2023

FERMILAB ANNUAL SITE

ENVIRONMENT REPORT

Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science

Fermi National Accelerator Laboratory

Fermilab

FERMILAB ANNUAL SITE ENVIRONMENT REPORT (ASER)

EXECUTIVE SUMMARY

Fermilab National Accelerator Laboratory located in the greater Chicago area is America's premier particle physics Laboratory with a mission to conduct pioneering research through the operation of world-class accelerators and detector facilities. Operated by the Department of Energy and managed by Fermi Research Alliance, Inc., the Laboratory takes pride in site stewardship, and 2023 operations demonstrated a continued commitment to environmental responsibility. Significant actions included the establishment of the Sustainability Management Group and Ecological Land Management Group within the Infrastructure Services Division and the Tritium Management Department within the Environmental, Safety, and Health Division. Staffing and resources were also increased for the Environmental Program Department, including the development of an Environmental Monitoring Group which collaborates closely with the newly formed Tritium Monitoring Group. These efforts highlight the Laboratory's efforts to minimize the environmental footprint associated with the operation of the facility. The Lab maintained compliance with federal, state, and local regulations, including the Clean Air Act and the Clean Water Act, and implemented measures to reduce environmental emissions. Fermilab also prioritized resource conservation through energy-efficient lighting upgrades, sustainable building features, and a zero-emission vehicle roadmap. The opening of the Integrated Engineering Research Center, designed with sustainable features as a focus, further exemplified this commitment. Additionally, Fermilab actively monitored and managed potential environmental impacts including tritium discharges and PFAS contamination. The Laboratory's proactive approach to environmental stewardship underscores its dedication to conducting scientific research responsibly while safeguarding the environment and the surrounding community.

U.S. DEPARTMENT OF ENERGY | Office of Science

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Acronyms/Abbreviations

The following acronyms and abbreviations are used in this report.

ALARA	As Low as Reasonably Achievable
ASER	Annual Site Environment Report
BNB	Booster Neutrino Beam
CAP88PC	Clean Air Act Assessment Package – 1988
CFR	Code of Federal Regulations
Ci	Curie
CRMP	Cultural Resources Management Plan
CUB	Central Utility Building
DCS	Derived Concentration Standard
DOE	Department of Energy
ELM	Ecological Land Management
EMS	Environmental Management System
EPCRA	Emergency Planning and Community Right-To-Know Act
EPD	Environmental Program Department
ES&H	Environment, Safety, and Health
EVSE	Electric Vehicle Charging Stations
Fermilab	Fermi National Accelerator Laboratory
FESHM	Fermilab Environment, Safety, and Health Manual
FSO	Fermilab Site Office
FY	Fiscal Year
GBq	Gigabecquerel
GHG	Greenhouse Gas
GIS	Geographic Information System
GQS	Groundwater Quality Standards
HCTT	Hazard Control Technology Team
IAC	Illinois Administrative Code
ICW	Industrial Cooling Water
IEPA	Illinois Environmental Protection Agency
IDNR	Illinois Department of Natural Resources
ISO	International Organization for Standardization
LBNF	Long-Baseline Neutrino Facility
MBTA	Migratory Bird Treaty Act
MCenter	Meson Center
MEI	Maximally Exposed Individual
MEOI	Maximally Exposed Off-site Individual
mg/L	Milligrams per Liter
mrem	Millirem
mSv	Millisieverts
MTest	Meson Test
mmBTU	Million British thermal units
NCRP	National Council on Radiation Protection & Measurements

Acronyms/Abbreviations
(continued)

NEPA	National Environmental Policy Act
NOvA	NuMI Off-axis ν_e Appearance
NPDES	National Pollutant Discharge Elimination System
NuMI	Neutrinos at the Main Injector
%	Percent
PCB	Polychlorinated Biphenyl
pCi/mL	Picocurie per milliliter
PFAS	Per- and Polyfluoroalkyl Substances
PIP	Proton Improvement Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
ROSS	Registration of Smaller Sources
SARA	Superfund Amendments and Reauthorization Act
SPCC	Spill Prevention Control and Countermeasures
Sv	Sievert
SWMU	Solid Waste Management Unit
SWPPP	Storm Water Pollution Prevention Plan
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
UST	Underground Storage Tank
USEPA	United States Environmental Protection Agency
ZEV	Zero-Emissions Vehicle

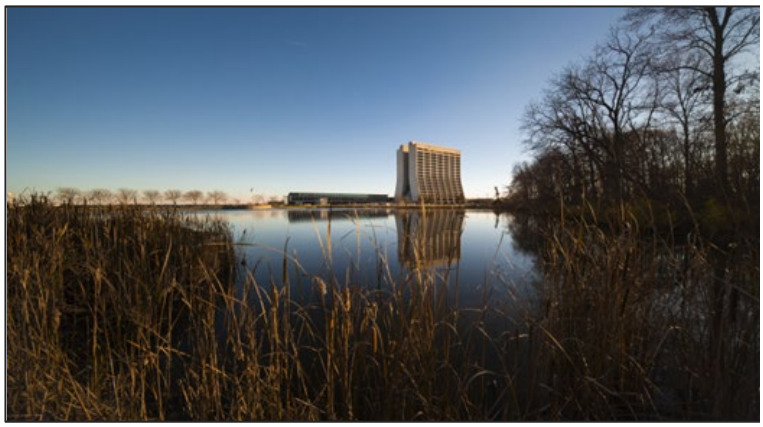
1. INTRODUCTION

Fermi National Accelerator Laboratory (Fermilab, Laboratory, Lab) is America's premier particle physics Laboratory with a mission to drive discovery in particle physics and encourage pioneering research by operating world-class accelerators and detector facilities. Operated by the Department of Energy (DOE), the Laboratory takes pride in the ongoing stewardship of the site and works diligently to minimize the environmental footprint associated with the operation of the facility.

The Fermilab site is located within the greater Chicago area and consists of approximately 10.6 square miles (27.5 square kilometers) within Kane and DuPage counties. Approximately nine million people reside within 50 miles (80 kilometers) of the site. Communities within 2 miles (3 kilometers) of Fermilab include the cities of Batavia (population 27,701), Warrenville (population 13,363), and West Chicago (population 26,475). Primary features include the accelerator complex and associated building infrastructure, an interconnected industrial cooling water (ICW) system, a housing complex for visiting researchers (the Village), row crop agriculture, and natural areas in various states of restoration consisting primarily of tall grass prairie, forest, and wetlands.

This Annual Site Environment Report (ASER) documents the performance of Fermilab's environmental program. The report presents the environmental objectives for the Laboratory and documents the compliance status of environmental requirements, which are managed under the scope of the lab's Environmental Management System (EMS). The EMS conforms to the core set of standards described in the International Organization for Standardization (ISO) 14001 standard, which specifies the requirements for an environmental management system. The EMS structure provides Fermilab with a practical framework from which to assess, manage, and enhance the environmental impacts of site operations.

A core component of the EMS is the environmental monitoring and surveillance program. This program provides for the measurement and interpretation of the impact of Fermilab operations on the environment. Surveillance and monitoring tasks are conducted to confirm compliance with established standards and specific permit limits and ensure the early detection of an unplanned pollutant release. Sample locations and frequency are based on established routines, operational considerations, and process assessments, as well as historic levels of pollutants found at particular locations. Sampling points are selected based on the potential for adverse impacts. Effluent samples from surface water and environmental media such as soil and groundwater are collected on the site and at the site boundary. Laboratory analytical results are compared to applicable guidelines and regulatory standards.



Autumn views of Swan Lake, the Integrated Engineering Research Center, and Wilson Hall

This ASER discusses the results of Fermilab's environmental monitoring and surveillance activities, the Laboratory's compliance with specific environmental regulations, progress on environmental restoration, and a summary of waste management and corrective action activities. The report is arranged by environmental topic and specific environmental requirements.

2. COMPLIANCE SUMMARY

Fermilab's compliance with environmental regulations and DOE Directives/Orders are provided below.

2.1 Environmental Restoration

2.1.1 Solid Waste Management Unit 12

The former Central Utility Building (CUB) Pipe and Clay Tile Field (SWMU 12) are located near the center of the Main Ring at the Fermilab site. The Laboratory continues to sample groundwater monitoring wells within this area on a semi-annual frequency. Nine monitoring wells at SWMU 12 were sampled during 2023 and analyzed for total chloride and total lead. Laboratory analytical data from glacial deposit monitoring wells are compared to applicable Groundwater Quality Standards (GQS) for Class II groundwater; data from bedrock wells are compared to applicable GQS for Class I groundwater.

- No GQS were exceeded during the 1st or 3rd quarter monitoring events.
- In the 2nd quarter, the total chloride concentration at MWD1 (1,370 mg/L) exceeded the GQS for Class II groundwater (200 mg/L), and the total lead concentration at MW9B (0.0166 mg/L) exceeded the GQS for Class I groundwater (0.0075 mg/L).
- In the 4th quarter, the total chloride concentration at MWD1 (1,450 mg/L) exceeded the GQS for Class I groundwater (200 mg/L), and the total lead concentrations at MW6B and MW7B (0.0106 mg/L and 0.0206 mg/L, respectively) exceeded the GQS for Class I groundwater (0.0075 mg/L).

2.1.2 Main Ring Service Buildings B1 and B4

Residual polychlorinated biphenyl (PCB) contamination at Main Ring service buildings B1 and B4 is classified as "disposed in place," requiring a deed restriction to indicate use is restricted and the identification of the location and extent of contaminated groundwater. The Lab is required to notify the USEPA in writing prior to conducting excavation activities that involve the removal of soil or other material in the area where PCB-contaminated groundwater exists. If groundwater is encountered during excavation, groundwater samples will be collected and analyzed, and results will be reported to USEPA. Internal mechanisms have been put in place to ensure that these requirements are met , including placement of signs at the affected locations, inclusion of these locations to the Geographic Information System (GIS), and modification of ES&H review procedures.

2.1.3 Underground Storage Tank System

Three underground storage tanks (USTs) are in place at the Site 38 Fuel Dispensing Facility. These tanks were operated and maintained according to Illinois administrative statutes, codes, and regulations. The Illinois State Fire Marshall inspects these tanks on a biennial basis to ensure that the internal and external leak detection systems continue to function properly. The most recent UST dispensing permit was approved in December 2021 and was valid through December 31st, 2023. The UST system at the fuel center has been discontinued. Removal activities expected to be conducted in FY2025.

2.2 Management of Hazardous Waste

Federal regulations provided in the Resource Conservation and Recovery Act (RCRA) govern the management of hazardous waste. Fermilab maintains a RCRA Part B permit to manage the hazardous waste generated at the Laboratory, to property store hazardous material on-site for a determined amount of time, and to transport hazardous material off-site for disposal and/or reclamation. Hazardous wastes removed from the Laboratory site are properly disposed of through licensed waste handling,

transportation, and disposal facilities. Regulated waste is not treated or disposed of on-site. A Hazardous Waste Report is transmitted to IEPA on an annual basis.

2.2.1 Radioactive Waste Management

The Fermilab Hazard Control Technology Team (HCTT) is responsible for the overall management of low-level radioactive waste, including transportation-related activities associated with shipping waste from Fermilab to designated DOE-approved disposal facilities. Radioactive waste is not governed under RCRA and is managed according to DOE Order 435.1. During CY2023, Fermilab shipped 271 cubic meters of radioactive debris off-site; this consisted primarily of Nevis shielding blocks used in experiments that had been stored on-site for radioactive decay.

2.2.1.1 Management of Tritiated Water

The primary source of tritiated water requiring off-site disposal is water from site MI-65; previously reduced by evaporation, water is now accumulated due to the evaporator being out of operation.

Water also continues to be generated from MI-12, although the amount that is generated has decreased. A below-ground collection system captures water associated with a compromised liner which surrounds the Booster Neutrino Beam Absorber at MI-12. Accumulated water is pumped to holding tanks at the surface where it is sampled for the analysis of tritium. Water with tritium concentrations above the Derived Concentration Standard of 1,900 pCi/mL is characterized as low-level radioactive waste.

The tritiated water collected from MI-65 and MI-12, as described above, is transported off-site as low-level radioactive waste and sent to the Energy Solutions Clive Disposal Facility in Utah for treatment and disposal. During CY2023, Fermilab transported 91,071 gallons of tritiated water off-site for disposal.

2.2.1.2 Regulated Waste Disposal and Reclamation Volumes

Radioactive waste and non-radioactive waste are managed by HCTT. The following volumes of regulated waste were managed in calendar year 2023:

Waste Material	**Volume (cubic meters)**
Hazardous Waste (RCRA + Toxic Substances Control Act [TSCA])	20.05
Non-Hazardous Special Waste	28.77
Radioactive Waste (DOE Regulated)	345
“Mixed Waste” (Radioactive + RCRA Waste)	271

The following volumes of waste were generated by Fermilab and managed for reclamation/recycling by HCTT in 2023:

Recycled/Reclaimed Waste Material	**Mass (kilograms)**
Mercury Containing Equipment	37
Safety Kleen® Solvent	450
Oil Filters	340
Used Oil	5422

2.3 Air Quality and Protection

2.3.1 Clean Air Act

Criteria Air Pollutants (CAP) include carbon monoxide, nitrogen oxides, particulate matter, sulfur dioxide, and volatile organic materials; these constituents are regulated through National Ambient Air Quality Standards (NAAQS) as defined in the Clean Air Act (CAA) by the USEPA. Fermilab is not a major source of CAPs; in 2023, the total actual annual air emissions was reported as 3.8762 tons per year, which is less than the maximum 5.0 tons per year allowed for a small emissions source. As a result, the Laboratory participates in the IEPA Registration of Smaller Sources (ROSS) Program. A CAP inventory and database is maintained to track and report air emissions to ensure continued compliance with the NAAQS and ensure continued eligibility for the IEPA ROSS Program.

The 2022 Radionuclide Air Emissions Annual Report was submitted to the DOE FSO in May 2023 and distributed to the USEPA and IEPA. Doses to the public from radioactive emissions in 2023 continued to be significantly below the USEPA standard of 10 mrem/year and less than the continuous monitoring threshold of 0.1 mrem/year. An estimated 118.4 Curies (Ci) (4.3808 TBq) were reported as released from various sources at the Lab.

The CAP-88 Gaussian plume diffusion model calculated the maximum dose equivalent delivered to a member of the public at distances to the site boundary to the nearest approximate 100 meters to be 7.96×10^{-2} mrem/year (7.96×10^{-4} mSv/year) in 2022; this has been determined to be consistent in 2023.

2.3.2 National Emission Standards for Hazardous Air Pollutants

Although several Fermilab air pollution sources are subject to the NSPS and NESHAP rules, as a small source the Lab is not required to obtain a permit under the New Source Performance Standards (NSPS) or under the National Emission Standards for Hazardous Air Pollutants (NESHAP) rules.

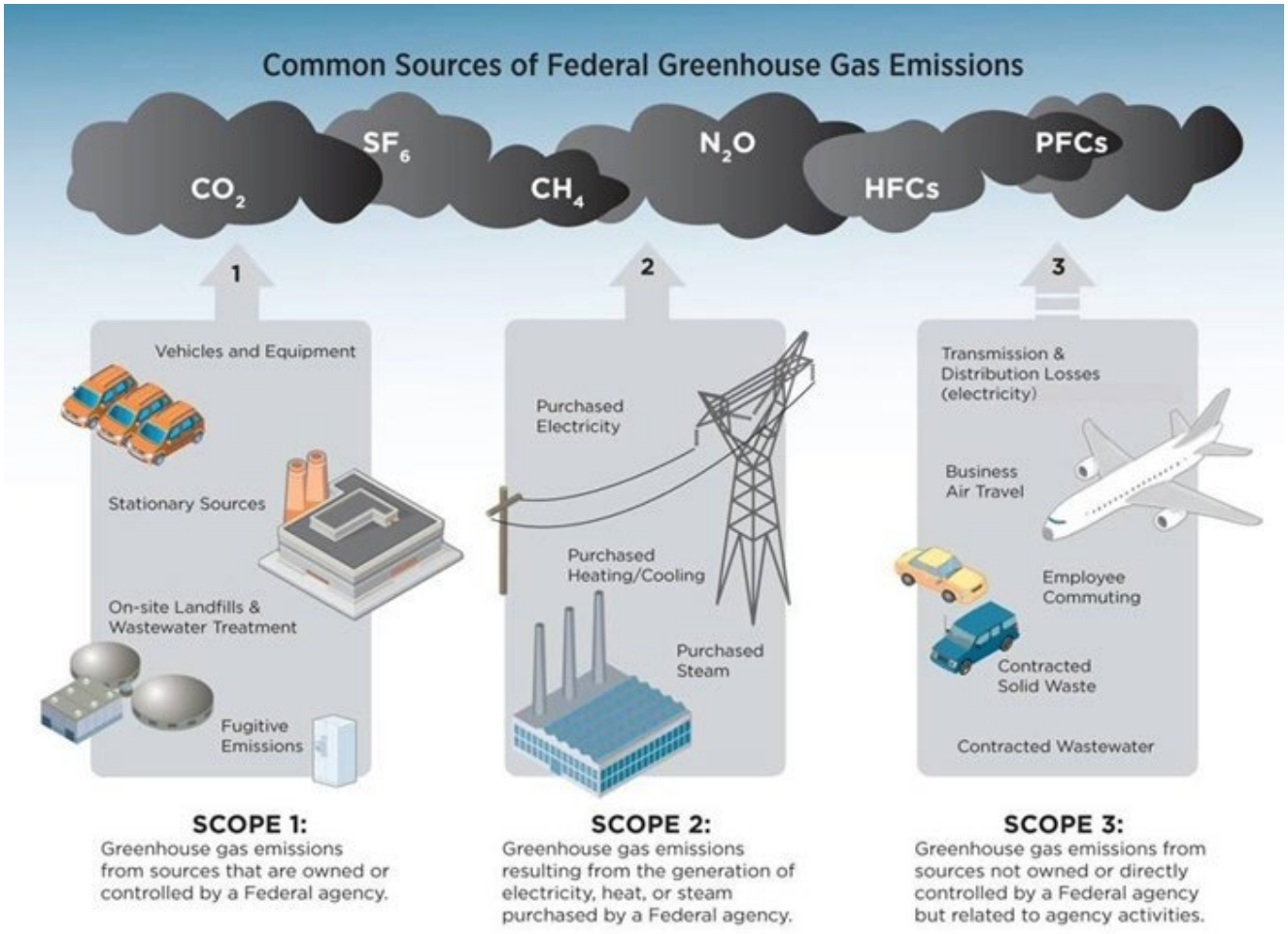
2.3.3 Hydrofluorocarbon Phasedown

In 2021, USEPA began the implementation of the hydrofluorocarbon (HFC) phasedown requirements of the American Innovation and Manufacturing (AIM) Act of 2020, which seeks to reduce HFC consumption and production to 15% of a 2011-2013 baseline by 2036.

