KESSELRING SITE

SITE DESCRIPTION

The Kesselring Site is located near West Milton, New York, approximately 17 miles (27.4 kilometers) north of the City of Schenectady, 9 miles (14.5 kilometers) southwest of Saratoga Springs, and 13 miles (21 kilometers) northeast of Amsterdam (see Figure 1). The surrounding area is a rural, sparsely populated region of wooded lands through which flow the Glowegee Creek and several small streams that empty into the Kayaderosseras Creek. The Kesselring Site consists of 3,900 acres on which two pressurized-water naval nuclear propulsion plants and support facilities are located, including administrative offices, machine shops, waste storage facilities, oil storage facilities, training facilities, equipment service buildings, chemistry laboratories, a boiler house, a cooling tower, and wastewater treatment facilities. In 2018 the S8G nuclear propulsion plant was shut down for refueling and overhaul and in 2019 the MARF plant was shut down permanently for dismantlement at a later date. The S8G refueling and overhaul is in progress and scheduled to be completed in April 2024. MARF defueling and dismantlement preparations are currently in progress.

The S3G and D1G Prototype reactor plants were shut down in May 1991 and March 1996, respectively. All spent nuclear fuel was removed from the S3G and D1G prototypes and shipped off-site in July 1994 and February 1997, respectively. Dismantlement of the S3G plant was completed in 2006 and dismantlement of the D1G plant is continuing. D1G dismantlement is scheduled to be completed in late 2023.

The climate in the region of the Kesselring Site is primarily continental in character, but is subjected to some modification from the maritime climate, which prevails in the extreme southeastern portion of NYS. Winters are usually cold and occasionally fairly severe. Maximum temperatures during the colder winter months often are below freezing and nighttime low temperatures frequently drop to 10° F or lower. Sub-zero temperatures occur rather infrequently, about a dozen times a year. Snowfall in the area is quite variable, averaging 68 inches per year. The mean annual precipitation for the area averages 43 inches per year. The prevailing winds are from the west.

The area surrounding the Kesselring Site has a complex geological history due to the processes of erosion, glaciation, folding, and faulting. The geological formations of the West Milton area are comprised of two major types: bedrock, which ranges in age from Precambrian to Ordovician, and unconsolidated deposits of Pleistocene and Recent age. Bedrock underlying the area crops out only on some steep hillsides and in some stream valleys. It is covered by the unconsolidated deposits in the remainder of the area. These unconsolidated deposits range in thickness from zero to 200 feet with an average thickness of 50 feet. Bedrock underlying the West Milton area may be divided into two groups: (1) metamorphosed rocks of Precambrian age and (2) sedimentary rocks of Paleozoic age. The older metamorphosed rocks consist of gneiss, schist, quartzite, and limestone (marble) of sedimentary origin and syenite and granite of igneous origin. These rocks are referred to as crystalline rocks. The Paleozoic rocks likewise consist of several types of rocks including sandstone, dolomite, limestone, and shale. The unconsolidated deposits can be subdivided into four groups: (1) till - an unstratified, dense heterogeneous mixture of glacially deposited rock particles ranging in size from clay to gravel; (2) ice-contact deposits - kames and eskers composed of stratified sand and gravel; (3) glaciolacustrine deposits - a homogeneous stratified layer of sand, silt, and clay; and (4) recent fluvial deposits consisting of sand and gravel.

Generally, the coarser-grained and stratified unconsolidated deposits form better aquifers than the fine-grained and unstratified unconsolidated deposits or bedrock foundations. Only small areas are underlain by these coarse-grained deposits. Percolating water from rainfall and snowmelt recharge the shallow, unconfined aquifers beneath the Kesselring Site, and in turn, streams are recharged by shallow groundwater. The Kayaderosseras Creek is underlain by coarse-grained glacial and fluvial valley-fill deposits from which all Site Service (drinking) Water is produced. The Kesselring Site drinking water well field is located near the eastern boundary of the Kesselring Site within the creek's floodplain. The Kesselring Site obtains all water for its operation from on-site production wells that are hydrogeologically separate from current and historical operational areas.

The Kesselring Site is located in the transition zone between the Adirondack Mountains and the Hudson-Mohawk Valley lowland. The Kayaderosseras Creek forms the main drainage system in the vicinity of the Kesselring Site. The average flow (1927–1994) in the Kayaderosseras Creek is 137.8 cubic feet per second (cfs) and the lowest recorded seven-day minimum flow is 12.4 cfs during August 1964. The Kayaderosseras gauging station was taken out of service in 1995.

The Glowegee Creek, Crook Brook, and Hogback Brook drain the Kesselring Site. Crook Brook directly joins the Kayaderosseras. Hogback Brook is a tributary to the Glowegee, which is the receiving water for Kesselring Site drainage. The average flow (1948–2022) in the Glowegee is 39.2 cfs and the lowest recorded seven-day minimum flow is 0.51 cfs during August 1949. The Glowegee Creek joins with the Kayaderosseras Creek approximately one mile east of West Milton.

The Glowegee and Kayaderosseras Creeks have a classification of Class C under NYCRR. Under this classification, the waters are suitable for fishing and fish propagation. Additionally, the water quality shall be suitable for primary and secondary contact recreation, even though other factors may limit the use for that purpose. Portions of each creek have also been assigned the Trout Stream standard. The NYSDEC has permitted the Kesselring Site to discharge effluent from various Kesselring Site operations to the Glowegee Creek as specified in the Kesselring Site's SPDES Permit (Reference (22)). Environmental monitoring has shown no measurable water quality degradation in the Glowegee Creek due to Kesselring Site operations.

LIQUID EFFLUENT MONITORING

Sources

Nonradiological: The primary sources of the effluent water at the Kesselring Site are:

1. *Site Boiler House Discharges* - Site boiler water is treated demineralized water. Operations that result in discharges are (1) annual boiler draining and periodic blowdowns to control the concentration of solids and (2) wastewater from a reverse osmosis water treatment system.

2. *Sanitary Wastewater Treatment Facility* - The Sanitary Wastewater Treatment Facility consists of influent wastewater grinding, a biological treatment process consisting of pre-equalization, sequencing batch reactors (SBR), post-equalization, aeration, and filtration. Waste sludge is stored in a holding tank and removed periodically by a licensed subcontractor for disposal at a State-approved facility.

3. *Cooling Tower Water* - Cooling tower water is treated to minimize scale formation, to prevent corrosion of system materials, and to inhibit the growth of algae and slime. The pH is normally maintained in the range of 7.1 to 7.6.

4. *Retention Basin Liquids* - The retention basins receive wastewater from prototype plant facilities including blowdown water from steam generators and drainage water from the engine rooms.

5. *Site Drainage Water* - Stormwater and groundwater also make up a portion of the liquid effluent.

6. *Site Service Water* - SSW is used for drinking water and non-contact cooling purposes. Sodium hypochlorite is added to the SSW system as a drinking water disinfectant.

With the exception of the Sanitary Wastewater Treatment Facility effluent and some stormwater, all of the above sources of effluent water are discharged into the Kesselring Site Lagoon and through a wastewater treatment system before ultimate off-site discharge into the Glowegee Creek. The Kesselring Site lagoon is a five-million gallon holding basin that was designed to accumulate effluent water for the purposes of pH control, thermal equalization, chlorine dissipation, and settling of solid particles.

Radiological: Some of the liquid effluent discharged from the retention basins contains low levels of radioactivity. The source of this radioactivity is small quantities of activation products. The activation products may include tritium and radionuclides of corrosion and wear products.

Tritium is present in the reactor coolant as the result of neutron interaction with naturally occurring deuterium present in the water. Tritium produced in the reactor exists in the oxide form and is chemically indistinguishable from water. Corrosion and wear products, in the form of small insoluble metal oxide particles, become radioactive as they pass through the reactor, with cobalt-60 being the predominant radionuclide. Operation of the prototype plant requires processing reactor coolant using radioactive liquid waste collection systems.

To minimize releases of radioactivity in liquid effluent to the environment, a water reuse system and evaporators are employed. The reactor coolant water that is discharged from the prototype plant to the radioactive liquid waste collection system is processed through a series of filters and demineralizers. The processing system removes nearly all of the radioactivity with the exception of tritium. After purification, the water is either reused as reactor coolant makeup and in other radioactive systems, or evaporated to reduce the amount of radioactivity that could be released as liquid effluent.

The low concentrations of radioactivity in the liquids released from the Kesselring Site have always been below all applicable Federal and State limits and have not resulted in any detectable radioactivity in the Glowegee Creek from Kesselring Site operations.

Effluent Monitoring

Nonradiological: Liquid effluents from the Kesselring Site enter the Glowegee Creek through two surface channels (Outfalls 001 and 002) and a submerged drain line from the Sanitary Wastewater Treatment Facility (Outfall 003) shown in Figure 5. A series of gates are located in the site's industrial wastewater conveyance system to provide a means to contain spills or upsets. An internal outfall (Outfall 02B) discharges groundwater to the main discharge channel upstream of the lagoon.

Since 1998, the Kesselring Site has operated a wastewater treatment system at the outlet of the lagoon. This treatment system is designed to treat for TSS, residual chlorine, pH, and temperature. The treatment system is necessary to maintain Kesselring Site operations and to ensure continued compliance with SPDES Permit limits. The system removes residual chlorine from the lagoon effluent using an automated sodium bisulfite system. Treatment is provided for pH using carbon dioxide, and temperature using SSW.

Effluent samples from the lagoon wastewater treatment system (Outfalls 001 and 002), the Sanitary Wastewater Treatment Facility (Outfall 003), and internal outfall (Outfall 02B) are collected and analyzed as required by the SPDES Permit.

Stormwater from the Kesselring Site enters the Glowegee Creek from stormwater Outfalls 01A, 02A, 004, 005, and 006 (Figure 5). Outfalls 01A and 02A were used for Kesselring Site discharge prior to the construction of the lagoon. These outfalls currently collect only stormwater.

Outfall 004, which discharges into the Glowegee Creek just below the main access road bridge, collects stormwater from the parking lot and the southern part of the Kesselring Site. Discharges through this outfall are controlled locally or remotely by a sluice gate. The sluice gate provides control for contaminants (i.e., oils and chemicals) which could reach this drainage way in the event of a spill, fire, or other emergency. Stormwater also collects in Outfall 005 from Hogback Road and enters the Glowegee Creek. Outfall 006 collects stormwater runoff from the landfill that was operated from the early 1950s until October 1993. The landfill was capped in 1994 in accordance with a closure plan approved by NYS. Currently, no routine sampling or monitoring is required for stormwater Outfalls 01A, 02A, 004, 005, and 006.

Radiological: Liquid discharges that might contain tritium are either sampled and analyzed individually or sampled and combined into a monthly composite that is then analyzed for tritium. Monthly grab samples are also taken at Outfalls 001 and 002.

Effluent Analyses

Nonradiological: The analyses performed for chemical constituents on effluent samples from each discharge point and the sanitary wastewater treatment facility are listed in Tables 32, 33, and 34. Analyses for chemical constituents are performed using procedures described in Standard Methods, Reference (10), or other EPA approved procedures. Flow, temperature, and total residual chlorine are measured at Outfalls 001 and 002 during every day on which there is a discharge from the lagoon, except when the flumes are flooded with Glowegee Creek water. Outfall 001 is flooded more often than Outfall 002 because its elevation is lower.

Radiological: Each liquid discharge that might contain tritium is sampled. The samples are combined into a monthly composite for each frequently used release point. Samples from other tritium release points are analyzed individually. Tritium analyses are performed by liquid scintillation counting. Additionally, the monthly grab samples are analyzed by gamma spectrometry.

Assessment

Nonradiological: The analytical results for the measurements of chemical constituents summarized in Tables 32, 33, and 34 show that average values are within the applicable effluent standards. Table 8 identifies the Kesselring Site SPDES noncompliances for 2022. Liquid effluent monitoring data is reported as required in Reference (22).

Radiological: The radioactivity released in Kesselring Site liquid effluent during 2022 totaled 2.69×10^{-5} Ci of tritium as shown in Table 35. The activity was contained in approximately 8.92×10^{4} liters of water. Tritium and gamma emitting radionuclides attributable to Kesselring Site operations were not detected in the monthly grab samples of the outfalls. The resulting annual average radioactivity concentration in the effluent corresponds to less than 0.1 percent of the DOE DCS, Reference (6), for the mixture of radionuclides present.

FIGURE 5

KESSELRING SITE, NEAR WEST MILTON, NEW YORK
GLOWEGEE CREEK SAMPLING LOCATIONS AND OUTFALL LOCATIONS

TABLE 32
CHEMICAL CONSTITUENTS AND TEMPERATURE IN KESSELRING SITE LIQUID EFFLUENT, OUTFALL 001

Parameter (units)	Number of Samples	Value			SPDES Permit Limit
		Minimum(1)	Maximum(1)	Average(2)	
Discharge Requirements (Reference (22))					
Flow (MGD)	115(8)	0.026	0.86	0.43	Monitor(3)
Temperature (°F)	115(8)	34	74	54	Note (4)
Residual Chlorine (mg/l)	115(8)	<0.02	<0.02	<0.02	0.04
pH (SU)	12	7.0	7.8	7.4	6.0 – 9.0
Oil and Grease (mg/l)	12	<5.0	<5.1	<5.0	15
Total Suspended Solids (mg/l)	12	5.0	28	13	45
Nitrite as N (mg/l)	12	<0.01	0.02	<0.01	0.04
Iron					
(mg/l)	12	0.16	0.48	0.27	Monitor(3)
(lbs/day)	12	0.18	0.62	0.33	Note (5)
Total Phosphorus					
(mg/l)	12	0.03	0.13	0.073	Monitor(3)
(kg/month)	12	0.52	3.3	1.1	Note (6)
Zinc					
(mg/l)	12	<0.005	0.039	<0.011	Monitor(3)
(lbs/day)	12	<0.005	0.06	<0.01	Note (7)
Boron (mg/l)	12	<0.05	0.12	<0.06	0.5
Sulfite (mg/l)	12	<2.0	<2.0	<2.0	2.0
Nitrogen, Ammonia (as NH_3, mg/l)	12	<0.1	0.1	<0.1	Monitor(3)

Notes for Table 32 are on page 89.

TABLE 33
CHEMICAL CONSTITUENTS AND TEMPERATURE IN KESSELRING SITE LIQUID EFFLUENT, OUTFALL 002 AND 02B

Parameter (units)	Number of Samples	Value			SPDES Permit Limit
		Minimum(1)	Maximum(1)	Average(2)	
Discharge Requirements (Reference (22))					
Flow (MGD)	116(9)	0.037	1.1	0.57	Monitor(3)
Temperature (°F)	116(9)	34	74	54	Note (4)
Residual Chlorine (mg/l)	116(9)	<0.02	<0.02	<0.02	0.04
pH (SU)	12	7.0	7.7	7.4	6.0 – 9.0
Oil and Grease (mg/l)	12	<5.0	<5.2	<5.0	15
Total Suspended Solids (mg/l)	12	4.5	18	9.4	45
Nitrite (as N, mg/l)	12	<0.01	0.02	<0.01	0.04
Iron					
(mg/l)	12	0.11	0.48	0.25	Monitor(3)
(lbs/day)	12	0.24	0.83	0.41	Note (5)
Total Phosphorus					
(mg/l)	12	0.04	0.12	0.07	Monitor(3)
(kg/month)	12	0.58	2.6	1.3	Note (6)
Zinc					
(mg/l)	12	<0.005	0.043	<0.01	Monitor(3)
(lbs/day)	12	<0.007	0.04	<0.02	Note (7)
Boron (mg/l)	12	<0.05	0.1	<0.06	0.5
Sulfite (mg/l)	12	<2.0	<2.0	<2.0	2.0
Nitrogen, Ammonia (as NH_3, mg/l)	12	<0.1	0.2	<0.1	Monitor(3)
OUTFALL 02B					
Residual Chlorine (mg/l)	0	NA(10)	NA(10)	NA(10)	Monitor(3)
Nitrite (as N, mg/l)	12	0.01	0.2	0.12	Monitor(3)
Nitrogen, Ammonia (as NH_3, mg/l)	12	0.2	1.0	0.6	2.0

Notes for Table 33 are on page 89.

NOTES FOR TABLES 32 AND 33

1. A value preceded by "<" is less than the RL for that sample and parameter.
2. Average values preceded by "<" contain at least one value less than the RL value in the average.
3. The Reference (22) permit requires the data to be reported but does not specify a limit for this discharge parameter.
4. During the period from May through October, the temperature of heated water discharges from Kesselring Site operations shall not exceed 75˚ F, except that if the ambient stream temperature exceeds 75° F, the temperature of the discharge can be equal to the stream temperature, up to a maximum of 78˚ F. During the period from November through April, the temperature of the heated water discharges from Kesselring Site operations shall not exceed 75˚ F. In addition, no discharges will occur which will raise the temperature of the stream by more than 5˚ F, or to a maximum of 55˚ F, whichever temperature is less, except that if the upstream temperature is > 55˚ F, the discharge to the stream shall be such that the downstream temperature is less than or equal to the upstream temperature. If the upstream creek temperature is > 55˚ F, the heated water discharges shall not exceed the upstream temperature of the creek.
5. Total Kesselring Site mass discharge limit of 4.0 lbs/day for Outfalls 001, 002, and 003 combined.
6. An action level of 50 kg/month has been assigned for the total mass discharged from Outfalls 001, 002, and 003 combined. An action level is not a limit, but a specified effluent level that requires additional short term monitoring upon exceedance.
7. Total Kesselring Site mass discharge limit of 0.5 lbs/day for Outfalls 001, 002, and 003 combined.
8. The Kesselring Site discharged 117 times during 2022. Outfall 001 was flooded 3 times, therefore representative flow, outfall temperature and total residual chlorine measurements/samples could not be collected during these events. No required samples were missed. Daily temperatures, flow and total residual chlorine were taken twice on April 1, 2022 due to two employess completing the measurements on two different shifts
9. The Kesselring Site discharged 117 times during 2022. Outfall 002 was flooded 2 times, therefore representative flow, outfall temperature and total residual chlorine measurements/samples could not collected during these events. No required samples were missed. Daily temperatures, flow and total residual chlorine were taken twice on April 1, 2022 due to two employess completing the measurements on two different shifts.
10. Chlorine treatment at the nitrite ammonia treatment facility was stopped on March 16, 2019 per NYSDEC approval. Therefore total residual chlorine was not sampled.

