Fermilab Environmental Monitoring Program

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Photo E. McCory

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I. Introduction

The goal of the Fermilab Environmental Monitoring Program is to assist Laboratory management in decision-making by providing data relevant to impacts that Fermilab operations have on the surrounding environment. Laboratory management may use elements of this program for various purposes that include identifying potential environmental vulnerabilities and to propose appropriate methods for understanding their underlying causes and processes. The program outlines the types and locations of samples that are routinely taken and the rationale behind sampling decisions. This program is effective only when used in conjunction with the Laboratory's comprehensive Environmental Management System (EMS). The EMS includes relevant environmental policies as set forth in the Director's Policy Manual and the Fermilab ES&H Manual. The EMS includes elements to identify significant environmental aspects of operations such as potential sources of contamination, the necessary information to identify pathways from sources to the environment and the public, and measures available to reduce the impact on the environment.

This program consists of two elements: effluent monitoring and environmental surveillance. Effluent monitoring pertains to compliance with permits and is conducted at specific locations. Environmental surveillance is conducted at various locations in the path of potential pollutants to receptors such as plants, animals or members of the public. Environmental data is collected for reporting purposes or whenever it is necessary or useful in conducting the business of the Laboratory. The operation of the program is primarily the responsibility of the Environmental Protection Group (EP Group), of the Environment, Safety & Health (ESH) Section.

Line organizations are responsible for recognizing and understanding the environmental consequences of all their operations and for conducting operations in an environmentally sound manner. Line organizations also design and implement sample scheduling and data collection appropriate to their operations. This includes sampling and monitoring necessary to maintain certain environmental permit conditions. The implementing authority for environmental permits managed outside the EP Group is described in FESHM 8010.[1] The EP Group is available to provide assistance to line organizations upon request. The EP Group is ultimately

responsible for overall coordination of environmental effluent and surveillance monitoring across the Laboratory. The primary environmental monitoring planning tool is the sampling schedule. The schedule indicates the location and frequency of sampling, based on established routines, operational considerations, and historic levels of pollutants found in each location. Laboratory management is advised when significant modifications to this schedule are necessary. The sampling schedule is intended to be a short to medium term plan that is modified as needed by evolving circumstances. A comprehensive review of the schedule is performed annually. A copy of the current schedule is maintained by the EP Group.

Analytical results are currently recorded in the LOCUS EIM database maintained by ESH/RAF. Results prior to 2013 are maintained in the Oracle ESH/EP Sample database. Thus, a comprehensive record of all environmental monitoring results is available to future planners and for retrospective baseline studies.

The generation of tritium is an expected by-product of accelerator operations. Because of tritium's prevalence and multiple pathways into the environment the Laboratory has established a Tritium Task Force (TTF) as a management framework. The TTF consists of members from various organizations across the Laboratory to support mitigation efforts. The TTF is charged with keeping the impacts of tritium to all pathways in the environment as low as reasonably possible and in compliance with governing requirements. Environmental monitoring and measurement of tritium will be done in correlation with the TTF's overall management strategy.

II. Objectives of the Fermilab Environmental Monitoring Program

Outlined below are the primary objectives of the program.

1. Provide meaningful data useful to assess the potential impacts of Fermilab operations on the environment and/or the public.
2. Verify compliance with legal requirements (e.g., permits and state standards) or other commitments (e.g., policy statements, As Low As Reasonably Achievable (ALARA) program, and National Environmental Policy Act (NEPA) commitments).

3. Characterize the environment in the vicinity of the Laboratory, including baseline studies or background data.
4. Help identify potential vulnerabilities that may arise due to flaws in design, construction, and/or the implementation of work.
5. Evaluate remedial measures that have been previously instituted.
6. Characterize and track releases of any contaminants into the environment.

III. Air Monitoring

Operations at Fermilab result in minor emissions of radionuclides, primarily from vent stacks located above beam enclosure areas; and non-radioactive emissions such as particulate matter, nitrogen oxides, carbon monoxide, volatile organic material and sulfur oxides. These emissions originate from boilers or heating units that burn natural gas or other fuel, internal combustion engines, experiment apparatus and other stationary emission sources.

