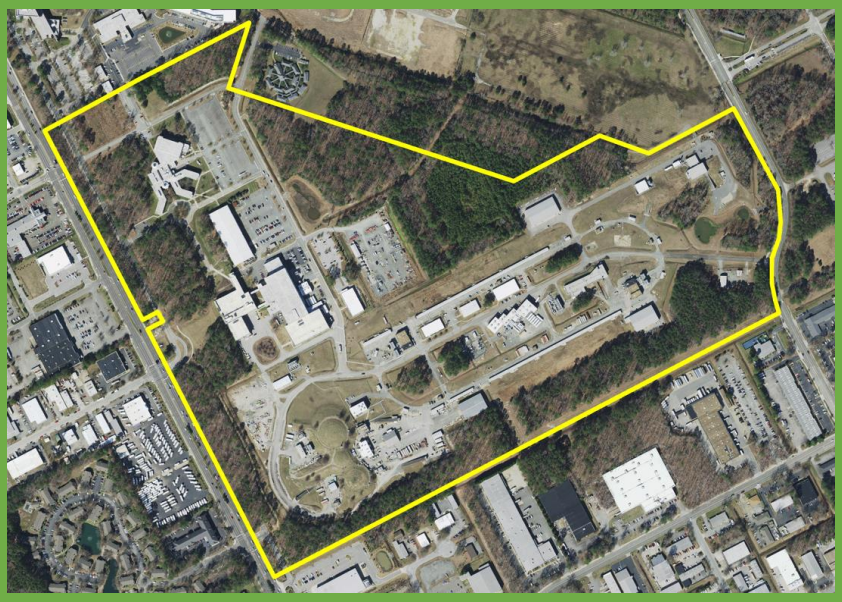
Jefferson Lab
Thomas Jefferson National Accelerator Facility

2021 Annual Site Environmental Report

For

Thomas Jefferson National Accelerator Facility



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United States Department of Energy

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EXECUTIVE SUMMARY

This Annual Site Environmental Report documents the U.S. Department of Energy's (DOE) Thomas Jefferson National Accelerator Facility's (TJNAF, also known as Jefferson Lab) environmental protection program and its performance in 2021. This report presents results from environmental compliance and monitoring programs that are within the scope of TJNAF's existing environmental permits, applicable regulations and the Environmental Management System (EMS). This report also provides the DOE and the public with information regarding the impact of radioactive and non-radioactive pollutants, if any, resulting from TJNAF operations.

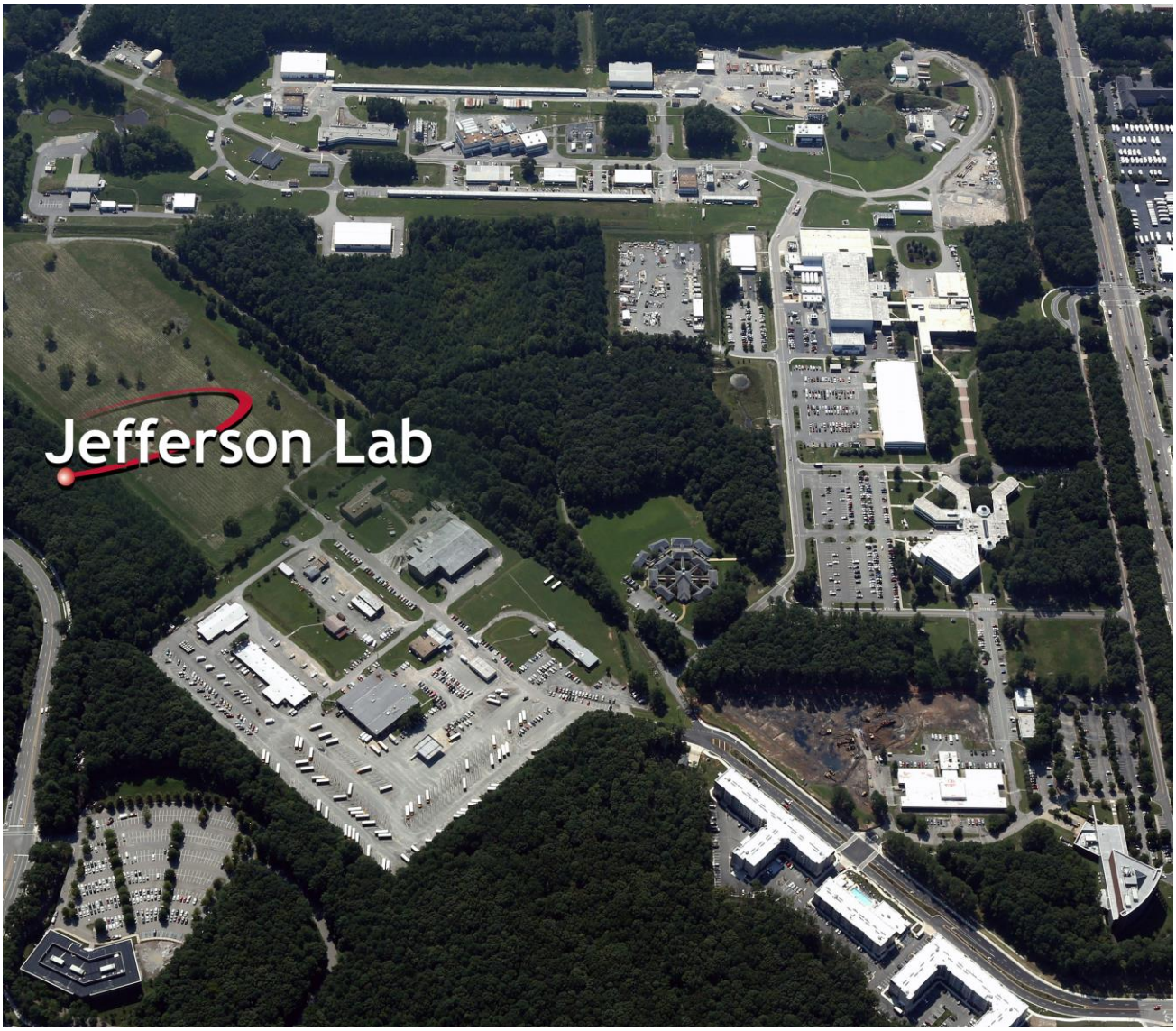
Jefferson Science Associates, LLC (JSA), is the managing and operating contractor of the TJNAF. JSA is a Southeastern Universities Research Association (SURA) owned Limited Liability Company committed to achieving Department of Energy science goals through a disciplined approach to laboratory operations and business management.

"TJNAF, a forefront U.S. Department of Energy Nuclear Physics research facility, provides world-class, unique research capabilities and innovative technologies to serve an international scientific user community. Specifically, the facility's mission is to:

- *Deliver discovery-caliber research by exploring the atomic nucleus and its fundamental constituents, including precise tests of their interactions;*
- *Apply advanced particle accelerator and detector technologies to address challenges of modern society;*
- *Advance knowledge of science and technology through education and public outreach, and;*
- *Provide responsible and effective stewardship of resources."*

At the Continuous Electron Beam Accelerator Facility (CEBAF), the electron beam begins its first pass at the injector and proceeds through the underground racetrack-shaped accelerator tunnel at nearly the speed of light. The accelerator uses Superconducting Radio-Frequency (SRF) technology to drive electrons to higher and higher energies. The accelerator's electron beam is capable of simultaneous use by four experimental halls, three of which are circular, partially buried domed chambers. A fourth experimental hall transitions from a below grade to an above grade facility. The special equipment in each experimental hall records the interactions between incoming electrons and the target materials. A continuous electron beam is necessary to accumulate data at an efficient rate, yet ensures that each interaction is separate enough for precise measurements.

In 2021, planning and design activities resumed for the CEBAF Center Renovation and Expansion project, as well as preliminary conceptual design for other projects including the Central Material Storage Area Expansion project and the City Water Reuse project.



Aerial view of TJNAF, facing towards the south. The racetrack outline of the Continuous Electron Beam Accelerator Facility (CEBAF) loop is located in the top portion of the photo, while the experimental halls are located to the right and the left of the accelerator loop.

LOW ENERGY RECIRCULATOR FACILITY (LERF)

TJNAF's Low Energy Recirculator Facility was developed using the facility's expertise in superconducting radiofrequency (SRF) accelerators. As an FEL, the facility provided a high-power tunable infrared laser while also providing ultraviolet laser light, including vacuum ultraviolet light, and Terahertz light. Currently, the facility is using the term Low Energy Recirculator Facility, or LERF, to refer to this facility, as future missions with potentially broader scope are under development. The LERF conducted a DarkLight Experiment in 2016. Planning for conducting a radioisotope production and development experiment began in 2018.

RESEARCH AREAS

Staff and visiting scientists continued using the Center for Advanced Studies of Accelerators (CASA), the Institute for SRF Science and Technology, and the Lattice Quantum Chromodynamics Computing Project to perform research and development programs. This research provides technology and associated experience for the construction of new accelerators for DOE Office of Science research projects at other facilities in nuclear physics, basic energy sciences, and high-energy physics.

INTEGRATED SAFETY MANAGEMENT (ISM) SYSTEM

Through ISM, TJNAF incorporates Environment, Safety, and Health (ES&H) requirements into all work procedures. The primary objective of ISM is to ensure that safety, health and environmental protection are a part of routine work that is always included in the planning and execution of routine work and projects.

ENVIRONMENTAL MANAGEMENT SYSTEM (EMS)

TJNAF's EMS is established and maintained to conform to the ISO 14001 Standard for Environmental Management Systems and DOE Order requirements. Its principles continually improve the practices of environmental stewardship at the facility. The EMS is integrated within the ISM System.

REQUIREMENTS IDENTIFICATION PROCESS

Requirements are comprised of the laws, regulations, and standards necessary and sufficient to ensure worker and public health and safety, and to protect the environment. TJNAF continually identifies new and changing requirements for inclusion into its programs. Subject matter experts

follow the development of new requirements, evaluating the applicability to existing facility operations.

IMPLEMENTATION OF THE NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

Construction activities, all accelerator upgrades and large/unique experiments are subject to review under the NEPA. The initial construction, two upgrades to CEBAF, and new buildings screened for compliance with NEPA regulations through the preparation of four Environmental Assessments (EAs). Site-specific NEPA Categorical Exclusions cover routine activities and special projects that do not have individual or cumulative significant environmental impacts and do not require the preparation of an EA or Environmental Impact Statement. All approved NEPA reviews and associated documentation are available on DOE's Public Reading Room.

RADIOLOGICAL AND NON-RADIOLOGICAL RELEASES TO THE PUBLIC FROM SITE OPERATIONS

In 2021, there were no unplanned radiological or non-radiological releases to the environment due to accelerator operations. Releases from normal operations were within permit and regulatory limits and had negligible impact to the public and no health or safety implications.