NA = Not Applicable

TABLE 34
CHEMICAL CONSTITUENTS AND TEMPERATURE IN KESSELRING SITE SANITARY WASTEWATER TREATMENT FACILITY EFFLUENT, OUTFALL 003

Parameter (units)	Number of Samples	Value			SPDES Permit Limit
		Minimum(1)	Maximum(1)	Average(2)	
Discharge Requirements (Reference (22))					
Flow (MGD)	365	0.001	0.02	0.008	0.09(3)
pH (SU)	365	7.5	8.1	7.8	6.0 - 9.0(4)
Settleable Solids (ml/l)	365	<0.1	<0.1	<0.1	0.1
Dissolved Oxygen (mg/l)	365	7.2	13	9.9	≥ 5.0(5)
Nitrite (as N, mg/l)	12	<0.01	0.06	<0.02	0.6
Cyanide, Available (mg/l)	12	<0.006	<0.006	<0.006	0.09
Ammonia (as NH_3, mg/l)	12	<0.1	<9	<0.8	25
Surfactants (MBAS) (mg/l)	12	0.02	0.04	0.03	0.7
Boron (mg/l)	12	<0.05	0.1	<0.07	1.2(6)
Dissolved Copper (mg/l)	12	<0.005	0.013	<0.008	Monitor(7)
Biological Oxygen Demand-5 (mg/l)	12	<2.4	<120(8)	<13(8)	30(9)
Total Suspended Solids (mg/l)	12	<1.0	2.3	<1.6	30(9)
Total Phosphorus					
(mg/l)	12	0.22	0.64	0.39	Monitor(7)
(kg/month)	12	0.24	0.5	0.35	Note (10)
Zinc					
(mg/l)	12	<0.005	0.02	<0.009	Monitor(7)
(lbs/day)	12	<0.0003	0.002	<0.0007	Note (11)
Total Copper (lbs/day)	12	<0.0004	0.002	<0.0009	0.06
Iron					
(mg/l)	12	<0.050	0.09	<0.06	Monitor(7)
(lbs/day)	12	<0.0026	0.009	<0.0043	Note (12)
Aluminum (mg/l)	12	<0.1	<0.1	<0.1	2.0(6)
Butyl Benzyl Phthalate (mg/l)	12	<0.005	<0.005	<0.005	0.1(6)

Notes:

NA Not Applicable
1. A value preceded by "<" is less than the RL for that sample and parameter.
2. Average values preceded by "<" contain at least one value less than the RL value in the average.
3. 30-day average.
4. The pH values are not averaged and are required to be in this range.
5. The average value is well above the limit, which is a minimum allowable value.
6. Values are action levels which are not a limit but a specified effluent level which requires additional short term monitoring upon exceedance.
7. The Reference (22) permit requires the data to be reported but does not specify a limit for this discharge parameter.
8. The elevated level was reported due to a laboratory error impacting the reporting limit for June BOD-5 effluent sample. No additional sample was collected.
9. The maximum limit for the 30-day arithmetic mean is 30 mg/l; the maximum limit for the 7-day arithmetic mean is 45 mg/l.
10. An action level of 50 kg/month has been assigned for the total mass discharged from Outfalls 001, 002 and 003 combined. An action level is not a limit but a specified effluent level that requires additional short term monitoring upon exceedance.
11. Total Site mass discharge limit of 0.5 lbs/day for Outfalls 001, 002, and 003 combined.
12. Total Site mass discharge limit of 4.0 lbs/day for Outfalls 001, 002, and 003 combined.

TABLE 35
KESSELRING SITE RADIOACTIVITY RELEASE IN LIQUID EFFLUENT

Radionuclide	Release Ci[1]	Half-life
H-3	2.69E-05	12.32 years

Note:
1. The total includes results that were less than or equal to the DLC.

AIRBORNE EFFLUENT MONITORING

Sources

Nonradiological: The principal sources of industrial gaseous effluents are three steam generating boilers (two 21 million BTU/hr boilers and one 14.3 million BTU/hr boiler). The Number 2 distillate fuel oil that is used to fire these boilers contains a maximum of 0.0015 percent by weight sulfur. Each boiler is connected to a dedicated exhaust stack. Other operations such as carpenter shops, welding hoods, abrasive cleaning, spray painting, and other miscellaneous internal combustion sources (e.g., emergency generators) constitute point sources of airborne effluents.

Radiological: Small quantities of particulate radioactivity, principally cobalt-60, are processed through controlled exhaust systems during reactor coolant sampling, draining, and venting operations. Gaseous radioactivity contained in the exhaust air consists principally of carbon-14, short-lived isotopes of xenon and krypton, argon-41, and tritium. Carbon-14 and argon-41 are the result of neutron interaction with isotopes of dissolved oxygen, nitrogen, and argon in the coolant. Other radioactive gases such as xenon and krypton are produced by neutron interaction with trace quantities of uranium impurities in structural members within the reactor. Prior to release from the exhaust stacks, the exhaust air is passed through HEPA filter systems to minimize particulate radioactivity content. Additionally, some processed water is evaporated to minimize releases of radioactivity in liquid effluent. The evaporator air effluent contains gaseous tritium. Potential diffuse sources are also evaluated and include emissions from D&D activities such as building demolition.

Effluent Monitoring

Nonradiological: For the Kesselring Site boilers, monthly usage records are tracked and tabulated to ensure compliance with regulatory requirements. Fuel oil supplier certification certificates for purchased distillate fuel oil are maintained by the Kesselring Site to confirm that the fuel oil burned in the Kesselring Site boilers contains a maximum of 0.0015 percent by weight sulfur and conforms to the ASTM Standards for distillate fuel oil. Semiannual reports demonstrating compliance with the fuel oil sulfur limitation are sent to the EPA, as required by EPA's New Source Performance Standards (NSPS), for these stationary combustion installations. Operating logs are maintained for other miscellaneous internal combustions sources to ensure site wide emissions remain below 50 percent of Title V thresholds. There are no direct exhaust gas monitoring requirements for nonradiological emissions.

Radiological: The air exhausted from the reactor plants is continuously monitored for particulate radioactivity with monitors that are equipped with alarm functions to provide an alert should an out-of-specification release occur. The air exhausted from all radiological work facilities is continuously sampled for particulate radioactivity. Reactor plant air emissions are also continuously sampled for radioiodine with activated charcoal cartridges. Sampling is performed for tritium and carbon-14 using appropriate absorbers.

Effluent Analyses

Radiological: The air particulate sample filters from the radiological emission points are changed routinely and analyzed by gamma spectrometry. A DLC of approximately 5×10^{-15} μCi/ml is achieved for cobalt-60. The activated charcoal cartridges are analyzed for radioiodine by gamma spectrometry to a DLC of approximately 5×10^{-15} μCi/ml for iodine-131. The tritium and carbon-14 absorbers are analyzed by liquid scintillation spectrometry. The DLCs of tritium and carbon-14 in air are approximately 5×10^{-11} μCi/ml for typical sampling parameters. The quantity of gaseous radioactivity released is calculated based on reactor plant operating parameters.

Assessment

Nonradiological: Emissions of NO_x continue to be well within the limits established by NYSDEC in the registration associated with the Kesselring Site boiler units. Emissions of SO_2 from the Kesselring Site boiler units are also well within the EPA's NSPS for stationary combustion installations.

Combined, Kesselring Site emergency generators operated less than 250 hours during 2022. An emergency generator would have to operate 500 hours or greater to trigger a NYSDEC permitting requirement. All other point source emissions also conform to the applicable Federal and State clean air standards.

Radiological: The radioactivity released in airborne effluent during 2022 is shown in Table 36. The radioactivity was contained in a total volume of 6.78×10^{11} liters of air. The average radioactivity concentration in the effluent air was well below the applicable standards listed in Reference (6). The average annual radioactivity concentration at the nearest Kesselring Site boundary, based on average annual diffusion parameters, was less than 0.01 percent of the DOE DCS, Reference (6), for the mixture of radionuclides present. Kesselring Site had one diffuse source of emission in 2022. Airborne effluent monitoring data is reported as required in Reference (8).

TABLE 36
KESSELRING SITE RADIOACTIVITY RELEASED IN AIRBORNE EFFLUENT

Radionuclide	Point Source Release Ci[1]	Diffuse Source Release Ci	Total Release Ci	Half-life
Fission & Activation Products[2]				
Ag-110m	0.00E+00	3.62E-13	3.62E-13	249.80 days
Ba-137m	0.00E+00	2.42E-13	2.42E-13	2.56 minutes
C-14	4.86E-03	9.06E-13	4.86E-03	5715 years
Co-58	0.00E+00	1.15E-11	1.15E-11	70.88 days
Co-60	3.49E-06	6.04E-11	3.49E-06	5.27 years
Cr-51	2.48E-17	0.00E+00	2.48E-17	27.70 days
Cs-134	0.00E+00	2.42E-14	2.42E-14	2.07 years
Cs-137	0.00E+00	2.42E-13	2.42E-13	30.07 years
Fe-55	0.00E+00	6.04E-11	6.04E-11	2.75 years
H-3	6.71E-02	0.00E+00	6.71E-02	12.32 years
I-129	0.00E+00	1.21E-17	1.21E-17	1.57E07 years
I-131	5.47E-07	0.00E+00	5.47E-07	8.02 days
K-40	1.58E-07	0.00E+00	1.58E-07	1.25E09 years
K-42	0.00E+00	0.00E+00	0.00E+00	12.36 hours
Mn-54	0.00E+00	4.83E-12	4.83E-12	312.10 days
Mn-56	0.00E+00	0.00E+00	0.00E+00	2.58 hours
Na-24	0.00E+00	0.00E+00	0.00E+00	14.97 hours
Nb-94	0.00E+00	1.21E-14	1.21E-14	2.00E04 years
Ni-59	0.00E+00	4.83E-14	4.83E-14	7.60E04 years
Ni-63	0.00E+00	4.83E-12	4.83E-12	101.00 years
Sb-125	0.00E+00	3.02E-13	3.02E-13	2.76 years
Sr-90	0.00E+00	1.21E-14	1.21E-14	28.80 years
Tc-99	0.00E+00	2.42E-14	2.42E-14	2.13E05 years
Y-90	0.00E+00	1.21E-14	1.21E-14	2.67 days
Zn-65	4.21E-10	4.83E-13	4.22E-10	244.00 days
Total Fission & Activation Products (Half-life >3hr)	7.20E-02	1.45E-10	7.20E-02	
Noble Gases[3]				

Notes:
1. The H-3, C-14, Co-60, and I-131 totals include results that were less than or equal to the DLC.
2. The number of radionuclides listed varies year-to-year based on the Kesselring Site's potential to emit evaluations for area or point releases from D&D type work. Those that are listed were detected in radiochemistry analysis of samples.
3. There was no generation/release of noble gases in 2022.

ENVIRONMENTAL MONITORING

Scope

Nonradiological: The nonradiological environmental monitoring program at the Kesselring Site during 2022 included monitoring and recording of the Glowegee Creek temperature conducted upstream of the Kesselring Site, between the discharge channels, and downstream of the Kesselring Site discharge locations each day the Kesselring Site discharged water through Outfalls 001 and 002 (See Figure 5). Flow measuring equipment is installed in the Kesselring Site's three non-stormwater discharge channels. In addition, Glowegee Creek flow is monitored by the U.S. Geological Survey (USGS) one-half mile downstream of the Kesselring Site at the West Milton Road gauging station (USGS No. 01330000).

A voluntary aquatic life sampling and evaluation program is conducted in the Glowegee Creek upstream, near the discharge channels, and downstream in the Glowegee Creek. Backpack electro-fishing techniques are used to collect the fish, which are identified, measured, and returned to the creek unharmed.

The Kesselring Site operated its own sanitary landfill for the disposal of nonradioactive and nonhazardous solid wastes until October 1993, when landfill operations permanently ceased. NYSDEC approved the final Landfill Closure Plan, and landfill closure construction was completed in October 1994. The closed landfill is maintained in accordance with a Post-Closure Monitoring and Maintenance Operations Manual, which has been approved by NYSDEC. Groundwater monitoring of the landfill is performed in accordance with this manual. All Kesselring Site groundwater monitoring data are discussed separately later in this report.

Radiological: The radiological environmental monitoring program at the Kesselring Site during 2022 included: (1) the collection of fish upstream and downstream of discharge locations to the Glowegee Creek, (2) the collection of quarterly samples of Glowegee Creek water and sediment at seven locations, and (3) the operation of continuous air samplers at stations located in the primary upwind and downwind directions from the Kesselring Site.

Three samples of sediment and one composite water sample are collected quarterly for radioanalysis across the creek at the seven locations shown in Figure 5.

Environmental air samplers are operated in the primary upwind and downwind directions from the Kesselring Site to measure normal background airborne radioactivity and to confirm that Kesselring Site effluents have no measurable effect on normal background levels.

Analyses

Radiological: The routine quarterly samples of Glowegee Creek water and bottom sediment samples are analyzed with a high-purity germanium gamma spectrometer system. In addition, a more sensitive gamma spectrometry analyses is performed annually on the fish and some of the water and sediment samples collected from the Glowegee Creek. The more sensitive analysis is intended to fully characterize the low levels of naturally and non-naturally occurring gamma-emitting radionuclides. The environmental air particulate sample filters are changed and analyzed routinely by high-purity germanium gamma spectrum analysis.

Assessment

Nonradiological: The Glowegee Creek fish survey results from 2022 are summarized in Table 37. The concentrations of chemical constituents in liquid effluent from the Kesselring Site resulted in no adverse effect on the quality of the Glowegee Creek. This conclusion is substantiated by results of the fish surveys that confirmed the existence of a diverse and healthy aquatic community in the creek water. The 2022 survey data is consistent with historical fish survey data. The different relative abundance of fish species at each sampling location reflects their different preferred habitats.

Radiological: The gamma spectrum analysis results for fish collected from the Glowegee Creek are shown in Table 38. The results show no radioactivity attributable to Kesselring Site operations. The only radionuclide observed in both fish samples was potassium-40. This naturally occurring radionuclide is frequently observed in fish.

Results of the gamma analysis of sediment and water samples are shown in Table 39. The data shows that there is no significant difference between radioactivity concentrations measured upstream and downstream. Only naturally occurring radionuclides were detected in the Glowegee Creek water samples. Results of the detailed gamma spectrum analyses performed on sediment samples also indicate low concentrations of potassium-40, cesium-137, and daughters of uranium and thorium. Potassium-40 and the daughters of uranium and thorium are naturally occurring radionuclides and are not associated with Kesselring Site operations. The EPA has attributed similar low levels of cesium-137 to fallout from low yield atmospheric nuclear weapon tests. Since the beginning of prototype operations more than 60 years ago, the release of radioactivity into the Glowegee Creek has been small and has had no adverse effect on the natural background radioactivity levels in the sediment.

The results for the environmental air samples show that there was no significant difference between the average upwind and downwind radioactivity concentrations. The average upwind radioactivity concentration was 1.52×10^{-14} μCi/ml and the average downwind radioactivity concentration was 5.73×10^{-15} μCi/ml. Gamma spectrum analyses indicated the presence of only background quantities of naturally occurring radionuclides.

RADIATION MONITORING

The purpose of the environmental radiation monitoring program is to measure the ambient radiation levels around the Kesselring Site to confirm that operations have not altered the natural radiation background levels at the Kesselring Site perimeter. The sources of radiation at the Kesselring Site are the operation and maintenance of the prototype reactor plants.

Scope

Environmental radiation levels were monitored at the perimeter of the Kesselring Site with a network of DT-702/PD lithium fluoride TLDs. The eight locations of the Kesselring Site perimeter TLDs are shown in Figure 6. Control TLDs were posted at four remote off-site locations to measure the natural background levels typical of the surrounding area. All TLDs were posted for quarterly exposure periods.

Analyses

The DT-702/PD lithium fluoride environmental TLDs are calibrated to a cesium-137 standard source. The TLD radiation exposures were measured quarterly utilizing an automated TLD readout system that was calibrated prior to the processing of the TLDs.

Assessment

The total annual radiation exposures measured with TLDs at the boundary of the Kesselring Site and at remote, off-site monitoring locations are summarized in Table 40. There is no statistically significant difference between the perimeter and the off-site measurements. This shows that Kesselring Site operations in 2022 had no measurable effect on natural background radiation levels at the Kesselring Site perimeter.

