

Kansas Department of Health and Environment
Report of Radiological Environmental Monitoring of the Environs Surrounding
Wolf Creek Generating Station



July 2014-June 2015
Division of Public Health, Bureau of Community Health Systems
Radiation Control Program
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Kansas Department of Health and Environment
 Environmental Radiation Surveillance Report
 Wolf Creek Generating Station
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Introduction

Wolf Creek Generating Station (WCGS) is a pressurized water nuclear reactor capable of producing over 1,200 megawatts of electrical power. Located near Burlington Kansas, the plant is operated by Wolf Creek Nuclear Operating Corporation (WCNOC). The facility releases radioactive material to the environment in the form of liquid and gaseous effluents. This report details the results of surveillance of the environs surrounding WCGS conducted by the Kansas Department of Health and Environment (KDHE) from July 1, 2014 through June 30, 2015.

KDHE's Wolf Creek Environmental Radiation Surveillance (ERS) program began in 1979 in accordance with Kansas Administrative Regulation (K.A.R.) 28-19-81 with the initial selection of surface water sampling locations. The ERS program parallels (and partially overlaps) the WCNOC Radiological Environmental Monitoring Program (REMP).

The purpose of the ERS program is to detect, identify, and measure radioactive material and direct radiation released to the environment from the operation of WCGS. Data indicating the release of elevated levels of radioactive material will be used to determine the need for corrective and/or protective actions to protect the health and safety of the public.

The ERS program includes the following monitoring methods:

- Measurement of ambient external radiation levels using optically stimulated luminescence dosimeters
- Monitoring of radionuclides present in ambient air through weekly collection and laboratory analysis of continuous air samples
- Monitoring of radionuclides present in water, terrestrial vegetation, aquatic vegetation, fish, sediments, and soil through scheduled and random sample collection and laboratory analysis.

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Results Summary

The most significant radionuclide present in surface water samples collected in the Coffey County Lake is tritium (^3H), a beta emitter. The highest ^3H concentration measured in the Coffey County Lake during SFY 2015 was 14,500 pCi/l in March, 2015. This maximum Coffey County Lake ^3H concentration is 73% of the National Primary Drinking Regulation maximum contaminant level (MCL) of 20,000 pCi/l. *The water from the Coffey County Lake is not used as a drinking water source.* The average CCL surface water ^3H concentration for SFY 2015 was 12,075 pCi/l, or 60% of MCL. Coffey County Lake is not approved for any aquatic recreation other than fishing. All other non-CCL surface water and offsite ground water samples collected in the environs of WCGS during SFY 2015 indicated no radionuclides present attributable to the operation of WCGS.

Aquatic vegetation samples are the best indicators for monitoring the seasonal fluctuations of fission and activation product levels in the Coffey County Lake. No aquatic vegetation sample showed any nuclides attributable to WCGS operation. Five trending samples and six random samples were analyzed.

Sediment samples have been excellent indicators for the long-term buildup of fission and activation product activity levels in the Coffey County Lake. The highest fission product activity in sediments during SFY 2015 was 121 pCi/kg-dry ^{137}Cs in a bottom sediment sample from the John Redmond Reservoir. No sediment samples showed any nuclides attributable to WCGS operation.

Airborne sample analysis indicated that no radionuclides attributable to the operation of WCGS were present above the lower limits of detection during SFY 2015.

Sample analysis of aquatic vegetation, offsite ground water, terrestrial vegetation, soil, milk, grain, and vegetable samples collected in the environs of WCGS during SFY 2015 indicated no radionuclides present attributable to the operation of WCGS.

Samples of nine species of fish were taken from the Coffey County Lake during SFY 2015. Sample analysis of edible fish portions collected in the environs of WCGS during SFY 2015 indicated that no gamma emitters attributable to WCGS operation were present. The highest ^3H concentration in tissue was 8,132 pCi/kg-wet found in a channel catfish sample taken from the CCL. Using an ICRP 30 dose conversion factor for ingestion ($h_{E,50}$) of 6.40×10^{-8} mrem per pCi ^3H ingested, a standard man consuming 21 kg/y of fish containing 8,132 pCi/kg ^3H would receive a committed effective dose equivalent of 0.010 mrem. The projected dose equivalent is far below the 100 mrem/yr regulatory limit for a member of the public.

Data from direct radiation monitoring sites revealed no significant changes from preoperational data. The lowest direct radiation levels are found closest to the WCGS. The direct radiation

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levels on the Coffey County Lake baffle dikes at the 1,200 m exclusion area boundary are the lowest of any monitored site. The limestone used to construct the baffle dikes has a lower natural background radioactivity than the original soil present before the construction of the Coffey County Lake. This effect of construction on the terrestrial component of natural background radiation was noted on radiation surveys conducted around the WCGS site before bringing the initial fuel load on the site. The water from the Coffey County Lake also acts as an effective shield from terrestrial radiation that was present before Coffey County Lake filling.

The ratio of KDHE results to WCNOG results ranged from 1.0-1.5. A summary of comparison data may be found in the Results Comparison Table.

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Results Summary Table

Type of Sample	Number of Sampling Stations	Total Samples Collected
Air (Particulate and Iodine)	5	520
Soil	5	5
Random Soil	10	10
Direct Radiation	31	248
Surface Water	4	38
Offsite Ground Water	6	23
Onsite Ground Water	3	12
Sediments	5	12
Random Sediments	16	16
Aquatic Vegetation	4	4
Random Aquatic Vegetation	7	7
Game Animals/Domestic Meat	1	1
Terrestrial Vegetation/Human, Animal Food	8	9
Random Terrestrial Vegetation/Human, Animal Food	10	10
Milk	2	8
Fish	2	19
Total	119	942

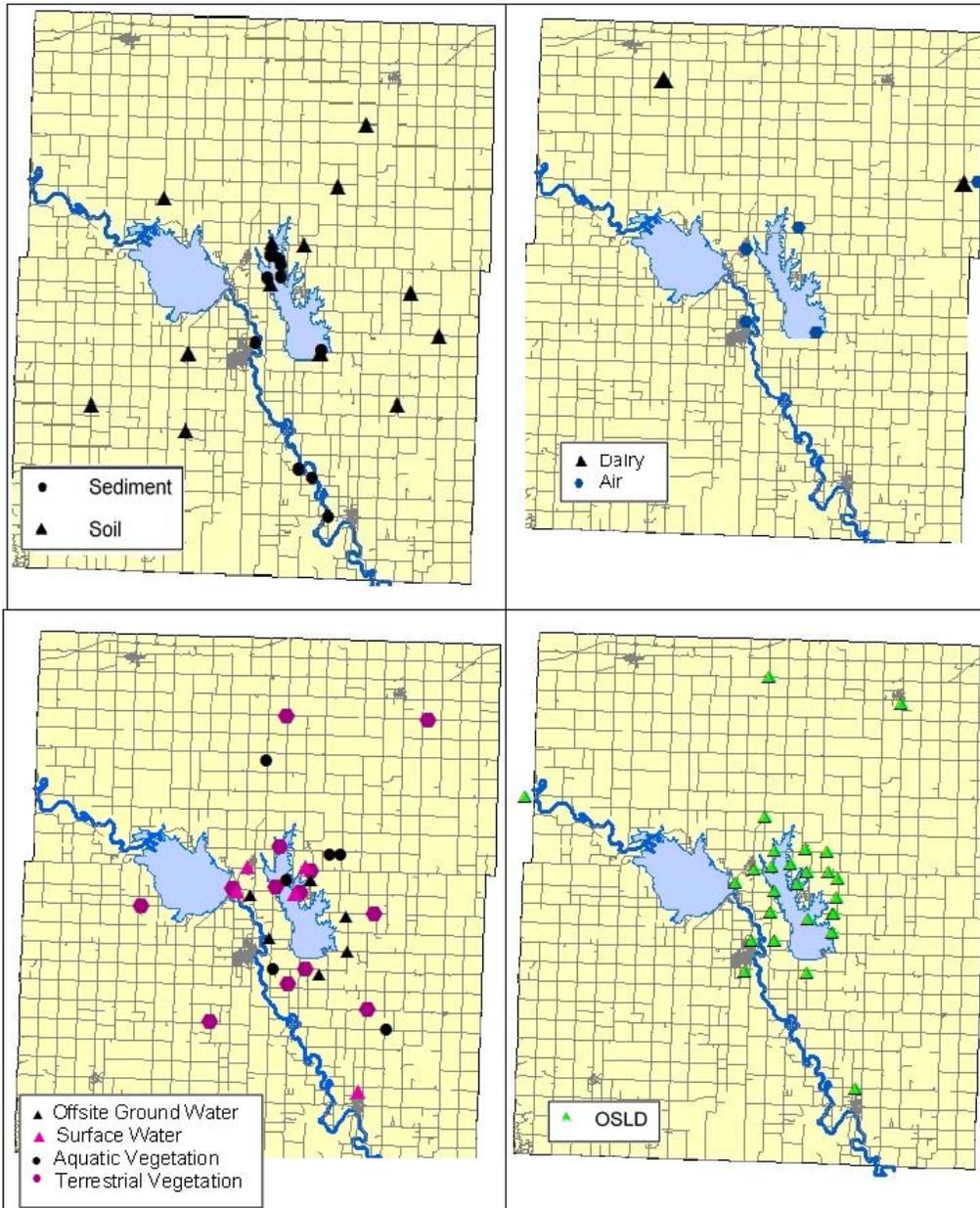
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Results Comparison Table