ENVIRONMENTAL PERFORMANCE MEASURES

TJNAF measures its environmental performance in several ways. In 2021, the DOE gave JSA a B+ for its ability to "Sustain Excellence and Enhance Effectiveness of Integrated Safety, Health, and Environmental Protection." Additionally, TJNAF reports annually to the Office of the Federal Environmental Executive and tracks numerous internal environmental performance metrics – all of which indicated success in 2021.

INSPECTION

TJNAF's inspection programs demonstrate its commitment to protect the environment, public health and safety. To ensure operations and activities are performed effectively staff and external agencies, including the DOE Site Office, State of Virginia, and the local sanitation district, conduct inspections. This report includes independent inspection results, including detailed comments on TJNAF's record of compliance with applicable laws and regulations. TJNAF also conducts routine self-inspections for onsite stormwater management, RCRA hazardous waste compliance inspections, TJNAF Hurricane Warden inspections and safety observations.

GENERAL COMPLIANCE

TJNAF's ES&H Manual facilitates integration of general environmental compliance initiatives into site operations. This report presents TJNAF's environmental compliance activity performance in 2021 and focuses on those dealing with water resources and public health. No significant environmental compliance issues arose during 2021.

AWARDS AND RECOGNITIONS

In 2021, TJNAF was awarded a DOE Gold GreenBuy Award from the Department of Energy's Office of Sustainable Environmental Stewardship for meeting leadership goals for 9 priority products in 6 different categories. TJNAF achieved the Gold level award for the fifth consecutive year, which also earned the Facility with the GreenBuy Superior Award.

TJNAF was awarded with a Hampton Roads Sanitation District (HRSD) Gold Award for perfect compliance with industrial wastewater discharges to sanitary sewer during 2021. Qualifying for this award requires maintaining a perfect compliance record for at least one year, and demonstrating a commitment to environmental excellence. Other criteria for receiving this award includes the requirement for an organization to meet HRSD compliance requirements and have no non-compliance or civil penalties.

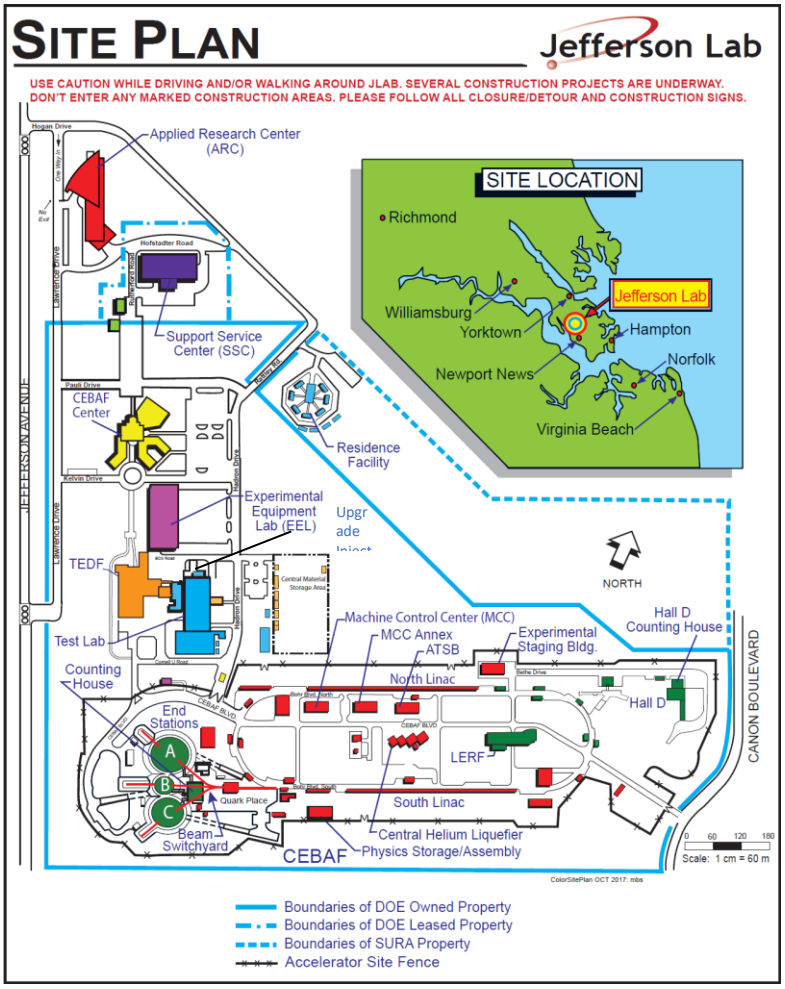
In 2021, TJNAF was also recognized by the Virginia Department of Environmental Quality (DEQ) as an Exemplary Environmental Enterprise (E3) facility within the Virginia Environmental Excellence Program (VEEP). The VEEP consists of three levels: E2 – Environmental Enterprise; E3 – Exemplary Environmental Enterprise; and E4 – Extraordinary Environmental Enterprise. The E3 level is for facilities with fully-implemented Environmental Management Systems (EMS), pollution prevention programs and demonstrated environmental performance.

1 INTRODUCTION

1.1 SITE LOCATION

The Thomas Jefferson National Accelerator Facility (TJNAF), also known as Jefferson Lab is located in the Oyster Point Business Park within the City of Newport News, Virginia. *Figure 1 – Regional and Site Map of TJNAF*, depicts the facility's location and buildings.

Figure 1 – Regional and Site Map of TJNAF



1.2 SITE HISTORY

Prior to the construction of TJNAF, there were several users of this general area of Newport News. The U.S. Department of Defense (DOD) acquired most of the Oyster Point area, including the land presently used by TJNAF. The U.S. Air Force later acquired the land and installed a Boeing and Michigan Aerospace Research Center (BOMARC) missile site on a portion of the property. After closure of BOMARC, the DOD decommissioned the property and conveyed some land to the Commonwealth of Virginia, the National Aeronautics and Space Administration (NASA), and others. Ownership of the NASA property, including 100 acres of undeveloped land, was conveyed to the DOE in 1987. An additional 52 acres of land was also transferred to the DOE from other sources. The total DOE-owned parcel, upon which TJNAF is built, is 169 acres.

1.3 ENVIRONMENTAL SETTING

The most comprehensive reviews that bound the site's environmental constraints are the four EAs completed under the NEPA. Each evaluated the potential impact of the site (or of proposed changes to the site) on cultural resources, air quality, water quality, noise, wetlands, endangered and threatened species, and a host of other subjects.
Environmental Assessments (EAs) conducted at TJNAF include:

- 1987 EA that yielded a "Finding of No Significant Impact (FONSI)" associated with the initial construction of the CEBAF;
- 1997 EA for the CEBAF upgrade (FONSI);
- 2002 EA for the LERF (formerly known as the FEL, or Free Electron Laser) upgrade/five building construction projects (FONSI), and
- 2007 EA for the 12GeV upgrade project (FONSI).

As a result, proposed projects have been completed with the assurance that no harm would come to the environment and therefore there was no need to prepare Environmental Impact Statements.

1.4 SITE MISSION

TJNAF, a U.S. Department of Energy nuclear physics research facility, provides world-class, unique research capabilities and innovative technologies to serve an international scientific user community.

Specifically, the mission is to:

- Deliver discovery-caliber research by exploring the atomic nucleus and its fundamental constituents, including precise tests of their interactions;
- Apply advanced particle accelerator, detector and other technologies to develop new basic research capabilities and to address the challenges of modern society;
- Advance knowledge of science and technology through education and public outreach, and;
- Provide responsible and effective stewardship of resources.

1.4.1 PRIMARY OPERATIONS AND ACTIVITIES AT THE SITE:

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY (CEBAF)

- The CEBAF accelerator provides continuous wave electron beams with energies of 0.5 to 12 GeV. During 2021, experiments were conducted in all four of CEBAF's experimental end stations at up to full beam energy.

END STATIONS

- The Experimental Hall End Stations have complementary experimental equipment to support their primary functions.
    - **Hall A** has a pair of superconducting, high-resolution magnetic spectrometers optimized for precision electron-scattering, coincidence experiments.
    - **Hall B** houses the CEBAF Large Acceptance Spectrometer for the 12 GeV Upgrade (CLAS12). CLAS12 supports studies of both electron- and photon-induced reactions with forward-focused reaction products at increased luminosities.
    - **Hall C** contains two spectrometers; the High Momentum Spectrometer, and the Super High Momentum Spectrometer, which enables measurements of particles scattered at up to full beam momentum.

- **Hall D** supports studies of photon-induced reactions using a solenoidal-based detector with high acceptance for charged particles and photons.

INSTITUTE FOR SUPERCONDUCTING RADIO FREQUENCY (SRF) SCIENCE AND TECHNOLOGY

- TJNAF's primary research and development facility provides continuous improvement efforts for the CEBAF and the LERF. Work includes:
  - Support of the operation, improvement and upgrade of the CEBAF.
  - Exploration of techniques for producing improved-performance SRF systems.

CENTER FOR ADVANCE STUDIES OF ACCELERATORS (CASA)

- CASA supports the site accelerators and evaluates future opportunities. Its primary mission is to generate, investigate, and distribute knowledge about advanced accelerator and beam physics, to facilitate and improve the results generated through the work performed at TJNAF. A secondary goal for the organization is to archive information generated by TJNAF's activities and make it available to guide future projects.

LOW ENERGY RECIRCULATOR FACILITY (LERF)

- Designed and built with TJNAF's expertise in SRF accelerator technology. The LERF (formerly known as the FEL) facility was the world's highest-power tunable infrared laser and also provided ultraviolet laser light, including vacuum ultraviolet light, and Terahertz light. Currently, the facility is referred to as the Low Energy Recirculator Facility, or LERF. The LERF accelerator is not routinely operated and ran for only a short period. However, the LERF's SRF infrastructure has been routinely used to support testing of superconducting cryomodules built by TJNAF for the LCLS-II accelerator at the SLAC National Accelerator Facility.

UPGRADED INJECTOR TEST FACILITY (UITF)

- The UITF is a small scale electron beam accelerator which is designed to support physics experiments and improve on the design of the CEBAF electron beam injector. Commissioning and operation of this accelerator was completed in 2020 and its experimental program began.

1.4.2 RELEVANT DEMOGRAPHIC INFORMATION

TJNAF is a world-class research facility. It attracts both resident and visiting physicists, and other scientists from around the world. In 2021, approximately 744 full-time physicists, engineers, technicians, and support staff worked at TJNAF and more than 1,623 academic and industrial researchers, from across the United States and approximately 37 countries and 277 institutions, participated in scientific collaborations.

