State of Illinois
Illinois Emergency Management Agency

2016 Radiological Environmental Monitoring Report for Sheffield Low-Level Radioactive Waste Site

IEMA

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Executive Summary

The Illinois Emergency Management Agency (IEMA) is mandated with protecting the citizens and environment of Illinois from the potentially harmful effects of radioactive materials. To that end, the IEMA's Division of Nuclear Safety monitors the environs of several locations within Illinois for the presence of radionuclides. IEMA's radiological environmental monitoring program has three primary functions: 1) collection of diverse samples from carefully chosen locations on a routine basis, including simultaneous field surveillance; 2) analyzing samples for radionuclides; and 3) evaluation of test results on both an annual and historical basis. One of the locations monitored by IEMA is the Sheffield Low-Level Radioactive Waste (LLRW) disposal site near Sheffield, Illinois. The purpose of this report is to provide updated results of monitoring conducted at the Sheffield LLRW site during calendar year 2016; however, monitoring results from other time periods have been included for purposes of clarity or continuity.

The Sheffield LLRW site is located near the town of Sheffield, in Bureau County, Illinois. The site consists of a 20.4 acre disposal site and a 196 acre buffer zone. The LLRW site received radioactive waste between 1968 and 1978 when the disposal site reached capacity. Approximately 3.2 million cubic feet of waste was buried in 21 shallow earthen trenches.

The state of Illinois has conducted radiological environmental monitoring at the site since 1967. Since radioactive waste was disposed of in earthen trenches, monitoring of the ground water on and around the site has been the primary focus of the monitoring program. Radioactive contamination was found in ground water in the southeast quadrant of the disposal site in 1976. As a result, extensive geological and hydrological studies have been completed to gain a better understanding of the movement of contaminants away from the disposal trenches and to determine the best approach to monitor that movement.

It was discovered that two ground water pathways flow away from the site. The primary pathway exists under the northern two-thirds of the disposal site, and the secondary under the southern one-third. Both pathways flow in a generally northeastern direction, and eventually discharge into Trout Lake. IEMA's radiological monitoring efforts focus on the contamination levels along these two main pathways; however, careful monitoring is done in other areas both on site and off to ensure that the contamination is contained within the disposal site and buffer zone.

The performance of the Sheffield LLRW site is measured by its ability to isolate the radioactive waste from the surrounding environment; thus minimizing the potential for public exposure. The radiological environmental monitoring program at the Sheffield LLRW site is designed to evaluate the site's performance by monitoring radionuclide movement, or lack thereof, away from the site.

Regulatory or "trigger" limits for specific radionuclides are defined in a settlement agreement between the State of Illinois and the original owner and operator of the site US Ecology, known as the Sheffield Agreed Order (Agreed Order). Results from samples collected on-site are compared to these limits, and to historical data to determine compliance with the agreement and to evaluate the site's performance. Off-site samples are compared to the more stringent United State Environmental Protection Agency (USEPA) and Illinois Environmental Protection Agency (IEPA) drinking water standards. Drinking water standards are regulated by the USEPA and IEPA, IEMA's purpose for sampling private wells and public water supplies is solely to screen for the presence of radionuclides.

As part of IEMA's Sheffield LLRW radiological environmental monitoring program, samples are collected and analyzed for a variety of radionuclides. Sampling is conducted at both on-site and off-site locations and includes ground water, surface water, water from public water supplies, vegetation, sediment, and air samples. Additionally, monitoring for ambient gamma radiation is conducted around the site and buffer zone. Sample and monitoring results are compared to the appropriate regulatory limits, evaluated against historical data to monitor for changes at specific sampling locations, and used to evaluate the overall performance of the LLRW site.

In 2016, with the exception of tritium concentrations found in on-site ground water samples at Well H and off-site surface water samples at Lawson Creek, results from IEMA's radiological environmental monitoring program at the Sheffield LLRW site were consistent with historical data and expected contamination levels. Tritium results from samples taken at Well H, although still well below the Trigger limits set in the Agreed Order, continue to show a gradual increase in concentration. Well H is located south of the disposal site and is one of the southernmost wells routinely sampled by IEMA. Tritium concentrations detected at Lawson Creek in September 2016 were well below the regulatory standards, and had returned to less than MDC with the following quarter's sampling. IEMA will continue to monitor the concentrations at both locations.

Introduction

The Illinois Emergency Management Agency (IEMA) is charged with protecting the citizens of Illinois from the potentially harmful effects of radioactive materials. To that end, IEMA's Division of Nuclear Safety monitors the environment in Illinois for the presence of radionuclides. One of the locations monitored by IEMA is the area around the Sheffield Low-Level Radioactive Waste (LLRW) disposal site. Appendix A includes maps of the area around the Sheffield LLRW site, indicating the locations of IEMA sampling points.

History of the Site

The Sheffield LLRW disposal site is located approximately three miles southwest of the town of Sheffield in Bureau County, Illinois. The town of Sheffield is about 120 miles west-southwest of Chicago, situated approximately midway between Peoria and Moline/Rock Island, just south of Interstate 80. The facility began disposing LLRW in 1967 and closed in 1978 upon reaching capacity. The LLRW disposal site includes 3.2 million cubic feet of LLRW buried in 21 shallow earthen trenches on 20.4 acres.

The state of Illinois began conducting an environmental monitoring program at the LLRW site in 1967. Between 1967 and 1980, the program was conducted by the Illinois Department of Public Health (IDPH). Since October 1980, the Illinois Emergency Management Agency (IEMA; formerly the Illinois Department of Nuclear Safety (IDNS)) has managed the monitoring program. Results of monitoring conducted between 1967 and 1988 were reported by IDNS in February 1991 (IDNS 1991), and the results of monitoring during 1989 and 1990 were reported in June 1992 (IDNS 1992). The June 1992 report also described features of the site including meteorological and hydrological factors that control the concentrations of radioactive contaminants in ground water and surface water.

Of note, in 1976 radioactive contamination was observed in ground water in the southeast quadrant of the original 20.4-acre disposal site. As a result, ongoing studies of the geology and hydrology of the site were expanded by both the Illinois State Geological Survey (Heigold and Larson 1984) and the United States Geological Survey (USGS) (Foster et al. 1984). These studies were designed to determine the best approach for monitoring the movement of the radioactive contamination in the ground water.

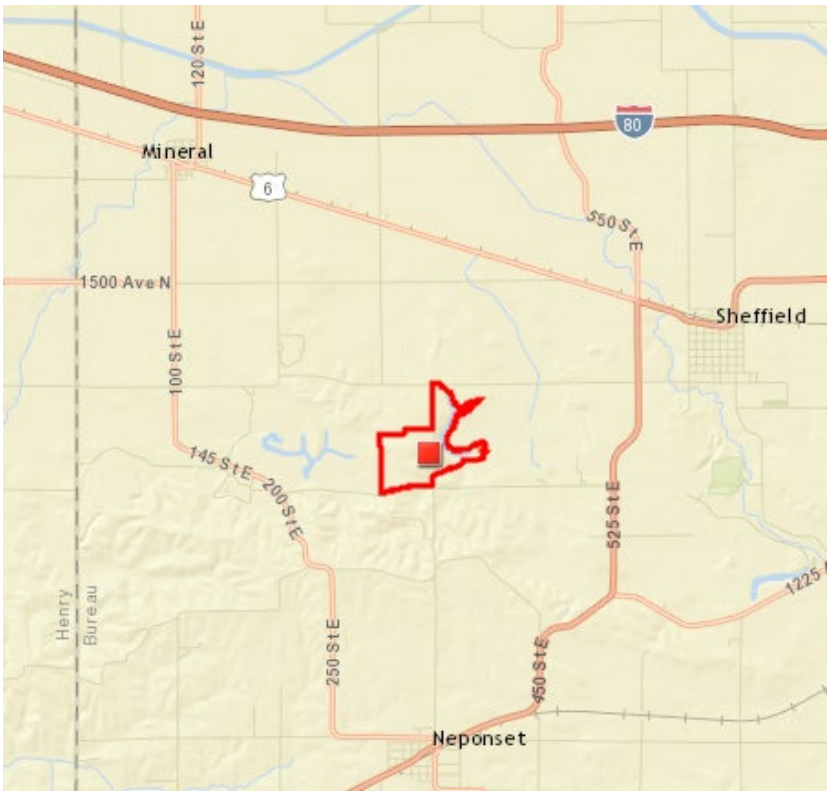
Since disposal of LLRW took place in earthen trenches, the major monitoring effort has been directed toward detecting radioactive contamination of ground water. Samples are analyzed for a variety of radionuclides. These radionuclides may emit alpha particles, beta particles, and/or gamma rays. The type of radioactive emission determines the type of analysis required to detect a radionuclide.

The performance of a LLRW site is measured by its ability to isolate the radioactive waste from the surrounding environment. The environmental monitoring program at the Sheffield LLRW disposal site is designed to evaluate the site's performance as defined above by monitoring radionuclide movement, or lack thereof, away from the site and into pathways of possible human exposure.

Description of the Sheffield LLRW Disposal Site

The Sheffield LLRW disposal site is located on rolling glaciated terrain in northcentral Illinois in Bureau County. The location of the site is shown in Figure 1. More detailed site maps and sampling locations are located in Appendix A.

Figure 1. Location of Sheffield Low-Level Radioactive Waste Disposal Site
(Disposal Site indicated by red square on the map. Buffer Zone is outlined in red.)



The area near the LLRW site is sparsely populated with less than 20 residences within a two mile radius. Sheffield, with a population of 926 (2010 Census), is three miles to the northeast. The unincorporated town of Mineral, population 237 (2010 Census), is five miles to the northwest; the town of Neponset, population 473 (2010 Census), is three miles south of the site.

The 20.4-acre disposal site contains 21 disposal trenches, varying from 8 to 25 feet deep. A 196-acre buffer zone surrounds the site which includes a small lake called Trout Lake (previously known as Strip Mine Lake and Barbed Wire Lake) and a small stream to the south and southeast. The facility was licensed to accept radioactive waste in August 1967, began disposing waste in 1968, and closed in 1978 after the shallow land burial trenches were filled with LLRW.

A precise inventory of LLRW buried in each trench was not kept by the site operator, but has been estimated in three separate studies (NUS 1979; Dragonette et al. 1979; MacKenzie et al. 1985). The estimated inventory of radionuclides is listed in Table 1.

Table 1. Maximum Values Estimated in the Sheffield Inventory
(Important Radionuclides with Half-Lives Greater than Five years)

Radionuclide	Curies	Half-Life (Years)
Tritium (H-3)	5,990	12.35
Carbon-14 (C-14)	450	5,730
Iodine-129 (I-129)	0.01	15,700,000
Strontium-90 (Sr-90)	3,690	28.1
Cesium-137 (Cs-137)	15,500	30
Cobalt-60 (Co-60)	20,000	5.27
Plutonium-238 (Pu-238)	7.5	87.74
Plutonium-239 (Pu-239); Plutonium-240 (Pu-240); Plutonium-241 (Pu-241)	4,870	24,065; 6,550; 14.4
Am-241	137.5	432

Two hazardous waste disposal areas are located to the north and northwest of the LLRW disposal site and are separated from it by at least 150 feet. These areas were used for the disposal of non-radioactive hazardous chemical waste. The first area accepted waste from 1968 to 1974 and the second area from 1974 to 1983.

The U.S. Environmental Protection Agency (USEPA) and the Illinois Environmental Protection Agency (IEPA) are the primary agencies responsible for regulation of the adjacent hazardous chemical waste sites. The site operator is working with USEPA and IEPA to remediate these sites and the surrounding area.

As part of this remediation effort, a single set of samples were collected during 1988 by SAIC, a US Ecology contractor, and analyzed for radionuclides as well as chemical contaminants. The results of this set of samples indicated extensive contamination of ground water to the northeast of the LLRW site (SAIC 1988). Ground water in this area contains tritium (hydrogen-3 or H-3, is a radioactive form of hydrogen that decays via beta emission) as well as a variety of chemical contaminants. Since tritium is chemically identical to non-radioactive hydrogen, it is readily assimilated into water (that is, one or both of the "Hs" in H_2O can be tritium, a form called "tritiated water"). This causes tritium to be very mobile in the natural environment. Tritium's half-life is 12.3 years, which means it will persist in the environment for about 100 years.

Hydrology of the Sheffield LLRW Disposal Site

The Sheffield LLRW site and its surrounding buffer zone are located on rolling glacial terrain. The shallow local aquifer is comprised of saturated glacial sediments and is isolated from the deep regional aquifer by a 450-foot sequence of Pennsylvanian shale bedrock. The piezometric surface of the glacial aquifer generally conforms to topographic drainage systems with gradients nominally trending west to east.

Northeast Pathway

The primary flow path for radiologically contaminated ground water begins in a pebbly sand deposit that exists under the northern two-thirds of the disposal site. This relatively permeable unit (Toulon Member of the Glasford Formation) extends to the northeast where it constricts, filling a narrow outwash channel in the bedrock surface. This narrow channel, filled with deposits of saturated sand and gravel, extends from the northeast portion of the LLRW site to Trout Lake.

Because the northeast pathway is the principal route for contaminants leaving the LLRW site, considerable effort has gone toward understanding radionuclide movement in this area. Monitoring wells in this pathway include 563, 575, 577, and 600. The ground water in these wells emanates from the continuous deposit of relatively permeable sand and gravel that underlies the northern two-thirds of LLRW site. This deposit of coarse grained soils narrows and extends in a northeasterly direction terminating along the western shore of Trout Lake. The above-cited wells are used to sample contaminated ground water as it moves through this narrow outwash channel from beneath the LLRW site.

Of the more than 100 ground water monitoring wells throughout the entire buffer zone, the most highly contaminated are in the northeast pathway. These wells run along a line originating near the eastern edge of the LLRW site and extend about 900 feet in a northeasterly direction.

Southeast Pathway

A second ground water pathway extends from under the approximate southern one-third of the LLRW site into the valley to the south and southeast. Unlike the northeast pathway, there is no continuous, spatially concentrated deposit of relatively permeable, coarse grained soils in the southeast pathway. Because of this, ground water flow velocities and volumes are relatively reduced, lessening the potential for movement of significant quantities of radiological contamination away from the disposal site. Consequently, areas of contamination are less extensive and contaminant concentrations are significantly less than those observed in the more permeable northeast pathway. Like the northeast pathway, the vast majority of radiological contamination moving along this pathway ultimately discharges into Trout Lake.

Monitoring wells in this pathway include 512, 525, 567, 602, and TB. The most highly contaminated wells in this pathway are 512 and 602. These wells are located in the buffer zone between the southeast corner of the LLRW site and the small stream (South Creek) located about 300 feet farther to the southeast. Due to equipment malfunctions, IEMA was not able to obtain samples from Well 512 between 2013 and 2016.

Settlement Agreement

In 1979, site operator US Ecology attempted to abandon the LLRW site, unilaterally terminating its US Nuclear Regulatory Commission and IDPH licenses and state lease. This led to investigations which revealed that there were faulty trench caps. Both state and federal regulators objected to the unilateral terminations, arguing that the site operator must first safely close the site before terminating either of the licenses. This resulted in both federal and state litigation. The federal litigation was administratively argued before the Atomic Safety and Licensing Board, which eventually ruled against the operator on all counts.

The state's complaint was argued before the Bureau County Circuit Court. After ten years of negotiations, in May 1988, the state of Illinois and US Ecology came to an agreement and the litigation was resolved in the form of a settlement agreement known as the Sheffield Agreed Order (Agreed Order).

The Agreed Order specified what the site operator must do to safely close the site and assure its continuing safety into the future. Provisions and consequences of the agreement have had a significant impact on the scope of the monitoring program. The closure plan for the site has four basic parts:

1) The operator agreed to install a new, low-permeability clay cap over all the waste trenches. The purpose of the cap is to significantly reduce the amount of radioactive material moving away from the site, reducing the potential for movement of radioactivity beyond the buffer zone.

2) The operator agreed to purchase a buffer zone around the site. The 196-acre buffer zone is designed to contain, delay, and dilute any contaminants leaching from the waste. This helps to ensure that any

discharges beyond the buffer zone are below the limits for release into unrestricted areas. Fences surrounding this zone were to be installed and maintained by the operator (See Figure A-1 in Appendix A).

3) The operator agreed to monitor and maintain the site and buffer zone until 1998, as well as establish a long-term care fund to pay for IEMA (formerly IDNS) maintenance and monitoring beyond 1998.

4) If radionuclides are discovered outside the buffer zone in concentrations equal to or exceeding the limits for release to unrestricted areas (see Table 2), the operator must remedy the situation at its expense or pay the state an additional $1.9 million.

Table 2. Regulatory Limits in Water for Selected Radionuclides

Trigger / Regulatory Limits in Water for Selected Radionuclides Per the Settlement Agreement of 1988		
Radionuclide	Half-Life	Limit in Water (picocuries per Liter)
H-3	12.35	3,000,000
C-14	5,730	800,000
I-129	15,700,000	60
Sr-90	29.12	300
Cs-137	30	20,000
Co-60	5.27	50,000
Pu-238	87.74	5,000
Pu-239	24,065	5,000
Am-241	432	4,000

In 1989, a new cap consisting of 4.5 feet of highly compacted clay and 6 inches of vegetated topsoil was installed. The cap is designed to significantly reduce the amount of precipitation that can infiltrate the trenches and mobilize the waste. As part of the effort to install the cap, a number of onsite monitoring wells, sump risers, and piezometers adjacent to the waste trenches were sealed and are no longer accessible. The new cap and its immediately surrounding area are inspected regularly by IEMA and US Ecology personnel for proper vegetative cover and evidence of erosion or burrowing animals. As part of the settlement agreement, the operator has committed to immediate repairs to damaged areas.

In 2008, IEMA had the cap surveyed to estimate if subsidence is occurring over the trench area and to assess if precipitation will drain from the site or pond on the surface. The survey concluded subsidence, if any, was minimal and the cap is draining as expected.

The Agreed Order defined terms that are only applicable to the Sheffield LLRW site, such as a "signaling event". A "signaling event" is defined as the occurrence within the Buffer Zone of any one of several events described in detail in the Agreed Order. In 1990, IDNS declared a "signaling event", because sampling and analyses detected that tritium had exited Trout Lake and the Buffer Zone Boundary. While the declaration of a signaling event does not indicate a threat to public health and safety, it serves as an official notice to the operator that events have occurred that may require attention and remedial action.

In accordance with the Agreed Order, the company was required to meet specified financial conditions or post letters of credit. The company did not meet the financial tests and did not post the required letters of credit in either 1996 or 1997. Due to the company's breach of the Agreed Order, in November 1997 the state brought suit in Bureau County to require the company to remain at the site and continue to provide site maintenance after May 1998. In April 1998, the Court ruled that the company was in breach of the agreement and could not turn the site over to the state in May 1998. The court encouraged the parties to settle remaining issues. The parties entered into an addendum to the 1988 agreement called the 1999 First Supplement, which requires the company to remain at the site until it has satisfied the financial conditions of the agreement, modifies some site monitoring requirements, and provides for transfer of private insurance for the site. Pursuant to the First Supplement, U.S. Ecology satisfied all its financial conditions in June 2001, and at that time the state took ownership of the LLRW site.US Ecology remains responsible for certain remedial actions at the facility should any become necessary. The company's liability for such an occurrence is limited to $1.9 million and expires in 2038. The state may take possession of the buffer zone at any time for a nominal fee, but must take ownership when the Agreed Order expires.

Tritium Migration

With historical failure of the individual trench caps, subsidence, and water in the trenches, it could be expected that leachate migration might ensue. IDPH began monitoring the Sheffield site in 1967, and when the opportunity arose in the form of a study proposed by the Illinois State Geological Survey (ISGS) to evaluate possible migration from the non-radioactive chemical waste site to the west, IDPH requested that the study ascertain whether chemical pollution from the "old" chemical site had entered state land and whether horizontal migration of radioactive waste occurred in the disposal trenches. In 1981, verifiable tritium was found offsite and off US Ecology property in well 563, leading to the idea of the buffer zone. Tritium was migrating across the site in concentrations that were measureable but well below levels considered to be a threat to public health. As a result of the discovery of migrating tritium, geology and hydrology studies were performed by both the Illinois State Geological Survey (Heigold and Larson, 1985) and the United States Geological Survey (Foster et al., 1984).