As of January 1, 2024, the HFC Phasedown schedule requires a 40% reduction in HFC production and consumption from the baseline (see illustration). The HFC Phasedown applies to newly produced HFCs that are manufactured or imported and have not been previously used or recycled.

Hydrofluorocarbons (HFCs) are greenhouse gases with very high global warming potentials (GWP) used as refrigerants, in fire suppressant systems, and in certain scientific and electrical equipment.

Fermilab supports the DOE effort to advance greenhouse gas (GHG) reduction at its facilities. In 2023, the Laboratory submitted GHG emissions data to the department via DOE's Sustainability Dashboard.



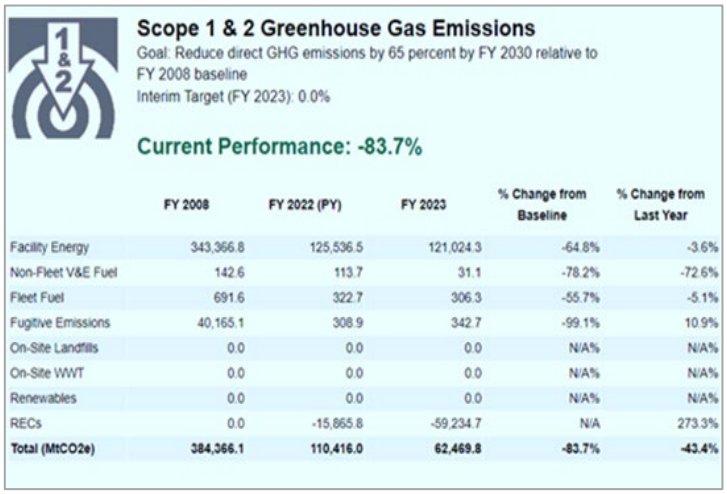
GHGs are divided into three categories: Scope 1, 2, and 3, as summarized below.

- Scope 1 emissions are greenhouse gases emitted from sources owned or activities controlled by Fermilab (e.g., boilers, emergency generators, fleet vehicles, and fugitive emissions).
- Scope 2 emissions are indirect emissions, such as from the purchase of electricity.
- Scope 3 emissions are other indirect emissions such as employee air travel, electrical transmission and distribution losses, waste generation, ground travel, and employee commuting.

The following illustrates the HFC production and consumption phasedown schedule as outlined in the AIM Act.

A summary of Fermilab's emissions, including the 2008 baseline, is illustrated in the Phasedown Schedule, above.

A summary of the performance status is provided below. These results indicates that Fermilab has reduced Scope 1 and 2 emissions by 83.7% over the 2008 baseline year, which demonstrates a 43.3% improvement in 2023. The consumption of electricity is Fermilab's dominant source of Scope 1 and 2 emissions. Scope 3 emissions were reduced by 3.6%.



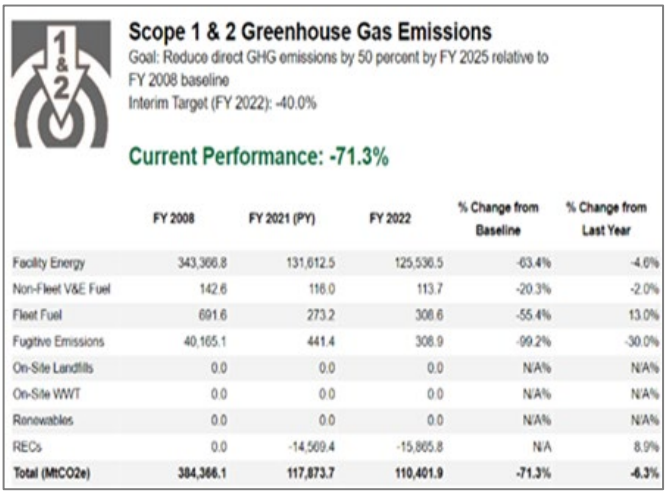
Scope 1 & 2 Greenhouse Gas Emissions

Goal: Reduce direct GHG emissions by 65 percent by FY 2030 relative to FY 2008 baseline

Interim Target (FY 2023): 0.0%

Current Performance: -83.7%

	FY 2008	FY 2022 (PY)	FY 2023	% Change from Baseline	% Change from Last Year
Facility Energy	343,366.8	125,536.5	121,024.3	-64.8%	-3.6%
Non-Fleet V&E Fuel	142.6	113.7	31.1	-78.2%	-72.6%
Fleet Fuel	691.6	322.7	306.3	-55.7%	-5.1%
Fugitive Emissions	40,165.1	308.9	342.7	-99.1%	10.9%
On-Site Landfills	0.0	0.0	0.0	N/A%	N/A%
On-Site WWT	0.0	0.0	0.0	N/A%	N/A%
Renewables	0.0	0.0	0.0	N/A%	N/A%
RECs	0.0	-15,865.8	-59,234.7	N/A	273.3%
Total (MtCO2e)	**384,366.1**	**110,416.0**	**62,469.8**	**-83.7%**	**-43.4%**



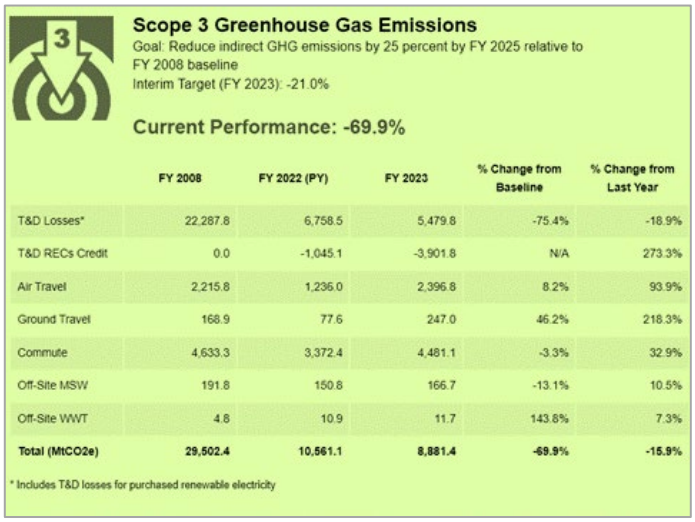
Scope 1 & 2 Greenhouse Gas Emissions

Goal: Reduce direct GHG emissions by 50 percent by FY 2025 relative to FY 2008 baseline

Interim Target (FY 2022): -40.0%

Current Performance: -71.3%

	FY 2008	FY 2021 (PY)	FY 2022	% Change from Baseline	% Change from Last Year
Facility Energy	343,366.8	131,612.5	125,536.5	-63.4%	-4.6%
Non-Fleet V&E Fuel	142.6	116.0	113.7	-20.3%	-2.0%
Fleet Fuel	691.6	273.2	308.6	-55.4%	13.0%
Fugitive Emissions	40,165.1	441.4	308.9	-99.2%	-30.0%
On-Site Landfills	0.0	0.0	0.0	N/A%	N/A%
On-Site WWT	0.0	0.0	0.0	N/A%	N/A%
Renewables	0.0	0.0	0.0	N/A%	N/A%
RECs	0.0	-14,569.4	-15,865.8	N/A	8.9%
Total (MtCO2e)	**384,366.1**	**117,873.7**	**110,401.9**	**-71.3%**	**-6.3%**



Scope 3 Greenhouse Gas Emissions

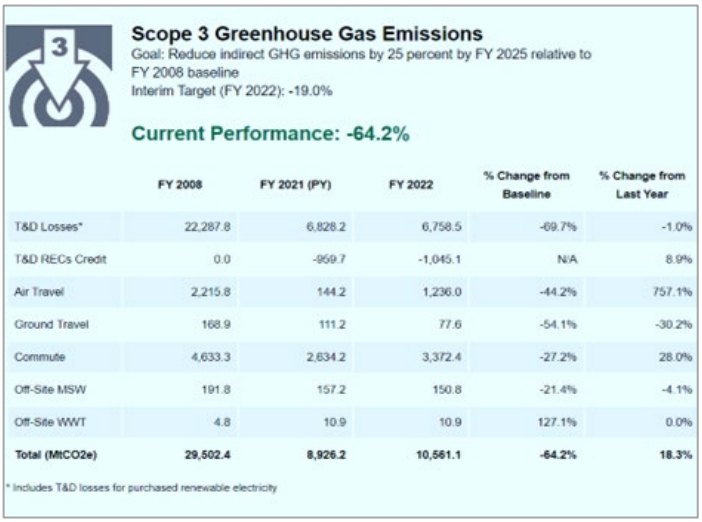
Goal: Reduce indirect GHG emissions by 25 percent by FY 2025 relative to FY 2008 baseline

Interim Target (FY 2023): -21.0%

Current Performance: -69.9%

	FY 2008	FY 2022 (PY)	FY 2023	% Change from Baseline	% Change from Last Year
T&D Losses*	22,287.8	6,758.5	5,479.8	-75.4%	-18.9%
T&D RECs Credit	0.0	-1,045.1	-3,901.8	N/A	273.3%
Air Travel	2,215.8	1,236.0	2,396.8	8.2%	93.9%
Ground Travel	168.9	77.6	247.0	46.2%	218.3%
Commute	4,633.3	3,372.4	4,481.1	-3.3%	32.9%
Off-Site MSW	191.8	150.8	166.7	-13.1%	10.5%
Off-Site WWT	4.8	10.9	11.7	143.8%	7.3%
Total (MtCO2e)	**29,502.4**	**10,561.1**	**8,881.4**	**-69.9%**	**-15.9%**

* Includes T&D losses for purchased renewable electricity



Scope 3 Greenhouse Gas Emissions

Goal: Reduce indirect GHG emissions by 25 percent by FY 2025 relative to FY 2008 baseline

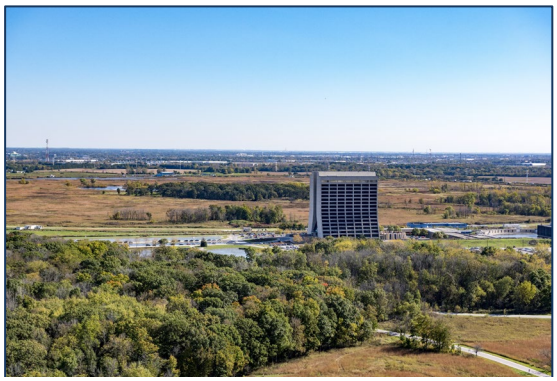
Interim Target (FY 2022): -19.0%

Current Performance: -64.2%

	FY 2008	FY 2021 (PY)	FY 2022	% Change from Baseline	% Change from Last Year
T&D Losses*	22,287.8	6,828.2	6,758.5	-69.7%	-1.0%
T&D RECs Credit	0.0	-959.7	-1,045.1	N/A	8.9%
Air Travel	2,215.8	144.2	1,236.0	-44.2%	757.1%
Ground Travel	168.9	111.2	77.6	-54.1%	-30.2%
Commute	4,633.3	2,634.2	3,372.4	-27.2%	28.0%
Off-Site MSW	191.8	157.2	150.8	-21.4%	-4.1%
Off-Site WWT	4.8	10.9	10.9	127.1%	0.0%
Total (MtCO2e)	**29,502.4**	**8,926.2**	**10,561.1**	**-64.2%**	**18.3%**

* Includes T&D losses for purchased renewable electricity

Fermilab remains committed to assisting DOE with meeting the reduction goals for Scopes 1, 2, and 3. During 2023, this strategy was highlighted by five focus areas: energy efficiency measures, fossil fuel use, carbon pollution-free electricity, energy infrastructure connections, and supply chain sustainability. Due to the large electricity consumption, the Lab will need to secure significant quantities of carbon-pollution-free electricity (CFE) to reduce Scope 2 emissions. This will involve a combination of on-site energy generation, off-site purchased CFE, and purchase of Environmental Attribute Certificates (EACs) which are in short supply. In addition, the Regional Transmission Authority has a backlog of projects waiting to be built within Fermilab's service area. The Laboratory intends to use Renewable Energy Certificates in the near term until EACs are available for purchase and continues pursuing additional strategies for reducing greenhouse gas emissions; these include implementing best practices for operational efficiencies, such as building retrofits and partnering with the scientific staff to explore greenhouse gas emissions savings opportunities in our scientific activities.



Wilson Hall surrounded by prairie and woodland.

2.3.4 Reduction in Overall Environmental Emissions

As the reduction of environmental emissions is a priority for the Lab, flexible work arrangements continue to be in place for those employees whose responsibilities allow them to work from home on a full or part-time basis.

2.4 Water Quality and Protection

2.4.1 Clean Water Act Wetland Impacts

Evaluation of potential wetland impacts due to operational activities continued to be accomplished primarily through the National Environmental Policy Act (NEPA) and the Infrastructure Services Division design, comment, and compliance review processes. The Laboratory continued to use Task Manager/Construction Coordinator training to instruct participants on ways to ensure that potential work areas are screened for the presence of wetlands and to be aware of the aspects of environmental compliance management. In July 2018, the United States Army Corps of Engineers issued a site-wide jurisdictional wetland determination for Fermilab; this determination allows the Lab to evaluate and perform work within non-jurisdictional exempt or isolated wetlands on-site. The determination is valid for five years.

2.4.2 NPDES Permits, Exceedances, and Noncompliance

Three National Pollutant Discharge Elimination System (NPDES) permits issued to Fermilab by IEPA were active in 2023. These permits are summarized below.

Individual NPDES permit for Non-Contact Cooling Water and Storm Water: This permit addresses combined stormwater and non-contact cooling water discharges associated with industrial activities. Six outfalls are associated with this permit:

- Outfall 001 discharging to Ferry Creek
- Outfall 002 discharging to Kress Creek
- Outfalls 003, 004, 005, and 006 discharging to Indian Creek

Outfall 004 addresses potential discharges from the Industrial Cooling Water (ICW) holding tank associated with the Main Injector Neutrino Oscillation Search experiment. Outfalls 005 and 006 address discharges from the Main Injector pond system. The permit requires Fermilab to record certain physical and chemical discharge parameters on a monthly basis and report them to IEPA: these include water temperature, pH, flow, and tritium from the six outfalls. Chlorine concentration is also measured and reported from outfalls 00 and 002 which discharge to both Kress and Indian Creeks. Permits are effective for five years; the most recent permit renewal became effective on September 4, 2019. IEPA most recently conducted a compliance evaluation inspection against elements of the permit in August 2022; no findings were reported.

Indian Creek, shown here, begins at Swan Lake and flows mostly to the southeast.

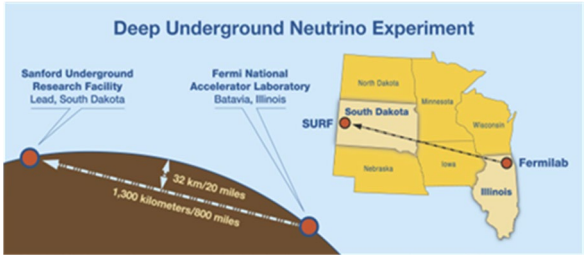
General NPDES Storm Water Permit for Construction Activities: This permit is required for projects that disturb greater than one acre, including the following projects during 2023:

- Fermilab Welcome and Access Center
- Proton Improvement Plan (PIP) II Project
- Long-Baseline Neutrino Facility

General NPDES Permit for Pesticide Application Point Source Discharge: This permit applies to facilities utilizing pesticides that may impact Waters of the State. A 5-year permit renewal application was submitted to IEPA in 2021.

View of the entrance to the DUNE/LBNF Project at the Sanford Laboratory in South Dakota.

The Deep Underground Neutrino Experiment will generate the world's most intense beam of high-energy accelerator neutrinos at Fermilab in Illinois and send them 800 miles (1,300 km) straight through the earth to mile-deep detectors at the Sanford Underground Research Facility in South Dakota. Neutrinos, which rarely interact with anything, pass through the earth with no tunnel required.



Industrial Wastewater Pretreatment Permits: The Lab holds two industrial wastewater pretreatment operating permits issued by IEPA (also covered under NPDES regulations and described under Section 2.4.5, *Releases to Sanitary Sewers*).

2.4.3 Surface Water Quality

Fermilab releases minor amounts of contaminants to surface water bodies. As part of the management of these discharges, the Laboratory holds NPDES permits that govern releases to surface water from stormwater runoff, cooling water, effluents from various on-site construction projects, and pesticide applications. In addition to monitoring the physical and chemical parameters required by NPDES permits, samples of surface water are taken monthly from selected water bodies and analyzed for radionuclides based on the anticipated potential for contamination. Regulatory aspects and responsibilities of the surface water program are documented in the Fermilab Environment, Safety, and Health Manual (FESHM) Chapter 8026, titled Surface Water Protection.

Aqueous process wastewaters are directed into sanitary sewers and ultimately discharged to publicly owned treatment works in the municipalities of Batavia and Warrenville/Naperville. Wastewater discharges are controlled by criteria described in FESHM Chapter 8025, titled Wastewater Discharge to Sanitary Sewers. There were no unplanned releases to sewer systems in 2023.

In addition, settleable solids at Fermilab are sampled at the discharge point to the Batavia municipal treatment system, the discharge point to the Warrenville/Naperville municipal treatment system, and at the site boundaries of Indian Creek, Kress Creek, and Ferry Creek. A background sample is collected within Kress Creek, located upstream of the Fermilab site boundary.

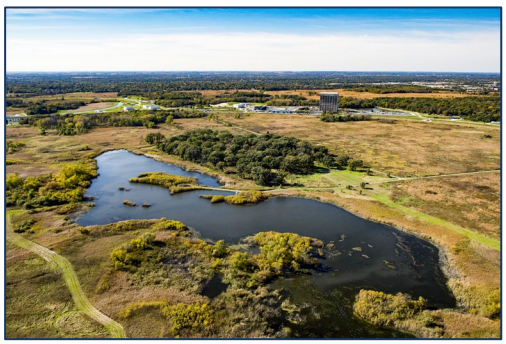
2.4.3.1 Non-Radioactive Releases to Surface Water

Monitoring for non-radiological chemical constituents in surface water was limited to NPDES permit parameters (temperature, flow, pH, and chlorine) during 2023. Discharge Monitoring Reports for six different outfalls were submitted on a monthly basis to IEPA. All outfall discharges were reported to be within the limits of permit parameters.

