17
2004	2.17E-16	8.26E-17	3.87E-16	8.33E-17	6.57E-16	2.26E-16	1.08E-16	5.36E-17	5.62E-17	6.07E-17
2005	3.17E-16	1.97E-16	3.51E-16	2.64E-16	3.41E-15	4.85E-16	4.81E-16	1.04E-16	1.05E-16	1.08E-16
2006	5.17E-16	2.91E-16	4.74E-16	1.77E-16	1.40E-15	4.73E-16	3.27E-16	2.73E-16	2.04E-16	2.85E-16
2007	6.62E-16	1.90E-16	4.32E-16	1.48E-16	1.05E-15	2.77E-16	2.23E-16	1.68E-16	1.57E-16	1.53E-16
2008	7.21E-16	1.87E-16	5.12E-16	1.32E-16	6.21E-16	2.88E-16	2.05E-16	1.11E-16	1.08E-16	1.16E-16

Notes: For station LP-1/2, data from 1980-1992 were collected at LP-1, and data from 1993-2008 were collected at LP-2. For station CC-1/2, data from 1979-1992 were collected at CC-1, and data from 1993-2008 were collected at CC-2.

Shaded cells are the highest annual averages for the calendar year; "--" indicates that no data are available because the station was not yet operating; bold cells are concentrations above Cotter Mill's regulatory limit

Table 54. Average Annual ^{232}Th Concentrations 2001-2008 (µCi/ml)

Year	Perimeter Monitoring Stations					Off-Site Monitoring Stations				
	AS-202	AS-203	AS-204	AS-206	AS-209	AS-210	AS-212	LP #2	CC #2	OV-3
2001	5.78E-17	7.62E-17	6.97E-17	6.37E-17	8.32E-17	4.58E-17	6.67E-17	6.85E-17	8.33E-17	5.68E-17
2002	4.67E-17	3.81E-17	3.09E-17	4.55E-17	4.34E-17	3.17E-17	3.35E-17	5.36E-17	3.51E-17	4.68E-17
2003	4.57E-17	4.14E-17	4.84E-17	2.06E-17	5.72E-17	4.61E-17	3.71E-17	6.21E-17	4.61E-17	3.96E-17
2004	1.39E-17	2.53E-17	2.53E-17	1.40E-17	1.57E-17	1.99E-17	1.65E-17	3.24E-17	2.28E-17	2.39E-17
2005	2.83E-17	2.40E-17	2.86E-17	3.09E-17	3.36E-17	2.53E-17	3.42E-17	3.99E-17	3.57E-17	3.45E-17
2006	4.11E-17	5.18E-17	4.82E-17	4.29E-17	5.54E-17	4.33E-17	4.79E-17	6.25E-17	4.98E-17	3.65E-17
2007	4.07E-17	3.47E-17	4.60E-17	4.14E-17	4.12E-17	3.99E-17	3.51E-17	5.43E-17	4.48E-17	3.92E-17
2008	1.08E-17	1.63E-17	1.15E-17	9.89E-18	1.57E-17	2.30E-17	1.26E-17	3.13E-17	2.25E-17	2.03E-17

Note: Shaded cells are the highest annual averages for the calendar year; "--" indicates that no data are available because the station was not yet operating

Table 55. Average Annual ^{226}Ra Concentrations 1979-2008 (µCi/ml)

Year	Perimeter Monitoring Stations					Off-Site Monitoring Stations				
	AS-202	AS-203	AS-204	AS-206	AS-209	AS-210	AS-212	LP-1/2	CC-1/2	OV-3
1979	1.55E-15	3.75E-16	7.89E-15	--	--	--	--	--	3.07E-16	--
1980	3.61E-15	7.81E-16	1.62E-15	--	--	--	--	2.78E-16	1.58E-15	--
1981	4.19E-15	2.35E-15	2.94E-15	2.96E-15	--	--	--	3.79E-16	4.59E-16	6.30E-16
1982	6.53E-15	6.92E-15	3.81E-15	3.82E-15	--	--	--	6.07E-16	4.02E-16	1.25E-15
1983	2.00E-15	5.08E-15	4.95E-15	2.85E-15	--	--	--	9.42E-17	1.76E-16	5.30E-16
1984	1.11E-15	1.84E-15	3.63E-15	2.20E-15	--	--	--	1.18E-16	1.67E-16	1.87E-16
1985	9.63E-15	1.11E-15	1.78E-15	1.97E-15	--	--	--	1.69E-16	1.88E-16	1.89E-16
1986	1.47E-15	1.98E-15	1.61E-15	2.60E-15	--	--	--	1.43E-16	3.45E-16	2.22E-16
1987	5.91E-16	7.52E-16	1.19E-15	4.74E-16	--	--	--	1.83E-16	1.15E-16	1.89E-16
1988	1.29E-15	2.05E-15	2.53E-15	3.60E-16	--	--	--	1.24E-16	5.09E-17	1.09E-16
1989	2.72E-16	1.81E-16	3.30E-16	4.79E-17	--	--	--	1.02E-16	8.89E-17	7.77E-17
1990	1.75E-16	1.68E-16	1.92E-16	4.36E-17	--	--	--	6.69E-17	8.36E-17	7.82E-17
1991	1.19E-16	1.25E-16	2.68E-16	6.17E-17	--	--	--	6.85E-17	7.16E-17	1.37E-16
1992	8.46E-17	7.30E-17	1.50E-15	3.71E-17	--	--	--	5.10E-17	5.80E-17	1.17E-16
1993	9.11E-17	1.14E-16	2.49E-16	5.99E-17	--	--	--	6.14E-17	6.72E-17	2.20E-16
1994	1.03E-16	7.57E-17	1.69E-16	4.96E-17	1.55E-16	--	--	7.80E-17	8.68E-17	2.64E-16
1995	1.21E-16	1.14E-16	2.07E-16	7.46E-17	2.06E-16	--	--	6.88E-17	1.05E-16	3.99E-16
1996	1.78E-16	1.02E-16	2.08E-16	5.33E-17	2.11E-16	5.82E-17	--	5.22E-17	6.67E-17	3.59E-17
1997	1.29E-16	7.55E-17	2.01E-16	5.66E-17	9.45E-16	1.06E-16	--	5.09E-17	5.40E-17	4.84E-17
1998	2.89E-16	8.22E-17	2.95E-16	9.43E-17	1.34E-15	1.21E-16	--	6.21E-17	6.71E-17	4.24E-17
1999	4.18E-16	1.29E-16	3.81E-16	1.02E-16	1.26E-15	1.46E-16	2.13E-16	8.27E-17	9.21E-17	5.90E-17
2000	3.37E-16	1.53E-16	4.64E-16	1.40E-16	2.38E-15	2.21E-16	4.60E-16	7.41E-17	4.64E-17	5.10E-17
2001	2.15E-16	2.09E-16	4.36E-16	1.38E-16	1.92E-15	1.51E-16	1.99E-16	7.01E-17	6.82E-17	5.16E-17
2002	1.55E-16	1.17E-16	2.34E-16	7.51E-17	3.83E-16	1.05E-16	1.14E-16	8.41E-17	6.07E-17	6.72E-17
2003	1.45E-16	1.10E-16	1.75E-16	8.02E-17	2.96E-16	1.23E-16	9.65E-17	9.70E-17	8.40E-17	8.93E-17
2004	7.81E-17	7.35E-17	1.41E-16	6.14E-17	3.30E-16	9.05E-17	8.14E-17	5.79E-17	6.26E-17	4.95E-17
2005	1.78E-16	1.56E-16	1.75E-16	1.97E-16	2.29E-15	2.49E-16	2.95E-16	1.08E-16	1.22E-16	9.58E-17
2006	4.10E-16	1.40E-16	2.17E-16	1.34E-16	7.52E-16	1.69E-16	1.42E-16	1.20E-16	1.03E-16	1.15E-16
2007	8.67E-16	1.11E-16	2.07E-16	1.00E-16	2.31E-16	1.16E-16	9.11E-17	1.09E-16	9.66E-17	1.11E-16
2008	7.92E-16	7.36E-17	2.00E-16	5.16E-17	1.78E-16	7.33E-17	5.71E-17	6.21E-17	5.91E-17	3.28E-17

Notes: For station LP-1/2, data from 1980-1992 were collected at LP-1, and data from 1993-2008 were collected at LP-2. For station CC-1/2, data from 1979-1992 were collected at CC-1, and data from 1993-2008 were collected at CC-2. Shaded cells are the highest annual averages for the calendar year; "--" indicates that no data are available because the station was not yet operating.

Table 56. Average Annual ^{210}Pb Concentrations 1979-2008 (µCi/ml)

Year	Perimeter Monitoring Stations					Off-Site Monitoring Stations				
	AS-202	AS-203	AS-204	AS-206	AS-209	AS-210	AS-212	LP-1/2	CC-1/2	OV-3
1979	2.11E-14	1.65E-14	2.08E-14	--	--	--	--	--	2.30E-14	--
1980	1.81E-14	1.69E-14	1.25E-14	--	--	--	--	1.86E-14	1.98E-14	--
1981	2.01E-14	1.72E-14	4.71E-14	2.34E-14	--	--	--	1.57E-14	1.70E-14	2.11E-14
1982	3.87E-14	4.35E-14	9.95E-14	4.07E-14	--	--	--	2.50E-14	3.31E-14	4.05E-14
1983	1.70E-14	1.73E-14	1.82E-14	1.95E-14	--	--	--	1.29E-14	1.79E-14	1.44E-14
1984	1.44E-14	1.46E-14	1.60E-14	1.43E-14	--	--	--	1.26E-14	1.15E-14	1.48E-14
1985	9.12E-15	8.12E-15	8.80E-15	9.30E-15	--	--	--	9.97E-15	1.14E-14	9.90E-15
1986	1.26E-14	1.19E-14	1.12E-14	1.22E-14	--	--	--	1.07E-14	1.22E-14	8.81E-15
1987	1.95E-14	1.92E-14	2.22E-14	2.35E-14	--	--	--	2.17E-14	2.01E-14	1.43E-14
1988	2.15E-14	1.94E-14	2.10E-14	1.93E-14	--	--	--	2.04E-14	2.11E-14	1.76E-14
1989	2.28E-14	2.30E-14	1.98E-14	2.34E-14	--	--	--	2.43E-14	2.35E-14	2.40E-14
1990	2.05E-14	2.10E-14	2.07E-14	2.07E-14	--	--	--	2.24E-14	2.00E-14	1.95E-14
1991	2.40E-14	2.15E-14	2.15E-14	2.13E-14	--	--	--	2.23E-14	2.15E-14	1.07E-14
1992	2.16E-14	2.00E-14	2.20E-14	2.19E-14	--	--	--	1.99E-14	1.61E-14	2.20E-14
1993	2.38E-14	2.35E-14	2.35E-14	2.49E-14	--	--	--	2.22E-14	2.13E-14	2.10E-14
1994	2.21E-14	2.07E-14	2.10E-14	2.24E-14	2.18E-14	--	--	2.33E-14	2.38E-14	2.06E-14
1995	2.07E-14	2.07E-14	2.02E-14	2.01E-14	2.11E-14	--	--	1.97E-14	2.03E-14	1.74E-14
1996	2.02E-14	2.01E-14	2.16E-14	2.21E-14	2.11E-14	--	--	2.08E-14	1.96E-14	1.98E-14
1997	2.21E-14	2.07E-14	2.12E-14	2.20E-14	2.26E-14	2.05E-14	--	2.13E-14	2.00E-14	1.98E-14
1998	2.01E-14	2.07E-14	1.98E-14	2.11E-14	2.01E-14	1.93E-14	--	2.01E-14	2.01E-14	1.93E-14
1999	2.14E-14	1.94E-14	1.83E-14	1.84E-14	2.03E-14	1.94E-14	2.03E-14	2.03E-14	1.94E-14	1.78E-14
2000	2.07E-14	2.05E-14	2.01E-14	2.23E-14	2.37E-14	2.00E-14	2.07E-14	2.16E-14	2.08E-14	2.03E-14
2001	3.10E-14	3.04E-14	2.91E-14	3.11E-14	3.06E-14	2.94E-14	3.12E-14	3.06E-14	2.96E-14	2.79E-14
2002	2.36E-14	2.20E-14	2.28E-14	2.25E-14	2.30E-14	2.37E-14	2.40E-14	2.46E-14	2.33E-14	2.17E-14
2003	2.19E-14	2.11E-14	2.16E-14	2.06E-14	2.28E-14	2.12E-14	2.18E-14	2.11E-14	1.94E-14	2.27E-14
2004	1.72E-14	1.64E-14	1.58E-14	1.60E-14	1.66E-14	1.45E-14	1.79E-14	1.56E-14	1.54E-14	1.59E-14
2005	2.45E-14	2.74E-14	2.82E-14	2.54E-14	3.11E-14	2.91E-14	2.92E-14	3.11E-14	3.15E-14	2.94E-14
2006	2.11E-14	2.31E-14	2.47E-14	2.31E-14	2.09E-14	2.08E-14	1.89E-14	1.98E-14	1.89E-14	2.12E-14
2007	1.88E-14	1.64E-14	1.79E-14	1.82E-14	1.54E-14	1.58E-14	1.49E-14	1.66E-14	1.61E-14	1.72E-14
2008	1.65E-14	1.48E-14	1.64E-14	1.93E-14	1.66E-14	1.73E-14	1.57E-14	1.67E-14	1.61E-14	1.61E-14

Notes: For station LP-1/2, data from 1980-1992 were collected at LP-1, and data from 1993-2008 were collected at LP-2. For station CC-1/2, data from 1979-1992 were collected at CC-1, and data from 1993-2008 were collected at CC-2.

Shaded cells are the highest annual averages for the calendar year; "--" indicates that no data are available because the station was not yet operating.

Table 57. ^{220}Rn/^{222}Rn Concentrations 2002-2008 (pCi/m^3)

Year	Perimeter Monitoring Stations					Off-Site Monitoring Stations				
	AS-202	AS-203	AS-204	AS-206	AS-209	AS-210	AS-212	CC-1	LP-1	OV-3
2002	543	975	1125	693	1475	700	698	875	673	625
2003	700	825	775	900	625	675	700	375	800	567
2004	1500	850	1025	950	1100	850	925	825	875	825
2005	925	1025	850	700	1025	675	775	700	900	800
2006	1250	1275	1275	1450	1400	1125	1275	1075	1375	1200
2007	1000	1100	1175	1100	1250	975	825	925	1175	975
2008	850	900	925	950	1075	950	850	800	925	825

Notes: Data are presented for only those years when measurements quantified combined levels of the two isotopes.
Shaded cells are the highest annual averages for the calendar year.

Table 58. Environmental TLD Measurements, 1979-2008 (µR/hr)

Year	Perimeter Monitoring Stations					Off-Site Monitoring Stations				
	AS-202	AS-203	AS-204	AS-206	AS-209	AS-210	AS-212	CC-1	LP-1	OV-3
1979	14.0	12.6	12.7	--	--	--	--	11.8	11.4	--
1980	13.4	11.7	12.9	--	--	--	--	10.4	11.4	--
1981	14.3	12.8	12.7	--	--	--	--	10.6	12.3	12.3
1982	13.7	12.6	14.7	20.4	--	--	--	9.9	11.2	12.7
1983	13.6	12.6	14.2	15.6	--	--	--	10.6	11.6	12.0
1984	14.5	14.3	14.6	14.8	--	--	--	12.3	11.2	13.2
1985	14.3	13.5	14.5	14.8	--	--	--	10.5	11.2	12.3
1986	13.9	13.7	14.5	14.2	--	--	--	11.0	10.7	11.8
1987	12.9	12.5	12.6	12.6	--	--	--	9.6	9.7	10.4
1988	15.0	13.6	12.8	13.4	--	--	--	9.3	11.6	10.2
1989	14.7	14.9	15.3	15.9	--	--	--	10.6	13.7	11.9
1990	13.2	13.1	14.8	15.2	--	--	--	9.6	11.5	11.7
1991	14.1	13.2	15.7	17.5	--	--	--	10.0	12.9	12.4
1992	13.7	13.2	16.0	18.3	--	--	--	9.6	12.1	11.3
1993	12.5	12.6	14.4	15.6	--	--	--	8.6	10.7	10.9
1994	14.3	13.8	15.9	16.2	27.8	--	--	10.8	12.1	12.3
1995	12.5	13.7	14.0	15.4	23.0	--	--	9.2	10.3	11.3
1996	13.1	13.2	14.5	16.2	27.2	13.0	--	9.7	10.9	11.4
1997	12.6	13.1	13.8	15.7	29.1	12.3	--	9.1	10.2	11.1
1998	12.3	12.0	13.4	15.9	28.0	12.0	--	9.0	10.3	11.5
1999	12.7	12.0	13.8	16.0	29.6	12.2	9.1	9.3	10.6	10.9
2000	12.7	12.6	14.7	16.6	27.7	12.5	9.3	9.5	10.7	11.4
2001	13.7	14.3	15.4	18.6	26.2	13.9	9.7	10.4	12.0	12.2
2002	14.0	14.4	15.9	17.7	30.3	14.3	10.5	10.5	12.3	12.6
2003	12.8	13.3	14.8	15.5	27.7	13.3	10.0	10.0	11.7	11.8
2004	13.6	14.1	15.5	14.7	25.5	14.2	10.9	10.5	12.2	12.5
2005	12.8	13.5	14.8	13.8	22.9	12.9	9.9	10.1	11.5	11.5
2006	12.7	13.4	14.6	14.2	21.5	12.6	9.5	10.1	11.5	11.7
2007	12.9	13.2	14.6	14.1	17.8	12.7	9.5	10.1	11.5	11.6
2008	13.9	13.5	15.5	14.9	18.7	13.3	10.2	10.8	12.2	12.6

Notes: Shaded cells are the highest annual averages for the calendar year; "--" indicates that no data are available because the station was not yet operating.

Table 59. TSP Air Concentrations (μg/m^3) from 1969-1987

Year	Cañon City		Lincoln Park	
	Maximum	Average	Maximum	Average
1969	172	64.2	--	--
1970	200	55.9	--	--
1971	148	58.7	--	--
1972	240	69.9	--	--
1973	229	66.1	--	--
1974	187	58	--	--
1975	419	73.7	--	--
1976	174	56.8	--	--
1977	227	62.7	--	--
1978	313	84.7	--	--
1979	286	72.6	--	--
1980	304	70.4	--	--
1981	180	56.8	61*	8.2*
1982	525	84	228	51.7
1983	187	65.2	106	77.6
1984	571	70.9	--	--
1985	334	64.8	--	--
1986	402	66.3	--	--
1987	385	65.2	--	--

Notes: Data downloaded from EPA’s Air Quality System database.
EPA’s former annual average National Ambient Air Quality Standard for TSP was 75 μg/m^3.
* The TSP monitoring station in Lincoln Park started operating late in 1981; therefore, the statistics reported are not representative of the entire calendar year.

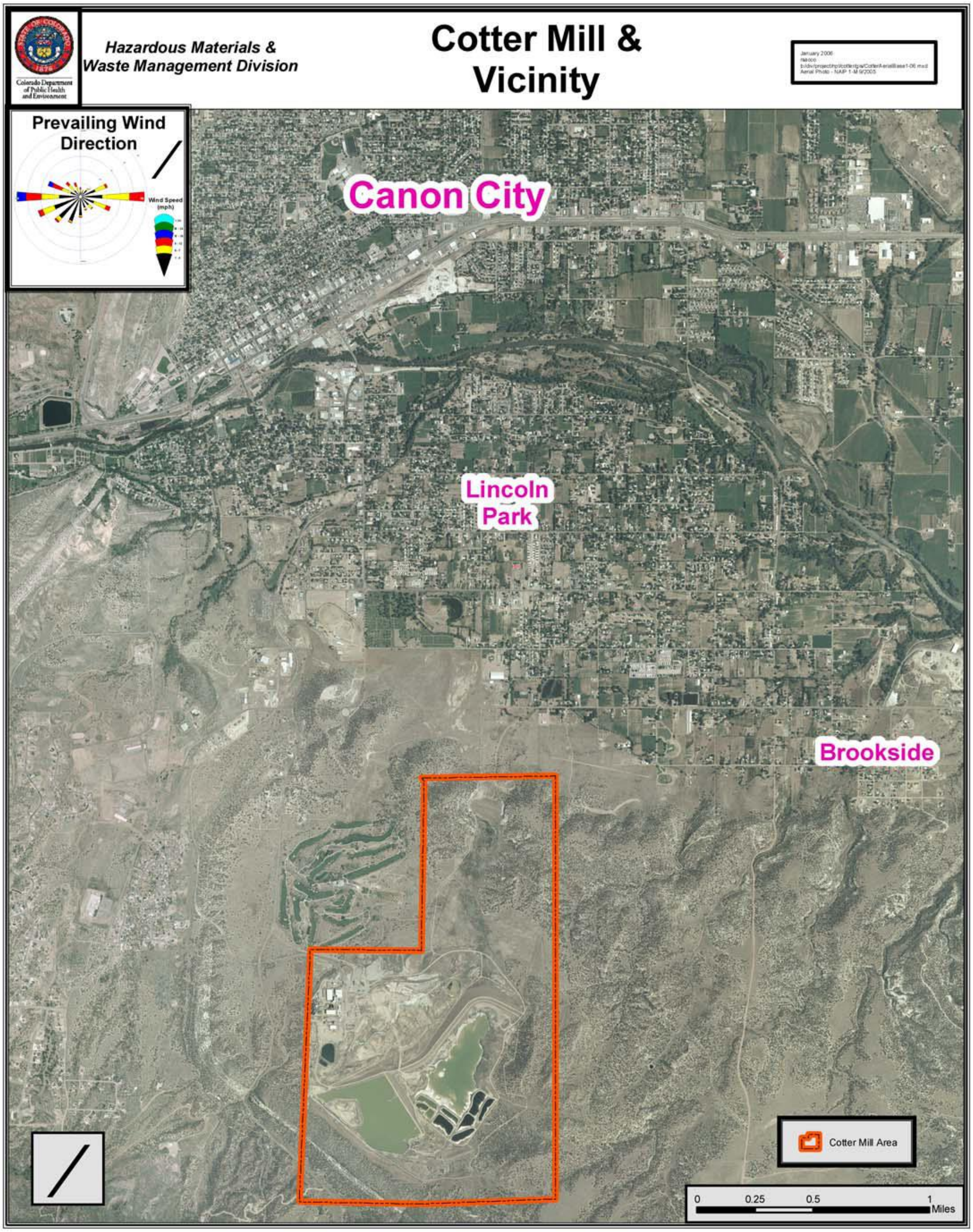
Table 60. Monitoring Data for Constituents in TSP (1978-1987)

Constituent	Location	Years of Data	Concentrations (μg/m^3)	
			Highest 24-Hour Average	Highest Annual Average
Iron	Lincoln Park	1981-1982	1.2	0.8
Lead	Lincoln Park	1981-1982	0.1	0.034
Manganese	Lincoln Park	1981-1982	0.03	0.0185
Nitrate	Cañon City	1978-1987	14.3	2.35
	Lincoln Park	1981-1982	4.7	1.81
Sulfate	Cañon City	1978-1987	18.4	5.99
	Lincoln Park	1981-1982	13	6.48
Zinc	Lincoln Park	1981-1982	0.04	0.0283

Notes Data downloaded from EPA’s Air Quality System database.

Appendix B - Site Figures

Figure 1. Location of the Cotter Mill, Lincoln Park, and Cañon City

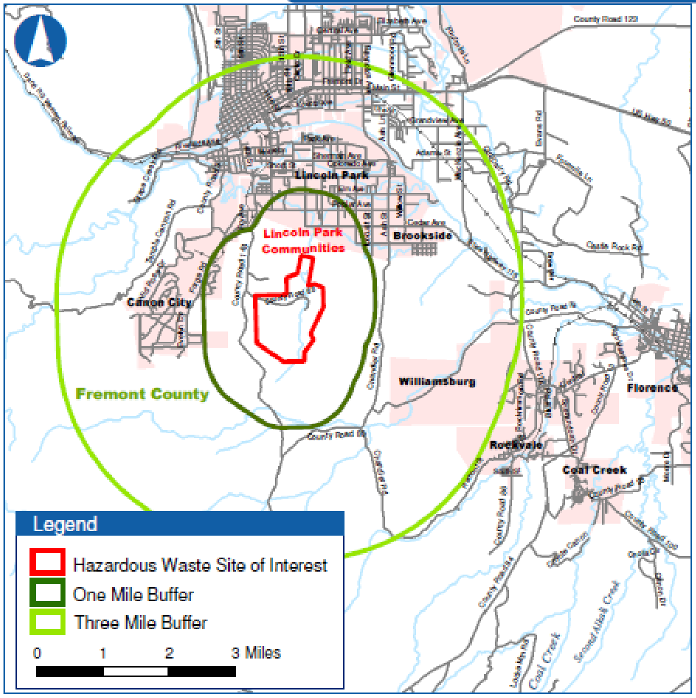


Source: Galant et al. 2007

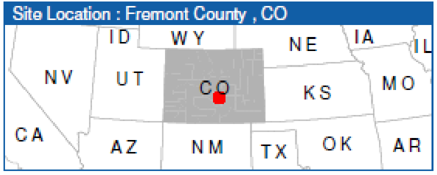
Figure 2. Demographics within 1 and 3 miles of the Cotter Mill property

EPA Facility ID :
COD042167858

LINCOLN PARK
FREMONT , CO



Site Location : Fremont County , CO

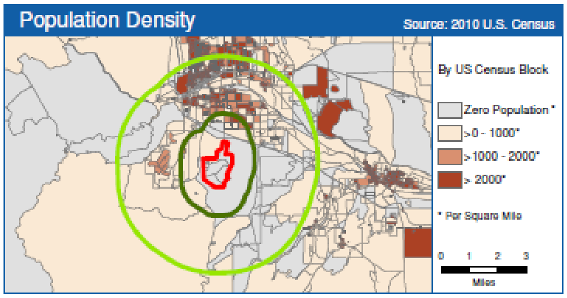


Demographic Statistics Within Area of Concern*	1mi	3mi
Total Population	833	14,976
White Alone	805	13,884
Black Alone	0	241
Am. Indian & Alaska Native Alone	8	188
Asian Alone	3	78
Native Hawaiian & Other Pacific Islander Alone	0	7
Some Other Race Alone	9	249
Two or More Races	8	329
Hispanic or Latino**	54	1,364
Children Aged 6 and Younger	44	1,086
Adults Aged 65 and Older	204	3,041
Females Aged 15 to 44	94	2,122
Total Housing Units	395	6,916

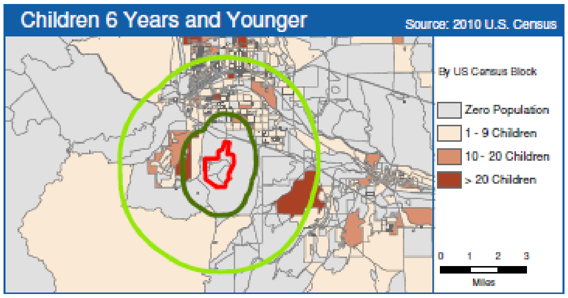
Base Map Source: Geographic Data Technology, May 2005.
Site Boundary Data Source: ATSDR Geospatial Research, Analysis, and Services Program, Current as of Generate Date (bottom left-hand corner).
Coordinate System (All Panels) : NAD_1983_StatePlane_Colorado_Central_FIPS_0502_Feet

Demographics Statistics Source: 2010 U.S. Census
* Calculated using an area-proportion spatial analysis technique
** People who identify their origin as Hispanic or Latino may be of any race.