Each year, research conducted at TJNAF produces more than one-third of all Nuclear Physics PhDs awarded in the United States. Research at TJNAF in 2021 produced five patents.

2 COMPLIANCE SUMMARY

The following sections summarize TJNAF's 2021 compliance status related to local, state, Federal, and DOE requirements.

2.1 COMPLIANCE STATUS

2.1.1 NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

NEPA requires that Federal agencies evaluate projects for the potential to have significant environmental impacts. All projects occurring at TJNAF are evaluated through the preparation of Environmental Assessments (EAs) or managed according to Categorical Exclusions, and no Environmental Impact Statement was necessary. During 2021, preliminary NEPA review was initiated for the Central Material Storage Area (CMSA) expansion project and the City Water Reuse project. However, the projects were temporarily placed on hold due to funding constraints and will be revisited in the future.

2.1.2 AIR QUALITY & PROTECTION

TJNAF currently has no process, or associated air emissions that exceed the threshold levels that require air permitting in the State of Virginia. Internal calculations are routinely conducted to confirm this status. All non-radiological emissions remained well below reportable thresholds in 2021, and radiological emissions were far below the applicable limits. The City of Newport News has met Environmental Protection Agency (EPA) and Virginia DEQ designated pollutant limits for National Ambient Air Quality Standards (NAAQS) since 2008.

STRATOSPHERIC OZONE-DEPLETING SUBSTANCES (ODS)

TJNAF minimizes the use of ODSs by using safe, cost-effective, environmentally preferable alternatives where possible.

To reduce the potential for emissions of ODSs, and comply with Section 608 of the Clean Air Act's Refrigerant Recycling Rule, TJNAF utilizes EPA certified subcontractors and

staff to perform all work involving ODS-containing refrigeration and air conditioning equipment on site. There is one ODS recovery machine on-site. The one remaining chlorofluorocarbon based chiller receives preventive and corrective maintenance by a qualified mechanical subcontractor to ensure optimal performance with minimal loss. An inventory of ODS containing equipment and annual usage onsite is submitted annually to the DOE.

GREENHOUSE GAS (GHG) EMISSIONS

During 2021, TJNAF and DOE continued to assess GHG emissions. Efforts to understand these various emissions allowed for the development of ways to minimize them. See "Department of Energy Executive Orders" section below.

2.1.3 WATER QUALITY & PROTECTION

TJNAF complies with all water quality protection requirements and performs monitoring in compliance with applicable State water quality permits. Combinations of engineering and administrative controls are utilized to maintain groundwater quality during operations. Discharges to surface water are permitted under TJNAF's Department of Environmental Quality (DEQ) Virginia Pollutant Discharge Elimination System (VPDES) Permit No. VA0089320. Outfall 001 consists of groundwater extracted from beneath Halls A, B and C; Outfall 002 consists of discharges from one of the site's cooling towers. Discharged wastewater flows to permit-authorized outfalls included in TJNAF's environmental monitoring program. Groundwater monitoring wells are sampled routinely under VPDES Permit VA0089320 to ensure that site operations do not degrade groundwater quality. All stormwater discharges are managed through structural and non-structural Best Management Practices (BMPs) in compliance with TJNAF's Municipal Separate Storm Sewer System (MS4) permit and the Virginia Stormwater Management Program (VSMP) regulations. Operational control measures include proper storage and minimizing the use of products that could pollute ground and surface water. Applicable site personnel have received training from the Virginia Department of Environmental Quality in the areas of Stormwater Management and Erosion & Sediment Control to conduct plan reviews and site inspections of all regulated land disturbances. TJNAF received initial approval from the DEQ in 2015 for the preparation of a Chesapeake Bay Total Maximum Daily Load (TMDL) Action Plan as part of Permit No. VAR040079 to meet the newly established requirements of the Virginia Stormwater Management Program (VSMP) set forth on July 1, 2014.

TJNAF held four active water permits in 2021 (*see Figure 2 below*). No regulatory limits were exceeded and all water quality programs were in compliance.

Figure 2 – TJNAF's Active Water Permits

PERMIT TYPE	# OF OUTFALLS	PARAMETER	# OF PERMIT EXCEEDANCES	# OF SAMPLES TAKEN	# OF COMPLIANT SAMPLES	PERCENT COMPLIANCE
Industrial Wastewater Discharge to Surface and Groundwater Quality (VPDES Permit VA0089320)	2 Outfalls (001 and 002) 16 wells*	Outfall 001 (pH, flow, temperature, Tritium, Sodium 22, Beryllium 7, Manganese 54, Gross Beta Activity); Outfall 002 (pH, flow, temperature, Ammonia, Chlorine, Copper, Zinc, Phosphorus, Hardness); A-ring/B-ring wells (groundwater elevation, pH, conductivity, total dissolved solids, Tritium, Sodium 22, Beryllium 7, Manganese 54, Manmade Radioactivity); GW-15a background well/C-ring wells (groundwater elevation, pH, conductivity, total dissolved solids, Tritium, Sodium 22, Beryllium 7, Manganese 54); Hall D wells (groundwater elevation, pH, conductivity, total dissolved solids, Tritium, Sodium 22, Beryllium 7, Manganese 54)	0	Outfall 001 (1); Outfall 002 (4); A-ring wells (8); B-ring wells (10); C-ring wells (3); GW-15a (1); Hall D wells (6)	Outfalls (5); Wells (28)	100 100
***Municipal Separate Storm Sewer System Permit (VAR-0400790)	3	NA	0	**NA	NA	100
Industrial Wastewater Discharge to Sewer (****HRSD Permit 0117)	4	Radionuclides, pH Flow Temperature	0	24	24	100
Groundwater Withdrawal (Virginia DEQ GW0047201)	1	Volume of dewatering	0	12	12	100

*TJNAF's VPDES permit includes two outfalls and the collection and reporting of radionuclide monitoring data from 16 groundwater mo nitoring wells located throughout the site. TJNAF applied for renewal of the existing VPDES permit during 2021 and anticipates receiving authorization from DEQ during 2022.

**The MS4 program requires TJNAF to implement a wide variety of BMPs to prevent contamination from entering the stormwater system and leaving the site. No sampling, analysis, and reporting of chemical constituents are currently required.

***TJNAF applied for renewal of the existing MS4 permit and received authorization during 2018.

****TJNAF applied for renewal of the existing HRSD permit during 2021 and anticipates receiving authorization from HRSD during 2022.

2.1.4 CONFORMANCE WITH ENERGY INDEPENDENCE AND SECURITY ACT (EISA) SECTION 438

During 2015, TJNAF conducted a conformance assessment of the current stormwater management program as related to EISA Section 438 requirements. Applicable projects were reviewed to determine conformance status and strategies were developed for future projects.

Projects are screened through an environmental compliance checklist that includes the requirement for conformance with EISA Section 438. During 2021, projects that were screened included the Central Material Storage Area (CMSA) Expansion project and the City Water Reuse project.

2.1.5 FUTURE STRATEGIES FOR EISA SECTION 438 CONFORMANCE

In December of 2009, the EPA released the "Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act". According to this guidance, conformance for future development, or redevelopment projects of >5,000 SqFt, is satisfied by implementing planning, design, construction, and maintenance strategies that achieve Option 1 – Retain the 95th percentile rainfall event to the Maximum Extent Technically Feasible (METF) from a sitewide perspective. This is accomplished through review of project design criteria to assure the following strategies have been considered:

- Apply 'runoff reduction' as the central stormwater management tool during planning stages of future development by incorporating the use of Low Impact Development (LID)/Green Infrastructure (GI) for stormwater management to the METF as mentioned above;
- Reduce clearing by preserving remaining natural areas as much as possible;
- Reduce regrading by preserving natural drainage patterns on a development site, where feasible;
- Minimize amount of imperviousness for planned development, where feasible;
- Promote runoff across natural features to reduce runoff volumes and pollutant loads.

During the conformance assessment conducted by TJNAF in 2015, it was determined that applicable projects occurring at TJNAF can conform to the technical requirements by:

- Calculating stormwater treatment requirements on a facility-wide basis, as opposed to a project/site specific level;

- The two stormwater retention ponds located on the facility have treatment storage capacity available to accommodate conformance with requirements for the remaining projects that qualify;
- Conformance for future projects may require the intentional routing of stormwater flows into the existing retention ponds for treatment.

2.1.6 OTHER ENVIRONMENTAL STATUTES & EXECUTIVE ORDERS

OIL POLLUTION CONTROL

A five year review of TJNAF's Spill Prevention, Control, and Countermeasure (SPCC) Plan occurred during 2021. The plan was deemed compliant with the requirements of 40 CFR Part 112 for Oil Pollution Prevention and no technical amendments were required. The SPCC Plan describes methods to prevent, control, and/or mitigate releases of oil and other petroleum substances to the environment. The Plan also describes the proper handling, use and transport of petroleum products on-site along with proper spill containment, clean-up, and disposal of the spilled material. To ensure proper handling and spill response, all staff, working with oil, receives annual SPCC training. On-site oil inventory comprises numerous oil-containing transformers, generators, compressors, above-ground storage tanks, and mechanical equipment. TJNAF's estimated volume of oil is approximately 56,211 gallons; this includes utility-owned electrical equipment. TJNAF implements an SPCC inventory spreadsheet to allow for management of 'real-time' inventory when new oil-containing equipment is brought onsite. Adherence to the SPCC plan continued in 2021 and administrative changes will be incorporated into the plan during 2022.

PFAS AND ADDITIONAL EMERGING CONTAMINANTS

An emerging contaminant includes chemical products that have a perceived threat to health and environment but may lack existing health standards. Emerging contaminants continue to be detected in surface waters across the United States, with the growing concern for the potential impacts on aquatic species and humans. On the forefront of these emerging contaminants is per-and polyfluoroalkyl substances (PFAS). PFAS substances have been generated through manufacturing and other industries since the 1940s that include clothing production, cookware/food packaging, and fire-fighting foams. Growing evidence shows that PFAS exposure to humans and the environment can have adverse impacts to health.

Due to the growing concern of potential impacts, there has been a growing focus on preventing and mitigating any impacts resulting from PFAS contamination. In September of 2021, DOE released information on the potential impacts of PFAS to DOE facilities. Included within this guidance was the requirement for DOE facilities to conduct surveys of their respective sites for the presence of PFAS contaminants, along with the requirement to report any releases of PFAS-containing Aqueous Film Forming Foams used during fire-fighting operations. In response to this, TJNAF initiated a gap analysis to identify any potential vulnerabilities onsite and any proposed program improvements. The gap analysis is anticipated for completion during 2022 and the results will be reported within next year's ASER for TJNAF. Any identified gaps discovered in our programs will be the focus of corrective actions.