IEMA Radiological Environmental Monitoring Program

The IEMA Radiological Environmental Monitoring program for the Sheffield LLRW site consists of sample collection and laboratory analysis, as well as review and analysis of the resulting data. Sample collection includes obtaining samples from both on-site locations (including the site and the buffer zone), and off-site locations (such as creeks and streams beyond the buffer zone, and Public Water Supplies in the area). A general description of sample collection and sample analysis follows, with results tables located in Appendix D. Results may be divided into separate tables representing on-site and off-site results, or may be combined into one table delineating on-site and off-site results.

Sample Collection

Surface water, drinking water, and ground water are sampled quarterly.

Air particulate samples are collected by a continuously running low-volume sampler near the cap and analyzed weekly.

Vegetation samples are collected during the second and third quarters of the year and analyzed for radionuclides that may have been transported from the environment and incorporated into plant tissue.

Sediment samples are collected during the second and third quarters of the year and analyzed for radionuclides that may have settled out of solution or suspension.

Measurements of direct gamma radiation are collected and analyzed quarterly using optically-stimulated luminescent dosimeters (OSLs) placed around the LLRW site.

IEMA makes every effort to collect all scheduled environmental samples; however, occasionally samples are unobtainable due to weather conditions, water levels, or obstructed access.

Laboratory Analysis

Sediment, vegetation, water, and air samples are analyzed by the IEMA Radiochemistry Laboratory located in Springfield. The laboratory uses standard published radioanalytical procedures and participates in semi-annual proficiency testing programs through Environmental Resource Associates, an accredited proficiency testing provider, and the Department of Energy (DOE) Radiological and Environmental Science Laboratory's Mixed Analyte Performance Evaluation Program (MAPEP).

Gross alpha/beta: Since the radionuclides in the disposal trenches emit either alpha or beta particles, water and air samples are analyzed for total alpha and beta radioactivity. This provides a good method of screening samples for the presence of radioactive material.

- All air samples are analyzed for gross alpha/beta concentration.
- Gross alpha/beta analysis is performed on water samples at least once per year from each routine sampling location.

Tritium and Carbon-14: Tritium and carbon-14 emit low energy beta particles, the beta energies are too low to be detected by ordinary analytical methodologies for evaluating gross beta activity. To measure the concentration of tritium and carbon-14, water samples are analyzed using liquid scintillation counting, a technique that is capable of measuring radioactive emissions at very low energies and very low concentrations.

- All water samples collected are analyzed for tritium concentration
- Carbon-14 analysis is performed on water samples at least once per year from each routine sampling location.

Total Strontium: Strontium is easily masked by other radionuclides, including those which are naturally occurring. Therefore, samples being analyzed for Total Strontium undergo preliminary chemical separation so that the strontium may be isolated for analysis.

- Total Strontium analysis is performed on water samples at least once per year from each routine sampling location.

Gamma: Gamma emitting radionuclides (Americium-241, Cobalt-60, and Cesium-137) are analyzed using a high-purity germanium detector in a process called gamma spectroscopy, which allows the identification of individual radionuclides.

- Gamma spectrometry analysis is performed on water samples at least once per year from each routine sampling location.
- Gamma spectrometry analysis is performed on all vegetation and sediment samples.

All analytical methods have limitations: amounts that are just too small to be detected. Each measurement technique has its own minimum detectable concentration (MDC) which is the smallest quantity of radioactive material per unit volume that can be detected reliably. An MDC is a function of the limitations of the nuclear counting equipment, the volume/weight of sample used, chemical separation techniques, and ambient natural background radiation present in the laboratory. The MDC is an "a priori" measure of these limitations – an estimate of the lower limit of detection. It is defined as the smallest quantity that an analytical method has 95% likelihood of detecting. For example, the MDC for IEMA's method for tritium in water is 200 pCi/L. Given a sample with a tritium concentration of 200 pCi/L, tritium would be detected approximately 95 times out of 100. Samples with concentrations less than 200 pCi/L could be detected, but with less certainty. Conversely, samples with concentrations higher than 200 pCi/L would be more likely to be detected, approaching 100% as concentrations increase.

Radiological Environmental Monitoring Results

The environmental monitoring program is designed to evaluate the environment in general and site performance specifically by monitoring the movement, or lack of movement, of radionuclides, and subsequently determine any potential for public exposure to radionuclides. On-site and off-site monitoring locations are shown in Appendix A, and results of sample analysis are shown in Appendix D.

On-Site Ground Water Sampling

Since the waste at the Sheffield facility is buried in shallow earthen trenches, the major emphasis of the environmental monitoring program involves the sampling and analysis of ground water. Although the new cap was constructed in 1989, the ground water travel time from the site to downstream monitoring wells is on the order of a few years (Garklavs and Toler, 1984). IEMA continues to monitor ground water through wells around the cap and in the buffer zone. As discussed in the Hydrology section of this report, there are two major pathways of ground water flow from beneath the site, the northeast and southeast pathways. The vast majority of ground water in both pathways eventually discharges into Trout Lake.

Considerable effort has gone toward describing radionuclide concentrations in the northeast pathway wells. Before the site was recapped, the factors which influenced these concentrations were:

- Precipitation on the disposal site;
- Condition of the trench caps during this precipitation; and
- Precipitation in other areas which also recharged the pathway wells.

These factors worked interdependently to affect concentrations observed at a given time in each well. Variations in precipitation on the LLRW disposal site resulted in variable amounts of moisture available for transport of tritium. When tritium was transported to ground water in the vicinity of a monitoring well, it was diluted by local precipitation. When combined, these variables resulted in a cyclical pattern of tritium concentrations in many of the northeast pathway wells. Since the installation of the new cap, it is expected that the leaching of contamination from the trenches will be minimized and the vast majority of contamination reaching the monitoring wells was in the saturated zone prior to the installation of the new cap. The only remaining factor which drives changes in contaminant concentration in monitoring wells is the precipitation in areas which recharge the wells.

Gross alpha/beta screening results for on-site ground water sampling locations appear in Table D.1. Results show that several sampling locations had gross alpha and/or gross beta concentrations above the set MDCs. Occasional sample results with gross alpha or gross beta concentrations above the MDC are consistent with historical data. No wells had results consistently above the MDC.

Tritium results for on-site ground water sampling locations are shown in Table D.2. Results indicate that all wells sampled within the Northeast and Southeast pathways had tritium concentrations above the established MDCs. Concentrations above MDC are expected from these sampling locations due to the flow of water through the pathways away from the disposal site, and are consistent with historical data. The general trend in tritium concentrations found on-site is decreasing. However, results from samples taken in 2016 at Well H were above the MDC and continue a trend of increasing tritium concentration at that well. All results were below the 3,000,000 pCi/L Triggering Limit set in the Agreed Order.

Gamma spectrometry results for on-site ground water sampling locations are shown in Table D.4. Results indicate no concentrations above the set MDCs.

Carbon-14 results for on-site ground water sampling locations are shown in Table D.4. Results indicate the presence of carbon-14 in concentrations above the established MDC in several on-site wells. All wells with carbon-14 concentrations significantly above the MDC are located within the known contaminated areas along the Northeast or Southeast groundwater pathways or on or near the disposal site cap. All results were well below the 300,000 pCi/L Triggering Limit set in the Agreed Order.

Total Strontium results for on-site ground water sampling locations are shown in Table D.4. Results indicate that Well 567 and Well 569 had a Total Strontium concentration slightly above the MDC. The concentrations were well below the 300 pCi/L Triggering Limit set in the Agreed Order. All other locations had results below the established MDC.

Appendix B provides a graphical depiction of tritium (H-3) results from on-site ground water sampling locations. The graphs include historical results for those sites, which are included to display the overall trends of tritium concentration over time. Additionally, the graphs show the MDC, as well as, the highest recorded tritium concentration as a percentage of the samples respective regulatory limit (3,000,000 pCi/L).

On-Site Surface Water Sampling

Surface water samples are taken quarterly from three different locations in Trout Lake and one from South Creek. Concentrations at the different sampling locations appear to depend on the following variables:

- Concentration of water from the springs;
- Amount of runoff from surrounding areas;
- Volume, if any, of lake discharge to the Lawson Creek tributary; and
- Presence or amount of ice on the lake.

Gross alpha/beta screening results for on-site surface water sampling locations appear in Table D.1. Results show that three surface water sampling locations at Trout Lake had gross beta concentrations above the set MDCs. Occasional sample results with gross alpha and/or gross beta concentrations above the MDC are consistent with historical data.

Tritium results for on-site surface water sampling locations are shown in Table D.2. Results from the South Creek and the Lunchroom Tap sampling location were below the MDC. Trout Lake sample results indicated concentrations above MDC. Concentrations above MDC are expected from these sampling locations due to the flow of water through the groundwater pathways into Trout Lake, and are consistent with historical data. All results were below the 3,000,000 pCi/L Triggering Limit set in the Agreed Order.

Gamma spectrometry results for on-site surface water sampling locations are shown in Table D.4. Results indicate no concentrations above the set MDCs.

Carbon-14 and Strontium results for on-site surface water sampling locations are shown in Table D.4. Results indicate no concentrations above the set MDCs.

Appendix B provides a graphical depiction of tritium (H-3) results from on-site surface water sampling locations. The graphs include historical results for those sites, which are included to display the overall trends of tritium concentration over time. Additionally, the graphs show the MDC, as well as, the highest recorded tritium concentration as a percentage of the samples respective regulatory limit (3,000,000 pCi/L for).

Off-Site Water Sampling

Drinking water samples are taken from offsite locations in the Sheffield area to assure that there is no impact to local water supplies. The Public Water Supplies (PWS) limits for radionuclides are based upon the U.S. Environmental Protection Agency (USEPA) and Illinois Environmental Protection Agency's (IEPA) drinking water standards. The US EPA drinking water standard (National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels, 2000) and the IEPA groundwater standard (Groundwater Quality Standards for Class I: Potable Resource Groundwater, 2013) both set the limit for tritium in groundwater at 20,000 pCi/L. Appendix C includes tables of historical data for tritium concentrations in off-site sampling locations, and the graphs show that the highest recorded concentration as a percentage of the drinking water standard for tritium of 20,000 picocuries per liter (pCi/L).

The following offsite locations are sampled on a regular basis:

- Lorenson Farm well
- Neponset public water
- Sheffield public water system
- Lawson Creek*
- Hossetter Lake
- Lorenson Farm Creek
- Mineral public water system
- Pencock Hill water system

The locations of these sampling points are shown in Figure A.5.

*Effluent from Trout Lake flows along an unnamed tributary of Lawson Creek to the creek itself. Lawson Creek monitoring results are important because they represent the only contaminated surface water flow path crossing the buffer zone boundary.

Gross alpha/beta screening results for off-site water sampling locations appear in Table D.1. Results above the MDC for gross alpha and/or gross beta were seen at the Mineral, Neponset, and the Pencock Hill PWS. Mineral and Neponset public water systems are supplied through ground water aquifers and Pencock Hill through a private ground water well. There is no treatment technologies for the removal of radium used at any of these locations. Therefore, it is likely that the increase in gross alpha/beta concentration is a result of natural radium in the water supply.

Tritium results for off-site water sampling locations are shown in Table D.3. Sample results from water collected in September 2016 at Lawson Creek show a tritium concentration in excess of the MDC. Samples collected in the following quarter indicate that the tritium concentration levels had returned to less than the MDC.

Gamma spectrometry results for off-site water sampling locations are shown in Table D.4. Results indicate no concentrations above the set MDCs.

Carbon-14 and Total Strontium results for off-site water sampling locations are shown in Table D.4. Results indicate no concentrations above the set MDCs.

Appendix C provides a graphical depiction of tritium (H-3) results from off-site water sampling locations. The graphs include historical results for those sites, which are included to display the overall trends of tritium

concentration over time. Additionally, the graphs show the MDC, as well as the highest recorded tritium concentration as a percentage of the samples respective regulatory limit (20,000 pCi/L).

Sediment Sampling

Samples of sediment are taken to determine whether contaminants previously in solution or suspension have settled out of a body of water and, therefore, cannot be identified by water sampling. Sediment sampling results from on-site sampling locations at Trout Lake and South Creek are shown in Table D.6. An off-site location at Lawson Creek has historically been sampled for sediment, but was not accessible for sampling in 2016 due to overgrown brush. IEMA is working with the local township to get the brush cleared to allow access to the sampling point.

Results from sediment sampling indicate the presence of Cesium-137. Cs-137 activity was seen in on-site sediment samples at levels equal to, or just above the established MDC. Historically, environmental sediment samples have contained Cs-137 concentrations ranging from 0.1-0.2 pCi/g as a result of atmospheric nuclear weapons testing.

Vegetation Sampling

Vegetation samples are taken to determine the degree of any bioaccumulation of radionuclides. Two composite samples were taken from the cap during the monitoring period, and two vegetation samples were collected near Trout Lake. Sampling results are shown in Table D.7.

Results from vegetation sampling indicate no radionuclides attributable to activities at the LLRW disposal site.

Air Monitoring

An air monitoring station is located near the northeast quadrant of the site. This sampler continuously collects particulates on a glass fiber filter. Filters are analyzed weekly for gross alpha and beta activity. Results vary seasonally, but compare well with other control locations within the state. Sample results are shown in Table D.8.

Air sampling results are similar to those seen at the background monitoring locations located in Springfield and Marion, IL.

Direct Radiation

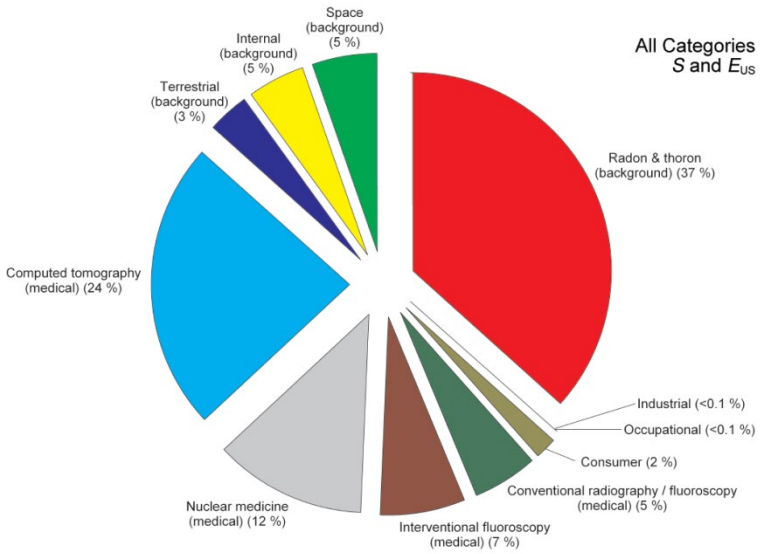
Unlike the environmental samples described above, dosimeters do not provide information on what radionuclides are found in the environment. Instead, dosimeters provide a direct measurement of the total dose produced by all sources of gamma radiation, including naturally occurring radionuclides and cosmic rays. The dosimeters are arrayed around the perimeter of the Sheffield site and are exchanged and analyzed quarterly. IEMA performs the analysis of the dosimeters. The dosimeters are used to monitor for small changes in ambient background levels of gamma radiation that could result from releases of radioactive material.

Table D.9 shows results for environmental dosimeters analyzed during 2016. In addition to the quarterly results, which are expressed as the average milliroentgen per quarter (mR/quarter), these results are used to calculate the approximate milliroentgen per year (mR/year) that would have been accrued by an individual at that location for an entire year. Those numbers can be compared to the average annual radiation exposure to an individual of 620 mR/year from various sources (according to the 2009 National Council on Radiation

Protection's Report 160). Approximately 8% (49.6 mR/year) of that exposure is from terrestrial and cosmic radiation (background radiation), Figure 2.

Results from direct radiation monitoring are similar to results found at background monitoring locations.

Figure 2. Sources of Radiation Exposure to Man



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Background Sampling Locations

IEMA has established the environs of Sangchris Lake State Park, a cooling lake for a coal-fired power station near Kincaid, IL, as the background sampling location for water, sediment, and vegetation samples. Air monitoring stations in Springfield and Marion, IL are used for background monitoring locations for air samples. To establish "background" radiation levels, samples are collected and analyzed utilizing the same procedures and methodologies used for the Sheffield LLRW site samples.

Results for background samples can be found in Appendix E.

Summary

Due to the original design of the disposal site, the flow of groundwater away from the site, and the radionuclides disposed of; the presence of radiological contamination at the disposal site and within the buffer zone is known to exist and is expected. Contaminants from the LLRW disposal operations were observed in ground water at the disposal site, as well as within groundwater and surface water collected from the buffer zone. Detectable concentrations of tritium were observed at many on-site sampling locations, with wells located along the ground water pathways containing the highest concentrations. Carbon-14 and Total Strontium concentrations above the MDC were detected within some on-site monitoring wells. Gross alpha and gross beta concentrations above the established MDC were seen intermittently in on-site ground water samples. Gamma Spectroscopy results from vegetation sampling indicate no radionuclides attributable to activities at the LLRW disposal site. Sediment samples analyzed using gamma spectroscopy, show only

concentrations of radionuclides attributable to fallout from atmospheric nuclear weapons testing several decades ago.

Contaminants attributable to the LLRW site were found in one sample collected from off-site locations in 2016. The Lawson Creek sampling location had a detectable amount of tritium in the third quarter of the year. The fourth quarter sample taken from that location indicated that the tritium levels had returned to less than the MDC. Gross alpha and gross beta concentrations above the established MDC were seen at three off-site PWS locations. However, the elevated concentrations are likely due to natural radium in the ground water supply. Tritium, carbon-14, Total Strontium, and gamma concentration in off-site samples were all below the set MDCs.

Results from air sampling were similar to those seen at background air sampling locations in Springfield and Marion, IL. Direct radiation measurements are typical of levels found at the background location established by IEMA, and are similar to historical levels found at the LLRW site.

In 2016, with the exception of tritium concentrations found in on-site ground water samples at Well H and off-site surface water at Lawson Creek, results from IEMA's radiological environmental monitoring program at the Sheffield LLRW site were consistent with historical data and expected contamination levels. Tritium results from samples taken at Well H, although still well below the Trigger limits set in the Agreed Order, continue to show a gradual increase in concentration. Well H is located south of the disposal site and is one of the southernmost wells routinely sampled by IEMA. Tritium concentrations detected at Lawson Creek in September 2016 were well below the regulatory standards, and had returned to less than MDC with the following quarter's sampling. IEMA will continue to monitor the concentrations at both locations.