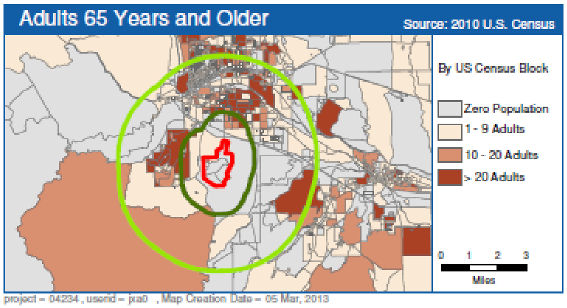
Population Density
Source: 2010 U.S. Census



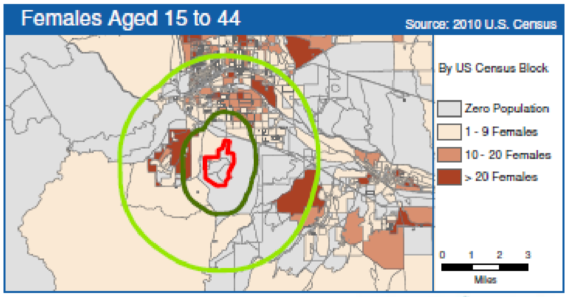
Children 6 Years and Younger
Source: 2010 U.S. Census



Adults 65 Years and Older
Source: 2010 U.S. Census



Females Aged 15 to 44
Source: 2010 U.S. Census



project = 04234 , userid = jxa0 , Map Creation Date = 05 Mar, 2013

GRASP

Centers for Disease Control and Prevention
Agency for Toxic Substances and Disease Registry

Geospatial Research, Analysis & Services Program

Figure 3. Wind Rose for Cotter Mill, 2008

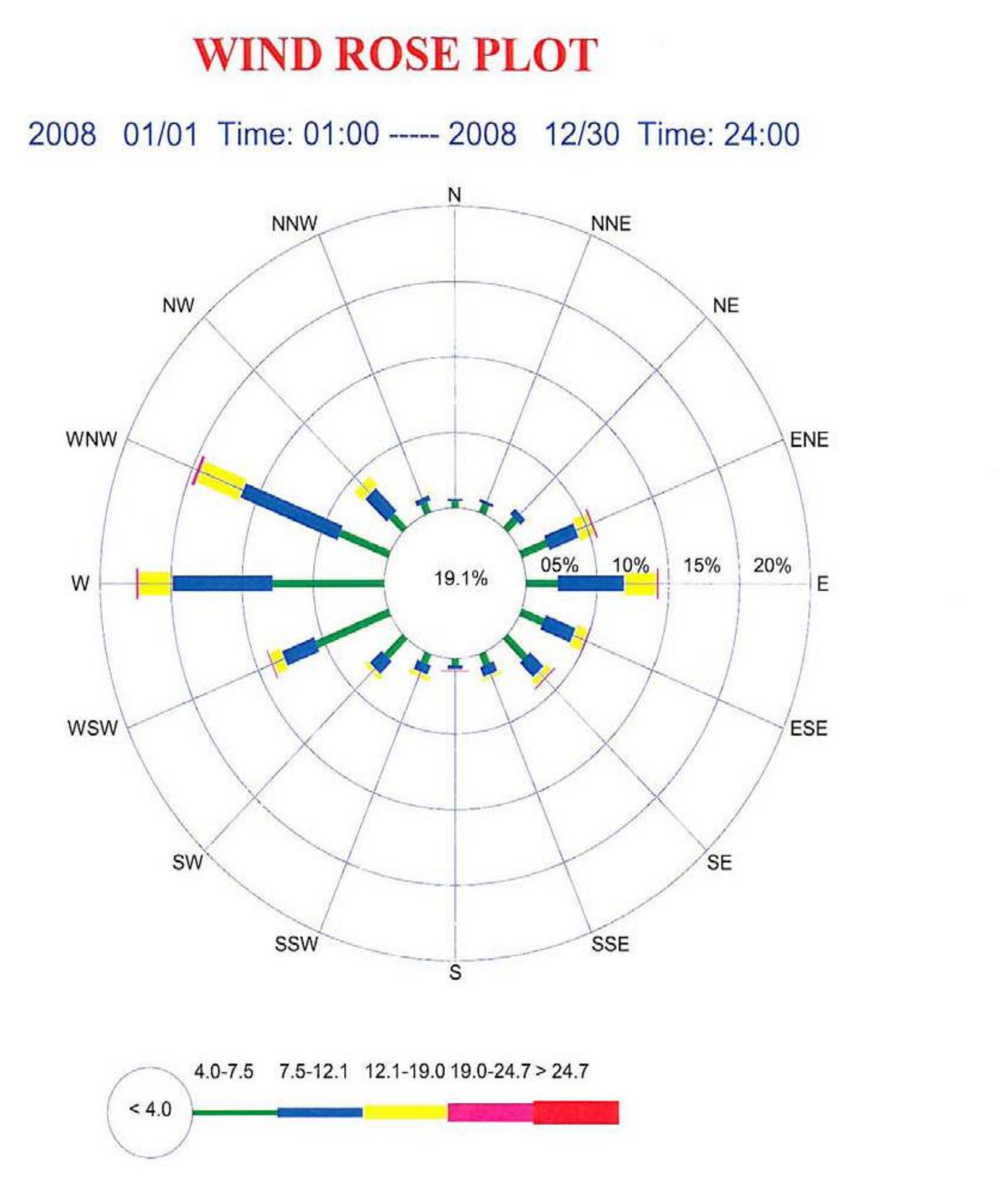
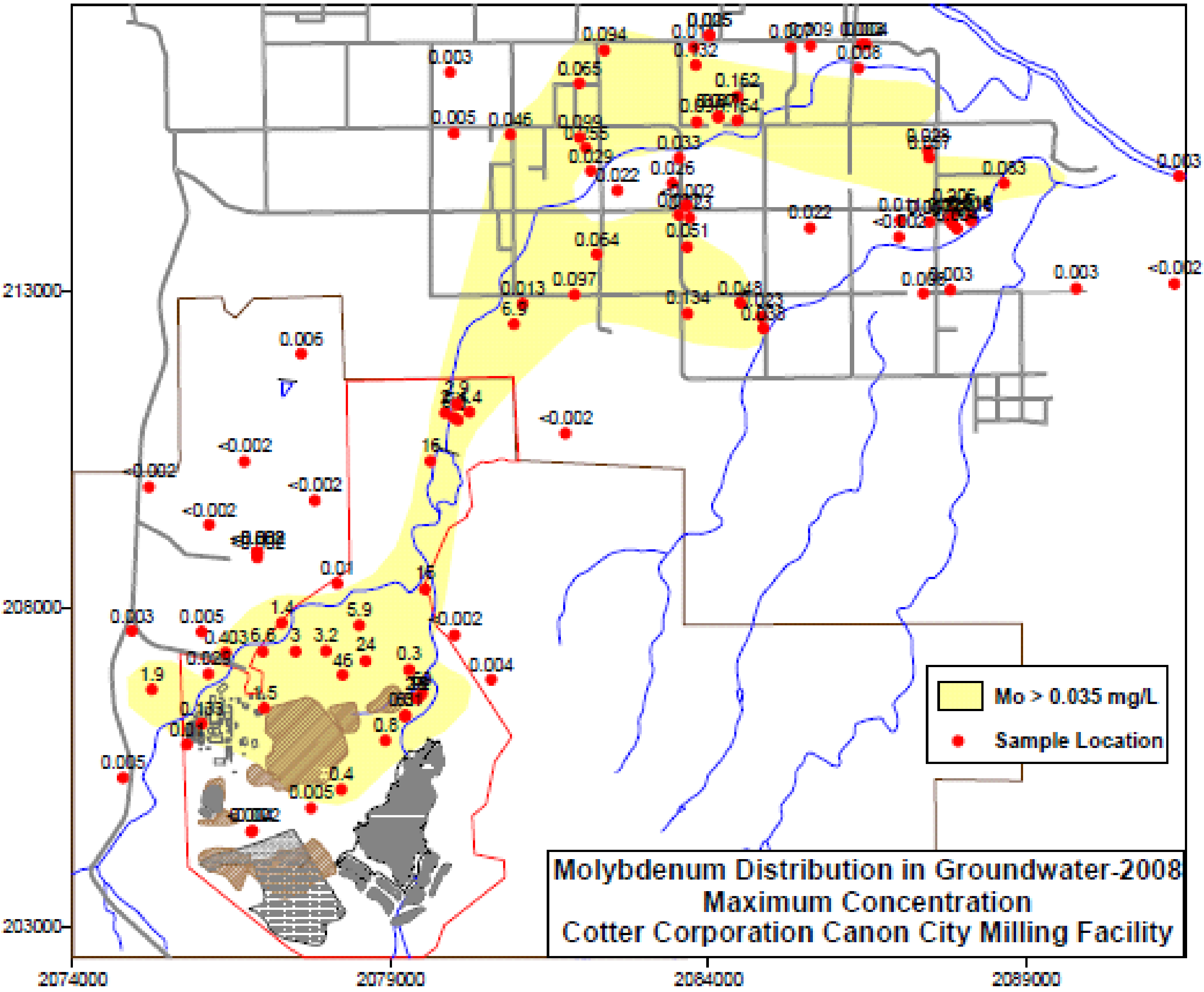
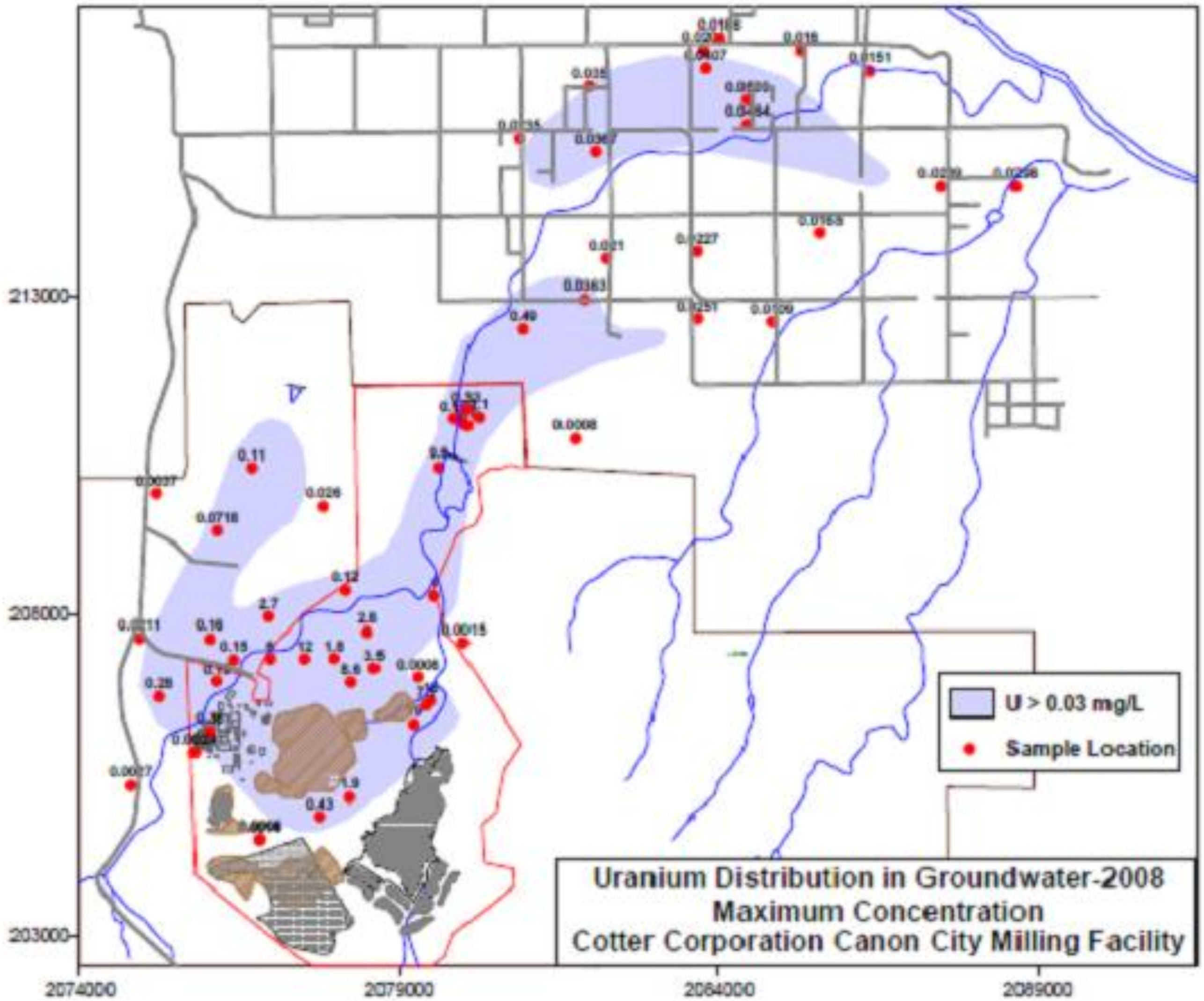


Figure 4. Molybdenum Plume Map



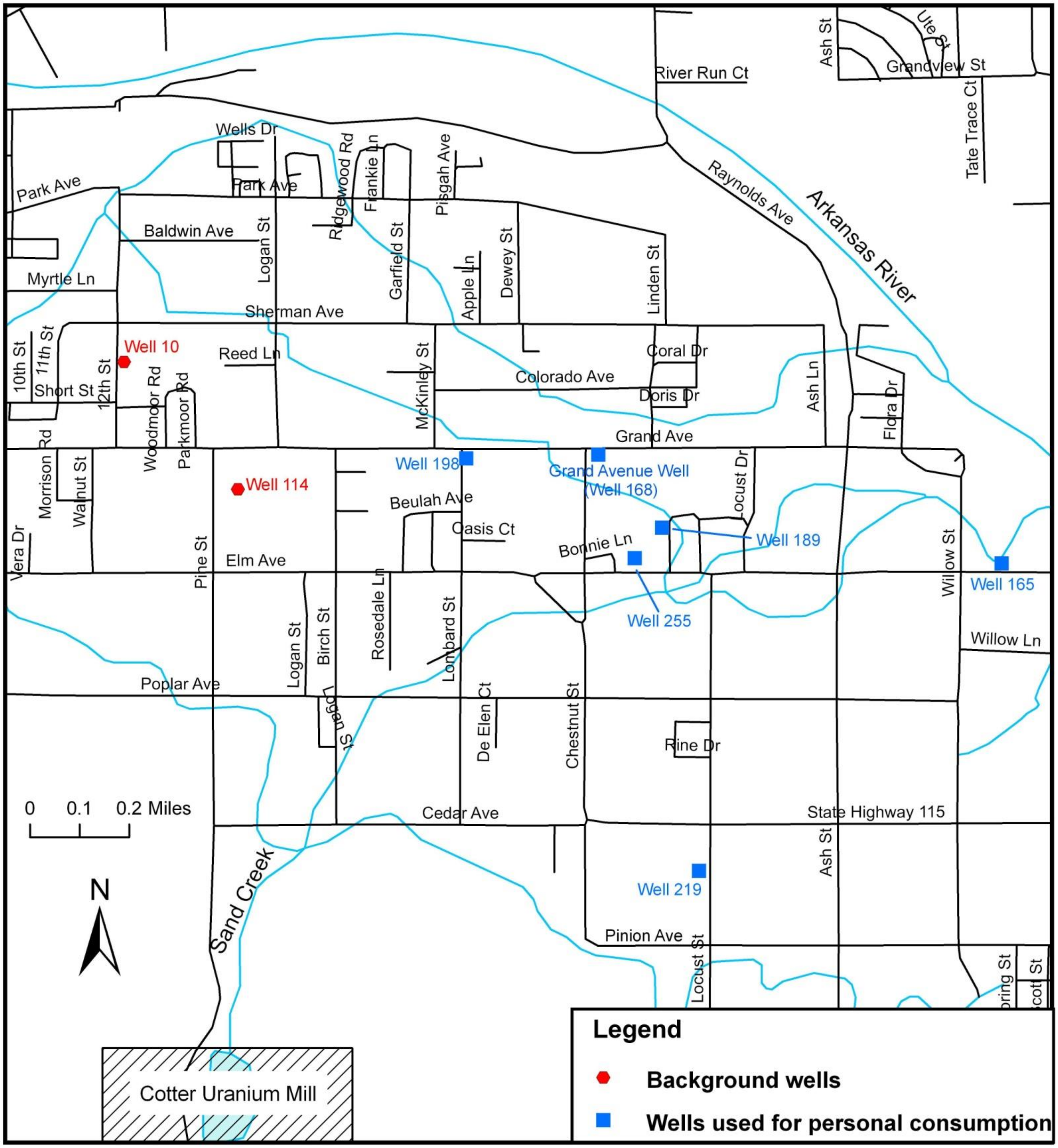
Source:

Figure 5. Uranium Plume Map



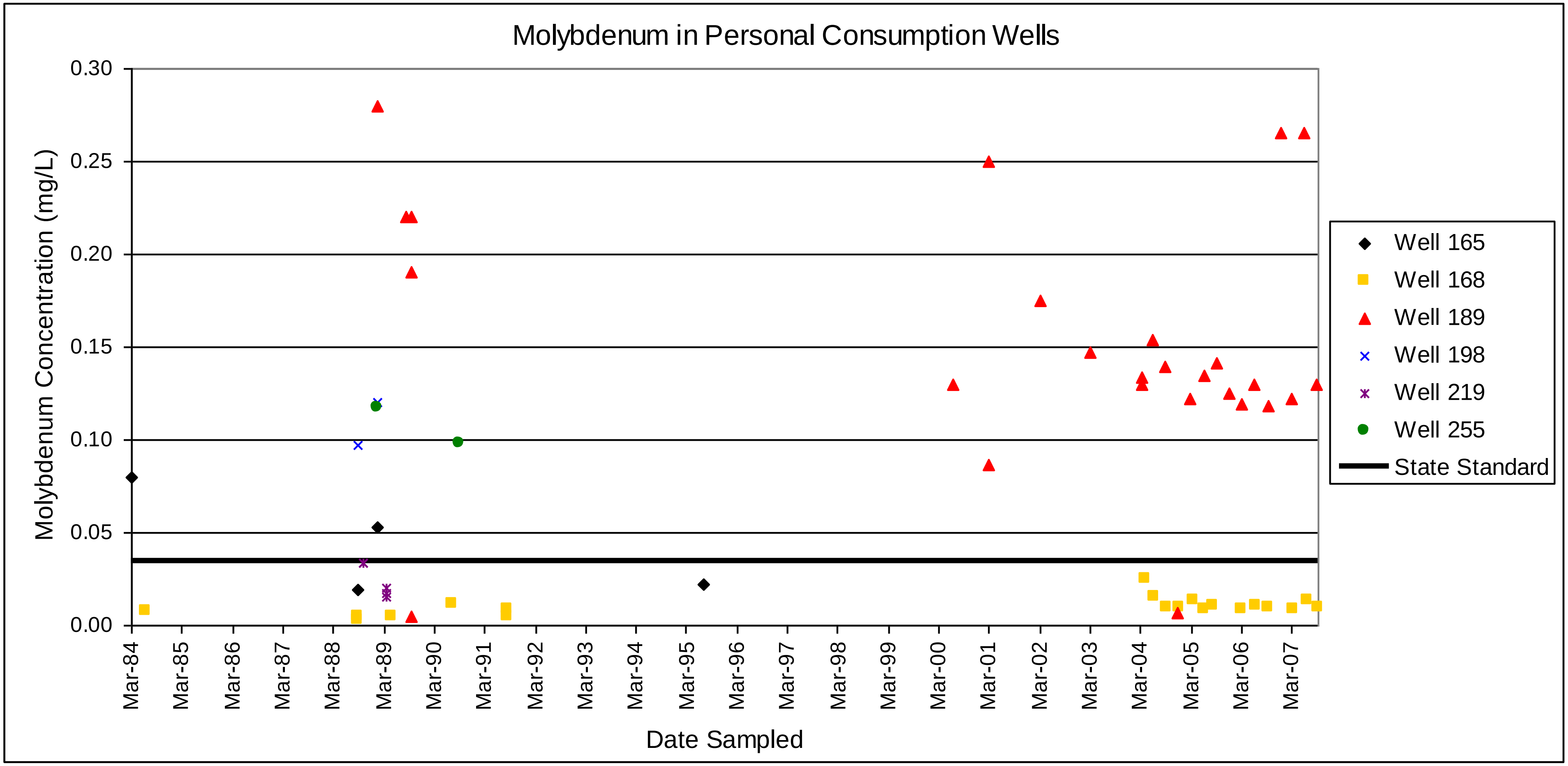
Source: Cotter 2008

Figure 6. Wells in Lincoln Park used for personal consumption



Source: CDPHE 2007b (coordinates)

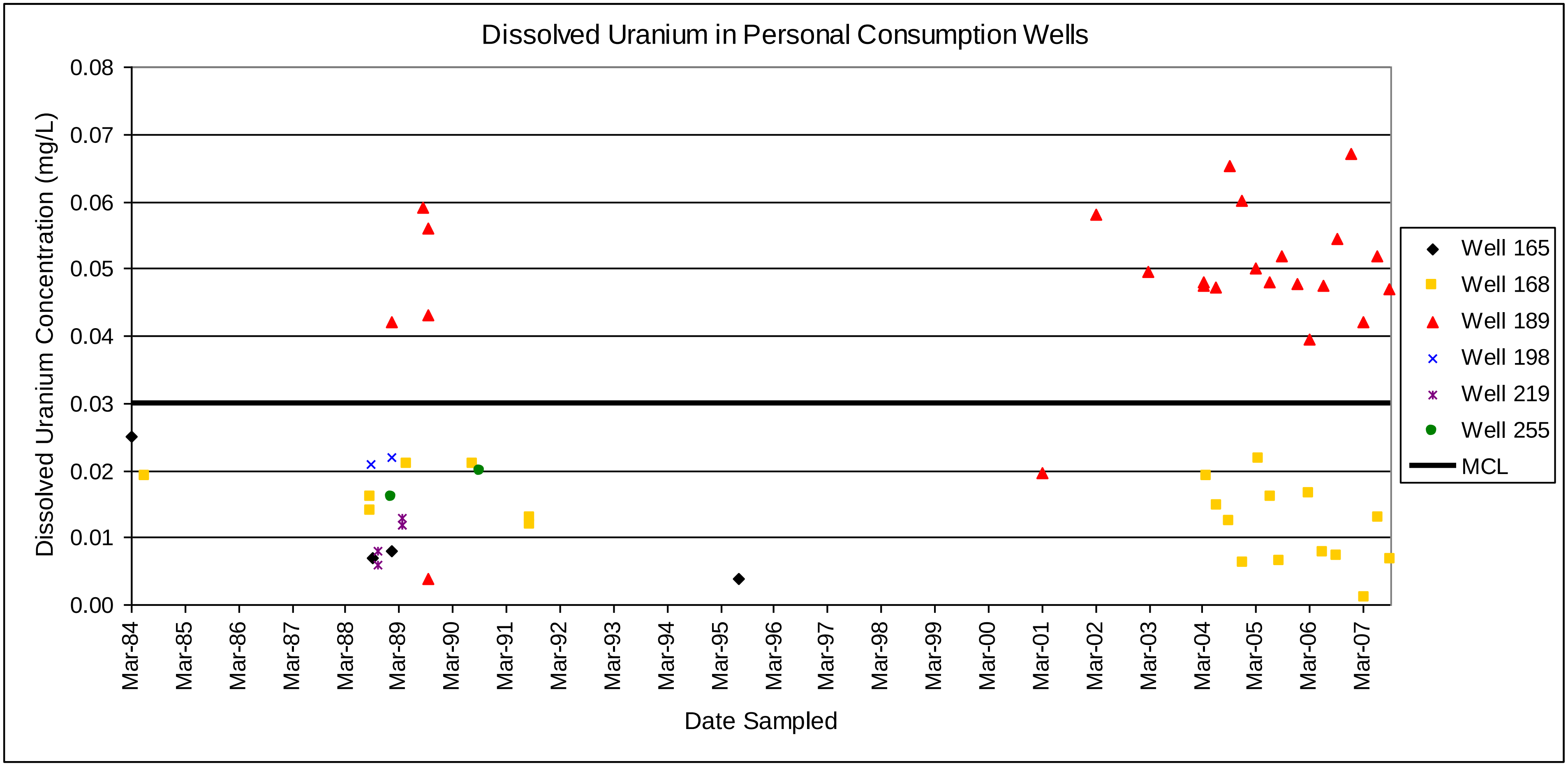
Figure 7. Molybdenum concentrations in wells used for personal consumption



Source: CDPHE 2007b

Non-detected concentrations were plotted as ½ the reporting detection limit.

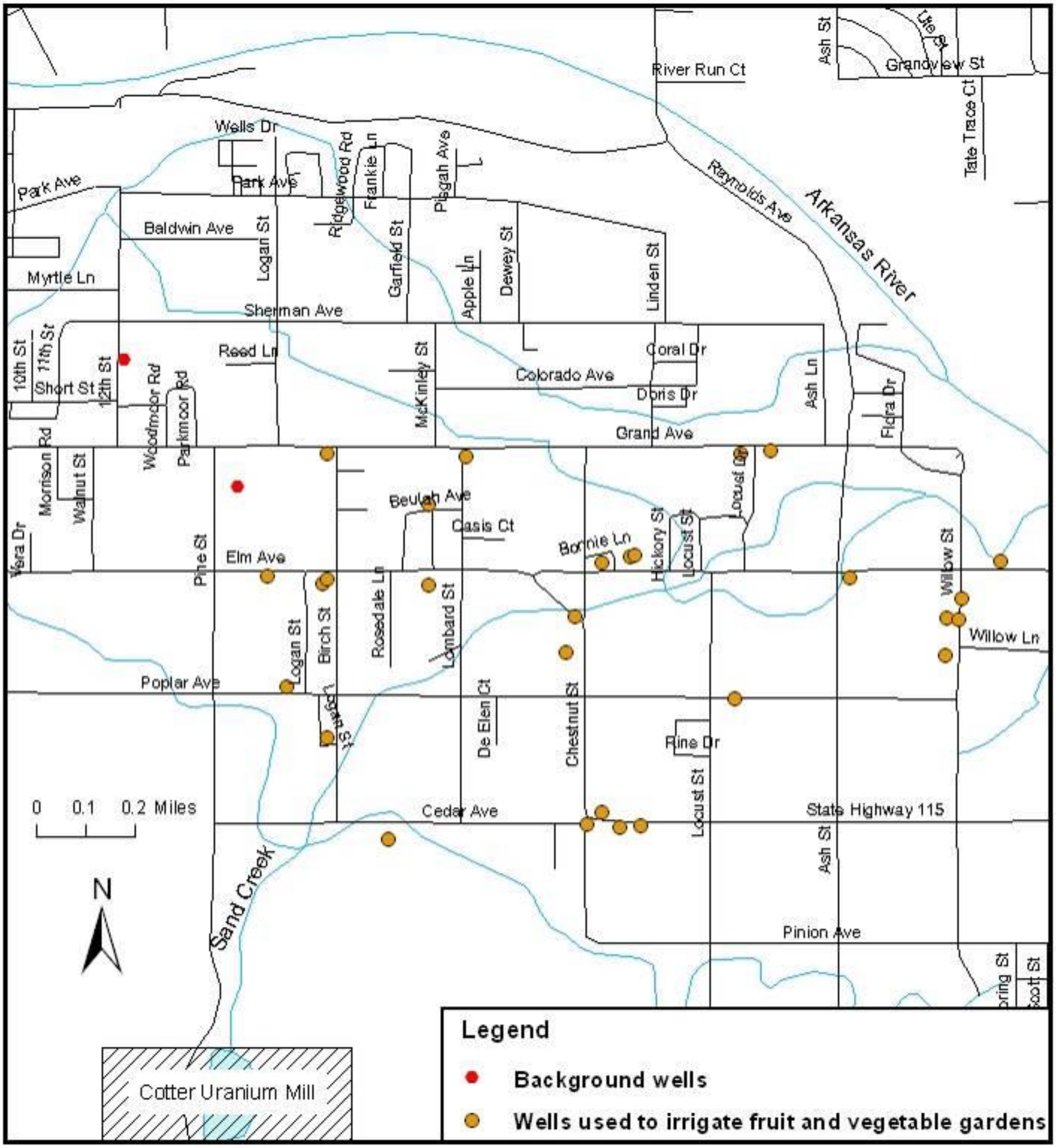
Figure 8. Dissolved uranium concentrations in wells used for personal consumption



Source: CDPHE 2007b

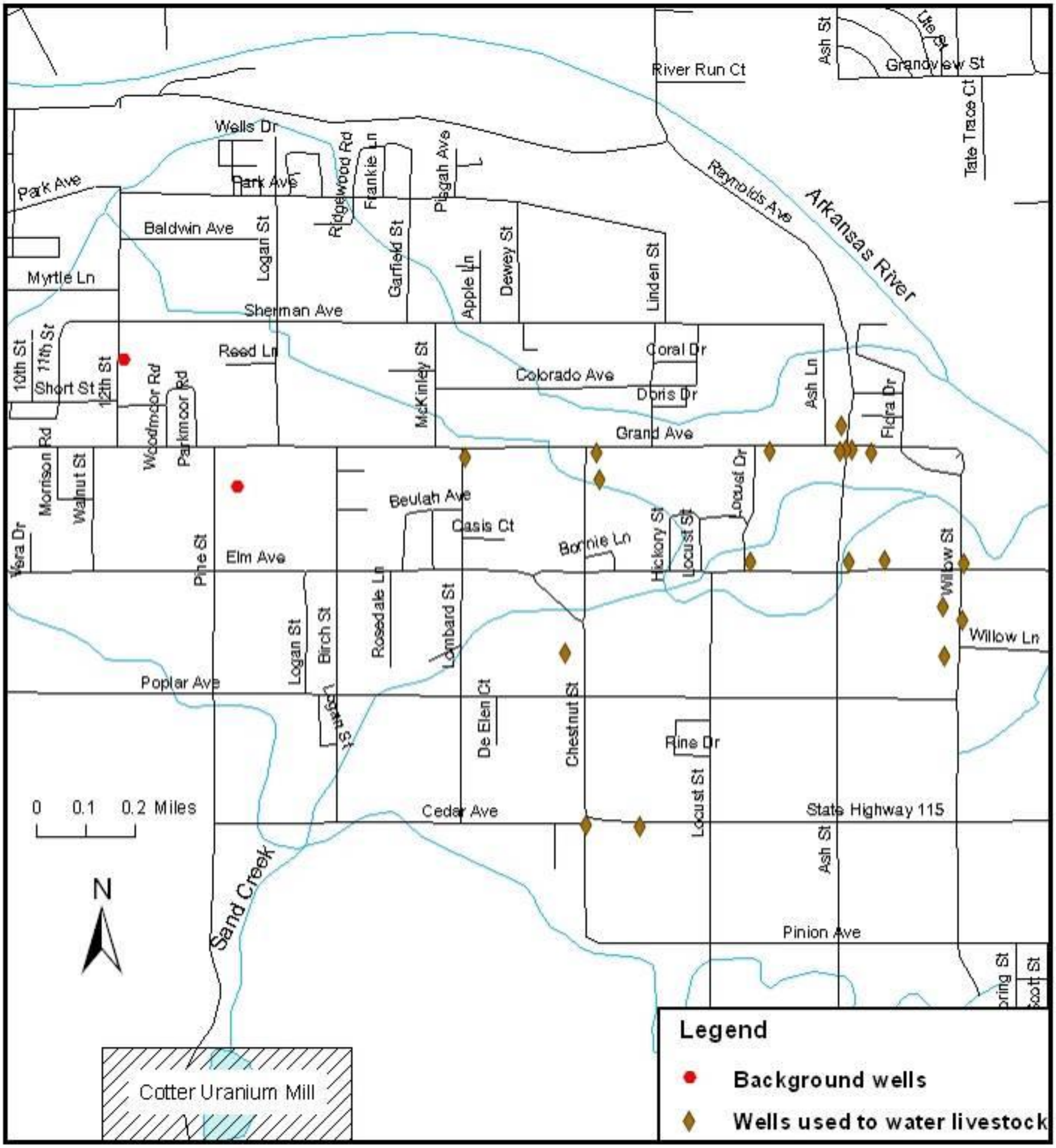
Non-detected concentrations were plotted as ½ the reporting detection limit.