Description	Average	Standard Deviation	Minimum	Maximum	N
OSLD direct radiation, mR per 90 day quarter	18.4	2.8	10.8	23.4	124
Airborne particulate and radioiodine cartridge gamma isotopic analysis (⁷ Be) pCi/m ³	0.115	0.038	<0.02	0.214	52
Coffey County Lake Surface Water tritium (³ H), pCi/l (Spillway)	12111	1139	10456	13700	12
John Redmond Reservoir, control (N-1) (³ H), pCi/l	<350	NA	NA	NA	12
Coffey County Lake MUDS (³ H), pCi/l	12039	1312	10455	14500	10
Neosho River Near LeRoy (³ H), pCi/l	<350	NA	NA	NA	3
New Strawn City Lake (³ H), pCi/l	<350	NA	NA	NA	1
Offsite ground water tritium (³ H), pCi/l (All Stations)	<350	NA	NA	NA	24
Onsite ground water tritium (³ H), pCi/l (Stations where activity was detected)	2633	1717	1510	6550	12
Surface and Offsite Ground Water Gamma Isotopic Analysis	Gamma isotopic analysis indicated that no gamma emitters attributable to Wolf Creek Generating Station operation were present above the lower limits of detection in any surface water or offsite ground water sample evaluated.				
Gamma isotopic analysis of soil, pasturage, garden vegetables, and grain.	Gamma isotopic analysis indicated that no gamma emitters attributable to Wolf Creek Generating Station operation were present above the lower limits of detection in any soil, milk, pasturage, garden vegetable and grain sample evaluated.				
Maximum activity attributable to Wolf Creek Generating Station operation, pCi/kg					
Coffey County Lake Fish	³ H, 8132 ± 125 pCi/kg (Channel Catfish)				
Comparison Of KDHE and WCNOG Results					
Analysis	Average Ratio of KDHE results to WCNOG results		Comments		
OSLD Direct Radiation	1.1		12 Collocated Sites		
Surface Water ³ H	1.03 (N=12)		CCL Spillway		
Sediment gamma isotopic Fish ³ H	1.06		¹³⁷ Cs, when detected		
Fish ³ H	1.12 (N=1)		CCL		
Offsite Ground Water ³ H	1.09		AUX, West-ESW-West		

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Sample Location Maps



Sample Results

Inhalation Pathway

Air Particulate and Iodine

Air samples were collected weekly. Five air-sampling sites, four of which are collocated with WCNOG, have continuously operating low-volume air samplers contained in a fiberglass housing mounted on utility poles approximately one meter from the ground. Air samplers are located at Sharpe, KS (A-1), east of the Coffey County Lake dam (H-1), Burlington, KS (L-1), New Strawn, KS (P-1), and near Westphalia, KS (D-2). The collocated sites include the highest calculated annual average ground level relative concentration (X/Q) area at Sharpe, the highest calculated annual average ground level relative deposition (D/Q) area at New Strawn, and a control location near Westphalia. An average flow rate of 30 liters per minute is used with 47 mm diameter glass fiber particulate filters and 5 percent triethylenediamine (TEDA) impregnated carbon cartridges for radioiodine activity (the major isotope of concern is ^{131}I). TEDA binds the iodine chemically and reduces losses from desorption.

Field assay of each particulate filter was performed at the time of collection. The particulate filter was counted using a thin window GM 'pancake' detector (Ludlum Model 44-40 or equivalent) and a count rate instrument. A sample net count rate of greater than two times the net count rate of the current control (Near Westphalia, D-2) air sample indicates a potential anomaly and the filter is then flagged for individual gamma isotopic analysis.

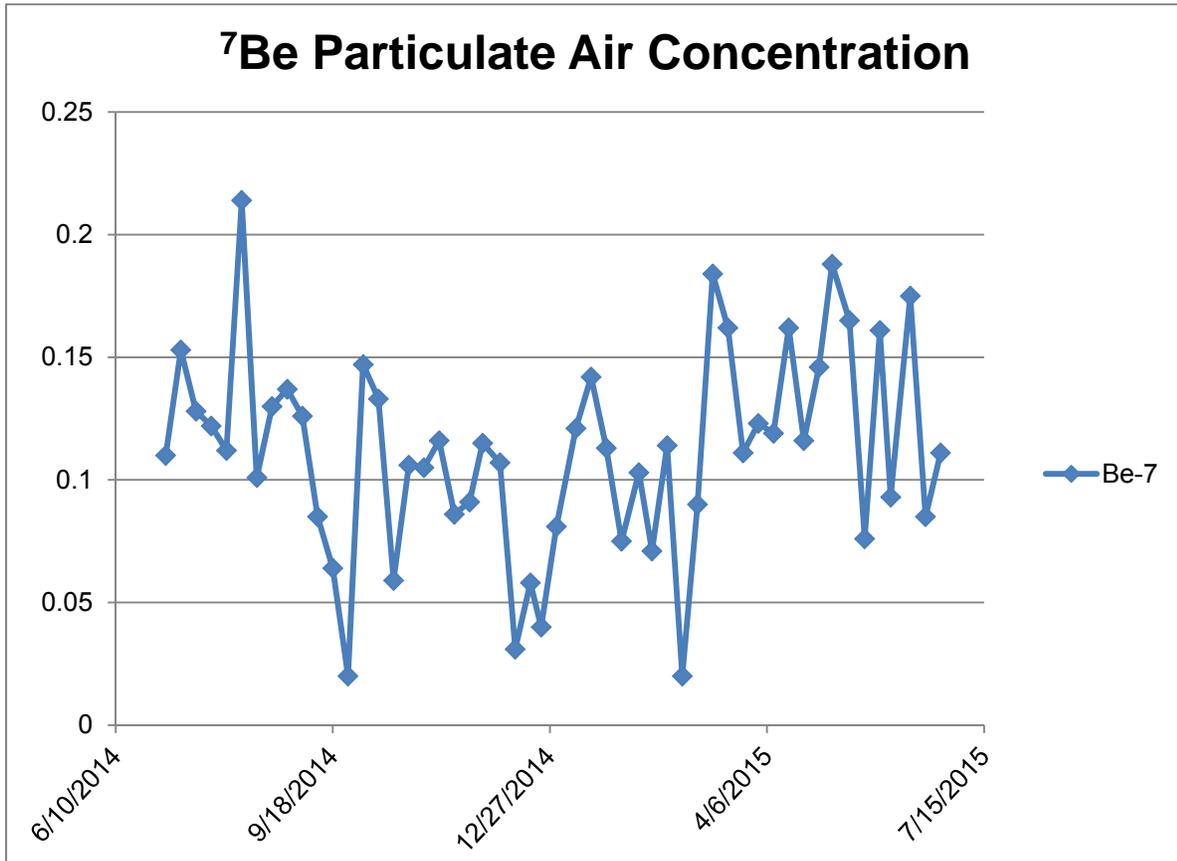
Gamma isotopic analysis was performed on two composite samples, one composed of the five particulate filters and the other of the five charcoal cartridges. Indication of ^{131}I or any other fission or activation product requires gamma isotopic analysis of each individual particulate filter and associated charcoal cartridge.

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Table 1 Weekly Air Particulate/Iodine Monitoring, pCi/m³

Number of Samples	Average ⁷ Be Concentration	Average Iodine Concentration
52	0.115 ± 0.10	<0.033

Graph 1 Weekly Particulate ⁷Be Concentration, pCi/m³



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Airborne Pathway

Soil

Four indicator, one control, and ten random annual soil samples were collected. Indicator soil samples were collected near Stringtown Cemetery, east of the CCL dam, at the CCL MUDS area, and at the public environmental education area. One control soil sample was collected east of WCGS at the Scott Valley Church. Random soil samples were collected at ten locations. Soil samples collected from the Coffey County public use areas are split with WCNOG.

A gamma isotopic analysis is performed on all soil samples collected.