Appendix A
Maps of IEMA Monitoring Locations for the Sheffield LLRW Site

Figure A-1. Sheffield Site and Approximate Groundwater Pathways

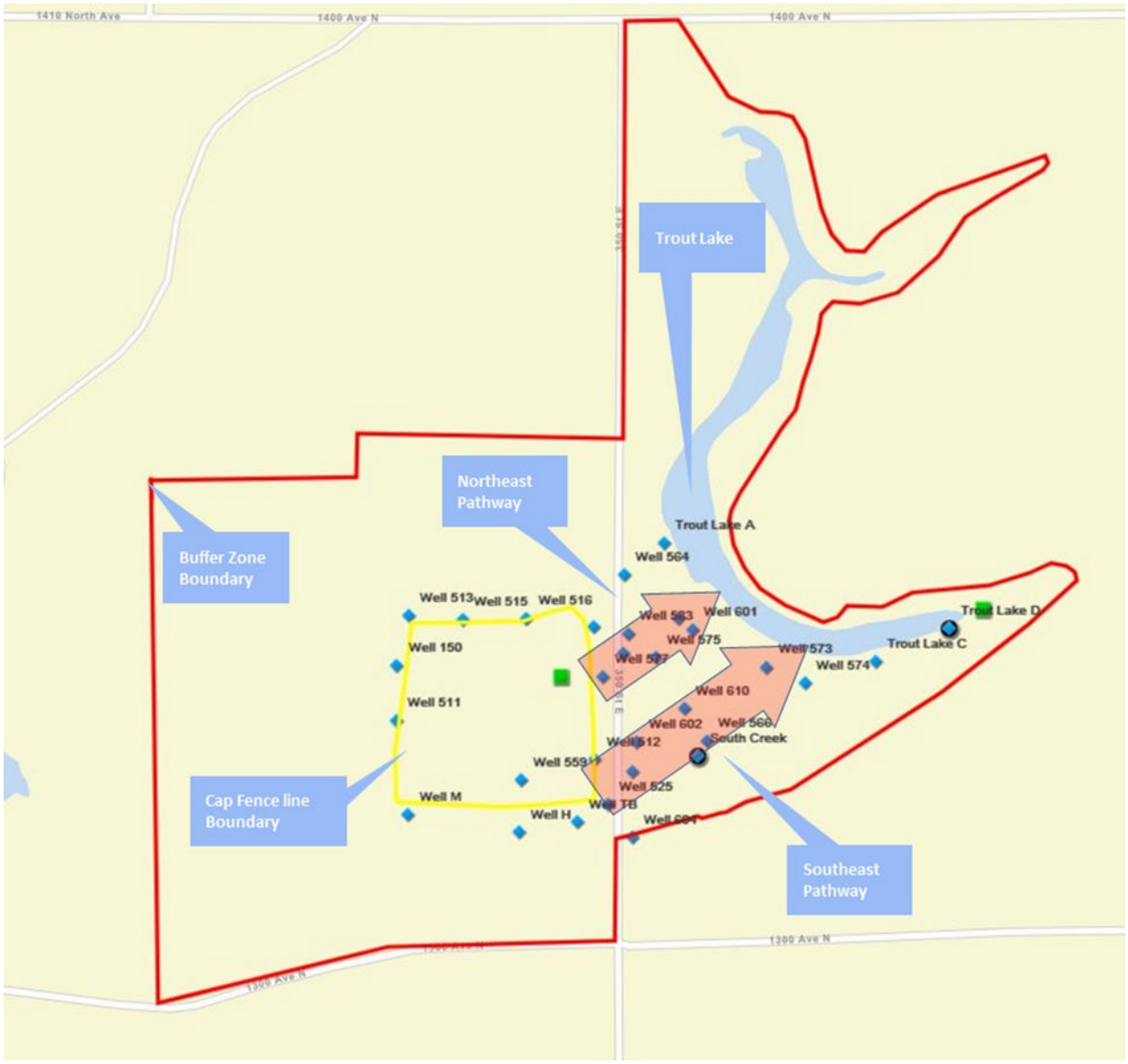
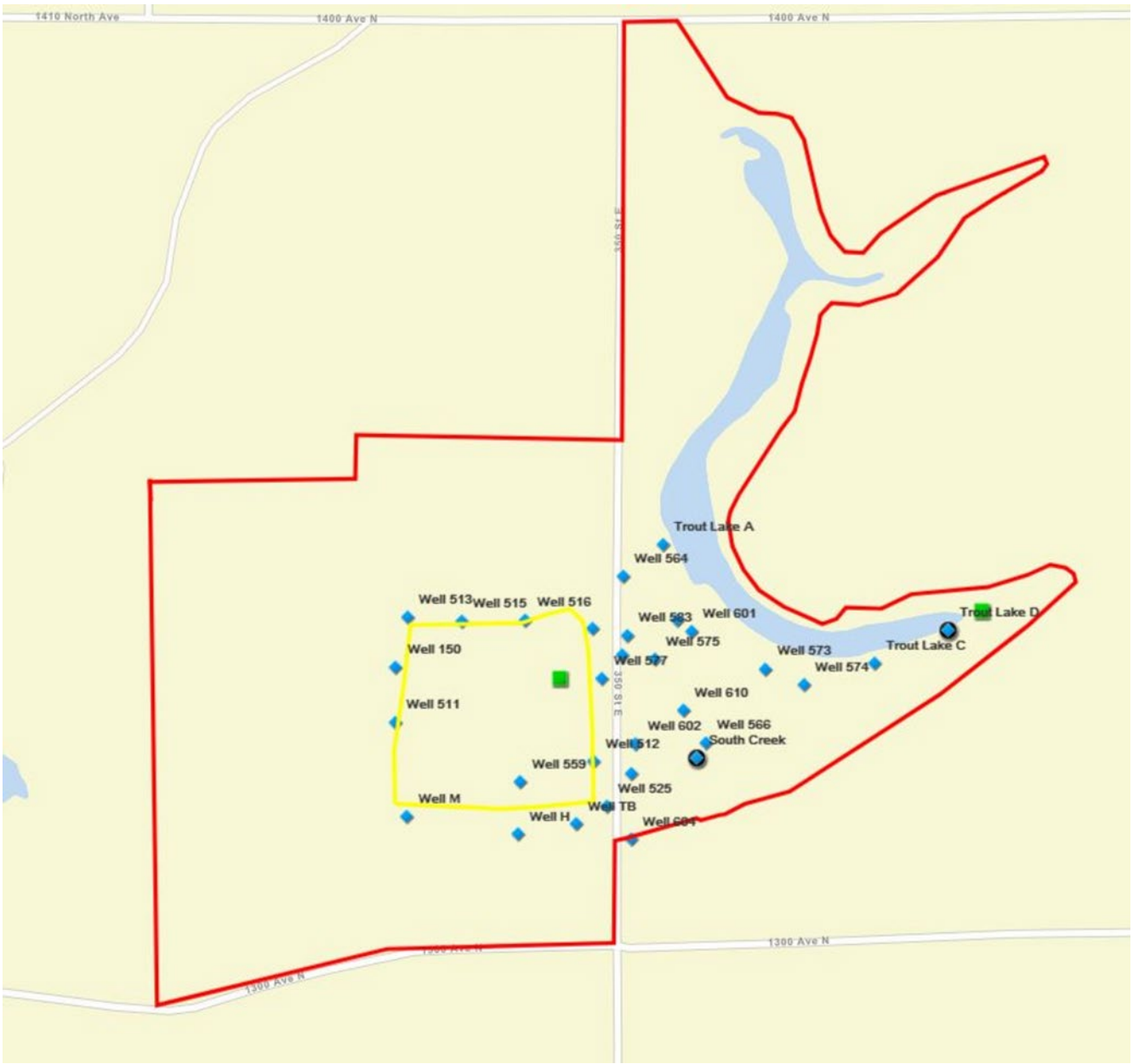


Figure A-2. Sheffield On-Site Sampling Locations



Map Key:

- OSL*
- Air Sampler
- Vegetation
- Sediment
- Water

* OSL = Optically-Stimulated Luminescence Dosimeter

Sample icons are stacked to indicate multiple types of samples collected at the same location.

Figure A-3. Sheffield On-Site Sampling Locations

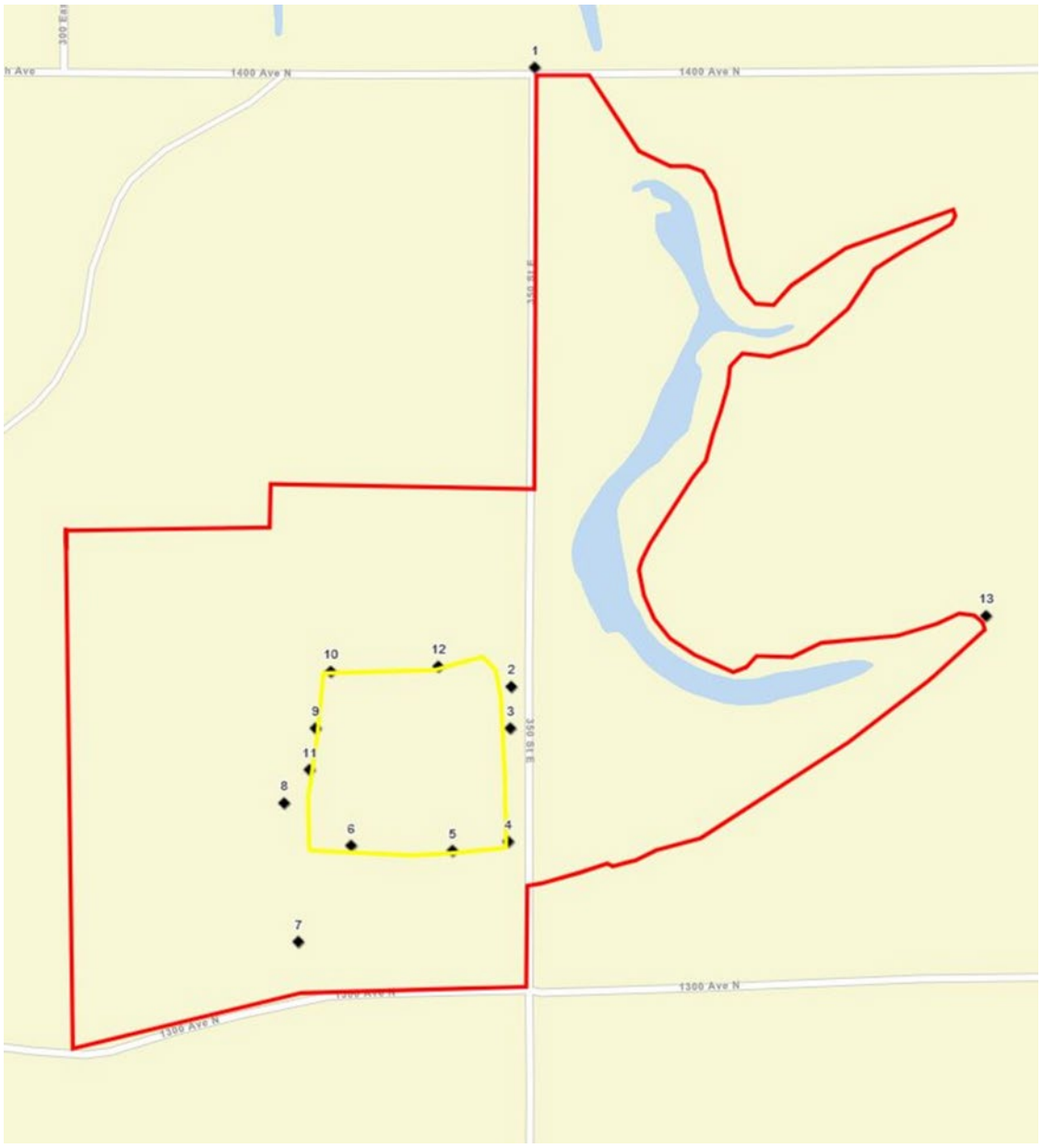
Map Key:

- OSL*
- Air Sampler
- Vegetation
- Sediment
- Water

* OSL = Optically-Stimulated Luminescence Dosimeter

Sample icons are stacked to indicate multiple types of samples collected at the same location.

Figure A-4. Sheffield OSL Monitoring Locations



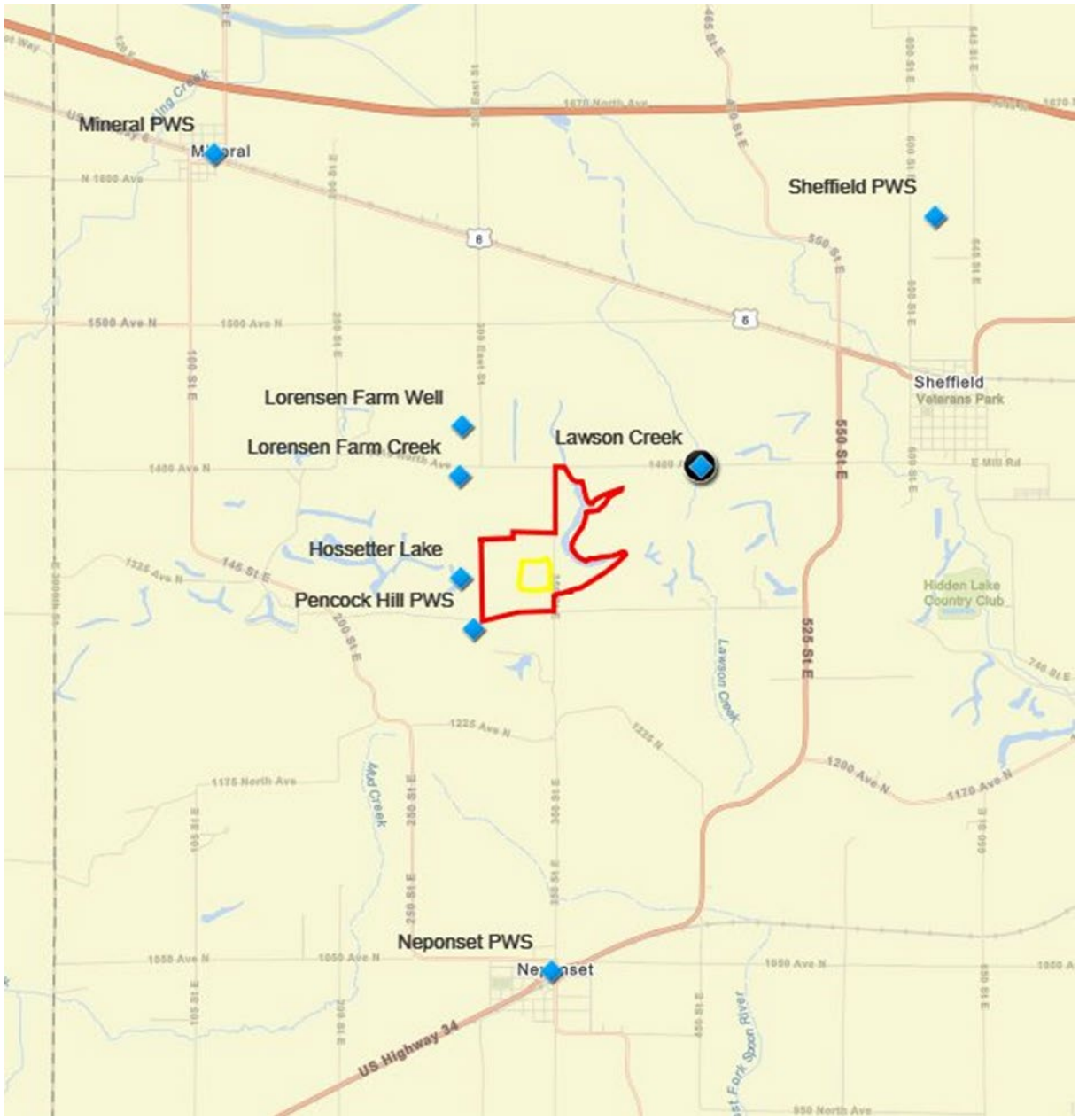
Map Key:

- OSL*
- Air Sampler
- Vegetation
- Sediment
- Water

* OSL = Optically-Stimulated Luminescence Dosimeter

Sample icons are stacked to indicate multiple types of samples collected at the same location.

Figure A-5. Sheffield Off-Site Monitoring Locations



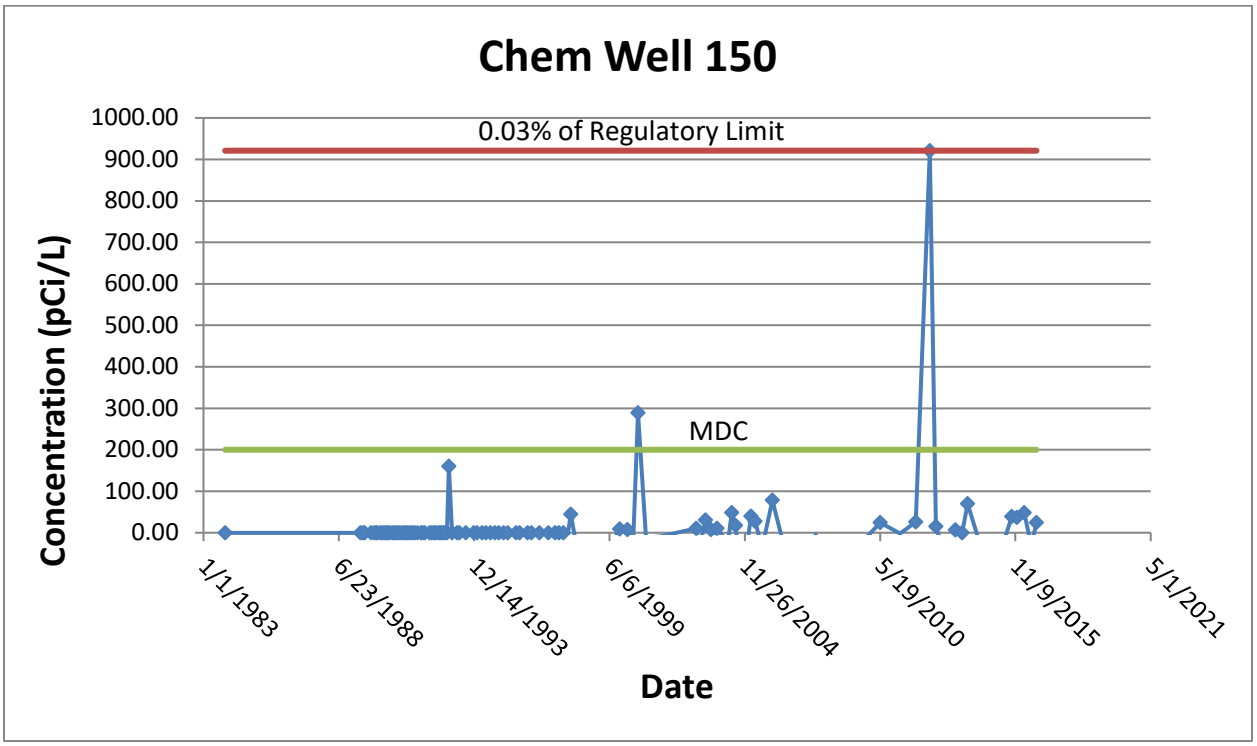
Map Key:

- OSL*
- Air Sampler
- Vegetation
- Sediment
- Water

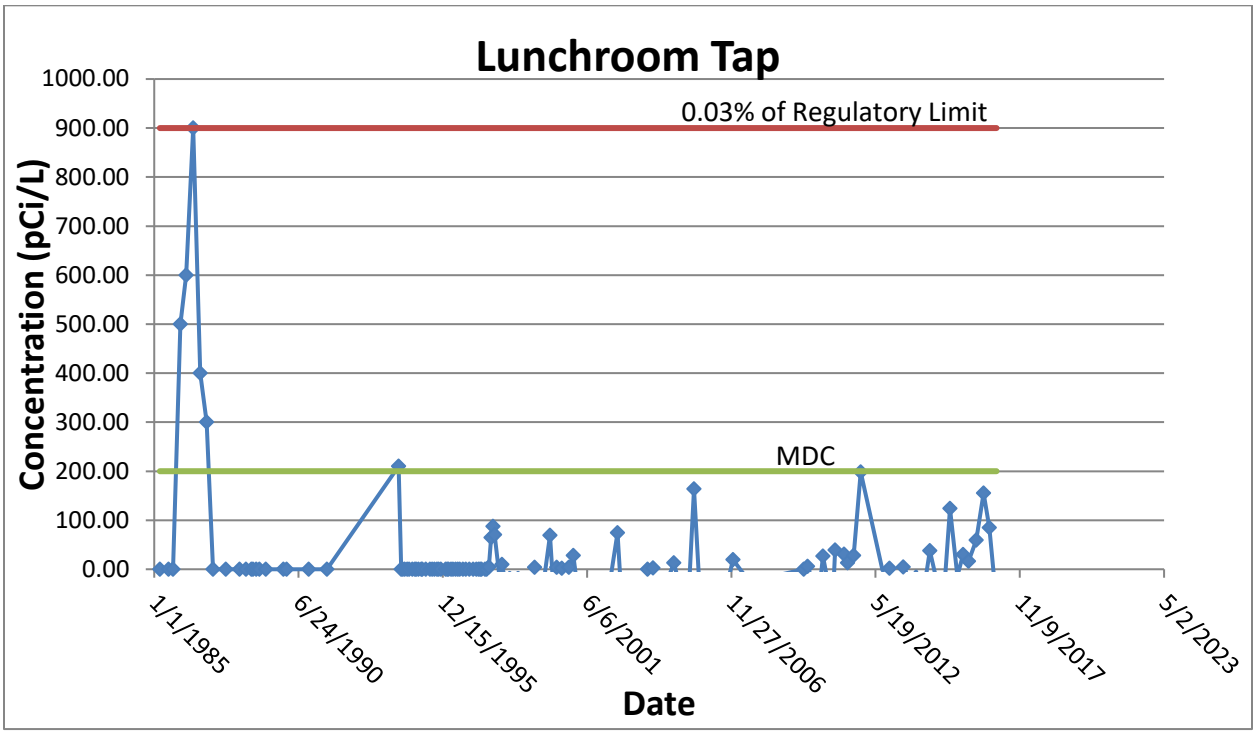
* OSL = Optically-Stimulated Luminescence Dosimeter

Sample icons are stacked to indicate multiple types of samples collected at the same location.