Figure 9. Wells in Lincoln Park used to irrigate fruit and vegetable gardens



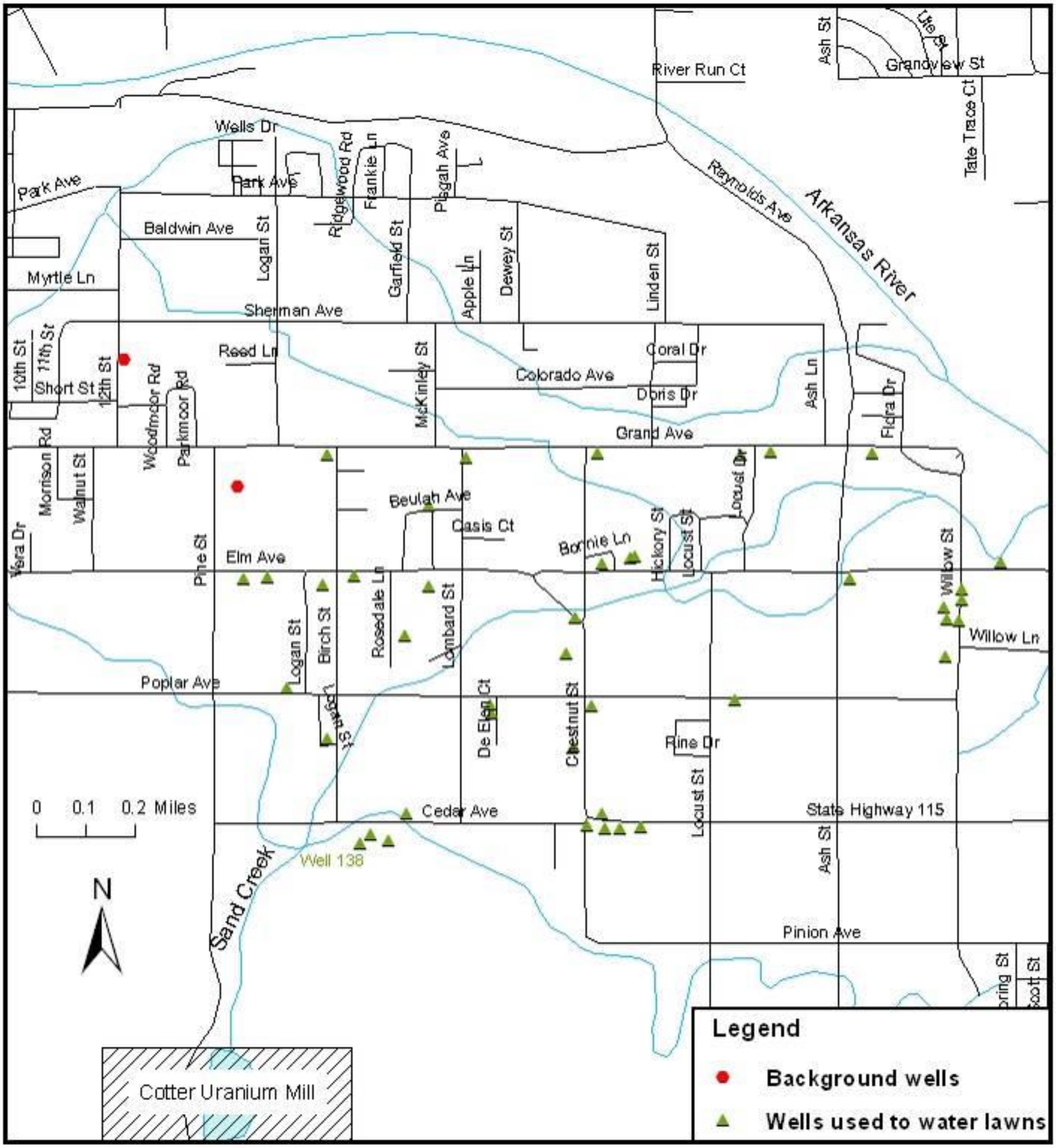
Source: CDPHE 2007b (coordinates)

Figure 10. Wells in Lincoln Park used to water livestock



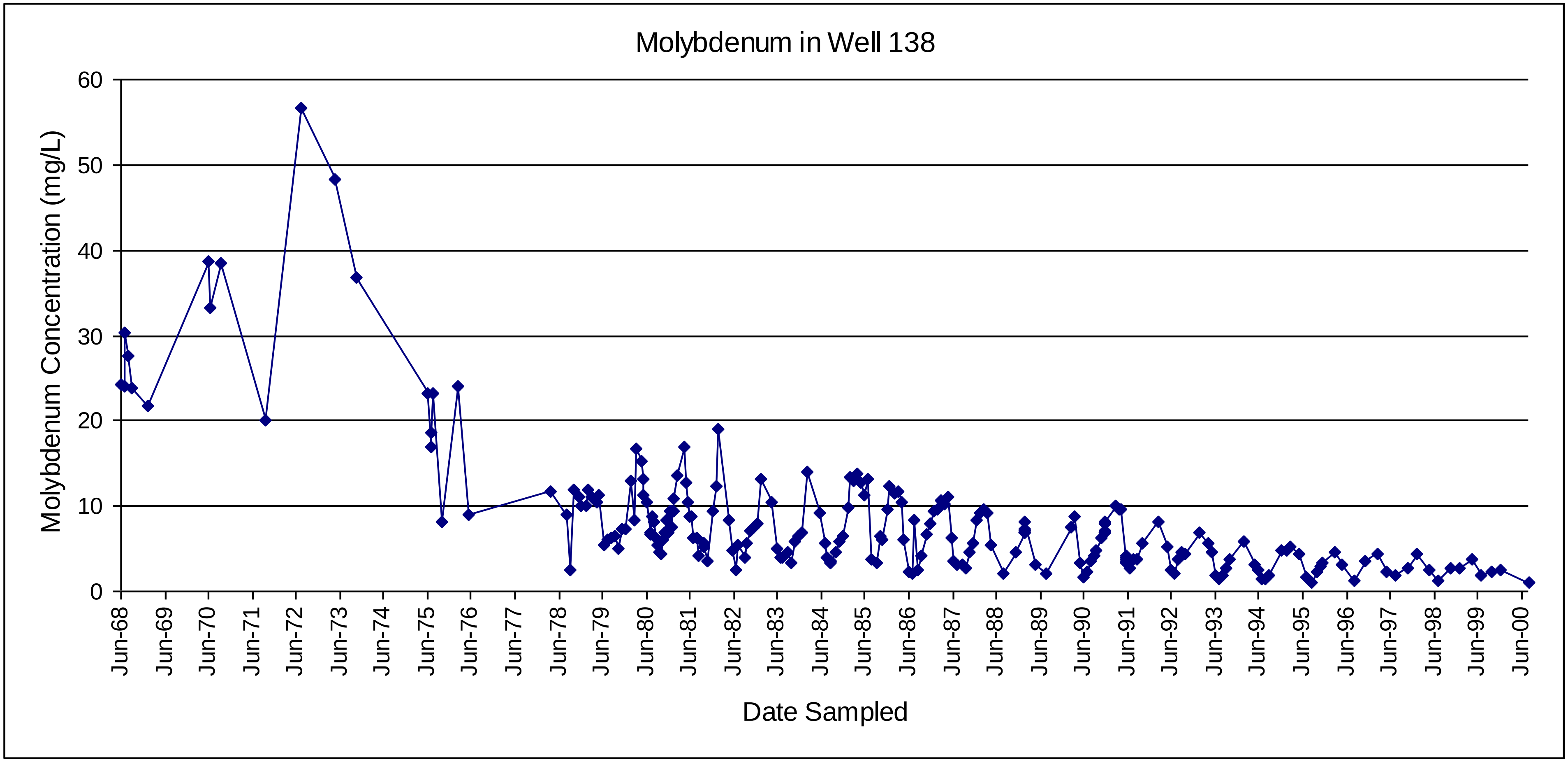
Source: CDPHE 2007b (coordinates)

Figure 11. Wells in Lincoln Park used to water lawns



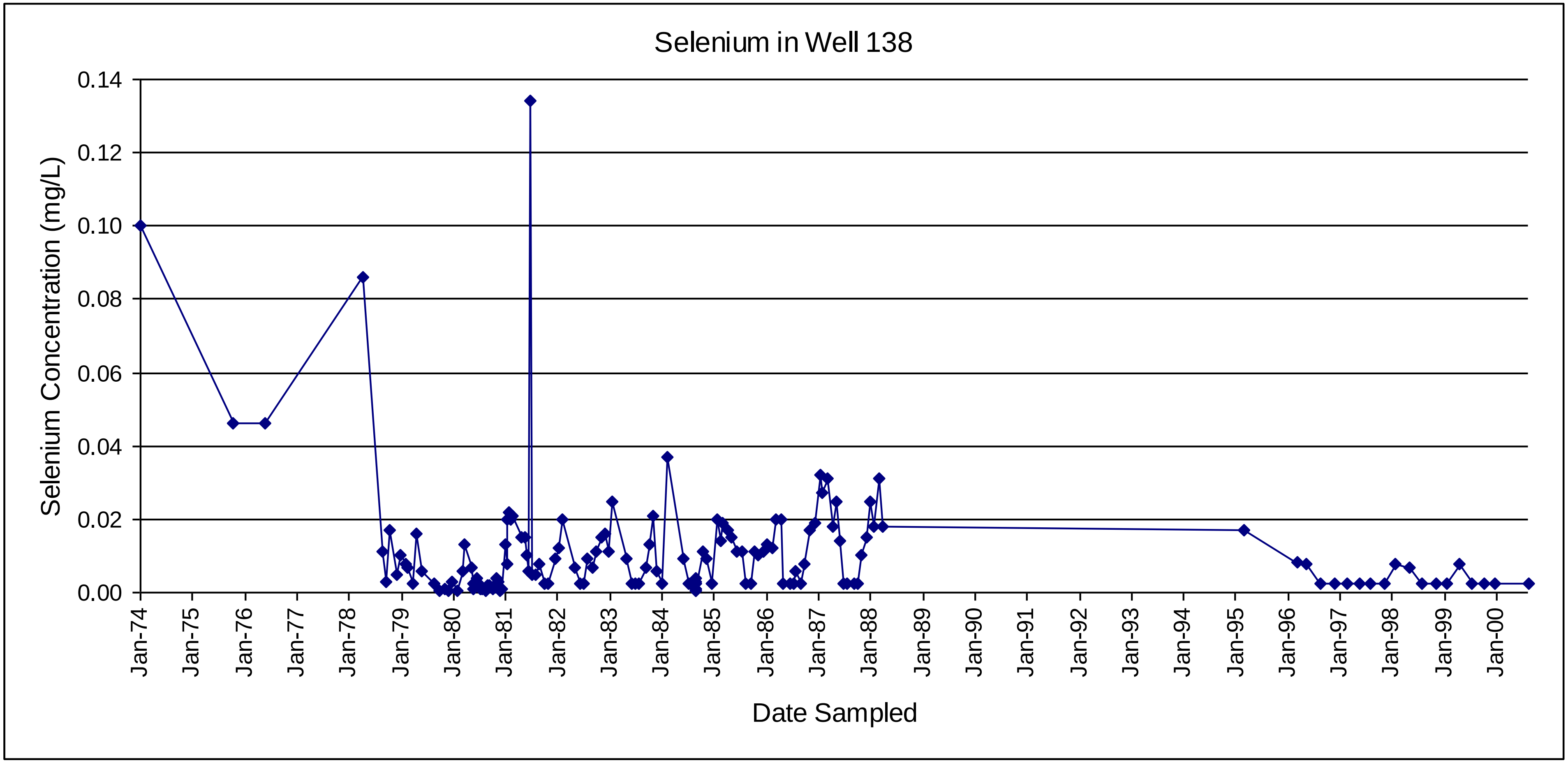
Source: CDPHE 2007b (coordinates)

Figure 12. Molybdenum concentrations in Well 138



Source: CDPHE 2007b
mg/L: milligrams per liter

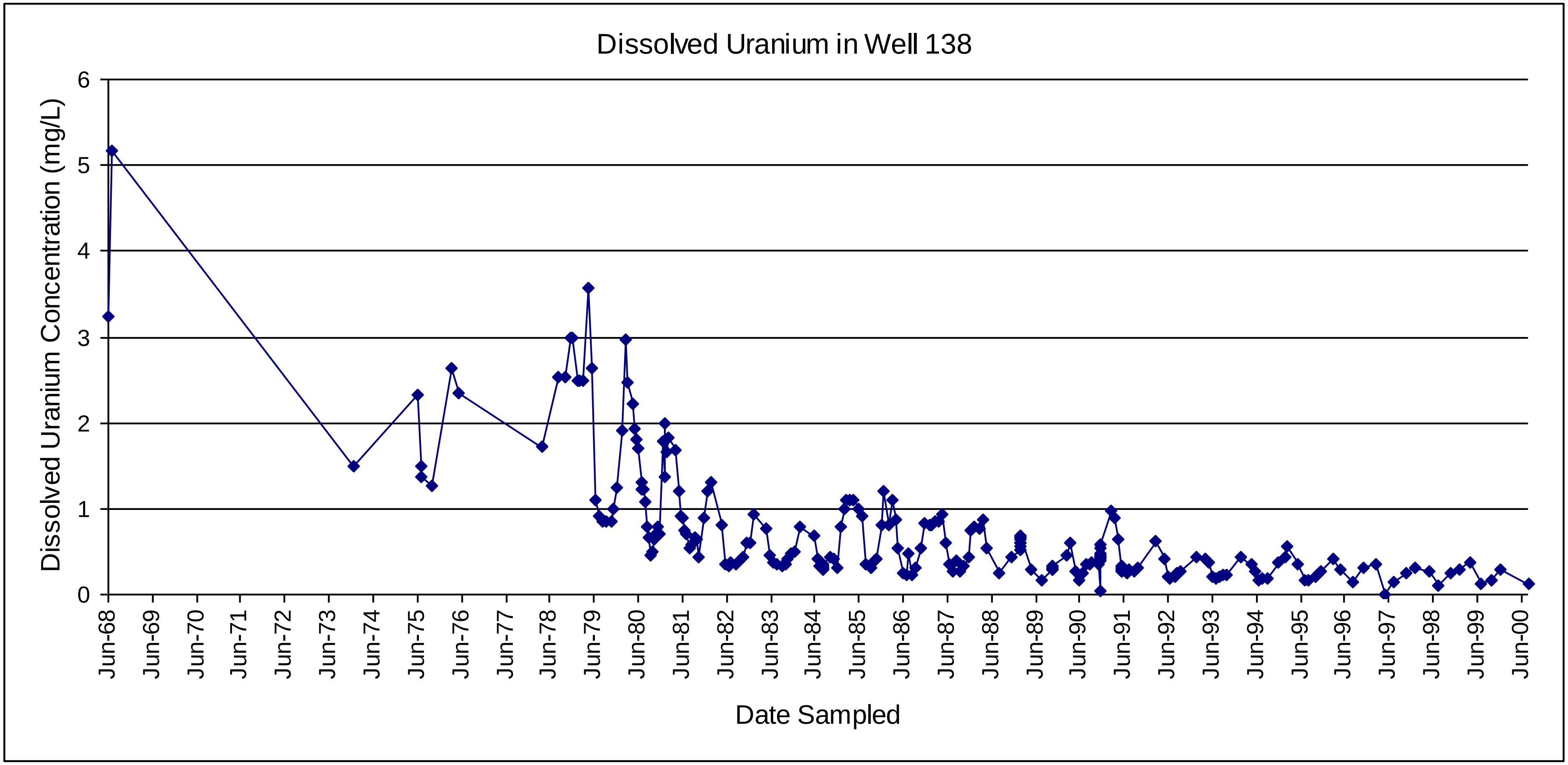
Figure 13. Selenium concentrations in Well 138



Source: CDPHE 2007b
mg/L: milligrams per liter

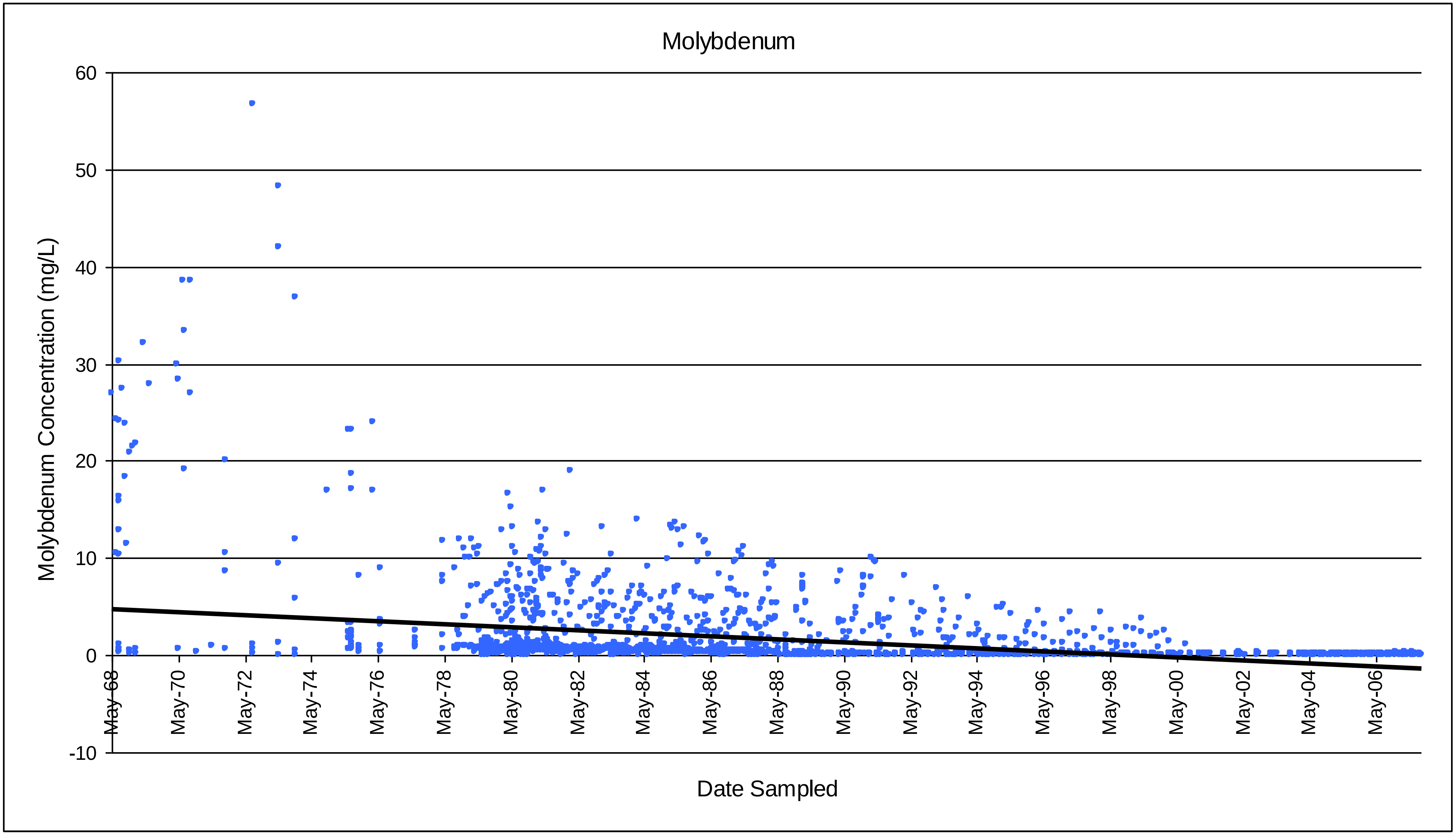
Non-detected concentrations were plotted as ½ the reporting detection limit.

Figure 14. Dissolved uranium concentrations in Well 138



Source: CDPHE 2007b
mg/L: milligrams per liter

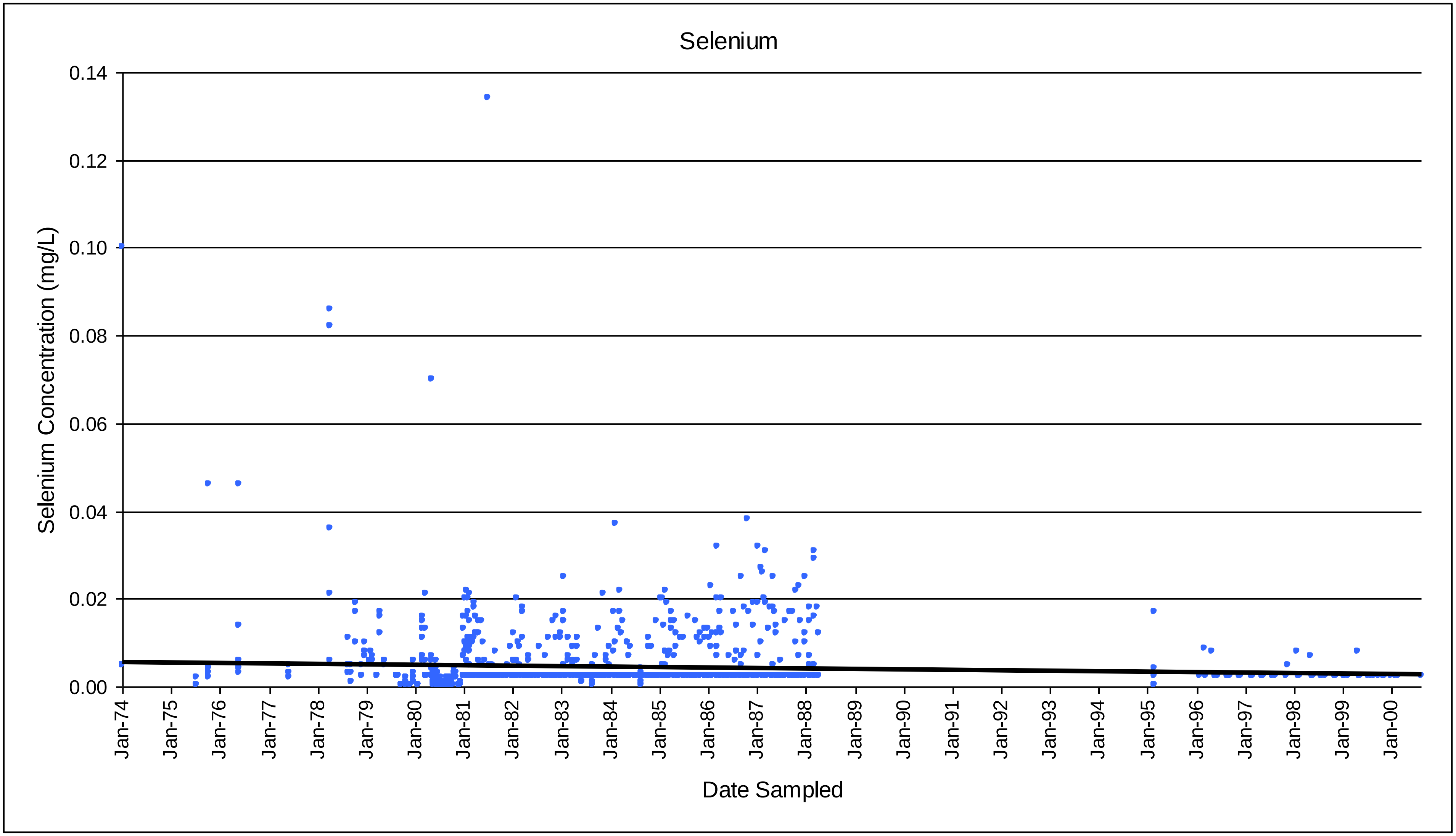
Figure 15. Molybdenum concentrations in all groundwater wells evaluated



Source: CDPHE 2007b
mg/L: milligrams per liter

Non-detected concentrations were plotted as ½ the reporting detection limit.

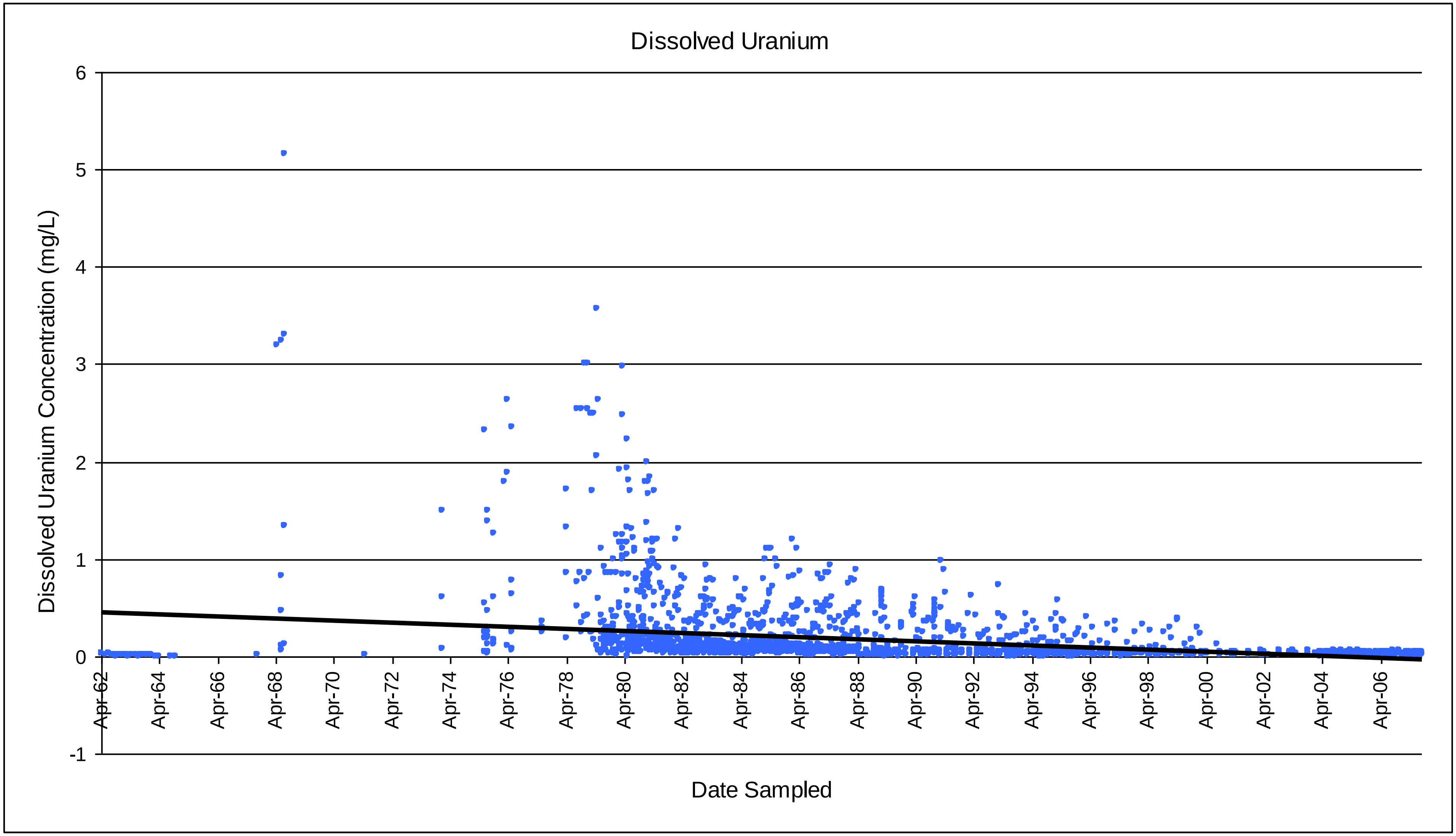
Figure 16. Selenium concentrations in all groundwater wells evaluated



Source: CDPHE 2007b
mg/L: milligrams per liter

Non-detected concentrations were plotted as ½ the reporting detection limit.