TABLE 37
GLOWEGEE CREEK FISH SURVEY

Location	Species	Number Collected	Length (mm)
400 Feet Upstream of 001	Blacknose Dace	10	34 -63
	Bluegill	-	-
U-2	Bluntnose Minnow	1	64
	Brook Stickleback	-	-
	Brook Trout	-	-
	Brown Bullhead	-	-
	Brown Trout	-	-
	Common Shiner	3	63 - 95
	Creek Chub	24	31 - 113
	Cutlips Minnow	8	53 - 84
	Fallfish	-	-
	Fathead Minnow	-	-
	Golden Shiner	-	-
	Largemouth Bass	-	-
	Longnose Dace	-	-
	Northern Redbelly Dace	-	-
	Pearl Dace	-	-
	Pumpkinseed	4	64-94
	Rainbow Trout	-	-
	Tessellated Darter	4	43-76
	White Sucker	53	47 - 111
	Yellow Bullhead	-	-
	Yellow Perch	-	-
50 Feet Upstream of 001	Blacknose Dace	29	23 - 58
	Bluegill	-	-
U-1	Bluntnose Minnow	-	-
	Brook Stickleback	-	-
	Brook Trout	-	-
	Brown Bullhead	-	-
	Brown Trout	-	-
	Common Shiner	7	32 - 66
	Creek Chub	52	22 - 109
	Cutlips Minnow	6	33 - 85
	Fallfish	-	-
	Fathead Minnow	-	-
	Golden Shiner	-	-
	Largemouth Bass	-	-
	Longnose Dace	1	66
	Northern Redbelly Dace	-	-
	Pearl Dace	-	-
	Pumpkinseed	1	78
	Rainbow Trout	-	-
	Tessellated Darter	2	41 - 42
	White Sucker	62	48 - 83
	Yellow Bullhead	-	-
	Yellow Perch	-	-
360 Feet Downstream of 001	Blacknose Dace	44	26 - 62
	Bluegill	-	-
M-1	Bluntnose Minnow	10	56 - 81
	Brook Stickleback	-	-
	Brook Trout	-	-
	Brown Bullhead	-	-
	Brown Trout	-	-
	Common Shiner	55	38 - 93
	Creek Chub	27	31 - 154
	Cutlips Minnow	1	48
	Fallfish	-	-
	Fathead Minnow	3	54 - 63
	Golden Shiner	-	-
	Largemouth Bass	-	-
	Longnose Dace	4	21 - 83
	Northern Redbelly Dace	-	-
	Pearl Dace	-	-
	Pumpkinseed	2	64 - 73
	Rainbow Trout	-	-
	Tessellated Darter	3	43 - 52
	White Sucker	23	53 - 91
	Yellow Bullhead	-	-
	Yellow Perch	-	-

TABLE 37 (continued)
GLOWEGEE CREEK FISH SURVEY

Location	Species	Number Collected	Length (mm)
2350 Feet Downstream of 001	Blacknose Dace	48	27 - 67
	Bluegill	-	-
D-2	Bluntnose Minnow	3	41 - 68
	Brook Stickleback	-	-
	Brook Trout	-	-
	Brown Bullhead	-	-
	Brown Trout	-	-
	Common Shiner	15	34 - 45
	Creek Chub	22	32 - 99
	Cutlips Minnow	1	96
	Fallfish	-	-
	Fathead Minnow	1	35
	Golden Shiner	-	-
	Largemouth Bass	-	-
	Longnose Dace	1	48
	Northern Redbelly Dace	-	-
	Pearl Dace	-	-
	Pumpkinseed	-	-
	Rainbow Trout	-	-
	Tessellated Darter	8	37 - 73
	White Sucker	17	54 - 82
	Yellow Bullhead	-	-
	Yellow Perch	-	-
2700 Feet Downstream of 001	Blacknose Dace	14	28 - 67
	Bluegill	-	-
D-1	Bluntnose Minnow	-	-
	Brook Stickleback	-	-
	Brook Trout	-	-
	Brown Bullhead	-	-
	Brown Trout	-	-
	Common Shiner	21	21 - 78
	Creek Chub	37	28 - 94
	Cutlips Minnow	2	71 - 72
	Fallfish	-	-
	Fathead Minnow	-	-
	Golden Shiner	-	-
	Largemouth Bass	-	-
	Longnose Dace	1	46
	Northern Redbelly Dace	-	-
	Pearl Dace	-	-
	Pumpkinseed	1	71
	Rainbow Trout	-	-
	Tessellated Darter	7	42 - 63
	White Sucker	6	55 - 70
	Yellow Bullhead	-	-
	Yellow Perch	-	-
5000 Feet Downstream of 001	Blacknose Dace	43	33 - 72
	Bluegill	-	-
D-3	Bluntnose Minnow	-	-
	Brook Stickleback	-	-
	Brook Trout	-	-
	Brown Bullhead	-	-
	Brown Trout	-	-
	Common Shiner	9	32 - 104
	Creek Chub	22	33 - 136
	Cutlips Minnow	3	36 - 91
	Fallfish	-	-
	Fathead Minnow	1	38
	Golden Shiner	-	-
	Largemouth Bass	-	-
	Longnose Dace	3	61 - 97
	Northern Redbelly Dace	-	-
	Pearl Dace	-	-
	Pumpkinseed	-	-
	Rainbow Trout	-	-
	Tessellated Darter	1	54
	White Sucker	13	61 - 132
	Yellow Bullhead	-	-
	Yellow Perch	-	-

TABLE 38
RESULTS OF ANALYSES OF GLOWEGEE CREEK FISH FOR RADIOACTIVITY

Sample Location	Radioactivity Concentration[1] (pCi/g wet wt)		
	K-40	**Cs-137**	**Co-60**
Upstream of Discharge			
Channel 001	2.639 ± 0.236	<0.006	<0.007
Downstream of Discharge			
Channel 002	2.352 ± 0.228	<0.006	<0.006

Note:
1. A value preceded by “<” is less than the DLC for that sample and parameter. The (±) value represents the statistical uncertainty at two standard deviations.

TABLE 39
RESULTS OF ANALYSES OF GLOWEGEE CREEK SEDIMENT AND WATER FOR RADIOACTIVITY

Sample Location	No. of Samples	Co-60 Radioactivity Concentration					
		Sediment (pCi/g, dry wt)[1,2]			Water (pCi/l)[2]		
	Sediment / Water	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
Upstream of Discharge							
Channel 001	12 / 4	<0.01	<0.02	<0.01	<6.68	<10.98	<9.34
Opposite Discharge							
Channel 001	12 / 4	<0.01	<0.02	<0.01	<6.71	<11.86	<9.68
Between Discharge							
Channels 001 & 002	24 / 8	<0.01	<0.02	<0.01	<8.20	<9.98	<9.11
Opposite Discharge							
Channel 002	12 / 4	<0.01	<0.02	<0.01	<6.00	<13.81	<9.93
Downstream of Discharge							
Channel 003	24 / 8	<0.01	<0.02	<0.01	<6.96	<11.64	<9.50

Notes:
1. Dry weight is based on sample weight with free water removed.
2. A value preceded by “<” is less than the DLC for that sample and parameter.

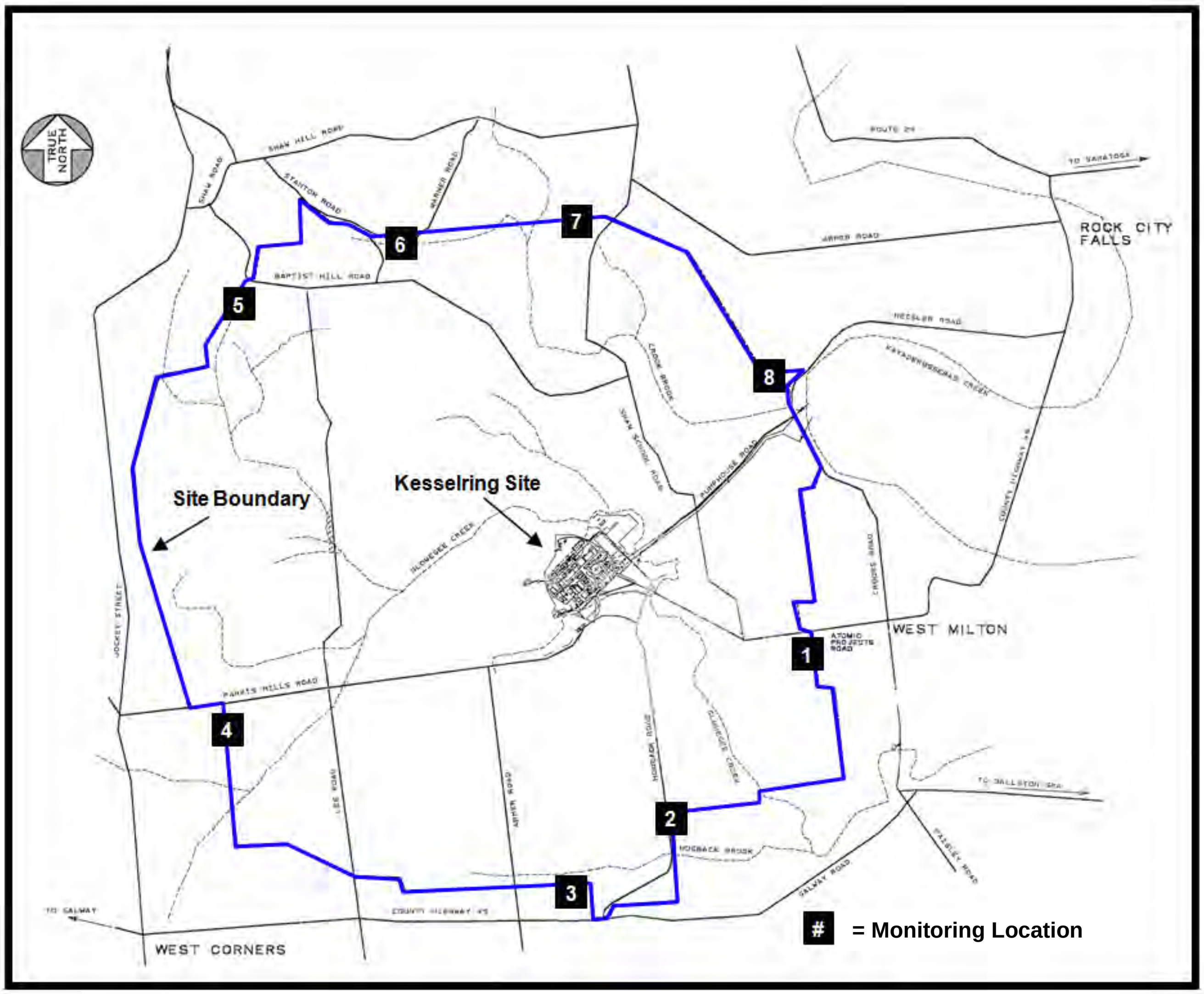

FIGURE 6
KESSELRING SITE, NEAR WEST MILTON, NEW YORK
PERIMETER MONITORING LOCATIONS

TABLE 40
PERIMETER AND OFF-SITE RADIATION MONITORING RESULTS
KESSELRING SITE

Monitoring Location[1]	Total Annual Exposure (millirem)[2]
1	57 ± 2
2	48 ± 2
3	49 ± 2
4	50 ± 2
5	56 ± 2
6	54 ± 2
7	55 ± 3
8	58 ± 2
Off-site locations	56 ± 9[3]

Notes:

1. See Figure 6 for monitoring locations.
2. The (±) values for individual locations are expressed at the 2 sigma confidence level based on the calculated measurement uncertainty.
3. Approximately 95% of natural background radiation measurements are expected to be within this range.

GROUNDWATER MONITORING

Scope

The Kesselring Site groundwater program includes environmental (nonradiological) monitoring of the closed Hogback Road Landfill in accordance with NYSDEC regulations and the voluntary monitoring of wells within the developed area of the Kesselring Site. Voluntary radiological monitoring of groundwater is also performed concurrently at the above locations and at several outlying areas of the Kesselring Site. The groundwater monitoring program is summarized in Table 41.

In 1993, the Hogback Road Landfill was closed, and in 1994 it was capped in accordance with a closure plan approved by NYS. Landfill capping minimizes the amount of precipitation moving through the fill material and serves to stabilize and lessen the generation of landfill leachate that would migrate into groundwater. The Hogback Road Landfill Post-Closure Monitoring and Maintenance Operations Manual documents all of the required measures the Kesselring Site takes to ensure the integrity of the landfill cap, and any associated impacts to the environment are tracked and understood.

The Landfill regulatory-required monitoring program consists of annually sampling six groundwater monitoring wells during the late summer to fall timeframe when groundwater tables are typically lowest. Five shallow overburden wells (HB-1A, LMW-4, HB-5A2, LMW-6, and HB-11A) and one deep bedrock well (HB-5B) are sampled for a focused list of analytical parameters approved by NYSDEC. The locations of all existing landfill groundwater monitoring wells are shown in Figure 7. In addition to annual groundwater monitoring, the Kesselring Site performs quarterly inspections of landfill integrity and an annual survey for explosive gases at the landfill gas vents.

The groundwater monitoring program for the developed area (Figure 8) typically consists of annual sampling of 18 monitoring wells. This sampling is performed as a best management practice to track known constituents and to provide early detection of unexpected releases.

The groundwater monitoring program for the former disposal areas consists of annual sampling of 13 monitoring wells (Figure 9) for radiological analyses. In 1999, the Kesselring Site evaluated each of the former disposal sites with regard to the nature of the disposal source material, hydrogeology, and historic analytical database, and concluded that no groundwater threat exists. These wells are monitored to maintain a record of negative radiological data.

Sources

Nonradiological: Elevated parameters in the landfill wells are associated with past disposal practices. The landfill, operated since 1951 and closed in 1993, was used predominantly for the disposal of sanitary wastes. Prior to enactment of Federal and State regulations for solid waste disposal activities that banned disposal of certain wastes in such facilities, asbestos scraps, scrap metal including lead, some oil and oily water, solvents, paint, and chemicals were disposed of in the landfill.

Elevated parameters in and adjacent to the developed area of the Kesselring Site are predominantly the result of operational activities, such as: historical material handling practices and construction activities, on-going use of roadway de-icing materials (e.g., sodium chloride, calcium chloride, etc.), cooling tower operations, and routine operations of SSW systems containing chlorine.

The five former disposal sites at the Kesselring Site were used for construction and demolition waste, limited amounts of acid waste, and some waste burning. These disposal practices were conducted prior to enactment of Federal and State regulations governing the disposal of these materials.

Analyses

Nonradiological: All groundwater samples are analyzed by a New York State Department of Health (NYSDOH) certified laboratory for chemical parameters in accordance with Reference (10) or other EPA approved methods. Field parameters, which include static water level, temperature, and pH, are measured on site at the time of environmental sampling. Specific conductance and turbidity are sampled on site at the time of sampling for some monitoring events and are analyzed at a certified laboratory for others.

TABLE 41
KESSELRING SITE GROUNDWATER MONITORING PROGRAM

Program Area	Monitoring Wells	Field Parameters & Modified Routine List & Halogenated VOCs(1,2)	Field Parameters & VOCs	Radioactivity
Landfill	HB-1A, HB-5A2, HB-5B, HB-11A, LMW-4, LMW-6	A, R		A, V
Developed Area	MW-1 to MW-4, MW-6 to MW-19(3)		A, V	A, V
Land Disposal Area	KBH-1 to KBH-4, KBH-6 to KBH-13, and T-3(3)			A, V

Notes:
A = Annual
R = Regulatory Required Monitoring
V = Voluntary Monitoring
1. Parameters are discussed in the tables of this section.
2. Filtered metals analysis is performed as necessary for verification of elevated metals which are attributable to sample turbidity (suspended clay/silt particles).
3. MW-5, MW-20, and KBH-5 were decommissioned in accordance with NYSDEC regulations.