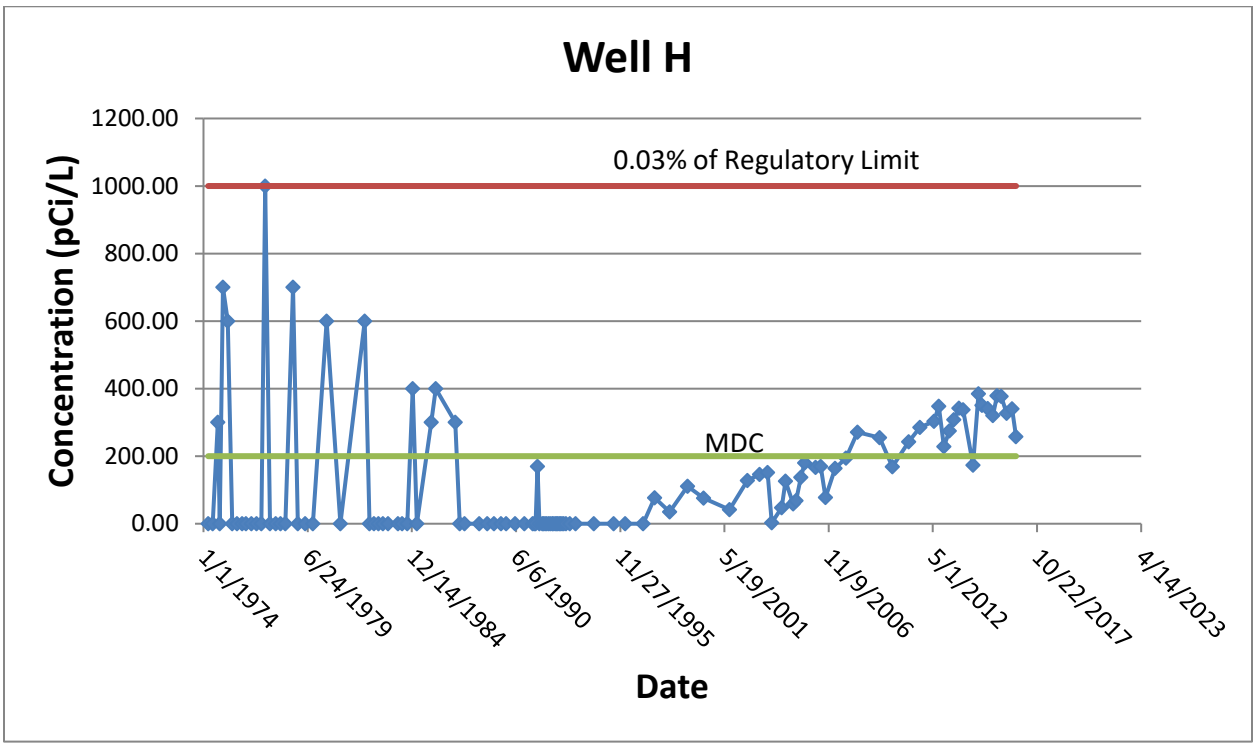
Appendix B
On-Site Tritium (H-3) Water Sample Result Graphs



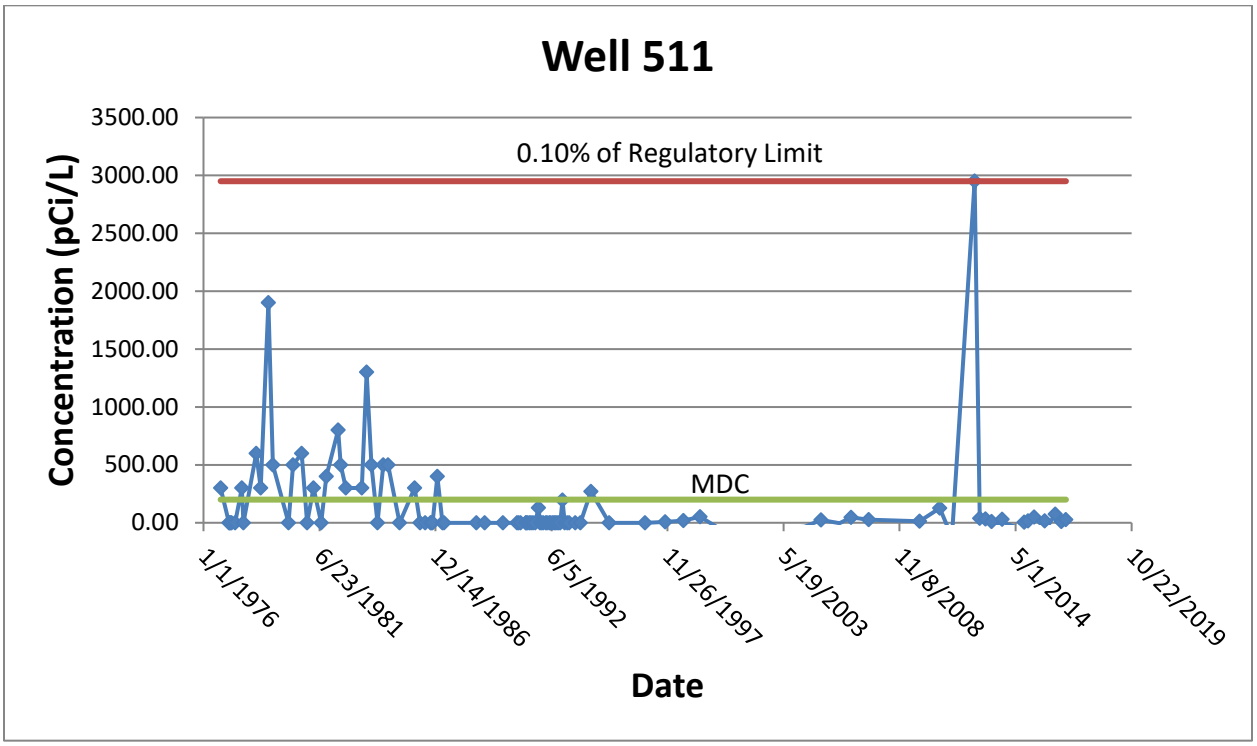
Chem Well 150 is located on the western edge of the Buffer Zone, close to the Chemical Waste site.



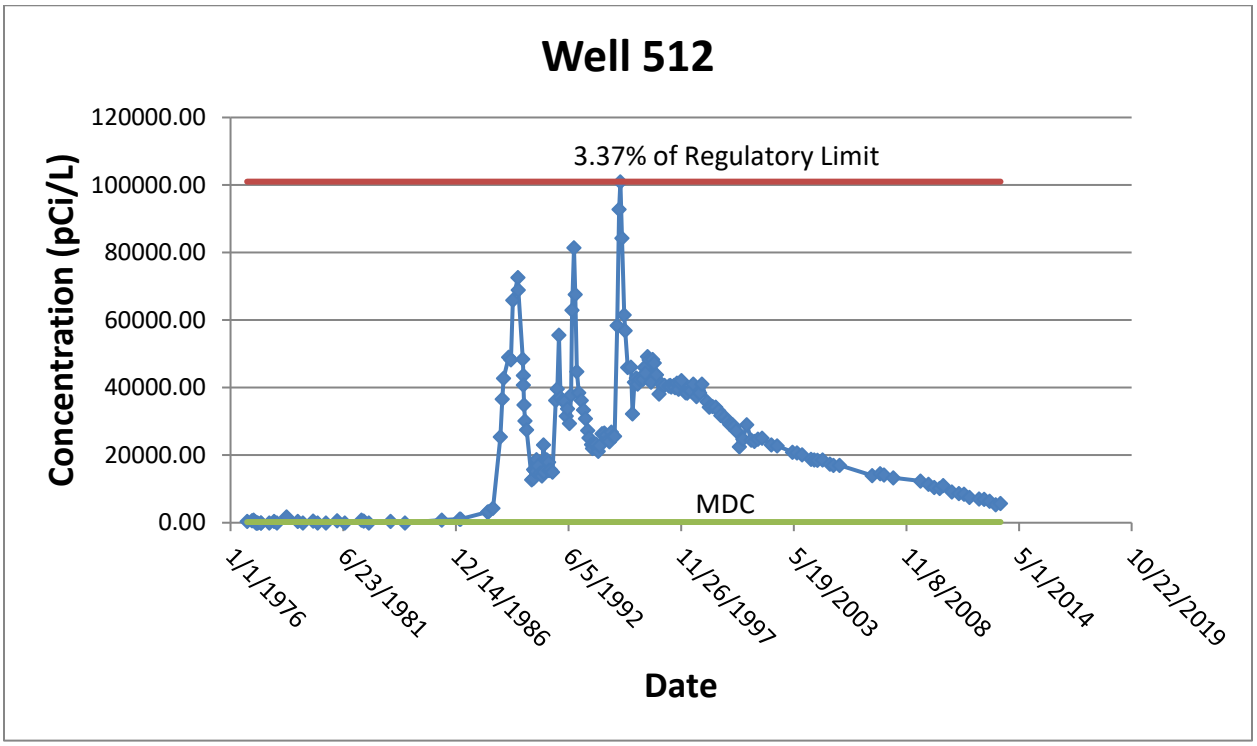
The lunchroom is not a well, but an on-site location fed by a local water supply.



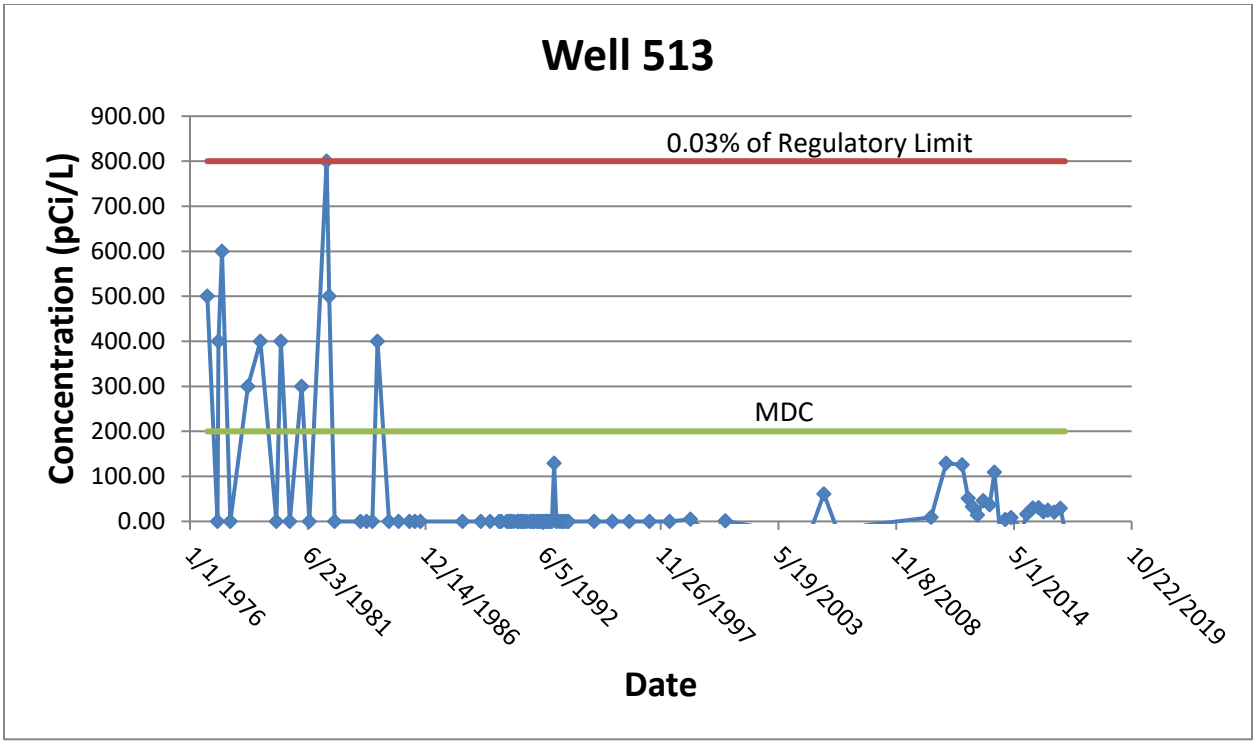
Well H is immediately to the south of the LLRW site.



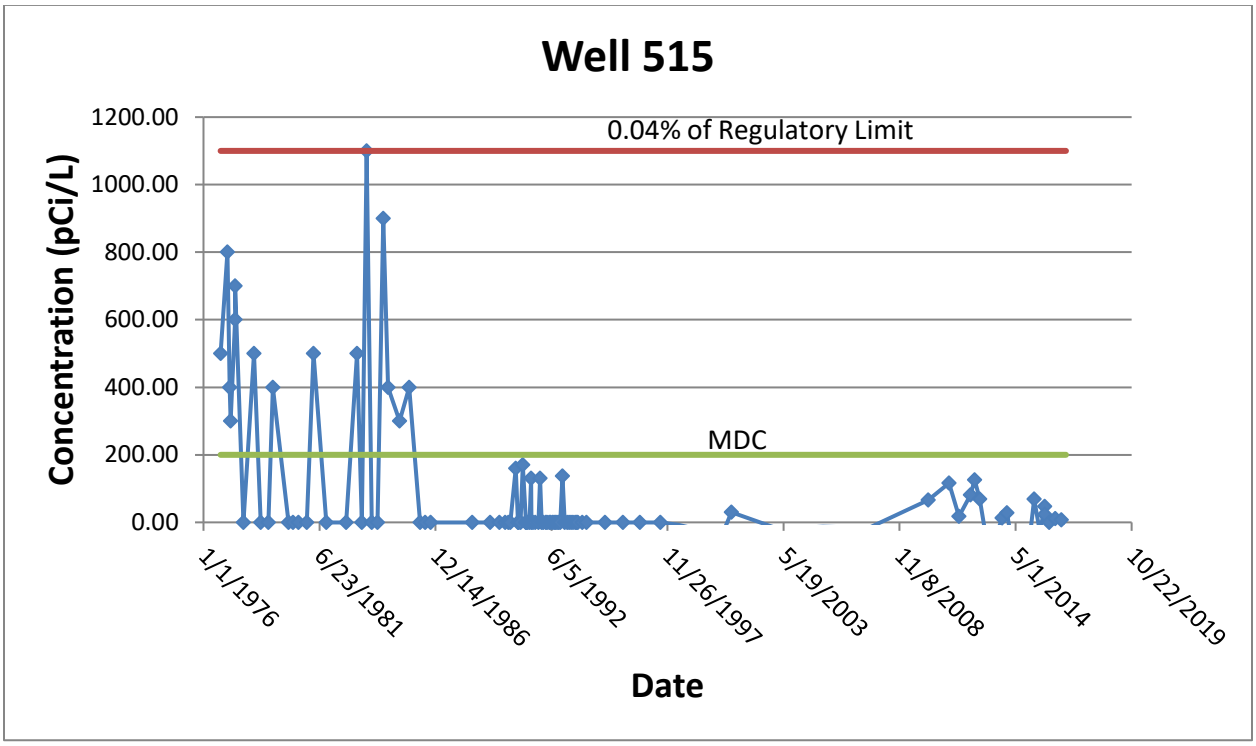
Well 511 is located immediately to the west of the LLRW site.



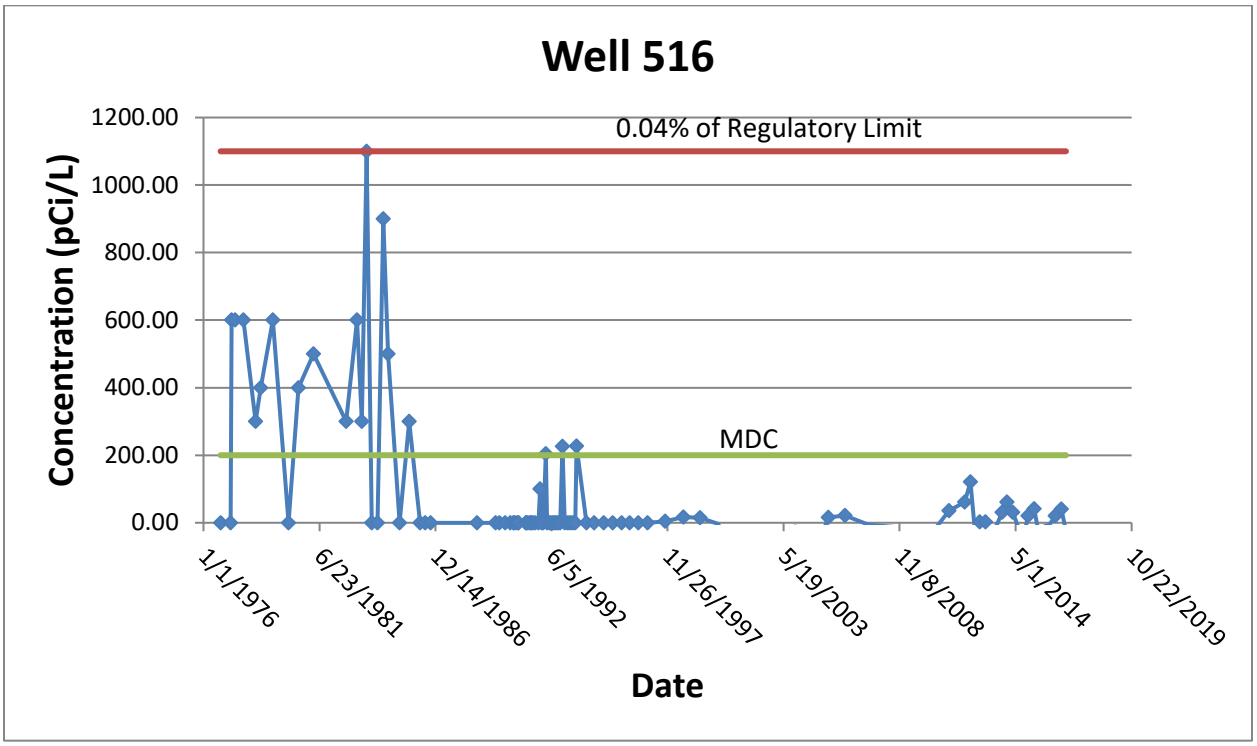
Well 512 is located south and east of the LLRW site, and is in the Southeast Pathway. Due to equipment malfunctions, samples have not been taken from Well 512 since June 2013.
*MDC is 200 pCi/L, not visible at this scale



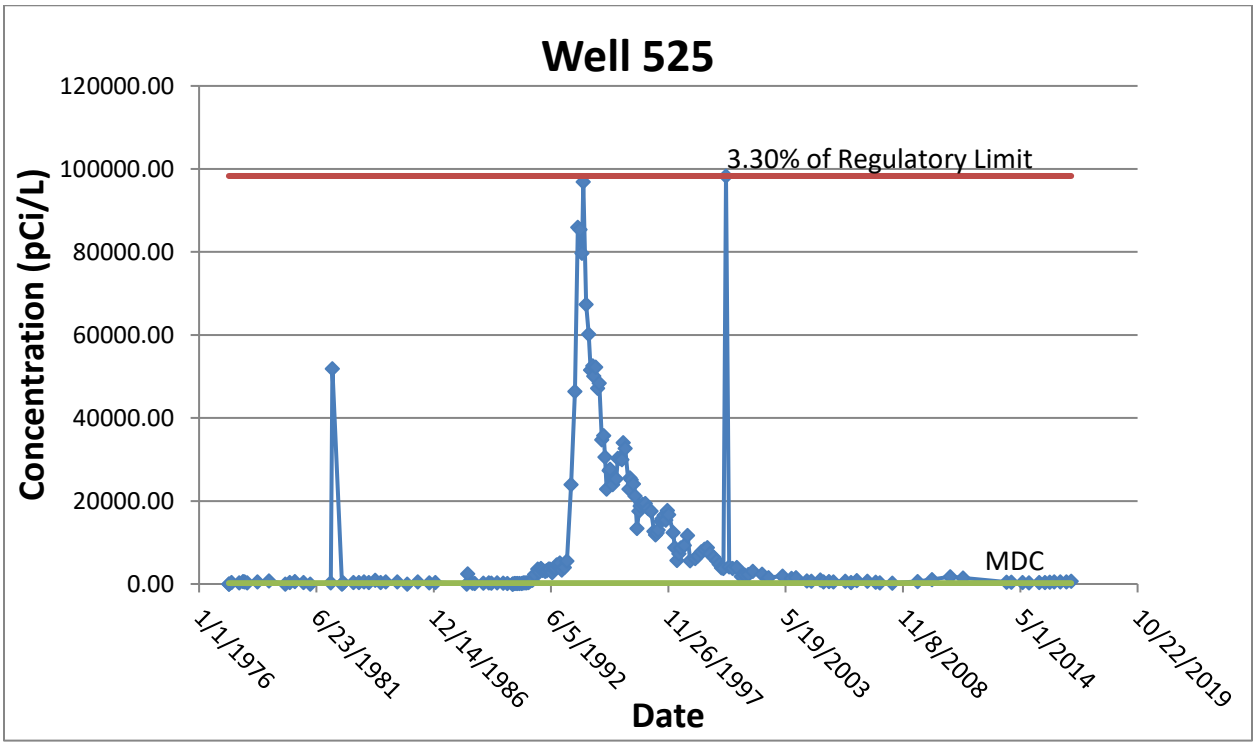
Well 513 is located near the northwest corner of the LLRW site.