2.4.3.2 Radioactive Releases to Surface Water

Numerous sumps collect and drain water from building footings and from under beamline tunnels in the Main Injector, former Tevatron, and the experimental areas. Water collected by these sumps may contain detectable concentrations of radionuclides (primarily tritium) that have leached out of radioactive soil near beam targets and absorbers due to precipitation. An additional source may be releases into sumps due to losses from beamline cooling water systems. These sumps discharge to on-site ditches and ponds.

Surface water is also collected from the Neutrinos at the Main Injector (NuMI) tunnel system. NuMI tunnel water contains measurable concentrations of tritium, the primary source of which is water contact with components within the tunnel. The majority of water that is collected consists primarily of groundwater that has infiltrated into the tunnel. This high-quality water is pumped from the tunnel and directed into the ICW system, where it is mostly utilized for make-up water for the CUB cooling towers. Excess NuMI water and excess effluent from the towers are directed to the ICW system.



Surface water at Fermilab includes 5 lakes.

Fermilab continued to discharge measurable concentrations of tritium to surface waters off-site. The concentrations measured were well below the DOE Order 458.1 Derived Concentration Standard of 2,600 picocuries per milliliter (pCi/mL). Releases depend on pond levels and the operational mode of the accelerator complex. Fermilab's site-specific NPDES permit includes monitoring requirements for tritium at 6 outfalls in 3 watersheds. In 2023, no measurable tritium was discharged to Ferry Creek. Indian Creek received low-concentration tritium discharges throughout the year, with the highest concentration detected during July, measuring 20.3 pCi/mL. Detectable tritium at a concentration of 1.0 pCi/mL occurred at the Kress Creek outfall during December.

Monthly data from measurements taken at outfall and site boundary locations are made publicly available through the *Tritium at Fermilab* website. Monitoring radioactivity in surface water continues to be a primary component of Fermilab's routine environmental surveillance program.

2.4.4 Operational Cooling Water System

Fermilab requires the circulation of large amounts of non-contact cooling water through various surface water bodies specifically designed to dissipate heat. A site-specific NPDES permit authorizes the treatment of water within the ICW system, in addition to the discharge of commingled cooling water and stormwater runoff through outfalls into Kress, Indian, and Ferry Creeks. These outfalls are the designated locations at which the surface water system becomes Waters of the State.

A Storm Water Pollution Prevention Plan (SWPPP) is required by the site-specific NPDES permit and addresses stormwater discharges associated with RCRA Solid Waste Management Units (SWMUs), certain industrial activity areas, and service support areas. An inspection report was completed in March 2023 and filed with the IEPA.

In 2023, Fermilab contracted with a state-licensed pesticide applicator to treat a limited number of ponds with aquatic herbicide in order to minimize plant growth. Additionally, an ongoing zebra mussel infestation occurring in the ICW system infrastructure was managed by using a continuous feed of sodium hypochlorite solution at the Casey's Pond pumphouse.

2.4.5 Releases to Sanitary Sewers

The Lab maintains an on-site piping system for the conveyance of sanitary effluent. This effluent is directed to the cities of Batavia and Warrenville/Naperville for treatment. In addition, Fermilab operated two systems in 2023 that require pretreatment prior to release into the sewers. These operations require IEPA wastewater pretreatment permits as follows:

- An Individual Industrial Wastewater Pretreatment Permit allows Fermilab to discharge wastewater effluent from deionized water regeneration operations occurring at the CUB into the City of Batavia sanitary sewer treatment works.
- An Individual Industrial Wastewater Pretreatment Permit allows metal finishing wastewater from the Applied Physics and Superconducting Technology Division's Cavity Processing Lab at Industrial Building 4 to be discharged into the City of Batavia sanitary sewage treatment works.

Samples of sewer discharges to the municipalities of Batavia and Warrenville are collected from monitoring stations located at or near the Laboratory boundary. The discharge at these locations is a mixture of effluents contributing to teach sanitary sewer system. Analytical results for metals are compared to municipal discharge limits to track compliance. Fermilab occasionally exceeds the limit for iron (5.0 milligrams per liter (mg/L)) in effluent released to both Warrenville and Batavia. Aging pipes are suspected to be the source of these exceedances, and the Lab maintains discussions with the municipalities.

Low levels of tritium have been detected in effluent discharged to the Batavia treatment works for the past two decades. All discharge samples analyzed in 2023 indicated results below the DOE Order 458.1 standard (total tritium 5 Ci) and are summarized below. No other isotopes were detected.

Total Tritium in 2023	**0.16 Curies**
Average Concentration	**2.9 pCi/mL**
Highest Concentration	**15.5 pCi/mL**
Total Sanitary Volume	**22,863,750 gallons**

The Fermilab Tritium Task Force Working Group continues to investigate sources of tritium in both the sanitary sewer system and the ICW system. As part of this review, a concerted effort is being undertaken to investigate sources of tritium in the sanitary system detected in the southern sections of the sewer system.

2.4.6 Stormwater Management

See Section 2.4.3 Surface Water Quality for information regarding stormwater management at Fermilab.

2.4.7 Floodplain Management

Impacts to floodplains are included within the Lab's environmental review process under NEPA. Project information, such as total project area or whether floodplain filling is required, are questions asked during a NEPA review. There were no floodplain issues encountered during 2023. As part of Fermilab's Surface Water Management Program, on-site streams have been surveyed and mapped to collect information regarding sediment depth, field tile invert depths, and in-stream structures. Hydrologic analysis was used to determine runoff from rainfall events of return frequencies ranging from one to 100 years and durations

of one to 48 hours. Hydraulic analysis has also been completed to create flood profiles and inundation maps for two, five, ten, and 100-year floods.

2.4.8 Safe Drinking Water Act

Fermilab's domestic water is purchased from the City of Warrenville. In addition, the Laboratory currently retains semi-private water supply wells at four sites: Site 29 (Director's residence), Site 52 (former Security Office/Bison Barn), Site 56 (former residence and horse barn], and Site 58 (former residence). These wells at Sites 29, 56, and 58 are sampled annually for general chemistry; no issues with water quality were reported in 2023 other than hardness. Estimates of water withdrawn from these wells are reported to the Illinois State Water Survey on an annual basis.

2.5 PFAS and Additional Emerging Contaminants

Following the framework for the evaluation of per- and polyfluoroalkyl substances (PFAS) uses at DOE-owned sites (*Guide for Investigating Historical and Current Uses of Per- and Polyfluoroalkyl Substances at Department of Energy Sites (January 2023), and* the *PFAS Strategic Roadmap: DOE Commitments to Action 2022-2025 (October 2023))*, Fermilab completed an assessment to initiate the evaluation and documentation of the purchase, use, storage, and disposal of per- and polyfluoroalkyl substances (PFAS) at Fermilab; activities are on-going.

2.6 Emergency Planning and Community Right-to-Know Act

The Emergency Planning and Community Right-to-Know Act (EPCRA) and Title III of the Superfund Amendments and Reauthorization Act (SARA) require Federal facilities that use, produce, or store extremely hazardous substances, hazardous substances, hazardous chemicals, and/or toxic chemicals in quantities that exceed specific thresholds to report these inventories and planned or accidental environmental releases to Federal, State, and local emergency planning authorities.

Status of EPCRA Reporting

EPCRA Section	***Description of Reporting***	***Status***
EPCRA Sec. 302-303	Planning Notification	No
EPCRA Sec. 304	EHS or HS Release Notification	No
EPCRA Sec. 311-312	SDS/Hazardous Chemical Inventory	No
EPCRA Sec. 313	TRI Reporting	Yes

Under SARA Title III Section 313, Fermilab is required to provide USEPA and the State of Illinois with an account of toxic chemicals over certain reporting thresholds that were manufactured, processed, or otherwise used within a given year. Reporting is accomplished through the Toxic Release Inventory (TRI) reporting system on an annual basis. Fermilab did not have any releases that exceeded the thresholds identified by the USEPA that would trigger a reporting requirement in 2023.

Under Tier II reporting requirements, Fermilab provides an annual report to state and local officials with a description of hazardous, toxic, and extremely hazardous chemicals used or stored on-site in quantities greater than their respective reporting thresholds.

2.7 Other Environmental Statutes and Executive Orders

Additional programs conducted at Fermilab are summarized below.

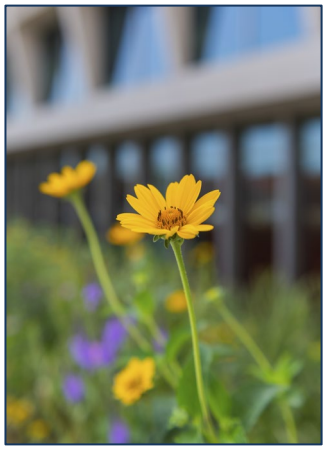
2.7.1 Oil Spill Prevention/SPCC Plan

Fermilab's Spill Prevention Control and Countermeasures (SPCC) Plan complies with 40 CFR Section 112, titled Oil Pollution Prevention. This USEPA-enforced regulation requires any facility that can use or store more than 1,320 gallons of oil (petroleum, plant or animal oils, and fats) to write and implement an SPCC plan that encompasses all oil sources with a capacity of 55 gallons or more. The Lab's plan is detailed in FESHM Chapter 8031. In addition, Fermilab requires annual SPCC training for those employees whose responsibilities include handling oil as defined within the regulations.

The Lab has over 700,000 gallons of oil on-site, including more than 350 oil-filled transformers. In 2015, Fermilab developed a new SPCC database to ensure that oil sources owned by each division/section remain in compliance with 40 CFR 112 through cataloging of the locations of oil sources and conducting routine inspections. The Laboratory continues to remain in compliance with 40 CFR 112. No reportable spills occurred in 2023.

2.7.2 Endangered Species

Impacts on endangered species are regulated under the Endangered Species Act (ESA) and evaluated through the formal Environmental Review Process for all projects, as required by NEPA. This review includes the definition of a project area and scope; if warranted, the evaluation will identify threatened or endangered species within the area, in addition to the potential to impact protected species and their critical habitat. No ESA compliance issues were identified in 2023.



Wildflowers at Wilson Hall.

The only federally endangered species observed at Fermilab is the rusty-patched bumble bee (*Bombus affinis*). In 2023, meander surveys were conducted in areas with historical records of the bumble bee to relocate the species. No bees were located during this effort; the last observation of the species at Fermilab was in 2018.

From 2017 to 2020, the federally endangered eastern prairie fringed orchid (*Platenthera leucophaea*) seed was given to Fermilab by the Fish and Wildlife Service (FWS) and sown in the areas of appropriate habitat. This project was possible through an agreement between FWS and DOE. As this species may take close to ten years to establish, surveys were initiated in 2023 in several of the areas seeded in 2017 in order to determine if any of the seeds had germinated. No plants were observed in 2023.

A vast number of invasive species occur in varying densities across the site. The Ecological Land Management (ELM) Committee has identified over 25 invasive species, including established plants like the common reed (*Phragmities australis*), teasel (*Dipsacus* spp.), common buckthorn (*rhmanus cathartica*), Oriental bittersweet (*Celastrus orbiculatus*), and crown vetch (*Securigera varia*). Species that are newly established or have localized populations include mugwort (*Artemisia vulgaris*), tansy (*Tanacetum vulgare*), and Japanese knotweed (*Reynoutria japanica*).

Prairie areas within the Tevatron Ring.

Priority is given to invasive species that are established, localized, or can be managed thoroughly to prevent spread. As several species are rampant at Fermilab, more diverse natural areas are prioritized to preserve diversity. ArcGIS is utilized to track each species and its density over time to measure progress and increase efficiency. Management of individual species ranges from multiple treatments of known plants, to partial or non-treatment, to mapping of full populations on the site.

Annual and biannual species are removed mechanically to the extent possible. This effort includes timed mowing with tractors utilizing brush cutters in addition to hand pulling. Most perennial species require an herbicide application for efficient removal. Plant lifecycles are evaluated as often as possible to provide herbicide treatments when the plants are most susceptible. Using the most effective herbicide for each species and associated site conditions reduces the potential of negatively impacting desirable species. Invasive brush species are typically managed through the dormant months of the year using cut-stump treatments where the shrub is cut several inches above the ground and the remaining stump is treated with herbicide to prevent resprouting. Lastly, prescribed burns reduce resprouts in areas recently cleared to remove the seed bank.

2.7.3 National Historic Preservation Act

Compliance with the National Historic Preservation Act, Archaeological Resources Protection Act, Native American Graves Protection and Repatriation Act of 1990, and DOE Order 450.1 is accomplished through the NEPA review process.

The Lab follows a site-specific DOE-required Cultural Resources Management Plan (CRMP) based on guidelines outlined in DOE Publication DOE/EH-0501. The CRMP assures continued compliance with regulations by providing a comprehensive overview of the locations and status of cultural resources within the Fermilab site boundaries, facilitating future NEPA reviews. An evaluation of proposed land-disturbing projects was conducted in 2022 to assess potential impacts on historic resources, and updates to the CRMP were completed in 2023.

2.7.4 Migratory Bird Treaty Act

General ecological land management at Fermilab aims to improve habitat for migratory bird species and follows the requirements of the Migratory Bird Treaty Act (MBTA). Specifically, two areas at the lab have been prioritized for migratory bird nesting potential. Management plans were created for both shrubland and grassland (generally non-native plant composition) to restore preferred structural habitat for declining bird species. These plans are carried out with the assistance of Fermilab Natural Areas (FNA), a 501(3)c non-profit organization. School groups, volunteers, and the general public continue to visit Fermilab to learn about the restoration and importance of restoring these critical habitats. In many cases, these groups also assist Fermilab and FNA with stewarding the natural areas.

During 2023, there was no intentional take of migratory bird species. On July 26, 2023, monitoring was initiated for the evaluation of window collisions at the Integrated Engineering Research Center. For the remaining months of 2023, 54 birds (subject to the MBTA) struck building windows and 52 of those observed were dead. One bird determined to be in poor health was taken to a wildlife rehabilitation center, and one was observed briefly before it took flight. A total of 20 native species were observed after collisions during 137 monitoring events at the Integrated Engineering Research Center.

Geese and goslings at Swan Lake outside Wilson Hall.

Fermilab maintains a proactive approach to the protection of the Canada Goose population on-site while also ensuring the safety of employees and visitors. The Laboratory has hired a subcontractor to use dogs to harass geese in order to displace them from the more heavily used operational areas of the site. The company holds a valid permit from the Illinois Department of Natural Resources (IDNR) to conduct this activity, which is carried out during the spring nesting season.

The Lab also possesses a Nuisance Wildlife Control Permit issued by the IDNR that allows for the destruction of Canada Goose nests if they become a safety hazard. The permit allows the Laboratory to destroy up to seven nests each year. During 2023, one nest was destroyed.

No other instances of known incidental take for species subject to the MBTA were observed during 2023.

2.7.5 Federal Insecticide, Fungicide, and Rodenticide Act

The use of pesticides and herbicides at Fermilab is managed in accordance with the Federal Insecticide, Fungicide, and Rodenticide Act. Fermilab adheres to the principles of Integrated Pest Management to minimize pollution and adverse environmental impacts.

2.8 Other Major Environmental Issues and Accomplishments

2.8.1 Natural Resources Conservation Programs and Projects

In addition to forming the Ecological Land Management Group, the Director of Fermilab established the Ecological Land Management Committee to recommend management practices based on sound ecological principles that enhance the natural resources of the Laboratory.

2.8.2 Site Stewardship

The Site Services Department and Roads & Grounds Department, both within the Infrastructure Services Division, oversee the management of nearly 4,000 acres of natural areas. Over half of these natural areas are currently being restored. Habitat communities include tallgrass prairie, oak savanna, open-water marsh, sedge meadow, buttonbush swamp, and floodplain forest. The primary goal of ecological land management is to increase the biodiversity of native flora and fauna while enhancing the functional services of these ecological systems. This type of site stewardship includes prescribed burning, controlling invasive species, monitoring threatened & endangered species, surveying plants and wildlife, and collecting seeds from over 200 native species to spread into recently restored areas. A portion of this work is carried out by trained volunteers who are provided by Fermilab Natural Areas, a 501(c)(3) not-for-profit corporation.

2.8.3 Deer Management

Fermilab manages the population of whitetail deer on-site by contracting annually with the United States Department of Agriculture Wildlife Services. Population modeling is conducted using data from vegetation surveys, vehicle accident reports, and aerial surveillance. Assessments in 2023 indicated the necessity to reduce the deer herd by 44 between January and March 2023.

Deer herd south of Wilson Hall.

2.8.4 Nuisance Animal Permit

In addition to the management of whitetail deer, a Nuisance Animal Permit issued by the IDNR allows for the trapping and elimination of nuisance animals. During 2023, 33 reports of wildlife were received. No nuisance animals were euthanized on-site.

2.8.5 Migratory Bird Protection and Conservation

DOE has a 2013 Memorandum of Understanding with the United States Fish and Wildlife Service which provides several measures designed to "protect and conserve" migratory bird habitat to the fullest extent practicable. Fermilab addresses this by evaluating migratory bird impacts during the completion of environmental reviews under NEPA to avoid or minimize impacts to even the most common birds as much as reasonable. Ecological land management across the Site continues to provide ample habitat communities and stopover resources for migratory birds. The ELM committee provides an annual plan to deliver these recommendations to the Lab.

2.8.6 Sustainable Resilient Remediation

The Laboratory does not have any active remediation projects; this includes Sustainable Resilient Remediation (SRR).

2.9 Site Resilience

Fermilab is addressing resilience to climate change by incorporating the increased or changing requirements into the operations and infrastructure of the Laboratory. Resilience efforts will enable the Site to prepare for and withstand climate change impacts with little or no damage and support quicker recoveries from anticipated events. A Vulnerability Assessment and Resilience Plan (VARP) identified heat waves, drought, and increased intensity of precipitation (rain and snow) as the climate changes most likely to impact the Laboratory.