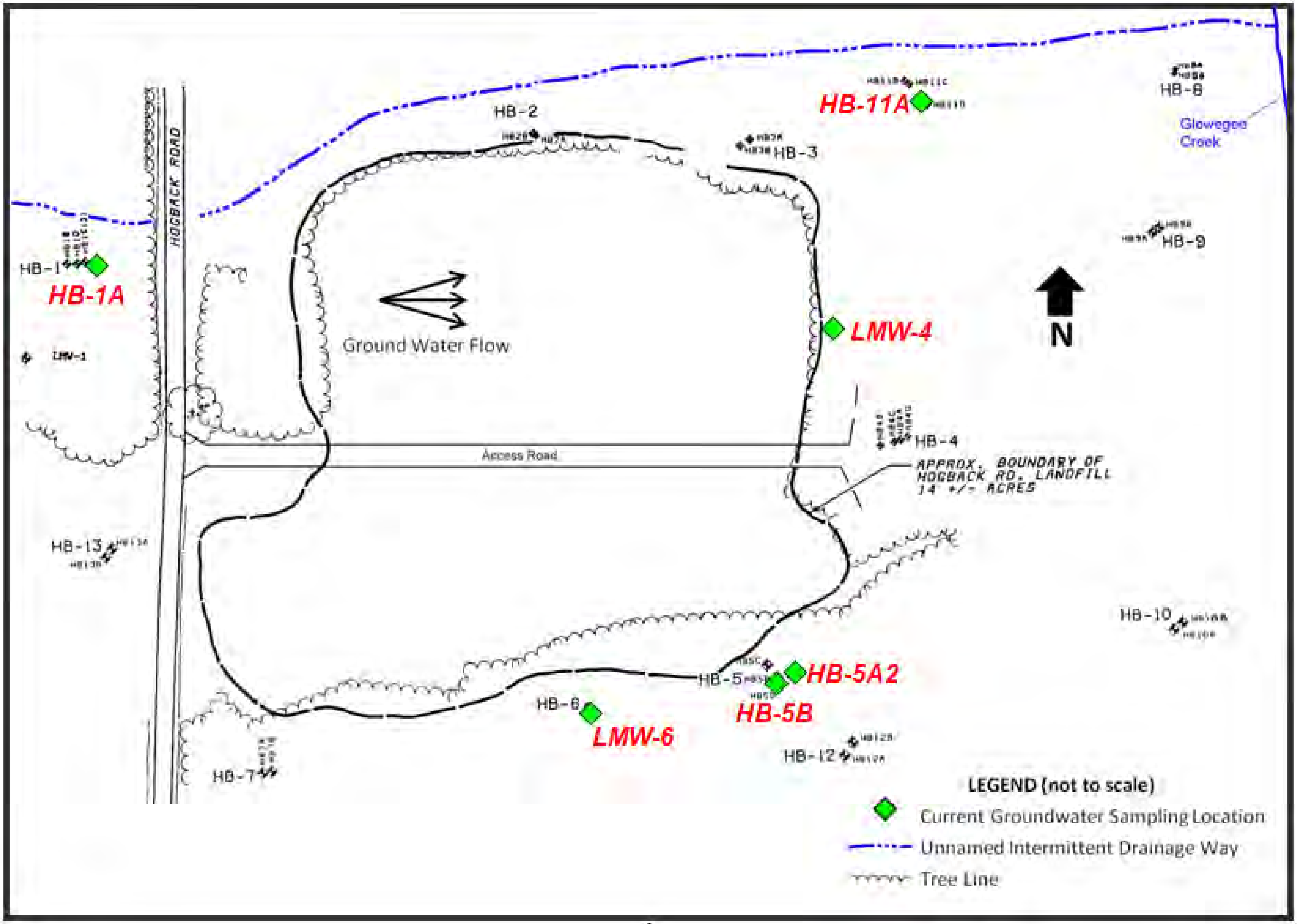

FIGURE 7
KESSELRING SITE, NEAR WEST MILTON, NEW YORK
LANDFILL GROUNDWATER MONITORING WELLS

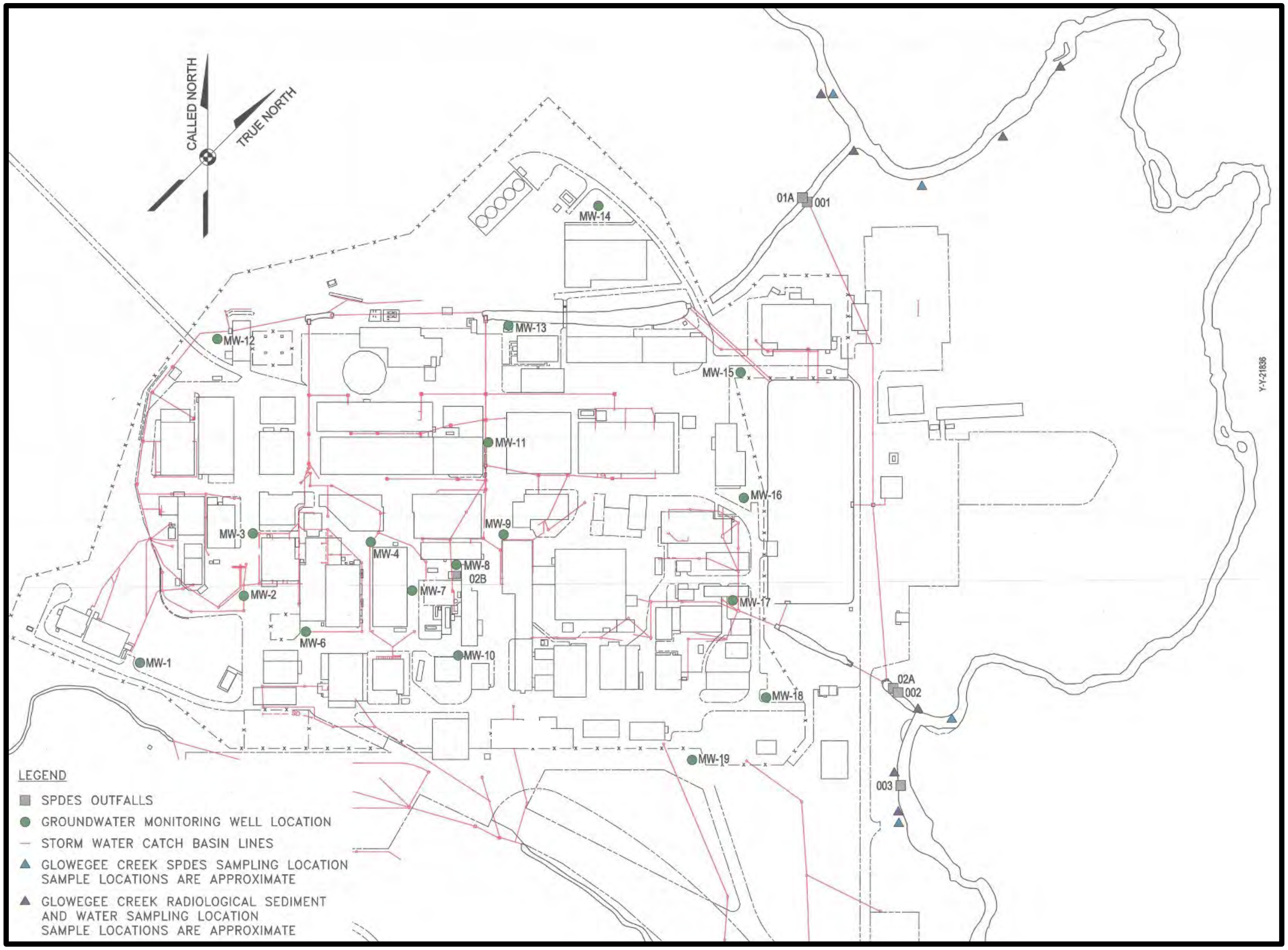

FIGURE 8

KESSELRING SITE, NEAR WEST MILTON, NEW YORK

DEVELOPED AREA GROUNDWATER MONITORING WELLS

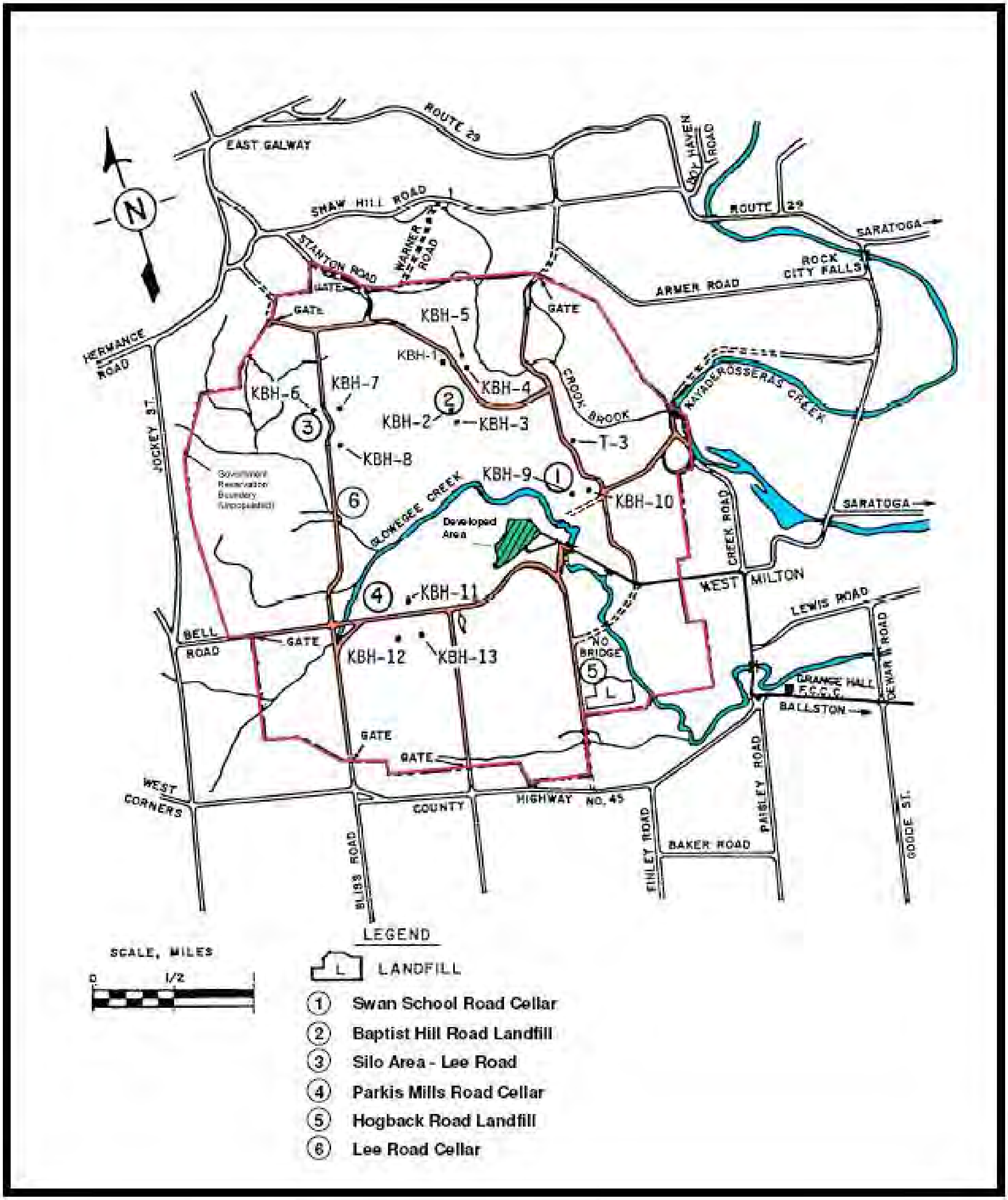

FIGURE 9

KESSELRING SITE, NEAR WEST MILTON, NEW YORK
DISPOSAL AREAS – GROUNDWATER MONITORING WELLS

Landfill samples are analyzed for a modified list of routine chemical and leachate-indicator parameters approved by NYSDEC in 2002. The modified routine parameter list includes alkalinity, ammonia, chemical oxygen demand (COD), chloride, hardness, nitrate, sulfate, TDS, total organic carbon (TOC), calcium, iron, manganese, magnesium, potassium, and sodium. The samples are also analyzed for halogenated and aromatic VOCs. All samples were collected in accordance with the procedures and requirements of the Post-Closure Monitoring and Maintenance Operations Manual. All routine parameter results are shown in Table 42. Gas monitoring was performed at the landfill in accordance with the post-closure monitoring requirements using an oxygen/explosive gas detector calibrated to the manufacturer's specifications.

Within the developed area, the 18 monitoring wells are sampled for both halogenated and aromatic VOCs. The VOC analysis suite consists of 29 halogenated and 5 aromatic compounds of which only a few have been detected above the practical quantitation limit/reporting limit in the past. VOC results are shown in Table 43. In addition, laboratory analyses are performed for chloride, nitrate, ammonia, and nitrite for the developed area monitoring wells.

Groundwater from four production wells located along the Kesselring Site's eastern property boundary is used to supply the drinking water system at the Kesselring Site. The drinking water is sampled in accordance with NYS drinking water regulations defined in Reference (23). The sample results are shown in Table 44.

Radiological: The Kesselring Site conducts voluntary radiological monitoring on the groundwater wells at the landfill area, the developed area, and four former disposal sites. The well locations are shown in Figures 7, 8, and 9. The well samples are analyzed by gamma spectrometry for cesium-137 and cobalt-60 and by liquid scintillation spectrometry for tritium. The results of the analyses are shown in Table 45.

Assessment

Nonradiological:

<u>Landfill</u>

Groundwater wells were sampled both upgradient and downgradient of the Hogback Road Landfill to monitor groundwater quality impacts from the landfill and for any indications of a breach in the integrity of the landfill cap. Analytical results obtained during 2022 remain consistent overall with historical data trends.

The 2022 analytical results continue to show that while certain routine parameters remain elevated in most of the downgradient wells when compared to the upgradient well (HB-1A) (Table 42), these parameters are either stable or decreasing over time, and there remains no indication of a breach in landfill cap integrity. The individual parameters that are typically elevated include: specific conductance, alkalinity, hardness, TDS, chloride, sulfate, magnesium, manganese, potassium, sodium, and calcium. A number of other parameters exhibit variability and are generally elevated in only a few downgradient wells. These parameters routinely include turbidity, COD, TOC, ammonia, nitrate, and iron.

TABLE 42
RESULTS OF KESSELRING SITE GROUNDWATER MONITORING, HOGBACK ROAD LANDFILL[1]

ROUTINE PARAMETERS (2002 MODIFIED LIST)

Sample Location	**HB-1A**	**LMW-4**	**HB-11A**	**HB-5A2**	**HB-5A2 Duplicate**	**HB-5B**	**LMW-6**	**Standard/ Criteria[2]**
Sample Date	**09/26/22**	**09/26/22**	**09/26/22**	**09/26/22**	**09/26/22**	**09/26/22**	**09/26/22**	
Field Parameters								
Groundwater Elevation (ft)	483.86	Dry	458.98	450.65	----	450.36	459.53	NC
Temperature (°C)	15.5	----	13.3	11.3	----	12.7	12.1	NC
pH (SU)	6.3	----	7.1	6.6	----	6.8	6.6	6.5 - 8.5
Specific Conductance (µmhos/cm)	57	----	860	1078	----	1154	1375	NC
Turbidity (NTU)	18	----	120	24	----	5	40	5
Indicator (mg/l, or as indicated)								
Alkalinity, as $CaCO_3$	44	----	370	500	520	550	450	NC
Ammonia (as N, mg/l)	<0.1	----	<0.1	<0.1	0.2	0.2	0.3	2
COD	7	----	<5	7	16	<5	<5	NC
Chloride	<2.00	----	44.4	13.4	13.5	32.4	141	250
Hardness, as $CaCO_3$	24	----	270	399	289	337	300	NC
Nitrate (as N, mg/l)	0.04	----	0.06	<0.04	<0.04	<0.04	<0.04	10
Sulfate	<2.00	----	5.19	6.21	6.32	7.12	11.0	250
TDS	5	----	440	625	560	720	705	500
TOC	1.9	----	1.7	2.4	2.2	1.5	1.9	NC
Metals (mg/l)[3]								
Calcium	8.45 / 8.15	----	94.0 / 95.7	150 / 132	106 / 122	116 / 151	107 / 107	NC
Iron	0.302 / <0.050	----	0.508 / <0.050	12.2 / 11.5	12.3 / 11.2	4.04 / 3.82	0.486 / <0.050	0.3
Magnesium	0.776 / 0.750	----	8.67 / 9.37	5.97 / 6.01	5.87 / 5.77	11.6 / 12.8	7.97 / 8.28	35.0
Manganese	<0.020/ <0.020	----	0.234 / 0.048	1.60 / 1.66	1.59 / 1.59	0.356 / 0.449	0.309 / <0.020	0.3
Potassium	0.286 / 0.285	----	1.55 / 1.57	1.99 / 1.82	2.05 / 1.74	2.82 / 2.31	2.31 / 2.30	NC
Sodium	0.938 / 1.33	----	18.0 / 23.4	4.42 / 5.11	4.54 / 5.06	27.9 / 29.7	98.8 / 97.0	20
Volatiles (µg/l)[4][5]								

Notes:

NC No Criteria Available (no standards or guidance values per Reference (1) and Reference (4).
1. Compounds that are not detected at or above the RL are reported in the table as less than (<) the RL.
2. Groundwater standards taken from Reference (1). Additional water standards and guidance values taken from Reference (4).
3. Total metal sample analysis data is shown preceding the dissolved metal result, i.e., total/dissolved. In some cases, the dissolved data is shown to be slightly higher than the total data. The analytical laboratory has stated that this data is correct, and that the total and dissolved results are within the margin of error for the analytical procedures.
4. VOCs analyzed but not detected at or above the RL in any of the presented sampling rounds are not listed in the table.
5. VOCs analyzed using method EPA SW-846 Method 8260C.

While a number of parameters continue to exceed groundwater quality standards per Reference (1) or guidance values per Reference (4), inorganic parameters detected in downgradient well samples are within, or below, representative ranges for inorganic parameters typical of leachate from sanitary landfills per Reference (15). VOC analytical results obtained during 2022 remain consistent with historical data trends and were all reported below the detection limit or groundwater standards

Ambient air gas monitoring was performed at the landfill gas vents. No detectable concentrations of explosive gases were observed. Quarterly landfill inspections were conducted and no degradation or breaches in the cap were identified. Routine landfill maintenance was performed to ensure continued integrity of the landfill cap.

TABLE 43
RESULTS OF KESSELRING SITE GROUNDWATER MONITORING, DEVELOPED AREA WELLS[1,2]

Well	Sample Date	Chloroform (µg/l)	Bromodichloromethane (µg/l)	Dibromochloromethane(µg/l)
MW-1[3]	08/31/22	9.4	3.7	<1.0
Standard[4][5]		7	50	50
RL		1.0	1.0	1.0

Notes:
1. All samples analyzed by EPA methods 601 and 602.
2. The listed VOCs in the table had detectable values above the RL. The other 17 monitoring wells analyzed for VOCs were below the RL of less than 1 ppb.
3. Upgradient well
4. Groundwater standards taken from Reference (1) and Reference (4).
5. Per Reference (23), total trihalomethane (THM) maximum contaminant level is 80 µg/l. Chloroform, bromodichloromethane, dibromochloromethane and bromoform equals THM. The THMs associated with MW-1 are attributed to site service water system (potable water) releases, and are not related to waste management or product spills.

Developed Area

The routine annual groundwater program for the developed area includes field parameters and VOC analyses. Field parameters include groundwater elevation, temperature, pH, specific conductance, and turbidity. Analyses for chloride, nitrate, ammonia, nitrite, and VOCs were performed at an off-site laboratory.

Due to elevated levels of ammonia detected in groundwater during the construction of Building 102 (2007), groundwater discharged from the Building 102 drainage system was treated for ammonia and nitrite. On March 16, 2019, NYSDEC approved suspension of the treatment facility because of low ammonia values. On October 26, 2020, KS submitted a report to NYSDEC in support of the permanent retirement of the Nitrite-Ammonia Treatment Facility (NATF) and removal of Outfall 02B from the SPDES permit.

Elevated chloride and turbidity levels are attributed to the on-going use of roadway de-icing materials and snow/ice removal operations. In 2022, groundwater chloride results ranged between 11.9 mg/l to 7260 mg/l, and turbidity ranged from 6 NTU to >999 NTU, consistent with elevated chloride levels. The 2022 pH results were all within the acceptable range for groundwater standards.