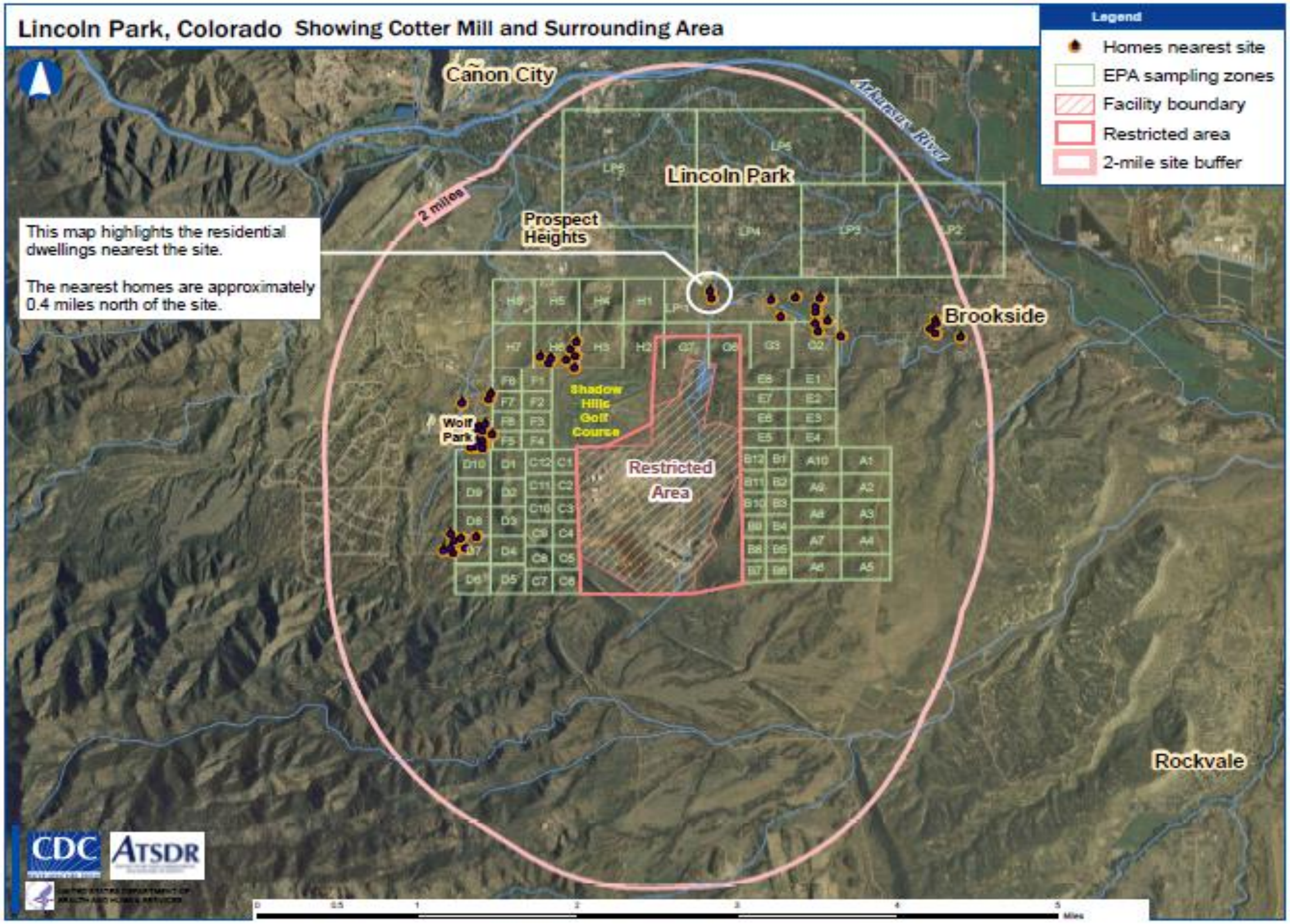
Figure 17. Dissolved uranium concentrations in all groundwater wells evaluated



Source: CDPHE 2007b
mg/L: milligrams per liter

Non-detected concentrations were plotted as ½ the reporting detection limit.

Figure 18. Sampling zones established during the 1998 Supplemental Human Health Risk Assessment

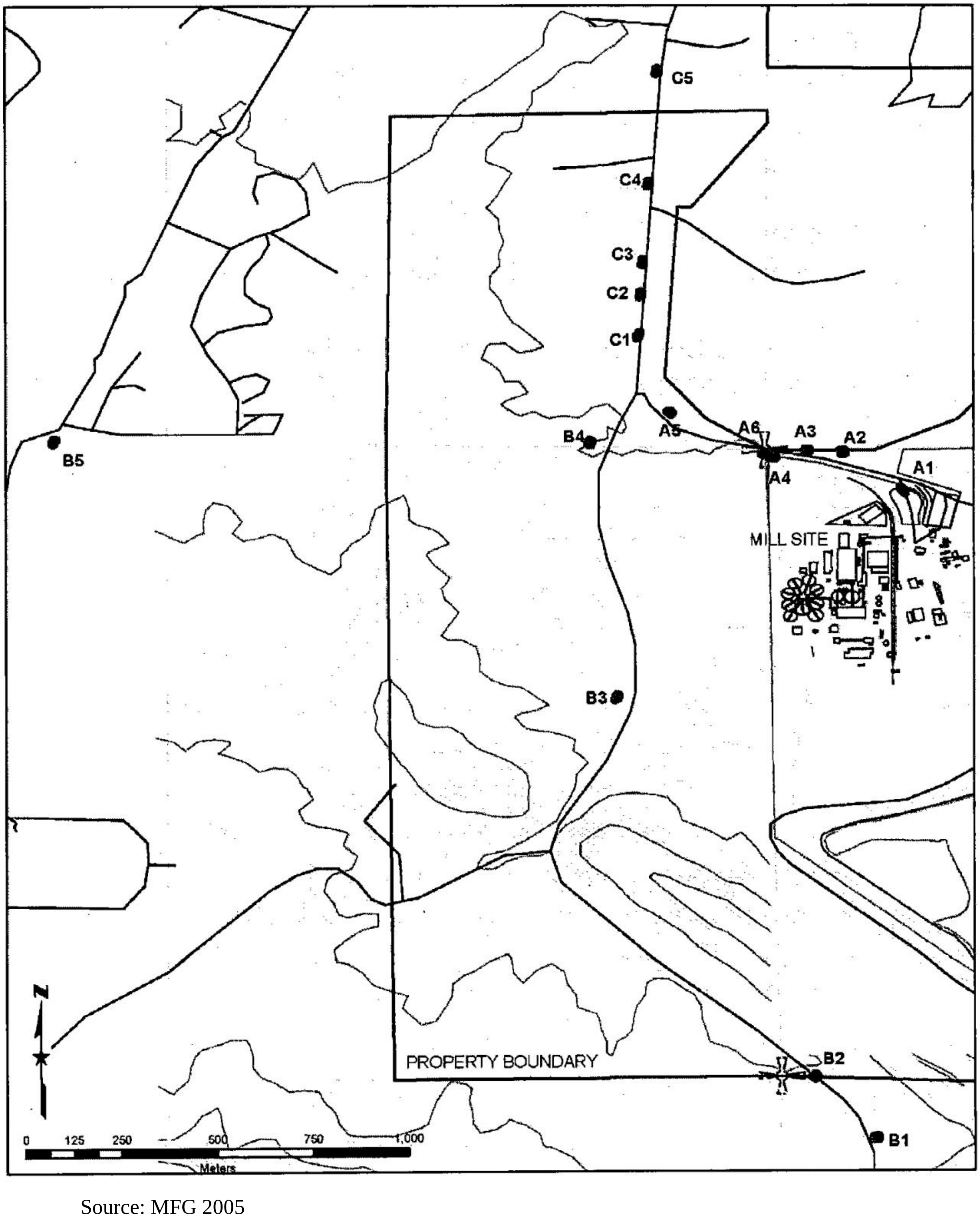


This map highlights the residential dwellings nearest the site.

The nearest homes are approximately 0.4 miles north of the site.

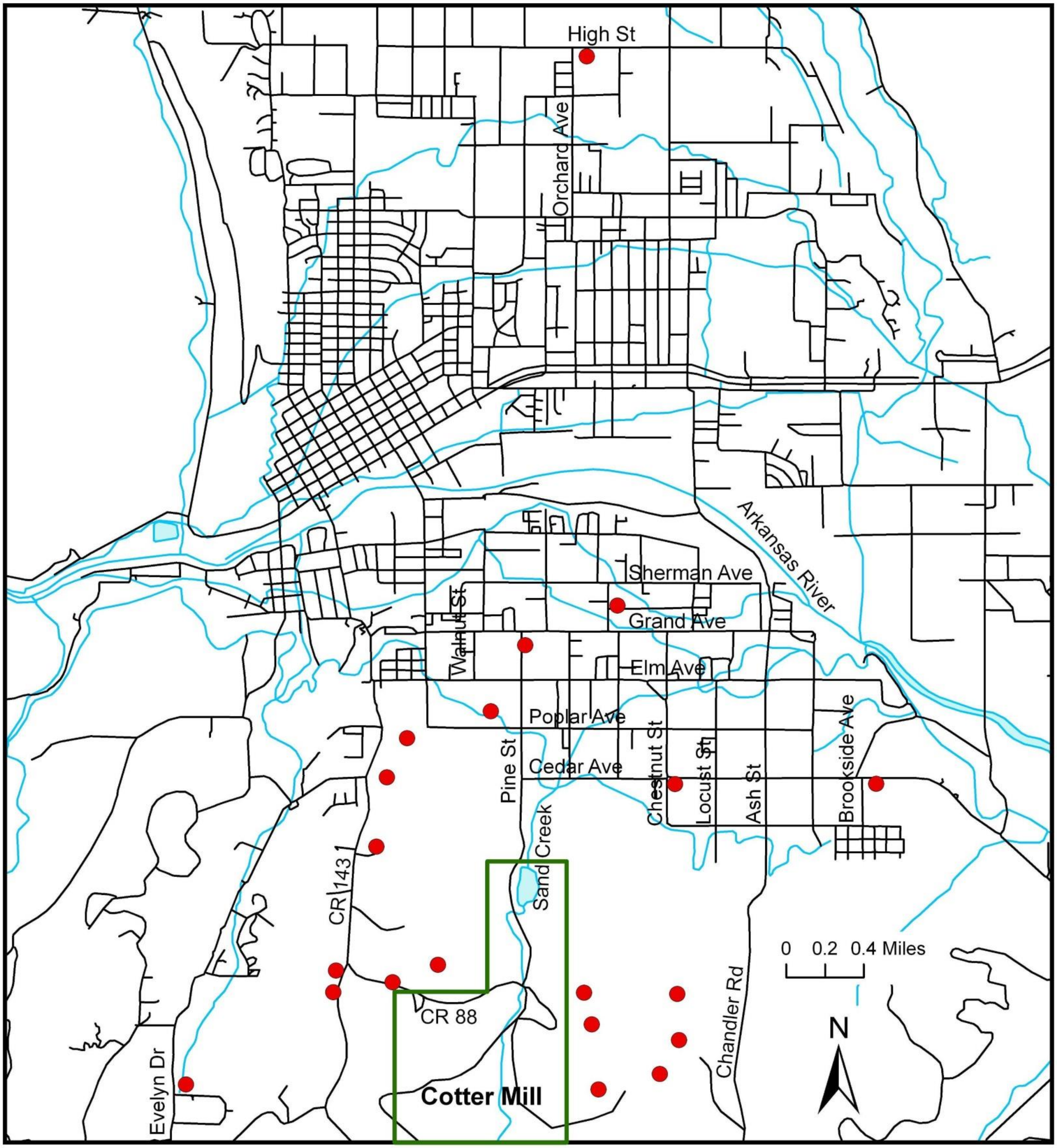
Source: Weston 1998; location of sampling zones (approximate). Mapping: ATSDR Geospatial Research, Analysis, and Services Program (GRASP)

Figure 19. Locations of soil samples taken along the county road and Cotter Mill's access road



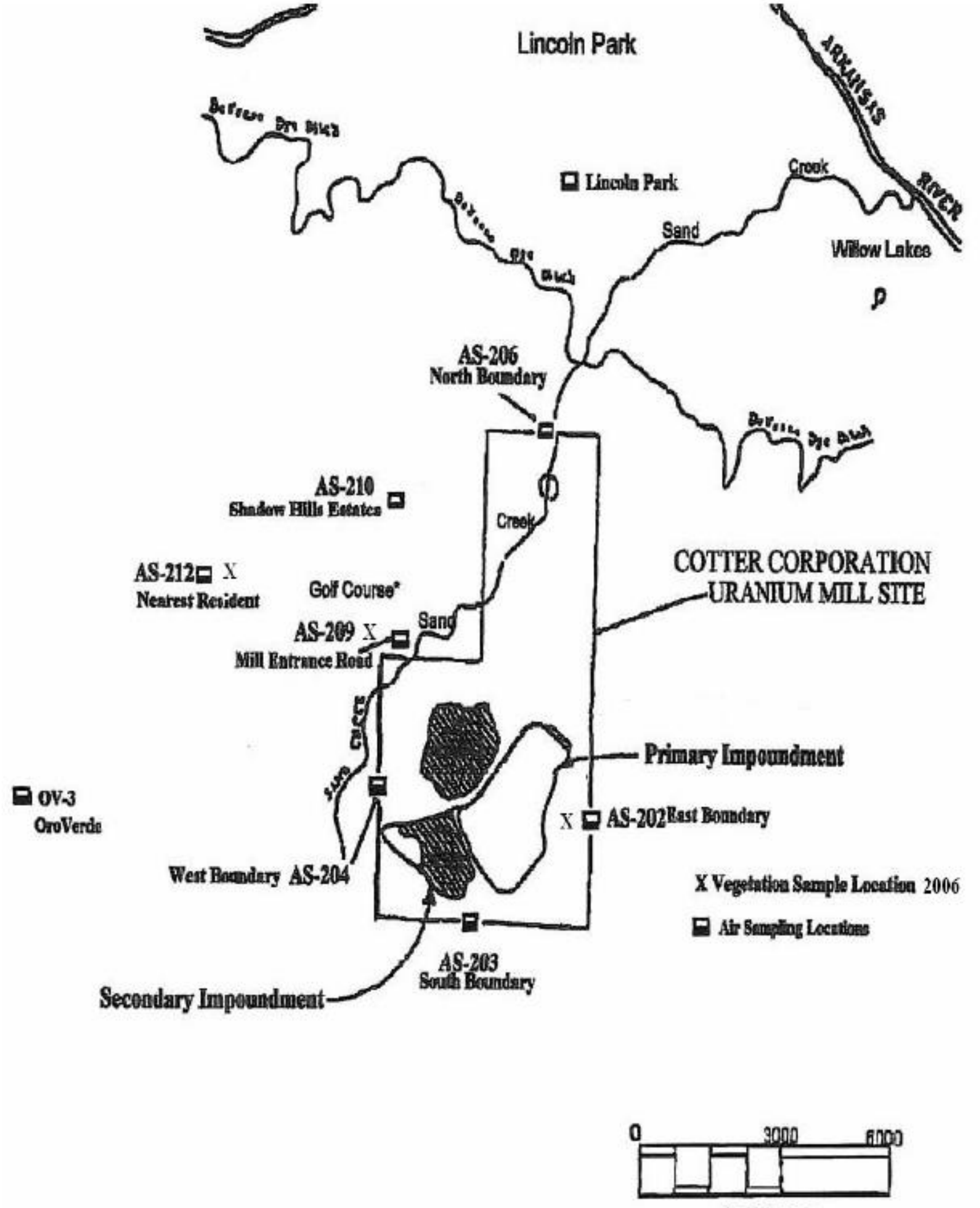
Source: MFG 2005

Figure 20. Locations of soil samples taken by CDPHE in January 2003



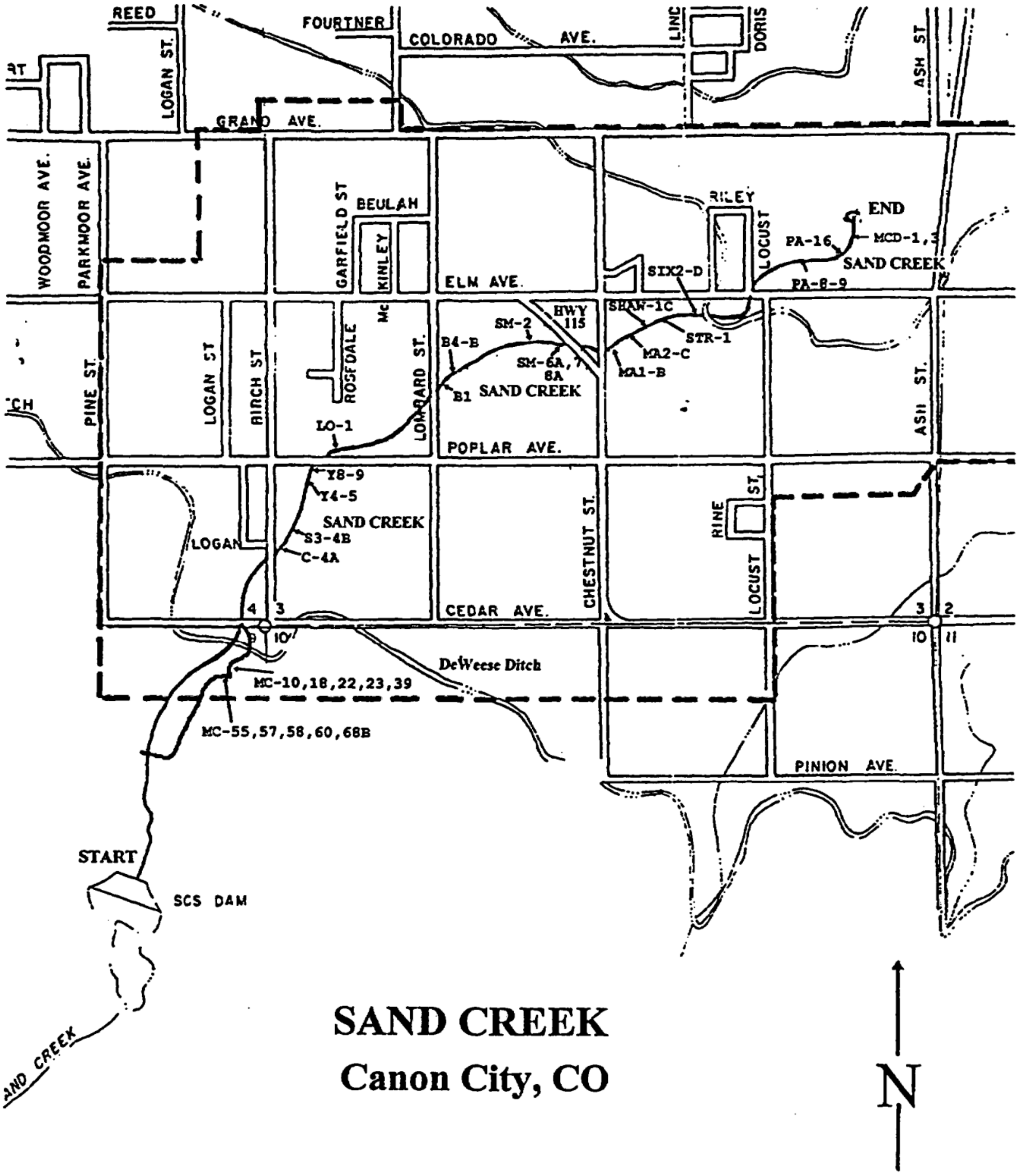
Source: CDPHE 2007b (coordinates)

Figure 21. Location of air sampling locations where soil samples are collected



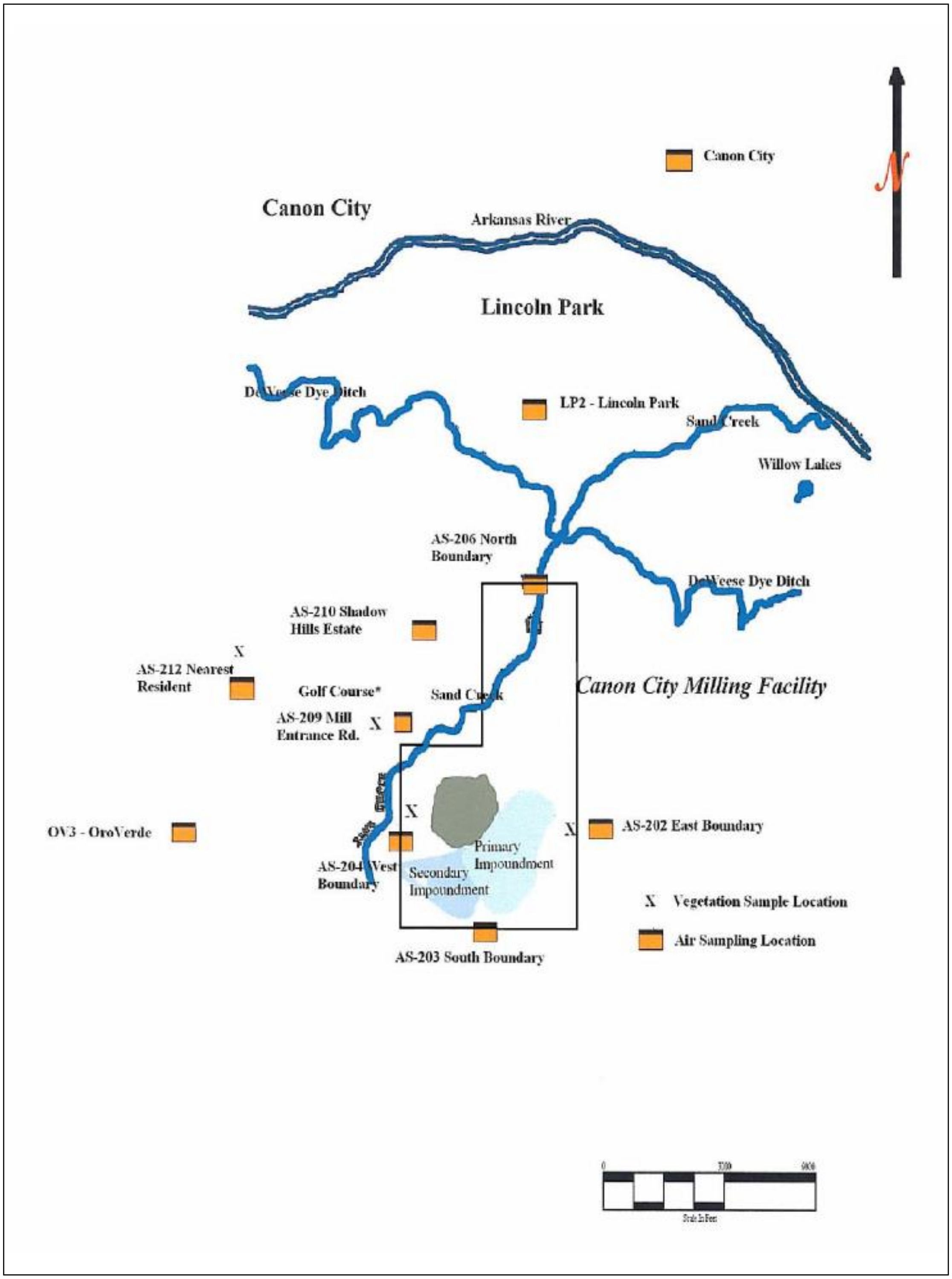
Source: Cotter 2007
Note: An additional air sampling station is located in Cañon City (not depicted on the figure).

Figure 22. Sand Creek Cleanup Project



Source: Cotter 2000

Figure 23. Approximate Locations of Cotter Mill Air Monitoring Stations



Notes: Figure reproduced from: Cotter 2008

APPENDIX C:
ATSDR's Evaluation Process
And
Exposure Dose Calculations

ATSDR's Evaluation Process

Step 1 – Comparison Values and the Screening Process

To evaluate the available data, ATSDR used comparison values (CVs) to determine which chemicals to examine more closely. CVs are the contaminant concentrations found in a specific media (for example: air, soil, or water) and are used to select contaminants for further evaluation. CVs incorporate assumptions of daily exposure to the chemical and a standard amount of air, water, or soil that someone may inhale or ingest each day. CVs are generated to be conservative and non-site specific. These values are used only to screen out chemicals that do not need further evaluation; CVs are not intended as environmental clean-up levels or to indicate that health effects occur at concentrations that exceed these values.

CVs can be based on either carcinogenic (cancer-causing) or non-carcinogenic effects. Cancer-based comparison values are calculated from the U.S. Environmental Protection Agency's (EPA) oral cancer slope factor (CSF) or inhalation risk unit. CVs based on cancerous effects account for a lifetime exposure (70 years) with an unacceptable estimated excess lifetime cancer risk of 1 new case per 1 million exposed people. Non-cancer values are calculated from ATSDR's Minimal Risk Levels (MRLs), EPA's Reference Doses (RfDs), or EPA's Reference Concentrations (RfCs). When a cancer and non-cancer CV exists for the same chemical, the lower of these values is used in the comparison for conservatism.

Step 2 – Evaluation of Public Health Implications

The next step in the evaluation process is to take those contaminants that are above their respective CVs and further identify which chemicals and exposure situations are likely to be a health hazard. Separate child and adult exposure doses (or the amount of a contaminant that gets into a person's body) are calculated for site-specific exposure scenarios, using assumptions regarding an individual's likelihood of accessing the site and contacting contamination. A brief explanation of the calculation of estimated exposure doses is presented below. Calculated doses are reported in units of milligrams per kilograms per day (mg/kg/day). Separate calculations have been performed to account for non-cancer and cancer health effects, if applicable, for each chemical based on the health impacts reported for each chemical. Some chemicals are associated with non-cancer effects while the scientific literature many indicate that cancer-related health impacts are not expected from exposure.

Exposure Dose Factors and Calculations

When chemical concentrations at the site exceed the established CVs, it is necessary for a more thorough evaluation of the chemical to be conducted. In order to evaluate the potential for human exposure to contaminants present at the site and potential health effects from site-specific activities, ATSDR estimates human exposure to the site contaminant from different environmental media by calculating exposure doses.

A discussion of the calculations and assumptions used in this assessment is presented below. The equations are based on the EPA Risk Assessment Guidance for Superfund, Part A (1989), or ATSDR's Public Health Guidance Manual (2005), unless otherwise specified. Assumptions used were based on default values, EPA's Exposure Assessment Handbook (1997, 2011) or Child-Specific Exposure Factors Handbook (2008), or professional (site-specific) judgment. When available, site-specific information is used to estimate exposures.

Ingestion of Chemicals in Well Water:

The exposure dose formula used for the ingestion of chemicals in well water is:

$$\text{Exposure Dose } (D) = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Where:

D = *exposure dose in milligrams per kilogram per day (mg/kg/day)*
C = *concentration of contaminant in water in milligrams per liter (mg/L)*
IR = *ingestion rate in liters per day (L/day)*
EF = *exposure frequency (days/year)*
ED = *exposure duration (years)*
BW = *body weight (kg)*
AT = *averaging time, days*

Note: In the intake equation, averaging time (AT) for exposure to non-carcinogenic compounds is always equal to D; whereas, for carcinogens a 70 year AT is still used in order to compare to EPA's cancer slope factors typically based on that value.

This pathway assumes that an adult resident drinks 2 liters (L) of water per day for 350 days per year. In terms of exposure duration (ED), the adult resident is assumed to live in the same home and drink the same well water for 30 years. The drinking water ingestion rate for children was assumed to be 1 L per day for 350 days per year for 6 years. For average body weight, 70 kg and 16 kg were used for adults and children, respectively.

ATSDR used the average chemical concentration in Well 189 to represent a high exposure scenario from a single well. Well 189 was selected because it consistently contained the highest chemical concentrations over time. The average concentration for all private wells was used to represent exposures to a typical well user.

Table C1. Summary of Exposure Factors and Exposure Doses for the Drinking Water Pathway for Chemicals at the Cotter Mill Site

Chemical	Chemical Concentration (mg/L)	Daily Ingestion Rate (L/day)	Exposure Frequency (days/yr)	Exposure Duration (yrs)	Body Weight (kg)	Averaging Time (days)	Exposure Dose (mg/kg/day)	Health Guideline (mg/kg/day)
Drinking Water Pathway: Ingestion – ADULT and CHILD								
Molybdenum ADULT	0.16 *WELL 189** HIGH EXPOSURE	2	350	30	70	10950	0.004	0.005 Chronic Oral RfD
Molybdenum CHILD		1	350	6	16	2190	**0.010**	
Molybdenum ADULT	0.082 All wells TYPICAL EXPOSURE	2	350	30	70	10950	0.002	
Molybdenum CHILD		1	350	6	16	2190	0.005	
Uranium ADULT	0.048 Well 189* HIGH EXPOSURE	2	350	30	70	10950	0.001	0.002 Intermediate Oral MRL
Uranium CHILD		1	350	6	16	2190	**0.003**	
Uranium ADULT	0.028 All wells TYPICAL EXPOSURE	2	350	30	70	10950	0.0008	
Uranium CHILD		1	350	6	16	2190	0.002	

Bolded type exceeds a comparison value.

* “Well 189” represents a high exposure scenario. This well contained the highest level of chemicals in the sampled group.