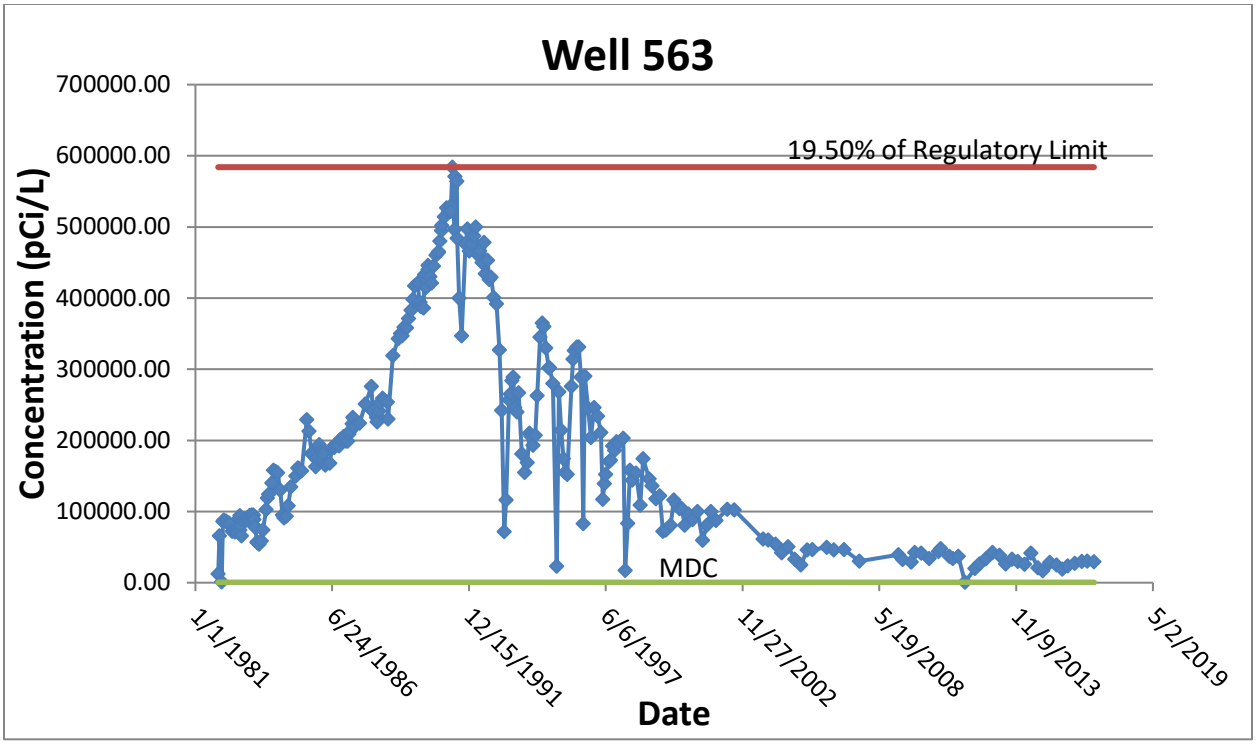
Well 515 is located along the north edge of the LLRW site.



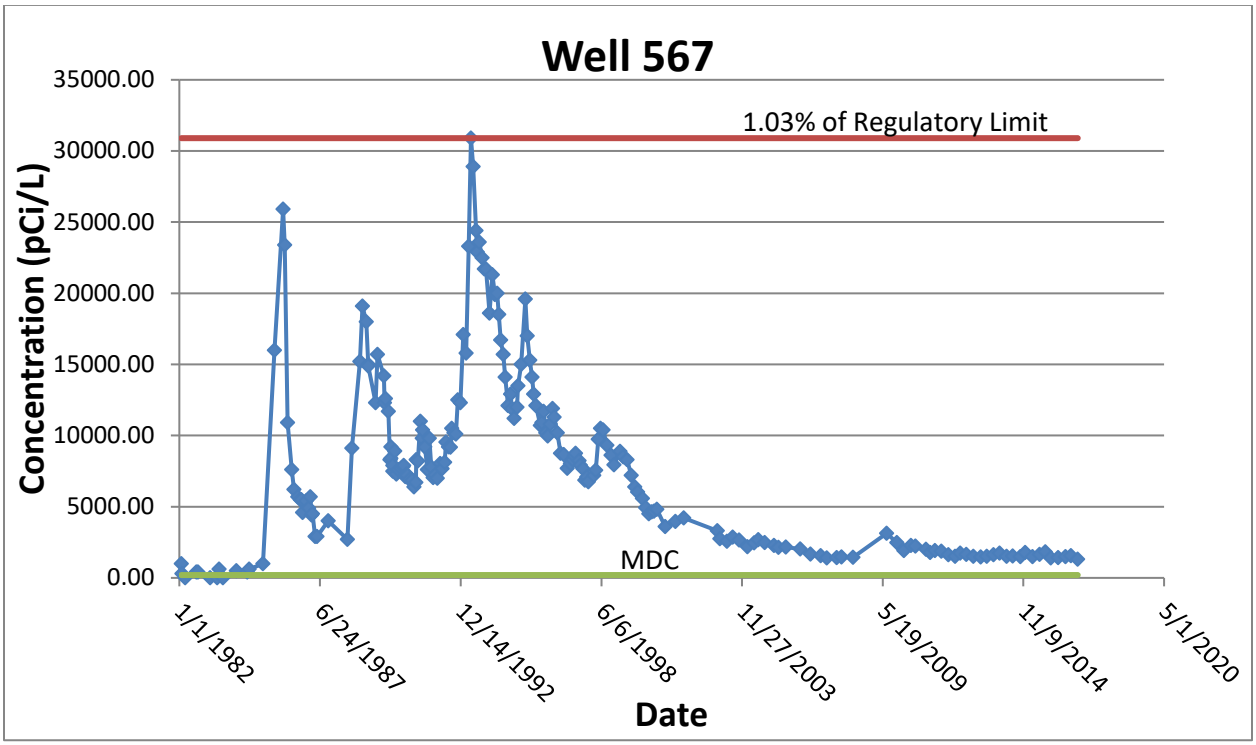
Well 516 is located along the north edge of the LLRW site.



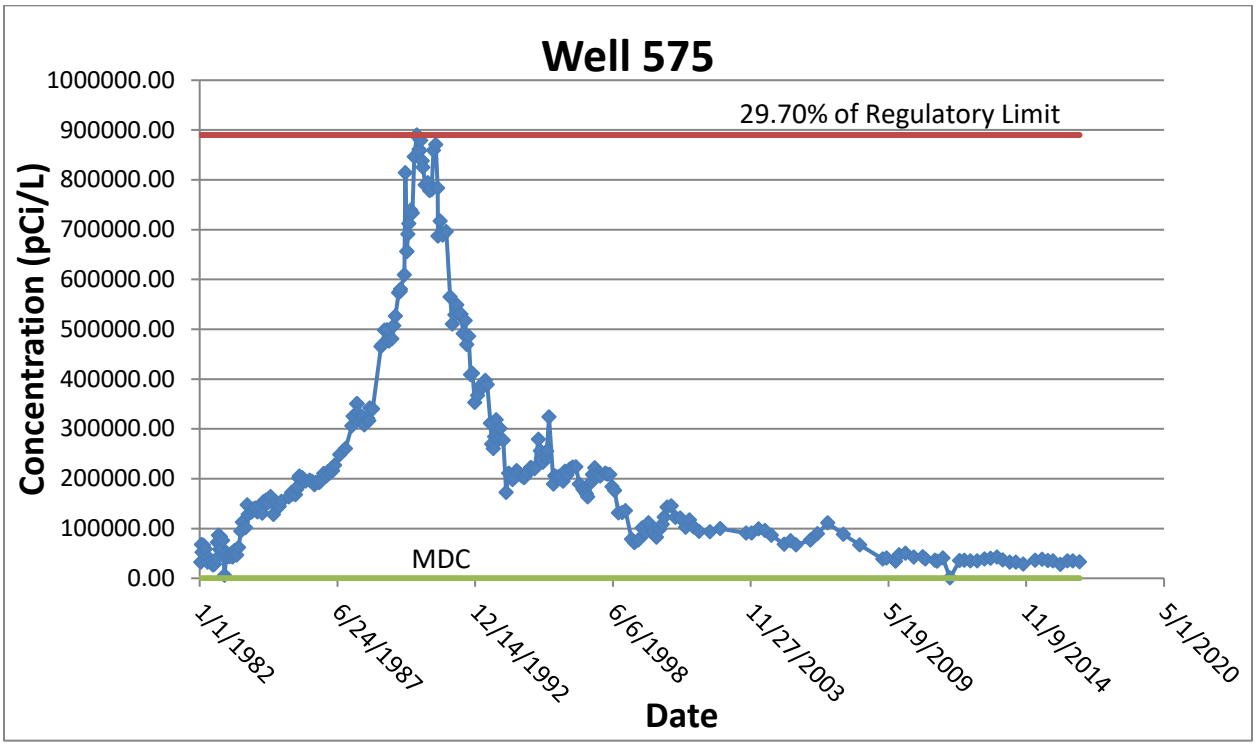
Well 525 is located south and east of the LLRW site, and is in the Southeast Pathway.
*MDC is 200 pCi/L, not visible at this scale



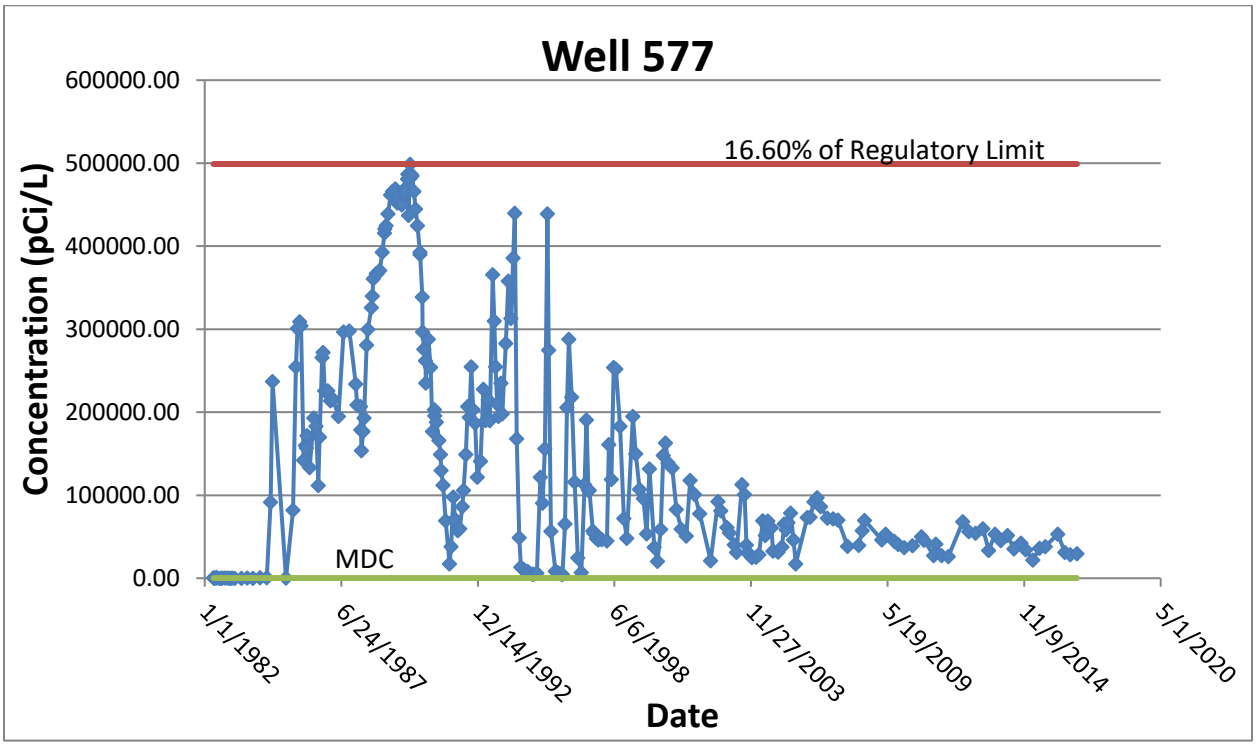
Well 563 is located east of the LLRW site, and is in the Northeast Pathway.
*MDC is 200 pCi/L, not visible at this scale



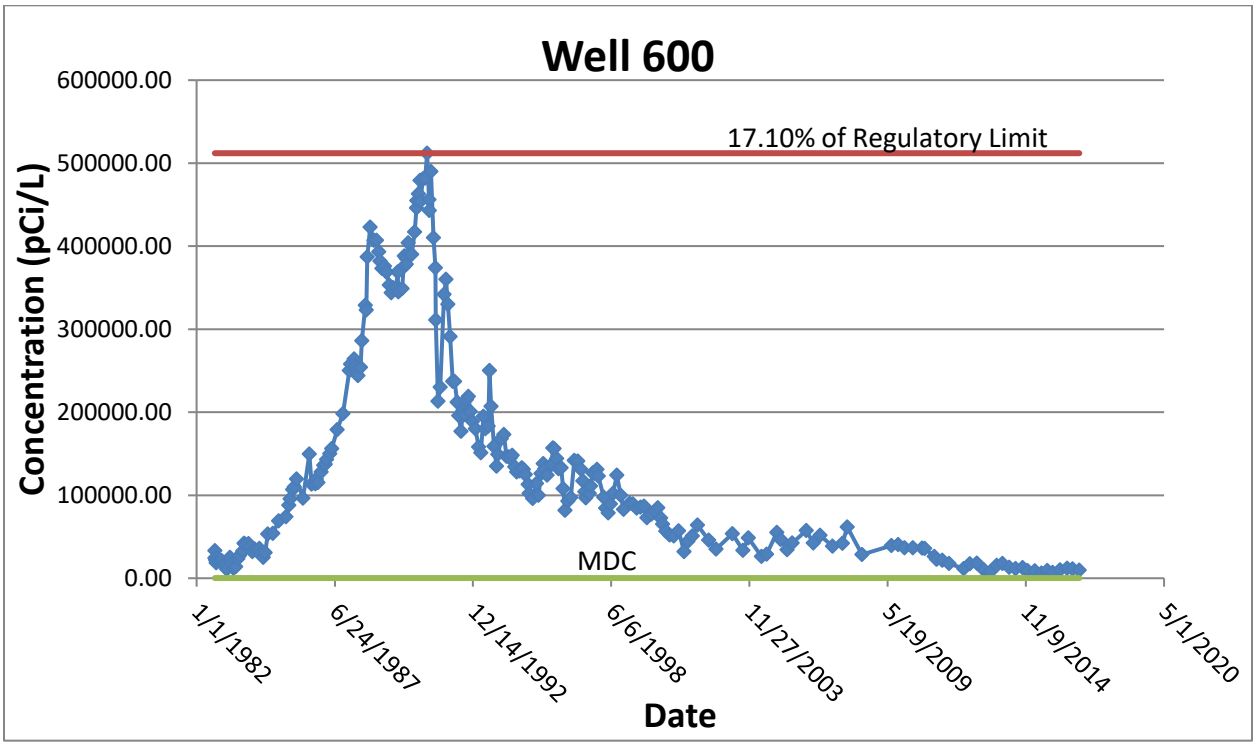
Well 567 is located east of the LLRW site, and is in the Southeast Pathway.
*MDC is 200 pCi/L, not visible at this scale



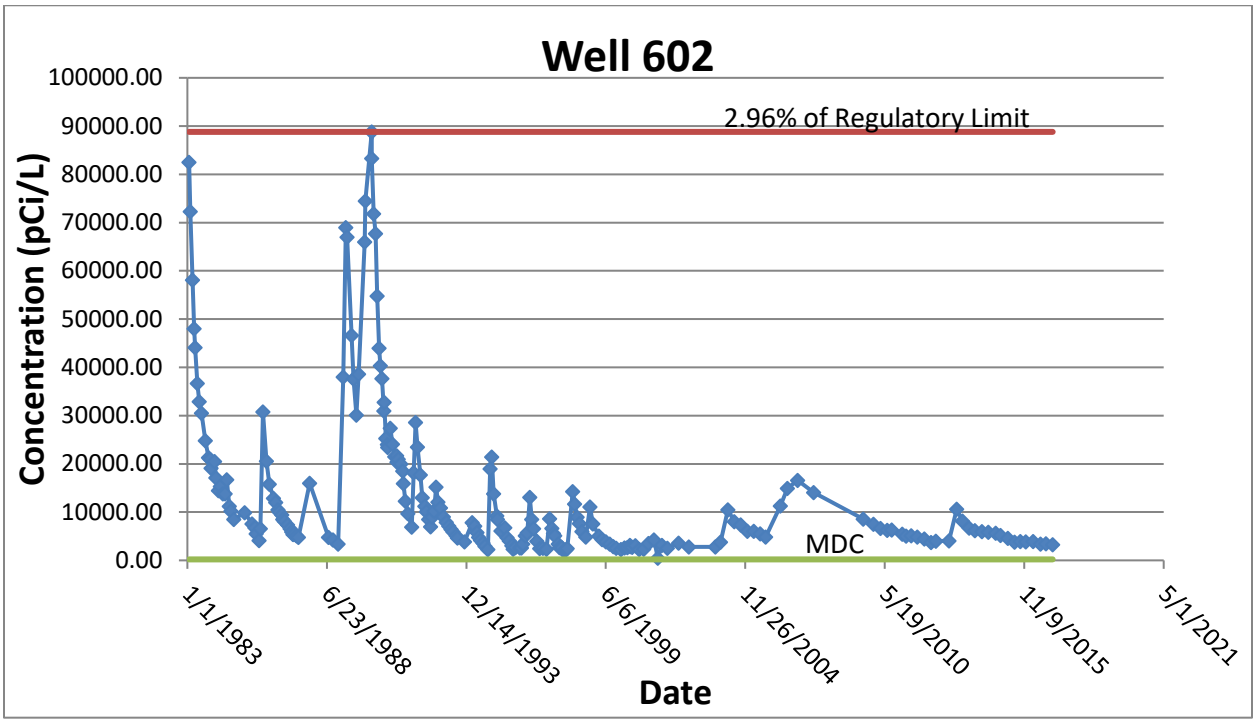
Well 575 is located east of the LLRW site, and is in the Northeast Pathway.
*MDC is 200 pCi/L, not visible at this scale