Table 2 Annual Samples for Radionuclide Deposition on Soil, pCi/kg KDHE (WCNOG)

	A-1	E-1	H-1
Nuclide	Near Stringtown Cemetery	Scott Valley Church (control)	East of CCL Dam
Date	12/10/2014	8/12/2014	10/24/2014
¹³⁷ Cs	69 ± 3	289 ± 10	23 ± 1
⁴⁰ K	12700 ± 363	11400 ± 347	12500 ± 351
	P-1 (MUDS)	R-1 (EEA)	
Date	4/1/2015	3/31/2015	
¹³⁷ Cs	242 ± 8 (214.7 ± 32.4)	232 ± 8 (244.7 ± 37.6)	
⁴⁰ K	10800 ± 300 (11234.0 ± 653.3)	<8732 (9710.8 ± 601.6)	

Table 3 Random Samples for Radionuclide Deposition on Soil, pCi/kg

Location	Date	Nuclide	
		¹³⁷ Cs	⁴⁰ K
29th and Quail	7/29/2014	250 ± 8	9880 ± 299
8th and Juneberry	8/7/2014	312 ± 9	11500 ± 332
Near 19th and Homestead Rd.	9/15/2014	330 ± 10	14200 ± 400
Field Near 9th and Emmer Rd.	10/7/2014	159 ± 8	15000 ± 400
23rd Rd Between Reaper and Shetland*	2/10/2015	<8*	<8732*
1/4 mi S of 12th on Juneberry	3/3/2015	222 ± 8	12900 ± 377
Kafir and 20th Rd	3/3/2015	331 ± 8	11900 ± 364
20TH & Verdure	3/9/2015	77 ± 8	16400 ± 461
13th and Wayside	6/8/2015	203 ± 6	10000 ± 300
10th & Underwood	6/19/2015	87 ± 8	9600 ± 281

*Suspected laboratory error, which was unable to be verified. This data is what was reported by the laboratory.

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Direct Radiation Pathway

Direct Radiation Monitoring

Direct radiation monitoring was accomplished using Landauer Luxel optically stimulated luminescence dosimeters (OSLDs). OSLDs are read by Landauer. OSLD readings are corrected for transit and handling exposure.

Thirty-one locations around the WCGS were monitored by KDHE, including three control locations greater than ten miles from WCGS. Two OSLDs were used per site to generate an average quarterly reading. The dosimeters are contained in specially constructed holders suspended approximately one meter above the ground. Staff members exchange OSLDs quarterly. KDHE has collocated OSLDs with WCNOG at twelve sites.

Table 4 Quarterly Direct Radiation Monitoring, mR/Standardized 90-day Qtr.

Location	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1. A-1 (1), North of WCGS	23.1	20.0	20.8	19.9
2. A-2, Sharpe	20.1	18.5	20.3	17.5
3. A-3, Forward Staging Area	18.1	18.0	19.8	16.1
4. B-1, East Sharpe	21.1	19.5	21.3	17.5
5. B-2, Waverly Control	20.6	19.0	23.4	18.4
6. C-1, near residence	19.6	18.5	20.3	18.0
7. D-1 (9), near residence	18.6	17.5	18.8	16.5
8. E-1, near residence	20.6	19.5	21.3	18.0
9. F-1, near residence	21.6	18.5	19.8	17.5
10. G-1 (14), WCNOG gate	22.6	20.0	22.8	19.4
11. H-0 (42), CCL baffle dike A	17.1	14.5	14.2	11.3
12. H-1, east of CCL dam	20.1	19.5	20.3	15.1
13. H-2, LeRoy Control	19.6	18.0	21.8	17.0
14. J-1, near residence	18.6	16.0	19.3	15.6
15. K-1 (29), near residence	17.6	16.0	16.7	15.1
16. L-1 (27), near residence	19.6	17.5	20.3	18.0
17. L-2, Burlington	20.1	18.0	20.8	17.5
18. L-3, Coffey County Shop	17.6	16.5	19.8	16.5
19. M-1 (26), near residence	19.1	19.5	20.8	16.1
20. N-1, near pasture	21.6	19.0	21.3	18.4
21. P-0 (43), CCL baffle dike B	16.6	13.5	16.2	10.8
22. P-1, New Strawn	21.6	19.5	21.8	18.4
23. P-2, Hartford Control	18.1	16.0	18.8	15.6
24. P-3, CCL entrance	21.1	18.5	20.3	17.0
25. P-4 (46), CCL near MUDS	20.6	19.0	21.3	17.0
26. P-5, JRR public use area	19.6	18.5	20.8	18.0
27. Q-1, near residence	20.1	18.0	19.3	17.5
28. R-0 (41), Stringtown cemetery	21.6	20.0	21.3	18.0
29. R-1 (37), near residence	20.1	18.0	20.8	17.0
30. R-2 (44), CCL EEA	21.6	19.0	20.8	17.0
31. R-3, near Coffey County Airport	20.6	19.0	21.3	18.9

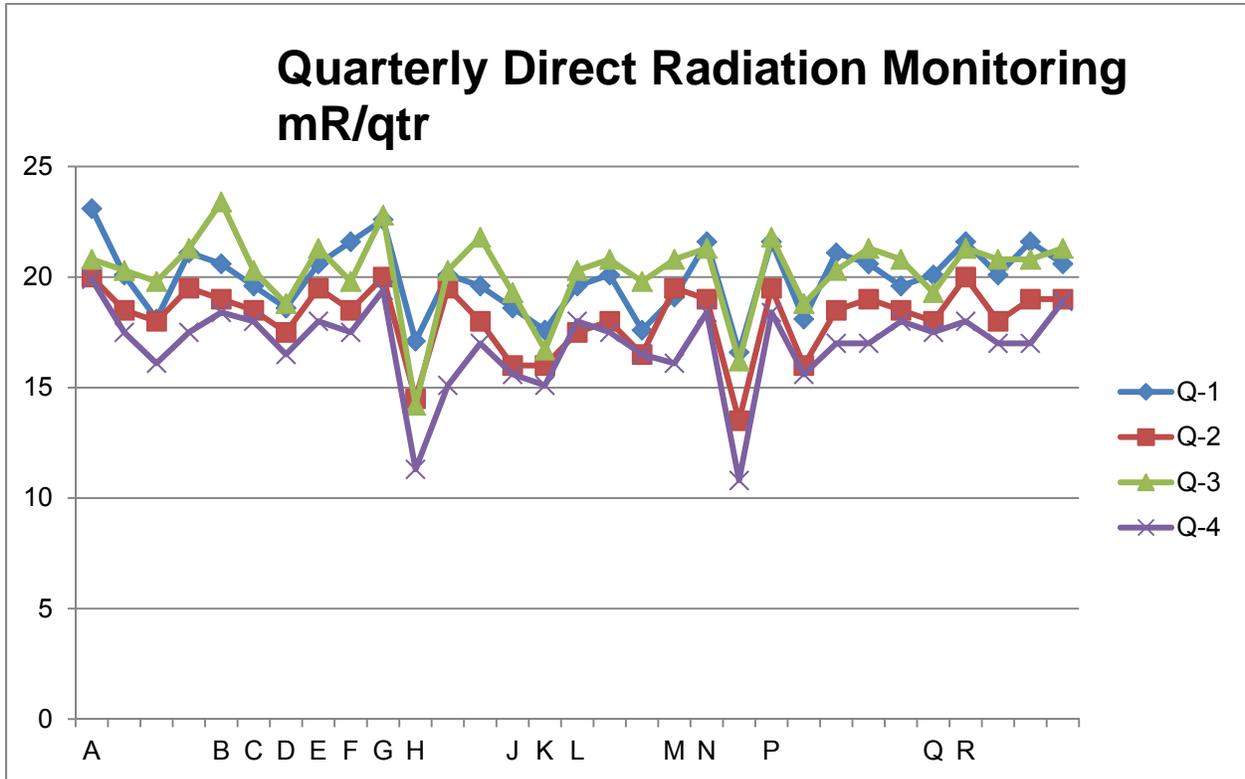
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Table 5 Quarterly Collocated Direct Radiation Monitoring, mR/Standardized 90-day Qtr.

Location	KDHE Monitoring Period	KDHE	WCNOC
KDHE(WCNOC)			
1. A-1 (1)	7/1/2014-10/7/2014	23.1	19.8
	10/7/2014-1/5/2015	20.0	15.8
	1/5/2015-4/3/2015	20.8	19.3
	4/3/2015-7/6/2015	19.9	19.3
2. D-1 (9)	7/1/2014-10/7/2014	18.6	17.1
	10/7/2014-1/5/2015	17.5	15.5
	1/5/2015-4/3/2015	18.8	13.5
	4/3/2015-7/6/2015	16.5	18.0
3. G-1 (14)	7/1/2014-10/7/2014	22.6	22.0
	10/7/2014-1/5/2015	20.0	17.6
	1/5/2015-4/3/2015	22.8	17.1
	4/3/2015-7/6/2015	19.4	18.9
4. H-0 (42)	7/1/2014-10/7/2014	17.1	15.8
	10/7/2014-1/5/2015	14.5	13.2
	1/5/2015-4/3/2015	14.2	11.4
	4/3/2015-7/6/2015	11.3	13.8
5. K-1 (29)	7/1/2014-10/7/2014	17.6	13.5
	10/7/2014-1/5/2015	16.0	14.1
	1/5/2015-4/3/2015	16.7	14.6
	4/3/2015-7/6/2015	15.1	16.3
6. L-1 (27)	7/1/2014-10/7/2014	19.6	18.1
	10/7/2014-1/5/2015	17.5	20.5
	1/5/2015-4/3/2015	20.3	18.3
	4/3/2015-7/6/2015	18.0	20.3
7. M-1 (26)	7/1/2014-10/7/2014	19.1	17.4
	10/7/2014-1/5/2015	19.5	16.1
	1/5/2015-4/3/2015	20.8	19.5
	4/3/2015-7/6/2015	16.1	17.8
8. P-0 (43)	7/1/2014-10/7/2014	16.6	10.4
	10/7/2014-1/5/2015	13.5	10.0
	1/5/2015-4/3/2015	16.2	12.0
	4/3/2015-7/6/2015	10.8	11.2
9. P-4 (46)	7/1/2014-10/7/2014	20.6	16.0
	10/7/2014-1/5/2015	19.0	16.7
	1/5/2015-4/3/2015	21.3	18.8
	4/3/2015-7/6/2015	17.0	20.8
10. R-0 (41)	7/1/2014-10/7/2014	21.6	21.4
	10/7/2014-1/5/2015	20.0	18.1
	1/5/2015-4/3/2015	21.3	17.7
	4/3/2015-7/6/2015	18.0	18.7
11. R-1 (37)	7/1/2014-10/7/2014	20.1	16.7
	10/7/2014-1/5/2015	18.0	18.0
	1/5/2015-4/3/2015	20.8	16.4
	4/3/2015-7/6/2015	17.0	17.7
12. R-2 (44)	7/1/2014-10/7/2014	21.6	20.8
	10/7/2014-1/5/2015	19.0	19.5
	1/5/2015-4/3/2015	20.8	17.7
	4/3/2015-7/6/2015	17.0	18.3