Site Service (Drinking) Water

The drinking water supply is part of the SSW system and is supplied from a deep (confined) groundwater aquifer. The drinking water system is sampled and monitored to ensure its quality meets NYSDOH drinking water regulations (Reference (23)). All 2022 sample results were compliant with the NYSDOH maximum contaminant levels. The sample results are shown in Table 44. The SSW well field is hydrogeologically separate from the Kesselring Site landfill and former disposal sites and is consequently not affected by materials at those locations.

Radiological: The groundwater sample results for radioactivity are summarized in Table 45. The levels of cesium-137, cobalt-60, and tritium were below DLCs in all wells. The concentrations for these radionuclides were less than 0.1 percent of the respective Reference (6) DCS values.

TABLE 44
CHEMICAL CONSTITUENTS IN KESSELRING SITE DRINKING WATER

Parameter / Units[1] (Units are mg/l unless otherwise noted)	Number of Samples	Value			Standard[4]
		Minimum[2]	Maximum[2]	Average[3]	
Drinking Water Standards (Reference (23))					
Nitrates (mg/l as N)	1	0.698	0.698	0.698	10
Total Coliform[5,6]	37	Negative	Negative	NA	None Detectable
Free Chlorine Residual	365	0.50	3.96	1.31	Note (7)
Free Chlorine Residual[6]	37	0.04	2.52	1.10	Note (7)
1,4-Dioxane	1	<0.00007	<0.00007	<0.00007	0.001
Perfluorooctanoic Acid (PFOA)	1	<0.000002	<0.000002	<0.000002	0.000010
Perfluorooctanesulfonic Acid (PFOS)	1	<0.000002	<0.000002	<0.000002	0.000010
1,1,1,2- Tetrachloroethane	1	<0.0005	<0.0005	<0.0005	0.005
1,1,1-Trichloroethane	1	<0.0005	<0.0005	<0.0005	0.005
1,1,2,2-Tetrachloroethane	1	<0.0005	<0.0005	<0.0005	0.005
1,1,2-Trichloroethane	1	<0.0005	<0.0005	<0.0005	0.005
1,1-Dichloroethane	1	<0.0005	<0.0005	<0.0005	0.005
1,1-Dichloroethene	1	<0.0005	<0.0005	<0.0005	0.005
1,1-Dichloropropene	1	<0.0005	<0.0005	<0.0005	0.005
1,2,3-Trichlorobenzene	1	<0.0005	<0.0005	<0.0005	0.005
1,2,3-Trichloropropane	1	<0.0005	<0.0005	<0.0005	0.005
1,2,4-Trichlorobenzene	1	<0.0005	<0.0005	<0.0005	0.005
1,2,4-Trimethylbenzene	1	<0.0005	<0.0005	<0.0005	0.005
1,2-Dichlorobenzene	1	<0.0005	<0.0005	<0.0005	0.005
1,2-Dichloroethane	1	<0.0005	<0.0005	<0.0005	0.005
1,2-Dichloropropane	1	<0.0005	<0.0005	<0.0005	0.005
1,3,5-Trimethylbenzene	1	<0.0005	<0.0005	<0.0005	0.005
1,3-dichlorobenzene	1	<0.0005	<0.0005	<0.0005	0.005
1,3-Dichloropropane	1	<0.0005	<0.0005	<0.0005	0.005
1,4-Dichlorobenzene	1	<0.0005	<0.0005	<0.0005	0.005
2,2-Dichloropropane	1	<0.0005	<0.0005	<0.0005	0.005
2-Chlorotoluene	1	<0.0005	<0.0005	<0.0005	0.005
4-Chlorotoluene	1	<0.0005	<0.0005	<0.0005	0.005
4-Isopropyltoluene	1	<0.0005	<0.0005	<0.0005	0.005

Notes for Table 44 are on page 113

TABLE 44 (continued)
CHEMICAL CONSTITUENTS IN KESSELRING SITE DRINKING WATER

Parameter / Units[1] (Units are mg/l unless otherwise noted)	Number of Samples	Value			Standard[4]
		Minimum[2]	Maximum[2]	Average[3]	
Drinking Water Standards (Reference (23))					
Benzene	1	<0.0005	<0.0005	<0.0005	0.005
Bromobenzene	1	<0.0005	<0.0005	<0.0005	0.005
Bromodichloromethane	1	<0.0005	<0.0005	<0.0005	0.005
Bromoform	1	<0.0005	<0.0005	<0.0005	0.005
Bromomethane	1	<0.0005	<0.0005	<0.0005	0.005
Carbon Tetrachloride	1	<0.0005	<0.0005	<0.0005	0.005
Chlorobenzene	1	<0.0005	<0.0005	<0.0005	0.005
Chloroethane	1	<0.0005	<0.0005	<0.0005	0.005
Chloroform	1	<0.0005	<0.0005	<0.0005	0.005
Chloromethane	1	<0.0005	<0.0005	<0.0005	0.005
cis-1,2-Dichloroethene	1	<0.0005	<0.0005	<0.0005	0.005
cis-1,3-Dichloropropene	1	<0.0005	<0.0005	<0.0005	0.005
Dibromochloromethane	1	<0.0005	<0.0005	<0.0005	0.005
Dibromomethane	1	<0.0005	<0.0005	<0.0005	0.005
Dichlorodifluoromethane	1	<0.0005	<0.0005	<0.0005	0.005
Hexachlorobutadiene	1	<0.0005	<0.0005	<0.0005	0.005
Isopropylbenzene	1	<0.0005	<0.0005	<0.0005	0.005
m,p-Xylene	1	<0.0005	<0.0005	<0.0005	0.005
Methyl tert-butyl ether	1	<0.002	<0.002	<0.002	0.010
Methylene chloride	1	<0.0005	<0.0005	<0.0005	0.005
n-Butylbenzene	1	<0.0005	<0.0005	<0.0005	0.005
Ethylbenzene	1	<0.0005	<0.0005	<0.0005	0.005
n-Propylbenzene	1	<0.0005	<0.0005	<0.0005	0.005
o-Xylene	1	<0.0005	<0.0005	<0.0005	0.005
sec-Butylbenzene	1	<0.0005	<0.0005	<0.0005	0.005
Styrene	1	<0.0005	<0.0005	<0.0005	0.005
tert-Butylbenzene	1	<0.0005	<0.0005	<0.0005	0.005
Tetrachloroethene	1	<0.0005	<0.0005	<0.0005	0.005
Toluene	1	<0.0005	<0.0005	<0.0005	0.005
trans-1,2-Dichloroethene	1	<0.0005	<0.0005	<0.0005	0.005
trans-1,3-Dichloropropene	1	<0.0005	<0.0005	<0.0005	0.005
Trichloroethene	1	<0.0005	<0.0005	<0.0005	0.005
Trichlorofluoromethane	1	<0.0005	<0.0005	<0.0005	0.005
Vinyl chloride	1	<0.0005	<0.0005	<0.0005	0.002
Haloacetic Acids[8]	1	0.0077	0.0077	0.0077	0.060
Total Trihalomethanes[8]	1	0.0077	0.0077	0.0077	0.080

Notes for Table 45 are on page 113

NOTES FOR TABLE 44

1. All samples were collected at the entry point to the distribution system unless otherwise noted.
2. A value preceded by "<" is less than the RL for that sample and parameter.
3. Average values preceded by "<" contain at least one value less than the RL value in the average.
4. Maximum Contaminant Level (MCL) per Reference (23).
5. Coliform sample results are now reported as positive or negative. No numerical value is provided thus no average value is presented.
6. These samples are taken at various locations in the distribution system when total coliform samples are taken.
7. The minimum specification is that the free chlorine residual is 0.2 mg/l at the entry point and detectable in the distribution system. The maximum average level is 4 mg/l as calculated by taking the annual average, computed quarterly, of the samples collected in the distribution system.
8. These samples are collected from the Head Tank 27B (Storage Tank B).

TABLE 45
RESULTS OF KESSELRING SITE GROUNDWATER MONITORING FOR RADIOACTIVITY[1]

LOCATION		Cs-137	Co-60	Tritium pCi/l x 10^2
		pCi/l		
LANDFILL AREA				
HB-1A[2]		<0.88	<0.72	<1.66
HB-1B[2]	Well Dry, Not Sampled	----	----	----
HB-5A2		<0.90	<0.75	<1.66
HB-5B		<0.92	<0.76	<1.66
HB-11A		<0.93	<0.77	<1.72
HB-11B	Well Dry, Not Sampled	----	----	----
LMW-4	Well Dry, Not Sampled	----	----	----
LMW-6		<0.91	<0.76	<1.66
DEVELOPED AREA				
MW-1[2]		<0.99	<0.79	<1.66
MW-2		<0.99	<0.80	<1.66
MW-3		<0.90	<0.73	<1.66
MW-4		<0.88	<0.73	<1.66
MW-6		<0.91	<0.74	<1.66
MW-7		<0.90	<0.72	<1.67
MW-8		<0.90	<0.74	<1.66
MW-9		<0.90	<0.79	<1.66
MW-10	Well Dry, Not Sampled	----	----	----
MW-11		<0.91	<0.76	<1.66
MW-12		<0.88	<0.75	<1.66
MW-13		<0.94	<0.78	<1.66
MW-14		<0.87	<0.69	<1.66
MW-15		<0.92	<0.75	<1.65
MW-16		<0.91	<0.76	<1.66
MW-17[4]	Partial Sample Obtained	<2.0	<1.9	<1.66
MW-18		<0.91	<0.74	<1.66
MW-19		<0.89	<0.72	<1.66
BAPTIST HILL ROAD LANDFILL				
KBH-1[2]		<0.89	<0.72	<1.76
KBH-2		<0.95	<0.75	<1.73
KBH-3		<0.92	<0.73	<1.73
KBH-4		<0.92	<0.77	<1.76
SILO AREA				
KBH-6[2]		<0.87	<0.73	<1.76
KBH-7		<0.88	<0.74	<1.76
KBH-8	Well Dry, Not Sampled	----	----	----
SWANN SCHOOL ROAD CELLAR				
KBH-9		<0.90	<0.74	<1.70
KBH-10		<0.87	<0.71	<1.70
T-3		<0.91	<0.76	<1.70
PARKIS MILLS ROAD CELLAR				
KBH-11		<0.89	<0.76	<1.76
KBH-12		<0.91	<0.76	<1.76
KBH-13		<0.90	<0.75	<1.76

Notes:

1. A value preceded by "<" is less than the DLC for that sample and parameter.
2. Background well for comparison purposes.
3. MW-5, MW-20, and KBH-5 were decommissioned in accordance with NYSDEC regulations.
4. A 2-Liter sample was obtained instead of the required 3-Liter sample for analysis. A DLC of 1 pCi/L was not achievable.

Conclusion

The 2022 groundwater data demonstrates no adverse changes from historical monitoring results. Past waste disposal practices at the landfill have resulted in observable effects on groundwater quality downgradient of the landfill. However, data trends show that groundwater quality has improved since the landfill was closed and that there is no indication of a breach in landfill cap integrity.

Within the industrial facility, groundwater results were obtained for chlorides, pH, and turbidity. These results are predominantly attributed to normal facility operations including the continued use of chlorinated SSW for drinking, fire protection, and system cooling needs; the operation of the Kesselring Site cooling tower; the on-going use of roadway de-icing materials during winter months; and limited effects from past operational practices. Results from 2022 are consistent with historical monitoring trends. Previously sampled downstream surface water analysis has consistently shown no adverse effects from developed area Kesselring Site operations.

CONTROL OF CHEMICALLY HAZARDOUS SUBSTANCES AND SOLID WASTE

Sources

Chemicals are not manufactured or disposed at the Kesselring Site. Nonhazardous chemical wastes and minimal quantities of hazardous wastes are generated by the necessary use of chemicals in Kesselring Site operations. To ensure the safe use of chemicals and disposal of the resulting wastes, the Kesselring Site maintains programs in waste minimization and hazardous waste control. Unless recycled, all chemical wastes are either treated or disposed of through permitted off-site facilities.

Chemical Control Program

A principal part of the waste minimization program is the control of the acquisition of hazardous substances for use at the Kesselring Site. Purchase requests for chemicals are reviewed to ensure that the materials are actually necessary for Kesselring's operations, the amount ordered is not excessive, and that methods for proper disposal are in place before the material is ordered.

Hazardous substance storage controls include at a minimum: labeling, segregation based on compatibility, limited storage volumes, appropriate use of secondary containment and weather protection. When required, large volumes of chemicals and petroleum products are stored in accordance with the NYS Chemical Bulk Storage regulations as specified in Reference (16) and the PBS regulations in Reference (17).

Chemical Disposal

After implementing chemical controls on purchases and pursuing green alternatives, there are still minimal quantities of hazardous wastes resulting from the necessary use of chemicals in Site operations. Larger quantities of hazardous wastes periodically result from one-time facility decommissioning and dismantlement activities as well as from routine construction and demolition efforts. Hazardous waste and mixed (radioactive and hazardous) waste storage facilities are operated at the Kesselring Site under provisions of the NYS regulation implementing RCRA and the FFCA. The Kesselring Site operates these facilities under a Part 373 permit issued by NYSDEC. During 2022, the Kesselring Site shipped approximately 652 tons of RCRA and NYS hazardous waste off-site for treatment and disposal. This includes approximately 437.6 tons of mixed waste, predominantly from facility decommissioning and dismantlement activities. Waste that is both radioactive and chemically hazardous is regulated under both the AEA and RCRA as "mixed waste." Additionally, per the NYSDEC, certain TSCA regulated PCB waste is also considered a hazardous waste.

Elementary neutralization of small volume laboratory waste also occurs on-site. This process is exempt from regulation as a RCRA treatment process. The neutralized discharge is controlled under the Kesselring Site SPDES permit.

Nonhazardous chemical waste is also sent off-site for disposal. The transportation vendors and the treatment, storage, and disposal facilities are typically the same as those used for hazardous waste disposal. These facilities operate under permits issued by the cognizant Federal and State regulatory agencies. The Kesselring Site also requires the disposal facility to provide itemized written verification that the waste was actually received. In 2022, approximately 556 tons of nonhazardous chemical waste was sent off-site for incineration, wastewater treatment, chemical treatment and/or land disposal. A significant fraction of this waste (over 550 tons) was the result of one-time dismantlement and/or renovation activities at the Kesselring Site.

In addition, the Kesselring Site hazardous waste control program is subject to periodic on-site inspections by NYSDEC and the EPA.

Solid Waste Disposal/Recycling

During 2022, approximately 4,484 tons of nonhazardous, solid wastes were generated from such waste streams as office and cafeteria trash, construction and demolition debris, and classified scrap paper. From these waste streams, the Kesselring Site recycles materials such as unclassified office paper, glass, plastic, aluminum, newspapers, magazines, corrugated cardboard, asphalt, computers, wood, precious metals, used oil, lead/lead acid batteries, scrap metal, concrete, universal waste (e.g., light bulbs, batteries, thermostats), printer cartridges, and cafeteria grease. Approximately 3,219 tons of materials were recycled.

CONTROL OF RADIOACTIVE MATERIALS AND RADIOACTIVE WASTE

Sources

Operations at the Kesselring Site result in the generation of various types of radioactive materials and wastes. Low level radioactive solid waste material that requires disposal includes filters, metal scrap, resin, rags, paper, and plastic materials.

Control Program

Detailed procedures are used for handling, packaging, and transportation of radioactive materials and disposal of radioactive waste at a government operated or licensed disposal site. Internal reviews are made prior to the shipment of any radioactive material from the Kesselring Site to ensure that the material is properly identified, surveyed, and packaged in accordance with Federal, State, and local requirements.

The volume of radioactive waste is minimized through recycling and the use of special work procedures that limit the amount of material that becomes contaminated during work on radioactive systems and reactor components. Radioactive liquid waste is processed into an absorbed form prior to shipment to an approved disposal facility. All radioactive wastes are prepared and shipped to meet applicable regulations of the DOT given in Reference (18). The waste packages also comply with all applicable requirements of the NRC, the DOE, and the disposal sites.

Disposal/Recycling

The shipments of low level radioactive solid wastes were made by authorized common carriers to disposal sites located outside NYS.

During 2022, approximately 74.5 cubic meters (97.5 cubic yards) of low level radioactive waste containing approximately 4.47×10^{-2} Curies (Ci) of radioactivity were shipped from the Kesselring Site for disposal. The Kesselring Site did not ship radioactive metal material for recycling.

CONTROL OF MIXED WASTES

Sources

Waste that is both radioactive and chemically hazardous is regulated under both the AEA and RCRA as "mixed waste." Ongoing operations at the Kesselring Site resulted in the generation of a very small proportion of the mixed waste generated at Kesselring. The majority of the mixed waste is generated as a result of dismantlement or refurbishment activities.

Control Program

Since mixed wastes are both RCRA hazardous and radioactive, the controls for hazardous wastes are applied to the hazardous constituents and the controls for radioactive wastes are applied to the radioactive constituents.

Mixed wastes are managed on-site in accordance with the Kesselring Site RCRA permit. The amount of mixed waste generated was minimized through the use of detailed work procedures and worker training.

Storage and Disposal

Mixed wastes were accumulated in designated regulated and permitted storage areas. The wastes were packaged for storage and shipment to off-site treatment facilities in accordance with DOT requirements for transport to and receipt at RCRA-permitted treatment and disposal facilities.

In 2022, there were twenty-five shipments totaling approximately 437.6 tons of various mixed wastes to treatment and disposal facilities.

RADIATION DOSE ASSESSMENT

The effluent and environmental monitoring results show that the radioactivity in liquid and gaseous effluents from 2022 operations at the Kesselring Site had no measurable effect on background radioactivity levels. Therefore, any radiation doses from Kesselring Site operations to off-site individuals were too small to be measured and must be calculated using conservative methods. Estimates of the radiation dose to the maximally exposed off-site individual in the vicinity of the Kesselring Site and the collective dose to the population residing in the 80 kilometer (50 mile) radius assessment area are summarized later in this report in the Radiation Dose Assessment and Methodology section.