Solutions are implemented through improved resilience of critical infrastructure, including support buildings, power supply and electric distribution systems, high-performance computing data centers, water/sewer systems, and outdoor workers. In 2023, the Sanitary Sewer System Upgrades and Repair project was completed, including lining or replacing 18,730 linear feet of sanitary sewer and 705 vertical feet of manhole lines. This is estimated to reduce the inflow and infiltration into the sanitary sewer system by 11%, or a monthly average of 350 kilogallons, which improves the system’s ability to handle increased precipitation.

The Lab is in the design phase of a Utilities Infrastructure Project which aims to revitalize and improve 50-year-old utilities to meet new demands and support resilience to climate change. The project includes the completion of a new chilled water plant and central utility plant upgrades, replacement of the Kautz Road Substation, and the replacement of linear utilities. Designs incorporate projected climate impacts and expect to improve the reliability, capacity, and condition of the critical utility systems.

Manuals, procedures, and processes across the Laboratory are being updated to incorporate the results of the VARP. Examples of these updates include the Infrastructure Services Division Engineering Design Guide, Utility Operations & Maintenance Manuals, Procurement Manuals, Project Management Manual, project-specific sustainability strategies, Fermilab Design Review, the Infrastructure Project Prioritization Process, and enterprise-level risk management analysis training.

2.10 Environmental Permitting

The following provides a summary of environmental permits in effect.

Operating Permits in Effect at Fermilab

Agency	Permit Type	Description/Permit #	Issue Date	Expire Date
IEPA	Discharge to Surface Water	IEPA Permit IL0026123 - Illinois NPDES General Permit for Storm Water Discharges Associated with Industrial Activities	09/04/2019 modified: 10/21/2021	8/24/2024
IEPA	Discharge to Surface Water	IEPA Permits ILR10ZDGE (FWAC), ILR10AP48 (PIP II), ILR10ZDG0 Long-Baseline Neutrino Facility, NPDES General Permits for Storm Water Discharge - Construction-site Activities	Prior Project Start	At project completion
IEPA	Discharge to Surface Water	IEPA Permit ILG870484 - Illinois NPDES General Permit for Pesticide Application Point Source Discharges	9/04/2022	9/30/2027
IEPA	Hazardous Wastes	RCRA IEPA I.D. 0890105010, USEPA I.D. IL 6890030046	12/27/2016 effective: 1/31/2017	1/31/2027
IEPA	Air Emissions (PSD)	IEPA ID043807AAI - Registration of Smaller Sources Program; multiple emission sources	annual registration submitted prior to December 30th	
IEPA	Air Emissions (PSD)	IEPA Permit 043115 App B2404012 - Open Burn Permit; 1000 acres of prairie, woodland, wetland, and brush piles for Ecological Management	4/15/2024	4/15/2025
IDNR	Wildlife	Nuisance Wildlife Control Permit Class C: Governmental – Mammals and Game birds	1/10/2024	1/31/2025
IDNR	Wildlife	Nuisance Wildlife Control Permit Class E: Governmental – Migratory birds (Canada Goose Depredation Permit)	3/01/2024	9/01/2024
IDNR	Other	IDNR Permit 21753-IL50350 - Operation of a Class III Dam	4/28/1994	Lifetime
IEPA	Other	IEPA Permit 2023-EP-68704 - Pretreatment System for Metal Finishing Rinsewaters - Tributary to City of Batavia WWTP	11/14/2023	10/31/2028
IEPA	Other	IEPA Permit No. 2019-EP-64805 - Demineralizer Regenerant Waste Pretreatment - Tributary to City of Batavia WWTP	12/04/2019	11/30/2024
IDNR	Other	IDNR Permit No. 12170 - Water intake from Fox River	May 2009	12/31/2049
USACE	Other	Regional Permit No. LRC-2013-00387 - Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment Project (Near Site)	March 2022	Open Permit

2.10.1 Nuisance Wildlife Control Permit

Fermilab holds two nuisance wildlife control permits with the IDNR.

- Class C: Governmental permit allows for the taking of any game mammals, fur-bearing mammals, other mammals (e.g., bats), or game birds that are causing damage to property or risks to human health or safety. Fermilab sends an annual report to the IDNR of the activities conducted to remove nuisance wildlife by January 31st of each year.

- Class E: Governmental permit allows for the destruction of Canada Goose nest and eggs on the premise that said nest is inhabited by a bird that is causing property damage, risks human health or safety, or nuisances lands governed, owned, or managed by that governmental body. Fermilab sends an annual report to the IDNR of the activities conducted to remove Canada Goose nests and eggs. The report is due on September 1st of each year. Upon the submission of the report, the permit is renewed for the following year.

2.10.2 Operation of a Class III Dam

An IDNR-issued permit classifies Fermilab's Main Injector berm as a small *Class III* dam. The dam provides limited flood control to areas downstream from the Site within the Indian Creek watershed. Reports of the condition of the dam are submitted to IDNR annually and a comprehensive inspection is completed on a five-year cycle. A comprehensive inspection was conducted in April 2018, and the *Owner's Maintenance Report* was transmitted to the IDNR. The dam was again inspected in October 2023; no non-routine action items were identified in the maintenance report transmitted to IDNR.

2.10.3 Pretreatment Permits

See Section 2.4.5 Releases to Sanitary Sewers.

2.10.4 Water Intake from the Fox River

Fermilab maintains a permit with the IDNR to withdraw water from the Fox River in order to supplement cooling water needs for the accelerator complex.

2.11 Inspections and Assessments

2.11.1 RCRA Facility Inspection by USEPA

In 2023, the USEPA performed an RCRA inspection of the Hazardous Waste Storage Facility located at Site 55 under observation of the IEPA. The purpose of the inspection was to evaluate compliance with the Laboratory's RCRA Part B Permit for the storage of hazardous waste. The inspection revealed no violations.

2.12 Continuous Release Reporting

There were no non-permitted hazardous substances released above IEPA requirements in 2023.

2.13 Unplanned Releases

There were no unplanned releases during 2023.

A colorful evening sky highlights the Center Reflecting Pond.

3. ENVIRONMENTAL MANAGEMENT SYSTEM

The Fermilab Environmental Management System (EMS) is the organizational framework that enables the Laboratory to minimize environmental impacts due to operations. The system functions via an ongoing cycle that focuses on planning, implementing, evaluating, and improving environmental performance. This process is used as a means to continuously focus on the environmental aspects of Laboratory operations to ensure compliance with regulations and to demonstrate that the facility is operating in an environmentally responsible manner. In addition, the elements of the EMS have been aligned with the principles of Fermilab's ES&H management system to form a combined process that addresses facility operational liabilities that have the potential to impact individuals and/or the environment.

The Laboratory continually evaluates operations and seeks to improve environmental performance. Environmental aspects have been identified and ranked for significance; these are reviewed and re-ranked annually. In areas where change is desired or required, milestones are established with measurable targets that seek to improve a particular aspect of operations. Goals are also outlined in the Site Sustainability Plan to document areas of significant emphasis where changes are being pursued.

Fermilab was first certified to the ISO14001 standard for environmental management in 2007. During 2017, the Laboratory transitioned to a self-declaration, which is an allowable option granted by DOE and ensures full compliance with the standard through internal assessments and third-party audits. The Laboratory's EMS was most recently audited against the elements of the ISO14001 standard by an external audit team in April 2021. The results of this audit resulted in zero major nonconformances, two minor nonconformances, four opportunities for improvement, two strengths, and one noteworthy practice. A corrective action plan addressing the minor nonconformances was formulated and submitted to the DOE FSO in May 2021; a Memorandum of Conformance was received on August 20, 2021.

3.1 Significant Environmental Issues

3.1.1 Tritium Discharges

The generation of tritium is an expected outcome of operating the accelerator complex and has been monitored throughout the history of the Laboratory. Detectable amounts of tritium have been observed in surface water discharges from the site since 2005, and Fermilab maintains permits for the release of tritium from regulated points on the site. Sanitary effluent discharged from the site to the municipal wastewater treatment plants of Batavia and Warrenville/Naperville are monitored. Low concentrations of tritium are regularly recorded in the discharge to Batavia.

In response to the persistence of observable tritium and the expectation that future operations will continue to generate additional tritium, the Fermilab Director formed a Tritium Working Group beginning in 2012. This evolved into the Tritium Task Force, which was established to identify, manage, and mitigate to the extent possible the quantity of tritium generated as a result of Laboratory operations. In 2023, the Director established the Tritium Management Department to focus additional resources on tritium issues throughout the Site.

3.1.2 Nevis Block Removal

In the Spring of 2021, the Laboratory received funds from the DOE Office of Environmental Management for use toward the management and disposal of Nevis shielding blocks, potentially contaminated soils associated with storage of the blocks, and the Nevis pole barn structure. The blocks were removed for final disposition during the year, and the activity was completed in 2023.

3.2 Environmental Operating Experience and Performance Measurement

The Site has a long history of environmental stewardship, with an early focus on ecological land management and prairie restoration dating back to the 1970s. Fermilab's vision is to be a global leader for sustainability in particle and accelerator physics and technology innovation. As a large user of energy, water, and other resources, the Lab has the responsibility to incorporate sustainability into the execution of the mission, joining the global concern over the threat of climate change and environmental issues. For over 15 years, efforts have increased to address site sustainability in support of DOE's sustainability goals and requirements. A strategic plan has been developed to guide the sustainability program and annual reports are outlined in the Site Sustainability Plan.

3.2.1 Sustainability Program

Sustainability at Fermilab is advanced by proactively seeking actions that minimize or eliminate emissions of greenhouse gases and other pollutants, reduce energy and water use, increase adaptation and resilience to the impacts of climate change, protect public and worker health, minimize waste, address anticipated harm from emerging contaminants of concern, conserve and restore ecosystems, preserve native landscapes, watersheds, and biodiversity, and deliver environmental justice.

Fermilab's sustainability program focuses on the following key strategies to achieve our vision and meet DOE's sustainability goals:

- **Making sustainability part of our culture** – We incorporate sustainability into how we meet our mission.
- **Applying best practices for sustainable operations** – We implement proven and impactful sustainability approaches into how we manage our campus infrastructure and execute our operational activities.
- **Driving discovery to achieve sustainability in science** – We discover new ways to integrate sustainability into our science strategy and execution of our mission.
- **Leveraging partnerships to drive impact** – We partner and collaborate with cross-division teams and external partners to increase the impact of our actions.

In 2023, the Lab documented significant progress in improving environmental performance across several key metrics that address priority areas of greenhouse gas emissions reduction, campus electrification, resource conservation, and education and planning.

3.2.1.1 Energy-Efficient Lighting

Fermilab continued to install energy-efficient lighting across the Laboratory to support safe and efficient workspaces. A highlight of this effort was a D-0 lighting upgrade with replacement of 36 bulbs in the high bay above a 70-foot pit. The area had been declared a "No Maintenance Zone" due to the extreme ceiling height. A special lift with a 75+ foot reach was used in the high bay area to reach the light fixtures. The lab replaced 1,080W bulbs with 320W bulbs for a savings of 26,000W; this project received a $30,000 rebate from ComEd.

3.2.1.2 Sustainable Building Features

The Laboratory took strides to plan and implement sustainable building features across the Site. Gas furnaces at 22 residential units in the Village were replaced with electric heat pumps. A Master Plan was completed for the renovation of Wilson Hall; the strategy included performance of end-of-life replacement

on two floors of Wilson Hall every year. The preliminary design for the CUB was also completed as a part of the Utilities Infrastructure Project, including the replacement of natural gas-fired boilers with electric boilers in addition to other facility upgrades. Eleven buildings on Fermilab's campus are now Guiding Principle compliant, and ten more buildings in design or construction will be compliant upon commissioning.

3.2.1.3 Zero-Emission Vehicle Roadmap

A zero-emission vehicle (ZEV) roadmap was prepared to establish a plan for converting the fleet to ZEVs, including the installation of electric vehicle charging stations (EVSE) to support the electrified vehicles. A major part of the roadmap was the development and planning of EVSE infrastructure across the Fermilab site. Alternative fuel vehicles were requested through the General Services Administration including a mix of battery electric vehicles and plug-in hybrid electric vehicles. The first phase of this EVSE deployment was completed in 2023 to support the forthcoming electric fleet of vehicles.

3.2.1.4 Integrated Engineering Research Center

Fermilab officially opened doors to its newest green building in 2023 with the Integrated Engineering Research Center, an 80,000-square-foot sustainable building designed according to the 2016 Guiding Principles for Federal Sustainable Buildings. The building provides space for research, design, construction, and testing for the development of technologies for particle detectors, including electronics and application-specific integrated circuits. The project was funded by the Science Laboratory Infrastructure program within the DOE Office of Science and is built to foster innovation across the lab by bringing scientists and engineers together under one roof. The Integrated Engineering Research Center was awarded a 2023 Best Projects Award from Engineering News-Record Midwest.

Sustainability was integral to the design and construction of the Integrated Engineering Research Center. Its state-of-the-art technical spaces and laboratories are programmed to adapt for multiple uses in the present time as well as into the future. Through modular planning principles, controllable building systems, and future-thinking performance parameters, the Center will meet the needs of today's—and tomorrow's—engineers and researchers, making it an intentionally resilient, long-lived facility.

Key sustainable features are highlighted below:

- Final project siting supports footprint reduction, infill development, and multi-modal transportation (car, bus, walking, biking) with building interconnection to Wilson Hall, leveraging amenities common to both facilities.
- Exceeds the American Society of Heating, Refrigeration, and Air-Conditioning Engineers 90.1 Standards by 25% with energy-efficient lighting, HV/AC, and design features.
- Integrated design elements reduce the need for artificial light or heating, ensuring the lab can be less energy intensive.
  - ✓ Overhangs built into the façade minimize direct sunlight.
  - ✓ Horizontal light shelves reflect daylight into deep spaces of open offices.
  - ✓ Large high clerestory windows allow natural light to penetrate further into interior spaces.
  - ✓ The design includes energy-efficient lighting and a daylight harvesting design.
- Night sky lighting for the parking lot is designed to reduce light pollution.
- The structure is 35% more water-efficient than the standard design.
- Native and drought-tolerant landscaping requires no watering.
- A 20,000-square-foot green roof allows the building to blend in with the surrounding landscape.

- Rainwater flow management controls the discharge of water from storm sewers.
- Roof and parking lot precipitation collection and drainage discharges to a bioswale and ultimately into the ICW system
- EV ready with electric conduit installed in the parking lot to enable future installation of EV charging stations.
- Bike racks promote personal use of bikes and host Fermilab bike-share bikes.
- Materials selected to prioritize waste minimization, recycling, and environmentally preferable products, including recycled and biobased content, in addition to low VOC alternatives.
- Diversion of more than 50% of clean construction demolition debris from landfills
- Purchase of Renewable Energy Credits to offset 100% of building energy consumption.

The Integrated Engineering Research Center incorporated sustainable design to establish building systems that could recover from, or mitigate the vulnerability to, climate change as weather events become more severe or unpredictable. Energy goals and other environmental performance factors were established by the integrated project team through preliminary design reports, meeting minutes, site assessments, and design charrettes. Sustainable features were implemented during the construction and project commissioning.

3.2.1.5 Dedicated Staffing

Fermilab continues to demonstrate its commitment to sustainability. In 2023, Fermilab added four full-time dedicated staff members to complement the existing matrix group of staff implementing sustainability activities. Dedicated staffing allows Fermilab to expand its matrixed sustainability team from approximately 12 individuals to 45 people who focus on strategy implementation. The expanded team had great success building valuable partnerships and recruiting many subject matter experts in 2023. New synergies were identified, fresh ideas were surfaced, and momentum grown across the Lab toward a greener, more resilient future.

3.3 Accomplishments, Awards and Recognition

3.3.1 Accomplishments

Fermilab operates an established comingled recycling program that includes the recovery of paper, glass, plastic, and metal containers. During 2023, 364 metric tons of municipal waste generated on-site were diverted for recycling. The Laboratory also recycles, when possible, various non-conventional items such as polystyrene packaging, disposable batteries, and scrap metal. The scrap metal recycling program continued to be paused throughout 2023 as part of a review of the release criteria for materials.

Several additional non-conventional recycling and repurposing programs are operated as part of waste management and diversion practices. These include a long-established agreement with local municipalities whereby neighboring cities are permitted to transport residential leaf litter they collect to the Lab; leaves are used as a soil amendment for row-crop agricultural land on-site. During 2023, 703 metric tons of yard material was delivered to the lab. In addition, composting for kitchen/food scraps from the cafeteria and three other location-sites generated 1.25 tons that were taken off-site for processing.

The Lab recycled, or donated for reuse, 100% of eligible used computer equipment that was generated in 2023, including computing and electronic equipment, including servers, printers, laptops, monitors, cell phones, tablets, and televisions. Donations for reuse are accomplished through the DOE Computers for Learning program. Recycled electronic waste was disposed of using a certified recycler. The total electronic waste generated for recycling or donation in 2023 was 59 tons.

Permanent dumpsters dedicated for the recycling of construction and demolition debris are staged on-site. These dumpsters are maintained to encourage the recycling of materials from small-scale construction projects and general maintenance activities. Contractors have been directed to use these dumpsters for waste generated from projects. Additionally, larger fixed-price construction projects are planned to include recycling opportunities. In 2023, Fermilab diverted 196 metric tons of construction and demolition waste for recycling.

3.3.2 Awards

The Laboratory was recognized with two DOE Sustainability Awards in 2023.

The long-standing partnership between Fermilab and Fermilab Natural Areas, a 501(c)3 non-profit, was awarded a DOE Strategic Partnerships for Sustainability Award for the successful ecological management of the Laboratory's campus. For nearly 20 years, this partnership has worked to maintain and enhance over four thousand acres of natural areas, including approximately 1,000 acres of restored prairie. Together, the Laboratory and Fermilab Natural Areas have maintained the iconic National Environmental Research Park, created invaluable site access opportunities for the public, preserved countless species, and carried on the original prairie restoration mission of ecologist Dr. Robert Betz. This partnership has resulted in thousands of volunteer hours each year to help maintain a healthy ecosystem. Weekly workdays allow for the public to visit the lab and work hands-on with our current ecology stewards. This opportunity establishes a sense of pride and fosters a healthy relationship with surrounding communities.

Fermi Natural Areas received the DOE Strategic Partnerships for Sustainability Award from Dr. Lia Merminga, Director of Fermilab.