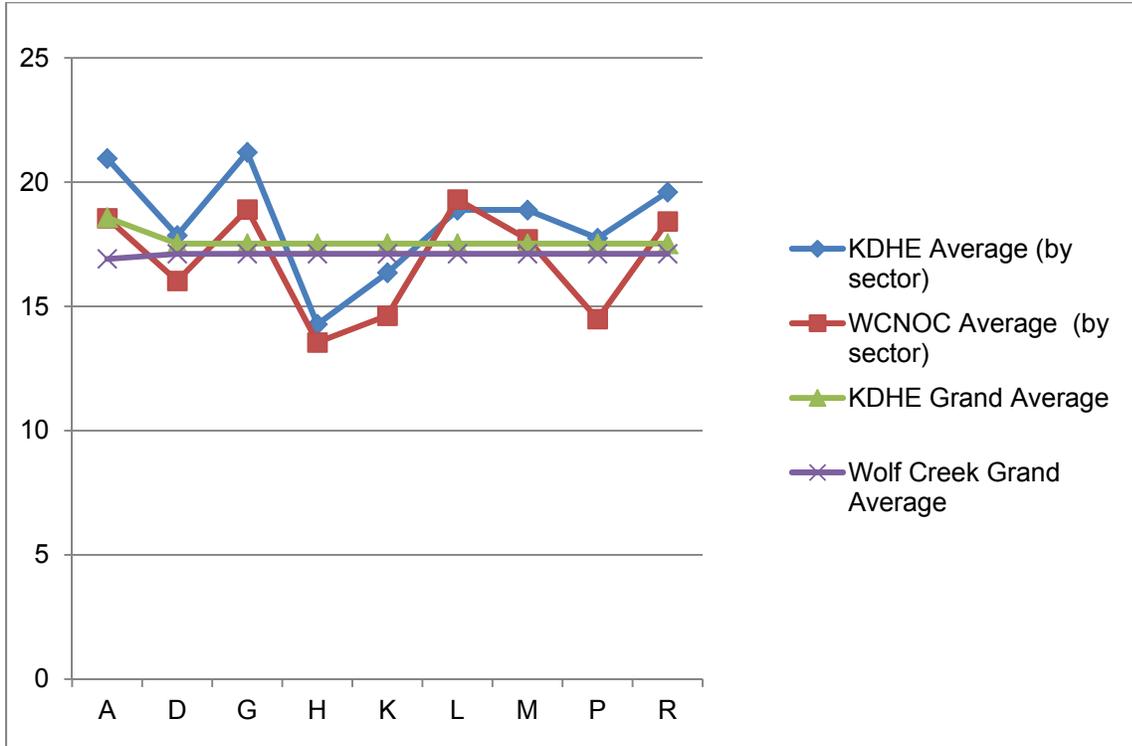
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Graph 2, Quarterly direct radiation results for KDHE OSLD sites

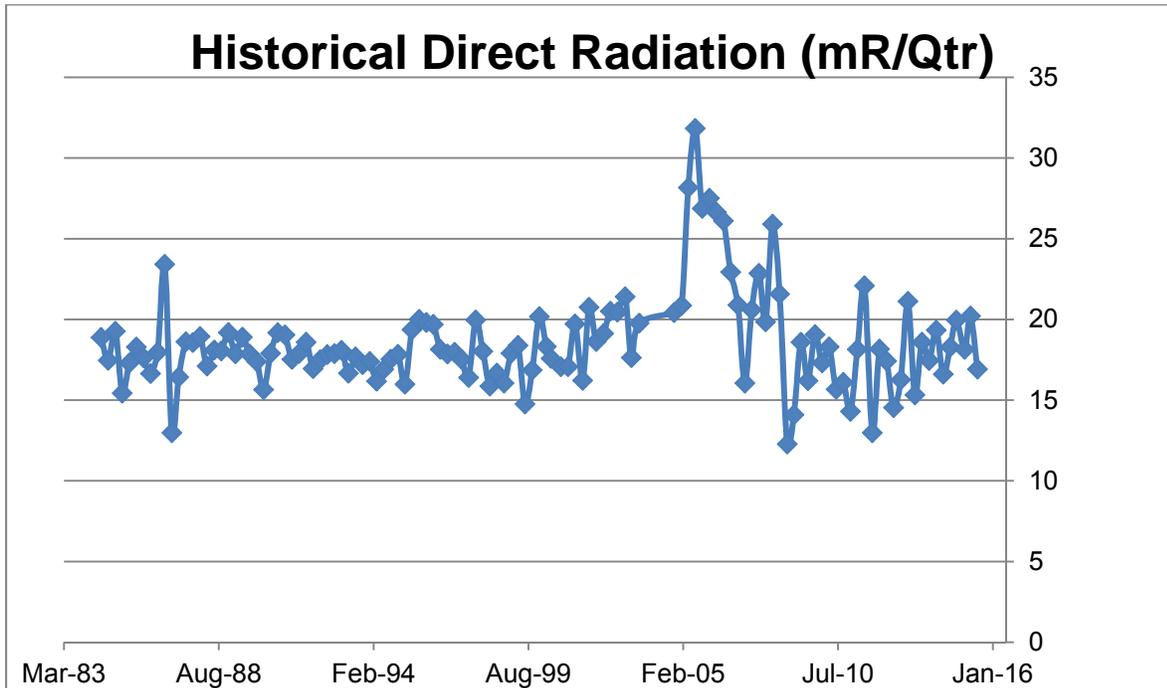


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Graph 3 Direct radiation monitoring results for co-located OSLD sites (mR/Quarter)



Graph 4 Historical KDHE direct radiation monitoring results (mR/Qtr)



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Waterborne Pathway

Surface Water

Surface water sampling was accomplished through the collection of one-gallon grab samples at the indicated locations. A control sample was collected monthly from John Redmond Reservoir. One sample was collected monthly from the Coffey County Lake (CCL) at the spillway. One sample was collected monthly (except for April and June, which were missed owing to administrative error) at the public fishing area on CCL, near the Makeup Discharge Structure (MUDS). Samples were collected monthly from the Neosho River near Leroy only when Coffey County Lake was overflowing to Wolf Creek at the spillway. Discharges to the river occurred during March, May and June of 2015. A sample was also collected annually from the New Strawn City Lake.

A gamma isotopic and tritium (^3H) analysis was done on each CCL water sample and ^3H analysis was done quarterly on a composite sample from JRR. Samples from John Redmond Reservoir and the Coffey County Lake Spillway were split with WCNOC.

Table 6 Monthly Samples for Waterborne Radionuclides (^3H) in Surface Water, pCi/L