The results show that the estimated doses were less than 0.1 percent of that permitted by the DOE radiation protection standards listed in Reference (19) and that the estimated dose to the population residing within 80 kilometers (50 miles) of the Kesselring Site was less than 0.001 percent of the natural background radiation dose to the population. In addition, the estimated doses were less than one percent of that permitted by the NRC numerical guide listed in Reference (20) for whole body dose demonstrating that doses are ALARA. The dose attributed to radioactive air emissions was less than one percent of the EPA standard in Reference (8).

The collective radiation dose to the public along travel routes from outgoing Kesselring Site shipments of radioactive materials during 2022 was calculated using data given by the NRC in Reference (21).

Based on the type and number of shipments made, the collective annual radiation dose to the public along the transportation routes, including transportation workers, was less than one person-rem. This is less than 0.001 percent of the dose received by the same population from natural background radiation.

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DOE-EM ACTIVITIES

BACKGROUND

From 2007 through 2018, DOE-EM performed remediation, demolition and disposal of the Cold War era facilities and impacted soil from legacy operations associated with the Separations Process Research Unit (SPRU) at the Knolls Laboratory. Following DOE-EM's efforts at the Knolls Laboratory to remove the SPRU facilities, the NNPP established a partnership with DOE-EM to remove the NNPP's legacy facilities at Knolls Laboratory and Kesselring Site. The NNPP maintains a cradle-to-grave responsibility for its actions, and consistent with this philosophy, the NNPP is dedicating funding to support remediation and demolition of these facilities.

In 2022, DOE-EM performed characterization sampling at the Knolls Laboratory in support of planned D&D activities at the Q-Complex, located in the Upper Level area. DOE-EM also conducted remediation of soil at the Kesselring Site D1G Ditch location. In addition, DOE-EM maintained and inspected the mixed transuranic (MTRU) waste storage area, located in the Knolls Laboratory lower-level area. This storage area includes wastes from the SPRU project that are pending offsite disposition. The DOE-EM areas are shown in Figures 10 and 11.

LIQUID EFFLUENT MONITORING

Sources

Nonradiological: The principal source of nonradiological effluent water from DOE-EM controlled land areas is stormwater run-off. Collection tanks are used when needed to collect groundwater and stormwater during work activities to ensure no contravention occurs to site discharges.

Radiological: DOE-EM performed no work activities in 2022 that created sources of radioactive water and had no sources of radiological liquid effluents.

Effluent Monitoring

Effluent monitoring is performed by the Knolls Laboratory and Kesselring Site and is described in the corresponding sections of this report.

Effluent Analyses

Effluent analyses are performed by the Knolls Laboratory and Kesselring Site and are described in the corresponding sections of this report.

FIGURE 10
DOE-EM LAND AREAS AT THE KNOLLS LABORATORY

FIGURE 11
DOE-EM LAND AREAS AT THE KESSELRING SITE

Assessment

See the Knolls Laboratory and Kesselring Site sections on this subject.

AIRBORNE EFFLUENT MONITORING

Sources

Nonradiological: In 2022, DOE-EM performed work at the Kesselring Site that created nonradiological air emissions during chemical remediation and backfill of the D1G Ditch. The principal sources of nonradiological air emissions are non-emergency diesel generators and equipment. These sources of air emissions meet the criteria for exempt and trivial sources under NYSDEC regulations and are not required to have air permits or registrations.

Radiological: In 2022, DOE-EM had no work activities at Knolls Laboratory or the Kesselring Site with the potential to generate airborne radioactivity.

Effluent Monitoring

Nonradiological: No emissions monitoring was required in 2022.

Radiological: No emissions monitoring was required in 2022.

Effluent Analyses

Radiological: No DOE-EM activities at the Knolls Laboratory or the Kesselring Site required airborne effluent monitoring.

Assessment

Radiological: No DOE-EM activities at the Knolls Laboratory or the Kesselring Site required radiological effluent assessment.

ENVIRONMENTAL MONITORING

Scope

In 2022, DOE-EM activities did not require any additional environmental monitoring to those performed by Knolls Laboratory and Kesselring Site. Environmental monitoring performed by Knolls Laboratory and Kesselring Site is described in the corresponding sections of this report.

RADIATION MONITORING

The environmental radiation monitoring programs are performed by the Knolls Laboratory and Kesselring Site and are described in the corresponding sections of this report.

GROUNDWATER MONITORING

The groundwater monitoring programs are performed by the Knolls Laboratory and Kesselring Site and are described in the corresponding sections of this report.

CONTROL OF CHEMICALLY HAZARDOUS SUBSTANCES AND SOLID WASTE

Sources

Chemicals are not manufactured at DOE-EM work sites for NNPP-related work activities. To ensure the safe use of chemicals and disposal of the resulting wastes, DOE-EM requires that contractors performing work maintain a hazardous waste control program. Hazardous wastes are disposed through permitted off-site treatment and disposal facilities.

Chemical Control Program

The control program minimizes the quantity of waste material generated, ensures safe usage and storage of the materials at DOE-EM work activities on NNPP sites, and provides for proper disposal of the wastes through vendors that operate under permits issued by Federal and State agencies.

The control of hazardous substances for use at DOE-EM work sites includes a review of waste minimization impact. Purchase orders for chemicals are reviewed to ensure that the materials are necessary for operations, the amount ordered is not excessive, and that methods for proper disposal are in place before the material is ordered. Hazardous substance storage controls include as a minimum: labeling, providing revetments as appropriate, segregation based on compatibility, limited storage volumes, and weather protection as appropriate. When required, large volumes of chemicals and petroleum products would be stored in accordance with the NYS Chemical Bulk Storage regulations (Reference (16)) and the PBS regulations (Reference (17)). DOE-EM contractors currently do not store any chemicals or petroleum products in quantities that are subject to the Chemical Bulk Storage regulations or the PBS regulations.

All personnel are provided with general information on the policies for the procurement, use, and disposal of hazardous substances. For individuals who use hazardous substances in operations, specific training is provided to ensure that they are knowledgeable of safe handling techniques and emergency response procedures. After chemicals are used and no longer needed, they are accumulated in designated staging and storage areas where they are segregated and packaged for shipment. Waste is temporarily stored only as necessary to accumulate sufficient volumes for shipment to a waste disposal vendor with the exception of mixed transuranic waste, which is stored under DOE-EM/NYSDEC Consent Order requirements. DOE-EM has an inspection program to routinely verify that hazardous substances are properly stored and controlled in accordance with approved procedures.

Chemical Disposal

DOE-EM did not generate hazardous waste during its activities at the Knolls Laboratory and the Kesselring Site.

Solid Waste Disposal/Recycling

During 2022, DOE-EM shipped 1,573 cubic yards of soil and 434,416 gallons of water from the Kesselring Site D1G Ditch remediation for off-site disposal.

During 2022, DOE-EM and its contractors generated small volumes of office and food trash from administrative office areas at Knolls Laboratory and the Kesselring Site. This waste was provided to Knolls Laboratory and the Kesselring Site for disposal and recycling. Materials that were recycled include unclassified office paper, glass, plastic, aluminum, newspapers, magazines, and corrugated cardboard. The volumes are included in the Knolls and Kesselring Site sections of this report.

CONTROL OF RADIOACTIVE MATERIALS AND RADIOACTIVE WASTE

Sources

Operations during 2022 from DOE-EM work did not result in the generation of radioactive materials.

Prior to 2018, during the SPRU project, DOE-EM activities generated waste that contained greater than 100 nCi of alpha-emitting transuranic isotopes per gram of waste with half-lives greater than 20 years (referred to as TRU waste). TRU waste is being temporarily stored and managed by DOE-EM until the waste is shipped to the DOE Waste Isolation Pilot Plant (WIPP) or processed at an off-site facility for disposal at another authorized disposal facility.

Control Program

Detailed procedures are used for handling, packaging, transportation, and disposal of radioactive waste at a government operated or licensed disposal site. As new projects generate waste, internal reviews will be made prior to the shipment of any radioactive material from DOE-EM projects to ensure that the material is properly identified, surveyed, and packaged in accordance with Federal requirements.

The volume of radioactive waste generated on new projects at the Knolls Laboratory and Kesselring Site will vary based on the project. However, waste from radiological control activities will be minimized through the use of work procedures that limit the amount of materials that become contaminated during work on radioactive systems and components. All radioactive wastes are prepared and shipped in accordance with written procedures to meet the applicable DOT regulations given in Reference (18). The waste packages also comply with all applicable requirements of the DOE and the disposal sites.

Disposal/Recycling

In 2022, no low level radioactive waste was shipped for disposal from DOE-EM work at the Knolls Laboratory and Kesselring Site. No radioactive materials were recycled.

CONTROL OF MIXED WASTE

Sources

DOE-EM did not generate any mixed wastes from activities on NNPP projects in 2022.

Control Program

New D&D project cleanup operations will take aggressive action to minimize the creation of mixed waste by reducing the commingling of radioactive and hazardous materials and avoiding the use of hazardous substances where practicable. The amount of generated mixed waste was also minimized through the use of detailed work procedures and worker training.

Storage and Disposal

Mixed TRU waste from the SPRU project is stored in containers and is managed by DOE-EM under a consent order with NYSDEC until a hazardous waste storage permit is obtained by DOE-EM. The mixed TRU wastes are being temporarily stored in a designated storage area.

RADIATION DOSE ASSESSMENT

The effluent and environmental monitoring results show that radioactivity present in liquid and gaseous effluents from 2022 operations at the Knolls Laboratory and Kesselring Site (including DOE-EM activities) had no measurable effect on normal background radioactivity levels. Therefore, any radiation doses from the Knolls Laboratory and Kesselring Site (including DOE-EM activities) operations to off-site individuals were too small to be measured and must be calculated using conservative methods. Estimates of the radiation dose to the maximally exposed individual in the vicinity of the Knolls Laboratory and Kesselring Site (including DOE-EM activities) and the collective dose to the population residing in the 80 kilometer (50 mile) radius assessment area are summarized in the Radiation Dose Assessment and Methodology section later in this report.

The results show that the estimated doses were less than 0.1 percent of that permitted by the radiation protection standards of the DOE listed in Reference (19) and that the estimated dose to the population residing within 80 kilometers (50 miles) of the Knolls Laboratory and Kesselring Site (including DOE-EM activities), was less than 0.001 percent of the natural background radiation dose to the population. In addition, the estimated doses were less than one percent of that permitted by the NRC numerical guide listed in Reference (20) for whole-body dose, demonstrating that doses are as low as is reasonably achievable. The dose attributed to radioactive air emissions from the Knolls Laboratory and Kesselring Site was less than one percent of the EPA standard in Reference (8).

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RADIATION DOSE ASSESSMENT AND METHODOLOGY

Measurements for radioactivity in environmental media representing an exposure pathway to humanity indicated no radioactivity attributable to operations at the Knolls Laboratory (including DOE-EM) and Kesselring Site. Therefore, potential doses to the general public from liquid and airborne effluents were too small to be measured and are estimated using conservative calculational techniques based on assumed pathways to humanity.

The exposure pathways via air and water considered for estimating radiation exposures were:

1. *Air Pathways*

   a. External exposure from airborne radioactivity and radioactivity deposited on the ground,
   b. Ingestion of food products, and
   c. Inhalation of airborne radioactivity.

2. *Water Pathways*

   a. Ingestion of water and fish,
   b. Ingestion of food products grown on irrigated land,
   c. External exposure from irrigated land, and
   d. Boating, swimming, and shoreline recreation.

For the Knolls Laboratory (including DOE-EM) and Kesselring Site, calculations were made to estimate: (1) the radiation dose to the maximally exposed individual in the vicinity of the two Sites, and (2) the collective dose to the population residing in the 80 kilometer (50 mile) radius assessment area. See Figure 12 for a map of the 80 kilometer (50 mile) assessment areas surrounding the two Sites.

The fundamental equation for calculation of the annual dose from a single radionuclide is:

$$D = XUK$$

where:

D	=	annual dose
X	=	the concentration of the radionuclide in the media of the exposure pathway of interest
U	=	the annual exposure time (hours) or intake (ml or kg) associated with the exposure pathway of interest
K	=	the annual dose factor for external exposure to a radionuclide or the dose commitment for a 50 year period from the current year's intake of a radionuclide

In estimating potential doses via the water pathway, the contribution from each radionuclide present in the liquid effluents to the effective dose equivalent was calculated using DOE dose conversion factors from Reference (24), Reference (19), and the Reference (25) liquid pathway model for both the Knolls Laboratory (including DOE-EM) and the Kesselring Site.

Estimates of potential doses via air pathways were calculated using CAP88-PC, Version 4.0, the EPA computer code package approved for use in Reference (26). The code package was prepared to implement the dose assessment required to demonstrate compliance with Reference (8). It includes the computer code AIRDOS2 and a file of the 50-year committed effective dose equivalent conversion factors calculated by the computer code DARTAB, which uses the dose factor database RADRISK using weighting factors from ICRP-72. CAP88-PC Version 4.0 is an updated version of CAP88-PC. It incorporates Federal Guidance Report 13 dose and risk factors.

In CAP88-PC Version 4.0, the area surrounding the site is divided into a circular grid defined by 16 pie-shaped segments, which are subdivided into sectors by annular rings out to 80 kilometers (50 miles). The computer code calculates the air concentration and surface deposition in each sector for each radionuclide released from each Site using site specific average atmospheric dispersion parameters. Dispersion parameters for each Site are based on on-site meteorological data summarized in accordance with Reference (27). Next, the radionuclide concentrations in meat, milk, and fresh vegetables produced in each sector are estimated using terrestrial food chain models. In CAP88-PC Version 4.0 the environmental radionuclide transfer factors were updated to the values from the National Council on Radiation Protection and Management Report 123. The code then calculates the effective dose equivalent to persons (adults) residing in each sector through the following exposure modes: (1) immersion in air containing radionuclides, (2) exposure to radionuclides deposited on ground surfaces, (3) inhalation of radionuclides in air, and (4) ingestion of food produced in the sector. The collective (population) effective dose equivalent is obtained by summing the product of the dose and population for each sector. The population residing within 80 kilometers (50 miles) of each site is based on the 2020 census data as reported in Reference (28).

The air pathway calculated doses are summarized in Tables 46 and 47. Inhalation and ingestion were the calculated principal exposure pathways for each hypothetical maximally exposed individual at the Knolls Laboratory and the Kesselring Site respectively.

A comparison of the estimated (calculated) radiation dose to the maximally exposed individual from Knolls Laboratory, Kesselring Site, and DOE-EM operations with the average radiation dose received from other sources is shown in Figure 13. Data in Figure 13 show that the maximum radiation dose that may have been received as a result of Knolls Laboratory, Kesselring Site, and DOE-EM operations is much lower than the DOE radiation protection standard and the drinking water and air emission standards established by the EPA, and considerably lower than the average dose received from other sources (natural and human-made) of radiation.

TABLE 46
ESTIMATED ANNUAL DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL AND ASSESSMENT AREA POPULATION FROM KNOLLS LABORATORY (INCLUDING DOE-EM ACTIVITIES)

Pathway	Dose to Maximally Exposed Individual[1] (mrem)	(mSv)	% of DOE 100 mrem/yr Limit	Estimated Population Dose (person-rem)	(person-Sv)	Population within 80 km	Estimated Background Radiation Population Dose (person-rem)
Air	4.8E-04[2]	4.8E-06	4.8E-04	1.8E-03	1.8E-05	1.37E06[3]	8.6E04[4]
Water	1.8E-04	1.8E-06	1.8E-04	3.3E-03	3.3E-05		
Other Pathways	None		None	None			
All Pathways	5.0E-04	5.0E-06	5.0E-04	5.0E-03	5.0E-05		

TABLE 47
ESTIMATED ANNUAL DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL AND ASSESSMENT AREA POPULATION FROM KESSELRING SITE (INCLUDING DOE-EM ACTIVITIES)

Pathway	Dose to Maximally Exposed Individual[1] (mrem)	(mSv)	% of DOE 100 mrem/yr Limit	Estimated Population Dose (person-rem)	(person-Sv)	Population within 80 km	Estimated Background Radiation Population Dose (person-rem)
Air	2.0E-04[2]	2.0E-06	2.0E-04	1.7E-03	1.7E-05	1.24E06[3]	6.9E04[4]
Water	1.2E-07	1.2E-09	1.2E-07	2.9E-08	2.9E-10		
Other Pathways	None		None	None			
All Pathways	2.0E-04	2.0E-06	2.0E-04	1.7E-03	1.7E-05		

Notes for Tables 46 and 47:

1. The Maximally Exposed Individual for the Water Pathway case is in a different location than the Maximally Exposed Individual for the Air Pathway and All Pathways cases.
2. The EPA Radionuclide NESHAP standard is 10 mrem/year.
3. Total population residing within 80 kilometers (50 miles) is based on 2020 census data as reported in Reference (28).
4. Dose based on average off-site background radiation level determined for the Knolls Laboratory and Kesselring Site with TLDs as reported in Tables 24 and 40, respectively. It does not include the estimated average annual effective dose equivalent of 29 mrem that a member of the population receives from naturally occurring radionuclides in the human body or the 228 mrem received from exposure to radon and its decay products as reported in Reference (29).