Eric Mieland received the DOE Sustainability Champion Award from Dr. Lia Merminga, Director of Fermilab

Eric Mieland, an Environmental Protection Specialist within the Environmental Program Department, was recognized by DOE as a "Sustainability Champion" for his decades-long efforts to improve the Laboratory's environmental performance. Eric was a key leader of early grassroots sustainability efforts at Fermilab more than 14 years ago. He was the founder and volunteer chair of the first sustainability committee and personally recruited others to assist. Over the years, Eric has led numerous sustainability projects, including waste diversion programs, incorporation of sustainability into food service and custodial contracts, and education and outreach efforts. Eric developed Fermilab's climate vulnerability and resilience plan, working with numerous stakeholders across the Lab.

4. RADIOLOGICAL PROTECTION/DOSE ASSESSMENT

4.1 Radiological Discharges and Doses

4.1.1 Total Effective Dose Equivalent

The total effective dose equivalent received by off-site and on-site members of the public during 2023 was a combination of the individual doses received through separate pathways. Doses were calculated following Fermilab procedure ESH-RP-ERPP-03, *Radiological Dose Assessment for the Annual Site Environment Report*.

4.1.2 Dose to the Maximally Exposed Off-site Individual at the Site Boundary

The dose potentially received by the Maximally Exposed Off-site Individual (MEOI) from airborne emissions was calculated by the CAP-88PC Version 4.1.1.0 software to be 7.76×10^{2} mrem (7.76×10^{-4} mSv). See Section 6.1 for additional details.

4.1.3 Dose to MEOI from Penetrating Radiation

The dose received to the MEOI from penetrating radiation (including muons and sky shine) was estimated to be 0.65 mrem (6.5×10^{-3} mSv). See Section 6.2 for additional details.

4.1.4 Dose to MEOI from Ingestion of Water

The dose of the MEOI from the ingestion of water was estimated using the Derived Concentration Standard (DCS) from DOESTD-1196-2021. The DCS is the concentration of the radionuclide in that medium that would result in an effective dose of 100 mrem (1 mSv) to a member of the public based on continuous exposure for one year. It should be emphasized that none of the water at the Fermilab outfalls is suitable for or known to be used as drinking water and would not be expected to be the only source of drinking water for an individual over a year; however, this method is used to determine the maximum potential dose to the MEOI. In 2022, the only radionuclide detected in surface water was tritium. The highest annual average concentration of tritium at a Fermilab outfall was 5.8 pCi/mL at the Indian Creek outfall. Using this concentration as a fraction of the per capita DCS, the dose to the MEOI was estimated to be 0.22 mrem (2.2×10^{-3} mSv).

4.1.5 Maximum Potential Dose from Ingestion of Fish

The maximum potential dose from the ingestion of fish in the water beyond the Fermilab outfalls was calculated using the per capita dose coefficient for tritiated water ingestion, 2.1×10^{-11} sievert per becquerel, as provided in DOE-STD-1196-2021. For this calculation, the MEOI was assumed to consume 50 pounds of fish (conservatively rounded up from the United States Department of Agriculture recommendation of 26 pounds per year). Other conservative measures include the assumption that all fish consumed were caught near the Indian Creek outfall, the concentration of tritium within the fish was equivalent to the concentration within the water, and no water was lost during the cooking process. Using this calculation, the maximum potential dose from eating 50 pounds of fish is estimated at 1.0×10^{-2} mrem (1.0×10^{-4} mSv).

4.1.6 Potential Total Effective Dose to MEOI

The potential total effective dose to the MEOI for 2023 was 1.0 mrem (1.0×10^{-2} mSv); this was calculated from the sum of the airborne, direct radiation, and water pathways. It is unlikely that such a combination of “maximized dose” to any single individual would occur, but the concept is useful for evaluating the maximum potential dose and risk to members of the public. The potential total effective dose of 1.0 mrem

(1.0×10^{-2} mSv) is well below the limit of 100 mrem/year (1 mSv/year) for a member of the public and is also far below the natural background dose received by the typical American of 311 mrem (3.1 mSv) from National Council on Radiation Protection and Measurements (NCRP) Report No. 160, *Ionizing Radiation Exposure of the Population of the United States*.

4.1.7 Dose to the MEI On-site

The dose to the maximally exposed individual (MEI) on-site from air emissions was calculated using CAP-88PC Version 4.1, similar to the dose off-site. For the on-site dose, the location used was the public area nearest the location of the stacks, approximately 300 meters in the north-northeast direction near the Lederman Science Center. To determine a maximum bounding dose, all emissions were assumed to be released from a central stack location in the Muon Campus; however, many stacks are located more than 300 meters from the location. For continuous occupancy, the dose received by the MEI on-site from air emissions would be 0.34 mrem (3.4×10^{-3} mSv); however, since the public is only permitted on-site from dawn to dusk, the maximum potential dose to the on-site MEI would be 0.17 mrem (1.7×10^{-3} mSv). Adjusting for a more realistic occupancy of 400 hours per year (approximately 1 day per week or 1 hour per day), the potential dose to the on-site MEI from airborne emissions would be 1.7×10^{-2} mrem (1.7×10^{-4} mSv).

A network of environmental dosimeters was placed in indoor and outdoor locations to assess potential doses to Fermilab workers and members of the public. The dose in most publicly accessible areas is indistinguishable from the background. Of the environmental dosimeters located in areas where public access is allowed, the highest dose would be received in a location along the Linac fencing. For continuous occupancy and assuming a member of the public occupied this location every day of the year, the maximum dose received from penetrating radiation by the on-site MEI would be 11 mrem (1.1×10^{-1} mSv) per year. Adjusted for the site access hours of dawn-to-dusk, the maximum dose received from penetrating radiation by the on-site MEI would be 5.5 mrem (5.5×10^{-2} mSv) per year. Adjusting for the more realistic occupancy of 400 hours per year, the potential dose to the on-site MEI would be 0.55 mrem (5.5×10^{-3} mSv) per year. It should be noted that it is extremely unlikely that a member of the public would reside in the location by the Linac fencing for the full 400 hours and would be more likely to occupy additional locations with lower dose rates during their time on-site.

The potential total effective dose to the on-site MEI for 2023 using realistic occupancy assumptions was the sum of the airborne and direct radiation pathways, 1.0 mrem (1.0×10^{2} mSv). As with the MEOI, it is highly unlikely that such a combination of “maximized dose” to any single individual would occur, but the concept is useful for evaluating the maximum potential dose and risk to members of the public. The potential total effective dose for 2023 of 1.0 mrem (1.0×10^{-2} mSv) is well below the limit of 100 mrem/year for a member of the public and is also far below the natural background dose received by the typical American of 311 mrem (3.1 mSv) from NCRP Report No. 160, *Ionizing Radiation Exposure of the Population of the United States*.

4.1.8 Collective Dose

Approximately nine million people were estimated to live within 50 miles (80 kilometers) of Fermilab, according to the 2020 census. For air emissions, the collective effective dose equivalent was calculated using CAP-88 as required for reporting under 40 CFR 61, Subpart H. The collective dose equivalent for 2023 was calculated to be 4.6×10^{-1} person-rem (4.6×10^{-3} person-sievert [Sv]).

For direct radiation, the site boundary dose discussed in section 9.1.2 was adjusted by the inverse square law to the midpoint distance of the population grid for each sector. This estimated dose was assigned to the population within the sector, and the dose for each sector was summed. The estimated dose from direct radiation for 2023 was 1.4 person-rem (1.4×10^{-2} person-Sv).

The only liquid discharge that is used for a community drinking water system is from the Batavia sanitary treatment plant, which is discharged into the Fox River. The City of Aurora (population 180,542 persons as of the 2020 census) uses the Fox River as a community drinking water system. Accounting for the minimum flow volume of the Fox River (101,000,000 gallons/day), the average tritium concentration in the Fox River in Aurora is estimated to be 1.9×10^{-3} pCi/mL (7.0×10^{-2} Bq/L). This average concentration resulted in an estimated collective dose of 1.3×10^{-2} person-rem (1.3×10^{-4} person-Sv) using the per capita DCS from DOE-STD-1196-2021. The total collective dose from all pathways was 1.9 person-rem (1.9×10^{-2} person-Sv). There is no regulatory limit for collective dose.

The dose to the MEOI and the collective population compared to the respective limits and doses received from natural background are summarized below.

Pathway	**Dose to the MEOI** mrem/year (mSv/year)	**MEOI Percent (%) of the DOE** 100 rem/year limit	**Estimated Natural Background** mrem/year (mSv/year)	**Estimated Annual Collective Dose** person-rem (person-Sv)	**Population within 80 km**	**Estimated Annual Background Radiation Population Dose** person-rem (person-Sv)
Air	8.0×10^{-2} (8.0×10^{-4})	0.08%	N/A	4.6×10^{-1} (4.6×10^{-3})	9.1×10^{6} persons	N/A
External	6.5×10^{-1} (6.5×10^{-3})	0.65%	N/A	1.4×10^{0} (1.4×10^{-2})	9.1×10^{6} persons	N/A
Water	2.3×10^{-1} (2.3×10^{-3})	0.19%	N/A	1.3×10^{-2} (1.3×10^{-4})	180,542 (City of Aurora)	N/A
All Pathways	1.0 (9.6×10^{-3})	1.0%	311 (3.1)	1.9 (1.9×10^{-2})	9.1×10^{6} (9.1×10^{4})	2.8×10^{6} (2.8×10^{4})

The dose to the on-site MEI compared to the respective limits and doses received from natural background is summarized below.

Pathway	**Dose to the On-site MEI (400-hour occupancy time)** mrem/year (mSv/year)	**On-site MEI Percentage of the DOE 100 mrem/year Limit**	**Estimated Natural Background** mrem/year (mSv/year)
Air	1.7×10^{-2} (1.7×10^{-4})	0.02%	N/A
External	5.5×10^{-1} (5.5×10^{-3})	0.55%	N/A
Water	N/A	N/A	N/A
All Pathways	5.7 x 10-1 (5.7×10^{-3})	0.6%	311 (3.1)

4.1.9 Penetrating Radiation - Off-site

Operation of the Fermilab accelerator and associated beamlines produces ionizing radiation such as neutrons and muons. Beamlines and experiments are designed so that most of the radiation is absorbed before reaching the ground surface and outdoor areas. The neutrons are absorbed by shielding; the remaining radiation that emerges above the surface presents a very small potential for radiation dose. Doses were calculated following Fermilab procedure ESH-RP-ERPP-03, *Radiological Dose Assessment for the Annual Site Environment Report*.

Small muon fields have been measured in conjunction with the operation of the beamlines in the past. The Meson Test (MTest) and Meson Center (MCenter) beamlines operated in 2022. The muon dose off-site due to the operation of Mtest and MCenter was 0.042 mrem (4.2×10^{4} mSv). Both the BNB and NuMI experiments have the potential to produce measurable muon flux; however, the eight giga-electron volt energy protons used in BNB are too low in energy to produce muons that can escape the bulk shielding surrounding the experiment. The NuMI beamline bends the beam down so that the muons produced are absorbed deep underground as part of the beamline design.

Another potential source of exposure to ionizing radiation is the centralized radioactive materials storage area referred to as the Railhead. This source of penetrating radiation was monitored continuously in 2022 by a large ionization chamber located in the Railhead, colloquially called a ‘Hippo.’ The Hippo measurements are supplemented by several environmental dosimeters placed around the storage area and by periodic on-site surveys. Based on measurements made, it is estimated that radioactive materials stored at the Railhead contributed no directly measurable equivalent dose at the site boundary in 2022.

Radiation doses at the site boundary can also potentially occur from sky shine, where radiation reaches the site boundary through reflection and scattering in the atmosphere back to the earth’s surface. Skyshine doses are typically too low to be directly measurable; therefore, Fermilab estimates skyshine using conservative assumptions when evaluating new facilities or activities. The sum of the estimated sky shine for current Fermilab activities is approximately 0.61 mrem (6.1×10^{-3} mSv), primarily from the Main Injector and booster.

The three sources of penetrating radiation were highest at different locations at the site boundary; however, for purposes of calculating a maximum bounding dose, they were added. The maximum total penetrating radiation equivalent dose in 2022 to an individual at the nearest off-site residence was thus estimated to be 0.65 mrem (6.5×10^{-3} mSv) and not directly measurable.

4.1.10 Penetrating Radiation - On-site

Environmental dosimeters were placed in approximately 250 indoor locations and 70 outdoor locations to assess potential doses to Fermilab workers and members of the public. The dose in most publicly accessible areas is indistinguishable from the background. Of the environmental dosimeters located in areas where public access is allowed, the highest potential dose was in a location along the Linac fencing. Assuming continuous occupancy of 24 hours per day, 365 days per year in the maximum public location, the maximum dose received from penetrating radiation would be 11 mrem (1.1×10^{-1} mSv) per year. Adjusted for the site access hours of dawn-to-dusk and assuming a member of the public resided in this location every day of the year, the maximum dose received from penetrating radiation by a hypothetical member of the public would be 5.5 mrem (5.5×10^{-2} mSv) per year. Adjusting for a more realistic occupancy of 400 hours per year (approximately 1 hour per day), the potential dose to the hypothetical maximum individual would be 0.6 mrem (6.0×10^{-3} mSv) per year.

4.2 Clearance of Property Containing Residual Radioactive Material

Fermilab has an established program that requires monitoring of potentially activated or contaminated material and equipment before release from control. Fermilab uses DOE pre-approved authorized limits for radioactive surface contamination. As DOE Order 458.1 does not prescribe a specific limit for the release of volumetrically activated materials, Fermilab survey procedures require monitoring such that equipment and materials being released contain no detectable radioactivity. The program involves many hundreds of radiological surveys annually. Fermilab does not release any residual radioactive material, such as contaminated concrete or soil, so there are no resulting dose impacts to the public.

Fermilab has operated an active scrap metal recycling program for many years. The program includes policies and procedures to ensure that the DOE secretarial mandates regarding the moratorium and suspension on the release of scrap metals from departmental sites are not violated. Historically, as a general operating principle, Fermilab has not released radioactive metals as scrap. Beginning in 2000, to comply with the suspension directive, the Laboratory began holding non-radioactive scrap metals originating from radiological areas (as defined by 10 CFR 835). This material has been accumulating since the suspension became effective. Direct impacts as a result of the suspension include the loss of scrap revenue, the costs associated with the management and storage of this material, and the potential future cost of disposal if it cannot be scrapped.

Fermilab's established material screening process has incorporated numerous ongoing improvements that have been made since 2000, including a Material Move Request form to identify and document which metals are eligible for recycling. These metals were then subjected to multiple hand-held radiation surveys and must have passed successfully through the vehicle scrap monitor before leaving the site. In 2021, Fermilab paused the clearance of metal to develop and implement enhancements to the program to incorporate the guidance from DOE-STD-6004-2016, *Clearance and Release of Personal Property from Accelerator Facilities* (May 2016). The new process was approved in 2022; however, metal was not cleared for recycling in 2023.

Fermilab did not release any real property in 2023.

4.3 Addressing Radiation Protection of Biota in ASERs

4.3.1 Dose Rate Limits for Protection of Biota

DOE Order 458.1 requires the protection of populations of aquatic animals, terrestrial plants, and terrestrial animals in local ecosystems from adverse effects due to radiation and radioactive material released from DOE operations. In 2023, Fermilab used the DOE Technical Standard, DOE-STD-1153-2019, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (February 2019) to evaluate compliance with the biota protection requirements of DOE Order 458.1. Doses were assessed for compliance with the biota dose rate criteria specified in DOE-STD-1153-2019, summarized below.

DOE Category	Average Dose Rate Criteria
Aquatic Animals	Absorbed dose < 1 rad per day (rad/d) (10 milligray per day [mGy/d])
Riparian Animals	Absorbed dose < 0.1 rad/d (1 mGy/d)
Terrestrial Plants	Absorbed dose < 1 rad/d (10 mGy/d)
Terrestrial Animals	Absorbed dose < 0.1 rad/d (1 mGy/d)

DOE-STD-1153-2019 provides a graded (tiered) approach to evaluating biota protection. DOE's graded approach for evaluating radiation doses to aquatic and terrestrial biota consists of a three-step process: Data Assembly, General Screening, and Analysis (if necessary). The first step, Data Assembly, involves the collection of environmental media data: the measured radionuclide concentrations in water, sediment, and soil.

In 2023, three radionuclides were detected in surface water: tritium, sodium-22, and sodium-24. The maximum surface water concentrations of tritium and sodium-22 were 25.72 pCi/ml (952 Bq/L) and 0.016 pCi/ml (0.59 Bq/L), respectively, both of which were detected in Kidney Pond. The maximum sodium-24 surface water concentration was 0.05745 pCi/ml (2.13 Bq/L), collected from Booster Pond. Tritium was the only radionuclide detected in sediment at a maximum concentration of 4.88 pCi/g (0.18 Bq/g), collected from Indian Creek at the Site Boundary. Tritium was the only radionuclide detected in soil at a maximum concentration of 6.51 pCi/g (0.24 Bq/g), collected near the AP0 Stack.

The second step of the process, General Screening, involves the comparison of the maximum measured radionuclide concentrations in water, sediment, and soil with Biota Concentration Guides (BCGs). Each radionuclide-specific BCG represents the limiting concentration of a radionuclide in water, sediment, or soil, which would not result in dose limits for biota (listed above) being exceeded. Doses to aquatic and terrestrial organisms were estimated using the maximum measured radionuclide concentrations in surface water, sediment, and soil and comparing them with BCGs in DOE-STD-1153-2019 and RESRAD-BIOTA.

4.3.2 The RESRAD-BIOTA Code as a Tool for Evaluating Doses to Biota

The graded approach presented in DOE-STD-1153-2019 is also intended for use with the RESRAD-BIOTA software. This dose evaluation code was specifically designed to complement the graded approach methodology for evaluating radiation doses to aquatic and terrestrial biota and contains BCGs for contaminated water, sediment, and soil. To complete the General Screening process, the maximum measured radionuclide concentrations in surface water, sediment, and soil were compared with BCGs in DOE-STD-1153-2019 and the associated RESRAD-BIOTA code (Version 1.8).

The BCG for tritium and the corresponding concentration-to-BCG ratio were calculated using the RESRAD-BIOTA code. Neither sodium-22 nor sodium-24 has a BCG listed in DOE-STD-1153-2019, and neither radionuclide is available to select in RESRAD-BIOTA. Therefore, BCGs for both sodium-22 and sodium-24 in water were determined for each DOE Category using the methodology in DOE-STD-1153-2019, and their corresponding concentration-to-BCG ratios were calculated.