2.1.7 DOE O 436.1 AND E.O. 13834 – SITE SUSTAINABILITY PLAN

The purpose of DOE Order 436.1 is to "….Provide requirements and responsibilities for managing sustainability within the DOE to 1) ensure the [DOE] carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges, and advances sustainable, efficient and reliable energy for

the future, 2) institute wholesale cultural change to factor sustainability and GHG reductions into all DOE corporate management decisions, and 3) ensure DOE achieves the sustainability goals established in its Strategic Sustainability Performance Plan pursuant to applicable laws, regulations and Executive Orders, related performance scorecards, and sustainability initiatives."

TJNAF satisfies this Order's requirements through the implementation of its EMS (see Section 3 – Environmental Management System below) and Site Sustainability Plan, summarized in *Figure 3 below*.

In 2021, TJNAF updated its Site Sustainability Plan. This plan addressed each specific goal in the DOE O 436.1, assessed performance status, and established planned actions and schedules for meeting them. *Figure 3* summarizes major 2020 activities associated with the plan.

Figure 3 – TJNAF's Sustainability Goal Performance

DOE Goal	Performance Status	Plans and Projected Performance
Energy Management		
Reduce energy use intensity (Btu per gross square foot) in goal-subject buildings	14.9% reduction from FY 2015 baseline, 10.5% increase from FY 2020 due to increased onsite workforce presence	Improve energy use intensity by 2% annually Seek alternative fuel and energysources for Goal-subject buildings and non-fleet vehicles
EISA Section 432 continuous (4 year cycle) energy and water evaluations.	Initial walk-through assessments of buildings conducted and high-priority buildings identified to conduct energy audits on during FY22 for benchmarking.	Continue to meet audit requirements by performing energy audits of 25% of required buildings annually.
Meter all individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate.	51.3% of assets do not require metering due to de minimis utility usage. 85.4% of relevant assets partially metered for electricity, natural gas, potable water.	Increase metering for electricity, natural gas and potable water usage in all relevant assets for compliance with Energy Act of 2020.
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Water Management		
Reduce potable water use intensity (Gal per gross sq. ft.). Reduce non-potable freshwater consumption (gal) for industrial,	17.8% reduction from FY2007 baseline. 32.6% reduction from FY2020 baseline due to reduced	Implementation of a stormwater reuse project that will reduce potable water consumption by 50 million gallons annually.

landscaping, and agricultural.	accelerator operations.	
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Waste Management		
Reduce non-hazardous solid waste sent offsite to treatment and disposal facilities.	74.7% of waste diverted from landfills (5.1% increase in diverted waste from FY2020).	Continue to seek new materials to divert to improve the existing process.
Reduce construction and demolition waste materials and debris sent offsite to treatment and disposal facilities.	100% of construction and demolition waste diverted from landfills (16.5% increase in diverted waste from FY2020).	Continue to seek new materials to divert to improve the existing process.
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Fleet Management		
Reduce petroleum consumption	85% reduction in FY2020 petroleum usage relative to FY2005 baseline	Continue to encourage use of alternative fuel
Increase alternative fuel consumption	133.7% increase in FY2020 alternative fuel consumption relative to FY2005 baseline	Continue to encourage use of alternative fuel
Acquire alternative fuel and electric vehicles	71% of all fleet vehicles are Hybrid Electric Vehicles (HEVs), Flex Fuel, or use altnernative fuel, such as E-85	Alternative fuel vehicles are always acquired when available and appropriate
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Clean and Renewable Energy		
Increase consumption of clean and renewable electric energy	Clean and renewable electric energy consumed at TJNAF (including renewable energy credits [RECs] and bonuses) accounted for 50.6% of overall electricity consumption , 24.5% increase in clean and renewable	Continue to identify potential onsite renewable energy projects, such as PV system, and purchasing RECs in the interim; Continue to perform measurements and verification on existing onsite renewable systems to ensure maximum amount of onsite renewable electricity is captured

	electric energy relative to FY2020	
Increase consumption of clean and renewable non-electric thermal energy	48% of energy is nonelectric thermal usage16% increase in clean and renewable non- electric thermal energy relativeto FY 2020	Continue to investigate cost-effective renewable energy opportunities, such as geothermal and solar thermalapplications on new construction Continue to perform measurements and verification on existing on-site renewable systems to ensure maximum amount of non- electric thermal usage
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Sustainable Buildings		
Increase the number of owned buildings that are compliant with the Guiding Principles for Sustainable Buildings	10% of TJNAF's buildings comply with the Guiding Principles 26.47% of GSF of facilities meet the Guiding Principles	Document and confirm compliance for newly constructed and renovated buildings Perform building assessments to determine potential opportunities for existing buildings to meet Guiding Principle requirements where cost effective
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Acquisition and Procurement		
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring all sustainability clauses are included as appropriate	100% of all applicable contracts contain sustainability clauses TJNAF was awarded the DOE Gold Level GreenBuy Award by the DOE for the 4th consecutive year, making the TJNAF one of two sites to receive the Prime Award	Continue to seek opportunities to include sustainability clauses in contracts. Continue to purchase biobased materials when appropriate
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Efficiency & Conservation Measure Investments		
Implement life-cycle cost effective efficiency and conservation measures withappropriated funds	Investigated the use of cost-effective options to improve energy performance. Identified a number of lighting upgrades	Continue to support the opportunity to award an ESPC toan ESCO to implement energy and conservation measures on TJNAF's campus. Investigate and

and/or performance contracts	across 24 buildings to improve energy performance. Engaged an energy services company (ESCO) to identify potential for energy savings performance contracts (ESPCs) at a site level for TJNAF TJNAF awarded $3.9 million from DOE to design and implement a water reuse project in conjunction with the City of Newport News; project is expected to reduce TJNAF's potable water consumption by approximately 50 million gallons	implement cost-effective measures across TJNAF'S campus to comply with the Energy Act 2020 ECM mandate In upcoming fiscal years, TJNAF is seeking to incorporate UESCs site-wide to identify and complete ECMs In upcoming fiscal years, TJNAF is also plans to train and certify two facility energy managers
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Electronic Stewardship & Data Centers		
Electronics stewardship from acquisition, operations, to endof life	97.4% of all eligible electronics purchases were environmentally sustainable requirements; 2.9% increase relative to FY 2020. 100% of all eligible monitors, laptops, and PCs actively use power management features 100% of all eligible printers actively use duplex printing 100% of electronics are reusedor recycled	Continue to implement powersaving and duplex printing across all eligible devices. Continue to recycle and disposeof electronics through certified recyclers. Continue to purchase environmentally sustainableelectronics when possible
Increase energy and water efficiency in high-performance computing and data centers	Data Center PUE of 1.3	Continue to improve efficiency of power and cooling equipment in current and any future data center expansion projects
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Adaptation & Resilience		
Implement climate adaptation and resilience measures	Last assessment completed in 2014; improvements to infrastructure and operations	Complete a Vulnerability Assessment and Resiliency Plan in conjunction with DOE VARP guidance in FY 2022.

	have significantly reduced risk of flooding and power outages in key facilities. Last assessment identified critical supply chain threats for deliveries of Nitrogen and Helium gases; TJNAF obtained additional suppliers to avoid this threat	Identify opportunities to improve resiliency site-wide and integrate findings into future emergency response operationsand infrastructure capital plans
DOE Goal	**Performance Status**	**Plans and Projected Performance**
Multiple Categories		
Reduce Scope 1 & 2 greenhouse gas emissions	77.6% reduction relative to FY 2008 baseline 27.2% reduction relative to FY 2020	Continue to identify opportunities to reduce facility energy consumption and non- fleet vehicle and equipment fuel consumption. Identify and implement opportunities to prevent and reduce fugitive emissions
Reduce Scope 3 greenhouse gas emissions	85.2% reduction relative to FY 2008 baseline 19.9% reduction relative to FY 2020	Develop a commuter assistance website to increase awareness and continue to promote alternative commuting options. Revamp sustainability awarenessat a laboratory level through theuse of a newly designed website and cross-departmental communication. Continue to utilize teleworking when applicable to decrease employee commute mileage and emissions During FY22, JSA plans to approve an official remote working policy, which will continue to contribute towards Scope 3 GHG reduction goals Investigate options for installation of electric vehicle charging stations for fleet and workplace reimbursable charging

2.1.8 REDUCTIONS IN THE GENERATION AND/OR TOXICITY OF HAZARDOUS WASTE THROUGH POLLUTION PREVENTION

In 2021, TJNAF continued to incorporate waste minimization and pollution prevention evaluations to site activities during early planning phases. Opportunities to reduce

waste generation were identified and implemented across the facility, notable activities include:

- Donating materials and supplies to local schools.
- Recycling over 127 tons of scrap metals.
- Re-use of on-site concrete construction debris.
- Re-utilizing equipment that was excessed from completed projects.

2.1.9 REDUCTION OR ELIMINATION OF ACQUISTION OF TOXIC AND HAZARDOUS CHEMICALS AND MATERIALS

Purchase requests for hazardous materials are approved by TJNAF's ES&H staff to ensure that the most environmentally preferable products are acquired and used.

2.1.10 ENVIRONMENTALLY PREFERABLE PURCHASING

TJNAF promotes the purchasing of DOE-Priority Products through the Greenbuy Program and provides ready access to recycled content/remanufactured products. Facilities Management and Logistics explores opportunities to find vendors that recycle items no longer needed for operations.

In 2021, TJNAF was awarded a DOE Gold GreenBuy Award from the Department of Energy's Office of Sustainable Environmental Stewardship for meeting leadership goals for 9 priority products in 6 different categories. TJNAF achieved the Gold level award for the fifth consecutive year, which also earned the Facility with the GreenBuy Superior Award.

2.1.11 ELECTRONIC STEWARDSHIP

TJNAF utilizes the EPA's Electronic Product Environmental Assessment Tool (EPEAT) when selecting energy efficient desktop/laptop computers and computer monitors, photocopies, televisions, printers, fax machines, tablets and scanners. The facility tracks the purchase of this type of equipment. Energy savings, based on the rated efficiencies of the equipment, can then be calculated and reported. The EPEAT Purchase Awards program honors organizations showing leadership in the procurement of sustainable products. Each star is awarded to an organization for each category in which eligibility requirements are met. During 2021, approximately 97.4% of eligible products were compliant with EPEAT (bronze, silver, or gold) registration requirements. A central power management system is utilized for desktop computers, laptops, and monitors that can hibernate without impacting Facility operations. Printers are managed with default settings for printing duplex copies in black and white. Power management settings on printers and copiers are set to sleep mode when idle for specific amount of time.

2.1.12 RECYCLING PRACTICES

Recycling is standard practice for TJNAF. Recycling containers are featured in every office, conference, and break room. TJNAF staff, users, and subcontractors also utilize facility-wide office product recycling centers. These collect: aluminum cans, small batteries, cardboard, printer cartridges, paper wastes, telephone books, and plastic and glass bottles.