Radionuclide monitoring

Radionuclides are considered by the U.S. Environmental Protection Agency (U.S. EPA) to be a Hazardous Air Pollutant, therefore, Fermilab is required to report annual radionuclide emissions under the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) program.[2]

Emissions from selected vent stacks are monitored directly, by continuous stack monitors, and indirectly, by taking representative soil samples in the vicinity of stacks.[3] Soil samples indicate the potential for deposition of radionuclides originating from the vent stacks. Both are analyzed for tritium and gamma-emitting radionuclides. The determination of which individual stacks to be monitored is based on the potential for airborne radioactivity at the stack location. Standard procedures are used to collect and analyze both the stack samples and the soil samples.[4]

Non-radionuclide monitoring

Fermilab is registered in the Illinois Registration of Smaller Sources (ROSS) program from the Illinois Environmental Protection Agency (IEPA). The ROSS program requires facilities with very low actual air emissions to comply with the requirements of the Clean Air Act and the

implementation of regulations without applying for construction or operating permits or submitting annual emissions reports. In order to comply Fermilab must maintain documentation, based on equipment parameters and fuel consumption data that verifies the site's actual emissions meet the ROSS program criteria. Emissions are calculated annually to ensure continued compliance with the ROSS requirements and a fee is sent to the IEPA. Emissions from these sources are not normally monitored directly but are estimated using U. S. EPA emission factors and fuel consumption data.

Ambient Air Monitoring

Ambient air is not monitored at Fermilab, because our emissions do not detectably modify the air quality. There are sources of regional air quality data available to us if needed. Argonne National Laboratory and O'Hare International Airport maintain National Oceanic and Atmospheric Administration (NOAA)-sanctioned ambient air quality monitoring stations. We have used data from both locations in the past as needed.

An on-site meteorological station is maintained near the New Muon Laboratory, north of Wilson Street, in the northern portion of the site. Air temperature, wind velocity and direction, relative humidity, precipitation, and solar radiation are logged at this site. The instruments are regularly monitored. Wind velocity data from this station is used to model air dispersion, using the U.S. EPA's CAP88-PC2 computer program. Results of this simulation are required for the annual NESHAPs report to the USEPA and IEPA.

IV. Surface Water Monitoring

Surface water sampling is a significant component of our monitoring program. Fermilab relies extensively on water to provide cooling for the accelerators and associated equipment. The Laboratory's surface water system is sampled for the following purposes.

- Assess the potential for direct or indirect impacts on the environment and the public;
- Identify actual impacts on the environment, e.g., the food chain;
- Confirm compliance with a number of permits and regulations, including Derived Concentration Standards specified by DOE.[5]

Precipitation that falls to the site is collected and retained in lakes and ponds for use primarily as cooling water. A network of pipes and ditches is used to transfer cooling water between operational locations. Excess surface water is released from the site to "Waters of the State" at six discharge locations (outfalls).[6] The outfalls are noted in Fermilab's Geographical Information System (GIS) and are generally described as follows.

1. Transfer Ditch from Casey's and Andy's Ponds to Kress Creek
2. The A.E. Sea spillway (eastern lake that flows to Ferry Creek)
3. Discharge weir from the Swan Lake water system to Indian Creek
4. Emergency overflow from the MINOS ICW holding tank (NuMI tunnel water)
5. Main Injector Pond C overflow
6. Main Injector Pond D overflow

Discharge from the outfalls is regulated by permit. Fermilab holds a site-specific permit under the state-run, federal National Pollutant Discharge Elimination System (NPDES). This permit addresses discharges associated with non-contact cooling water (non-process), including building and tunnel sump discharges, and stormwater. Fermilab is required to monitor for specified parameters at each outfall and report the results monthly to the IEPA.

Outfall Monitoring

During periods of discharge at the outfalls the site specific NPDES permit requires monitoring of temperature, pH, tritium, and an estimate of flow at all locations. Total residual chlorine is monitored at Indian and Kress Creeks. We also monitor temperatures "upstream" and "downstream" of our discharge to Kress Creek,[7] and during periods of discharge from MI Ponds C and D. The permit prescribes procedures for these analyses.[8] Analyses are performed once per month, based on discharge. Because much of the impounded surface water is recirculated for cooling, water does not continuously leave the site at the Kress and Ferry Creek outfalls. MI Ponds C and D typically only discharge during extreme precipitation events. Sampling specifically occurs at an outfall when water is observed

discharging. These locations are surveyed periodically to ensure an adequate sampling frequency.

As part of a more comprehensive monitoring strategy for tritium, this radionuclide is sampled in proximity to the outfalls regardless of flow offsite. No additional chemical analysis is scheduled unless a specific spill or other release warrants it.

Storm Water Monitoring

Storm water run-off is regulated through two types of NPDES permits to control "non-point source" contamination of water bodies: individual construction project permits and the site-specific permit. Storm water and runoff associated with construction projects must follow the requirements outlined in FESHM 8012, Sedimentation and Erosion Control Planning.