DOE Category	Sum of Fractions	Sum of Fractions < 1.0?
Aquatic Animals	3.6×10^{-4}	Yes
Riparian Animals	3.7×10^{-3}	Yes
Terrestrial Plants	1.6×10^{-5}	Yes
Terrestrial Animals	5.1×10^{-4}	Yes

The sum of fractions (the summed ratios between the radionuclide concentrations in water, sediment, and soil and the radionuclide specific BCGs) for each DOE Category is summarized below. Each category has a sum of fractions that is less than 1.0, indicating the dose to an aquatic or terrestrial organism is below the biota dose limit. Therefore, all locations passed the General Screening phase using maximum radionuclide concentrations and default parameters for Biota Concentration Guides, and the evaluation is complete.

4.4 Unplanned Radiological Releases

There were no unplanned releases of radionuclides during 2023.

4.5 Environmental Radiological Monitoring

4.5.1 Radioactive Air Emissions

Fermilab monitors radioactive air emissions associated with operations. These emissions are kept as low as reasonably achievable (ALARA) and fall well below the United States Environmental Protection Agency (USEPA) emission standards.

4.5.1.1 Off-site Radioactive Air Emissions

Airborne radionuclides are normally released into the atmosphere from operating target stations, accelerators, and beamlines. Measures to keep these releases ALARA are incorporated into operating processes and procedures at these facilities and in design efforts for new projects. Monitoring is conducted in areas with significant radioactive air emissions.

The radiation doses potentially received by the off-site public due to Fermilab operations are calculated from data gathered through environmental surveillance of the on-site sources. Selected vent stacks are monitored directly with stack monitors and indirectly by taking soil samples near the stacks. The dose for the air pathway is calculated using a Gaussian plume computer simulation model called Clean Air Act Assessment Package-1988 (CAP88PC Version 4.1.1.0). This model was created by the USEPA to predict the movement of airborne radionuclides, and its use is dictated by regulations governing hazardous air pollutants (CFR 61). Fermilab is subject to Subpart H of this regulation, which specifically exempts Fermilab from the requirements of 40 CFR 61.10. Since Fermilab emissions have always been kept below 1% of the 10 millirem (mrem) per year maximum allowed by the standard (i.e., 0.1 mrem), continuous monitoring is not required. Maximum calculated concentrations off-site are predicted to be below the level that could be detected by direct monitoring. Because the doses are calculated based on actual radionuclide concentration release rates rather than directly measured concentrations, they represent potential or estimated doses.

Radionuclide	Half-life	Annual Quantity
O-15	2.0 minutes	1.24×10^{1} Ci (4.59×10^{2} GBq)
C-11	20.3 minutes	2.82×10^{1} Ci (1.04×10^{3} GBq)
N-13	10.0 minutes	1.33×10^{1} Ci (4.92×10^{2} GBq)
Ar-41	1.8 hours	1.93×10^{1} Ci (7.14×10^{2} GBq)
H-3	12.3 years	9.23 Ci (3.42×10^{2} GBq)
Total	82.5 Ci (3.05×10^{3} GBq)	

In 2023, the accelerator and the experiments operated throughout the calendar year, except for the standard annual maintenance shutdown that lasted anywhere from ten to twelve weeks for different machines and periodic maintenance activities throughout the year. The Muon Campus used eight giga-electron volt protons for muon production for the Muon g-2 experiment. The NuMI Off-axis ν_e Appearance experiment (NOvA) operated in the NuMI beamline, approaching 900-Kilowatt proton beam.

The MicroBooNE experiment on the Booster Neutrino Beam (BNB) beamline and a series of experiments that operated in the Meson Center and Meson Test Areas were the Fixed Target experiments operating during 2023. The MeV Test Area operated as an irradiation test facility. Two agents were debonded at the Magnet Debonding Oven facility.

The total radioactive air emissions in 2023 were approximately 82.5 Ci.

Doses to the public off-site from emissions in 2023 continued to be well below the USEPA standard of 10 mrem (1 x 10^{-1} millisieverts [mSv]) in a year and less than the USEPA's continuous monitoring threshold of 0.1 mrem (1 x 10^{-3} mSv) in a year. Using the CAP88-PC Version 4.1.1.0 Gaussian dispersion model and adult dose and risk factors from Federal Guidance Report 13, the highest dose equivalent to a member of the public off-site was estimated to be 5.63 x 10^{-2} mrem (5.63 x 10^{-4} mSv). Fermilab's 2023 Radionuclide Air Emissions Annual Report will be submitted to the DOE FSO in Spring 2024. The report is distributed by DOE FSO to the USEPA and IEPA.

4.5.1.2 On-site Radioactive Air Emissions

The dose to the MEI on-site from air emissions was calculated using CAP-88PC Version 4.1.1.0, similar to the dose off-site. For the on-site dose, the location used was the public area on-site nearest the location of the stacks, approximately 300 meters in the north-northeast direction. For continuous occupancy, the dose received by the MEI on-site would be 0.33 mrem (3.3 x 10^{-3} mSv); however, since the public is only permitted on-site from dawn to dusk, the maximum potential dose to the on-site MEI would be 0.17 mrem (1.7 x 10^{-3} mSv). Adjusting for a more realistic occupancy of 400 hours per year (approximately 1 day per week or 1 hour per day), the potential dose to the on-site MEI from airborne emissions would be 0.017 mrem (1.7 x 10^{-4} mSv).

4.5.2 Radioactive Surface Water Monitoring

Fermilab has conducted an environmental monitoring program on-site for roughly 50 years. In November of 2005, for the first time, the lab detected low levels of tritium in Indian Creek, one of three creeks that travel through the Fermilab site. Low but measurable levels of tritium continue to be detected in the three creeks. All tritium levels found on-site are well below the corresponding federal health and environmental standards.

Winter hues and reflections at Fermilab

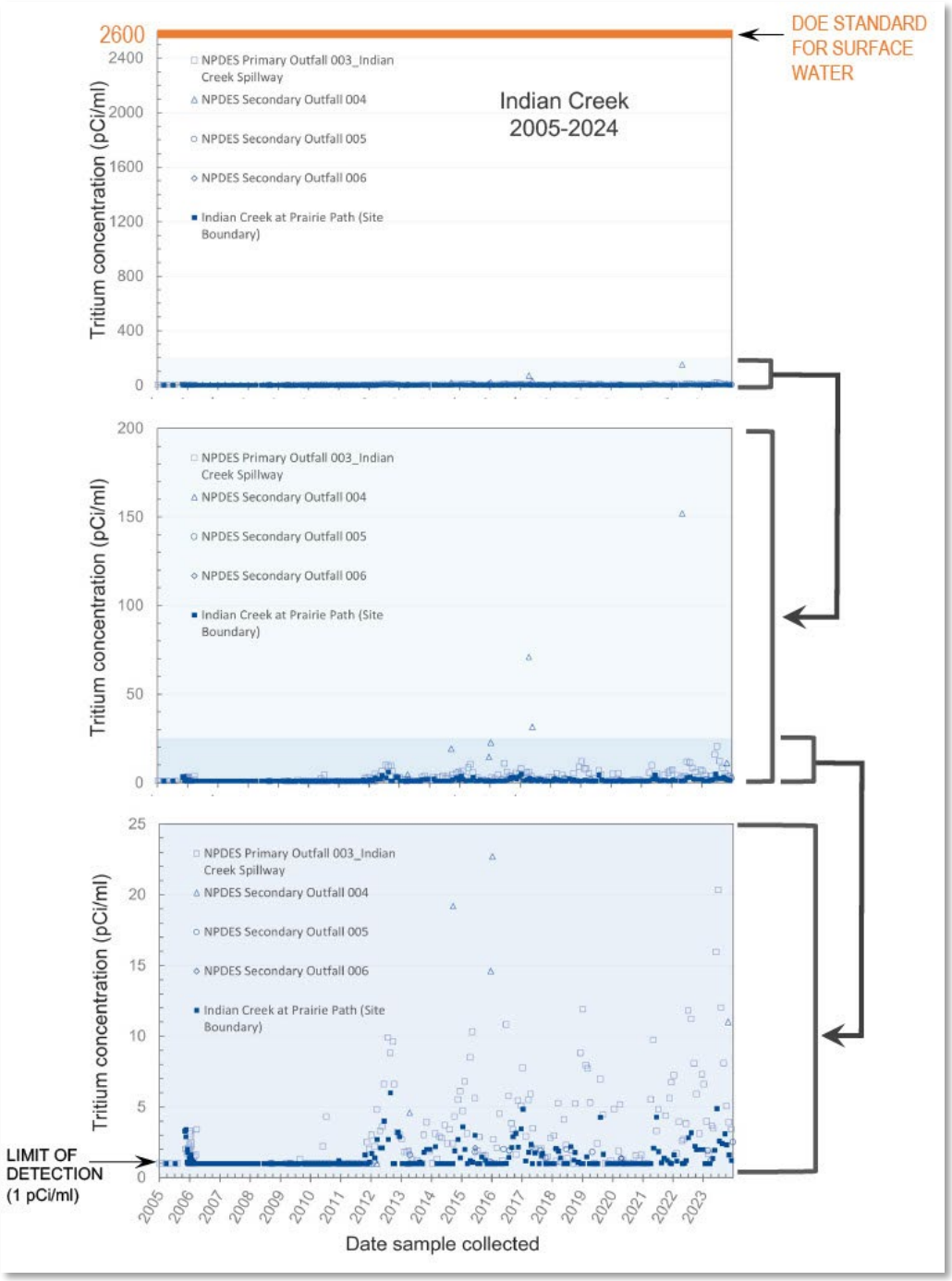
The Department of Energy standard for surface water is 2,600 picocuries per milliliter, and the lab's readings at the site boundaries to date have remained in the single digits. In our ponds, the levels are typically less than 20 picocuries per milliliter. The levels of tritium detected in the creeks and ponds on-site are extremely low compared to what is safe for a lifetime of continuous exposure to tritium in surface water.

The low levels of tritium in the surface water on-site stem from particle beams produced in accelerator tunnels. Water with low levels of tritium is pumped out of the accelerator tunnels and used in our cooling systems and ponds. Some of that water flows into the creeks on-site. Samples are collected monthly at many locations on-site to monitor tritium in this water flow.

These low tritium levels are reduced to undetectable levels as the tritiated water is quickly diluted flowing through the creek. For example, the amount of tritium that Indian Creek adds to the Fox River is less than that added naturally by rainwater.

Fermilab regularly samples the water from Indian Creek, Kress Creek and Ferry Creek at least once per month when there is water flowing. The results of samples taken near the property boundary (indicated on the map) are posted on to Fermilab's tritium webpage. In addition, we report results taken in surface water on-site to the Illinois Environmental Protection Agency in compliance with permits for surface water flowing off-site.

In 2023 tritium levels in surface water remained low. The highest outfall concentration was observed at Outfall 003 in Indian Creek (20.3 pCi/mL).



Tritium concentrations from the Indian Creek Watershed. Results are shown against the Derived Concentration Standard (2,600 pCi/mL) and the Federal drinking water standard (20 pCi/mL).

4.5.3 Radioactive Settleable Solids Monitoring

The purpose of monitoring settleable solids is to ensure that liquid discharges containing radionuclides from Fermilab do not contain radionuclides above the levels specified in DOE Order 458.1 section 2.g.(4) and to detect potential long-term buildup of radioactive material that could build-up in sediments. In 2023 Fermilab monitored for settleable solids at 6 locations. No APIs were detected in any of the 6 samples.

4.5.4 Groundwater Monitoring for Radioactive Constituents

The purpose of groundwater sampling is to assess subsurface conditions and to ensure that discharges to and activation of groundwater are in compliance with the following:

- Illinois Administrative Code (IAC) Part 620 for Class I groundwater quality standards (GQSs; <20 pCi/mL federal drinking water standard for tritium)
- IAC Part 620.301(a)(2) [Section 620 (ilga.gov)] non-degradation clause for tritium in Class I groundwater in bedrock

Groundwater monitoring is performed to ensure that possible sources of, and potential for, radiological contamination are identified and assessed in accordance with DOE Order 458.1 2.i.(2)(b). Monitoring of groundwater beneath the Site is critical to identify impacts of past, current, and/or future Site activities as well as characterization of contamination to allow for implementation of remediation as necessary.

piezometer: a monitoring well used solely for the measurement of water levels rather than the collection of samples, or a transducer encased within a borehole construction (e.g., vibrating wire transducers installed at LBNF)

Monitoring is also essential to quickly identify radioactive contamination of groundwater resources if radionuclides migrate downward from activated soil in the vicinity of beamlines or other experimental areas, and to monitor for the existence and subsequent migration of any chemical contamination.

Five monitoring wells screened in the upper dolomite (one upgradient and four downgradient of historic activation areas in the Meson/Neutrino Fixed Target area) monitor for the presence of tritium and accelerator-produced isotopes in Class I groundwater. This area was removed as a SWMU from the RCRA Part B Permit but is monitored annually. The upgradient well is MS-1 and downgradient wells are NS1-4, NS2-4, NS2-5 and S-1290. Five piezometers supplement information for groundwater levels to ensure that monitoring wells remain downgradient of areas of concern; no radionuclides have been detected in any of these wells. In 2023, no radionuclides were detected in the Class I groundwater beneath the Meson/Neutrino Fixed Target area.

Six “sump” wells at BNB are routinely sampled for tritium. Different from typical monitor wells, these sump wells drain the north and south ends of the interior interstitial space and exterior of the dual-liner system around the decay pipe via lateral pipes. Water in the interior and interstitial sump wells originates from surface infiltration that flows through the damaged liner system near the north end, which is also adjacent to the Main Injector 13A building. Most of the water in the exterior wells originates from surface and lateral infiltration that makes its way to the sides and underside of the liner system. An amount of water in these wells also comes from infiltration from leaks in the laterals that lead to the interior and interstitial sump wells.

- A canopy and surface liner constructed in 2018-2019 redirect water from the MI-12/BNB area.
- Four 33-foot monitor wells installed around the BNB canopy in September 2021 evaluate lateral flow into or from the decay pipe liner system; results of samples through 2023 were non-detect (<1 pCi/mL) for tritium.
- Tritium results in 2022 ranged between <1 and 12,300 pCi/mL; this water was routed to the Main Injector ponds or Casey's Pond; if concentrations exceeded 2,600 pCi/mL, it is contained and shipped off-site for disposal.
- Tritium concentrations and volumes of infiltration water in the BNB sump wells have decreased through 2023 and will continue to be monitored to evaluate the potential impact on groundwater.

At MI-65, one groundwater monitoring well was installed in September 2021 immediately adjacent to the southwest roof downspout. The tritium results in this well have decreased from 83 pCi/mL since 2021. In addition, a borehole was installed between the downspouts located to the southwest and southeast; groundwater was collected from the shallow groundwater zone (seven to 12 feet below ground surface). Tritium was detected from this well at 251 pCi/mL.

Five utility-backfill wells were installed within the area of MI-65 in September 2021 to evaluate utility line impact on subsurface migration. Most utility backfill wells were dry in 2021, 2022, and 2023, with non-detect results southeast of MI-65 and results of <10 pCi/mL in the sanitary sewer backfill northeast of MI-65. No additional utility backfill wells are planned.

Groundwater samples were collected from two monitoring wells located adjacent to the NuMI Target Hall in the bedrock Brainard Formation intersecting the bottom of the NuMI Target Hall (i.e., S1423-2 and S-1426-2). These wells were sampled in March and again in December 2023; no tritium or other API were detected above the reporting limit.

Designs for additional monitoring well(s) in the deep till zone (~30-40 feet bls) will be evaluated.

4.5.5 Radioactive Sanitary System Monitoring

As part of the environmental monitoring program, Fermilab routinely samples the sanitary sewer discharge released to the wastewater treatment systems in the cities of Batavia and Warrenville. Analyses of samples taken from sanitary sewer water discharged to the Batavia Wastewater Treatment Facility indicate small but measurable levels of tritium. The tritium levels found on-site are well below federal health and environmental standards.

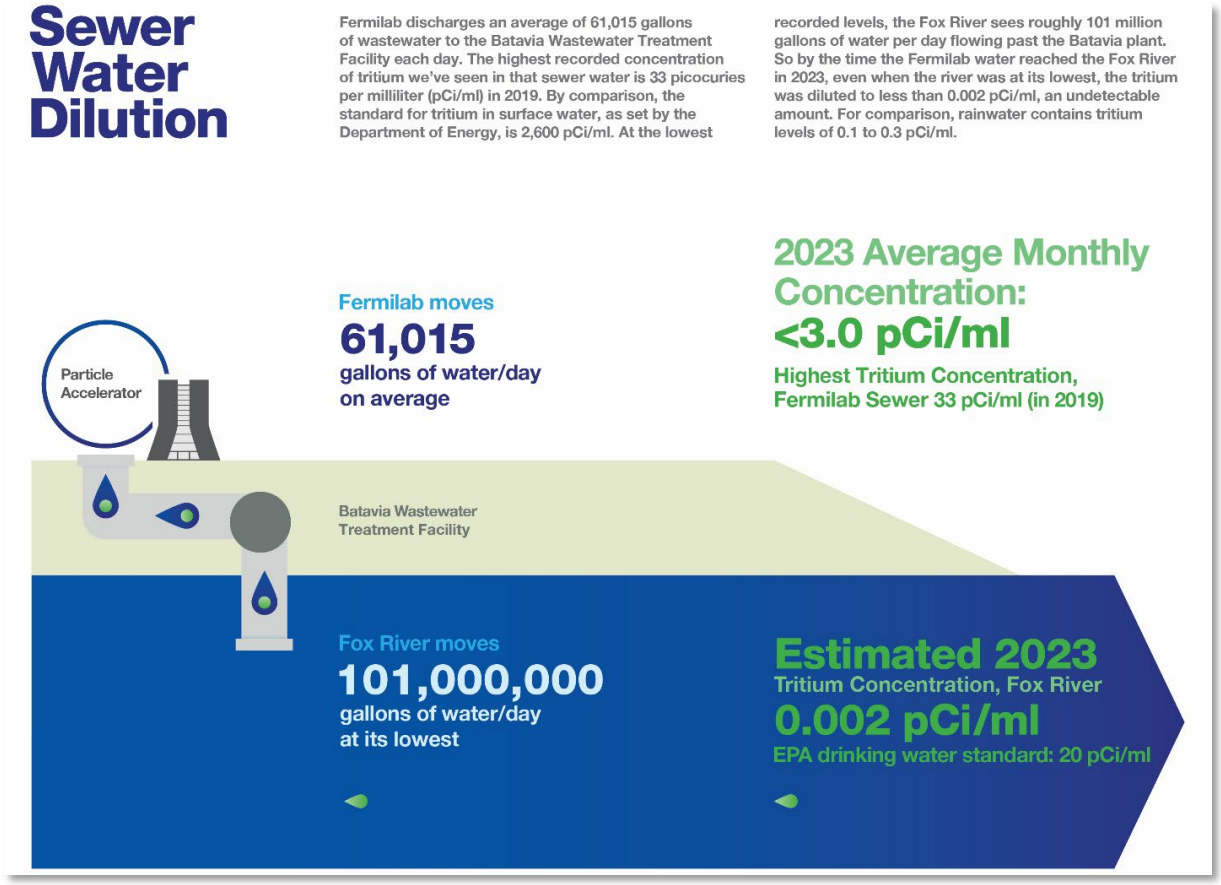
An average of 61,015 gallons of sewer water is discharged to the wastewater treatment facility in Batavia each day. The lab has conducted environmental monitoring of the sanitary sewer water since the mid-1990s. In 2005, low levels of tritium were detected in sanitary sewers for the first time. To date, the annual average level detected in the sanitary sewer water discharged to the city of Batavia is roughly five to ten picocuries per milliliter (pCi/mL). The lab is required to meet the DOE requirement of discharge concentrations less than five Ci of tritium total per year. The annual load in 2023, based on the discharge volumes and the plotted concentrations, was less than 0.3 Ci.