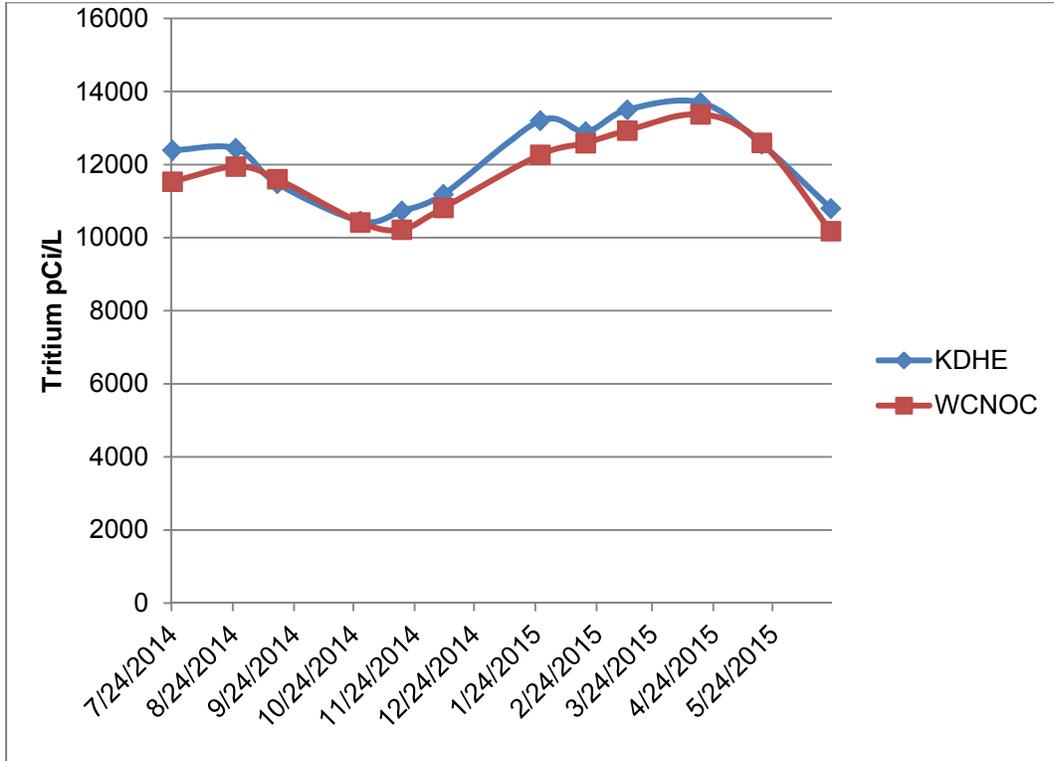
CCL Spillway			John Redmond Reservoir (Control)			MUDS ¹	
Date	KDHE	WCNOC	Date	KDHE	WCNOC	Date	KDHE
7/24/2014	12391 ± 337	11534 ± 309	7/24/2014	<350	<136	7/16/2014	12100 ± 415
8/25/2014	12443 ± 328	11950 ± 305	8/25/2014	<350	<176	8/22/2014	12204 ± 316
9/15/2014	11478 ± 314	11606 ± 337	9/15/2014	<350	<156	9/18/2014	11388 ± 318
10/27/2014	10456 ± 310	10419 ± 363	10/27/2014	<350	<169	10/16/2014	10455 ± 254
11/17/2014	10730 ± 308	10222 ± 361	11/17/2014	<350	<179	11/14/2014	11060 ± 312
12/8/2014	11185 ± 325	10817 ± 372	12/8/2014	<350	<166	12/8/2014	11488 ± 172
1/26/2015	13200 ± 333	12270 ± 402	1/26/2015	<350	<192	1/16/2015	13900 ± 352
2/18/2015	12900 ± 300	12590 ± 330	2/18/2015	<350	<148	2/10/2015	12500 ± 300
3/11/2015	13500 ± 347	12932 ± 338	3/11/2015	<350	<148	3/19/2015	14500 ± 348
4/17/2015	13700 ± 350	13376 ± 342	4/17/2015	<350	<152	5/18/2015	10800 ± 320
5/18/2015	12560 ± 340	12598 ± 336	5/18/2015	<350	<154	¹ Not sampled in April and June	
6/22/2015	10800 ± 291	10179 ± 299	6/22/2015	<350	<148		
H-1 Neosho River Near Leroy							
Date	KDHE						
3/3/2015	<350						
5/18/2015	<350						
6/8/2015	<350						

Table 7 Annual Samples for Deposition of Airborne Radionuclides in Surface Water, pCi/L

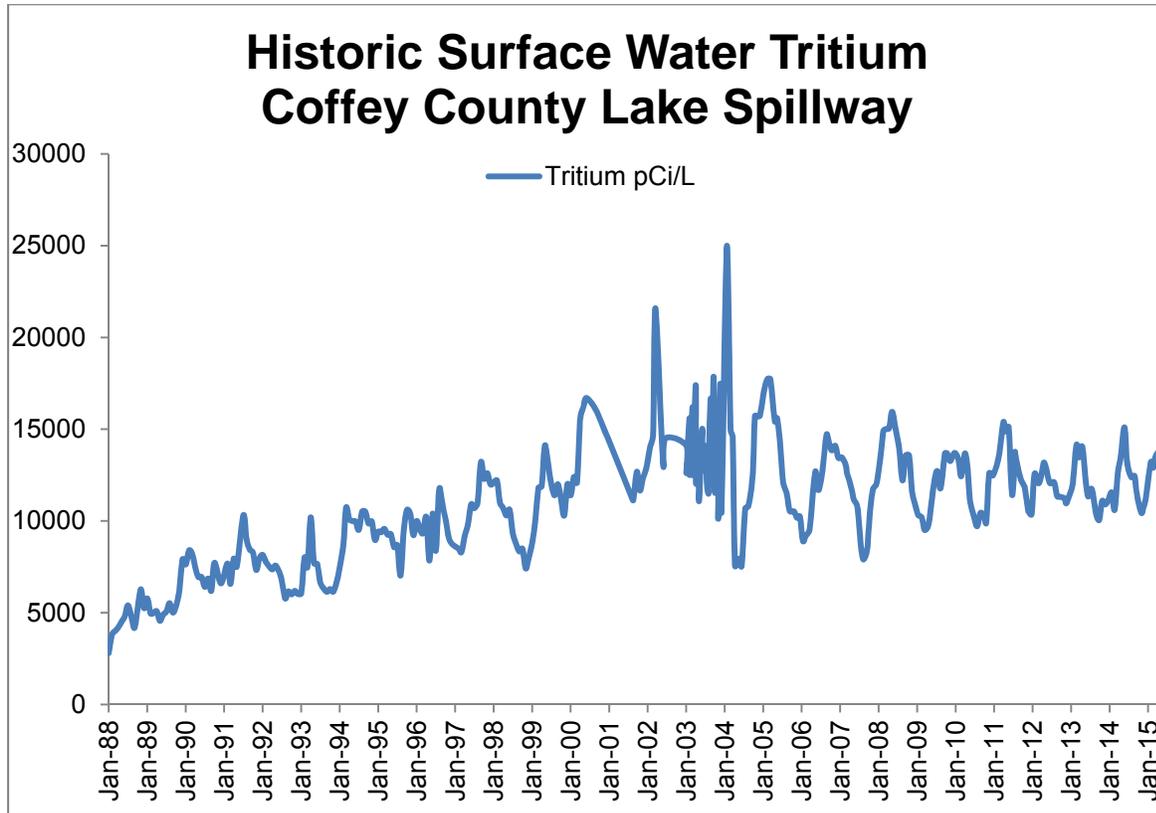
New Strawn City Lake	
Date	^3H
4/1/2015	<350

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Graph 5 Comparison of CCL Spillway Monthly Surface Water Tritium Results (pCi/L)



Graph 6 Historical KDHE Surface Water Tritium Results (CCL Spillway)



Ground Water

Ground water was collected quarterly offsite at wells in sectors B (control), C, F, G, and J. The control sample location was hydrologically up gradient from the facility and the other five are hydrologically down gradient. Samples were split with WCNOG. Samples were collected within the Wolf Creek owner controlled area along the Essential Service Water-buried pipe (two locations) and in the Wolf Creek protected area near the Auxiliary Building.

Gross alpha, beta, tritium and gamma isotopic analysis are done on each sample.

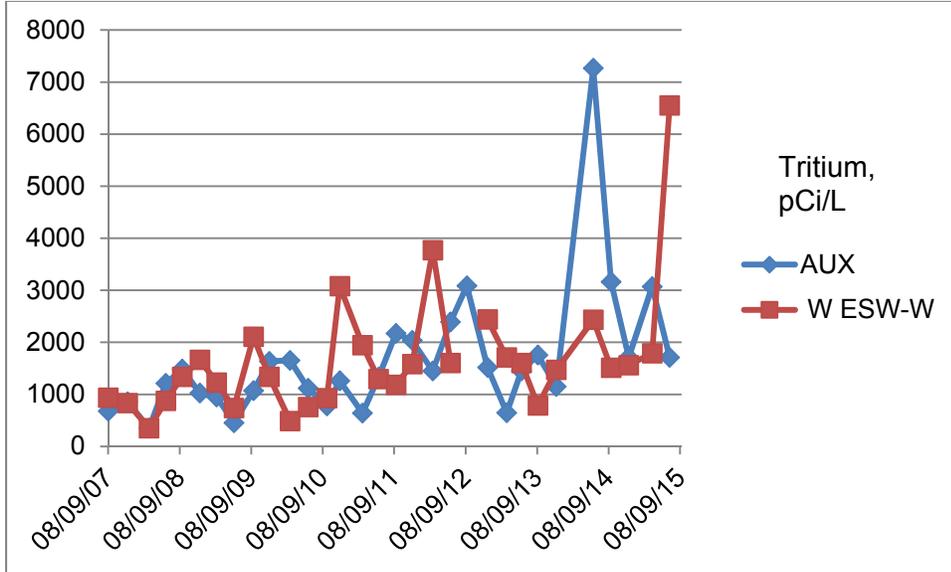
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Table 8 Quarterly Samples for Waterborne Radionuclides in Ground Water, pCi/L