Construction storm water NPDES permits are required for areas over one acre. Subcontractors working on permitted construction projects are required to carry out and document inspections on a regular schedule. A Storm Water Pollution Prevention Plan (SWPPP) details specific requirements to manage storm water discharge at the construction site. In response to significant storms, subcontractors must ensure that control measures remain intact and effective.

The site specific NPDES permit requires Fermilab to prepare and maintain a separate SWPPP to address the prevention of storm water pollution from areas of industrial activity or where significant material storage occurs on site. These areas include solid waste management units (SWMUs),[9] and support areas such as the Roads and Grounds salt dome and the railhead storage area. Quarterly visual inspections of outfalls are required by the permit, as well as an annual written report to the IEPA on areas addressed in the site specific SWPPP.

Sump Monitoring

Numerous sumps located throughout the site collect, store and discharge water that drains from below ground tunnels, buildings, other structural footers and from "bathtubs" in experimental areas.[10] Collected water, especially those in experimental areas, may be contaminated with radionuclides. As defined in FESHM 8026, Surface Water Protection, an

operational Division or Section has overall responsibility for these areas to ensure that sump contents are appropriately monitored and discharged to the industrial cooling water system. ESHQ radiological control technicians provide assistance to the Accelerator Division and Particle Physics Division in the form of sampling services for the ongoing monitoring of sumps associated with the accelerator complex.

Normally sumps are analyzed for radionuclide concentrations only, unless a chemical spill has been detected. Analytical results from these samples are valuable in detecting changes in operational conditions that may indicate an event that needs attention. While these samples are not considered to be strictly "environmental" monitoring, their results are useful to fully characterize sources, and as input to the development of the overall sampling schedule. The EP Group coordinates with other organizations that collect samples of this kind to ensure that the most useful information possible is obtained, or if further monitoring in sump receiving ditches is warranted.

Sediment Monitoring

Surface water sampling and monitoring also may include the collection and testing of sediment samples from selected surface water bodies, such as the outfall locations for radionuclides. Results from these samples are used to alert to potential accumulation of contaminants in sediments. Additionally, in conjunction with the Laboratory's Environmental Radiation Protection Program, gravimetric settleable solids monitoring and analysis is performed at the outfalls to screen material in suspension for potential radioactive contamination.

Pesticide Monitoring

Fermilab's integrated pest management philosophy is described in FESHM 8040.2, Specific Chemical Hazards. Fermilab uses limited amounts of pesticides for land and water management purposes. In addition, the Laboratory leases a significant area to local farmers who raise row crops. This agricultural activity involves additional pesticide use. Farmers who lease land at Fermilab must submit an annual plan that details the amounts and methods of application for pesticides they intend to use. These plans are reviewed and approved by Roads and Grounds. Pesticides used by the Fermilab Roads and Grounds crews are also subject

to review prior to use. These administrative controls are designed to minimize the cumulative impact of pesticides in the environment.

Algae can inhibit the quality of the water for cooling and creates fouling problems in machinery if allowed to go unchecked. Fermilab holds an NPDES pesticide permit that governs the application of algaecide to reduce algal growth in the cooling ponds. Fermilab must also control against an ongoing threat of Zebra Mussel infestation to the Industrial Cooling Water system. Treatment involves continuous dosing of sodium hypochlorite into the piping system. Discharge monitoring requirements related to this treatment is dictated by our site specific NPDES permit.

Off-site Monitoring

Water samples are not routinely taken from off-site locations. Sampling from points beyond the site are only taken on as needed basis to track potential unpermitted releases from the site, or to characterize make-up water that is imported into the Fermilab cooling system from the Fox River.

V. Sanitary Discharge Monitoring

Fermilab maintains a piping system for conveying sanitary sewer waste resulting from site activities. Fermilab does not operate a treatment system. Sanitary effluent is discharged either to the Warrenville municipal treatment system to the east or the Batavia municipal treatment system to the west.

Sanitary sewage also contains some process wastewater that may be discharged to the sanitary sewers in accordance with requirements described in FESHM 8025, Wastewater Discharge to Sanitary Sewers. Pretreatment permits with the City of Batavia and the IEPA are required for metal finishing activities in the Industrial Area, and for industrial water treatment at the Central Utilities Building. Divisions and Sections have direct responsibility for process related effluents generated in their areas, including monitoring and reporting for permits.