In 2021, with construction debris, scrap metal, and automatic data processing equipment included, approximately 206.5 tons of material was recycled. The overall percentage of material diverted from landfills in 2021 was 69.3%.

2.1.13 RESOURCE CONSERVATION & RECOVERY ACT (RCRA)

RCRA promotes the protection of health, the environment, and conservation of valuable material and energy resources. As a "Small Quantity Generator (SQG)," TJNAF generates less than 1000 kilograms (kg) of hazardous waste per month (but more than 100 kg). In 2021, approximately 1,240.12 kg of RCRA hazardous waste was generated. TJNAF does not store (outside of SQG allowed quantities/time limits), treat, transport, or dispose of RCRA-regulated waste on site. All RCRA wastes are disposed through licensed waste-handling transport and disposal facilities.

The two largest-volume hazardous wastes generated in 2021 were liquid scale dissolver, used for the cleaning of copper surfaces and refrigerant oil removed from cooling system equipment upgrades.

2.1.14 EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT (EPCRA)

Under EPCRA, as aligned with the Superfund Amendments and Reauthorization Act (SARA), TJNAF provides hazardous material data (characteristics, quantities, and storage locations) to local entities for planning purposes so they can prepare to provide adequate chemical and other emergency response services.

TJNAF meets applicable reporting requirements, such as toxic chemical usage and environmental releases, as required. See Figure 4 below.

Figure 4 – Status of EPCRA Reporting in 2021

EPCRA Section	Description of Reporting	Status
EPCRA § 302-303	Planning Notification	Completed
EPCRA § 304	EHS Release Notification	Not Required (No releases occurred)
EPCRA § 311-312	Safety Data Sheets/Chemical Inventory	Completed
EPCRA § 313	Toxic Release Inventory Reporting	Not Required (No reporting thresholds exceeded)

2.1.15 ENVIRONMENTAL RESTORATION & WASTE MANAGEMENT

Waste streams at TJNAF include Resource Conservation and Recovery Act (RCRA) hazardous waste, non-hazardous solid waste, universal waste, used oil, non-RCRA low-level radioactive waste (LLW), mixed RCRA-LLW (MLLW), and medical wastes. In 2021, TJNAF conducted waste management activities in accordance with applicable standards and requirements. No environmental restoration activities were required under the Comprehensive Environmental Response, Compensation, and Liability Act.

2.1.16 OTHER WASTES

Other wastes generated at TJNAF include wastewater discharges to sanitary sewer, non-hazardous solid waste from construction/maintenance activities and office waste bins. The vast majority of this waste is non-hazardous solid, consisting of routine office trash and construction debris. TJNAF has an extensive recycling program that resulted in the recycling of 68.1% of the overall waste generated on site (195.6 tons of material) in 2021.

LLW is generated and managed in accordance with DOE Order 435.1 – Radioactive Waste Management. TJNAF disposed of approximately 8500 kg of LLW in 2021, and about 33 kg of MLLW. Radioactive waste is disposed of at a licensed commercial facility, and is generally shipped to the facility in 25 cubic yard containers.

Only a minor amount of medical waste was generated by TJNAF's on-site clinic in 2021. Its disposal was in accordance with all applicable regulations.

2.1.17 RELEVANT DEMOGRAPHIC INFORMATION

TJNAF is a world-class research facility. It attracts both resident and visiting physicists, and other scientists from around the world. In 2021, approximately 744 full-time physicists, engineers, technicians, and support staff worked at TJNAF and more than 1,623 academic and industrial researchers, from across the United States and approximately 37 countries and 277 institutions, participated in scientific collaborations.

Each year, research conducted at TJNAF produces more than one-third of all Nuclear Physics PhDs awarded in the United States. Research at TJNAF in 2021 produced five patents.

2.1.18 FEDERAL INSECTICIDE, FUNGICIDE, & RODENTICIDE ACT (FIFRA)

FIFRA applies to the storage and use of herbicides and pesticides. Use of these substances has environmental implications, especially where water quality is concerned. Consequently, only subcontractors who have completed the certification program administered by the Commonwealth of Virginia perform the application of herbicides and pesticides at TJNAF.

In order to minimize the chances of herbicides and pesticides washing into local stormwater channels, TJNAF requires that there be no outdoor application of these compounds when rain is expected; no industrial-strength herbicides or pesticides are stored or disposed of on TJNAF property; and only small amounts are allowed to be mixed on site.

2.2 UNPLANNED RELEASES

During 2021, TJNAF ES&H staff continued to provide environmental guidance on spill prevention strategies to incorporate during activities occurring at the facility. Environmental guidance was provided to project managers during the initial planning phases of projects in order to identify potential contaminant sources along with providing strategies for pollution prevention during activities. Oil worker training and chemical safety training was also provided to applicable staff in order to update knowledge of spill prevention and the control of releases that may occur onsite. TJNAF ES&H continued to document all spills and releases onsite in the effort to identify any potential trends that could lead to potential improvements in spill prevention measures.

The following list summarizes the unplanned releases that occurred onsite during 2021:

September 1, 2021

JSA staff responded to a small fuel leak from a personal vehicle located in the parking lot adjacent to Building 90 (EEL – Experimental Equipment Lab) in the central portion of the campus. JSA staff and subcontractor staff immediately responded to the leak by removing the spilled contents located on the paved parking lot surface, applying absorbent materials and contacting the Newport News Fire Department for onsite response to confirm that there was no risk of ignition source. All materials discharged from the release were contained to the immediate area and did not migrate offsite.

2.3 SUMMARY OF PERMITS

TJNAF held four active environmental permits in 2021:

Figure 5 – Environmental Permits in 2021

Permit Number	Permit Type
GW0047201	Groundwater withdrawal
VA0089320	Industrial Wastewater to Surface – Groundwater Quality
VAR040079	Municipal Separate Storm-Sewer System (MS4)
HRSD 0117	Industrial Wastewater to Sanitary Sewer

During 2018, TJNAF received a five year extension of the existing MS4 Permit (VAR040079). There were no major changes to the permit, with the exception of new Best Management Practices implemented within the Minimum Control Measures section of the Permit. During April of 2021, TJNAF applied for the five year renewal of the Virginia Pollution Discharge Elimination System (VPDES) permit VA0089320 and anticipates receiving the five year extension in 2022. During October of 2021, TJNAF applied for the five year renewal of the Hampton Roads Sanitation District (HRSD) permit #0117 and anticipates receiving the five year extension during 2022.

2.4 RADIATION PROTECTION

All TJNAF activities in 2021 were in full compliance with applicable limits for occupational and environmental radiation protection. See Section 4.0 – Environmental Radiological Protection Program and Dose Assessment below.

2.5 ENVIRONMENTAL OVERSIGHT

TJNAF's exemplary environmental performance is due to the constant attention it receives from all parties involved in facility operations. The DOE Site Office, JSA, subcontractors, and various Commonwealth and local authorities provide continuous oversight of the Facility's environmental program. This includes routine inspections of construction projects, the MS4 System through Illicit Discharge Detection & Elimination (IDDE) inspections (12 monthly inspections in 2021), routine observations of effluent discharge locations for the sanitary sewer system (6 inspection in 2021), waste storage inspections (50 RCRA CAA inspections; 12 RCRA SAA inspections), MS4 High-priority Areas (12 monthly inspections in 2021) and review of other potential contaminant sources.

Self-assessments, inspections, and work observations are utilized to measure program effectiveness.

3 ENVIRONMENTAL MANAGEMENT SYSTEM

3.1 ENVIRONMENTAL OPERATING EXPERIENCE

TJNAF's Environmental Management System (EMS) is designed to:

- Identify facility activities with the potential for environmental impacts.
- Mitigate and otherwise manage the impacts of these activities.
- Maintain compliance with applicable environmental protection requirements.
- Promote the long-term stewardship of the Facility's and our neighbors' natural resources.
- Encourage understanding and promote dialogue with interested parties.
- Assess performance, implement corrective actions where needed, and ensure continual improvement.

TJNAF has invested in a multi-dimensional process to assure that its staff and contractors understand the potential impacts (both positive and negative) of their work on the environment and have the tools and training necessary to minimize the negative ones and maximize the positive ones.

As our compliance history and awards demonstrate, that on-going process has been successful.

Because EMS is about continuous improvement, a cross-cutting team of engineers, and other professionals are assembled, at least annually, to review progress, identify issues, and brainstorm possible solutions to better the system. This group reviews the previous year's EMS performance, discusses changes to facility operations, how these would affect the environment, and determines where the facility should focus its improvement activities. This analysis is reviewed by organizational leadership and identifies major focus areas (Objectives) as well as specific projects to support each focus area (Success Metrics).

Figure 6 below summarizes the Objectives for 2021.

Figure 6 – 2021 EMS Objectives Summary

EMS Objective	Success Metric(s)	Status
OBJECTIVE 1 Energy Usage and Emissions: Utilizing the specific Turtle diagram for this process, conduct remote/desktop audit of contributing processes to Cryogenics Operations: Compressed Cryogenics Gases delivery through Turtle diagram analysis	Conduct audit/assessment of contributing processes such as: routine gas delivery, spill response practices. Identify any opportunities for continuous improvement.	Accomplished
OBJECTIVE 2 Water Usage and Discharge: Utilizing the specific Turtle diagram for this process, conduct remote/desktop audit of contributing processes to General Infrastructure: Cooling Tower through Turtle diagram analysis	Conduct audit/assessment of contributing processes such as: BMPs practiced, routine maintenance schedule. Identify any opportunities for continuous improvement.	Accomplished
OBJECTIVE 3 Hazardous/Toxic Materials Management: Pilot-test of digital/remote hazardous waste management inventory system during FY21	Successfully utilize upgraded hazardous waste logbook to prepare hazardous waste shipment inventory for FY21 summer shipment for disposal.	Accomplished
OBJECTIVE 4 Ionizing Radiation Production Management: Upgrade VPDES groundwater statistical analysis database for managing radionuclide data for permit groundwater monitoring	Work with Radiation Control Group to implement use of statistical analysis database during FY21.	Accomplished

*Excerpts taken from the CY2021 Environmental Management System Objective Implementation Plan.

3.2 ACCOMPLISHMENTS, AWARDS & RECOGNITION

TJNAF was awarded with a DOE Gold GreenBuy Award in 2021 from the Department of Energy's Office of Sustainable Environmental Stewardship for meeting leadership goals for 9 priority products in 6 different categories.

TJNAF received a 2021 Gold Award from the Hampton Roads Sanitation District (HRSD) for perfect compliance with industrial wastewater discharges to sanitary sewer.