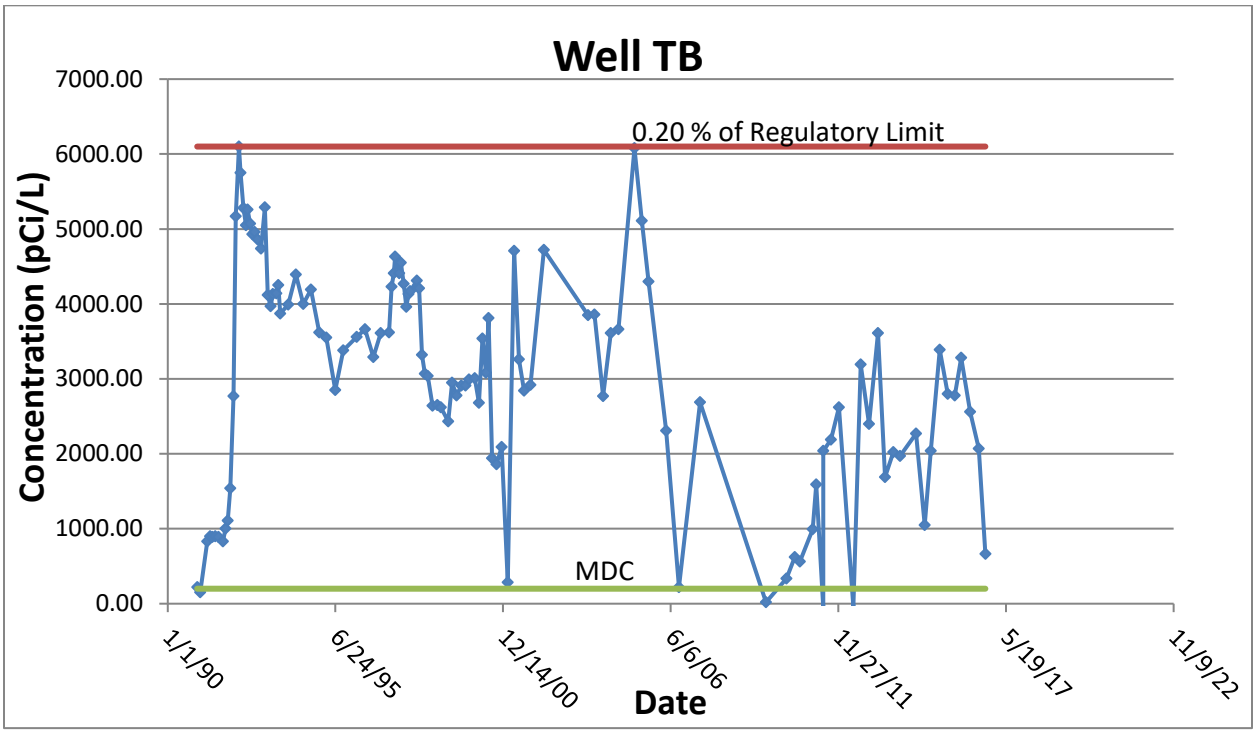
Well 577 is located east of the LLRW site, and is in the Northeast Pathway.
*MDC is 200 pCi/L, not visible at this scale



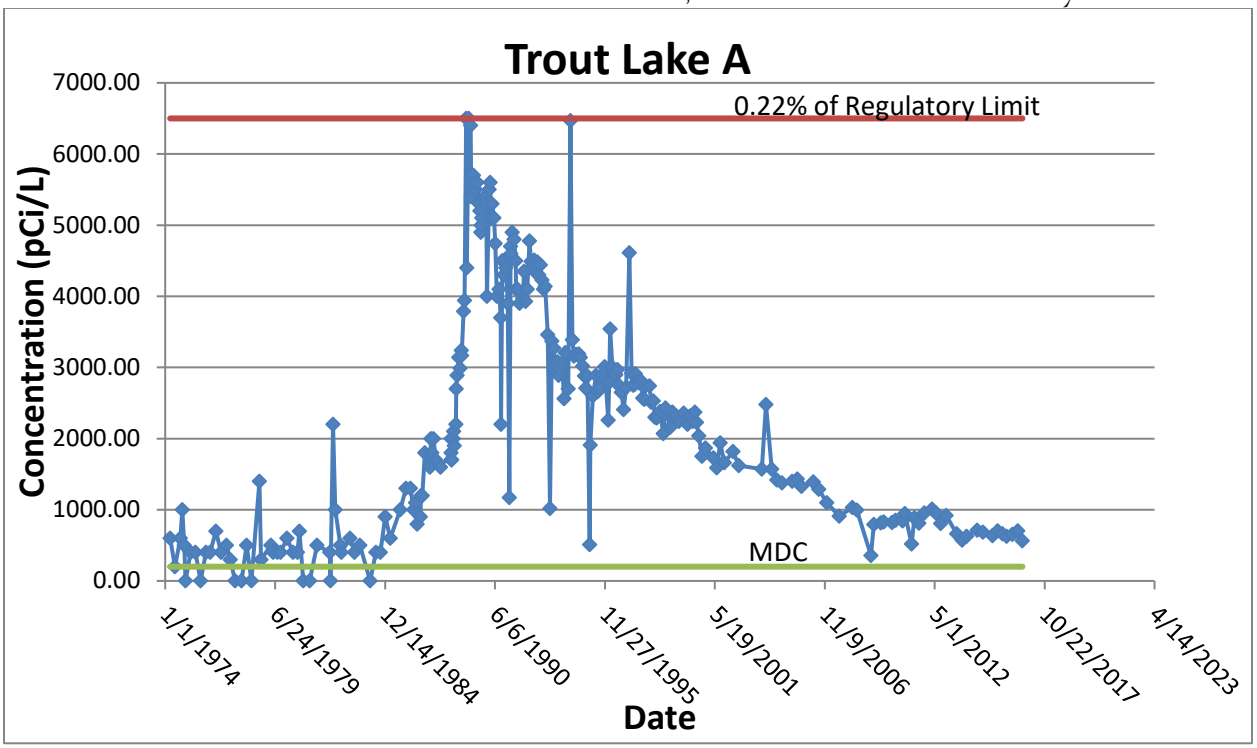
Well 600 is located east of the LLRW site and is in the Northeast Pathway.
*MDC is 200 pCi/L, not visible at this scale



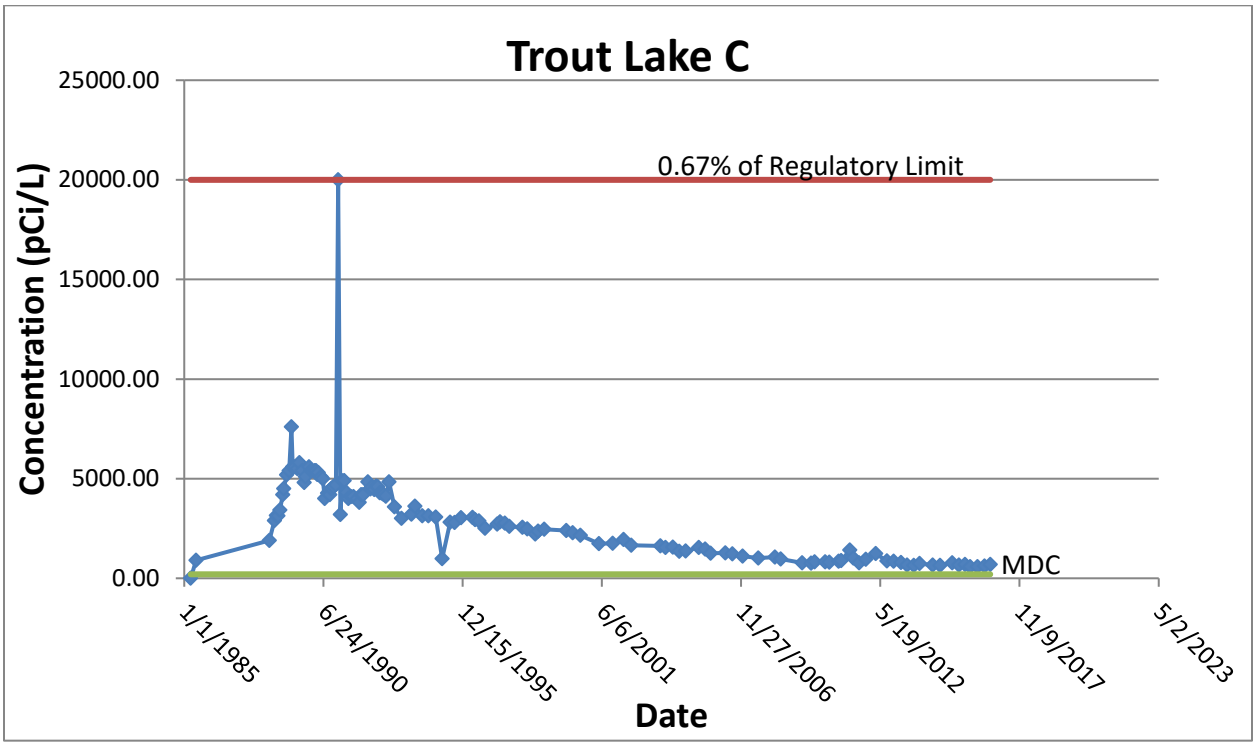
Well 602 is located east of the LLRW site, and is in the Southeast Pathway.
*MDC is 200 pCi/L, not visible at this scale



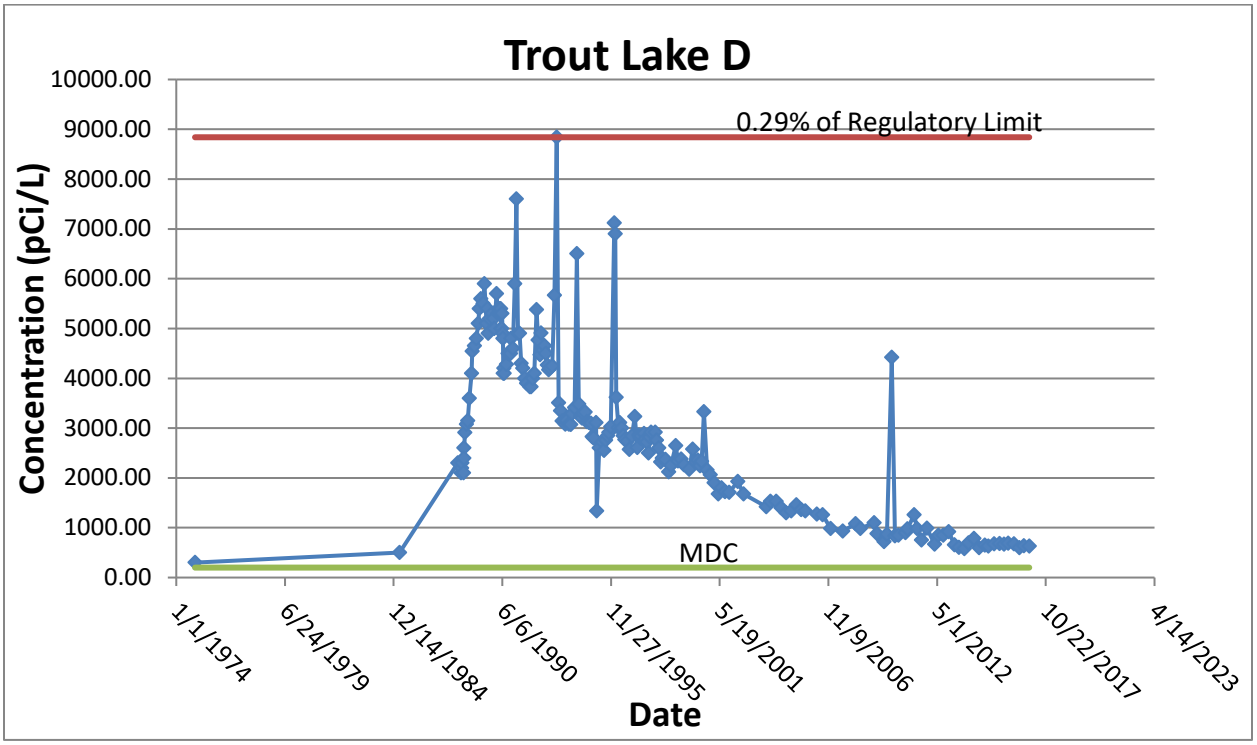
Well TB is located south of the LLRW site, and is in the Southeast Pathway.



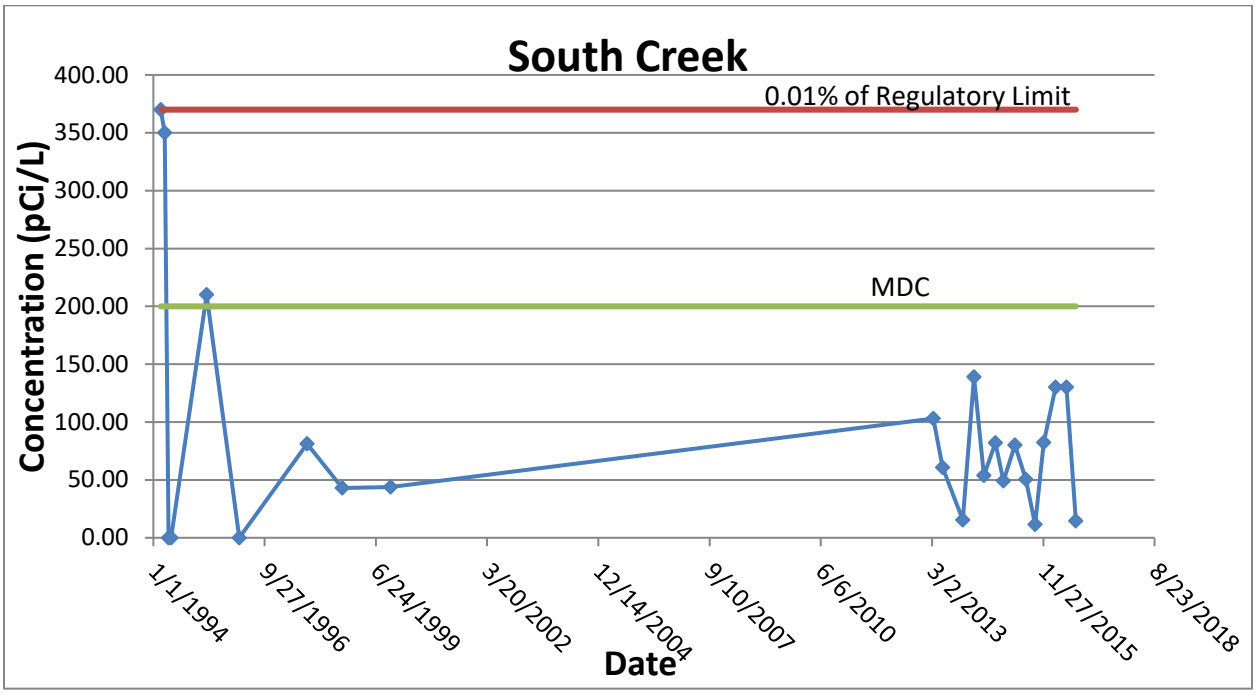
Trout Lake A is located on the north western edge of Trout Lake.



Trout Lake C is located approximately in the middle of Trout Lake.
*MDC is 200 pCi/L, not visible at this scale

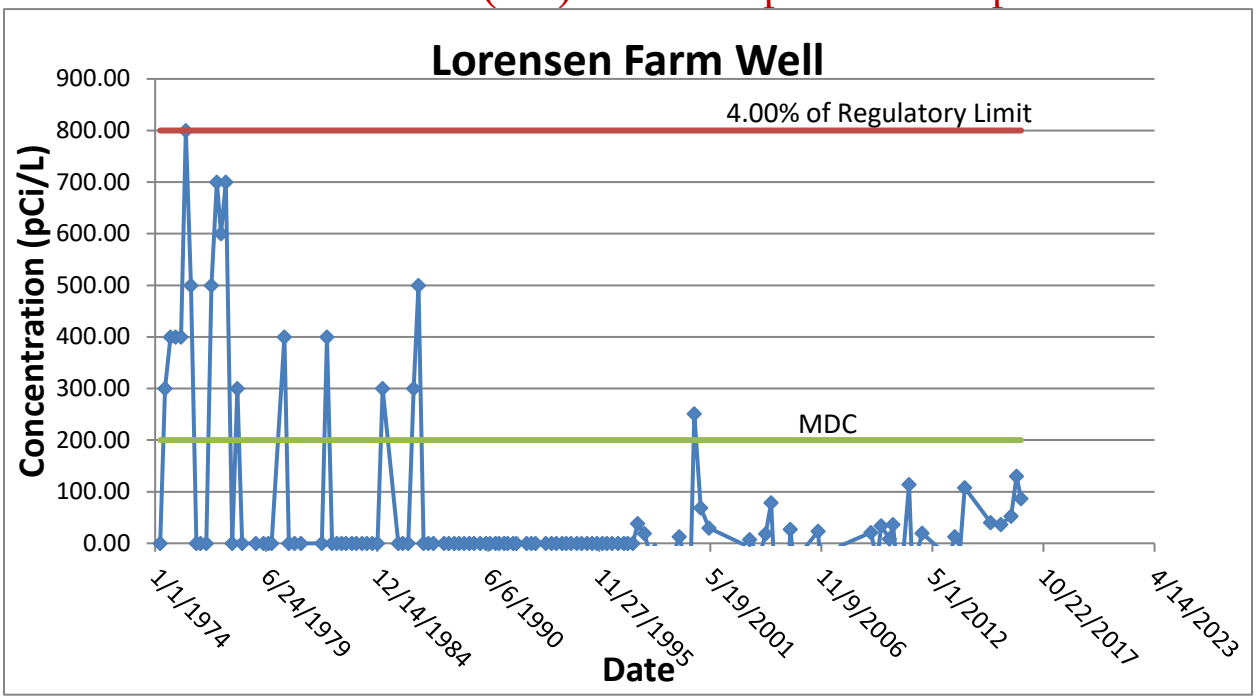


Trout Lake D is located on the eastern end of Trout Lake.

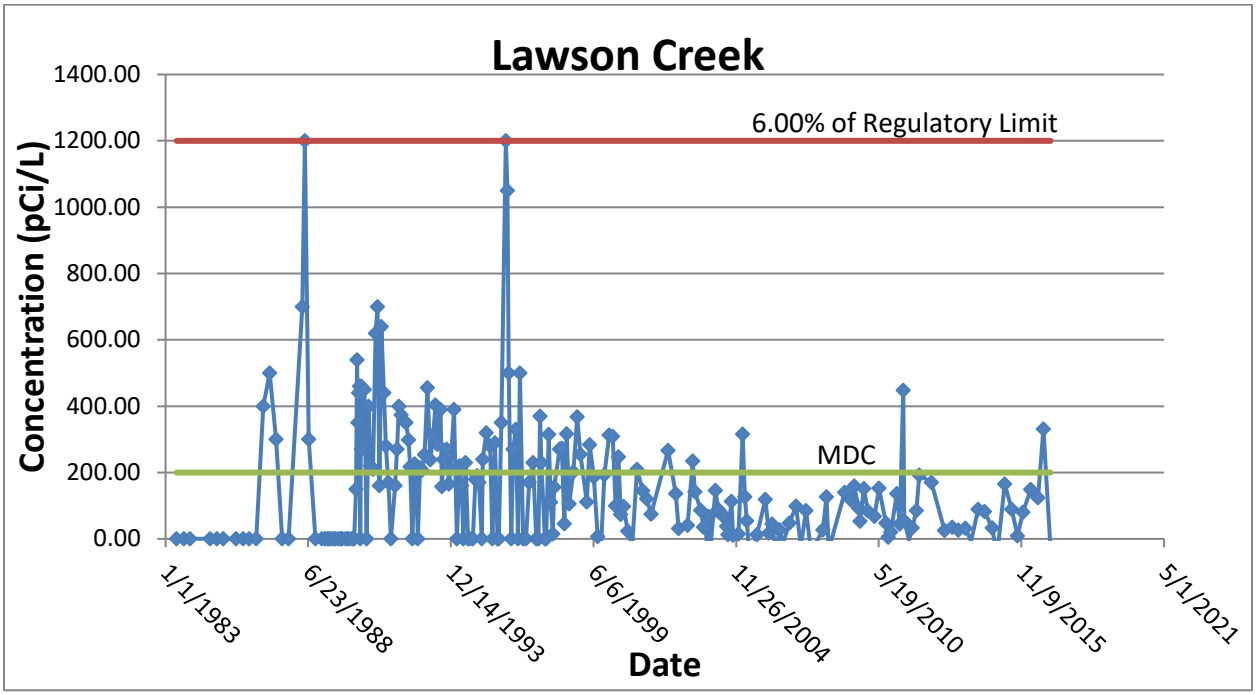


South Creek is located to the South of the site after confluence with cap runoff.