At the point of discharge from Fermilab's sewage piping system to the two municipal sewer systems we operate two automated, self-contained samplers that are programmed to take composite effluent samples on a

continuous basis from the waste streams. The samples are analyzed monthly for tritium and heavy metals as these are the potential contaminants most likely generated from Fermilab activities. Data from the samplers are used to confirm compliance of Fermilab's sanitary discharge with DOE requirements and state and local regulations. Additionally, gravimetric settleable solids monitoring and analysis is performed to screen for potential radiological contamination from solids in suspension in conjunction with the Laboratory's Environmental Radiation Protection Program.

VI. Ground Water Monitoring

Fermilab routinely conducts groundwater surveillance and compliance monitoring. There are three primary purposes for this activity: to monitor the impacts of current physics operations; to determine the extent and understand the impact of past activities; and to provide a basis for projecting the potential impacts of planned activities on future groundwater conditions through computer groundwater flow modeling. Past activities specifically require groundwater sampling and monitoring for compliance purposes associated with historical areas of concern at Solid Waste Management Units (SWMU), as required by the Resource Conservation and Recovery Act.

The general procedure for constructing monitoring wells is to characterize the underlying geology and hydrogeology and then construct the well to capture water from a specific depth. Five groundwater zones ("aquifers") of varying depths within the subsurface glacial and bedrock units are monitored at Fermilab. The locations of all active monitoring wells are in the lab's GIS (http://fesspsde.fnal.gov:8095/FessViewer/index.html, (open the Layer List and check Land Planning and the Monitoring Wells layer). For additional detail on Fermilab hydrogeology and the active monitoring well network see the Groundwater Management Plan.

Source-specific Monitoring Well Sampling

Source-specific monitoring wells are located and constructed solely for the purpose of the early detection of radioactive contamination of groundwater resources.[11] Should radionuclides migrate downward from activated soil or groundwater in the vicinity of beamlines and other

experimental areas quick and effective preventive or remedial action can be taken.

Currently, six such wells finished in the upper bedrock aquifer are sampled quarterly to monitor for any potential radionuclide release (NS1, NS2 (2), MS1 and PE3 in the fixed target beamline area and MI65 in the main injector area). Groundwater is also sampled in the vicinity of some SWMUs to monitor for the presence of other potential contaminants as part of the RCRA Permit. There are four monitoring wells finished in the upper bedrock aquifer at an abandoned tile field near the center of the Main Ring to monitor chloride ion and total lead. Six additional wells constructed at this location monitor the glacial deposits. There are eight wells in the vicinity of the Meson Hill Landfill to monitor for the presence of general chemistry and metals within the near-surface glacial till.

Four additional wells in the upper bedrock aquifer upgradient of Laboratory operational areas are sampled to monitor background chemical and radiochemical concentrations.

Piezometers

Piezometers are monitoring wells installed to specific depths in the subsurface to monitor groundwater elevations in those aquifer zones. They are used to determine groundwater gradients and therefore flow directions and are part of the process of determining the appropriate site and depth for source-specific monitoring wells. A network of piezometers remains in place for the purpose of monitoring the groundwater gradient change over time to confirm that the monitoring wells continue to serve their intended purpose.

A computer groundwater flow model is being developed that simulates the elevations of groundwater in the various aquifer zones across and surrounding Fermilab. The groundwater model will be calibrated to the groundwater elevations measured in this area over the past fifty years, and will be used to predict changes to the groundwater aquifer zones due to changes in climate, operations or experimental construction. In the event that groundwater flow should change direction, new source-specific wells would be considered.[12]

Pre-existing Residential Wells

Old farm wells, were installed by residents prior to the existence of the Laboratory. Some of these have been modified to serve as additional piezometers to monitor groundwater elevations in the upper bedrock and other aquifers, and they help extend the information on flow directions beyond operational areas. The wells are not optimally useful for discovering contaminant releases, however, because of their construction. In the past radiochemical analyses have been carried out on samples from these wells, since they were the only groundwater sampling locations available. No significant contamination was ever detected in any of the wells. As new wells have been installed to monitor specific sites for specific contaminants, the use of residential wells for sampling was eliminated. Less than ten former farm wells are still in use as piezometers in the groundwater monitoring network.

VII. Penetrating Radiation Monitoring

Penetrating radiation (muons, gamma rays, and neutrons) is present as a result of Fermilab operations. The ESH&Q Radiological Protection Group monitors at various points to ensure that the public is not exposed to harmful levels of radiation. There are published limits for radiation exposure, however, the most important principle for minimizing exposure is the As Low as Reasonably Achievable (ALARA) criterion.[13] This principle, as well as much of the controlling policy, including environmental radiation monitoring, can be found in the Fermilab Radiological Control Manual.