TJNAF was also recognized by the Virginia Department of Environmental Quality (DEQ) during 2021 as an Exemplary Environmental Enterprise (E3) facility within the Virginia Environmental Excellence Program (VEEP). The VEEP consists of three levels: E2 – Environmental Enterprise; E3 – Exemplary Environmental Enterprise; and E4 – Extraordinary Environmental Enterprise. The E3 level is for facilities with fully-implemented Environmental Management Systems (EMS), pollution prevention programs, and demonstrated environmental performance.

During 2021 a formal audit of the TJNAF EMS was conducted by a qualified outside party. The audit determined that the TJNAF EMS was in conformance with the requirements of the ISO 14001:2015 Standard.

3.3 ENVIRONMENTAL PERFORMANCE MEASUREMENT

An existing program on www.FedCenter.gov allows Federal agencies to measure EMS performance using metrics developed to gauge the maturity and health of environmental programs, based on the requirements of the ISO 14001 standard. In 2021, TJNAF's EMS received the highest score.

4 ENVIRONMENTAL RADIOLOGICAL PROTECTION PROGRAM AND DOSE ASSESSMENT

4.1 RADIOLOGICAL DISCHARGES & DOSES

4.1.1 RADIATION IN THE ENVIRONMENT

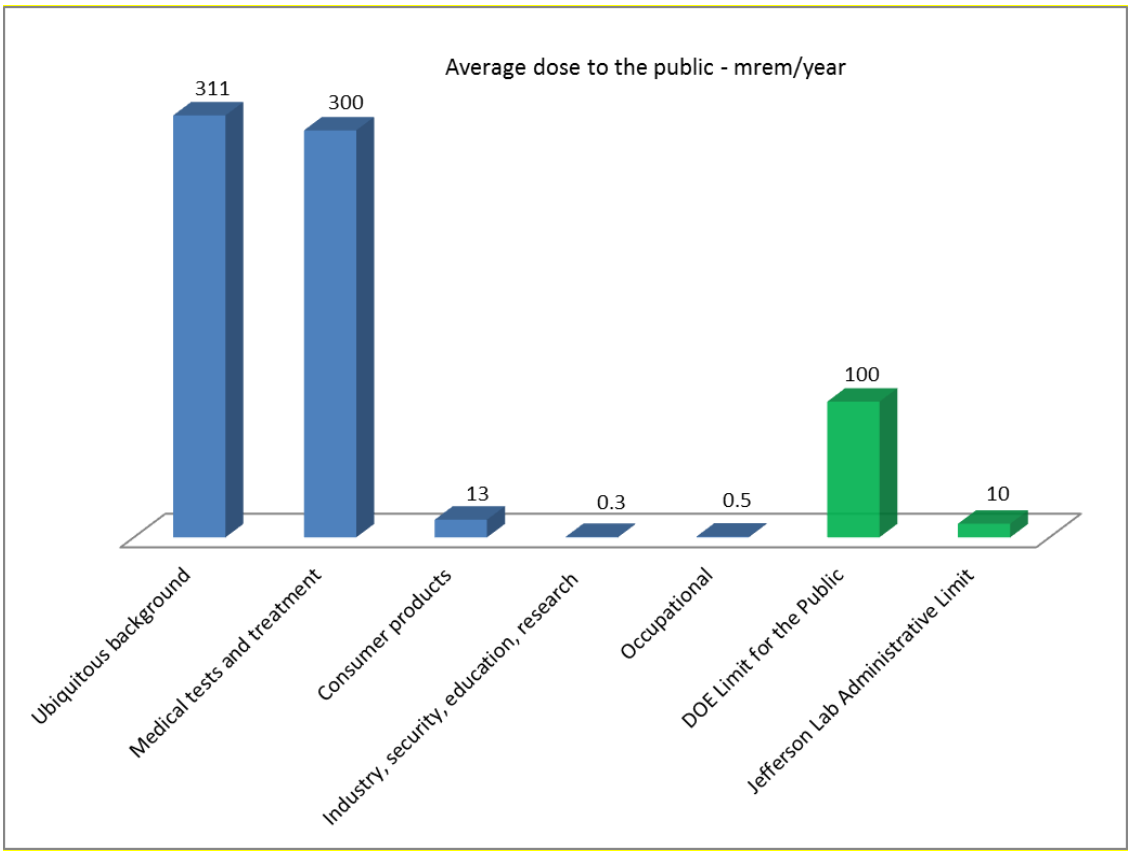
People are exposed to radiation constantly:

- Cosmic radiation from extraterrestrial sources;
- Terrestrial radiation from naturally-occurring elements in the earth's crust; and
- Man-made sources of radiation, notably from medical procedures.

Radiation exposure or "dose" is quantified in units of *rem (roentgen equivalent man)*, and may be expressed as an individual dose or average amounts among groups or populations. Usually the millirem (mrem) is used to express the small doses associated with occupational and environmental exposure (1 mrem is 1/1000 of a rem). The SI unit in which dose is expressed is the *sievert* or millisievert (mSv). A sievert is equal to 100 rems, so 1 mSv is equal to 100 mrem.

Figure 7 – Comparison of Sources of Radiation Exposure shows the relative significance of various sources of radiation exposure to the average member of the public. According to the National Council on Radiation Protection and Measurements, as of 2006, the average individual radiation exposure in the U.S. from all sources now totals about 620 mrem per year, up from an estimated 360 mrem in the early 1980's. The increase can be attributed to medical uses of radiation.

Figure 7 – Comparison of Sources of Radiation Exposure



The DOE limits the potential dose to the public that is attributable to DOE facility operations to 100 mrem per year. TJNAF has established an Alert Level of 10 mrem, either measured or estimated, for protection of the general public.

4.1.2 RADIATION EXPOSURE PATHWAYS AT TJNAF

Two broadly-defined sources of potential radiation exposure exist at the facility: *direct (or "prompt") radiation* and *induced radioactivity*. Both types are produced during accelerator operations, but direct radiation has a potential impact only within close proximity to an operating accelerator on the site. Accelerator operation (i.e., running an electron beam) produces significant levels of direct radiation within the accelerator enclosure. This radiation is produced within the beam enclosure and its production stops when an accelerator is turned off. Almost all direct radiation is absorbed by

extensive shielding, which is an integral part of accelerator design. Any possible exposure to this radiation decreases rapidly with distance from the accelerators, and is extremely small at the site boundary.

TJNAF has an extensive radiation monitoring network in and around the accelerator. There are approximately 50 active, real-time radiation monitors and a series of passive integrating detectors deployed around the accelerator site. Among these, eight monitors collected direct radiation data around the site boundary in 2021. These monitoring stations are equipped with specialized detection devices, optimized for measuring radiation at close to background levels.

In addition to prompt radiation, the interaction of the accelerator beam with matter can cause the formation of radioactive materials through activation of matter (*induced radioactivity*). The beam lines, magnets, beam line components, targets, detectors, other experimental area equipment, and the energy dissipating devices (beam dumps) used to contain the beam's energy, may become activated. Cooling water, lubricants, and air in the beam enclosure may also become activated. Strict controls limit possible radiation exposure from these activated items and materials.

All materials exposed to the beam or to potential sources of transferable contamination are monitored for radioactivity prior to being released from local control. TJNAF adheres to the DOE release limits for surface contamination, and follows DOE guidance for ensuring that materials being released contain no detectable induced radioactivity.

Controls are in place to minimize exposure from both direct and induced radiation to facility personnel, the environment, and the public. Access to the accelerator site and to areas containing radioactive material is strictly limited. Fencing, safety interlocks, signs, training, and other engineered and administrative controls prevent inadvertent or unnecessary exposures to direct radiation and induced radioactivity.

The largest potential source of environmental impact of a radiological nature at TJNAF is the operation of the CEBAF accelerator. CEBAF has been increasing its operating schedule since the completion of the 12 GeV upgrade in 2014. Little or no high power operations occurred in 2014. A reasonable proxy for the overall environmental radiological impact of operating the CEBAF accelerator is the beam power delivered to experimental halls. Halls A and C receive by far the greatest fraction of beam power. The table below depicts the approximate total beam power delivered to these two halls since 2016. The impact of this beam delivery is reflected in the historical data presented in the following sections.

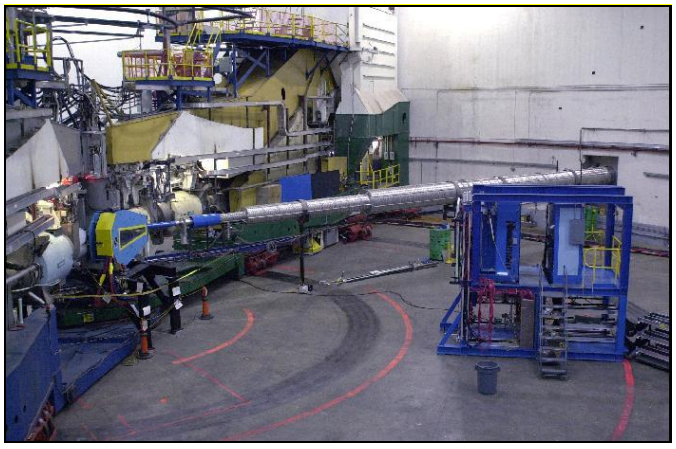
Beam Power Delivered to Halls A and C

Calendar Year	Beam Power (MW-hr)
2016	184
2017	16
2018	1025
2019	481
2020	586
2021	577

4.1.3 MONITORING OF POTENTIALLY ACTIVATED WASTEWATER

Water that could potentially become activated is sampled, analyzed, and discharged under HRSD Permit No. 0117 and VPDES Permit No. VA0089320. These wastewaters can include:

- CEBAF accelerator enclosure and experimental hall floor drainage
- Beam dump and target cooling water
- Environmental samples, once analyzed
- Groundwater extracted from beneath Halls A, B, and C



Hall A Beam Line to Beam Dump toward Right

The potential radiological constituents of TJNAF's wastewater discharge to HRSD in 2021 (*see Figure 8 – Radioactive Discharges to HRSD, 2021*) totaled 0.0859 curies (Ci) of tritium (versus a limit of 5 Ci) and 0.0000899 Ci of total gamma-emitters (limit = 1 Ci). These values represent over-estimates since sample data yielding a zero or negative result (statistically expected for some samples with no radioactivity) are replaced with the minimum detectable activity value for the analysis.