Offsite Ground Water					
B-1 (B-12)			G-1 (G-2)		
Date	³ H KDHE	³ H WCNOG	Date	³ H KDHE	³ H WCNOG
8/25/2014	<350	<176	8/25/2014	<350	<176
11/17/2014	<350	<179	11/17/2014	<350	<179
3/11/2015	<350	<148	3/11/2015	<350	<148
5/18/2015	<350	<154	5/18/2015	<350	<154
F-1 (F-1)			C-2 (C-49)		
Date	³ H KDHE	³ H WCNOG	Date	³ H KDHE	³ H WCNOG
8/25/2014	<350	<176	8/25/2014	<350	<176
11/17/2014	<350	<179	11/17/2014	<350	<179
3/11/2015	<350	<148	3/11/2015	<350	<148
5/18/2015	<350	<154	5/18/2015	<350	<154
J-1 (J-2)			C-1 (C-10)		
Date	³ H KDHE	³ H WCNOG	Date	³ H KDHE	³ H WCNOG
8/25/2014	<350	<176	8/25/2014	<350	<176
11/17/2014	<350	<179	11/17/2014	<350	<179
3/11/2015	<350	<148	3/11/2015	<350	<148
5/18/2015	<350	<154	5/18/2015	<350	<154
Onsite Ground Water					
Auxiliary Building			EAST ESW-W		
Date	³ H KDHE	³ H WCNOG	Date	³ H KDHE	³ H WCNOG
8/21/2014	3162 ± 210	2637 ± 163	8/21/2014	<350	<171
11/19/2014	1710 ± 183	1304 ± 154	11/19/2014	<350	<179
3/19/2015	3070 ± 218	2898 ± 169	3/19/2015	<350	<145
6/16/2015	1710 ± 191	1694 ± 141	6/16/2015	<350	<146
WEST ESW-W					
Date	³ H KDHE	³ H WCNOG			
8/21/2014	1510 ± 175	1136 ± 127			
11/19/2014	1560 ± 177	1298 ± 153			
3/19/2015	1790 ± 195	1726 ± 138			
6/16/2015	6550 ± 264	6647 ± 247			

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Graph 7 Historic Owner Controlled Area (Onsite) Groundwater Tritium, pCi/L



Shoreline and Bottom Sediments

Shoreline sediment and bottom sediment were collected in the environment surrounding WCGS. Indicator bottom sediment samples were collected in the Coffey County Lake discharge cove, public environmental education area, and the CCL MUDS public access fishing area. A control sample of bottom sediment was obtained from John Redmond Reservoir. Indicator shoreline sediment was collected at the CCL discharge cove, the CCL MUDS public access fishing area, Wolf Creek below the CCL dam, and Stringtown Cemetery. A control sample of shoreline sediment was collected at JRR. Nine random bottom sediments were collected on CCL. Seven random shoreline sediments were collected on CCL and the Neosho River. The CCL and JRR samples are split with WCNOG.

A gamma isotopic analysis is done on all sediment samples collected.

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Table 9 Annual Samples for Waterborne Radionuclides in Sediments, pCi/kg dry

Location	Type	Date	¹³⁷ Cs	⁶⁰ Co	⁴⁰ K
			KDHE (WCNOC)	KDHE (WCNOC)	KDHE (WCNOC)
Wolf Creek	Shoreline	8/1/2014	26 ± 2	<11	13800 ± 397
JRR	Bottom	11/5/2014	121 ± 44 (119.6 ± 41.9)	<11 (<11.4)	19800 ± 553 (17639.0 ± 878.9)*
CCL Discharge Cove	Bottom	11/5/2014	119 ± 39 ± (117.9 ± 44.6)	<11 (<18.5)	13600 ± 397 (12932.0 ± 746.2)*
JRR	Shoreline	11/5/2014	<8 (<18.7)	<11 (<11.0)	13000 ± 837 (12704.0 ± 648.7)*
CCL Discharge Cove	Shoreline	11/5/2014	<8 (<20.0)	<11 (<10.1)	7240 ± 20 (8551.8 ± 558.5)*
EEA	Bottom	3/31/2015	72 ± 3 (74.7 ± 34.2)	<11 (<11.2)	13900 ± 396 (12389.0 ± 696.8)
EEA	Shoreline	3/31/2015	25 ± 2 (40.1 ± 15.4)	<11 (<19.9)	13500 ± 395 (11775.0 ± 587.2)
MUDS	Bottom	5/4/2015	24 ± 8 (<21.1)	<11 (<10.4)	11700 ± 338 (10121.0 ± 601.5)
CCL Discharge Cove	Bottom	5/12/2015	109 ± 8 (108.5 ± 32.4)	<11 (<14.9)	15000 ± 828 (12963.0 ± 701.3)
CCL Discharge Cove	Shoreline	5/12/2015	10 ± 8 (<16.2)	<11 (<15.7)	5820 ± 171 (5555.7 ± 464.7)
JRR	Bottom	5/13/2015	115 ± 4 (109.6 ± 36.9)	<11 (<17.2)	20100 ± 574 (16612.0 ± 851.7)
CCL Discharge Cove	Bottom	6/29/2015	32 ± 8 (<26.1)	<11 (<17.0)	14500 ± 43 (11349.0 ± 660.5)

*Samples from 11/5/2014 were not split with WCNOC, WCNOC sample results are from WCNOC 10/6/2015 (which was not split with KDHE) sample and are provided for qualitative comparison only.

Table 10 Random Samples for Waterborne Radionuclides in Sediments, pCi/kg dry

Date	Location	Type	⁶⁰ Co	¹³⁷ Cs
9/22/2014	Neosho River at LeRoy	Shoreline	<11	<8
9/22/2014	East of Dam	Shoreline	<11	<8
10/6/2014	Central CCL	Bottom	<11	23 ± 8
10/6/2014	CCL North End	Bottom	<11	58 ± 3
10/6/2014	CCL North End	Bottom	<11	70 ± 8
10/6/2014	CCL North End	Bottom	<11	26 ± 2
10/6/2014	CCL North End	Bottom	<11	23 ± 2
10/24/2014	Neosho River	Shoreline	<11	<8
11/5/2014	Black Bear Bosin Recreation Area	Shoreline	<11	<8
1/16/2015	Neosho River 2 Miles NW of LeRoy	Shoreline	<11	19 ± 2
4/13/2015	Neosho River by Planter Rd	Shoreline	<11	<8
4/17/2015	East of Dam	Shoreline	<11	10 ± 7
6/2/2015	CCL	Bottom	<11	34 ± 3
6/2/2015	CCL	Bottom	<11	21 ± 2
6/2/2015	CCL	Bottom	<11	26 ± 2

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Aquatic Vegetation and Algae

Annual aquatic vegetation (algae and/or rooted) indicator samples were collected from the Coffey County Lake and Wolf Creek below the Coffey County Lake dam. Control samples of aquatic vegetation were obtained at John Redmond Reservoir. The Coffey County Lake samples are split with WCNOG.

Gamma isotopic analysis is performed on all aquatic vegetation samples.

Table 11 Annual Samples for Waterborne Radionuclides in Aquatic Vegetation KDHE, pCi/kg (dry) (WCNOG), pCi/kg (wet)

Location	Sample Type	Date	⁴⁰ K	⁷ Be
Wolf Creek	Arrowhead	8/1/2014	35800 ± 1140	1070 ± 120
JRR	Algae	4/1/2015	21200 ± 763	4770 ± 215
CCL MUDS	American Pondweed & Naiad	8/22/2014	10300 ± 397 (2547.9 ± 255.7)	1210 ± 8 (286.7 ± 102.3)
CCL ALT DC	American Pondweed	9/29/2014	13690 ± 530 (2369.7 ± 252.0)	1340 ± 105 (311.2 ± 105.2)
CCL EEA	Water Primrose	6/19/2015	18100 ± 628 (3314.2 ± 403.9)	3980 ± 192 (691.7 ± 197.3)

Table 12 Random Samples for Waterborne Radionuclides in Aquatic Vegetation KDHE, pCi/kg

Location	Sample Type	Date	⁴⁰ K	⁷ Be
Pond Near 8th and Trefoil	American Lotus	7/7/2014	20700 ± 696	<360
Low Water Crossing on Quail S. of 12th Rd	Water Plantain	7/16/2014	14700 ± 152	2400 ± 125
Ditch off US 75 0.25 Mi. S. of 22nd Rd.	Bulrush	7/16/2014	13100 ± 465	3680 ± 159
Pond Near 25th and Iris	Calamus	7/23/2014	25100 ± 802	1920 ± 117
Mathias Lake	Rose Mallow	8/1/2014	<152	<360
Central CCL	Pondweed	10/6/2014	22200 ± 800	709 ± 110

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Ingestion Pathway

Milk

Milk was sampled quarterly in Coffey County at two locations. Indicator samples were obtained from the Sunrise Dairy near Westphalia, KS. Control samples were obtained from Linsey Dairy near Lebo, KS. Each milk sample is analyzed for low levels of radioiodine and other gamma emitting nuclides. No gamma emitting nuclides attributable to Wolf Creek operation were detected in any milk sample.