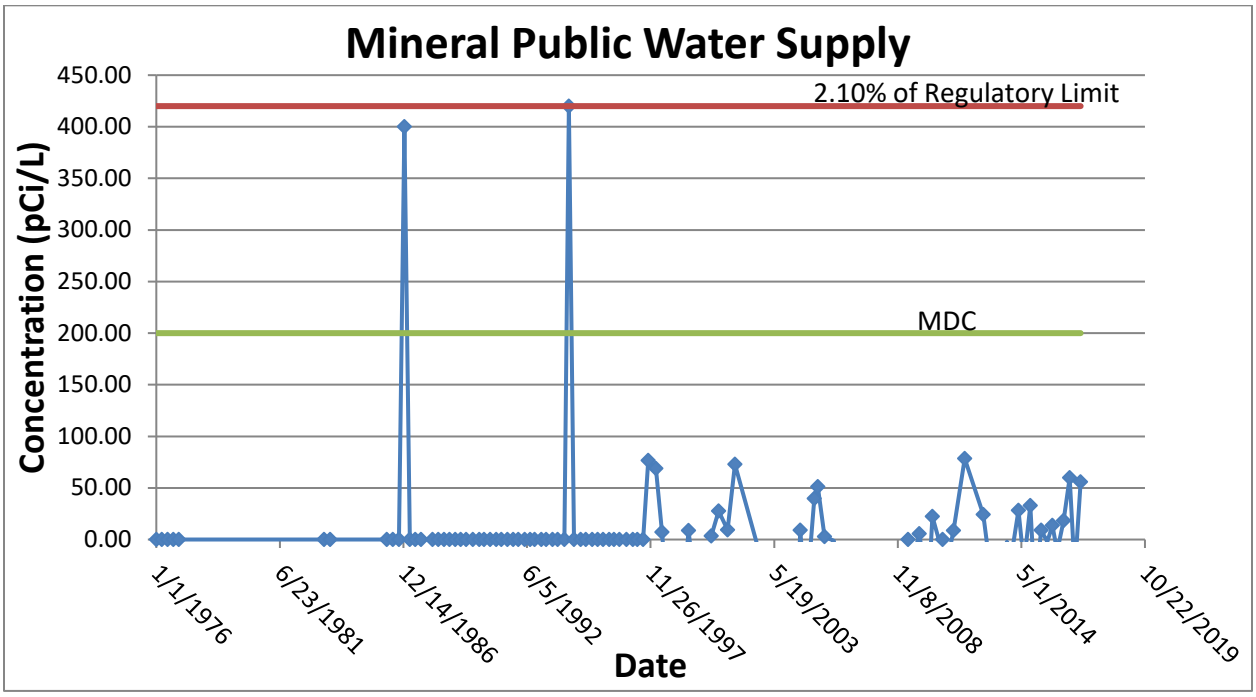
Appendix C
Off-Site Tritium (H-3) Water Sample Result Graphs



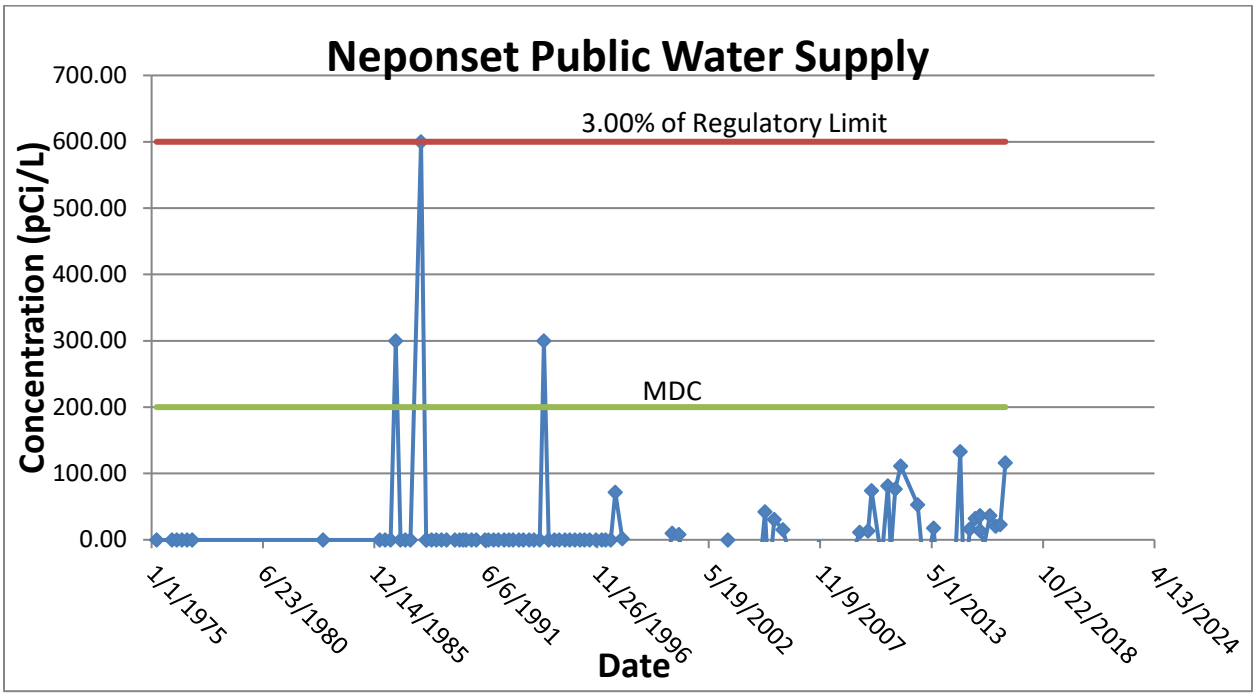
Lorenson Farm Well is located north and slightly west of the LLRW site.



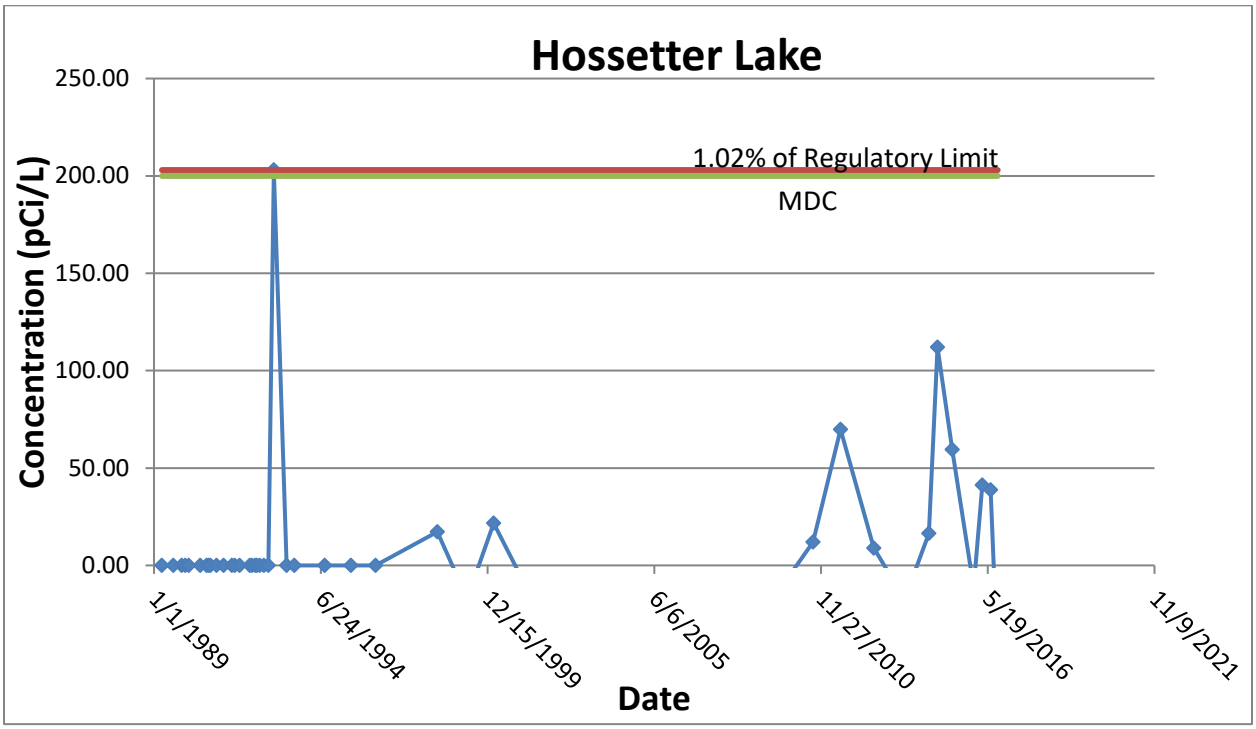
The Lawson Creek sampling point is located east and north of the LLRW site.



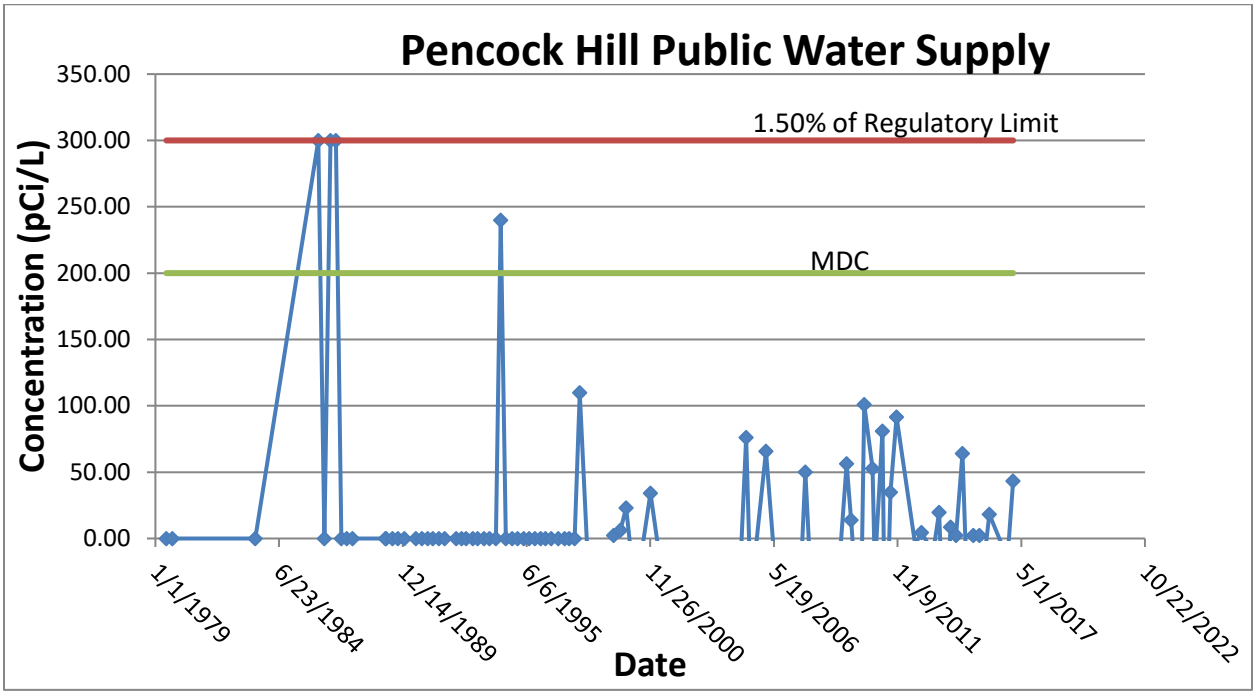
The Mineral PWS sampling point is located northeast of the LLRW site.



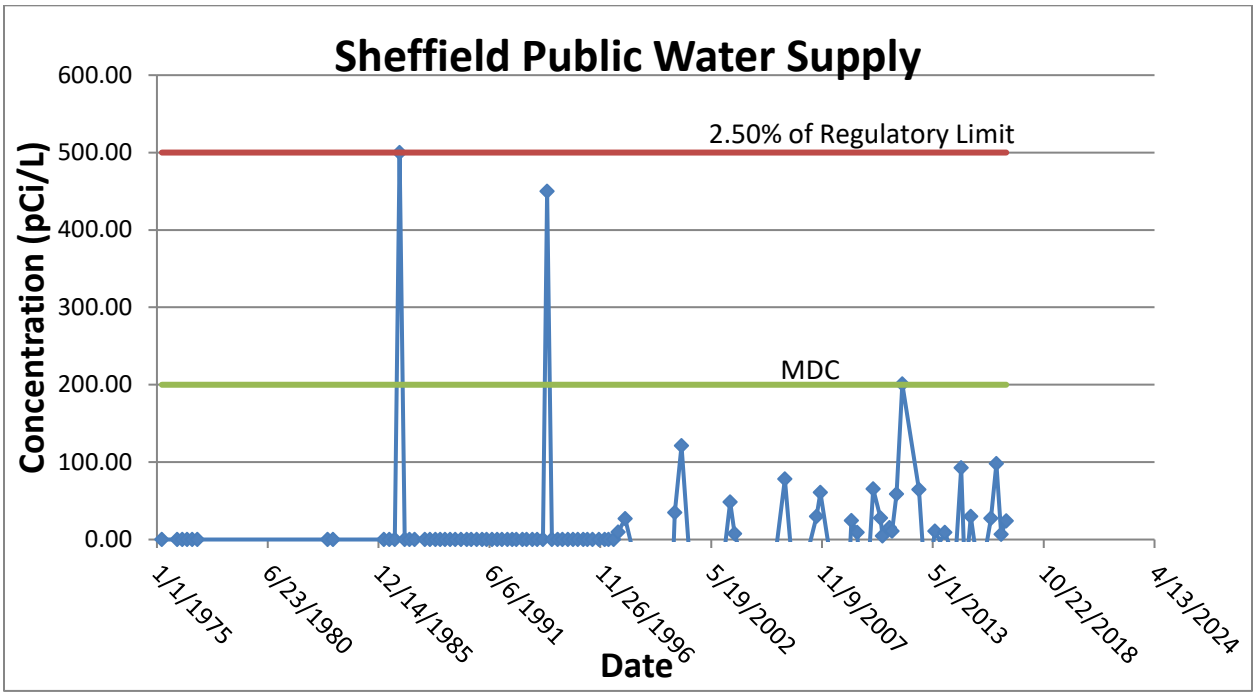
The Neponset PWS sampling point is located south of the LLRW site.



Hossetter Lake is located west of the LLRW site.



The Pencock Hill PWS sample location is south of the LLRW site.



The Sheffield PWS sampling location is northwest of the LLRW site.

Appendix D
Sheffield Sample Results

Table D.1 Gross Alpha/Beta Results for All Water Samples
Results are in picocuries per Liter (pCi/L)

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
Hossetter Lake				
9/15/2016	<MDC	2.1	5.4	4.0
Lawson Creek				
12/21/2016	<MDC	2.1	<MDC	4.0
Lunchroom Tap				
3/16/2016	<MDC	2.1	7.3	4.0
Mineral PWS				
6/23/2016	6.0	2.1	7.3	4.0
12/15/2016	2.4	2.1	5.8	4.0
Neponset PWS				
9/13/2016	3.4	2.1	9.7	4.0
Pencock Hill PWS				
12/21/2016	<MDC	2.1	7.9	4.0
Sheffield PWS				
3/16/2016	<MDC	2.1	<MDC	4.0
South Creek				
3/16/2016	<MDC	2.1	<MDC	4.0
Trout Lake A				
6/23/2016	<MDC	2.1	10.0	4.0
Trout Lake C				
9/14/2016	<MDC	2.1	6.1	4.0
Trout Lake D				
6/23/2016	<MDC	2.1	7.6	4.0
Well 150				
9/15/2016	<MDC	2.1	<MDC	4.0
Well 513				
6/28/2016	<MDC	2.1	<MDC	4.0
Well 515				
3/17/2016	<MDC	2.1	<MDC	4.0

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
Well 525				
9/15/2016	<MDC	2.1	<MDC	4.0
Well 563				
6/28/2016	2.3	2.1	6.3	4.0
Well 567				
12/21/2016	2.2	2.1	4.0	4.0
Well 570				
6/28/2016	<MDC	2.1	<MDC	4.0
Well 572				
9/15/2016	<MDC	2.1	<MDC	4.0
Well 574				
9/15/2016	<MDC	2.1	<MDC	4.0
Well 575				
9/15/2016	<MDC	2.1	5.5	4.0
Well 577				
3/17/2016	3.9	2.1	6.6	4.0
Well 600				
12/21/2016	7.3	2.1	5.6	4.0
Well 602				
6/28/2016	<MDC	2.1	6.3	4.0
Well H				
6/28/2016	<MDC	2.1	<MDC	4.0
Well M				
3/17/2016	<MDC	2.1	<MDC	4.0
Well TB				
3/17/2016	<MDC	2.1	<MDC	4.0
Well 569				
3/17/2016	<MDC	2.1	10.2	4.0

Table D.2 Tritium (H-3) Results for On-Site Water Samples
Results are in picocuries per Liter (pCi/L)

Location	H-3	
Date	Result	MDC
Lunchroom Tap		
3/16/2016	<MDC	200
6/23/2016	<MDC	200
9/13/2016	<MDC	200
12/21/2016	<MDC	200
South Creek		
3/16/2016	<MDC	200
6/23/2016	<MDC	200
9/15/2016	<MDC	200
Trout Lake A		
3/16/2016	652	200
6/23/2016	702	200
9/14/2016	562	200
Trout Lake C		
3/16/2016	585	200
6/23/2016	616	200
9/14/2016	691	200
Trout Lake D		
3/16/2016	674	200
6/23/2016	601	200
9/14/2016	640	200
12/21/2016	633	200
Well M		
3/17/2016	<MDC	200
Well TB		
3/17/2016	2560	200
6/28/2016	2070	200
9/15/2016	665	200
Well 569		
3/17/2016	<MDC	200

Location	H-3	
Date	Result	MDC
Well 150		
3/17/2016	<MDC	200
6/28/2016	<MDC	200
9/15/2016	<MDC	200
Well 511		
3/17/2016	<MDC	200
6/28/2016	<MDC	200
9/15/2016	<MDC	200
Well 516		
3/17/2016	<MDC	200
6/28/2016	<MDC	200
9/15/2016	<MDC	200
Well 525		
3/17/2016	503	200
6/28/2016	517	200
9/15/2016	704	200
Well 563		
3/17/2016	27300	200
6/28/2016	29600	200
9/15/2016	30200	200
12/21/2016	29400	200
Well 567		
3/17/2016	1410	200
6/28/2016	1480	200
9/15/2016	1550	200
12/21/2016	1310	200
Well 570		
6/28/2016	<MDC	200
Well 572		
9/15/2016	<MDC	200
Well 574		
9/15/2016	<MDC	200

Location	H-3	
Date	Result	MDC
Well 513		
3/17/2016	<MDC	200
6/28/2016	<MDC	200
9/15/2016	<MDC	200
Well 515		
3/17/2016	<MDC	200
6/28/2016	<MDC	200
9/15/2016	<MDC	200
Well 575		
3/17/2016	27600	200
6/28/2016	35000	200
9/15/2016	34900	200
12/21/2016	33200	200
Well 577		
3/17/2016	53200	200
6/28/2016	31300	200
9/15/2016	28400	200
12/21/2016	29600	200
Well 600		
3/17/2016	10000	200
6/28/2016	11900	200
9/15/2016	11200	200
12/21/2016	9720	200
Well 602		
3/17/2016	3920	200
6/28/2016	3420	200
9/15/2016	3470	200
12/21/2016	3270	200
Well H		
3/17/2016	327	200
6/28/2016	340	200
9/15/2016	258	200