“All wells” is used to represent an average exposure scenario for the average private well drinker.

Accidental Ingestion of Chemicals in Soil

The exposure dose formula for incidental ingestion of chemicals soil and/or sediment is:

$$\text{Exposure Dose (D)} = \frac{C \times IR \times EF \times ED \times CF}{BW \times AT}$$

Where:

D = *exposure dose in milligrams per kilogram per day (mg/kg/day)*
C = *concentration of contaminant in soil in milligrams per kilogram (mg/kg or ppm)*
IR = *ingestion rate in milligrams per day (mg/day)*
EF = *exposure frequency (days/year)*
ED = *exposure duration (years)*
CF = *conversion factor* (10^{-6} *kg/mg)*
BW = *body weight (kg)*
AT = *averaging time, days*

This pathway assumes that the average adolescent (11 to 16 years of age) or adult resident accidentally ingests 100 milligrams of soil per day. Because the area is in a primarily vacant "buffer zone" between the Cotter Mill and residential homes, ATSDR assumed that very young children would not access the area. Adolescent and adults would access the site infrequently. Therefore, exposure duration (ED) for an adolescent and adult resident was assumed to be 2 days per week (or 104 days/year) for 30 years. For average body weight, 57 kg was used for an adolescent and 70 kg was used for an adult.

For the residential area north and west of the mill, ATSDR used a residential exposure scenario for adults and children. We assumed that an adult would ingest 100 milligrams of soil per day and for 350 days/year for 30 years. A child was assumed to ingest 200 milligrams of soil per day for 350 days/year for 6 years. For average body weight, 70 kg and 16 kg were used for adults and children, respectively.

In this evaluation, the bioavailability from incidental ingestion of arsenic in soil was assumed to be 80% because it is protective of health. Cadmium was assumed to be 100% bioavailable, which is also conservative but protective of health.

Direct Skin (Dermal) Contact with Chemicals in Soil

Dermal absorption of chemicals from soil depends on the area of contact with exposed skin, the duration of contact, the chemical and physical attraction between the contaminant and soil, the ability of the chemical to penetrate the skin, and other factors.

The exposure dose formula for dermal absorption of chemicals soil and/or sediment is:

$$\text{Exposure Dose (D)} = \frac{C \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT}$$

Where:

D *= exposure dose in milligrams per kilogram per day (mg/kg/day)*
C *= chemical concentration (mg/kg)*
SA *= surface area exposed (square centimeters/day or* cm^2*/day)*
AF *= soil to skin adherence factor (milligrams per square centimeters or* mg/cm^2*)*
ABS *= Absorption factor (unitless)*
EF *= exposure frequency (days/year)*
ED *= exposure duration (years)*
CF *= conversion factor (*10^{-6} *kg/mg)*
BW *= body weight (kg)*
AT *= averaging time (days)*

Note: Absorption factors (ABS) are used to reflect the desorption of the chemical from soil and the absorption of the chemical across the skin and into the bloodstream.

For the dermal contact pathway, ATSDR assumed that the surface area available in an adolescent for direct skin contact is 2,635 square centimeters per day (cm^2/day); for an adolescent is 4,300 (cm^2/day); and for an adult is 5,000 cm^2/day. An adherence factor of 0.07 milligrams per cubic centimeter (mg/cm^3) was used. An absorption factor of 0.03 was used for arsenic and 0.01 was used for cadmium. Individuals were assumed to weigh 57 kg as an adolescent and 70 kg as an adult, and to be exposed for 6 and 30 years, respectively.

The total soil oral and dermal non-carcinogenic dose was estimated as follows:

Total Dose (TD) = ***ID + DD***

Where:

TD *= total soil ingestion and dermal non-carcinogenic dose*
ID *= Soil ingestion non-carcinogenic dose (mg/kg/day)*
DD*= Soil dermal non-carcinogenic dose (mg/kg/day)*

Cancer Risk Estimates

EPA classifies arsenic as a Class A known human carcinogen by the oral and inhalation routes. Cadmium is classified by EPA as a probable human carcinogen, but only via the inhalation route of exposure. Therefore, only arsenic is evaluated for its carcinogenic risk.

The Lifetime Estimated Cancer Risk for arsenic is estimated as follows:

LECR = ***TDs x CSF x EF***

Where:

LECR *= lifetime estimated cancer risk*

TDs *= total soil oral and dermal non-carcinogenic dose (mg/kg/day)*
CSF *= cancer slope factor ((mg/kg-day)$^{-1}$)*
EF *= Exposure factor (unitless) = exposure duration / lifetime = (30 years) / (70 years) = 0.4*

The cancer slope factor for arsenic is 1.5 mg/kg-day. Therefore, the LECR for arsenic is 1 x 10^{-5} and 4 x 10^{-5} for nonresidential and residential areas, respectively, near the mill.

Table C2. Summary of Exposure Factors and Exposure Doses for the Soil Exposure Pathway for Chemicals Near the Cotter Mill

Chemical	Chemical Concentration (mg/kg)	Daily Intake Rate (mg/day)	Exposure Frequency (days/yr)	Exposure Duration (years)	Body Weight (kg)	Averaging Time (days)	Exposure Dose (mg/kg/day)	Health Guideline (mg/kg/day)
Soil Exposure Pathway: Accidental Ingestion and Direct Skin Contact - ADULT and ADOLESCENT in non-residential area near the Cotter Mill								
Arsenic (ingestion)	45	100	104	30	70	10950	0.00002	0.0003 MRL
Arsenic (dermal)		NA	104	30	70	10950	0.000002	
TOTAL DOSE ARSENIC - Adult							0.000022	*Below Guideline*
Cadmium (ingestion)	37	100	104	30	70	10950	0.00002	0.0001 MRL
Cadmium (dermal)		NA	104	30	70	10950	0.0000005	
TOTAL DOSE CADMIUM -Adult							0.0000205	*Below Guideline*
Arsenic (ingestion)	45	100	104	6	54	2190	0.00002	0.0003 MRL
Arsenic (dermal)		NA	104	6	54	2190	0.000002	
TOTAL DOSE ARSENIC - Adolescent							0.000022	*Below Guideline*
Cadmium (ingestion)	37	100	104	6	54	2190	0.00002	0.0001 MRL
Cadmium (dermal)		NA	104	6	54	2190	0.0000006	
TOTAL DOSE CADMIUM - Adolescent							0.0000206	*Below Guideline*

Table C3. Summary of Exposure Factors and Exposure Doses for the Soil Exposure Pathway for Chemicals On Residential Property

Chemical	Chemical Concentration (mg/kg)	Daily Intake Rate (mg/day)	Exposure Frequency (days/yr)	Exposure Duration (years)	Body Weight (kg)	Averaging Time (days)	Exposure Dose (mg/kg/day)	Health Guideline (mg/kg/day)
Soil Exposure Pathway: Accidental Ingestion and Direct Skin Contact - ADULT and CHILD in residential areas near the Cotter Mill								
Arsenic (ingestion)	44	100	350	30	70	10950	0.00006	0.0003 MRL
Arsenic (dermal)		NA	350	30	70	10950	0.000006	
						TOTAL DOSE ARSENIC - Adult	0.000076	*Below Guideline*
Cadmium (ingestion)	21	100	350	30	70	10950	0.00003	0.0001 MRL
Cadmium (dermal)		NA	350	30	70	10950	0.000002	
						TOTAL DOSE CADMIUM -Adult	0.000032	*Below Guideline*
Arsenic (ingestion)	44	200	350	6	16	2190	0.0005	0.0003 MRL
Arsenic (dermal)		NA	350	6	16	2190	0.00001	
						TOTAL DOSE ARSENIC – Child	**0.00051**	*Above Guideline*
Cadmium (ingestion)	21	200	350	6	16	2190	0.0003	0.0001 MRL
Cadmium (dermal)		NA	350	6	16	2190	0.000002	
						TOTAL DOSE CADMIUM - Child	**0.000302**	*Above Guideline*

Incidental Ingestion of Chemicals in Surface Water

The ATSDR exposure dose formula used for the ingestion of chemicals in surface water while wading or swimming is:

$$\text{Exposure Dose } (D) = \frac{C \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

D = *exposure dose in milligrams per kilogram per day (mg/kg/day)*
C = *concentration of contaminant in water in milligrams per liter (mg/L)*
IR = *ingestion rate in liters per day (L/day); based on contact rate of 50 ml/hr*
ET = *exposure time (hours/event)*
EF = *exposure frequency (events/year)*
ED = *exposure duration (years)*
BW = *body weight (kg)*
AT = *averaging time, days*

This pathway assumes that adult and children residents would accidentally swallow 50 milliliters of water per hour while swimming, wading or recreating in Sand Creek or the DeWeese Dye Ditch. In terms of exposure time and frequency, ATSDR conservatively assumed an adult and child resident would recreate in these waters for 2 hours per day, 2 days per week (or 104 days/year) for 30 years and 6 years, respectively. For average body weight, 70 kg and 16 kg were used for adults and children, respectively.

Direct Skin (Dermal) Contact with Chemicals in Surface Water

ATSDR's exposure dose formula for dermal absorption of chemicals soil and/or sediment is:

$$\text{Exposure Dose } (D) = \frac{C \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where:

D = *exposure dose in milligrams per kilogram per day (mg/kg/day)*
C = *chemical concentration (mg/L)*
SA = *surface area exposed* (cm^2)
PC = *chemical-specific dermal permeability constant (cm/hr)*
ET = *exposure time (hours/day)*
EF = *exposure frequency (days/year)*
ED = *exposure duration (years)*
CF = *volumetric conversion factor for water* ($1L/1000\ cm^3$)
BW = *body weight (kg)*
AT = *averaging time (days)*

The dermal contact pathway assumes that the total body surface area available for contact with water is 20,000 cm^2 for adults and 9,300 cm^2 for children. Adults were assumed to weigh 70 kg and to be exposed for 30 years. Children were assumed to weigh 16 kg and to be exposed for 6 years. Adults and children were conservatively assumed to swim in the contaminated water 2 days per week (104 days per year) for 2 hours per recreating event. A dermal permeability constant of 0.001 cm/hr was used for both manganese and molybdenum.

Table C4. Summary of Exposure Factors and Exposure Doses for the Surface Water Pathway for Chemicals at the Cotter Mill Site

Chemical	Chemical Concentration (mg/L)	Daily Ingestion Rate (L/day)	Exposure Frequency (days/yr)	Exposure Duration (yrs)	Body Weight (kg)	Averaging Time (days)	Exposure Dose (mg/kg/day)	Health Guideline (mg/kg/day)
Surface Water Exposure Pathway: Accidental Ingestion and Direct Skin Contact while Wading or Swimming – ADULT and CHILD								
Manganese* Adult Ingestion	1.9	0.1	104	30	70	10950	3.9 x 10^{-4}	0.05 Oral RfD
Manganese Adult Dermal		NA	104	30	70	10950	3.1 x 10^{-4}	
		TOTAL DOSE MANGANESE – Adult					7 x 10^{-4}	*Below Guideline*
Manganese Child Ingestion		0.1	104	6	16	2190	1.7 x 10^{-3}	0.05 Oral RfD
Manganese Child Dermal		NA	104	6	16	2190	6.3 x 10^{-4}	
		TOTAL DOSE MANGANESE - Child					2.3 x 10^{-3}	*Below Guideline*
Molybdenum† Adult Ingestion	0.051	0.1	104	30	70	10950	1.0 x 10^{-5}	0.005 Oral RfD
Molybdenum Adult Dermal		NA	104	30	70	10950	8.3 x 10^{-6}	
		TOTAL DOSE MOLYBDENUM - Adult					1.8 x 10^{-5}	*Below Guideline*
Molybdenum Child Ingestion		0.1	104	6	16	2190	4.5 x 10^{-5}	0.005 Oral RfD
Molybdenum Child Dermal		NA	104	6	16	2190	1.7 x 10^{-5}	
		TOTAL DOSE MOLYBDENUM - Child					6.2 x 10^{-5}	*Below Guideline*

*Maximum concentration of manganese in surface water detected in DeWeese Dye Ditch

†Maximum concentration of molybdenum in surface water detected in Sand Creek

Consumption of Homegrown Fruits and Vegetables

The following formula presents the method for calculating an exposure dose for a typical consumer of homegrown fruits and vegetables:

Exposure Dose (mg/kg/day) = **C x IR x CF**

Where:

C *= contaminant concentration (mg/kg)*
IR *= intake rate of fruit or vegetable (g/kg/day)*
CF *= conversion factor (1 x* 10^{-3} *kg/g)*

Exposure doses for ingestion of garden vegetables were calculated using the average detected concentration of each contaminant measured in fruit and vegetable samples, in mg/kg, multiplied by average consumption rates of homegrown fruits or vegetables in grams per kilogram of body weight per day (g/kg/day). Intake rates were taken from EPA's Exposure Factors Handbook for adults, and EPA's Child-Specific Exposure Factors Handbook for children, for the Western United States. The average consumption rate was used to represent a "typical" fruit and vegetable consumer. The 95 percentile consumption rate was used to represent an "above average" consumer of fruits and vegetables. The calculated value was multiplied by a conversion factor of 0.001 kilograms per gram.

Table C5. Summary of Exposure Doses for Local Fruits and Vegetables Irrigated with Contaminated Well Water

Chemical	Chemical Concentration/ Exposure Group	Exposure Dose Fruits (mg/kg/day)	Exposure Dose Vegetables (mg/kg/day)	Total Exposure Dose Fruits & Vegetables (mg/kd/day)	Health Guideline (mg/kg/day)
Arsenic	Average consumer	0.0001	0.0001	0.0002	0.0003, Chronic Oral MRL
	Above Average Consumer	**0.0006**	**0.0005**	**0.001**	
	Child	0.0002	0.0002	**0.0004**	
	Infant	**0.0004**	**0.0004**	**0.0008**	
Barium	Average consumer	0.001	0.003	0.004	0.2 Chronic Oral MRL
	Above Average Consumer	0.005	0.010	0.015	
	Child	0.002	0.004	0.006	
	Infant	0.004	0.008	0.012	
Cadmium	Average consumer	0.0001	0.0001	0.0002	0.001, RfD
	Above Average Consumer	0.0005	0.0002	0.0007	
	Child	0.0002	0.0001	0.0003	
	Infant	0.0004	0.0002	0.0006	
Chromium	Average consumer	0.0001	0.0001	0.0002	1.5 RfD
	Above Average Consumer	0.0006	0.0003	0.0009	
	Child	0.0002	0.0001	0.0003	
	Infant	0.0005	0.0003	0.0008	
Cobalt	Average consumer	ND	0.00004	0.00004	0.01 Intermediate MRL
	Above Average Consumer	ND	0.00012	0.00012	
	Child	ND	0.00005	0.00005	
	Infant	ND	0.0001	0.0001	
Lead	Average consumer	0.0003	0.0004	0.0007	NA
	Above Average Consumer	0.001	0.001	0.002	
	Child	0.0005	0.0005	0.0010	
	Infant	0.001	0.001	0.002	
Manganese	Average consumer	0.002	0.004	0.006	0.14 RfD
	Above Average Consumer	0.01	0.02	0.03	
	Child	0.004	0.006	0.010	
	Infant	0.008	0.01	0.009	

Chemical	Chemical Concentration/ Exposure Group	Exposure Dose Fruits (mg/kg/day)	Exposure Dose Vegetables (mg/kg/day)	Total Exposure Dose Fruits & Vegetables (mg/kd/day)	Health Guideline (mg/kg/day)
Molybdenum	Average consumer	0.0003	0.001	0.0013	0.005 RfD
	Above Average Consumer	0.001	0.004	**0.005**	
	Child	0.0005	0.002	0.0025	
	Infant	0.001	0.004	0.005	
Nickel	Average consumer	ND	0.0001	0.0001	0.02 RfD
	Above Average Consumer	ND	0.0005	0.0005	
	Child	ND	0.0002	0.0002	
	Infant	ND	0.0004	0.0004	
Strontium	Average consumer	0.004	0.009	0.013	0.6 RfD
	Above Average Consumer	0.02	0.03	0.05	
	Child	0.007	0.01	0.017	
	Infant	0.01	0.03	0.04	
Uranium	Average consumer	0.00002	0.00001	0.00003	0.0002 Intermediate MRL
	Above Average Consumer	0.00008	0.00004	0.00012	
	Child	0.00003	0.00002	0.00005	
	Infant	0.00006	0.00004	0.00010	
Vanadium	Average consumer	ND	0.00008	0.00008	0.003 Intermediate MRL
	Above Average Consumer	ND	0.0003	0.0003	
	Child	ND	0.0001	0.0001	
	Infant	ND	0.0002	0.0002	
Zinc	Average consumer	0.004	0.006	0.010	0.3 Chronic Oral MRL
	Above Average Consumer	0.02	0.02	0.04	
	Child	0.006	0.008	0.014	
	Infant	0.01	0.02	0.03	

Bolded text exceeds a health guideline.
ND = not detected

ATSDR's Evaluation of Cancer and Non-Cancer Health Effects

Non-Cancer Health Effects

The doses calculated for exposure to each individual chemical are compared to an established health guideline, such as a MRL or RfD, in order to assess whether adverse health impacts from exposure are expected. These health guidelines, developed by ATSDR and EPA, are chemical-specific values that are based on the available scientific literature and are considered protective of human health. Non-carcinogenic effects, unlike carcinogenic effects, are believed to have a threshold, that is, a dose below which adverse health effects will not occur. As a result, the current practice for deriving health guidelines is to identify, usually from animal toxicology experiments, a No Observed Adverse Effect Level (or NOAEL), which indicates that no effects are observed at a particular exposure level. This is the experimental exposure level in animals (and sometimes humans) at which no adverse toxic effect is observed. The NOAEL is then modified with an uncertainty (or safety) factor, which reflects the degree of uncertainty that exists when experimental animal data are extrapolated to the general human population. The magnitude of the uncertainty factor considers various factors such as sensitive subpopulations (for example; children, pregnant women, and the elderly), extrapolation from animals to humans, and the completeness of available data. Thus, exposure doses at or below the established health guidelines are not expected to result in adverse health effects because these values are much lower (and more human health protective) than doses, which do not cause adverse health effects in laboratory animal studies. For non-cancer health effects, the following health guidelines are described below in more detail. It is important to consider that the methodology used to develop these health guidelines does not provide any information on the presence, absence, or level of cancer risk. Therefore, a separate cancer evaluation is necessary for potentially cancer-causing chemicals detected in samples at this site. A more detailed discussion of the evaluation of cancer risks is presented in the following section.

Minimal Risk Levels (MRLs) – developed by ATSDR

ATSDR has developed MRLs for contaminants commonly found at hazardous waste sites. The MRL is an estimate of daily exposure to a contaminant below which non-cancer, adverse health effects are unlikely to occur. MRLs are developed for different routes of exposure, such as inhalation and ingestion, and for lengths of exposure, such as acute (less than 14 days), intermediate (15-364 days), and chronic (365 days or greater). At this time, ATSDR has not developed MRLs for dermal exposure. A complete list of the available MRLs can be found at http://www.atsdr.cdc.gov/mrls.html.

References Doses (RfDs) – developed by EPA

An estimate of the daily, lifetime exposure of human populations to a possible hazard that is not likely to cause non-cancerous health effects. RfDs consider exposures to sensitive sub-populations, such as the elderly, children, and the developing fetus. EPA RfDs have been developed using information from the available scientific literature and have been calculated for oral and inhalation exposures. A complete list of the available RfDs can be found at http://www.epa.gov/iris.

If the estimated exposure dose for a chemical is less than the health guideline value, the exposure is unlikely to result in non-cancer health effects. Non-cancer health effects from dermal exposure were evaluated slightly differently that ingestion and inhalation exposure. Since health guidelines are not available for dermal exposure, the calculated dermal dose was compared with the oral health guideline value (RfD or MRL).

If the calculated exposure dose is greater than the health guideline, the exposure dose is compared to known toxicological values for the particular chemical and is discussed in more detail in the text of the PHA. The known toxicological values are doses derived from human and animal studies that are presented in the ATSDR Toxicological Profiles and EPA's Integrated Risk Information System (IRIS). A direct comparison of site-specific exposure doses to study-derived exposures and doses found to cause adverse health effects is the basis for deciding whether health effects are likely to occur. This in-depth evaluation is performed by comparing calculated exposure doses with known toxicological values, such as the no-observed adverse-effect-level (NOAEL) and the lowest-observed-adverse-effect-level (LOAEL) from studies used to derive the MRL or RfD for a chemical.

Cancer Risks

Exposure to a cancer-causing compound, even at low concentrations, is assumed to be associated with some increased risk for evaluation purposes. The estimated excess risk of developing cancer from exposure to contaminants associated with the site was calculated by multiplying the site-specific adult exposure doses, with a slight modification, by EPA's chemical-specific Cancer Slope Factors (CSFs or cancer potency estimates), which are available at http://www.epa.gov/iris. Calculated dermal doses were compared with the oral CSFs.

An increased excess lifetime cancer risk is not a specific estimate of expected cancers. Rather, it is an estimate of the increase in the probability that a person may develop cancer sometime during his or her lifetime following exposure to a particular contaminant. Therefore, the cancer risk calculation incorporates the equations and parameters (including the exposure duration and frequency) used to calculate the dose estimates, but the estimated value is divided by 25,550 days (or the averaging time), which is equal to a lifetime of exposure (70 years) for 365 days/year.

There are varying suggestions among the scientific community regarding an acceptable excess lifetime cancer risk, due to the uncertainties regarding the mechanism of cancer. The recommendations of many scientists and EPA have been in the risk range of 1 in 1 million to 1 in 10,000 (as referred to as 1×10^{-6} to 1×10^{-4}) excess cancer cases. An increased lifetime cancer risk of one in one million or less is generally considered an insignificant increase in cancer risk. Cancer risk less than 1 in 10,000 (or 1×10^{-5}) are not typically considered a health concern. An important consideration when determining cancer risk estimates is that the risk calculations incorporate several very conservative assumptions that are expected to overestimate actual exposure scenarios. For example, the method used to calculate EPA's CSFs assumes that high-dose animal data can be used to estimate the risk for low dose exposures in humans. As previously stated, the method also assumes that there is no safe level for exposure. Lastly, the method computes the 95% upper bound for the risk, rather than the average risk, suggesting that the cancer risk is actually lower, perhaps by several orders of magnitude.

Because of the uncertainties involved with estimating carcinogenic risk, ATSDR employs a weight-of-evidence approach in evaluating all relevant data. Therefore, the carcinogenic risk is also described in words (qualitatively) rather than giving a numerical risk estimate only. The numerical risk estimate must be considered in the context of the variables and assumptions involved in their derivation and in the broader context of biomedical opinion, host factors, and actual exposure conditions. The actual parameters of environmental exposures have been given careful and thorough consideration in evaluating the assumptions and variables relating to both toxicity and exposure. A complete review of the toxicological data regarding the doses associated with the production of cancer and the site-specific doses for the site is an important element in determining the likelihood of exposed individuals being at a greater risk for cancer.

Appendix D. ATSDR Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-800-CDC-INFO (1-800-232-4636).

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Aerobic
Requiring oxygen [compare with anaerobic].

Ambient
Surrounding (for example, ambient air).

Anaerobic
Requiring the absence of oxygen [compare with aerobic].

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Antagonistic effect
A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation
Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Biologic indicators of exposure study
A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance [also see exposure investigation].

Biologic monitoring
Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic uptake
The transfer of substances from the environment to plants, animals, and humans.

Biomedical testing
Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

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 Community Assistance Panel.]

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A estimated risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Case study
A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

CAS registry number
A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Community Assistance Panel (CAP)
A group of people from a community and from health and environmental agencies who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause

harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Delayed health effect
A disease or an injury that happens as a result of exposures that might have occurred in the past.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Descriptive epidemiology
The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease prevention
Measures used to prevent a disease or reduce its severity.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD
United States Department of Defense.

DOE
United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose” is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

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 relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

EPA
United States Environmental Protection Agency.

Epidemiologic surveillance [see Public health surveillance].

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often

and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing followup of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Geographic information system (GIS)
A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life (t½)
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical 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 disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous Substance Release and Health Effects Database (HazDat)
The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Health promotion
The process of enabling people to increase control over, and to improve, their health.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Indeterminate public health hazard
The category used in ATSDR’s public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

In vitro
In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

In vivo
Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Medical monitoring
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

Metabolite
Any product of metabolism.

mg/kg
Milligram per kilogram.

mg/cm^2
Milligram per square centimeter (of a surface).

mg/m^3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period

(acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

Mutagen
A substance that causes mutations (genetic damage).

Mutation
A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

National Toxicology Program (NTP)
Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Physiologically based pharmacokinetic model (PBPK model)
A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevalence survey
The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public availability session
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public health surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Public meeting
A public forum with community members for communication about a site.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RFA
RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Substance-specific applied research
A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR’s toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)]

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance [see public health surveillance]

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Synergistic effect
A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Teratogen
A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

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

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people’s sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Urgent public health hazard
A category used in ATSDR’s public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)
National Library of Medicine (NIH)
(http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

APPENDIX E

RESPONSE TO COMMENTS

This section addresses questions and comments received by ATSDR during the public comment period for the Lincoln Park/Cotter Mill Public Health Assessment. The public was invited to review the draft document and provide comments to ATSDR. The original public comment period was from September 9, 2010 until November 9, 2010. After receiving a request, ATSDR extended the public comment period until December 9, 2010 to ensure all interested parties had a reasonable opportunity to comment.

ATSDR received comments from many sources. In some instances, we received the same or similar comment from multiple sources. If so, ATSDR summarized similar comments and responded once. The comment is followed by a response from ATSDR. Correction of typos and minor additions or deletions of text were incorporated without need of a response. A summary of the comments is included below.

In general, the comments are grouped according to the location of the reference in the document. However, ATSDR will first address two issues raised most by commenters – the lack of current data and the recent finding of volatile organic compounds (VOCs) in groundwater. We address these issues first to ensure their prominent location to the public and to set the proper context for the rest of the comments.

Comment:

The most repeated comment was that the draft PHA did not include information more current than 2008. Several commenters noted that much water and air information has been gathered since 2008 and should be included. Most notably, Cotter Corporation performed a water use survey in 2008 to update the previous 1989 survey. The goals of the 2008 Lincoln Park Water Use Survey were to establish the extent of the groundwater plume using updated groundwater standards (effective May 31, 2008), and to identify any households within the updated survey boundary were using water for personal consumption. Also, commenters wanted Table I (Activity Timeline) updated to include investigations not included in the initial document.

Response:

The document has been updated. However, a small lapse between data generation and data evaluation, and subsequent publication, is inevitable and unavoidable. Because activities at the site are on-going under various monitoring and remedial plans, and because it takes time to evaluate the data and get this document published, ATSDR will not be able to make the timeline or analysis of data current to the latest site-related event. Additionally, ATSDR delayed the release of this document for some time to accommodate the request of some community members to have one comprehensive document (all media/pathways) instead of two documents (separate air document). After our air evaluation was delayed, ATSDR delayed the release of the rest of the document, causing some additional time to lapse. Some of the new information was produced and released during the interim timeframe of these events.

Regarding the Activity Timeline (Table 1), the purpose of the timeline is to give the reader a general idea of process events, remedial activities, and government actions most pertinent to ATSDR's evaluation of potential exposures. The timeline is not intended to be inclusive all site-related events.

To respond to these concerns, ATSDR has included a more current analysis of data. We updated the Activity Timeline (Table 1) to reflect some of the most relevant events and/or reports since the publication of the initial document. We also added statements which refer readers to the CDPHE and EPA websites for the most current information regarding the site, since new information is produced on a regular basis.

We also amended the discussion on well water consumption. We included the results of the 2008 Lincoln Park Water Use Survey as a separate evaluation and made revisions to the Conclusions and Recommendations accordingly. It is important to point out that our previous evaluation using data from the 1989 water use survey is still appropriate to define past exposures. The 2008 water use survey is valuable because it allows us a snapshot of current and potential future exposures, but it does not alter conclusions regarding past exposures and health effects.

Comment:

Residents may also have questions about whether ATSDR will evaluate new data regarding VOC contamination in wells.

Response:

In October 2010, Cotter discovered elevated concentrations of trichloroethane (TCE), a volatile organic compound (VOC), in groundwater beneath the property [Cotter, 2011]. The highest TCE concentration was 1,800 ppb, which exceeds EPA's Maximum Contaminant Level (MCL) of 5 ppb for TCE in drinking water. Cotter will be conducting further investigations to determine the nature and extent of VOC contamination in the area. Because TCE is a VOC, it can readily evaporate at room temperature, including out of groundwater and into aboveground living spaces (vapor intrusion). For this reason, ATSDR has identified VOCs in groundwater as a potential exposure pathway for humans until further information is known.

ATSDR's Colorado Cooperative Agreement Program will review the additional groundwater data that is being collected by Cotter for the Hazardous Materials and Waste Management Division of the CDPHE in order to define the extent of TCE on-site and off-site. Currently, TCE has been detected in four on-site wells. The additional data will be reviewed to evaluate whether there are potential receptors to TCE via the vapor intrusion pathway. When the additional data becomes available, the Colorado Cooperative Program will discuss with ATSDR/Atlanta the appropriate follow-up action(s) from the public health perspective (i.e., health consultation or health education activities).