Table 13 Quarterly Samples for Radionuclides in Milk, pCi/L

Linsey Dairy			Sunrise Dairy		
Date	¹³¹ I	⁴⁰ K	Date	¹³¹ I	⁴⁰ K
8/7/2014	<1	1440 ± 49	09/11/14	<1	1370 ± 51.8
12/10/2014	<1	<1300	12/16/2014	<1	<1300
2/12/2015	<1	1300 ± 50	03/05/15	<1	1470 ± 50
4/17/2015	<1	<1300	06/11/15	<1	1330 ± 51

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Fish/Game Animals/Domestic Meat

Fish samples were collected from the Coffey County Lake and below John Redmond Reservoir on the Neosho River. Sample portions from fish collected in the Coffey County Lake and below John Redmond Reservoir on the Neosho River were split with WCNOG. Fish collected at John Redmond Reservoir are used for control samples. Twenty fish from a total of nine species were sampled.

Game animal sampling is usually limited to the collection of edible meat portions from road-killed deer. Sample portions of road-killed deer are usually collected as available by WCNOG and split with KDHE for laboratory analysis. One deer sample was obtained during SFY 2015.

A gamma isotopic analysis is done on all samples collected. Sample portions were edible. Tritium analysis is done on at least one species of fish from each location sampled.

Table 14 Annual Samples for Radionuclides in Fish pCi/kg, wet)

Location	Date	Type	³ H KDHE (WCNOG)	Gamma Activity
Coffey County Lake	10/21/2014	Freshwater Drum	NA (7136 ± 274)	No Gamma Activity Above MDA was Detected in any Fish Sample
		Common Carp	NA (6703 ± 281)	
		Smallmouth Buffalo	NA (7321 ± 275)	
		Wiper	NA (6166 ± 265)	
		Blue Catfish	NA (8049 ± 300)	
		Channel Catfish	8132 ± 125 (7237 ± 282)	
White Bass	NA (7969 ± 291)			
John Redmond Reservoir	11/05/2014	Common Carp	NA (<143)	
		Channel Catfish	<1200 (<141)	
		Smallmouth Buffalo	NA (<149)	
Coffey County Lake	4/28/2015	Common Carp	NA (9142 ± 244)	
		Blue Catfish	NA (8775 ± 241)	
		Smallmouth Bass	NA (8274 ± 238)	
		White Crappie	NA (8739 ± 247)	
		Smallmouth Buffalo	NA (8737 ± 241)	
John Redmond Reservoir	5/13/2015	Channel Catfish	NA (<117)	
		Freshwater Drum	NA (<118)	
		Common Carp	NA (<87)	
		Smallmouth Buffalo	NA (<120)	

Table 15 Random Samples for Radionuclides in Game, pCi/kg

Sample Location	Date	Sample Type	⁴⁰ K KDHE (WCNOG)
Sector A, 1.0 Miles from Wolf Creek	9/17/2014	Roadkill Deer	3520 ± 123 (2553.8 ± 393.4)

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Terrestrial Vegetation and Food Products

Terrestrial vegetation samples were taken at various locations around WCGS. This includes samples of crops grown throughout Coffey County, broadleaf vegetation taken from gardens near the WCGS boundary, and pasturage near WCGS. Samples collected on WCNOG property and samples of crops were split with WCNOG. A control sample was collected at Scott Valley Church approximately 6 miles from WCGS. Ten random samples were collected from locations around WCGS within the 50 mile zone.

A gamma isotopic analysis was done on each vegetation sample and edible portions of food products collected.

Table 16 Annual Samples for Terrestrial Vegetation and Food Products, pCi/kg

Sample ID	Location	Sample Type	Date	⁴⁰ K KDHE (WCNOG)	⁷ Be KDHE (WCNOG)
WCFV-1-H-157-3.1	East of Dam	Pasturage	7/29/2014	15400 ± 504	1590 ± 88
WCFV-1-E-087-5.8	Scott Valley Church (Control)	Pasturage	8/12/2014	8510 ± 390	4030 ± 179
WCFV-3-P-289-1.6	MUDS	Pasturage	8/22/2014	10300 ± 397 (4016.0 ± 497.4)	1210 ± 88 (1612.3 ± 300.3)
NR-D2	Kerry Trostle Farm	Irrigated Corn	9/29/2014	2900 ± 97 (2788.4 ± 227)	<360 (<49.1)
NR-U1	4.5 mi. SSW of Wolf Creek	Irrigated Corn	10/2/2014	1900 ± 66 (2045.7 ± 214.2)	<360 (<49.2)
NR-D1	Coffey County	Irrigated Soybeans	10/30/2014	15500 ± 435 (12544.0 ± 548.3)	<360 (<104.3)
WCFV-1-A-005-2.5	Sharpe	Soybeans	11/17/2014	14000 ± 393	<360
NR-U1	4.5 mi. SSW of Wolf Creek	Irrigated Soybeans	11/17/2014	14200 ± 397 (13841.0 ± 483.5)	<360 (<78.3)
WCFV-1-R-330-2.9	EEA	Pasturage	6/19/2015	5050 ± 218 (5713.1 ± 528.5)	2150 ± 163 (2128.1 ± 291.3)

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Table 17, Random Samples for Vegetation and Food Products, pCi/kg

Location	Sample Type	Date	⁴⁰ K	⁷ Be
Field near 5th Ln & Planter Ln	Wheat	7/7/2014	3750 ± 196	1550 ± 77
Field Near 8th and Kafir	Corn on Cob	9/12/2014	2350 ± 74	<360
Near 24th and Native Rd.	Milo	9/12/2014	4520 ± 154	897 ± 41
14th and Shetland Ln.	Corn on Cob	9/12/2014	2660 ± 83	<360
16th Rd. and Oxen Lane	German Millet	9/22/2014	5850 ± 241	1120 ± 65
24th Rd Between Underwood and Verdure	Red Milo	9/29/2014	3470 ± 132	421 ± 26
Field Near 14th and Garner Rd	Soybeans	10/17/2014	14400 ± 400	1470 ± 60
Field Near 9th and Shetland	Sunflower Seeds	10/24/2014	9840 ± 319	<360
Near 10th and Oxen Rd	Soybeans	11/5/2014	15800 ± 449	<360
20th & Underwood	Wheat	6/19/2015	5050 ± 218	2150 ± 159

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KDHE Radiochemistry Laboratory

Quality Assurance

The KDHE Radiation Laboratory has an established internal Quality Assurance program. Quality Control elements include routine calibrations and performance checks on counting equipment and participation in an environmental radioactivity laboratory intercomparison studies program. This program is currently accomplished with blind samples purchased from Environmental Resource Associates. Results for SFY 2015 are presented in Table 18.

Equipment

The following is a description of the equipment used by the KHEL Radiochemistry laboratory.

Multichannel gamma-spectrometer

Gamma radiation is measured spectra determined with a Canberra Genie-2000 Multichannel Analyzer (MCA) system. Detectors available are three high purity germanium detectors (efficiencies – 20 % - 40%) and one germanium-lithium (GeLi) Detector (efficiency 20%).

Low background alpha/beta system

Low background alpha/beta gas-flow internal proportional counters – one Tennelec LB5100, one Oxford Series 5XLB, one Tennelec LB4000 multi-detector and one Canberra 2201.

Internal proportional counter (IPC)

Gross alpha and radium analyses are performed with windowless gas-flow internal proportional counters – four Protean MPC 2000 and two NMC PC5.

Liquid scintillation

Analysis for tritium in water is performed using a one Wallac 1409 and one PE Tri-Carb 3100 TR.

Miscellaneous equipment

The Radiochemistry Section has various devices used for special purposes. A Ludlum Model 2200 single channel analyzer is used with a radon flask scintillation counter for radon and radium analyses. Another Ludlum Model 2200 single channel analyzer is used with a halogen quenched GM pancake probe for routine monitoring of personnel and incoming samples.

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Table 18 KDHE Radiochemistry Laboratory ERA Intercomparison Studies