Table D.3 Tritium (H-3) Results for Off-Site Water Samples
Results are in picocuries per Liter (pCi/L)

Location	H-3	
Date	Result	MDC
Hossetter Lake		
3/16/2016	<MDC	200
6/23/2016	<MDC	200
9/15/2016	<MDC	200
Lawson Creek		
3/16/2016	<MDC	200
6/28/2016	<MDC	200
9/13/2016	331	200
12/21/2016	<MDC	200
Lorensen Farm Creek		
3/16/2016	<MDC	200
9/13/2016	<MDC	200
Lorenson Farm Well		
3/16/2016	<MDC	200
6/23/2016	<MDC	200
9/13/2016	<MDC	200

Location	H-3	
Date	Result	MDC
Mineral PWS		
3/16/2016	<MDC	200
6/23/2016	<MDC	200
9/13/2016	<MDC	200
12/15/2016	<MDC	200
Neponset PWS		
3/16/2016	<MDC	200
6/23/2016	<MDC	200
9/13/2016	<MDC	200
12/15/2016	<MDC	200
Pencock Hill PWS		
6/23/2016	<MDC	200
9/13/2016	<MDC	200
12/21/2016	<MDC	200
Sheffield PWS		
3/16/2016	<MDC	200
6/23/2016	<MDC	200
9/13/2016	<MDC	200
12/15/2016	<MDC	200

Table D.4 Additional Radionuclide Results for On-Site Water Samples
Results are in picocuries per Liter (pCi/L)

Location	Am-241		Co-60		Cs-137		Total Sr		C-14	
Date	Result	MDC	Result	MDC	Result	MDC	Result	MDC	Result	MDC
Lunchroom Tap										
3/16/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
South Creek										
3/16/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Trout Lake A										
6/23/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Trout Lake C										
9/14/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Trout Lake D										
6/23/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Well 150										
9/15/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Well 513										
6/28/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Well 515										
3/17/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Well 525										
9/15/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	55.6	15.2
Well 563										
6/28/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	793.8	15.2
Well 567										
12/21/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	2.4	1.6	52.6	15.2
Well 570										
6/28/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Well 572										
9/15/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1			<MDC	15.2
Well 574										
9/15/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2

Table D.4 (Cont'd.) Additional Radionuclide Results for On-Site Water Samples
Results are in picocuries per Liter (pCi/L)

Location	Am-241		Co-60		Cs-137		Total Sr		C-14	
Date	Result	MDC	Result	MDC	Result	MDC	Result	MDC	Result	MDC
Well 575										
9/15/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	378.0	15.2
Well 577										
3/17/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	421.3	15.2
Well 600										
12/21/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	96.6	15.2
Well 602										
6/28/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Well H										
6/28/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Well M										
3/17/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Well TB										
3/17/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	106.1	15.2
Well 569										
3/17/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	1.7	1.6	<MDC	15.2

Table D.5 Additional Radionuclide Results for Off-Site Water Samples
Results are in picocuries per Liter (pCi/L)

Location	Am-241		Co-60		Cs-137		Total Sr		C-14	
Date	Result	MDC	Result	MDC	Result	MDC	Result	MDC	Result	MDC
Hossetter Lake										
9/15/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Lawson Creek										
12/21/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Mineral PWS										
6/23/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Neponset PWS										
9/13/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Pencock Hill PWS										
12/21/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2
Sheffield PWS										
3/16/2016	<MDC	46.0	<MDC	4.5	<MDC	4.1	<MDC	1.6	<MDC	15.2

Table D.6 Sheffield On-Site Sediment Sampling Results
Results are in picocuries per gram (pCi/g)

Location	Am-241		Co-60		Cs-137	
Date	Result	MDC	Result	MDC	Result	MDC
South Creek						
6/28/2016	<MDC	0.12	<MDC	0.01	0.03	0.01
9/15/2016	<MDC	0.12	<MDC	0.01	0.01	0.01
Trout Lake D						
9/14/2016	<MDC	0.12	<MDC	0.01	0.02	0.01

Table D.7. On-Site Vegetation Sampling Results
Results are in picocuries per gram (pCi/g)

Location	Am-241		Co-60		Cs-137	
Date	Result	MDC	Result	MDC	Result	MDC
Onsite Composite						
6/28/2016	<MDC	0.7	<MDC	0.1	<MDC	0.1
9/15/2016	<MDC	0.7	<MDC	0.1	<MDC	0.1
Trout Lake D						
6/28/2016	<MDC	0.7	<MDC	0.1	<MDC	0.1
9/14/2016	<MDC	0.7	<MDC	0.1	<MDC	0.1

Table D.8 Air Monitoring Gross Alpha/Beta Results for Sheffield Site
Results are in femtocuries per cubic meter (fCi/m³)

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
Site Air				
1/4/2016	3.1	3.0	22.3	6.9
1/11/2016	<MDC	3.0	12.4	6.9
1/18/2016	<MDC	3.0	21.9	6.9
1/25/2016	<MDC	3.0	15.7	6.9
2/1/2016	<MDC	3.0	22.3	6.9
2/8/2016	<MDC	3.0	19.3	6.9
2/15/2016	<MDC	3.0	10.3	6.9
2/22/2016	<MDC	3.0	11.0	6.9
2/29/2016	<MDC	3.0	10.7	6.9
3/7/2016	<MDC	3.0	8.7	6.9
3/14/2016	<MDC	3.0	14.0	6.9
3/21/2016	3.2	3.0	<MDC	6.9
3/28/2016	3.9	3.0	<MDC	6.9
4/5/2016	<MDC	3.0	8.0	6.9
4/11/2016	<MDC	3.0	7.1	6.9
4/18/2016	<MDC	3.0	8.5	6.9
4/25/2016	<MDC	3.0	9.7	6.9
5/2/2016	<MDC	3.0	9.6	6.9
5/9/2016	<MDC	3.0	<MDC	6.9
5/16/2016	<MDC	3.0	9.4	6.9
5/23/2016	<MDC	3.0	7.1	6.9
5/31/2016	4.5	3.0	18.1	6.9
6/6/2016	<MDC	3.0	16.2	6.9
6/13/2016	<MDC	3.0	13.9	6.9
6/20/2016	<MDC	3.0	20.7	6.9
6/27/2016	<MDC	3.0	15.9	6.9

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
Site Air				
7/5/2016	<MDC	3.0	14.6	6.9
7/10/2016	<MDC	3.0	11.0	6.9
7/19/2016	<MDC	3.0	12.6	6.9
7/25/2016	<MDC	3.0	8.9	6.9
8/2/2016	<MDC	3.0	7.3	6.9
8/8/2016	<MDC	3.0	9.3	6.9
8/15/2016	<MDC	3.0	9.8	6.9
8/22/2016	<MDC	3.0	<MDC	6.9
8/29/2016	<MDC	3.0	7.2	6.9
9/6/2016	<MDC	3.0	<MDC	6.9
9/12/2016	<MDC	3.0	<MDC	6.9
9/19/2016	<MDC	3.0	9.9	6.9
9/26/2016	<MDC	3.0	12.9	6.9
10/3/2016	<MDC	3.0	<MDC	6.9
10/10/2016	<MDC	3.0	12.3	6.9
10/17/2016	<MDC	3.0	9.0	6.9
10/24/2016	<MDC	3.0	<MDC	6.9
10/31/2016	<MDC	3.0	7.9	6.9
11/7/2016	<MDC	3.0	13.3	6.9
11/14/2016	<MDC	3.0	8.9	6.9
11/21/2016	<MDC	3.0	19.5	6.9
11/28/2016	<MDC	3.0	10.9	6.9
12/5/2016	<MDC	3.0	7.6	6.9
12/12/2016	<MDC	3.0	<MDC	6.9
12/19/2016	<MDC	3.0	13.8	6.9
12/27/2016	<MDC	3.0	8.8	6.9

Table D.9 Summary of Ambient Gamma Results

Location	Quarter 1 mR/quarter	Quarter 2 mR/quarter	Quarter 3 mR/quarter	Quarter 4 mR/quarter	Annual Exposure mR/year
SHER-01	11.9	11.9	14.5		51.0
SHER-02	10.9	9.7	12.5	8.7	41.7
SHER-03	10.3	11.3	13.1	10.3	45.1
SHER-04	11.2	12.5	13.4	11.5	48.6
SHER-05	11.8	10.3	14.4	10.5	47.0
SHER-06	11.7	13.0	14.8	10.7	50.1
SHER-07	9.3		14.5	10.8	46.1
SHER-08	9.9	9.9	12.6	9.9	42.2
SHER-09	6.7	7.7	9.4	7.8	31.5
SHER-10	11.0	12.6	13.9	9.9	47.4
SHER-11	9.8	12.2	13.0	11.0	45.9
SHER-12	9.9	10.5	13.9		45.6
SHER-13	9.6	10.0	14.6	9.6	43.8

Blanks in the table indicate that dosimeters were missing at the end of the quarter.
Annual Exposure column based on averages of all available data.
Quarter length is estimated to be 91.25 days.

APPENDIX E
Background Sample Results

Table E.1 Gross Alpha/Beta Results for All Water Samples
Results are in picocuries per Liter (pCi/L)

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
East Boat Dock				
1/27/2016	<MDC	2.1	<MDC	4.1
4/14/2016	<MDC	2.1	<MDC	4.1
7/7/2016	<MDC	2.1	<MDC	4.1
10/13/2016	<MDC	2.1	<MDC	4.1
Strawkaws Boat Ramp				
1/27/2016	<MDC	2.1	<MDC	4.1
4/14/2016	<MDC	2.1	<MDC	4.1
7/7/2016	<MDC	2.1	4.6	4.1
10/13/2016	<MDC	2.1	<MDC	4.1
West Boat Ramp				
1/27/2016	<MDC	2.1	<MDC	4.1
4/14/2016	<MDC	2.1	<MDC	4.1
7/7/2016	<MDC	2.1	<MDC	4.1
10/13/2016	<MDC	2.1	<MDC	4.1

Table E.2 Tritium (H-3) Results for Water Samples from Background Location
Results are in picocuries per liter (pCi/L)

Location	H-3	
Date	Result	MDC
East Boat Dock		
1/27/2016	<MDC	200
4/14/2016	<MDC	200
7/7/2016	<MDC	200
10/13/2016	<MDC	200
Strawkaws Boat Ramp		
1/27/2016	<MDC	200
4/14/2016	<MDC	200
7/7/2016	<MDC	200
10/13/2016	<MDC	200
West Boat Ramp		
1/27/2016	<MDC	200
4/14/2016	<MDC	200
7/7/2016	<MDC	200
10/13/2016	<MDC	200

Table E.3 Gamma Results for Water Samples from Background Location
Results are in picocuries per liter (pCi/L)

Location	Am-241		Co-60		Cs-137	
Date	Result	MDC	Result	MDC	Result	MDC
East Boat Ramp						
1/27/2016	<MDC	46	<MDC	4.4	<MDC	3.7
4/14/2016	<MDC	46	<MDC	4.4	<MDC	3.7
7/7/2016	<MDC	46	<MDC	4.4	<MDC	3.7
10/13/2016	<MDC	46	<MDC	4.4	<MDC	3.7
Strawkaws Boat Ramp						
1/27/2016	<MDC	46	<MDC	4.4	<MDC	3.7
4/14/2016	<MDC	46	<MDC	4.4	<MDC	3.7
7/7/2016	<MDC	46	<MDC	4.4	<MDC	3.7
10/13/2016	<MDC	46	<MDC	4.4	<MDC	3.7
West Boat Ramp						
1/27/2016	<MDC	46	<MDC	4.4	<MDC	3.7
4/14/2016	<MDC	46	<MDC	4.4	<MDC	3.7
7/7/2016	<MDC	46	<MDC	4.4	<MDC	3.7
10/13/2016	<MDC	46	<MDC	4.4	<MDC	3.7

Table E.4 Gamma Results for Vegetation Samples from Background Location
Results are in picocuries per liter (pCi/g)

Location	Am-241		Co-60		Cs-137	
Date	Result	MDC	Result	MDC	Result	MDC
East Boat Ramp						
7/7/2016	<MDC	0.5	<MDC	0.1	<MDC	0.1
Strawkaws Boat Ramp						
7/7/2016	<MDC	0.5	<MDC	0.1	<MDC	0.1
West Boat Ramp						
7/7/2016	<MDC	0.5	<MDC	0.1	<MDC	0.1

Table E.5 Air Monitoring Gross Alpha/Beta Results for Background Location (Springfield)
Results are in femtocuries per cubic meter (fCi/m³)

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
Knotts Street, Springfield				
1/4/2016	6.8	3.3	46.3	8.3
1/11/2016	<MDC	3.3	18.3	8.3
1/19/2016	4.5	3.3	44.7	8.3
1/25/2016	<MDC	3.3	34.5	8.3
2/1/2016	<MDC	3.3	33.1	8.3
2/8/2016	<MDC	3.3	24.4	8.3
2/16/2016	<MDC	3.3	28.2	8.3
2/22/2016	<MDC	3.3	24.7	8.3
2/29/2016	3.4	3.3	28.8	8.3
3/7/2016	<MDC	3.3	21.9	8.3
3/14/2016	<MDC	3.3	26.3	8.3
3/21/2016	<MDC	3.3	15.9	8.3
3/28/2016	<MDC	3.3	17.3	8.3
4/4/2016	<MDC	3.3	22.0	8.3
4/11/2016	<MDC	3.3	17.8	8.3
4/18/2016	<MDC	3.3	27.6	8.3
4/25/2016	<MDC	3.3	28.9	8.3
5/2/2016	<MDC	3.3	19.8	8.3
5/9/2016	<MDC	3.3	20.1	8.3
5/16/2016	<MDC	3.3	13.7	8.3
5/23/2016	3.4	3.3	21.5	8.3
5/31/2016	3.4	3.3	21.6	8.3
6/6/2016	<MDC	3.3	24.5	8.3
6/13/2016	<MDC	3.3	20.5	8.3
6/20/2016	3.5	3.3	26.5	8.3
6/27/2016	3.5	3.3	30.6	8.3

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
Knotts Street, Springfield				
7/5/2016	<MDC	3.3	19.0	8.3
7/11/2016	<MDC	3.3	27.6	8.3
7/18/2016	<MDC	3.3	24.7	8.3
7/25/2016	<MDC	3.3	29.1	8.3
8/1/2016	<MDC	3.3	32.2	8.3
8/8/2016	<MDC	3.3	26.7	8.3
8/16/2016	<MDC	3.3	31.1	8.3
8/22/2016	<MDC	3.3	34.3	8.3
8/29/2016	3.5	3.3	22.8	8.3
9/6/2016	<MDC	3.3	28.6	8.3
9/12/2016	<MDC	3.3	17.8	8.3
9/20/2016	<MDC	3.3	38.9	8.3
9/26/2016	<MDC	3.3	58.4	8.3
10/3/2016	<MDC	3.3	14.8	8.3
10/11/2016	5.9	3.3	35.8	8.3
10/18/2016	<MDC	3.3	30.2	8.3
10/24/2016	<MDC	3.3	23.5	8.3
10/31/2016	<MDC	3.3	34.6	8.3
11/7/2016	4.3	3.3	38.0	8.3
11/14/2016	<MDC	3.3	28.6	8.3
11/21/2016	4.2	3.3	58.3	8.3
11/28/2016	<MDC	3.3	37.0	8.3
12/6/2016	<MDC	3.3	24.7	8.3
12/12/2016	4.1	3.3	30.9	8.3
12/19/2016	6.7	3.3	42.2	8.3
12/27/2016	5.7	3.3	39.7	8.3

Table E.6 Air Monitoring Gross Alpha/Beta Results for Background Location (Marion)
Results are in femtocuries per cubic meter (fCi/m³)

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
Marion Office				
1/4/2016	4.4	1.5	35.9	4.5
1/11/2016	<MDC	1.5	18.5	4.5
1/19/2016	3.6	1.5	36.8	4.5
1/25/2016	2.8	1.5	28.5	4.5
2/2/2016	1.8	1.5	30.4	4.5
2/8/2016	2.1	1.5	26	4.5
2/16/2016	<MDC	1.5	22.7	4.5
2/22/2016	1.6	1.5	26.4	4.5
2/29/2016	3.2	1.5	25	4.5
3/7/2016	2	1.5	23.7	4.5
3/14/2016	2.6	1.5	15.4	4.5
3/21/2016	<MDC	1.5	15.4	4.5
3/28/2016	2.7	1.5	18.6	4.5
4/4/2016	4.8	3	45.7	4.5
4/11/2016	2.1	1.5	17.4	4.5
4/18/2016	2.1	1.5	25.2	4.5
4/25/2016	<MDC	1.5	26.6	4.5
5/2/2016	1.6	1.5	16.2	4.5
5/16/2016	<MDC	1.5	48.1	4.5
5/23/2016	3.7	1.5	23.3	4.5
5/31/2016	3.4	1.5	23.7	4.5
6/6/2016	4.3	1.5	24.1	4.5
6/13/2016	4.6	1.5	29.2	4.5
6/20/2016	3.2	1.5	26.9	4.5
6/27/2016	2.6	1.5	30	4.5

Location	Alpha		Beta	
Date	Result	MDC	Result	MDC
Marion Office				
7/11/2016	1.9	1.5	19.1	4.5
7/18/2016	3.3	1.5	31	4.5
7/25/2016	2.6	1.5	31.4	4.5
8/1/2016	2.4	1.5	25.9	4.5
8/8/2016	<MDC	1.5	25.5	4.5
8/15/2016	<MDC	1.5	21.4	4.5
8/22/2016	<MDC	1.5	6.5	4.5
8/29/2016	2.7	1.5	24.7	4.5
9/6/2016	2.3	1.5	30	4.5
9/12/2016	1.9	1.5	20.3	4.5
9/19/2016	1.7	1.5	34	4.5
9/26/2016	1.7	1.5	53.8	4.5
10/3/2016	<MDC	1.5	18.4	4.5
10/11/2016	6.3	1.5	40.5	4.5
10/17/2016	1.6	1.5	37	4.5
10/24/2016	<MDC	1.5	23.5	4.5
10/31/2016	4.6	1.5	44.3	4.5
11/7/2016	4.1	1.5	28.5	4.5
11/14/2016	3.4	1.5	30.3	4.5
11/21/2016	4.1	1.5	51.3	4.5
11/28/2016	1.9	1.5	39.8	4.5
12/6/2016	3.9	1.5	25.7	4.5
12/12/2016	4.9	1.5	27.9	4.5
12/27/2016	4.2	1.5	35.2	4.5

Table E.7 Summary of Ambient Gamma Results for Background Location

Location	Quarter 1 mR/quarter	Quarter 2 mR/quarter	Quarter 3 mR/quarter	Quarter 4 mR/quarter	Annual Exposure mR/year
KC-01	11.3	9.3	8.9	9.9	39.3
KC-02	10.4	7.9	11.0	10.3	39.6
KC-03	10.3	9.4	8.9	8.6	37.1
KC-04	10.6	8.6	9.9	9.7	38.8
KC-05	9.5	10.8	7.5	8.2	36.0
KC-06	8.0	7.5	6.8	7.9	30.2
KC-07	9.2	8.9	8.1	9.3	35.5
KC-08	8.2	8.9	9.4		35.4
KC-09	10.2	10.2	8.8	7.5	36.7
KC-10		10.3	8.7	9.4	37.8
KC-11	11.8	10.2	10.8	9.4	42.2
KC-12		10.9	10.6	9.0	40.6
KC-13	11.0	9.9	10.7	9.7	41.2
KC-14	11.3	11.1	9.3	9.1	40.9

Blanks in the table indicate that dosimeters were missing at the end of the quarter.
Annual Exposure column based on averages of all available data.
Quarter length is estimated to be 91.25 days.

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