Beam-related Radiation

Radiation, primarily in the form of muons, is produced during the operation of the Fermilab experimental program. We monitor radiation at the site boundary by using a Mobile Environmental Radiation Laboratory (MERL) equipped as a mobile detector. Using the MERL, we can conduct measurements of radiation at each point along the site boundary to produce a profile of radiation. These data have proven useful for demonstrating the extremely low off-site radioactive emissions resulting from Lab operations.

Radioactive Material Storage

Radioactive materials are stored in the railhead storage area near the northern boundary of the site. Radioactivity emitted from these materials is relatively weak, however, we monitor radioactivity from this source using a large ionization chamber (called a "Hippo") that is permanently located between the source and the site boundary. The radiation measurements detected at this close range to the radioactive material are then used to extrapolate a site boundary dose.

VIII. Ecological Surveillance

The purpose of sampling plant and animal tissue directly is to track the bioaccumulation of contaminants, including both radiological and non-radiological. The levels of contaminant present in the ambient environment are sufficiently low at Fermilab that we do not routinely sample in this way. Additionally, Fermilab implements strict radiation exposure controls based on limits to humans. Because these limits are much more conservative biota is considered adequately protected.

Biological surveillance was carried out on various samples of vegetation and fish from 1981 to 1989. Analyses were done for tritium, other radionuclides, heavy metals and PCBs. Levels of all contaminants were either extremely low or less than the detection limit. Tissue sampling has been discontinued since that time, because it is considered to be unnecessary and of little value, given the extremely low levels of contaminants found. In 1998, deer tissue was sampled for documentation before beginning a long-term deer control/maintenance program.

Fermilab has also used a computer model, DOE's technical guidance (DOE-STD-1153-2002) and companion tool, the RAD-BCG Calculator, to address radiological protection of aquatic and terrestrial biota. DOE considers use of the model a graded approach to evaluate the radiological impact of site operations on biota. Media samples at all locations analyzed consistently passed the site screens using the model. Thus, the radiological protection of biota is considered to be adequate.

In the event a significant release and pathway were identified that could potentially impact the environment or the public we would re-institute tissue sampling program.

[1] Where it has been deemed beneficial to do so, agreements between ESHQ and a division/section have been established whereby the D/S takes responsibility for the monitoring and sampling program associated with a specific environmental permit.

[2] NESHAPs applicable standards and regulations are published at 40 CFR 61 Subpart H.

[3] See discussion of procedures in Fermilab EP Note #9. NESHAPs standards dictate continuous stack monitoring only for emissions above a certain threshold. We have never reached this threshold, and therefore are not technically required to monitor stacks continuously. We have adopted this practice for several stacks as a "best management practice".

[4] Soil sampling and analysis is described in the Environmental Protection Procedures Manual (EPPM).

[5] Derived Concentration Standards are calculated limits and are discussed and tabulated in DOE-STD-1196-2011 as referenced by DOE Order 458.

[6] Waters of the U.S. / Waters of the State / Navigable waters are those waters that are legally protected by state and federal laws. See 33 Code of Federal Regulations (CFR) 328.3 for expanded definition of Waters of the U.S. and Title 35 of the Illinois Administrative Code (IAC) 301.440 for Waters of the State

[7] The NPDES permit requires that upstream and downstream temperatures are monitored and recorded, but must only must be reported when a temperature differential exceeds five degrees F.

[8] Approved procedures and methods are located at 40 CFR 136, and the current edition of Standard Methods.

[9] SWMUs are areas where historical hazardous waste or product use has caused contamination that is being managed in situ. Fermilab's active SWMUs have been identified as part of a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI). The RFI process is used to identify and investigate potential sources of contamination.

[10] Bathtubs are impermeable liners that are designed to intercept or retard water flow from areas where soil is activated, to ground water at lower elevations. This intercepted water is collected in sumps for subsequent release to surface water.

[11] Derived Concentration Standards for radionuclides as tabulated in DOE-STD-1196-2011 as referenced by DOE Order 458.1 The state of Illinois has ground water standards, published at 35 IAC 620. Fermilab meets administrative controls with the requirements of a 1 pCi/ml lower limit of detection for ^{3}H analysis

[12] Flow of ground water in the upper bedrock aquifer is generally very stable in this region, and under normal circumstances, the horizontal gradient would not be expected to change. However, production wells typically distort the gradient within an area determined by the flow rate of the well. In the event that new production wells are added at Fermilab or in the surrounding communities, or existing well pumping rates are modified, the horizontal gradient could be substantially changed.

[13] DOE has regulations at 10 CFR 835 covering Occupational Radiation Exposure.