Figure 8 – Radioactive Discharges to HRSD, 2021

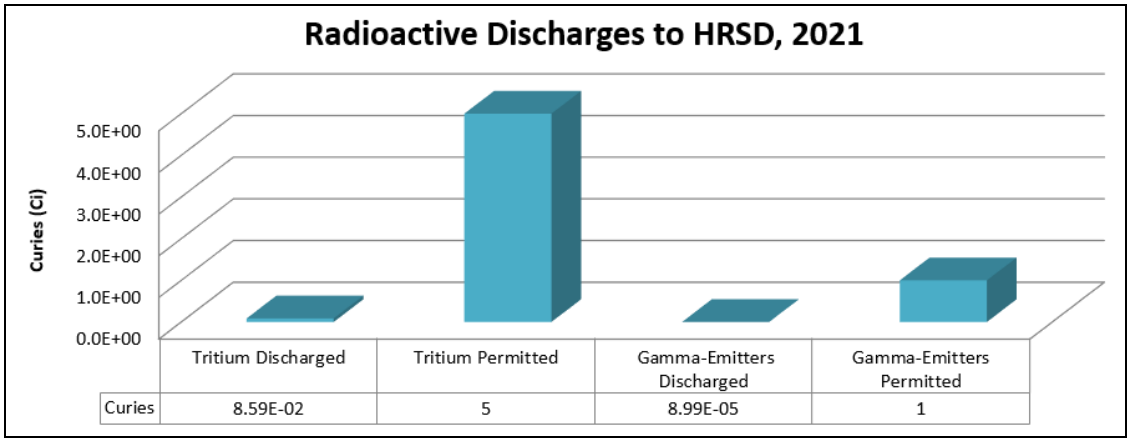


Figure 8A – Five Year Summary of Radioactive Discharges to HRSD

Five Year Summary of Radioactive Discharges to HRSD					
Year	Unit	Tritium Discharged	Tritium Permitted	Gamma-Emitters Discharged	Gamma-Emitters Permitted
2021	Curies	8.59E-2	5	8.99E-5	1
2020	Curies	2.62E-03	5	8.78E-07	1
2019	Curies	3.58E-01	5	4.92E-04	1
2018	Curies	8.28E-02	5	2.44E-04	1
2017	Curies	3.27E-03	5	2.42E-04	1

DOE regulates radiological wastewater effluents under DOE Order 458.1. The Order requires wastewater treatment to reduce radioactivity content using the best available technology (BAT) at specified concentration thresholds, in keeping with the ALARA (As Low As Reasonably Achievable) principle. Average discharge concentrations in 2021 remained a small fraction of the BAT treatment threshold.

4.1.4 AIRBORNE RADIONUCLIDES

Essentially all airborne radionuclide emissions from the facility are the result of the release of air from accelerator enclosure vaults containing activation products resulting from beam interactions with the air. The interaction of the beam with air produces short-lived radionuclides such as Oxygen-15, Nitrogen-13, and Carbon-11, and smaller amounts of the longer-lived Hydrogen-3 (tritium). Measurable quantities of airborne radionuclide production (and emission) occur almost exclusively in the CEBAF accelerator at experimental Halls A and C and the beam switchyard portion of the accelerator. Other areas of CEBAF and the LERF contribute only a very small amount to the total emissions. See Figure 9 – Atmospheric Discharges of Radionuclides, 2021 below for a summary of estimated atmospheric releases from TJNAF in 2021.

Figure 9 – Atmospheric Discharges of Radionuclides, 2021

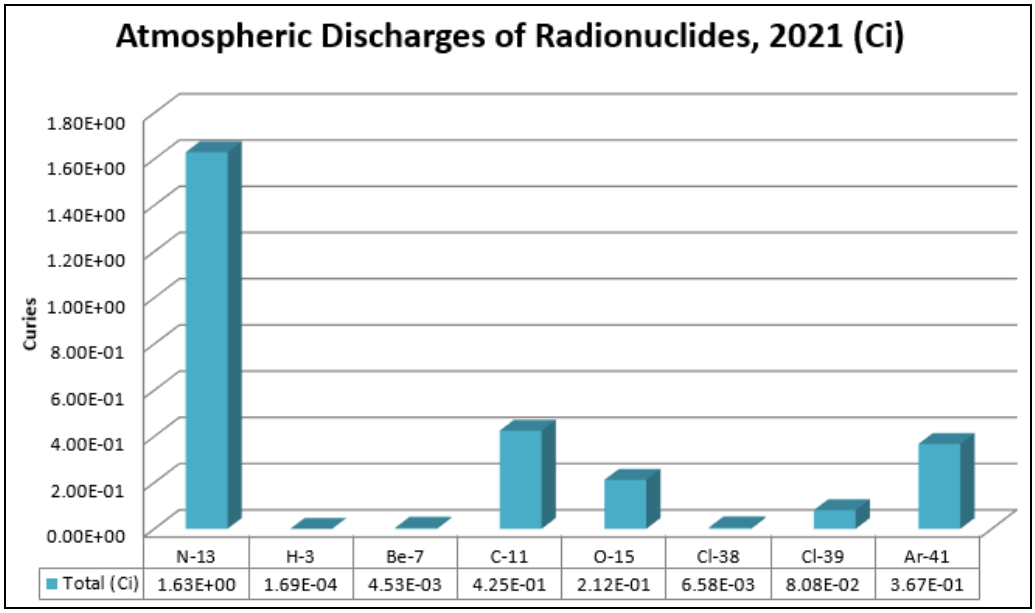


Figure 9A – Five Year Summary of Atmospheric Discharges of Radionuclides

Five Year Summary of Atmospheric Discharges of Radionuclides									
Year	**Unit**	**N-13**	**H-3**	**Be-7**	**C-11**	**O-15**	**Cl-38**	**Cl-39**	**Ar-41**
2021	Curies	1.63E+00	1.69E-04	4.53E-03	4.25E-01	2.12E-01	6.58E-03	8.08E-02	3.67E-01
2020	Curies	3.16E+00	2.08E-04	5.34E-03	6.26E-01	9.92E-01	1.50E-02	1.84E-01	3.71E-01
2019	Curies	6.75E+00	2.61E-04	6.54E-03	9.58E-01	2.60E+00	3.14E-01	3.82E-01	3.07E-01
2018	Curies	6.58E+00	1.31E-01	9.20E-03	1.16E+00	2.07E-00	2.91E-02	2.63E-01	6.46E-01

2017	Curies	2.49E-01	7.51E-03	1.45E-04	3.65E-02	1.20E-01	1.24E-03	1.46E-02	8.24E-03

Compliance with EPA regulations (40CFR61) requires TJNAF to determine the potential for the maximum exposure to this radioactivity by a member of the public. Annual calculations using an EPA-approved computer model (CAP-88 PC, Ver. 4), show that TJNAF's operational emissions remain several orders of magnitude lower than the EPA's 10 mrem/year dose limit for a member of the general public. The calculated 2021 dose to the Maximum Exposed Individual (MEI) among members of the public was 0.0063 mrem/year due to airborne releases. The location of the MEI was approximately 225 meters south of the accelerator, in the Oyster Point office park. This MEI dose represents a very conservative estimate, as the population in the office park would be expected to occupy their location for only 40 hours/week. CAP-88 does not distinguish between commercial or residential (up to 24 hour/day) presence.

4.1.5 DIRECT RADIATION MONITORING

Active (real-time) radiation measurement devices installed along the accelerator site boundary continued to be used to measure dose from direct radiation attributable to facility operations. Figure 11 shows the approximate locations of the Radiation Boundary Monitors (RBMs) that measure and log radiological information, along with the groundwater monitoring well network.

Figure 10 – Direct Radiation Dose at Site Boundary, 2021 displays the radiation doses in mrem at the detectors that saw the largest dose from accelerator operations in 2021. This dose represents direct radiation exposure that would be experienced at the actual on-site boundary monitor location during accelerator operations. Note that the boundary dose shown is the total cumulative dose for the year. This does not, however, represent an estimate of the potential dose to a member of the public; under any credible scenario, that dose would be a small fraction of this amount.

Figure 10 – Direct Radiation Dose at Site Boundary, 2021

Period*	Neutron (mrem)	Gamma (mrem)	Total (mrem)
Aug-Dec (RBM-3)	1.07	0.29	1.36
TOTAL	1.07	0.29	1.36

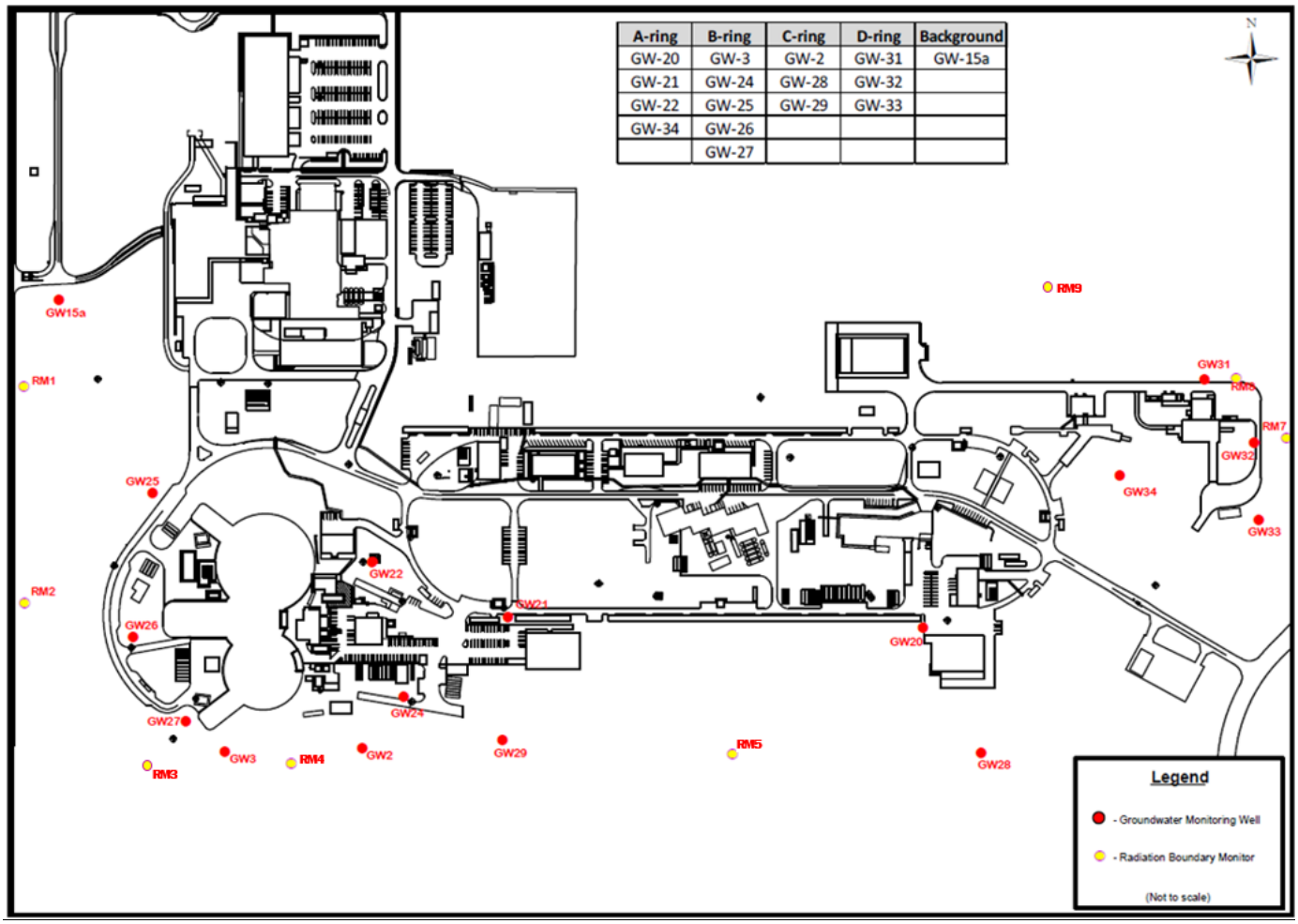
*CEBAF operations in 2021 occurred only from August to December