Water from the sanitary sewer treated in Batavia's wastewater treatment facility is discharged into the Fox River. While no treatment removes tritium from water, the low levels measured in the sanitary sewers are diluted to undetectable levels by the time they reach the Fox River. The amount of tritium added to the Fox River is less than that added naturally by rainwater.

Tritium has not been detected in sanitary sewer water discharged from Fermilab to the City of Warrenville.

Fermilab takes the release of tritium seriously and is not satisfied with merely meeting regulatory requirements. The lab's Tritium Task Force, comprised of physicists, scientists, and engineers from across the Laboratory, actively investigates the sources of tritium in the sewer water and determines how to minimize it.

The lab routinely collects samples from the sanitary sewers on site and posts the results of these readings at https://www.fnal.gov/pub/tritium/index.html.



Fermilab has housed a herd of bison since 1969 when Robert Wilson, the first Lab Director, established the bison as a symbol of Midwestern prairie and the Lab's pioneering research at the frontiers of particle physics.

5. NON-RADIOLOGICAL ENVIRONMENTAL MONITORING

The goal of Fermilab's Environmental Monitoring Program is to assist Laboratory management in decision-making by providing data relevant to the impacts the facility operations have on the surrounding environment. The program includes effluent monitoring, which is used to confirm compliance with permits associated with various discharge points from the facility.

Environmental surveillance is conducted at locations to intercept the pathway of potential pollutants to receptors such as plants, animals, or members of the public. Fermilab collects environmental data for regulatory compliance, reporting requirements, and other purposes deemed necessary or useful in conducting the business of the Laboratory. Line organizations have the responsibility to recognize and understand the environmental aspects of their operations and to conduct their work in an environmentally-sound manner.

Collection and analysis of samples of various media and measurements of penetrating radiation (e.g., muons) are conducted within and at site boundaries. The pathways with the greatest potential for the transport of chemical or radioactive materials resulting from Fermilab operations to the environment include the atmosphere, surface water (including sewer systems), groundwater, and roadways (transportation of materials to and from the site).

In addition to monitoring for potential chemical constituents, surface water, groundwater, soil, sediment, and air samples are routinely analyzed for radionuclide concentrations. Groundwater and surface water are routinely sampled at locations near operating areas, potential contamination sources, and along potential transport pathways. In addition to air and water surveillance, soil samples are collected and analyzed for radioactivity to ascertain whether the build-up of radioactive materials has occurred in the environment due to long-term operations. While levels of penetrating radiation are measurable near some operational areas on the site, these levels have been shown to decrease rapidly with distance from the sources. External penetrating radiation and airborne emissions are routinely detected below instrument detection levels at the site boundary; further evaluation of these numbers includes estimations to assess the maximum potential radiation doses to off-site populations.

The results of the environmental surveillance program are interpreted and compared with environmental standards where applicable. The Fermilab Environmental Monitoring Plan, which is maintained by the Environmental Program Department (EPD) within the ES&H Division, provides more details.

5.1 Non-Radioactive Air Emissions

Fermilab is registered as a small source of air pollution emissions with IEPA under the State's Registration of Smaller Sources (ROSS) Program. The lab demonstrates continued compliance with the conditions of the ROSS program by tracking and reporting air emission sources as required by the program. These monitored sources include the following:

- Natural gas-fired boilers
- Gasoline storage tank
- Radionuclide emission stacks
- Standby diesel generator
- Cavity processing lab
- Magnet de-bonding oven

From these sources, emissions are tracked and reported for five CAPs (particulate matter, carbon monoxide, nitric oxide, sulfur dioxide), volatile organic material, and/or total hazardous air pollutants.

5.2 Non-Radioactive Surface Water Monitoring

Fermilab's NPDES permit for Non-Contact Cooling Water and Storm Water This permit addresses combined stormwater and non-contact cooling water discharges associated with industrial activities. Six outfalls are associated with this permit:

- Outfall 001 discharging to Ferry Creek
- Outfall 002 discharging to Kress Creek
- Outfalls 003, 004, 005, and 006 discharging to Indian Creek

Outfall 004 addresses potential discharges from the Main Injector Neutrino Oscillation Search experiment ICW holding tank. Outfalls 005 and 006 address discharges from the Main Injector pond system. The permit requires Fermilab to record and report to IEPA monthly certain physical and chemical discharge parameters. From all six outfalls, water temperature, pH, flow, and tritium are reported. Additionally, chlorine concentration is reported from outfalls 001 and 002 discharging to Kress and Indian Creeks.

5.3 Non-Radioactive Groundwater Monitoring

Fermilab monitors groundwater for non-radioactive constituents at the location of the former CUB Tile Field (SWMU 12). Sampling is conducted quarterly, and groundwater samples are analyzed for total chloride and total lead. The list of constituents was historically longer and included a total of 27 parameters; however, COC was removed from the list with IEPA concurrence as the data indicated they were no longer a concern for this SWMU. The monitoring events conducted in Q1 and Q3 included just four wells screened in the deep till aquifer, and the monitoring events conducted in Q2 and Q4 included all nine monitoring wells that make up the SWMU 12 network.

Fermilab compared the groundwater analytical results to the Groundwater Quality Standards (GQS) for Class I and Class II groundwater. Laboratory analytical data from glacial deposit monitoring wells are compared to applicable Groundwater Quality Standards for Class II groundwater. Laboratory analytical data from Bedrock monitoring wells are compared to applicable Groundwater Quality Standards for Class I groundwater. No GQS were exceeded during the Q1 and Q3 monitoring events. In Q2 and Q4, the total chloride concentration at MWD1 was 1,370 and 1,450 mg/L, respectively, which exceeded the GQS for Class II groundwater (200 mg/L). The total lead concentrations in bedrock wells MW6B (0.0106 mg/L), MW7B (0.0208 mg/L), and MW9B (0.0166 mg/L) exceeded the GQS for Class I groundwater (0.0075 mg/L) in 2023.

Groundwater samples collected from the four background monitoring wells (BMW) were also analyzed for total chloride and total lead. Although low levels of total lead and chloride were detected in some of the BMW, none of the concentrations exceeded the applicable GQS for Class I groundwater. Additional information regarding Fermilab's groundwater monitoring program is presented in Section 6.

5.4 Non-Radioactive Sanitary System Monitoring

Two industrial wastewater pretreatment operating permits have been issued to Fermilab by IEPA. Aqueous process wastewaters are directed to sanitary sewers and ultimately discharged to publicly owned treatment works in the municipalities of Batavia and Warrenville/Naperville. Wastewater discharges are controlled by criteria described in FESHM 8025, Wastewater Discharge to Sanitary Sewers. Fermilab monitors for Silver, Arsenic, Barium, Cadmium, Chromium, Copper, Iron, Manganese, Nickle, Lead, Selenium, and Zinc in the sanitary system at the site boundary. There were no unplanned releases to sewer systems in 2023.

5.5 Monitoring of PFAS in the Area of AFFF Release

In 2017 and 2018, the Fermilab Fire Department held training exercises where a total of up to fifteen 5-gallon buckets of expired AFFF (aqueous film-forming foam) were flowed on the road east of Site 40 (mislabeled as “Rd A” in Google Earth 3D®). The AFFF was of two types: 3M Light Water ATC 3% or 6% (known to contain PFAS per the SDS) and Chubb National Foam Universal Plus 3%/6% (believed to have contained PFAS). Following the training exercises, the residual foam was hosed off the road. The figure below indicates the approximate foam-flow area as indicated by fire Department personnel.

Reported approximate firefighting training foam flow area east of Site 40 at Fermilab

Further accuracy of the road area subjected to training foam-flow and hosing is indicated by historical photographs available in Google Earth 3D®. Comparable aerial images from June 2016 and April 2017 indicate a lighter asphalt area in the 2017 image across the road and along the road edges extending north toward the ditch to Casey’s Pond.

Lighter area of the road likely indicates where the foam flow occurred.

The goal of the DOE PFAS Strategic Roadmap is to “develop information concerning PFAS uses and environmental releases to characterize and assess the Department’s potential liabilities and risks.” During the initial characterization of the AFFF Training Area in 2023, 17 composite samples were collected along the edges of the road (see Figure). Each location was separated by approximately 30 feet, except for two offset locations further south from the foam flow area. Samples were collected in sequential order from south to north and were preceded by a collection of samples from three background locations.

5.6 Fire Protection Management and Planning

Due to wildfires potentially affecting DOE property and impacting certain operational activities, this section should discuss any annual fire management planning actions. Certain DOE field sites, such as LANL and INL, have initiated prescribed (controlled) fire burns on select portions of DOE property and other related fire suppression actions to reduce ground fuel levels. These controlled burns serve to provide further protection to workers, site facilities, and local communities adjacent to DOE sites. Other sites have started select forest harvesting practices and clearing of fire break zones as further protective actions to minimize or eliminate wildfire damage.

Location of surface soil samples collected in December 2023; analytical results indicate an area of PFAS contamination on both sides of the road.

Prescribed burning is conducted at Fermilab on an annual basis as part of natural area management. An open burn permit to allow natural area burning was renewed by the IEPA in 2023. Fuel types at Fermilab consist of prairie and wetland vegetation with mixed deciduous shrub clumps to deciduous forests with herbaceous

understories with leaf litter. Before the prescribed burn season starts, each area is assessed to identify new hazards that could be a safety issue or compromise a burn break. These issues are corrected before the planned burn takes place in the area. Planned burn breaks are also mowed around burn units to create a safer work zone during the prescribed burn. Prescribed burns occur at a determined frequency, which ranges from 2-5 years in between prescribed burns so that approximately 1/4 to 1/3 of the natural areas have burns conducted in a given burn season. This rotational method ensures that natural areas periodically be assessed for potential burn hazards and that they will be removed before causing an issue.

5.7 Recreational Hunting and Fishing

No recreational hunting or fishing is allowed at Fermilab.

Wilson Hall with reflection at sunrise; the central laboratory building, it is the heart of the 6,800-acre Fermilab site.

6. GROUNDWATER PROTECTION PROGRAM

Groundwater is a valued resource at Fermilab and is monitored and protected to ensure it is not negatively impacted by site operations. Groundwater monitoring has occurred at the lab since its inception in 1971. The original monitoring network primarily consisted of existing potable water wells that serviced historical farmsteads. Over the last 50 years, Fermilab has amended this network of farm wells with wells designed to monitor groundwater quality at specific locations and depths relative to the Site's infrastructure. Monitoring originally focused on radionuclides due to the nature of the experiments conducted at the lab and was expanded in the 1990s following the RCRA Facility Investigation (RFI) to include hazardous substances associated with other lab operations. Groundwater is considered during the construction of experiment infrastructure and other site improvements to minimize impact.

Row-crop agricultural land at Fermilab.

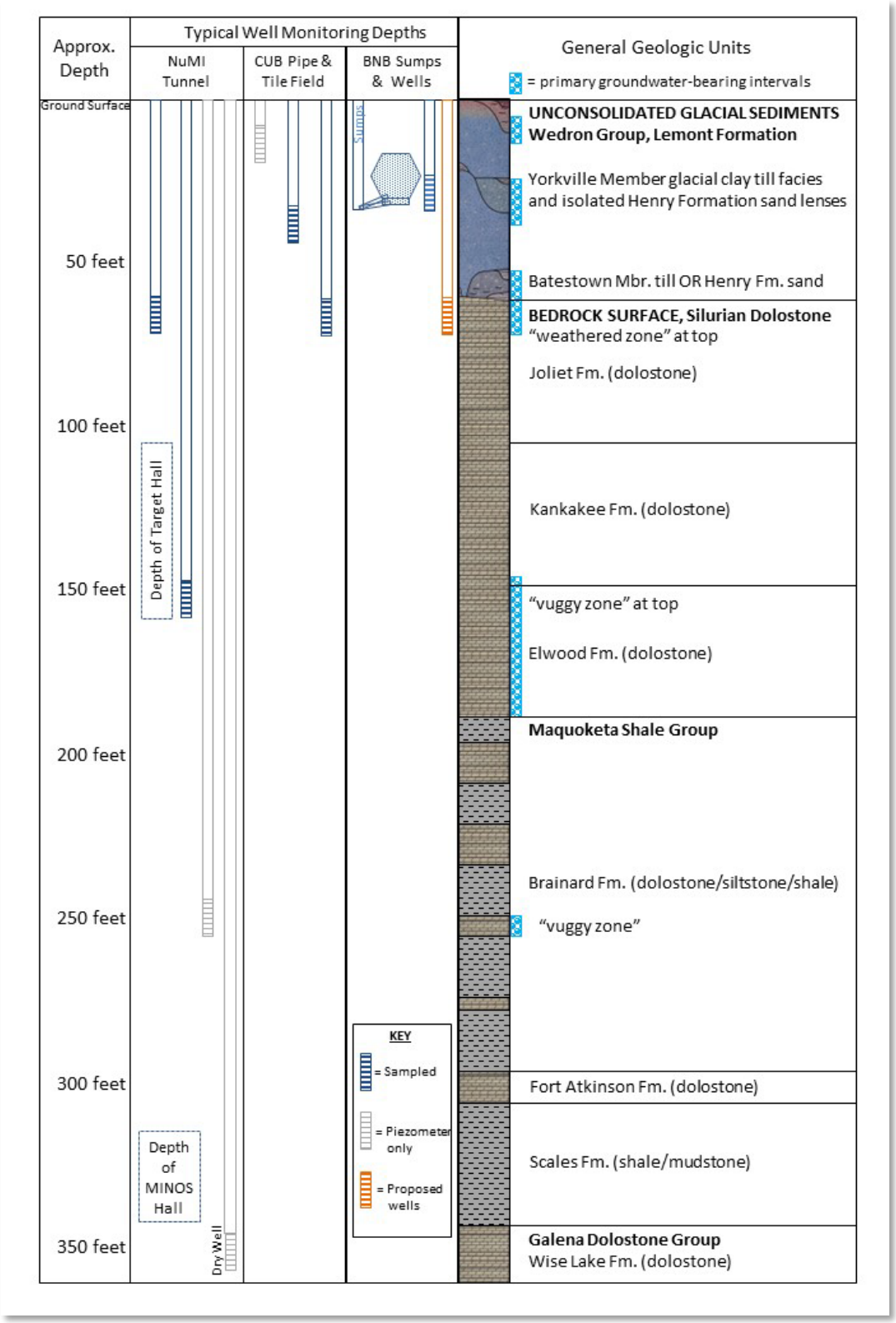
An annual Groundwater Management Plan (GMP) describes the investigation and monitoring activities planned each year. The Fermilab monitoring network consists of approximately 120 monitoring wells and piezometers. The data gathered from the installation of wells, as well as the subsequent sampling and gauging events assists Fermilab scientists with a better understanding of the site's geology.

6.1 Geologic and Hydrogeologic Site Conditions

Multiple groundwater zones (aquifers) are present at Fermilab and range in depth from several feet below the ground surface (bgs) to more than 400 feet bgs, as depicted in Figure 1. The aquifers are present in both the unconsolidated glacial sediments and the underlying bedrock. Up to three groundwater zones have been observed in the glacial sediments, and three groundwater zones are monitored in the bedrock beneath the site.