II. BACKGROUND

Comment:

Please note that the name of the NPL site, as designated in the Federal Register, is the Lincoln Park site (the "Site"). The Site is referred to incorrectly throughout the document and the Site boundaries, which contain the Cotter Mill facility as well as the Lincoln Park neighborhood and other areas, are also incorrectly delineated. This can be confusing when reading some site related documents as the Site is defined differently and more broadly for the purposes of the Superfund program than under the Colorado Radiation Control Program license. It is recommended that the draft PHA be clearer with respect to this issue and preferably conform to the Superfund definition, except when an explanation of the radiation license is appropriate. It is also important to be clear that there are possible contamination sources in the area of the Site in addition to the Cotter Mill facility. While these are sometimes noted, such as with the lead contamination discussed on page 33, it is not always noted with other contamination, such as with the arsenic contamination on page 62.

Response:

The site name was taken from CDPHE's website/documents and was selected to be consistent with other site references. The site boundaries were taken from published reports, including EPA's 2007 five-year review. EPA's 2007 five-year review contains the following text:

> *The Site is located in Fremont County, approximately 1.5 miles south of Cañon City, Colorado, and includes Cotter Corporations (Cotter's) Cañon City uranium mill facility, a portion of the surrounding property, and a portion of the unincorporated community of Lincoln Park.*
>
> *The Site has been divided into two operable units (OUs) including:*
>
> - *OU1 – Cotter's Cañon City mill property*
> - *OU2 – Lincoln Park Study Area*
>
> *The Lincoln Park Study Area has been further subdivided based on the principal environmental media; soils and ground water.*

ATSDR used this and other site-related documents to define the site boundaries. Our evaluation of sampling data is difficult to limit to a defined area because of the migration of contaminants in different media across many areas (e.g., air and groundwater). Therefore, ATSDR chose not to make the distinction between operable units a focus of our analysis. Instead, sampling results for a particular media are referred to by the sample location instead of the applicable operable unit or site boundary.

To address the commenter's concern regarding the site name, ATSDR revised the name of the document to the "Lincoln Park Superfund Site and Associated Activities at the Cotter Corporation Uranium Mill". We believe it important to include the name of the Cotter Uranium Mill in the title to alert the public to the fact that the mill is the main focus of the report. The other potential sources of contamination at the site, including potential natural sources, are noted in the document where possible. However, it is beyond ATSDR's scope to determine the source(s) of contamination.

Comment:

Cotter does not have two inactive mills. The site contains only one inactive mill, and one dismantled and removed mill. According to EPA website, the Lincoln Park Site (the "site") is a uranium ore processing mill on 2,600 acres. The former mill site and the current mill buildings are in the Restricted Area. Whether ATSDR is counting "uranium and vanadium" as two mills or counting the "old" mill, which has been dismantled and buried, and the new mill (the current building) is not clear. This document shows in Table I that in 1979 the old mill was "demolished" and "new mill constructed". The summary should be revised to accurately reflect one mill on site. Also, please include the acreage of the Restricted Area.

Response:

ATSDR revised the Summary and Background sections to reflect that only one inactive mill remains on the site. The site acreage was revised to reflect approximately 2,600 acres instead of 2,500 acres. We also added the acreage for the current mill and associated facilities as 82 acres.

Comment:

The following statement in Table 1 is incorrect: *October 2005 - Survey of lead in indoor dust, soils, and blood in Lincoln Park to investigate potential impacts of historic smelters*. CCAT and local physicians requested recommendation for an epidemiological study from EPA and then ATSDR in 2004. ATSDR offered the PHA which had not been performed prior, and began with a Health Consultation on lead exposure in Lincoln Park. We welcomed the investigation due to high levels of Pb-210 found in Lincoln Park attic dust samples in the early 1990's. The consultation was never presented by ATSDR or EPA as an attempt to "investigate potential impacts of historic smelters." The ATSDR 2006 Health Consultation, *Lead in Indoor Dust, Outdoor Soil and Blood of Lincoln Park Residents* states, "One facility, the Cotter Mill, currently mills uranium ores. Residents of the Lincoln Park neighborhood (located just south of Canon City) expressed concerns regarding potential contamination, in particular lead, associated with these operations." EPA insisted repeatedly that they would not test, as we wished, for Pb-210, a radioactive isotope from the decay chain of radon and uranium, because they would not attempt to identify the source of any lead contamination found. Lead from the smelters has nothing to do with the Lincoln Park Superfund Site Site.

Response:

We revised the statement as follows: "*October 2005 - Survey of lead in indoor dust, soils, and blood in Lincoln Park [ATSDR 2006a, 2006b, 2006c, 2006d]"*

Comment:

Regarding the following statements: "*Groundwater remediation activities have shown some positive results. However, the balance of the remedial activities listed in the Consent Decree have not been successful enough in mitigating the plume, and most have been discontinued (e.g., barrier wall, dam to ditch flushing, calcium-polysulfide fix/flush, and permeable reactive treatment wall).*" This statement is misleading in that the barrier wall and the SCS Dam and the permeable reactive treatment wall continue to isolate surface and groundwater on site from the Lincoln Park area. Onsite waters are returned to the impoundments for evaporation.

Response:

ATSDR updated the statements and revised for clarity as follows:

- *Groundwater remediation activities have shown some positive results, although restoring groundwater quality has had some setbacks. Many of remedial measures specified in the Concent Decree have been discontinued (e.g., barrier wall, dam to ditch flushing, calcium-polysulfide fix/flush, and permeable reactive treatment wall) [CDPHE 2008]. Until a solution is reached, contaminated groundwater is captured at the SCS Dam and pumped back to the on-site impoundments [Cotter 2011]. Volatile organic compounds (VOCs) were discovered in the groundwater beneath the Cotter facility during sampling in October 2010. Cotter is investigating the nature and extent of VOC contamination in groundwater at the Cotter Mill and surrounding areas and is seeking to identify the source area [Cotter 2011].*

Comment:

Hydrogeology should include a description of how the geology controls the flow off the site. A description of the impact of ditches and the Arkansas River on groundwater flow should also be noted.

Response:

Various reports summarizing groundwater migration pathways, reports and investigations are available on the state website and in the many documents prepared by Cotter for the site. A more accurate account of the site conditions which influence groundwater migration is likely to emerge from the on-going groundwater investigations at the site.

Comment:

Regarding ATSDR's Exposure Investigation of Blood Lead Levels. Of the 115 children approximately 80% or more were students bused into the Fremont County Headstart School from outside Lincoln Park. Though CCAT argued repeatedly during teleconferences for a blood lead study of just Lincoln Park children, we were told that ATSDR headquarters would not fund a study that excluded any child in the wider area of

Fremont County. The results from the study of school children offered little insight into Lincoln Park children. Even when the 21 extra households added some children to the database, it was still such a small population of Lincoln Park children that it was not capable of giving a true picture of the potential impact from lead in Lincoln Park. In addition, the lead study came about because of high levels of Pb-210 found in Lincoln Park attics in early 1990's sampling. Pb-210 is a daughter of radon that attaches to dust within 2-3 days, one of the most concerning air pollutants from a uranium mill. Though CCAT asked EPA and ATSDR repeatedly to sample attics where dust gets trapped, and asked that they analyze for Pb-210, EPA refused to test for constituents that might fingerprint the source. To add insult to injury, Cotter claimed the studies proved lead was from the old smelters, and the ATSDR reports claimed there was no lead contamination of concern. We're sorry to say that after all the effort on everyone's part, and the expense to our government, we believe the studies were not designed to answer the questions most important to the community. In fact, we can't help but suspect that the studies were designed to fail.

<u>Response</u>:

The blood lead investigation was conducted according to approved protocol and investigational techniques that are standard practice for these types of investigations. They have been used by ATSDR at this and many other sites. Here, we only report the outcome of the already-completed investigations. We cannot at this point go back and change the details of the investigation. We believe the results were helpful and informative to some in the community.

Lead-210 is a radon decay product and would only be a health issue if radon were elevated in the home. It is the responsibility of each individual homeowner to mitigate elevated radon, as it is a naturally occurring radionuclide in the soil.

<u>Comment</u>:

A four-page Health Assessment was submitted by ATSDR in October 1983. After 1986, ATSDR should have returned and made an evaluation of the Cotter/Lincoln Park EPA National Priorities Listed site, but they did not. I was part of a group of citizens that requested a comprehensive Health Assessment in 1989. ATSDR's response was to give the community information on obtaining a Technical Assistance Grant.

<u>Response</u>:

Information about some of ATSDR's historical involvement at the site is detailed in the Background section. In addition to the listed activities, ATSDR preformed various other public health activities and produced health consultations (HC) for the site in July 1989, February 1992, November 1993, and 1995. The Public Health Assessment produced in 1983 was performed in accordance with public health assessment guidelines at the time. A new PHA would not have been required if no significant new environmental data was produced since the last PHA. A HC would have been appropriate to update the PHA under these circumstances.

Comment:

The southern city limits of Canon City, share a common fence line with Cotter on the west, and the unincorporated area of Lincoln Park shares their southern border with Cotter. The nearest residence is within 1,000 feet of the mill. The Cotter property encompasses about 4 Sections, most of which has been declared as agricultural property, but no agricultural activity has taken place for many years. Contamination was first discovered before 1979, but that year a nearby property owner filed suit against Cotter for contamination to his underground water and real estate, and for the illness and death of his livestock. That case was settled out of court and sealed, so many neighbors did not know what was going on.

Let people know that thousands of our citizens live in close proximity to Cotter, sharing a common boundary. A mile radius does not include all of the Superfund Site with the Ground Water Study Area in Lincoln Park. The map provided in Appendix B, Figure 2, makes it visually clear that a 2-mile radius would have included the entire Superfund Site and several thousand more residents in close proximity to Cotter's pollution. This paragraph gives the uninformed an erroneous impression of the number of neighbors to the Cotter Mill.

Response:

ATSDR updated Figure 2 in Appendix B to include a 2-mile radius, which now includes more of the Lincoln Park community. We updated the demographics accordingly. It is important to point out that the map provides basic demographic information about the area surrounding the mill, and is not intended to coincide with any other site-related demarcations, including the Water Study Area.

Comment:

What information did ATSDR gather from people who live or work near Cotter?

Response:

ATSDR held public availability sessions and participated in conference calls with local citizens to gather information to include in our report. Community members are a resource for and primary audience and beneficiaries of our public health assessments. Some local groups and organizations, particularly CCAT and the CAG, provided ATSDR with valuable input throughout the public health assessment process.

Comment:

Mobile Home Parks are a much more appropriate term. Please change the terminology. Trailer parks are more indicative of something one might find in the South.

Response:

The terminology has been changed to “mobile home parks”.

Comment:

It should be noted that prevailing wind patterns measured at Cotter Mill may not be representative of surface winds throughout the area, especially considering the proximity of nearby terrain features. Cotter’s measurement of prevailing wind patterns is averaged before being provided in their Annual Environmental reports, and does not reflect sudden unusual high wind events that occur frequently, and often in directions other than the average prevailing wind directions. This gives a false impression that the wind seldom blows Cotter’s contamination toward Lincoln Park, when we do have high winds from the south several times a year, as well as powerful gusty days when the wind blows in varied directions.

Response:

ATSDR agrees that in any area there may be short term unusual wind patterns. However, these short term unusual wind patterns would not result in chronic exposure. ATSDR focused on longer term chronic exposures from air releases, since the concentrations of radioactive contaminants could not result in acute health effects.

Comment:

High wind events occur, gusty winds that don’t follow the annual average prevailing wind pattern. The “buffer zone” to the east and west of the site, particularly west, is now populated with housing developments. The east zone also includes homes to the east of Chandler Road and over the ridge, and homes northeast into Brookside, Lincoln Park, and the Headstart School. Please consider recommending additional air monitors in these locations. This has been requested for some time by our community with no result. You won’t find anything if you don’t look for it.

Response:

The West buffer of the site has hills blocking East to West air circulation. The current air monitoring system has not found evidence of elevated airborne resuspension of contamination and ATSDR can not find any justification to recommend further air monitoring stations.

III. EVALUATION OF EXPOSURE PATHWAYS

Comment:

The use of "may have," “not likely,” or “could” throughout the document is disturbing. If a fact can’t be stated clearly, then don’t substitute a guess. While ATSDR states wind-blown contamination is "*not likely a considerable source*" because of extensive remediation,

it is an extensive source none the less according to the CDPHE (Decommissioning Funding Plan letter 04/21/10) and Cotter (2008 "Estimate of the Volume of Contaminated Soil") estimating 1,087,151.4 cubic yards of contaminated soil require remediation on site. Over time this contribution continually re-suspends and is cumulative, while half lives of these materials are many thousands of years long, and the soil sampling program in Lincoln Park has been haphazard and lacking a quality design. It's also a fact that irrigating with contaminated water deposits contaminants in the soil, irrigation that goes on every year in Lincoln Park, a fact that could be validated if a truly scientific soil sampling program was put in place. This pathway is not something that "could" happen – it "has" happened, and continues to happen in Lincoln Park.

Response:

ATSDR often uses reasonable "assumptions" when evaluating exposures and health risks. Assumptions are used in the absence of site-specific information or when attributing a factor to a population instead of an individual. Sometimes this requires the use of wording that expresses the "likelihood of an event" rather than a definite occurrence. Use of such language is standard practice in evaluating environmental health hazards. ATSDR attempts to use conservative assumptions that are most protective of public health.

While investigating this potential pathway, ATSDR used the Weston reference to investigate two possible migration pathways: 1) windblown dust from soil or tailings on the site and 2) chemicals accumulating in soil from using contaminated groundwater for irrigation. According to Weston [Weston 1998], the east-west wind patterns in the area suggest that Lincoln Park, which is north of the facility, is not likely a significant deposition point for wind-blown contamination. However, ATSDR does not rule out this potential pathway based on this suggestion alone. We agree that soil in Lincoln Park is a completed exposure pathway at this site and conducted a full evaluation of exposures there.

Comment:

Please make it clear in your report that the DeWeese-Dye Ditch water is NOT contaminated.

Response:

The statement has been revised as follows: *Many Lincoln Park residents have orchards and gardens. Water from the DeWeese Dye Ditch, which is not known to be contaminated, is primarily used to irrigate the orchards and gardens*.

Comment:

While some fruits and vegetables may be grown in uranium-contaminated media, we have seen no studies showing human exposure via this pathway.

Response:

A completed exposure pathway exists for a past, current, or future exposure if contaminant sources can be linked to a receptor population. All five elements of the exposure pathway must be present, and people must have or are likely to come in contact with site-related contamination at a particular exposure point via an identified exposure route. Here, many Lincoln Park residents have orchards and gardens; some residents report growing and eating fruits and vegetables from their gardens. Therefore, ATSDR believes this pathway to be complete.

Comment:

Concerning the past completed pathway for surface soil and dust in/on residential lawns and gardens: what is the reference for demonstrating this completed pathway? We know of no event where windborne soil or dust has measurably impacted Lincoln Park. We also know of no remediation concerning surface soil and dust that would eliminate this as a current or future pathway.

Response:

As a reference, ATSDR used EPA's 2002 Record of Decision (ROD) to assist in our evaluation of this exposure pathway. The ROD contains the following statement:

> *Contamination was also spread in the past, via wind blown material, to soils adjacent to the mill, along the Sand Creek drainage on the mill property (causing contamination of sediment within the drainage), and into the community of Lincoln Park.*

Contaminants were detected in soil from residential lawns and gardens in Lincoln Park (see Tables 26 through 37 in Appendix B). It is reasonable to assume that residents came into contact with these contaminants while engaging in outdoor activities. Therefore, ATSDR believes this pathway to be complete. Additionally, the human risk assessments completed for this site include an evaluation of the risks posed by surface soils (among other exposure pathways) within the Lincoln Park area.

The soil remediation event referred to is the Sand Creek soils cleanup action. This action was performed within the Lincoln Park Study Area and was designed to address contaminated soil and sediment. This action involved the removal of contaminated tailings, soil, and sediment from the (Sand Creek) creek bed as a result of surface water runoff from the mill site. Cotter also remediated soils adjacent to the access road in 2007 and 2008. The removal of these potential contamination source areas served as the basis for ATSDR's decision that surface soil (residential) was a past exposure pathway. The noted reduction in airborne releases would also limit migration of contaminants via the air pathway, making past exposures more likely than current or future exposures. However, ATSDR concedes that current or future exposures are still possible if people come into contact with contaminated soil that has not been remediated, and because not all potential on-site and off-site sources have been eliminated. We revised the document to reflect that surface soil is a current and future potential exposure pathway.

Comment:

Sand Creek does not contribute any water to the DeWeese Dye Ditch so there is no exposure there. The ditch does not intercept Sand Creek. The ditch is above the local water table. Also, no elevated uranium concentrations have been found in the Arkansas River.

Response:

The DeWeese Dye Ditch has been removed from the potential surface water pathway. The Arkansas River remains a potential surface water pathway until it is ruled out as a discharge point for surface or subsurface contaminants.

Comment:

The Exposure Pathways table summarizes the exposure pathways, sources of contamination and routes of exposure, etc. The accompanying text describes groundwater as a potential exposure pathway and also points to the potential for the groundwater to be used in the irrigation of family gardens. However, the table only identifies the soil as a pathway for the groundwater contamination to garden fruits and vegetables and does not account for the direct uptake of groundwater contamination to fruit and vegetables. Consequently, recommendations of the PHA are to manage the impact of only soil contamination to fruit and root vegetables through washing and peeling the produce. It does not appear that the PHA accounts for any direct uptake of groundwater contaminants into the edible portions of the produce. Please clarify and support in the document why this approach is appropriate.

Response:

The exposure pathways table identifies groundwater as a source of potential contamination to fruits and vegetables in the Locally Grown Produce pathway, Fate and Transport element. ATSDR used sample results taken from the whole fruit or vegetable, which would include any direct uptake of groundwater contaminants into the edible portions of the produce. We also include a recommendation for residents to not use an impacted private well for household purposes, including watering crops.

Comment:

The 2008 Lincoln Park Water Use Survey identified seven wells used for personal consumption. Cotter did not identify the seven well number locations. It would be informative to know if the number of wells used for personal consumption increased or changed from 1989 to 2008, or not. In spite of the inconsistencies in sampling frequency, and known contaminants of concern at uranium mills, Cotter was allowed to drop radionuclides and many chemicals and heavy metals from the sampling program for Lincoln Park wells many years ago. These inadequacies should concern ATSDR, especially when there is no routine check on these constituents at some periodic interval, and knowing that the Primary Impoundment is leaking into ground water.

Response:

ATSDR agrees with this comment. We have made the following recommendations to address this concern:

- *Consider monitoring private wells that are use for personal consumption to ensure continued compliance with drinking water standards. Consider a sampling plan that allows comparison of sampling results from one sampling event to the next (i.e., routinely sampling the same well for the same contaminants over time), and that tests for all site-related constituents, including VOCs.*

- *Consider updating the 2008 water use survey to include well numbers or locations for comparison to the previous 1989 water use survey. This information would assist in evaluating current and future exposures.*

Comment:

If one has a well, all one pays for is the electricity cost and ongoing well maintenance to get the water out of the ground. The cost of hookup to city, while it is not insignificant will pale in time to the cost of paying the city for water quarter after quarter. People's rights to well water were taken from them and now they are forced to pay for city water. Refusing to connect to city water could very well be an issue of affordability, not unwillingness.

Response:

ATSDR agrees that affordability could be a deterrent to hooking up to the public water supply. We believe that all residents should be protected from harm, regardless of their ability to pay. The educational efforts implemented by the State should help those who want to continue to use their private wells for household purposes in knowing ways to do so safely.

Comment:

Please explain what grass cover has to do with lack of exposures to impacted soil at the Shadow Hills Golf Course? On average, most golfers spend as much time in the rough where there is no grass, as they do in the fairways, and at the golf course bordering Cotter, there is definitely no grass in the roughs. If the above statement is to remain, please add a statement that golfers need to be warned not to retrieve balls hit into the rough for the reason that they have the potential of being exposed to impacted soil.

Response:

The grass cover on the fairways limits golfer’s exposure to soil underneath. Golfers occasionally venture into the rough to retrieve balls, but usually do not linger there. The limited time a golfer spends in the rough is not enough to cause harmful health effects. Health effects from acute exposures to contaminated soil are not expected.

Comment:

ATSDR wrote: *"Sand Creek is on private land until it goes under the river walk and enters the Arkansas River, and is generally not used for recreational activities [Phil Stoffey, CDPHE, personal communication, June 2007.]"*

What Mr. Stofey was seemingly unaware of is that a major part of the private land was owned by a game warden who used to stock Sand Creek with trout so kids could come to fish there. As a young boy throughout the late 50's and early 1960's my brother and I used to catch and eat trout out of the perennial part of Sand Creek all spring, summer, and fall long. How do you think that makes me feel today?

Response:

The information we obtained on Sand Creek may indicate that the use has changed since the 50’s and 60’s. ATSDR has no way to quantify what, if any, exposures may have occurred to people as a result of recreating in Sand Creek during that time. The cleanup that was performed as part of the Sand Creek Cleanup project eliminated any potential future exposures.

Comment:

Re: *If fruits and vegetables are grown in contaminated soil and/or irrigated with contaminated water, the people who eat this produce could be exposed to contamination.* This is one of the more frustrating statements in the PHA, because it presents an undefined risk and offers no resolution. Offering a few educational presentations today will not protect future residents from a long-term risk. Add to Recommendations specific controls that will warn people of this potential exposure from produce irrigated with well water far into the future.

Response:

ATSDR included two recommendations which should protect current and future residents.

- Discontinue use of any impacted private wells for household purposes, including watering livestock and crops.

- Wash crops collected from home-grown fruit and vegetable gardens thoroughly before eating them. This measure is a precaution to remove soil adhering to the surface of the crop.

Additionally, the institutional controls implemented by the State should provide notification to and limit the number of uninformed residents in the future.

IV. EVALUATION OF ENVIRONMENTAL CONTAMINATION

Comment:

One commenter claims that ATSDR was incorrect in stating during the public meeting that records from 1957 to 1981 do not exist. The commenter claims that CDPHE and Cotter conspired to allow records to disappear, and that copies of thousands of records, including from 1957 to 1981, are available at a collection at the University of Colorado Archives at Boulder Colorado – "Atomic West".

The commenter also alleges that there are other items which the State, EPA and ATSDR have conspired to cover-up; reports/actions which implicate Cotter in wrongdoing, including but not limited to, the following:

- **the work-related death of a former employee of Cotter from non-Hodgkin's lymphoma reportedly caused by radiation exposure;**
- **reports from the Colorado Bureau of Investigation, Wahler (1972), and the National Institute of Safety and Health (worker health); and**
- **various lawsuits filed and won by plaintiffs against Cotter**

Response:

ATSDR believes the commenter misunderstood our remarks at the public meeting regarding the absence of data from 1957 to 1981. The remark applied only to air data - the question and response at the meeting were specific to air. Data from other environmental media are available during the specified timeframe and were used by ATSDR in our evaluation.

ATSDR also wants to assure the public that there was no collusion between ATSDR, other agencies or third parties to suppress data. Most of the information we obtained from other agencies is in the public domain and can be accessed via public websites or electronic databases. We also submitted our exposure assessment to independent review by involved agencies and interested third parties to ensure accurate accountability with regard to data (i.e., data validation) and exposure analyses. After some comments, reviewers concurred that the exposures and the data were properly portrayed (for that time period).

As for the claim that additional records exist at the University of Colorado Archives at Boulder Colorado – "Atomic West," ATSDR performed a preliminary (online) search of the referenced information. We understand that the archive is a collection of personal papers, court appeals records, loose papers, transcripts, letters, reports, schedules, data, correspondence, and newspaper clippings pertaining to the Cotter Uranium Mill submitted by Cotter's Chief Chemist, now deceased. Although we consider this information to be valuable for a personal perspective, we do not consider data in these reports suitable for assessing possible human exposures to the general public.

Finally, investigating worker health is outside of ATSDR's scope of authority. Therefore, we encourage those in the public who may be concerned about employee health issues to contact the Mine Safety Health Administration or CDPHE.

Comment:

Cotter has processed ores from the western slope that contain 4-5 times the amount of vanadium than uranium, yet the report is silent on vanadium. Consider some discussion of vanadium since it is a major product Cotter has produced. We note that the ATSDR Toxicological Profile for Vanadium (current draft) states that IARC has listed vanadium as a potential human carcinogen.

Response:

Vanadium was not selected as a contaminant of concern, thus triggering a detailed evaluation of the chemical, because the average (and maximum) concentrations of vanadium in all environmental media evaluated did not exceed the applicable comparison values for vanadium. Vanadium was not detected in any of the groundwater or produce samples evaluated by ATSDR. Vanadium was not detected in the one private well for which ATSDR had sample results for vanadium. Vanadium concentrations in sediment (up to 26 ppm) did not exceed the comparison value of 200 ppm for vanadium in soil. ATSDR did not have data for vanadium in surface soil or surface water.

Comment:

ATSDR did not reference risk assessment data from the following reports:

- **Cotter submitted the health risk assessment data in October 1991. After review by the state and EPA, the report was found to be unacceptable in May 1992, as several areas of concern were identified.**
- **CDPHE required that a Supplemental Risk Assessment be performed for the site. The purpose of this Supplemental Risk Assessment was not to replace or repeat the efforts completed in 1991, but to focus on the specific concerns expressed by CDPHE, EPA, and area citizens. The re-assessment of risks to citizens of Lincoln Park was based on environmental conditions in the 1988 time frame and was completed in 1996.**
- **An additional study considered risks to current and potential future residents in Lincoln Park and other areas in the vicinity of the Lincoln Park mill site based on environmental conditions in the 1994-1996 time frame, after remedial activities required by the Consent Decree had been implemented. This study was completed in 1998.**
- **An Ecological Risk Assessment (ERA) that was completed in January 1999 determined that risks to animals and plants were low.**

Response:

ATSDR does not include every report that has been written about the site. ATSDR uses as many reliable sources as possible to collect environmental data and to assist with our understanding of exposures at the site. We did include data gathered during the time frames of the referenced documents. However, we conduct an independent analysis of the data and draw our own conclusions regarding risks to humans.

Comment:

Concentrations of uranium and molybdenum in the DeWeese Dye Ditch are cited using 1995 concentrations. Is there not a more current data set for uranium and molybdenum concentration than 14 year old data?

Response:

We are unaware of more current data for the DeWesse Dye Ditch. We used the most current data available to us.

Comment:

Are there updated ground water iso-concentration maps for uranium and molybdenum?

Response:

ATSDR updated the groundwater plume maps for uranium and molybdenum from 2007 to 2008, which is the most current data available to us.

Comment:

The Federal and State of Colorado Drinking water standards are stated correctly but the Site RAP decree compliance goals for uranium and molybdenum are 35 and 100 *µg/L,* respectively. Prior to June 2008, there was no state ground water standard for uranium or molybdenum.

Response:

This fact has been footnoted in the current version of the document.

Comment:

The last paragraph of the CDPHE 2007a letter referenced in this document states, "At the completion of the Readiness Review and the De-watering and Dry Placement studies, the Department will determine the impact of this leakage on facility operations." A Readiness Review must be provided when Cotter is ready to reopen, which isn't likely to happen any time in the near future, and the Dewatering and Dry Placement studies have been completed over a year ago. We are more concerned about the impact to ground water with contamination that lingers on for decades and migrates downhill into Lincoln Park and to the Arkansas River than we are to the impact on Cotter operations.

Cotter's Vice-President stated publicly that cleaning the groundwater on and off site could take a 100-years or more, especially if Cotter uses passive methods like natural attenuation in Lincoln Park. Since 2009, the Radiation Management Unit has allowed Cotter to proceed with decommissioning the impoundments without the regulation required Revised Decommissioning and Reclamation Plan, and without public vetting of a plan that is non-existent yet being carried out daily. CDPHE staff have repeatedly told the public that drying of the deep parts of the impoundment could take many decades, and that the weight of earth cover on top of the impoundment will squeeze the spongy tailings, potentially releasing more liquids through a leaking liner. Our concern is that is has now been over 3-years, and we've seen nothing about the promised determination of the impact of this leakage which is contributing contamination to the Superfund Site Operation Unit 1 on Cotter's facility. Also, regulations require that a liner with tailings left in place during decommissioning must not leak during its active life, and it obviously has leaked.

Response:

Involvement in regulatory matters is outside of ATSDR's scope of authority, unless those matters are relevant to public health. Here, ATSDR is concerned if groundwater contamination poses a health risk to people. To address this concern, ATSDR recommended that officials continue to monitor the groundwater plume to assess whether additional wells are impacted in the future, or whether any other changes of environmental significance occur in areas of concern. The results of the monitoring will determine whether additional mitigative measures are needed in residential areas where people might be exposed.

Comment:

This section fails to inform the public that the plume has been reported to have increased into a never before reported area, known about since the 1980's, but just revealed to the public in 2008. CDPHE cited Cotter with a Notice of Violation on July 28, 2008, for groundwater contamination on the Shadow Hills Golf Course adjacent and north of the Mill, *"Cotter Corporation is directed to take timely corrective action to mitigate the contamination from the Cotter facility in the area north and west of the mill complex. We expect that this corrective action will initially include additional characterization of the plume, and investigation of sources in the mill area."*

Response:

ATSDR added the following text to the environmental contamination section:

Groundwater north and west of the facility, outside the Restricted Area under the adjacent Shadow Hills Golf Course, is also contaminated [Hydrosolutions 2010]. In October 2010, Cotter discovered elevated concentrations of trichloroethane (TCE), a volatile organic compound (VOC), in groundwater beneath the property [Cotter, 2011].