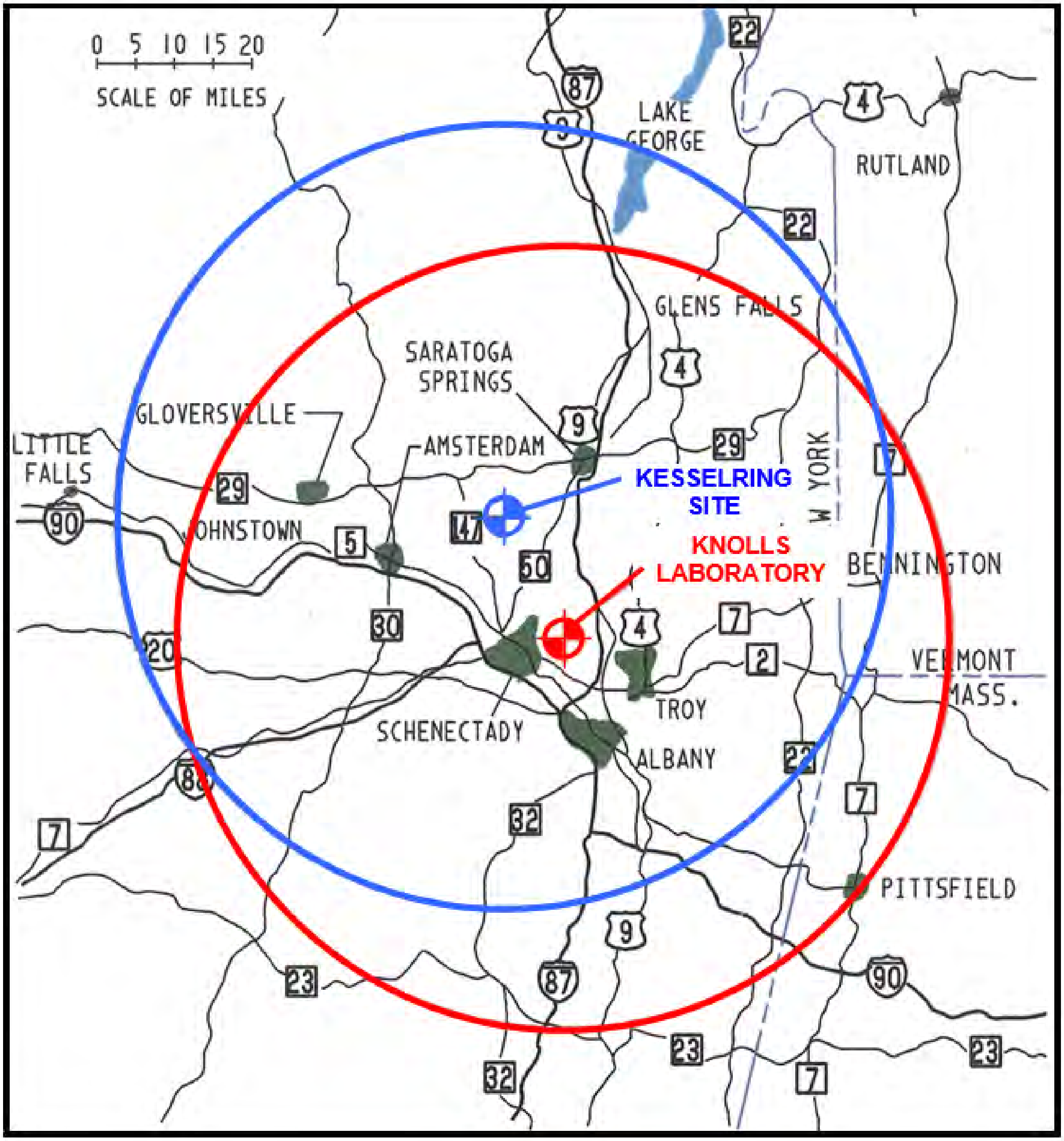

FIGURE 12
EIGHTY KILOMETER (50 MILE) ASSESSMENT AREA MAP FOR KNOLLS LABORATORY, KESSELRING SITE, AND DOE-EM ACTIVITIES

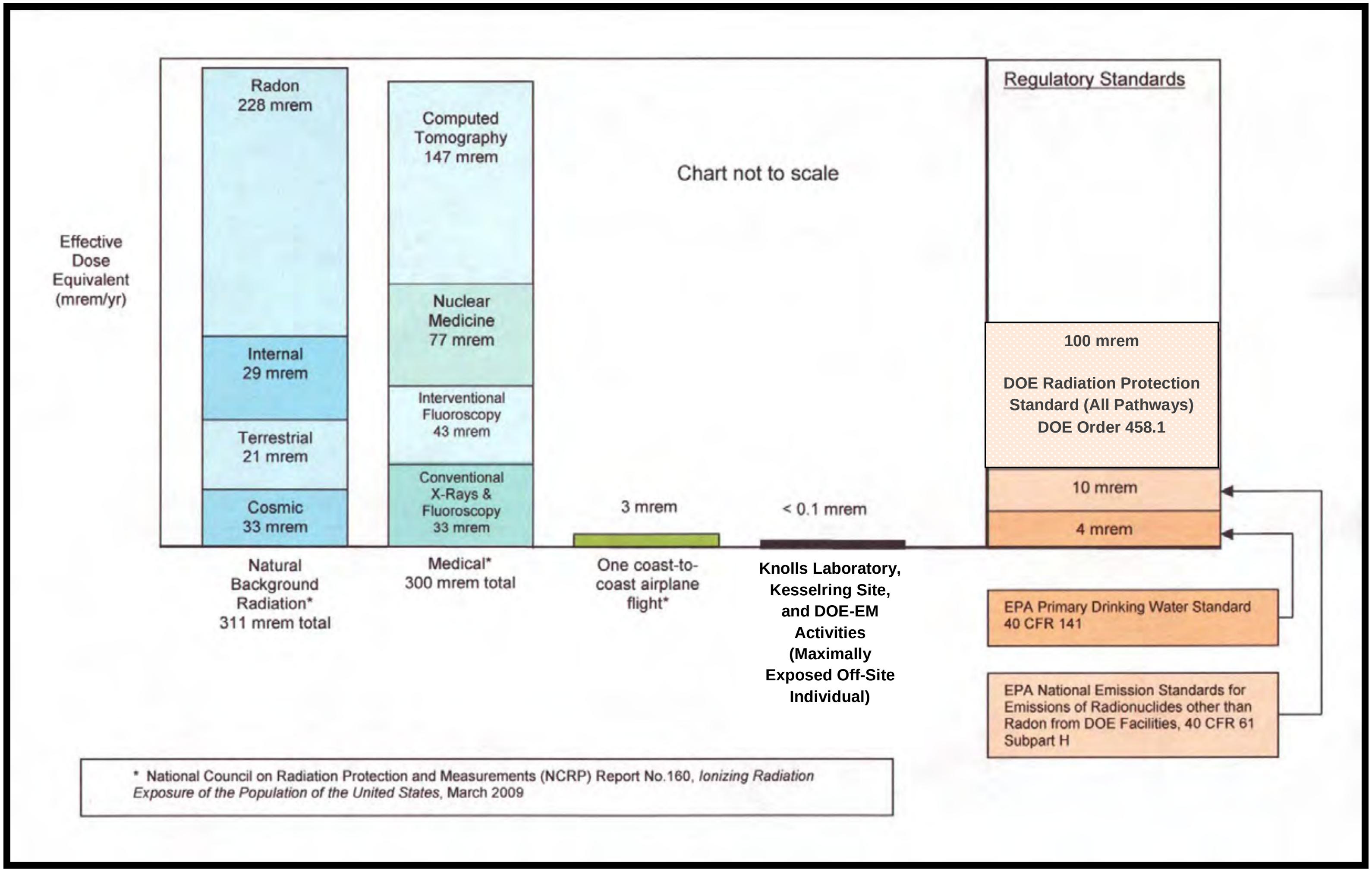

FIGURE 13
COMPARISON OF THE ESTIMATED RADIATION DOSE FROM KNOLLS LABORATORY, KESSELRING SITE, AND DOE-EM ACTIVITIES WITH DOSES FROM OTHER SOURCES

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QUALITY ASSURANCE PROGRAM

The Knolls Laboratory and Kesselring Site Quality Assurance Program is conducted to ensure the accuracy and precision of effluent and environmental sampling, analysis, and reporting. The program is based on the guidance contained in several DOE, EPA, and NRC documents on the subject (References 30, 31, and 32, respectively).

The program for 2022 consisted of the following elements:

1. Internal quality assurance procedures

    a. Personnel training and qualification
    b. Written procedures for sampling, sample analysis, and computational methods
    c. Calibration of sampling and sample analysis equipment
    d. Internal quality assurance sample analyses
    e. Data review and computation check

2. Participation in a Quality Assurance Program (QAP) administered by a commercial laboratory, Environmental Resource Associates (ERA) for Knolls Laboratory only.

3. Subcontractor quality assurance procedures

4. Program audits

The internal quality assurance procedures start with the training of all personnel involved in the collection and analysis of samples, in accordance with established Knolls Laboratory and Kesselring Site policies. Personnel are not permitted to perform sampling and sample analysis until they are trained and have demonstrated the ability to properly perform their duties. Written procedures, based on the methods recommended in References (30) and (32), cover collection and analysis of samples, the computation of results, and the calibration of sampling and analytical equipment, as required. Radioactivity counting equipment is, whenever possible, calibrated using standards that are traceable to the National Institute of Standards and Technology. Internal quality assurance procedures also provide for a system of duplicate (or replicate) analyses of the same sample and the analyses of spiked samples to demonstrate precision and accuracy. All measurement data are assessed to detect anomalies, unusual results, and trends.

The Knolls Laboratory participates in a QAP administered by a commercial laboratory, ERA. The Kesselring Site participates in a QAP administered by the Knolls Laboratory in accordance with NNPP requirements. The QAP provides an independent verification of the accuracy and precision of Knolls Laboratory and Kesselring Site analyses of effluent and environmental monitoring samples. The results of Knolls Laboratory participation in the ERA QAP are summarized in Table 48. The data demonstrate satisfactory Knolls Laboratory performance. The Knolls Laboratory has verified satisfactory performance of the Kesselring Site.

Vendor subcontractor laboratories perform nonradioactive environmental sample analyses. The Knolls Laboratory and the Kesselring Site maintain a quality assurance program to ensure the accuracy and precision of the subcontractor analytical results. This includes submitting blanks and replicate samples along with routine samples for analysis. If unsatisfactory results are obtained, follow-up investigations are performed to correct the problems. The Knolls Laboratory and the Kesselring Site also require vendor laboratories that perform analyses for the sites be certified by the NYSDOH under the ELAP.

Periodic audits are conducted that examine the effluent and environmental monitoring programs to ensure compliance with all Knolls Laboratory and Kesselring Site procedures and applicable Federal and State regulations.

TABLE 48
KNOLLS LABORATORY PERFORMANCE IN THE ENVIRONMENTAL RESOURCE ASSOCIATES (ERA) QUALITY ASSURANCE PROGRAM

Study & Study Dates(1)	Sample Type	Analysis	Knolls Laboratory Result(2)	ERA Assigned Value(2)	Acceptance Limits(3)
MRAD-36 03/21/22 - 05/20/22	Soil	Potassium-40	41,800	37,900	26,100 – 45,300
		Cobalt-60	2,680	2,820	2,220 – 3,480
		Strontium-90	5,930	6,720	2,090 – 10,500
		Cesium-137	6,370	6,760	5,110 – 8,550
		Plutonium-238	287	289	144 – 439
		Plutonium-239	1,110	1,180	643 – 1,700
MRAD-36 03/21/22 - 05/20/22	Water	Tritium	29,500	28,200	21,300 – 34,300
		Cobalt-60	2,800	2,710	2,340 – 3,110
		Strontium-90	633	628	452 – 776
		Cesium-137	1,140	1,120	959 – 1,270
		Plutonium-238	143	147	88.4 – 190
		Plutonium-239	71.5	71.9	44.5 – 88.6
		Uranium-234	47	44.1	33.6 – 50.4
		Uranium-238	49.8	43.7	33.9 – 51.4
		Gross Alpha	67.7	79.4	29.0 – 109
		Gross Beta	65.5	65.0	32.5 – 89.4
MRAD-36 03/21/22 - 05/20/22	Air Filter	Gross Alpha	71.5	94.2	49.2 – 155
		Gross Beta	76.2	66.8	40.5 – 101
		Cobalt-60	926	885	752 – 1,120
		Cesium-137	1,390	1,320	1,080 – 1,730
MRAD-37 09/19/22 - 11/18/22	Soil	Potassium-40	42,500	43,100	29,700 – 51,500
		Cobalt-60	1,490	1,500	1,180 – 1,850
		Cesium-137	7,690	7,890	5,970 – 9,980
MRAD-37 09/19/22 - 11/18/22	Water	Tritium	19,300	18,800	14,200 – 22,900
		Cobalt-60	1,460	1,420	1,220 – 1,630
		Cesium-137	1,240	1,250	1,070 – 1,420
		Gross Alpha	30.7	42.7	15.6 – 58.9
		Gross Beta	97.9	111	55.5 – 153
MRAD-37 09/19/22 - 11/18/22	Air Filter	Gross Alpha	46.5	55.5	29.0 – 91.4
		Gross Beta	70.8	64.8	39.3 – 97.9
		Cobalt-60	212	191	162 – 243
		Cesium-137	843	795	653 – 1,040

Notes:
1. The study dates are assigned by ERA.
2. The results are expressed in pCi/L for water, pCi/kg for soil, and pCi/Filter for air filters.
3. The Acceptance Limits range is provided by ERA.

DOE-EM Quality Assurance Program

The DOE-EM QAP described in Revision 0 EM-QA-001 establishes DOE-EM expectations for quality assurance programs and the implementation of quality assurance requirements DOE-EM complex-wide in the context of DOE Order 414.1C and 10 CFR 830 Subpart A. The DOE-EM QAP further adopts the use of the 2004 Edition of the American National Standards Institute (ANSI)/American Society of Mechanical Engineers (ASME) NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications," Part I and the applicable subparts of Part II with Addenda through 2007 as a national consensus standard for quality assurance requirements that apply to work accomplished by DOE- EM and work accomplished by private organizations under contract with the DOE-EM. Together, EM-QA-001, DOE Order 414.1C, 10 CFR 830 Subpart A and ANSI/ASME NQA-1-2004 Part I and the applicable subparts of Part II form the basis for the DOE-EM quality assurance programs.

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RADIATION AND RADIOACTIVITY

This section provides general information on radiation and radioactivity for those who may not be familiar with the terms and concepts.

Humanity has always lived in an environment where natural background radiation is present. This background radiation is as much a part of the Earth's environment as is light and heat from the sun's rays. There are three principal sources of natural background radiation: cosmic radiation from the sun and outer space, radiation from the natural radioactivity in soil and rocks (called “terrestrial radiation”), and internal radiation from natural radioactive chemical elements that are part of our bodies. A basic knowledge of the concepts of radiation and radioactivity is important in understanding how effective control programs are in reducing radiation exposures and minimizing radioactivity releases to levels that are “as low as is reasonably achievable,” or ALARA.

RADIATION

In simple terms, radiation is a form of energy. Microwaves, radio waves, X-rays, light, and heat are all common forms of radiation. The radiation from radioactive materials (radionuclides) is in the form of particles or rays. During the decay of radionuclides, alpha, beta, and gamma radiation can be emitted.

Alpha radiation consists of small, positively charged particles of low penetrating power that can be stopped by a sheet of paper. Radionuclides that emit alpha particles include radium, uranium, and thorium.

Beta radiation consists of positively or negatively charged particles that are smaller than alpha particles but generally have more penetrating power and may require up to an inch of wood or other light material to be stopped. Examples of beta emitters include strontium-90, cesium-137, and cobalt-60.

Gamma radiation is an energy emission similar to an X-ray. Gamma rays have great penetrating power but can potentially be stopped by several feet of concrete or several inches of lead. The actual thickness required of a particular shielding material depends on the quantity and energy of the gamma rays to be stopped. Most radionuclides emit gamma rays along with beta or alpha particles.

Each radionuclide emits a unique combination of radiations that is like a "finger print" of that radionuclide. Alpha or beta particles and/or gamma rays are emitted in various combinations and energies. Radionuclides may be identified by measuring the type, relative amounts, and energy of the radiations emitted. Measurement of half-life and chemical properties may also be used to help identify radionuclides.

Radiation and Dose

Body tissue can be damaged if enough energy from radiation is absorbed. The amount of energy absorbed by body tissue during radiation exposure is called an "absorbed dose." The potential biological effect resulting from a particular dose is based on a technically defined quantity called a "dose equivalent." The unit of dose equivalent is called the Roentgen equivalent man or “rem.” Another quantity called "effective dose equivalent" is a dose summation that is used to estimate the risk of health-effects when the radiation dose is received from sources that are both external to the body and from radioactive materials that are within the various body tissues. The traditional unit of effective dose equivalent, which is used in the United States, is the rem while the standard international (SI) unit is the Sievert (One Sievert is equal to 100 rem). The rem is a large unit when compared with radiation doses received from natural background radiation or projected as a result of releases of radioactivity to the environment. The millirem (mrem, or one thousandth of a rem), is frequently used instead of the rem. The rem and mrem are better understood by relating to concepts that are more familiar.

Radiation comes from both natural and human-made sources. Natural background radiation includes cosmic radiation from the sun and outer space, terrestrial radiation from radioactivity in soil, radioactivity in the body, and inhaled radioactivity.

The National Council on Radiation Protection and Measurements estimates that the average member of the population of the United States receives an annual effective dose equivalent of approximately 311 mrem from natural background radiation. This is composed of approximately 33 mrem from cosmic radiation, 21 mrem from terrestrial radiation, 29 mrem from radioactivity within the body and 228 mrem from inhaled radon and its decay products. The cosmic radiation component in the United States varies from 22 mrem in Honolulu, Hawaii to 65 mrem in Colorado Springs, Colorado. The terrestrial component varies from about 10 mrem in the Atlantic and Gulf Coastal Plain to about 40 mrem in the mountainous regions of the west. The dose from inhaled radon and its decay products is the most variable component of dose from natural background radiation because radon concentrations can fluctuate within houses due to changes in weather patterns and other factors such as changes in living habits.