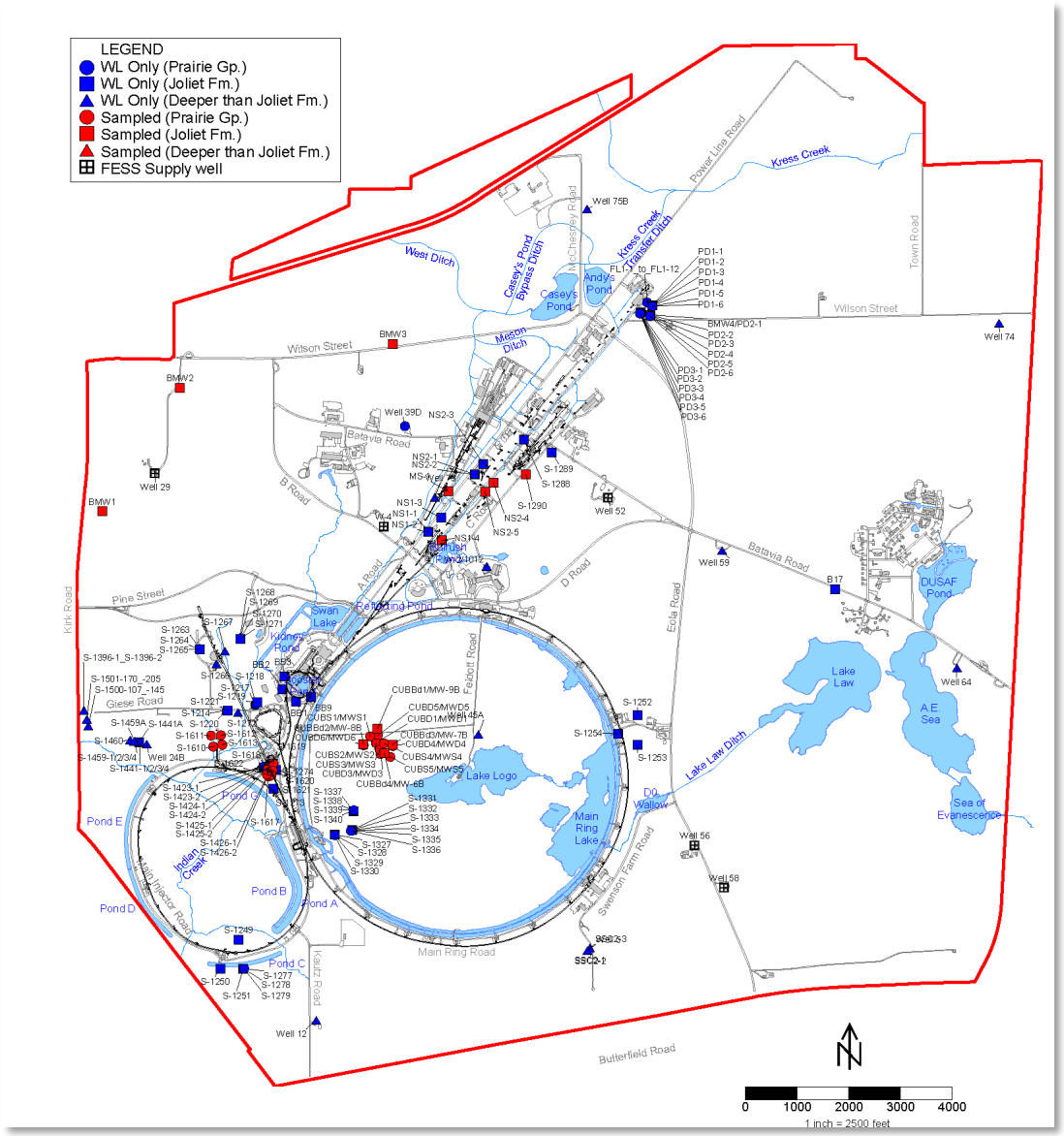
The uppermost aquifer (as deep as 15 feet bgs) in the unconsolidated glacial sediments (comprising the Prairie Aquigroup) frequently exhibits hydraulic connection with nearby surface water bodies, including lakes, ponds, and ditches. An intermediate aquifer in the Prairie Aquigroup (approximately 20-40 feet bgs) exists at some locations at Fermilab. The depths of these relatively shallow glacial aquifers overlap and have a potential interaction with the majority of Fermilab's subsurface accelerator structures. An additional aquifer (approximately 40-60 feet bgs) exists at the base of the glacial sediments in either the Batestown Member till or Henry Formation sand at several locations and could be in direct hydraulic connection with the underlying aquifer at the top of the bedrock. In previous communications with IEPA, groundwater in the glacial deposits overlying the bedrock at Fermilab has been determined to be Class II General Resource Groundwater. The Illinois Pollution Control Board (IPCB) publishes groundwater quality standards for Class II groundwater in 35 IAC Part 620.

Groundwater residing in or below the Silurian dolostone bedrock aquifer, the upper surface of which is 50 to 80 feet below the ground surface in the Joliet Formation at Fermilab, is classified as Class I potable resource groundwater. The IPCB has established groundwater quality standards found in 35 IAC Part 620 and defines Class I groundwater as a non-degradable resource that is to be highly protected. The classification of an aquifer as a Class I groundwater resource involves numerous criteria, including a hydraulic conductivity of 0.28 feet/day (typical of sands or fractured bedrock) or greater, a sustained yield of 150 gallons/day or more, and a depth of at least 10 feet bgs. Deeper experiment structures such as the NuMI tunnels directly intersect and interact with the bedrock aquifers to a depth of approximately 360 feet bgs.



General Fermilab geologic section (based on NuMI Tunnel) illustrating typical monitoring depths and groundwater-bearing intervals.

The locations and general aquifer designations of groundwater monitoring wells at Fermilab are shown in Figure 2. Wells sampled for environmental surveillance monitoring or as part of ongoing RFI corrective actions are colored red. An additional 124 wells are used as piezometers (pore-water pressure measuring apparatus) to gather information on groundwater flow directions site-wide. This data is used in conceptualizing the horizontal and vertical flow of groundwater in addition to the potential transport of contaminants from past, present, and future operational areas.



Location of groundwater monitoring wells at Fermilab National Accelerator Laboratory.

A total of four semi-private water supply wells are presently in use across the Fermilab site. Most of these supply wells are installed in the Joliet Formation and deeper Silurian limestone formations (approximately 100 to 240 feet deep) and are of minor use. An exception to this, Well W-4, is installed to a depth of 1,432 feet into the Ironton-Galesville Formation regional Cambrian-Ordovician sandstone aquifer system and serves as a backup supply for ICW needs. Fermilab's primary source of domestic water is provided by Warrenville's municipal supply system.

6.1.1 Subsurface Groundwater Migration

Groundwater elevation data is collected from each well location in the monitoring well network at least once per year. In November 2023, EPD personnel accessed each well location evaluated its condition, and measured the depth of groundwater. The elevation data was used to develop contour maps and evaluate groundwater flow direction, as depicted and discussed below.

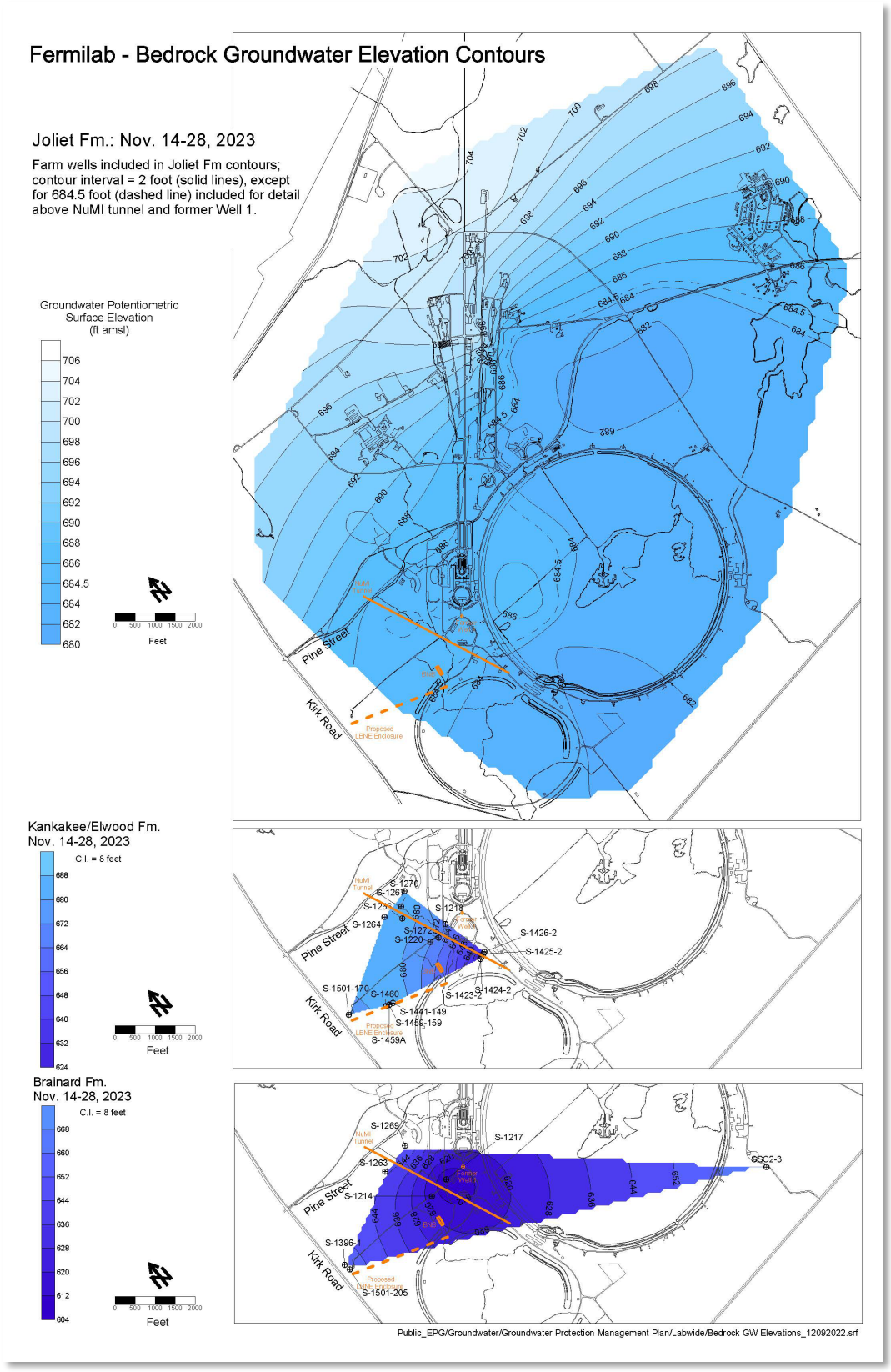
6.1.1.1 Glacial Deposits

Groundwater flow direction in the glacial deposits is either downward through the till units to the underlying aquifers or laterally to nearby discharge sinks such as field tiles, ditches, creeks, or ponds. Due to the high vertical gradient, downward flow is a major component of the flow direction within the upper glacial deposits. Horizontal flow is only a factor locally in the vicinity of discharge sinks. Based on Shelby Tube samples collected in limited locations, vertical seepage velocities range between 0.036 to 0.12 feet/year, and horizontal seepage velocities range between 0.0006 to 0.14 feet/year.

Groundwater monitoring well.

6.1.1.2 Upper Bedrock

The groundwater flow direction in the upper bedrock aquifer (Joliet Formation) is toward the east (generally following the regional dip of the formation) and toward the south (following the bedrock surface topography) but is locally dependent on groundwater withdrawals (Figure 3). The NuMI tunnel captures groundwater in its vicinity, acting as a drain and creating an oblong cone of depression in the groundwater elevation contour map. This cone of depression also includes a recovering cone of depression centered on former drinking water supply Well 1, which ceased operation in 2005 and was sealed in 2013. Future projections of the response of groundwater flow direction to withdrawal stresses will continue to be evaluated.



Groundwater elevation contours measured in November 2023.

6.2 Groundwater Monitoring Programs

Monitoring groundwater beneath Fermilab is important to evaluate the impacts of current or ongoing Laboratory activities as well as to characterize contamination from past practices; consequently, Fermilab has several groundwater monitoring programs in place to evaluate groundwater quality across the site. These programs include background monitoring wells (BMW), the CUB tile field (SWMU 12), accelerator and experiment areas, and semi-private drinking water wells.

GROUNDWATER MONITORING PROGRAM STATISTICS	Remediation	SWMU 12 Waste Management	Environmental Surveillance	Background Monitoring
Number of Active Wells Monitored On- site	0	9	21	4
Number of Active Wells Monitored Off- Site	0	0	0	0
Number of Samples Collected	0	26	19	4
Number of Analyses Performed	0	2	3	4
% of Analyses that Report Non-Detects	N/A	50%	90%	75%
% of Analyses within an Acceptable Range	N/A	90%	100%	100%

6.2.1 Background Monitoring Wells

Four background groundwater monitoring wells (Joliet Formation) were sampled to assess base-line tritium levels at the up-gradient (north) edge of the Laboratory property (BMW-1 through BMW-4).

6.2.2 CUB Tile Field (SWMU 12)

In 2022, nine glacial and Silurian dolostone (Joliet Formation) monitoring wells at the CUB Pipe and Clay Tile Field (SWMU 12) were sampled as part of ongoing RFI corrective actions at this location.

6.2.3 Monitoring in the Accelerator and Experiment Areas

During 2006, the Meson and Neutrino Soil Activation Areas were removed from the RFI as a SWMU; however, sampling of five monitoring wells screened within the Joliet Formation continues under the Laboratory's environmental surveillance program. Results are reported to the IEPA annually. In addition, two monitoring wells screened within the Elwood Formation were sampled to assess tritium levels near the NuMI Target Hall (S-1423-2 and S-1426-2).

6.2.4 On-Site Water Supply Wells

Four semi-private water supply wells located at the Laboratory draw water from the Joliet Formation and deeper Silurian limestone formations (approximately 100 to 240 feet bls). Groundwater samples were collected from the water wells in 2023 and shipped to GEL Laboratories for PFAS analysis by Method 537. No PFAS compounds were detected.

Fermilab monitors groundwater quality at three on-site semi-private water supply wells on an annual basis. These wells draw groundwater from the Joliet Formation and the deeper Silurian limestone formations (approximately 100 to 240 feet below land surface). Samples were collected and submitted for the following analyses: hardness, iron, sodium, lead, manganese, chloride, fluoride, nitrite, nitrate, pH, sulfate, total dissolved solids, and bacteria (including e-coli and total coliform). Analytical data indicates the following:

- Water from wells servicing Sites 29, 56, and 58 exhibit significant levels of hardness
- Secondary MCLs for iron and TDS were exceeded; these levels were established for aesthetic considerations such as taste, color, and odor and are not considered a risk to human health.
- Results of 2023 sampling are consistent with previous data.

6.2.5 PFAS & Other Emerging Contaminants

In addition to annual water quality sampling from the private water supply wells on-site, groundwater samples were collected in 2023 for analysis of PFAS compounds. These samples were shipped to GEL Laboratories for PFAS analysis by Method 537. No PFAS compounds were detected.

Potential Contaminants of Concern	Ranges of Results for Positive Detections			
	Remediation	Waste Management	Environmental Surveillance	Other Drivers
Tritium (pCi/ml)	N/A	N/A	5.2 - 58	ND
API (pCi/mL)	N/A	N/A	ND	ND
Chloride (mg/L)	N/A	2 – 1,510	N/A	10.5 - 23.8
Lead (mg/L)	N/A	0.004 – 0.039	N/A	0.00190
PFAS (ng/L)	N/A	N/A	ND	N/A

Swan Lake on a foggy morning.

7.0 QUALITY ASSURANCE

The environmental programs at Fermilab are subject to routine assessments, inspections, and quality assurance measures conducted by Fermilab, DOE, and regulatory agencies. Those conducted during 2023 are reported below.

7.1 Assessments

External assessments by DOE or regulatory agencies are conducted periodically at Fermilab. During 2023, no external assessments were performed.

Internal assessments are conducted regularly to evaluate the efficiency and effectiveness of programs and systems at the lab. Six assessments associated with environmental programs were conducted in 2023.

Assessment Title	Completion Date
2023 EMS self-assessment – Environmental Management System Compliance to ISO140001	December 29, 2023
PFAS Assessment	December 29, 2023
Sampling Plan Review 2023	February 15, 2023
Groundwater Monitoring Program Surveillance Review	December 22, 2023
Radiological and Chemical Release Emergency Response Procedures	In Progress
Annual SWPPP Inspection	March 29, 2023

7.2 Inspections

Periodic inspections of Fermilab's environmental programs are performed by federal, state, and local environmental regulatory agencies. An inspection of the groundwater program under RCRA was conducted by IEPA on May 16th, 2023. The inspection resulted in no violations.

7.3 Quality Assurance

Quality assurance (QA) applies to all work conducted at Fermilab, and the Laboratory has worked diligently to establish an overarching institutional approach to QA. This approach applies program controls using a graded approach, based on an analysis of identified risks where work is to be performed. It also outlines the requirements necessary to consistently meet the contract obligations throughout the Laboratory.

Quality at Fermilab is integrated into one lab-wide Quality Assurance Management System, a set of interrelated elements that Fermilab uses to plan, direct, control, assure, and improve how quality policies and procedures are established, implemented, and monitored. The Quality Assurance Manual is a living document that contains Fermilab's policies and procedures designed to manage the requirements of the DOE Quality Assurance Order.

Fermilab has a Contractor Assurance System (CAS) owned jointly by DOE as sponsor/steward, the M&O contractor as holder of the Prime Contract, and the Laboratory as performer of the work. CAS is managed

and overseen by the Chief Operating Officer. Fermilab executes the Prime Contract by employing eleven management systems that encompass all work activities and apply to all personnel performing work at Fermilab and Fermilab leased spaces, including subcontractors and guests. The management systems are periodically reviewed and improved through a variety of devices, including self-assessments, peer reviews, benchmarking efforts, and operational readiness reviews.

Fermilab views the Contractor Assurance Program as the primary tool for demonstrating operations are compliant, safe, secure, efficient, and providing quality products and services. Assurance activities cut across every function within the Laboratory and are used as a learning vehicle to highlight and facilitate change and continual improvement.

7.3.1 Environmental Non-Radiological Program Quality Assurance

Non-radiological programmatic quality assurance/quality control (QA/QC) is governed by the Environmental Program Department (EPD) and Tritium Management Department (TMD). QA/QC is primarily accomplished through Fermilab's sampling process design. The details of sample size, frequency, type of analysis, and methods necessary to produce accurate, precise, and representative data for EPD and TMD are established within their respective procedures and policies as documented in FESHM and reviewed regularly. Subcontracted laboratories utilize their standard operating procedures for analytical quality, internal assessments, and data validation. Procedures are in development to address periodic internal assessments, internal QC checks, and performance and system assessments. These procedures are updated as changes in the program occur. Additionally, the development of a programmatic Quality Assurance Project Plan (QAPP) was initiated in 2023 for EPD and TMD and is anticipated to be completed by the end of CY 2024. This plan will capture both department's QA/QC practices into one all-encompassing document.

7.3.2 Environmental Radiological Program Quality Assurance

Radiological programmatic QA/QC is governed by the Fermilab Environmental Radiological Protection Program (ERPP). DOE Order 458.1 Radiation Protection of the Public and the Environment requires sites to have a compliant ERPP. This document applies to the activities described in the Scope of Radiological Operations of Fermilab and constitutes the Lab's implementation plan for the requirements of the Order. Fermilab maintains and implements several plans and programs for ensuring that the management of facilities, wastes, effluents, and emissions does not present risk to the public, workers, or the environment. Specific radioanalysis Laboratory procedures, data validation, and reporting of analytical results for environmental sampling activities, are governed by the Fermilab Radioanalysis Facility (RAF). To ensure quality, the RAF participates in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) on a biannual testing cycle. In CY 2023, Fermilab participated in 2 cycles of the MAPEP performance tests for tritium, Co-57, Co-60, Cs-134, Cs-137, Mn-54, Zn-65, and K-40 with acceptable results.