Comment:

A reader that does not understand radiation may not understand the statement " .. . 10.2 µR/hr equals 89 mrem/year. .. ". Suggest comparing this value (89 mrem/year) to background levels in either Colorado or in the U.S as mentioned in NCPR Report No. 160. NCRP No. 160 indicates background averages 311 mrem/year effective dose per individual in 2006 U.S. population (NCRP No. 160, 2009).

Response:

The total annual effective radiation dose to the average person, including that from medical diagnostic imaging is 620 mrem/year, per NCRP No. 160. The 89 mrem/year is inclusive of background and is consistent with the local range of background.

Comment:

Radon emissions from the mill's primary tailings pond were sampled and results sent to EPA Region 8 Office in accordance with National Emissions Standards for Hazardous Air Pollutants (NESHAPS) Subpart W. Results may be found at CDPHE web site, http://www.cdphe.state.co.us/hm/cotter/.

Response:

We did use the data from the CDPHE website. The on-site outdoor radon emissions were irrelevant to public health. The measurement of Lead-210 was used as a surrogate of all the attached radon decay products, which is more relevant to the true lung dose, since the EPA assumptions about attached fraction are only valid indoors.

Comment:

First, it's possible that Table 27 with soil concentrations may have an error. The last two rows for 234U and 238U have identical data results. Second, to fully understand whether soil sampling in Lincoln Park has been adequate in sample points compared to total area of approximately 2,200 acres, it would have been helpful if the total number of soil samples taken in Lincoln Park over the years was put onto a chart with columns, for instance, for the year of sampling, each grid and number of samples taken and size, contaminants sampled for, and number of acres in the grid. From a back of the envelope perspective, it still appears that the total number of soil samples collected over the years in Lincoln Park is small when compared to the total acreage. We still believe that some systematic, rather than the historically haphazard, method of soil sampling needs to be done to confirm that soil contamination from irrigation and windblown soils in Lincoln Park is not an ongoing pathway of exposure. The first gamma survey of crossroads was deficient in our opinion, because it was taken where road work and constant traffic disturb the soils. Despite the several 1987 to 2005 sampling events, we are not convinced the area has been thoroughly evaluated. The statement about the 73 soil samples taken in Lincoln Park from the HHRA III still appears to be reflective of the basic problem even though there have been a few other sampling events, "...even though each sample was a composite of four sub-samples, the sampling area covered by the subsamples was only a small fraction of the total area

within each grid. Thus, the measured value for any particular grid may or may not reflect the true mean concentration over the entire grid [HHRA III, 1998, p. 6-2].” Sampling for the HHRA III appears to have taken approximately 10 to 11 samples from each 250x400 acre grid area. In CCAT’s research, we came across this EPA soil sampling Guideline. According to Lesnik & Crumbling (of the EPA) in Guidelines for Preparing SAPS Using Systematic Planning and PBMS, 2001, data collection using “low quality” methods (such as gamma surveys) works well to find hot spots and define an area of contamination “only” if a high number of sample points are used in a given area. A Gamma survey would have been appropriate in Lincoln Park if many gamma readings throughout an area bounded by four crossroads had been taken, instead of just at crossroads. That might conceivably have discovered some hot spots, and then “high quality” data collection (such as soil sampling) could have been used in a more limited area. Please note the diagrams below illustrating this point, taken from Lesnik’s & Crumbling’s paper, where hot spots are indicated by two circles in the diagrams: It appears that the sampling events off site of the Cotter Mill over the years have not been designed as recommended by Lesnik and Crumbling, unless they were in specific areas Cotter was planning to clean up: e.g. Sand Creek, the railroad depot, NW golf course thorium in soils, etc. Sampling that has taken place in Lincoln Park and other residential areas always comes back with conclusions that are not definitive, because the study design did not guarantee a reflection of the overall site condition.

<u>Response</u>:

ATSDR has requested additional soil sampling for lead in the residential area north and west of the mill (adjacent to the Shadow Hills Golf Course). This is the only area the ATSDR identified as not having enough sampling data to make a health call. Surface soil in Lincoln Park and other surrounding areas remains a potential exposure pathway until all potential on- and off-site sources are eliminated.

ATSDR rechecked the original reference [Weston 1998] against Table 27 entries for U-238 and U-234. The numbers agree and this is not a typographical error.

<u>Comment</u>:

In the last two years Cotter has made some “substantial changes” at the Mill, decommissioning many areas, where you would expect to see changes in air quality. These events are not included in the list in the document:

- **2008 Excavated 233,000 cubic yards of Old Tailings Pond Area soils, moved by truck to stockpile in the Primary Impoundment.**
- **2008 Evaporating surface water from the Primary and Secondary Impoundments.**
- **2009 Excavated two ore pads.**
- **2009 Demolished 9 CCD tanks with a 300-500,000 gallon capacity each.**
- **2009 Demolished Kiln and several old mill buildings, trucked to Primary Impoundment.**

- **2009-2010 Dewatered and covered Secondary Impoundment with recently excavated Old Tailings Pond soils.**
- **2010 Began excavation of extensive areas and depth of contaminated soils in the CCD tank area.**

This is disappointing because these actions are significant, unusual, and one-time events at the Mill affecting air quality. Evaporating and dewatering the impoundments should have increased radon emissions and flux, as well as increasing the potential for fugitive dust. At the same time, Cotter refused to conduct the Subpart W required radon flux tests at the Primary in summer 2010, and refused to conduct radon flux tests at the Secondary in 2009. Oct 21, 2009 letter from EPA to Cotter declared Cotter was required to follow Subpart W regulations; in a July 23, 2010, letter Cotter wrote to EPA stating they were decommissioning the Primary Impoundment and again refused to do any further radon flux tests. EPA again notified Cotter in a letter of August 25, 2010, that they are subject to regulations requiring radon flux tests at the Primary Impoundment.

Response:

As stated in the PHA, ATSDR only assessed data collected prior to 2008. Soil radon flux measurements have not historically correlated well with the decay products measured outdoors. Also, excavation events in the past did not result in off-site air concentrations that would have an adverse impact on public health. It is not expected that there would be any difference this time.

Comment:

Inclusion of this fact *height of the sampling inlet probes was not specified in the reports that ATSDR reviewed* can only be interpreted as meaning that height of inlet probes has some impact on the quality of data collected at the air stations, yet no explanation is offered about the relevance of this information, nor was any effort made to find the answer.

Questions:
1. What is the recommended height of sampling inlet probes?
2. Does Cotter's equipment comply with those recommendations?

Response:

The inlet height and sampler placement is different for gaseous versus particulate, but ATSDR recommends somewhere between three and five feet. This is covered by 40CFR58 Subpart G and is the responsibility of EPA and CDPHE to verify compliance.

Comment:

TSP levels at the perimeter of Cotter were 1/2 of levels in Lincoln Park, a fact hard to believe when the LP station is such a short distance away. Because Cotter's Restricted Area has a great deal of open space with little vegetation through the summer months, and sprinkling to reduce dust happens only sporadically and mainly on Cotter roads with

trucks dwarfed by the size of the area, we wondered why this didn't raise a red flag for ATSDR. While ATSDR may feel assured about the quality of the monitoring data, CCAT does not. No explanation of how or why concentrations would be lower at the mill perimeter than in the outlying areas of Canon City and Lincoln Park is offered. Many residents from the west and northwest of Cotter, that overlook the property, can attest to the fact that enormous clouds of dust engulf Cotter and the whole area during windstorms numerous times a year. This makes it difficult to believe that TSP concentrations off-site are this much higher. It would be more believable if they were close to the same concentrations. This is similar to CCAT's observation that Cotter's radon flux measurements at the impoundments rose 230% over a couple of years, while radon at the mill boundary went down 30% over the same time interval.

<u>Response</u>:

The above statement from the PHA is very plausible. TSP is generally highest along public roads due to automobile traffic kicking up particulates. Nevertheless, TSP is not a quantity related to public health. PM-10 and more importantly PM-2.5 are the relevant health related suspended dust/particulate quantities.

<u>Comment</u>:

We lack confidence in Cotter's environmental sampling and analysis prior to October 2007 due to numerous laboratory deficiencies found by regulators, and therefore lacks confidence in ATSDR's conclusion that Cotter's annual average concentrations were always lower than the health-based regulatory limits. CCAT provided documentation of laboratory deficiencies to ATSDR during this review. For the record, CCAT also notes that the Colorado Air Pollution Control Division of CDPHE does not take split air samples at Cotter to compare and confirm results, nor does the Radiation Management Unit to the best of our knowledge. In 2001, the State threatened to suspend Cotter's CLIA certificate which would have prohibited Cotter from performing laboratory testing, because the Laboratory Director and Technical Supervisor did not hold required degrees (copy available at CDPHE). A lack of training and qualifications of laboratory staff was again noted as deficient in a November 2, 2004, report by Mr. Ed Wallace (obtained by ATSDR). The quality of work from Cotter's laboratory resulted in an April 2005 Notice of Violation and Order to employ the services of an outside radiochemistry laboratory. Cotter met the requirements to cancel that Compliance Order, and a CDPHE letter of October 24, 2007, lifting the Order again referred to the original deficiencies, "Enough significant deficiencies were noted in the radiochemistry procedures for Mr. Wallace to classify the Isotopic Thorium, Radium-226, Polonium-210, and Lead-210 analyses as unusable. This was for occupational as well as environmental samples. Numerous other deficiencies were noted for uranium analysis, as well as supporting procedures for maintenance and calibration of laboratory equipment, training and qualifications of laboratory staff, and deficiencies in the QA/QC Program." (Emphasis added). In spite of ATSDR's knowledge of the above issues, the quote at the beginning of this comment states that ATSDR has "some assurance that samples are collected and analyzed with fine attention to data quality," but then points out another problem about reports not presenting "the actual data quality metrics." We

understand that the conclusions presented on each of the radionuclides are from the only data available, which was produced by the Cotter Corporation. What we do not understand is why ATSDR did not alert the public to the fact that the data, at least up to 2007, might not be accurate due to documented deficiencies in laboratory procedures and staff qualifications.

Response:

Cotter's laboratory was not analyzing samples throughout much of 2005 and 2006, and these samples were not in question. ATSDR must unfortunately rely on others to collect and analyze environmental data.

So long as the regulatory agency (CDPHE) receives the data quality metrics, it should not be necessary to put them in the summary reports.

Comment:

The unit of measure used for particle-bound radionuclides in Section IV is µCi/ml with the concentration expressed as an equation, e.g. (9.0 x 10-14 µCi/ml). Looking at examples from other PHA's, we noticed that in Monticello, for instance, Ra226 and Th230 in air used units in pCi/m3, and for U238 the unit used was µg/m3 where the concentration is expressed in a number rather than an equation. It is difficult for most citizens to compare equations to equations in order to calculate a difference. It is much easier to compare concentrations expressed in simple
numbers, e.g. (3 µg/m3 or 6 pCi/m3).

> **Question: Is it possible to convert the units used for air concentrations by Cotter in this report to pCi/m3 or µg/m3 where numbers can express the concentrations?**

Response:

In the above example of 9.0 x 10^{-14} µCi/ml, the best that can be done is 0.009 pCi/m^3. The data was expressed in scientific notation, as that was how it was expressed in the source documents. ATSDR's policy is that data are retained in the original units from source documents to insure that there are not conversion errors and to aid comparison to the referenced data. We also try to stay in the same units throughout the document to aid comparisons. In the Monticello PHA, the data from DOE was provided in those units.

Comment:

We believe an annual total effective dose equivalent to the public of 50 mrem limit or standard is incorrect for natural uranium. If we are correct, this will hold true for each of the radionuclides in this section. It is our understanding that Cotter has a constraint of 10 mrem total effective dose equivalent to the public per year that is ALARA [10 CFR 20.1101]; and, as a uranium fuel cycle facility, an annual 25 mrem dose equivalent "limit" to the whole body [40 CFR 190.10] Colorado 6 CCR 1007-1, Part 4 – *Standards for*

Protection Against Radiation **have the same dose equivalent limits. Therefore, the calculations that compared average concentrations measured at Cotter to the regulatory limit (determining to what degree Cotter was lower than the limit) would also be incorrect.**

> **Regulations:**
> ***10 CFR 20.1101 (Subpart B) (b) The licensee shall use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA). (d) To implement the ALARA requirements of § 20.1101 (b), and notwithstanding the requirements in § 20.1301 of this part, a constraint on air emissions of radioactive material to the environment, excluding Radon-222 and its daughters, shall be established by licensees other than those subject to § 50.34a, such that the individual member of the public likely to receive the highest dose will not be expected to receive a total effective dose equivalent in excess of 10 mrem (0.1 mSv) per year from these emissions.***
> ***10 CFR 20.130 (e) In addition to the requirements of this part, a licensee subject to the provisions of EPA's generally applicable environmental radiation standards in 40 CFR part 190 shall comply with those standards.***
> ***40 CFR 190.10: Operations covered by this subpart shall be conducted in such a manner as to provide reasonable assurance that (a): The annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations.***

Though Cotter data may still not exceed the regulatory dose limit of 25 mrem, there may be more instances unreported in this section where Cotter did exceed the limit. In addition, in the last two and a half years Cotter has made some "substantial changes" at the Mill that are one-time events and unusual. They have decommissioned many areas (e.g. excavating and moving 233,000 cubic yards of contaminated soil from the Old Tailings Ponds Area in 2009 and 2010, and etc.) where you would expect to see changes in air quality or spikes in concentrations as has been the case historically. Data from environmental sampling during that time period was not evaluated for the PHA as it should have been, because it was available in Cotter's Semi-Annual Effluent reports from 2008 through 2010 on the CDPHE-Cotter website, prior to and during the time when the Air evaluation was being conducted by ATSDR.

Response:

The pertinent regulatory limit as an NRC Licensee is that specified in Table 2 of 10CFR Part 20 Appendix B for air effluent and the limit is 50 mrem TEDE annually. The more recent data wasn't available to ATSDR until recently. To be timely, we are releasing this report without evaluating said data. CDPHE will evaluate the referenced data.

Comment:

There is an elevated amount of Th-230 in soil on 5.4 acres of Cotter property that is between County Road 143 and the upper NW portion of the Shadow Hills Golf Course. A golf course green borders on the west, and a residence is adjacent and approximately 200' away on the north. The AS-210 station is on this 5.4 acre spot. Though the public has been unaware until recently, Cotter and CDPHE had knowledge and concerns about thorium in this area since 1994, or earlier. Cotter submitted a report November 4, 2009, *Radiological Survey Plan and Dose Assessment Approach For Evaluation of Cotter Property near Air Particulate Monitoring Station AS-210*, to investigate this area. Cotter's report acknowledges the potential of exposure for children at a nearby school bus stop, golfers, and people in nearby residences; and, acknowledges a concern regarding any earthmoving activity in this area. CCAT is concerned about the unique nature of thorium, namely that it is a radionuclide that disintegrates into fine microscopic particles which are easily air-borne and can travel long distances. We are concerned that ATSDR made no mention of this particular issue; and, that Mr. Brooks indicated during a conversation about it, at a community meeting, that these higher concentrations of thorium were probably "naturally occurring," a judgment made prior to results of Cotter's investigation. Cotter's aforementioned report charts unusually higher levels of thorium in soil along County Road 143 bordering the golf course, and along Cotter's entrance road, concentrations that drop significantly the farther you get from Cotter's property and the golf course, certainly evidence of a possible connection to the mill site.

Response:

ATSDR did not identify Thorium-230 as a health concern because it never exceeded health based comparison values in off-site air samples.

Comment:

We object to the suggestion attributing 210Pb concentrations to background levels due to a lack of variability in data. No background data for similar areas without a uranium mill is offered as a comparison, nor is any scientific theory cited supporting this conclusion about lack of variability. Lack of variability might also be credited to a steady source of contamination such as radon from the mill site which is very close to these air monitors. If there was no close source of Lead-210, then a lack of variability in 210Pb data might be interpreted to mean the 210Pb is just background. That is not the case in this instance.

Response:

Levels of Lead-210 are not elevated nor a health hazard around the Cotter Site or in Lincoln Park. The only time the levels rose at all were during the past excavation on site and still were not levels that would cause adverse health effects.

Comment:

We have two major concerns regarding the approach used by Cotter and approved by the RMU at CDPHE in 2004 for screening 220Rn/ 222Rn concentrations and determining if perimeter radon is within regulatory limits.

First Concern: **The *NRC INTEGRATED MATERIALS PERFORMANCE EVALUATION PROGRAM REVIEW OF COLORADO AGREEMENT STATE PROGRAM, March 13-17, 2006* (IMPEP) for the Radiation Management Unit (RMU) at CDPHE stated that the RMU lacked "expertise for radon analyses":** ***The Colorado Agreement State program is administered by the Radiation Management Program (the Program), which consists of two units: the Radioactive Materials Unit and the XRay/Mammography Unit Introduction, p. 1). …In reviewing this sub-indicator, the review team evaluated the uranium recovery program staffing level, the technical qualifications of the staff, staff training, and staff turnover. …The review found that the expertise for radon analyses and cap design in the Program was not evident at the time of the review. The review team discussed with the Program the need for expertise in this area because as the Program reviews and approves Cotter Mill's Revised Reclamation Design and Decommissioning Plan the expertise for effective radon analyses becomes more significant (4.4.1, Technical Training and Staffing, p. 15).[Emphasis added].***

No mention of a resolution to this problem was made in the next IMPEP Review of April 12-16, 2010. When Mr. Tarlton was questioned at a Community Advisory Group meeting, we were told that no new staff had been hired with radon expertise, but we never saw any documentation on how it was resolved.

Second Concern: **CDPHE approved Cotter's EEL method two years prior to this NRC review and finding of a lack of radon expertise in the RMU, which brings into question whether the RMU had the training and expertise to properly evaluate Cotter's method. Because of this doubt, we consulted with three experts on environmental risk assessment and radioactive air emissions about Cotter's "effective effluent limit"(EEL) method, i.e. the concentration used for screening purposes (Bernd Franke's 2005 report was provided to ATSDR). All three experts concluded that using three (3) data points and adding 2 standard deviations to the mean is not appropriate to determine background. One expert pointed out that to be conservative in determining background, if the standard deviation is taken into account at all, it should be subtracted rather than added. Adding the deviation increases the level of background, and is not conservative, and the purpose of the compliance test is to make sure that the releases from the facility are below some limit, with a given probability. This requires the use of the lower confidence level (if any) of background. When using the mean background without adding the 2 standard deviations, only some values would exceed the limit (e.g. in the 2001-2003 period – AS 206 and AS209). If the 2 standard deviations are subtracted as suggested to be a conservative action, Cotter's compliance would be really poor. We were also repeatedly told that air monitoring stations determining background cannot be in close proximity to a site where radium in soil from the facility can contribute to radon, and two of Cotter's air stations used to determine background are close to the mill. The station on the west is in fact downwind of Cotter in the predominant wind pattern direction. One expert pointed out that Cotter's MFG 2004 paper cited referenced no source that would justify this method, while other**

experts commented that they had never encountered use of this method at comparable facilities.

CCAT Director, Paul Carestia, with extensive experience and education in statistics, also prepared a paper listing concerns and questions about the method used in the EEL that was presented to CDPHE's RMU and EPA, and later to ATSDR. CDPHE's RMU did not give a serious and detailed response answering his questions, and EPA gave no response. ATSDR also did not give a written, detailed response to the points in Mr. Carestia's paper, instead deferring judgment on the EEL to the RMU, and referring us back to the RMU. Regardless of whether another method would produce significantly different results in regard to Cotter being within regulatory limits, the concerns about the validity of this method remove any confidence in the PHA's conclusions derived from Cotter's radon sampling data.

Response:

Radon is only a health hazard in confined spaces where it can accumulate. Radon in an outdoor environment does not pose the same health risk and only the concentration of its decay products (e.g., Lead-210) is relevant.

Comment:

For many years there was an ore pile with pad next Cotter's entrance by the guard shack that was the subject to at least three (3) "items of concern" in Notices of Violation letters to Cotter. The gamma radiation from this ore pad was high and Cotter was asked three (3) times to move the ore, which they finally moved. A June 24, 2009, letter from CDPHE to Cotter stated:
Repeat items of concern include: "Gamma exposure rates at the inactive ore pad adjacent to the guard shack are not ALARA, and remain elevated despite not using this pad for more than 2 years. The Division has noted this for three consecutive inspection reports. …Failure to address this pad during the next inspection period may result in a violation." **In light of the fact that this gamma emission area went unchecked for years, an area across from and near the golf course, and an area near many employees in Cotter's offices and those entering and leaving the facility, gamma radiation should have included health-based screening evaluations for measurements.**

Response:

ATSDR did not find this to be a completed exposure pathway, since it was not an area where members of the public spent any time.

V. PUBLIC HEALTH EVALUATION

Comment:

The PHA does not examine public health data available from the Colorado Department of Health's Cancer Registry of Birth Defects Registry. It does not reference available cancer data analyses published by the State of Colorado in 1991, 1993 and 1998.

Response:

ATSDR uses a process to decide whether to evaluate epidemiological health studies or other health and exposure research activities, in order to assess the potential scientific value and utility of such an evaluation. The scientific validity of the epidemiological study is based upon accurate exposure classification and appropriate study designs that can definitively demonstrate whether associations between exposure and health outcomes exist. Without both strong exposure and health information, a study is prone to misclassification and bias that would compromise the accuracy of the study results.

Accurate classification of historical exposures to contaminated groundwater in Lincoln Park would be challenging. The greatest levels of exposures in the population occurred many years ago. It would be very difficult to locate all former residents and to ascertain an accurate measure of the concentration, frequency, and duration of their past exposures. Environmental monitoring of the wells was conducted previously, but the results were inconsistent. Also, there are no records of well usage before the public water supply was installed.

Additionally, there is not a large enough sample size or statistical power to distinguish if health outcomes are a result of exposure or a chance occurrence. Without adequate statistical power, any reported study could not reflect statistically significant associations, if they exist.

Comment:

Is there any risk assessment available for children exposed chronically to molybdenum? It is unclear in this section whether *acute, intermediate,* or *chronic* exposure was used in this evaluation. The references cited for health guidelines on molybdenum are dated and weak. Though cited as reference, *ATSDR's Minimal Risk Levels* does not include molybdenum, and
***EPA's Reference Doses* offer the same dated study [Koval'skiy et al., 1961] as this Assessment for health effects. EPA's IRIS database, "Confidence in the Oral RfD," states:**

> ***The level of confidence in the oral RfD for molybdenum is medium. It is based on the results of a study [Koval'skiy, et al] that examined only gross physical effects of a gout-like disease and examined some blood chemistry parameters normally associated with gout. An exhaustive analysis of blood chemistry and individual dietary habits was not done. Therefore, the results are clearly generalized for a large population.* [Emphasis added]**

Based on the above, stating that the level of exposure to molybdenum in children at our site was 14 times lower than the LOAEL from the 1961 Koval'skiy study is extremely misleading, especially when you take into consideration that all pathways to molybdenum were not evaluated, only exposure from groundwater, and not exposure from soils or

produce. It leaves the erroneous impression that there is no evidence of danger to children's health from exposure to molybdenum at this site.

Response:

The health guideline for molybdenum used in this document is based upon EPA's current Reference Dose (RfD) for molybdenum, which represents chronic exposure, and was derived from a human epidemiological study. The 1961 Koval'skiy study represents the most significant study for molybdenum in drinking water after a comprehensive review of chronic toxicity data by EPA health scientists. Other supporting studies are listed by EPA on the IRIS database, but none were found to be as relevant as the Koval'skiy study.

The RfD accounts for sensitive populations, including children, as set forth in the following statements by EPA: *In general, the RfD is an estimate (with uncertainty spanning perhaps a factor of 10) of a daily exposure to the human population (including sensitive subgroups) [*emphasis added*] that is likely to be without an appreciable risk of deleterious effects during a lifetime.* The RfD also "*…satisfies molybdenum nutrient requirements for all healthy members of the population…*"

Generally, it is prudent to focus on the most sensitive members of the population. Therefore, regulatory efforts are generally made to keep exposures below the population threshold, which is defined as the lowest of the thresholds of the individuals within a population.

Here, ATSDR concluded that children may be at risk for harmful effects based upon exposure to molybdenum in drinking water. Molybdenum contributions from other sources (e.g., food, produce, etc.) would not produce additional harmful effects other than those already discussed. Health effects from acute exposures to molybdenum at this site are not expected.

Comment:

The information given about uranium is one of the most disturbing parts of this Assessment, due to the fact that current research has been completely ignored. First, by leading off with the two paragraphs about natural uranium, ATSDR seems to be promoting the idea that the uranium contamination in groundwater in Lincoln Park is from natural sources and poses no health danger. Second, this Assessment is using dated and inaccurate information. BEIR VII findings, published in 2005 and based on current research, including cellular biology studies, should have been included. BEIR VII clearly states that scientific research has proven that there is no threshold of exposure below which even low levels of ionizing radiation is harmless. It goes on to state that health risks from solid cancers in organs rise with chronic lifetime exposure to low levels of ionizing radiation, and that animal studies have produced extensive evidence that cell mutations can be passed on to offspring, and that there is no reason to believe the same wouldn't be true for human offspring.

The "National Apology," which compensates workers at uranium mines and mills for exposure to uranium, *The Radiation Exposure Compensation Act of 1990* and subsequent

compensation program lists numerous types of cancer and other illnesses from exposure to uranium, not just bone cancer. Obviously due to health effects, Canada, Australia, California, and Vermont have uranium MCLs of 0.020 mg/L, and Canada then recommends that no one drink water with more than 0.010 mg/L. Germany just passed a new standard of 0.010 mg/L. Bottled drinking water for babies now has a standard of 0.002 mg/L.

Response:

“Natural uranium” or “naturally-occurring uranium” is a mixture of three radionuclides (^{234}U, ^{235}U, and ^{238}U) which exists in natural deposits as 99.28% ^{238}U, 0.71% ^{235}U, and 0.0057% ^{234}U, by weight. These percentages are in contrast to “enriched uranium” which has higher percentages of ^{235}U and ^{234}U after going through enrichment processes and “depleted uranium” which has lower percentages of ^{235}U and ^{234}U.

Milling uranium ore changes the amount of uranium in the product, in the tailings, and potentially in the environment including the groundwater, but it does not change the percentages of the three radionuclides from what is removed from the earth. Therefore, it is still referred to as “natural uranium.” All three radionuclides in uranium decay by both alpha and gamma emissions but are predominantly considered “alpha emitters”.

The (Board on Radiation Effects Research) BEIR VII report “Health Risks from Exposure to Low Levels of Ionizing Radiation”was not included as a reference for this report since the subjects of this report are low linear-energy-transfer (LET) radiations, such as x-rays or gamma rays (not alpha emitters). However, this report does contain some pertinent information for all types of radiation which will be discussed below. BEIR IV is the most recent BEIR report for internally deposited alpha-emitters other than radon. More recent publications on the subject include additional research, but the results are quite the same for human health effects. In the World Health Organization (WHO) background document for the development of WHO Guidelines for Drinking Water Quality dated 2011, one of the conclusions of this report was “the data also show that there is no significant risk of radiation induced cancers from levels of natural uranium found in drinking water.”

This comment made concerning BEIR VII is incorrect: BEIR VII does NOT “clearly state that scientific research has proven that there is no threshold of exposure below which low levels of ionizing radiation is harmless.” The Committee went to great lengths to review all current scientific evidence and concluded that it is “consistent with the *hypothesis* that there is a linear dose-response relationship between exposure to ionizing radiation and the development of radiation-induced solid cancers in humans. The Committee further judges that it is unlikely that a threshold exists for the induction of cancers but notes that the occurrence of radiation-induced cancers at low doses will be small.” They also noted that “at doses below 40 times the average yearly background exposure (100 mSv), statistical limitations make it difficult to evaluate cancer risk in humans.” (Approximately 42 out of 100 people in a lifetime will be diagnosed with cancer from causes unrelated to radiation.)

The statement that the "National Apology, which compensates workers at uranium mines and mills for exposure to uranium and *The Radiation Exposure Compensation Act of 1990* and subsequent compensation program lists numerous types of cancer and other illnesses from exposure to uranium, not just bone cancer" is not accurate. Uranium miners and millers are covered under the Radiation Exposure Compensation Act (RECA) due to the range of hazards presented by the uranium mine and mill environment. These hazards include radioactive decay products of uranium such as thorium, radium, radon, lead and polonium; heavy metals from the ore such as vanadium, arsenic, selenium, and chromium; and workplace chemicals such as diesel and gasoline fumes, blasting residues, sulfuric acid, kerosene, and other reagents. The types of cancers and other illnesses listed for RECA are potentially a result from inhalation of a combination of these products. This program is adjudicated by the Department of Justice, as opposed to the Energy Employees Occupational Illness Compensation Act (EEOICPA) program which is adjudicated by the Department of Labor. Uranium miners and mill workers who have previously been awarded benefits by the Department of Justice under Section 5 of RECA are automatically approved for compensation under EEOICPA. These employees do not need to demonstrate that they developed cancer related to their employment.