The average natural background radiation level measured in the vicinity of the Knolls Laboratory and the Kesselring Site is approximately 70 mrem per year. Individual locations vary depending on soil composition, soil moisture content and snow cover.

In addition to natural background radiation, people are also exposed to human-made sources of radiation, such as medical and dental X-rays and conventional fluoroscopy, computed tomography, nuclear medicine, and interventional fluoroscopy. The average radiation dose from these sources is about 300 mrem per year. Other sources include consumer products such as building products (brick and concrete), lawn and garden fertilizer, loose-leaf spinach, and bananas. Additionally, an airplane trip typically results in a radiation exposure. A round-trip flight between the east and the west coast results in a dose of about six mrem.

RADIOACTIVITY

All materials are made up of atoms. In the case of radioactive material, these atoms are unstable and give off energy in the form of rays or tiny particles as they attempt to reach a stable state. Each type of radioactive atom is called a radionuclide. Each radionuclide emits a characteristic form of radiation as it gives off energy. Radionuclides change as they emit radiation, and this transition is called radioactive decay. The rate at which a particular radionuclide decays is measured by its half-life. A half-life is the time required for one-half the radioactive atoms in a given amount of material to decay. For example, the half-life of the human-made radionuclide cobalt-60 is 5.3 years. This means that after a 5.3 year period, half of the original cobalt-60 atoms present will have decayed. The following 5.3 year period will result in half of the remaining cobalt-60 atoms to decay, and so on.

The half-lives of radionuclides vary greatly. For instance, the half-life of naturally occurring radon-220 is only 55 seconds, but the half-live of uranium-238, another naturally occurring radionuclide, is 4.5 billion years.

Through the decay process, each radionuclide changes into a different nuclide or atom - often becoming a different chemical element. For example, naturally occurring radioactive thorium-232, after emitting its radiation, transforms to a second radionuclide, which transforms to a third, and so on. Thus, a chain of 11 radionuclides is formed including radon-220, before nonradioactive lead-208 is formed. Each of the radionuclides in the series has its own characteristic half-life and type of radiation. The chain finally ends when the newest nuclide is stable. The uranium chain starts with uranium-238 and proceeds through 13 radionuclides, ending with stable lead-206. All of these naturally occurring radionuclides are present in trace amounts in the soil in your backyard as well as in many other environmental media.

Measuring Radioactivity

The curie (Ci) is the traditional unit used for expressing the magnitude of radioactive decay in a sample containing radioactive material. The analogous SI unit to the Ci is the becquerel (Bq). Specifically, the Ci is the amount of radioactivity equal to 3.7×10^{10} (37 billion) disintegrations per second and a Bq is equal to one disintegration per second. For environmental monitoring purposes, the Ci is usually too large a unit to work with conveniently and is broken down into smaller values such as the microcurie (μCi, one millionth of a curie or 10^{-6} Ci) and the picocurie (pCi, one trillionth of a Ci or 10^{-12} Ci). Older wristwatches that were painted with radium to allow the numbers or segments to “glow in the dark” contained about one (1) μCi of radium. The average person has about one tenth (0.1) of a μCi of naturally occurring potassium-40 in their body. Typical soil and sediment samples contain about one (1) pCi of natural uranium per gram.

Sources of Radioactivity

Some of the radioactive atoms that exist in nature have always existed and natural processes are continually forming others. For example, uranium has always existed, it is radioactive, and it occurs in small but variable concentrations throughout the earth. Radioactive carbon and tritium, on the other hand, are formed by cosmic radiation striking atoms in the atmosphere. Radionuclides can also be created by humanity. For example, fission products and activation products are created in nuclear reactors. Fission products are residues of the uranium fission process that produces the energy within the reactor. The fission process also produces neutrons that interact with structural and other materials in the reactor to form activation products. Because of the nature of the fission process, many fission products are radioactive. Most fission products have short half-lives and are retained within the nuclear fuel itself; however, trace natural uranium impurities in reactor structural materials release small quantities of fission products to the reactor coolant.

It should be noted that a certain level of background fission-product radioactivity also exists in the environment, primarily due to past atmospheric nuclear weapons testing. Although the level is very low, these fission products are routinely detected in air, food, and water when analyzed with extremely sensitive instruments and techniques.

CONTROL OF RADIATION AND RADIOACTIVITY

To reduce the exposure of persons to ionizing radiation to ALARA, controlling the use and disposal of radioactive materials and comprehensive monitoring programs to measure the effectiveness of these controls is required. Effluent streams that may contain radioactive materials must be treated by appropriate methods to remove the radioactive materials and the effluent monitored to ensure that these materials have been reduced to concentrations that are ALARA and are well within all applicable guidelines and requirements prior to discharge.

GLOSSARY

Activation Products - As cooling water circulates through the reactor, certain impurities present in the water and even components of the water itself can be converted to radioactive nuclides (they become "activated"). Important activation products present in reactor coolant water include radionuclides of corrosion and wear products (cobalt-60, iron-59, cobalt-58, chromium-51), of impurities dissolved in the water (argon-41, sodium-24, carbon-14) and of atoms present in the water molecules (tritium). The predominant radionuclide, and also the one with the most restrictive limits, is cobalt-60.

Algae - Simple rootless plants that grow in bodies of water in relative proportion to the amount of nutrients available. Algae blooms, or sudden growth spurts can affect water quality adversely.

Alkalinity - The measurable ability of solutions or aqueous suspensions to neutralize an acid.

Alpha Radioactivity - A form of radioactivity exhibited by certain radionuclides characterized by emission of an alpha particle. Many naturally occurring radionuclides including radium, uranium, and thorium decay in this manner.

Benthic Macroinvertebrates - Small organisms inhabiting the bottom of lakes and streams or attached to stones or other submersed objects. The study of macroinvertebrate communities gives an indication of the overall quality of the body of water from which they are taken.

Beta-Gamma Radioactivity - A form of radioactivity characterized by emission of a beta particle and/or gamma rays. Many naturally occurring radionuclides such as lead-212, bisthmuth-212, and bisthmuth-214 decay in this manner.

Biochemical Oxygen Demand (BOD) - The BOD test is used to measure the content of organic material in both wastewater and natural waters. BOD is an important parameter for stream and industrial waste studies and control of waste treatment plants because it measures the amount of oxygen consumed in the biological process of breaking down organic materials in the water.

Birge-Ekman Dredge - A device used for sampling the bottom sediment in rivers, streams, lakes, etc. The Birge-Ekman dredge is lowered to the bottom on a line and its spring-loaded "jaws" are remotely tripped from the surface. It samples an area of approximately 230 cm^2 to an average depth of 2.5 cm.

British Thermal Unit (BTU) - A unit commonly used to quantify the heat output of boilers, furnaces, etc. Specifically, the amount of heat necessary to raise 1 lb. of water one degree Fahrenheit.

Chain Electro-Fishing Techniques - A technique of collecting samples of fish from a body of water whereby the fish are stunned with an electric current, categorized, and returned to the water unharmed. Also called Backpack electro-fishing.

Chemical Oxygen Demand (COD) - A measure of the oxygen required to oxidize all compounds in water, organic and inorganic.

Collective Dose Equivalent and Collective Effective Dose Equivalent - The sums of the dose equivalents or effective dose equivalents of all individuals in an exposed population within an 80-km radius and they are expressed in units of person-rem.

Committed Dose Equivalent (CDE) - The predicted total dose equivalent to a tissue or organ over a 50-year period after a known intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem.

Committed Effective Dose Equivalent (CEDE) - The sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem.

Composite Sample - A sample that is comprised of a number of grab samples over the compositing period. In some cases the composite sample obtained may be proportional to effluent flow and is called a proportional sample or flow-composited sample.

Conductance – A measure of water's capacity to convey an electrical current. This property is related to total concentration of the ionized substances in water and the temperature at which the measurement is made.

Confidence Interval - Statistical terminology for the error interval (±) assigned to numerical data. A two sigma (2σ) confidence interval means there is 95% confidence that the true value (as opposed to the measured one) lies within the (±) interval. The 95% is the confidence level (See (±) value, Standard Deviation of the Average).

Corrosion and Wear Products - Piping and components used in construction of a nuclear reactor are fabricated from extremely durable, corrosion and wear resistant materials. Even under the best circumstances, however, small amounts of these materials enter the reactor coolant due to wear of moving parts and corrosion of the water contact surfaces of reactor plant components. While this does not affect operational characteristics or reactor plant integrity, some of these corrosion and wear products may become activated as they pass through the reactor core. This necessitates that the reactor coolant be processed by filtration or other methods of purification before it is discharged or reused (See Activation Products).

Curie (Ci) - The common unit used for expressing the magnitude of radioactive decay in a sample containing radioactive material. Specifically, the curie is that amount of radioactivity equal to 3.7×10^{10} (37 billion) disintegrations per second. For environmental monitoring purposes, the curie is usually too large a unit to conveniently work with and is broken down to smaller values (See microcurie and picocurie).

Decision Level Concentration (DLC) - The quantity of radioactivity above which a decision is made that a net amount of radioactivity is present with a five percent probability of erroneously reporting net radioactivity when none is present (i.e., false positive).

Derived Concentration Guide (DCG) or Derived Concentration Standard (DCS) - The concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in an effective dose equivalent of 100 mrem (0.1 rem).

Dose Equivalent - The quantity that expresses the biological effects of radiation doses from all types (alpha, beta-gamma) of radiation on a common scale. The unit of dose equivalent is the rem.

Downgradient - Referring to the flow of groundwater, downgradient is analogous to downstream and is a point that is “after” an area of study that is used as a baseline for comparison with upgradient or upstream data.

Duplicate Sample - A sample that is created by splitting existing samples before analysis and treating each split sample as a separate sample. The samples are then analyzed as a quality assurance method to assess the precision in the analytical process.

Effective Dose Equivalent - The sum of the dose equivalent to the whole body from external sources plus the dose equivalents to specific organs times a weighting factor appropriate for each organ. The weighting factor relates the effect of individual organ exposure relative to the effect of exposure to the whole body. The unit of effective dose equivalent is the rem.

Field Blank - A sample of laboratory distilled water that is put into a sample container at the field collection site and is processed from that point as a routine sample. Field blanks are used as a quality assurance method to detect contamination introduced by the sampling procedure.

Fission Products - During operation of a nuclear reactor, heat is produced by the fission (splitting) of "heavy" atoms, such as uranium, plutonium or thorium. The residue left after the splitting of these "heavy" atoms is a series of intermediate weight atoms generally termed "fission products." Because of the nature of the fission process, many fission products are unstable and, hence, radioactive. Most fission products have short lives and are retained within the nuclear fuel itself; however, trace natural uranium impurities in reactor structural materials release small quantities of fission products to the reactor coolant.

It should be noted that fission product radioactivity exists in the environment, primarily due to atmospheric nuclear weapons testing. The level is very low, but may be detectable when environmental samples are analyzed with extremely sensitive instruments and techniques such as those used in the NNPP.

Grab Sample - A single sample that is collected and is representative of the stream or effluent.

Half-life - A value assigned to a radionuclide that specifies how long it takes for one half of a given quantity of radioactivity to decay away. Half-lives may range from fractions of a second to billions of years.

High Purity Germanium Gamma Spectrometry (HPGe) - A gamma ray measuring system designed for qualitative and quantitative determination of radionuclides present in a sample. Gamma spectrometry systems make use of the fact that during the decay of most radionuclides, one or more gamma rays are emitted at energy levels characteristic of the individual radionuclide. For example, during the decay of cobalt-60, two gamma rays of 1.17 and 1.33 million electron volts (MeV) are emitted while the decay of argon-41 produces one gamma ray of 1.29 MeV. The high purity germanium detectors used in these systems are capable of detecting and very precisely resolving differences in gamma ray energy levels.

Long-Lived Gamma Radioactivity - Two very important characteristics of radionuclides are the length of time it takes for a given amount to decay away and the type of radiation emitted during decay. From an environmental standpoint, some of the most significant radionuclides are those whose half-lives are relatively long and that also emit penetrating gamma radiation during decay. Two radionuclides of concern in these respects are cobalt-60 (a corrosion and wear activation product) and cesium-137 (a fission product). (See Half-life, Beta-Gamma Radioactivity)

Macrophyton - Macroscopic plants in an aquatic environment.

Method Detection Limit - The lowest value at which a nonradiological sample result shows a statistically positive difference from a sample in which no constituent is present.

microcurie (μCi) - One millionth of a curie (10^{-6} curie). A typical smoke detector contains 1 μCi of americium-241 radioactive material (See curie and picocurie).

millirem (mrem) - One thousandth of a rem (10^{-3} rem).

Mixed Waste - Waste that contains both hazardous (regulated by EPA/NYSDEC) and radioactive material (regulated by DOE).

Outfall - A point of discharge (e.g., drain or pipe) of liquid effluent into a stream, river, ditch, or other water body.

Parshall Flume - A specially constructed channel designed such that discharge water flow rate can be accurately measured. The Parshall Flume may also be instrumented to record the total volume of flow over long periods of time.

Periphyton - Communities of microorganisms growing on stones, sticks, and other submerged surfaces. The quantities and types of periphyton present are very useful in assessing the effects of pollutants on lakes and streams.

Person-Rem - The sum of the individual dose equivalents or effective dose equivalents received by each member of a certain group or population. It is calculated by multiplying the average dose per person by the number of persons within a specific geographic area. For example, a thousand people each exposed to 0.001 rem would have a collective dose of one person-rem.

pH - A measure of the acidity or alkalinity of a solution on a scale of 0 to 14 (low is acidic, high is alkaline or caustic, 7 is neutral).

picocurie (pCi) - One trillionth of a curie (10^{-12} curie). Typical soil and sediment samples contain about 1 pCi of natural uranium per gram. (See curie and microcurie.)

Plankton - Tiny plants and animals that live in water.

± Value (plus or minus value) - An expression of the uncertainty in sample results. The magnitude of the (±) value depends on the number of samples, the size of the sample, intrinsic analytical uncertainties and the degree of confidence required. The (±) value assigned to data in this report is for the 95% confidence level (See Confidence Interval).

Polychlorinated Biphenyls (PCBs) - Halogenated aromatic hydrocarbons formed by the chlorination of biphenyl molecules. PCB's were commonly used in transformers as a dielectric fluid because of their stability.

Radionuclides - Atoms that exhibit radioactive properties. Standard practice for naming radionuclides is to use the name or atomic symbol of an element followed by its atomic weight (e.g., cobalt-60 or Co-60, a radionuclide of cobalt). There are several hundred known radionuclides, some of which are man-made and some of which are naturally occurring. Radionuclides can be differentiated by the types of radiation they emit, the energy of the radiation and the rate at which a known amount of the radionuclide decays away (See Half-life).

Roentgen Equivalent Man (Rem) - The unit of dose equivalent and effective dose equivalent.

Reporting Limit (RL) - The lowest concentration of an analyte that can be reliably reported in nonradiological samples within specified limits of precision and accuracy during routine laboratory operating conditions.

Reverse Osmosis - Also known as hyper-filtration, it is a process that allows the separation of solutes (i.e., dissolved substances) from a solution by forcing the solvent through a semi-permeable membrane by applying a pressure greater than the osmotic pressure associated with the solutes. A semi-permeable membrane is a membrane that allows diffusion of solvent molecules through it, while retarding the diffusion of solute molecules.

Settleable Solids - A measurement of the amount of solids that will settle out of a sample of water in a certain interval of time. This parameter commonly applies to water being processed in sewage treatment plants and is used to control the operation and evaluate the performance of these plants.

Short-Lived Gamma Radioactivity - Radioactive material of relatively short life that decays with the emission of gamma rays. It is generally not important with respect to environmental discharges because of the short life span. Some examples of short-lived gamma emitting radionuclides are argon-41 (an activation product gas), krypton-88 (a fission product gas), and xenon-138 (a fission product gas).

Spiked Sample - A sample to which a known quantity of the material that is being analyzed for has been added for quality assurance testing.

Standard Deviation of the Average - A term used to characterize the uncertainty assigned to the mean of a set of analyzed data (See Confidence Interval, (±) Value).

Suspended Solids - Particulate matter, both organic and inorganic suspended in water. High levels of suspended solids not only affect the aesthetic quality of water by reducing clarity, but also may indirectly indicate other undesirable conditions present. The analysis for suspended solids is performed by passing a sample of water through a filter and weighing the residue.

Thermoluminescent Dosimeters (TLDs) - Sensitive monitoring devices that absorb and store energy from radiation. The TLDs used by the Knolls Laboratory and the Kesselring Site for environmental monitoring consist of small chips of lithium fluoride (LiF) encased in appropriate materials and strategically located at site perimeter and off-site locations. Thermoluminescent Dosimeters derive their name from a property that certain crystals exhibit when exposed to radiation and subsequently heated- that of emitting light proportional to the amount of radiation exposure received (thermoluminescence). The emitted light can then be read out on special instrumentation and correlated to the amount of radiation dose accumulated.

Turbidity - A cloudy condition in water due to suspended silt or organic matter. Turbidity is measured in nephelometric turbidity units (ntu).

Upgradient - Referring to the flow of groundwater, upgradient is analogous to upstream and is a point that is “before” an area of study that is used as a baseline for comparison with downgradient or downstream data.

Volatile Organic Compound (VOC) - An organic (carbon-containing) compound that evaporates (volatilizes) readily at room temperature.

Weight Percent - A term commonly used to describe the amount of a substance in a material. For example, oil containing 0.5 lb. sulfur per 100 lb. oil would contain 0.5 percent by weight sulfur.

Weighting Factor - Tissue-specific representation of the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue.

Whole Effluent Toxicity (WET) - The aggregate toxic effect to aquatic organisms from all pollutants contained in a facility’s wastewater. WET tests measure wastewater’s effects on specific test organisms’ (plants, vertebrates and invertebrates) ability to survive, grow, and reproduce.

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