Analyte	Analysis Date	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation
Barium-133	7/11/2014	pCi/L	61.8	68.7	57.3-75.6	Acceptable
	10/8/2014	pCi/L	38.6	49.1	40.3-54.5	Not Acceptable
	1/12/2015	pCi/L	57.0	67.6	56.4-74.4	Acceptable
	4/8/2015	pCi/L	77.3	82.5	69.3-90.8	Acceptable
Cesium-134	7/11/2014	pCi/L	65.9	72.3	59.0-79.5	Acceptable
	10/8/2014	pCi/L	72.3	89.8	73.7-98.8	Not Acceptable
	1/12/2015	pCi/L	118	124	112-139	Acceptable
	4/8/2015	pCi/L	69.6	75.7	61.8-83.3	Acceptable
Cesium-137	7/11/2014	pCi/L	171	163	147-181	Acceptable
	10/8/2014	pCi/L	84.9	98.8	88.9-111	Not Acceptable
	1/12/2015	pCi/L	118	124	112-139	Acceptable
	4/8/2015	pCi/L	198	189	170-210	Acceptable
Cobalt-60	7/11/2014	pCi/L	79.9	75.5	68.0-85.5	Acceptable
	10/8/2014	pCi/L	77.2	92.1	82.9-104	Not Acceptable
	1/12/2015	pCi/L	58.0	62.4	56.2-71.2	Acceptable
	4/8/2015	pCi/L	85.3	84.5	76.0-95.3	Acceptable
Gross Alpha	7/23/2014	pCi/L	53.4	45.4	23.6-57.4	Acceptable
	1/23/2015	pCi/L	61.2	62.3	32.6-77.3	Acceptable
	5/14/2015	pCi/L	44.0	42.6	22.1-64.0	Acceptable
Gross Beta	8/9/2014	pCi/L	36.0	33.4	21.7-41.1	Acceptable
	1/29/2015	pCi/L	40.1	48.9	33.1-56.0	Acceptable
	4/16/2015	pCi/L	43.3	32.9	21.3-40.6	Not Acceptable
Tritium	7/11/2014	pCi/L	10800	11200	9750-12300	Acceptable
	11/15/2014	pCi/L	6920	6880	5940-7570	Acceptable
	1/9/2015	pCi/L	10500	10600	9220-11700	Acceptable
	5/17/2015	pCi/L	3700	3280	2770-3620	Not Acceptable
Iodine-131	7/11/2014	pCi/L	24.2	26.1	21.7-30.8	Acceptable
	1/7/2015	pCi/L	22.5	22.3	18.5-26.6	Acceptable
	4/8/2015	pCi/L	24.8	23.8	19.7-28.3	Acceptable
Strontium-89	7/11/2014	pCi/L	45.2	42.7	32.9-49.8	Acceptable
	1/13/2015	pCi/L	46.9	52.1	41.2-59.6	Acceptable
	4/17/2015	pCi/L	67.2	63.2	51.1-71.2	Acceptable
Strontium-90	7/11/2014	pCi/L	30.0	31.7	23.1-36.7	Acceptable
	1/27/2015	pCi/L	27.7	32.4	23.7-37.5	Acceptable
	4/17/2015	pCi/L	37.3	41.9	30.8-48.1	Acceptable
Zinc-65	7/11/2014	pCi/L	90.0	82.0	73.8-98.5	Acceptable
	10/8/2014	pCi/L	276	310	279-362	Not Acceptable
	1/12/2015	pCi/L	99.2	98.7	88.8-118	Acceptable
	4/8/2015	pCi/L	224	203	183-238	Acceptable

¹ The KDHE radiochemistry laboratory, under certification of the Environmental Protection Agency is required to pass one PT study for certified analytes per year, and participates in extra PT studies throughout the year as additional Quality Assurance checks.

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Table 19 Method Detection Limits

GeLi [HPGe] detection system ^a						
Environmental Sampling						
	Water and Milk	Filter	Wipe	Soil and Sediment	Biota	Vegetation and Food Products
Minimum sample size	2000 ml	1500 m ³	Total	0.45 kg	0.3 kg	1 kg
Minimum Counting Time	8 hr.	3 hr	3 hr.	15 hr.	15 hr.	15 hr.
Method Detection Limit	pCi/L	pCi/m ³	pCi/wipe	pCi/kg-dry	pCi/kg-wet	pCi/kg-dry
⁷ Be	64 [22]	0.03 [0.02]	N/A	346 [186]	231 [144]	35 [19]
⁴⁰ K	88 [39]	0.03 [0.02]	N/A	828 [654]	459 [262]	360 [72]
⁵¹ Cr	52 [32]	0.01 [0.009]	5 [3]	35 [22]	41 [32]	55 [46]
⁵⁴ Mn	4 [2]	0.004 [0.003]	1 [0.7]	7 [11]	30 [15]	51 [24]
⁵⁸ Co	4 [2]	0.008 [0.002]	2 [1]	11 [23]	37 [20]	60 [36]
⁵⁹ Fe	8 [3]	0.01 [0.01]	3 [2]	22 [16]	41 [15]	107 [52]
⁶⁰ Co	11 [7]	0.01 [0.0053]	2.5 [1.7]	11 [35]	43 [26]	56 [50]
⁶⁵ Zn	8 [4]	0.01 [0.007]	N/A	48 [30]	38 [22]	125 [63]
⁹⁵ Nb	7 [3]	0.009 [0.007]	2.5 [1.4]	13 [30]	44 [26]	48 [4]
⁹⁵ Zr	6 [3]	0.01 [0.002]	0.5 [0.3]	20 [27]	27 [19]	86 [54]
⁹⁹ Mo	5 [3]	0.002 [0.0014]	1 [0.6]	83 [43]	33 [21]	****
¹⁰³ Ru	10 [7]	0.004 [0.003]	N/A	10 [20]	29 [21]	44 [47]
¹⁰⁶ Ru	55 [43]	0.07 [0.05]	1.5 [1]	100 [192]	43 [29]	46 [65]
^{110m} Ag	4 [3]	0.006 [0.0002]	N/A	47 [33]	47 [34]	86 [55]
¹²⁵ Sb	35 [12]	0.02 [0.01]	N/A	30 [44]	96 [51]	126 [6]
¹³¹ I	5 [3] (1) ^b	0.00027 [0.00027] ^c	1.5 [1]	10 [20]	37 [23]	45 [13]
¹³⁴ Cs	5 [3]	0.007 [0.004]	1.4 [1]	14 [29]	37 [24]	57 [39]

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¹³⁷ Cs	7 [4]	0.006 [0.004]	1 [0.3]	11 [29]	32 [21]	52 [56]
¹⁴⁰ Ba	10 [6]	0.004 [0.003]	N/A	36 [17]	24 [15]	157 [39]
¹⁴⁰ La	9 [5]	0.01 [0.02]	N/A	12 [9]	34 [21]	47 [6]
¹⁴¹ Ce	8 [3]	0.002 [0.001]	N/A	19 [23]	22 [13]	63 [3]
¹⁴⁴ Ce	35 [14]	0.013 [0.0096]	N/A	96 [103]	110 [70]	267 [14]
²²⁶ Ra	116 [69]	0.05 [0.03]	N/A	828 [654]	323 [195]	858 [51]
²²⁸ Ac	30 [18] 15 h	0.0127 [0.0099]	N/A	68 [33]	146 [87]	27 [12]
²²⁸ Th	387 [142]	0.09 [0.06]	N/A	859 [317]	944 [356]	2100 [167]
²³⁴ Th	618 [87] 15 h	0.159 [0.0423]	N/A	1009 [378]	1300 [556]	570 [94]
²³⁵ U	N/A	N/A	45 [30] 15 h	N/A	N/A	N/A
²³⁹ Np	41 [33]	0.01 [0.009]	5 [3]	64 [44]	40 [30]	97 [71]

^a GeLi = Germanium lithium; HPGe = High purity germanium.

^b Two methods of analysis are done: **1)** 8 hour direct gamma isotopic analysis of a 2000 mP milk or water sample that has a method detection limit (MDL) of 3 pCi/P, and **2)** 3 hour gamma isotopic analysis of ion exchange resin after a 1500 mP milk sample is filtered through an ion exchange column that has an MDL of 1 pCi/P.

^c The MDL for ¹³¹I when analyzing a charcoal cartridge is 0.03 [0.02] pCi/m³ based upon a 250 m³ sample volume. If the sample volume is increased to 1500 m³, the MDL is 0.002 [0.001] pCi/m³.

Method detection limits of present analytical methods for selected radionuclides monitored by the KHEL Radiochemistry Laboratory. These limits are intended as guides to order of magnitude sensitivities and are calculated with a 95% level of confidence (activity will be detected 95% of the time if it is present).

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Low Background Alpha and Beta Counting System					
	Water	Milk	Wipe	Soil & Sediment	Vegetation & Food Products
Minimum Sample Size	1000 ml	1000 ml	Total	0.01 kg	0.1 kg
Minimum Counting Time	200 min.	200 min.	200 min.	200 min.	200 min.
Method Detection Limit	pCi/L	pCi/L	pCi/wipe	pCi/kg-dry	pCi/kg-dry
⁸⁹ Sr	1	2	3	200	500
⁹⁰ Sr	1	2	4	200	500
¹³¹ I	1	N/A	N/A	N/A	N/A
²²⁸ Ra	1.2	N/A	0.3	60	N/A
Gross Beta					
	Water	Filter	Wipe	Soil and Sediment	
Minimum Sample Size	200 ml	250 m ³	Total	0.001 kg	
Minimum Counting Time	200 min.	100 min.	100 min.	100 min.	
Method Detection Limit	4 pCi/l	0.004 pCi/m ³	2 pCi/Wipe	160 pCi/kg-dry	
Gross Alpha					
	Water	Filter	Wipe		
Minimum Sample Size	200 ml	250 m ³	Total		
Minimum Counting Time	200 min.	100 min.	100 min.		
Method Detection Limit	1 pCi/l	0.0006 pCi/ m ³	0.5 pCi/Wipe		

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Random Scintillation Counting System				
^{226}Ra (radium) in water				
Minimum Sample Size		1000 ml		
Minimum Counting Time		200 min.		
Method Detection Limit		0.04 pCi/l		
Liquid Scintillation Counting System				
	Tritium (^3H)		^{222}Rn (Radon)	
	In water	In Tissue	In Water	
Minimum Sample Size	10 ml	3 g	10 ml	
Minimum Counting Time	100 min.	120 min.	60 min.	
Method Detection Limit	350 pCi/l	1200 pCi/kg-wet	25 pCi/l	