Comment:

My husband was hired in Grand Junction as Assistant Chief Chemist at Cotter in 1957. He moved his family to Canon City in 1958. He became ill in 1972 and died in 2001. His death certificate (available upon request) lays blame for his radiation induced non-Hodgkin's Lymphoma on exposure to uranium at a uranium Mill. A Workmen's Compensation court found Cotter responsible for his illness and subsequent death and invoked a substantial penalty.

Correct the misinformation on cancer attributable to uranium exposure and update with information on the qualifying cancers and illnesses for compensation for uranium workers under EEOICPA ("National Apology"), and the volumes of current studies showing the health effects of exposure to uranium.

Response:

We extend our deepest condolences to this family in the loss of their loved one. As mentioned previously, the employee's occupational exposures would have been very different than exposures to the public from uranium in drinking water.

Comment:

It is really hard to believe that a quote of Eisenbud's opinion from 1955 has been included, since it has been completely refuted by research that ultimately led to the lowering of the MCL for uranium in the U.S. and around the world. There are many "published studies" that arrive at a completely different conclusion. A 2003 study from the University of New Mexico Health Sciences Center, prepared for the New Mexico Environment Department, compiled all research to that date from around the world on uranium and kidney toxicity (Malczewska, et al, *Recommendations for a Uranium Health-Based Ground Water Standard,*

2003). Based on all the evidence, they recommended a uranium MCL standard of 0.007 mg/L in drinking water due to toxicity to kidneys, and to avoid permanent damage, a standard far more protective than the EPA's 0.030 mg/L cost vs. benefit derived standard. EPA's MCL is not without risk to kidneys.

Response:

There have been many "published studies" since Eisenbud's, but they mostly come to similar conclusions. The metal toxicity of uranium varies according to its chemical form, route of exposure, and water solubility. Although uranium is not considered very water-soluble, the more soluble forms are the more potent renal toxicants. However, in comparison to the toxicity of other metals such as arsenic, mercury, cadmium, lead and thallium, uranium is considered to have a low order of metallotoxicity.

A study published in the Journal of Environmental Radioactivity in 2002 (Assessing potential risks from exposure to natural uranium in well water by Hakonson-Hayes, Fresquez, and Whicker) looked at the estimated doses from 72 private wells in New Mexico from ingestion of water and food products. They estimated the radiological doses to the kidney, bone, and other tissues for chronic 50-year and 70-year exposures for the mean and maximum uranium concentrations. Exposure to well water containing the maximum concentration of uranium (1200 micrograms U per liter) did not result in a significant increase in the risk for adverse health effects.

This study also recommended using a limit for renal toxicity of 1 microgram U per gram of kidney tissue. If incorporating a safety factor between 10 and 50, the possible threshold would be between 0.1 and 0.02 micrograms/gram of kidney tissue. For a young child chronically ingesting the average concentration for the maximum well at Lincoln Park, ATSDR estimated that the maximum kidney burden could be 0.01 micrograms per gram of kidney tissue. For an adult chronically ingesting this concentration for 25 years or longer, ATSDR estimated that the maximum kidney burden could be 0.02 micrograms per gram of kidney tissue.

Comment:

The guideline given in the uranium discussion is not the correct EPA regulatory MCL for uranium. It is listed as 0.035 mg/L and it should be 0.030 mg/L, and it's not a "guideline" but rather a regulatory standard. Colorado Water Quality Control Commission implemented a standard for uranium in groundwater of 0.030 mg/L in 2008.

Response:

We corrected the typo and changed the value to 0.03 mg/L.

EPA regulates public water systems. EPA does not regulate private drinking water wells. EPA's maximum contaminant levels in drinking water are regulatory *standards* required for public water systems. These values are also used as non-regulatory *guidelines* for private wells. However, we will call it a standard for consistency.

Comment:

EPA withdrew their cancer classification in 1993, certainly not updated since then to reflect current research. EPA's website last updated in 2000 (10 years ago) states, "Uranium may cause lung cancer and tumors of the lymphatic and hematopoietic tissues. EPA has not classified uranium, radon or radium for carcinogenicity." This is in complete contradiction to the 2005 BEIR VII report, numerous studies in cellular biology, and obviously needs to be updated to reflect current research.

Response:

Any reference to lung cancer and tumors of the lymphatic and hemopoietic tissues are referring to potential adverse health effects from inhalation, not ingestion of uranium. In response to references to the BEIR VII report, refer to the previous comment on this matter.

Comment:

The report states that Molybdenum levels were equal to the chronic health guideline in fruits and vegetables. This statement alone makes me wonder how the ATSDR review can state, "Eating locally grown fruits and vegetables will not harm your health". The very study itself contradicts that.

Response:

The health guideline used by ATSDR was the EPA's chronic oral reference dose (RfD) for molybdenum. An RfD is an estimate of a lifetime daily exposure level for humans that is likely to be without risk of harmful effects. Therefore, a dose equal to or below the RfD is not expected to cause adverse health effects.

Comment:

I have a comment about the way that the doses from the different radionuclides are handled (see pages 42-46). The radionuclide concentrations were compared to an "effluent concentration which is defined as a radionuclide concentration which, if inhaled continuously over the course of a year, would produce a total effective dose equivalent of 50 mrem." When determining doses from radiation, the energy deposited by the radiation in tissue is measured. This allows the doses from different radionuclides to be summed and treated as a single dose. In the PHA, the doses from the radionuclides were never summed, they were just compared to a 50 mrem marker. It is possible that the doses from the five different radionuclides could never individually exceed 50 mrem, but when summed could exceed 100 mrem (the dose limit established by the NRC for the protection of the public). I do not believe that this is the case in this study, but I would like to see the doses summed.

Response:

The sum of the doses was in all cases equivalent to one significant digit. We used a screening technique to exclude doses below our screening values. We used the worst case isotope for the worst year at each station as a screening tool and all other radionuclide contributions were at least a factor of ten lower, which meant that when summed there was no difference to one significant digit.

Comment:

Another item of concern is the small child ingestion values used on page 58. The ingestion value of 200 mg/day does not account for children with pica; the incidence of which can be as high as 20%. However, the overall dose is not significantly changed when using the default soil ingestion rates for children with pica.

Response:

The doses do not approach levels that cause harmful effects; therefore, the risk of harm for children with soil pica behavior was not evaluated. The doses were calculated for annual average intakes and not for acute exposures.

Comment:

This PHA for the most part assumes that all the radiation exposure to the surrounding community is a result of the activities at the uranium mill. There has been a comparison of some of the results to a comparison values, but it is unclear if these comparison numbers are true background values. For example, on page 58 the report states that "Ra-226 was the only radionuclide to exceed its comparison value" resulting in a dose of 58 mrem/year to an individual staying at that location 12 hours/day, 365 days/year. It is not determined if the high Ra-226 levels are natural or if it is the result of activity at the mill. In addition, it appears that the entire Ra-226 concentration is used to determine the dose, not just the contribution from the mill.

Response:

The radium levels were not separated, since the legal level for former uranium mill sites (Uranium Mill Tailings Radiation Control Act (UMTRCA)) is set at 5 pCi/g in the topmost layer of soil. The gamma dose rate corresponding to that soil concentration is less than 1 mrem/yr. Therefore, this did not change the estimated dose.

Comment:

Another cause for concern is how the average radionuclide concentrations are calculated. For those concentrations that are <MDA the report assumes assume a value of 1/2 the MDA and averages that in. I approached Jon Griggs, a center director at one of the EPA radioanalytical laboratories and he relayed the following information from one of his statisticians: My recommendation from a public health protection viewpoint would be to use the MDA as a substitute value. This will result in an upper limit for the average and

thus be conservative. The real answer is not to report "less than" numbers, but rather the result and its uncertainty. That being said, people have used 0, 0.5 MDA or 1.0 MDA. None has any real mathematical justification. There are very complicated statistical ways to do better, but almost no one uses them.

Response:

Table 25 in Appendix A clearly states that averages were calculated using ½ the reporting detection limit for non-detects. This one method that can be used when there is not sufficient sampling to perform more complex statistical analysis. As methods of statistical analysis advance, this approach may change.

Comment:

I have a comment about the gamma exposure rates provided in table 58 of Appendix A. At first glance most of the exposure rates (10- 15 µR/hr) appear to be high. After accounting for the prevailing terrestrial and cosmic exposure rates in Colorado the expected exposure rate is 13-17 µR/hr (data for these projections is available from the US Geological Survey at http://pubs.usgs.gov/of/20051l413/maps.htm). These values are to help make an initial assessment of the data. Based on these preliminary values, the major area of concern is the sampling point associated with AS-209 and to a lesser extent AS-206.

Response:

Thank you. We agree; that is where we focused our concern for crafting our conclusions.

Comment:

Cadmium is carcinogenic to humans according to current research, but was downplayed in the report.

Response:

Cadmium carcinogenicity has not been associated with the oral route of exposure.

Comment:

Was a RESRAD program ever used at Cotter? If not, why was only MILDOS used?

Response:

ATSDR used RESRAD version 6.5 to model doses to the highest soil concentrations of radionuclides.

Comment:

We question the assumption or conclusion that the Uranium Mill Tailing Act (UMTRA) standard does not apply in this case, because Cotter is decommissioning much of the facility, including the impoundment ponds that have areas of high contamination surrounding them and most, if not all, facility structures. The groundwater and soil contamination on the facility is high in contaminant concentrations and volume, and part of the Superfund site. CDPHE's RMU has allowed piecemeal decommissioning projects before approval and public participation in a Revised Decommissioning and Reclamation Plan that has been required since Fall of 2005. This has left many gray areas and confusion for the public at this site regarding convoluted and complicated determination of authority from different agencies.

Response:

ATSDR has no regulatory authority, but Cotter will be bound to comply with the Uranium Mill Tailings Radiation Control Act (UMTRCA). In the "Atomic Energy Act section 11e.(2)"; material (i.e., certain mill tailings and related waste containing thorium or uranium), the NRC is required to make a determination that all applicable standards and requirements have been met by uranium mills before termination of their license.

Comment:

It is our understanding that Cotter has a constraint of 10 mrem total effective dose equivalent to the public per year that is ALARA [10 CFR 20.1101]; and, as a uranium fuel cycle facility, an annual 25 mrem dose equivalent "limit" to the whole body [40 CFR 190.10] Why is ATSDR's health-based comparison at 100 mrem instead of the 25 mrem limit?

Response:

ATSDR uses a health-based, rather than a risk-based comparison value. An MRL of 1.0 mSv/yr (100 mrem/yr) above background has been derived for chronic-duration external ionizing radiation exposure (365 days or more). No individual studies were identified that could be used to base a chronic-duration external exposure MRL that did not result in a cancer-producing end point. However, BEIR V (1990) reports that the average annual effective dose to the U.S. population is 3.6 mSv/yr. A total annual effective dose equivalent of 3.6 mSv (360 mrem)/year to members of the U.S. population is obtained mainly by naturally occurring radiation from external sources, medical uses of radiation, and radiation from consumer products. Since this annual dose of 3.6 mSv/yr has not been associated with adverse health effects or increases in the incidences of any type of cancers in humans or other animals, the 3.6 mSv/yr is considered a NOAEL for purposes of MRL derivation. An uncertainty factor of 3 (for human variability) was applied to the NOAEL of 3.6 mSv/yr to derive the MRL of 1.0 mSv/yr. The chronic MRL value is supportive of the 1 mSv/yr (100 mrem/yr) dose equivalent limit to the public that is recommended by the International Commission on Radiological Protection and required by the

Nuclear Regulatory Commission. The EPA has derived neither an oral RfD nor an inhalation RfC for ionizing radiation [IRIS 1999].

Comment:

Several times in the PHA, the year 1982 was reported as when highest annual radionuclide concentrations were measured, with the explanation that this was due to on site excavations at the time. We believe this emphasizes the importance of ATSDR updating and evaluating air monitoring results between 2008 and 2010 for this PHA, because during that time period Cotter evaporated and began dewatering the impoundment ponds, conducted extensive excavation of Old Tailings Pond Area soils, and performed other significant demolition work. If the health-based comparison value should be the regulatory limit of 25 mrem, please reevaluate conclusions.

Response:

ATSDR reviewed the more recent data, and it did not change our conclusions.

Comment:

Evaluate air monitoring data between 2008 and 2010 and include findings and implications of effect to health in the PHA.

Response:

ATSDR reviewed the more recent data, and it did not change our conclusions.

Comment:

We object to the suggestion attributing 210Pb concentrations to background levels due to a lack of variability in data. During discussions with ATSDR, when asked if there had been baseline radon data taken *prior to* the building of the Cotter Uranium Mill or any data on background radon for this area, Mr. Brooks referred us to the Eisenbud book, *Environmental Radioactivity from Natural, Industrial & Military Sources, Fourth Edition: From Natural, Industrial and Military Sources, 1963.* We purchased the book and there were only general references to the amount of radon in the State of Colorado. There was no data provided for the Canon City area. Radon background therefore is being determined solely on data from three Cotter air monitors (two of which are very near the Mill) and Cotter's questionable EEL method.

Response:

ATSDR has included the highest (i.e., statistical outliers) measurements of Lead-210 as a screening approach to exclude it as a contaminant that requires further analysis. Lead-210 was excluded as a contaminant of concern, because levels were not high enough to pass the screening test.

Comment:

Either provide additional supporting evidence for radon background for this area, or remove the guess that, "Radon decay product concentration off-site did not appear to be related to releases from the site."

Response:

EPA's Map of Radon Zones, EPA publication 402-R-83-028, dated September 1993, lists Freemont County as a Category 1 radon zone, meaning average levels of radon will exceed 4 pCi/l in homes. EPA also classifies Freemont County as a high geologic radon area. ATSDR does not consider outdoor radon concentrations to be relevant to public health, and instead looks at radon decay product concentrations (e.g., Lead-210). Lead-210 was excluded as a contaminant of concern, because levels were not high enough to pass the screening test.

Comment:

Why has ATSDR not asked for further soil sampling especially when it comes to Pb 210 and other heavy metals which are by products of the yellowcake milling process?

Response:

Lead-210 is primarily an inhalation hazard and therefore ATSDR was primarily concerned with air concentrations rather than soil concentrations.

Comment:

What should be concluded from this comment: "*However, it should be noted that prevailing wind patterns measured at Cotter Mill may not be representative of surface winds throughout the area, especially considering the proximity of nearby terrain features.*"? Should it be that the data at Cotter is not a valid representation for the surrounding area? Should it be that other more relevant data for the surrounding area should have been taken and used? Should it be that air born particulate conclusions drawn may not be valid based upon lack of appropriate, relevant wind patterns for the Lincoln Park affected area? The above gives little to no information, except to cause concern that invalid data may have been used to draw conclusions about airborne contamination. Please clarify the implications of the statement.

Response:

It means that terrain features channel air flow in the area, blocking flow into some areas. This does not mean the sample locations are inappropriate, but is meant to clarify why some areas have significantly lower concentrations than expected in flat terrain.

Comment:

Why was radon gas, especially its daughter products explicitly not mentioned when discussing air emission sources?

Response:

That section discusses the rationale for which environmental media ATSDR looked at. It was not discussing specific chemicals or radionuclides. Radon is discussed explicitly in Chapter IV, Section E.2.b on page 52 of the PHA.

Comment:

Windborne dust is what radon gas attaches itself to. Why is there no mention of radon gas in any of this discussion? When these particulates have half lives of centuries, what difference does it make that several of these sources have been controlled or eliminated? There were many years of operation where control and elimination were not the mantra. Please acknowledge the fact that the effects of these windborne particulates is cumulative.

Response:

Radon decay products have half-lives measured in minutes.

		Main radiation energies and intensities					
		ß				τ	
Radionuclide	**Half-life**	**MeV**	**%**	**MeV**	**%**	**MeV**	**%**
Rn-222	3.824 d	5.49	100	-	-	-	-
Po-218	3.11 min	6.00	100	-	-	-	-
Pb-214	26.8 min	-	-	1.02	6	0.35	37
		-	-	0.70	42	0.30	19
		-	-	0.65	48	0.24	8
Bi-214	19.7 min	-	-	3.27	18	0.61	46
		-	-	1.54	18	1.77	16
				1.51	18	1.12	15
Po-214	163.7µs	7.69	100	-	-	-	-

Comment:

It would be very useful if ATSDR would indicate that the mill was in stand-down in 2008, and it was at the peak of operation prior to 1985. It would also be useful if ATSDR would indicate just how high those "between 10 and 100 times" numbers were prior to 1985.

Response:

Those comparisons are are made in Chapter V, Section G and in Table 11. Also, several times in the PHA we mention the 2008 stand-down.

VI. COMMUNITY HEALTH CONCERNS

Comment:

CCAT Board Director Jody Enderlee sent several requests for an epidemiological study of our Superfund Site to EPA and ATSDR in 2003 and 2004. From our notes, as communicated during a teleconference on May 5, 2004, EPA and ATSDR stated that a health risk assessment would determine if it is necessary to do an epidemiological study. ATSDR then began Health consultations and the Public Health Assessment which had not been conducted for this Superfund Site previously. CCAT began our Health Survey due to concerns about possible cancer clusters and illnesses/disease reported anecdotally in the community, some very rare, that can be attributed to exposure from contaminants at a uranium mill (though other causes might be identified is a scientifically designed study).

The health survey was never presented to EPA or ATSDR as a scientific study where one could draw definitive links between exposure and health effects or use it in *"determining the prevalence of adverse health effects present in the entire community,"* nor did we expect or request that from ATSDR. It was presented as a grassroots survey that was intended to assist EPA and ATSDR in any future epidemiological study (as we hoped for) by gathering contact information on citizens with specific illnesses in the community surrounding the Cotter Mill, including contact information on people who had moved from this area.

We do not see evidence in the PHA, as claimed, that ATSDR used the survey results "to focus our [ATSDR] attention and pursue a more in-depth scientific analysis of the health conditions identified by the community." The PHA focused on very few of the health conditions identified by the community that could be associated with Mill contaminants (cancer, kidney disease, and disease from molybdenum exposure). No associations were reported as having been looked for in the PHA regarding Mill contaminants and some of the many illnesses reported (e.g. myelopathy, 7 cases of congenital defects, 22 cases of autoimmune disease, 45 cases of thyroid cancer, 7 cases of lymphoma, 12 cases of reproductive disorders, miscarriages, and chromosomal disease, to name a few).

Finally, a concern brought to EPA, CDPHE and ATSDR during this whole period is that the last cancer review was in 1995, 15-years ago, (published in 1998). Cancer often manifests years after exposure, sometimes decades. With contamination from the Cotter Mill still present in the community, these reviews should be conducted periodically, at least every 5-10 years.

Response:

ATSDR uses a process to decide how to address a community's health concern. The first step in the process is to determine to what chemical a person was exposed, the route of exposure, when were they exposed, and the duration of the exposure. With this background information, ATSDR then determines if the community's health concerns can be further addressed by conducting an epidemiological study. The scientific validity of the epidemiological study is based upon accurate exposure classification and appropriate study designs that can definitively demonstrate whether associations between exposure and health outcomes exist. Without both strong exposure and health information, a study is prone to misclassification and bias that would compromise the accuracy of the study results.

Accurate classification of historical exposures to contaminated groundwater in Lincoln Park would be challenging. The greatest levels of exposures in the population occurred many years ago. It would be very difficult to locate all former residents and to ascertain an accurate measure of the concentration, frequency, and duration of their past exposures. Environmental monitoring of the wells was conducted previously, but the results were inconsistent. Also, there are no records of well usage before the public water supply was installed.

According to the 2008 Lincoln Park Water Usage Survey, only a few people currently utilize water from the contaminated wells. Therefore, there is not a large enough sample size or statistical power to distinguish if health outcomes are a result of exposure or a chance occurrence. Without adequate statistical power, reported study could not reflect statistically significant associations, if they exist.

In conclusion, an epidemiological study in Lincoln Park would not be feasible due to poorly defined exposure histories and small sample size.

VII. CONCLUSIONS

Comment:

The stated purpose of the PHA is evaluate data on releases from Cotter to determine if there could be harm from those substances and recommend actions to protect public health. Conclusion 2 recommends that lead be revisited near the mill facility but the report does not tie lead to Cotter. Lead sources are likely from lead/zinc smelters nearby. Conclusion 3 recommends that residents limit use of well water for crops based on exposure to arsenic but the report does not tie arsenic to Cotter. Arsenic may be from lead/zinc smelters and/or from the practice of using arsenic insecticides for apple orchards.

Response:

ATSDR evaluates all chemicals - natural and man-made, site and non-site related - for exposure to and potential harm to human populations. Other potential sources of contamination at the site are noted in the document, when possible. However, it is beyond ATSDR's scope to definitely determine the source(s) of contamination.

Comment:

Conclusion 1 should note the Cotter connected houses using domestic wells in the area by a certain date. In addition, institutional controls have been in place through the State Engineer's office, and it was recommended by CDPHE that the Fremont County Commissioners establish a hazard zoning overlay for the contaminated groundwater area. Also, the statement that there is a public health hazard is not demonstrated. The report has not shown any evidence that exposure has impacted human health.

Response:

We added information regarding the institutional controls put in place through the State Engineer's Office and the Uranium Processing Accountability Act (2010).

ATSDR does not require unequivocal evidence that exposure has impacted human health to conclude that a specific exposure is a public health hazard. The process for making this determination is explained in *Appendix C: ATSDR's Evaluation Process*.

Comment:

Molybdenum in private wells has been a public health hazard. The family was not notified. Your conclusion is late, and molybdenum is not the only contaminant in Lincoln Park wells that can harm people's health. The PHA admits there is no testing for arsenic or anything other than uranium and molybdenum in nearly all private wells.

Response:

According to our assessment, molybdenum was the only detected contaminant that posed a risk to human health. Notification of individuals whose private wells contain contaminants above a health guideline was undertaken by the State; additional notifications may have occurred as recently as 2009 as a result of the 2008 well usage survey. Further private well sampling (e.g., expanding the range of chemicals analyzed) is warranted in light of the discovery of volatile organic compounds (VOCs) in groundwater in 2010. Follow-up on this recommendation/activity will be performed by the ATSDR Colorado Cooperative Agreement Program.

Comment:

The conclusion regarding eating and touching soil and sediment is confusing and contradictory in the way it is written. If true that eating soil near Cotter property will not harm health, then that should be equally true for all property near Cotter, developed or undeveloped. There are already residences and a business located on properties closest to the facility (e.g. the home approximately 200' north of Cotter property at the NW corner of the Shadow Hills Golf Course, the Shadow Hills Golf Course itself, and a number of residences bordering Cotter's northern boundary). To draw this conclusion, define what you mean by properties "closest to the facility," and explain how they differ from private properties already bordering Cotter's boundary.

Response:

ATSDR agrees that the statements were confusing and the location specifications were vague. We added information and maps to help clarify the statements.

Generally, we review land use patterns to evaluate potential exposures pathways and receptor populations. Land use at or near a site provides valuable information about the types and frequency of human activity and the probability for human exposure. Usually, a developed area (e.g., residential, industrial, mixed use communities) has more human activity than an undeveloped area.

Here, the areas between the Cotter facility and residential areas are described as "buffer zones," or primarily vacant areas. To investigate this delineation more closely, ATSDR produced Figure 18 to graphically depict the areas where soil samples were taken as part of the 1998 human health risk assessment (Weston) and the location of residential dwellings closest to the mill. Areas north, west and east of the site were divided into zones (A-H, and LP for Lincoln Park) and sampled. Zones F and H, which lie north and west of the site, contain the highest concentrations of lead (up to 800 ppm and 1,400 ppm respectively), and cadmium (up to 110 ppm and 51 ppm, respectively) in soil. Zone H also contains the highest concentration of arsenic (86 ppm) in soil. Zone H also contains residential properties. These are the properties closest to the facility, although properties north of the site are closest to the restricted area.

ATSDR revised this section in the document with more careful attention to the location of residential properties in area between the facility and Lincoln Park. We believe our revised discussion will clarify some of the more confusing portions of the draft document. We also strengthened our recommendation for sampling for lead in the area north and west of the facility since it is now confirmed that the area contains residential properties.

Comment:

Conclusion 3 about fruits and vegetables is contradictory. If produce irrigated with contaminated well water will not harm your most people's health (which has not been proven in my opinion due to not sampling produce from the most contaminated wells) then why would people be motivated to be cautious? This sends a mixed message with a predictable outcome where little caution will be taken.

According to the conclusion, if a person consumed 4 times the amount of vegetables as the average person they would have an increased risk of cancer over a life time. Considering the fact the average person in our country doesn't consume a fraction of the required amount of vegetables, I don't think this statement has much validity.

I recall one Lincoln Park newsletter that came out telling the citizens to only eat half the produce that they grow. How ludicrous is that? I ask you hypothetically, what if they eat the wrong half? A person should have the freedom to be able to grow their own produce

and eat as much as they want without having to worry that this could be the bite that gives them cancer.

Response:

ATSDR agrees that the statements are confusing. It's a very difficult message and we have revised the message in the document to do a better job of explaining it.

The commenter's statement regarding being told to eat only half of the produce they grow or to eat only a particular half of a fruit or vegetable is particularly troublesome. These statements are not grounded in any science and give the absolute incorrect message. It is a known fact that eating fruits and vegetables is health protective and improves a person's overall health. Therefore, we encourage people to eat as many homegrown fruits and vegetables as they like, but they should not use contaminated well water to water them. Since contaminants do not distribute in half of a fruit or vegetable and skip the other half, it is best for people to simply wash their homegrown fruits and vegetables and eat the whole thing.

Comment:

The other thing I would like to mention regarding consumption of fruits and vegetables is the assumption the report made that people will only eat produce 3-4 months out of the year. I know people who grow their gardens, can, and freeze or dehydrate the produce and eat that all year long.

Response:

ATSDR used EPA's Exposure Factor guideines when determining intake rates of homegrown fruits and vegetables for the Western United States. These guidelines account for the various eating habits of many people, including people who can, freeze, or dehydrate their produce and eating them all year long. ATSDR did not assume that people will eat product only 3-4 months out of the year. We conservatively assumed people would eat fruits and vegetables daily.

Comment:

Please specify what types of crops should be of most concern for bioaccumulation? This will go a great way in helping people be more cautious.

Response:

Please see Table 8 in the document.

Comment:

Regarding the conclusion about fruits and vegetables - with so many unknown variables impacting the calculation of the amount of contamination ingested, the opening sentence is misleading, leaving the impression that produce has been tested thoroughly and there's no

contamination problem. The HHRA III admitted that produce used in the study was not grown with water from the most contaminated wells. The HHRA III states, *"...exposure via ingestion of produce irrigated with contaminated water could be higher than calculated for current or hypothetical future residents who employ water from the most heavily impacted part of the plume for irrigation,"* (p. 6-2).

Response:

ATSDR used available data on fruits and vegetables. ATSDR had no input into the design of the referenced study, although there are usually (exposure-related) limitations associated with any study design. It is our opinion that advising people to not use water from contaminated wells to irrigate their crops should resolve any issue regarding contamination to fruits and vegetables from well usage.

VIII. RECOMMENDATIONS

Comment:

Recommendation bullet 2 in Section VIII recommends not using contaminated water for livestock yet there is no exposure pathway for livestock addressed in this section.

Response:

The 1989 and 2008 water use surveys identified private wells that are being used to provide water to livestock. In the 1989 survey, some of the contaminated private wells for personal consumption are also used to water livestock. (The 2008 survey does not allow ATSDR to know which wells are used for a specific purpose.) Therefore, a potential exposure pathway exists for livestock to be exposed to the same contaminants in private wells as humans.

IX. PUBLIC HEALTH ACTION PLAN

Comment:

ATSDR says that it *"will update the action plan for this site as needed. New environmental, toxicological, health outcome data, or implementing the above proposed actions may necessitate the need for additional or alternative actions at this site."* Please define the mechanisms that will insure that this will happen. How does ATSDR intend to keep itself in the loop with appropriate state and federal agencies?

Response:

ATSDR's Regional Office in Denver, Colorado and the ATSDR Colorado Cooperative Agreement Program will be responsible for initiating and implementing follow-up activities related to this site.

APPENDICES

Comment:

Figures 15 and 17 are unreadable as you come forward in years on the horizontal axes of the time scale. Because the concentration scale on the vertical axes is in mg/L, and the MCL goal is in ug/L, and the range of concentrations is so wide between the 1960's and 1982, and because there are a few very high concentrations in the earlier years, the graph is unreadable in later years, though there are wells above the MCL. A second graph, as a detail of the first, with a shorter time scale on the horizontal axes, using a ug/L concentration scale on the vertical axes, would be beneficial, making the changing data points visible, readable and comparable to the MCL goal. It would give a more honest representation of what we have faced in terms of time to reach remediation goals.

Response:

Figures 15 and 17 are included for trend analysis only, and should not be used to determine individual sampling results. Individual sampling results are available from many sources, including the CDPHE website. Figures 12 through 14 in this document depict concentrations of contaminants in some greater detail.

The vertical axes depict contaminant concentrations in mg/L to be consistent with groundwater units used throughout the document. To change the units to µg/L on just these figures would be confusing to readers.