Figure 10A – Five Year Summary of Direct Radiation Dose at Site Boundary

Five Year Summary of Direct Radiation Dose at Site Boundary			
Period	**Neutron (mrem)**	**Gamma (mrem)**	**Total (mrem)**
2021	1.07	0.29	1.36
2020	1.30	0.25	1.55
2019	2.45	0.50	2.95
2018	1.10	0.28	1.38
2017	0.071	0.018	0.09

The measured dose in 2021 is approximately 13% of the Facility's design goal of 10 mrem/year (one-tenth of the DOE dose limit). See Potential Dose to the Public and to Biota for estimates of potential doses to the public.

Figure 11 – Radiation Boundary Monitors and Groundwater Monitoring Wells



4.1.6 GROUNDWATER MONITORING

The underground CEBAF and associated experimental end stations lie in the Yorktown Formation. Groundwater occurs site-wide at a depth of approximately 3 to 25 feet below ground surface.

Under VPDES Permit No.VA0089320, TJNAF monitors groundwater that is pumped from around the experimental halls and is discharged through Outfall 001 to the surface. The vast majority of the surface water leaving the site flows to the Big Bethel Reservoir via Brick Kiln Creek; with a smaller amount going to the lower James River.

In 2021, sixteen wells (*See Figure 11 – Radiation Boundary Monitors and Groundwater Monitoring Wells*) were routinely monitored for radioactivity, using EPA or other approved sampling and analysis protocols. Wells are designated as A-ring, B-ring, C-ring, Hall D, or background. A-ring wells, located closest to the accelerator, are most

likely to show the effects of soil and groundwater activation. B-ring wells are located further from potential sources of activation. Both A-ring and B-ring wells are sampled semi-annually. C-ring wells, positioned to represent conditions near the property boundaries, are sampled annually, along with the background well. Monitoring of Hall D wells were conducted on a semiannual basis.

Groundwater samples are analyzed for H-3 (tritium), Be-7 (beryllium 7), Mn-54 (manganese 54), and Na-22 (sodium 22). The VPDES permit specifies limits for radioactivity in the wells based on their location with respect to the accelerators. No accelerator-related radionuclides were detected in the groundwater and no permit exceedances occurred in 2021.

4.1.7 OTHER ENVIRONMENTAL SURVELLIENCE

TJNAF routinely collects environmental samples not required by any regulation or permit. Sediments from storm drainage channels and soils in areas that could potentially be affected (by contaminated runoff or storage and handling of radioactive materials) are sampled at a variety of locations on a location-specific frequency. Results of sampling continue to show that no significant radioactivity is being released to the environment through these pathways.

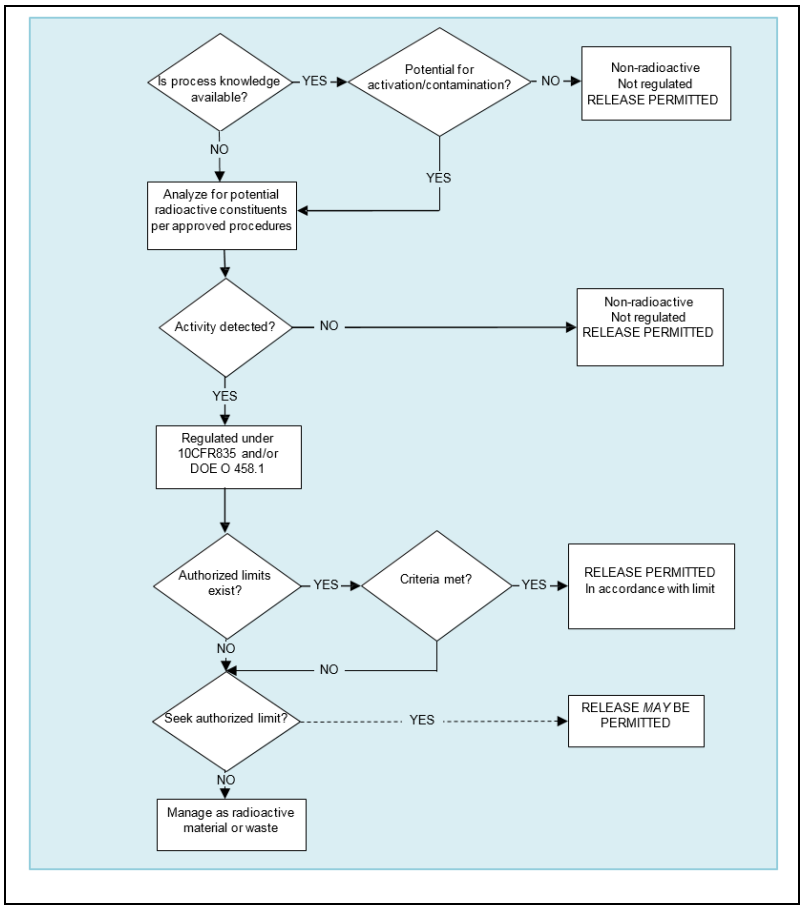
4.2 CLEARANCE OF PROPERTY CONTAINING RESIDUAL RADIOACTIVE MATERIAL

TJNAF does not release to the public any residual radioactive material, such as contaminated concrete or soil, so there are no resulting dose impacts to the public. The Facility has developed a process to determine if potentially radioactive materials are to be managed as material containing residual radioactivity or as non-radioactive. All potentially activated or contaminated material and equipment is monitored prior to release from control. The program involves many hundreds of radiological surveys annually.

TJNAF adheres to DOE limits for radioactive surface contamination (although little material with surface contamination is generated here). DOE Order 458.1 does not prescribe a specific limit for release of volumetrically-activated materials; therefore, the Facility has adopted methods and procedures that ensure equipment and materials being released contain no volumetric radioactivity distinguishable from background. Materials with potential for internal contamination or volumetric radioactivity that cannot be reliably assessed are treated as radioactive materials and are not released to the public.

Figure 12 – General Process for Materials Classification - summarizes TJNAF's process. This process is consistent with the approach recommended by a multi-agency task group regarding defining impacted areas and classifications of material.

Figure 12 – General Process for Materials Classification



The application of process knowledge comprises the first step in the characterization of materials for possible release. The approach at TJNAF has historically been a conservative one: if materials were in the accelerator enclosure during beam operations, it is assumed that they may be activated, and they are subject to further analysis. Surveys and sampling and analysis are conducted by trained technicians using formal, written procedures. Results of the surveys or other analyses are documented appropriately.

In 2021, the estimated volume of materials released through the process described above was about 8.7 tons of solid waste and an estimated 12.7 tons of scrap metals for recycling.

Potential doses to the public from undetected radioactivity in released materials have been assessed and documented as prescribed in various national and international standards. These standards and DOE requirements apply a dose constraint of 1 mrem/year for determining the significance of potential dose to the public. The measurement sensitivity of the Facility's procedures was evaluated against this benchmark as part of its technical basis, confirming that potential dose to a member of the public through this pathway is insignificant.

Independent review of TJNAF's process for releasing materials from radiological control is conducted periodically by DOE or a designated third party.

TJNAF sought no Authorized Limits for the release of material containing residual radioactivity in 2021. All materials that exhibit radiation above background levels were managed as radioactive material, and either saved for beneficial reuse, or classified as waste. Almost all radioactive waste generated at TJNAF is low-level waste (LLW), with an occasional small additional amount of mixed-LLW (MLLW). In 2021, approximately 18,740 pounds of LLW and 73 pounds of MLLW were transferred for offsite disposal at an authorized disposal facility.

4.3 POTENTIAL DOSE TO THE PUBLIC

Controls are in place to minimize exposure from both direct radiation and radiation from activated materials to facility personnel, the environment, and the public. Access to the Accelerator Site and to areas housing radioactive material is strictly limited. Fencing, safety interlocks, signage, training, and other engineered and administrative controls prevent inadvertent exposures to direct and induced radiation.

The direct dose and air emissions discussed above are the only sources for which any contributions to public dose can be directly measured or calculated. Other sources involve only hypothetical doses. In *Figure 13 – TJNAF Radiological Dose Summary for 2021* - the maximum possible dose to the public assumes a 24-hour a day, 365-days-a-year exposure to the highest levels measured at the site boundary. However, it is not credible under any plausible conditions for a member of the public to actually receive this dose. The southern and western boundaries of the site, where the monitors are located, are heavily wooded and mostly undeveloped or adjacent to a major roadway. All site boundaries are also posted with "U.S. Government – No Trespassing" signs.

Figure 13 - TJNAF Radiological Dose Summary for 2021

Pathway	Dose to Maximally Exposed Individual, mrem	% of 100 mrem/yr DOE Limit	Estimated Population Dose, person-rem
Air*	0.0063	0.0063	0.0131
Water**	~0	~0	~0
Release of materials**	≤1	≤1	~0
Direct radiation***	1.36	1.36	~0
Total, all pathways	≤2.37	≤2.37	~0
Plausible scenario †	0.079	0.079	-

*From 2021 atmospheric modeling results for National Emission Standards for Hazardous Air Pollutants (NESHAP) reporting

** See text below

*** From Boundary Radiation Monitors, before applying realistic exposure scenario (see text)

† Total effective dose using a conservative, reasonable exposure scenario (see text)

One can construct an exposure scenario in which a more realistic estimate of the maximum potential dose to a member of the public is obtained. A reasonably conservative scenario might involve exposure at the boundary in which an individual spent two hours per day walking along the site boundary or waiting for a Jefferson Avenue bus, and did so for 250 days of the year. Under this scenario, we can assign the average dose rate from monitoring to the individual for the entire occupancy duration. This hypothetical case represents a reasonably conservative scenario for the MEI for this source. Given these conditions, the MEI for this exposure path would have received 0.078 mrem in 2021 from direct radiation, 0.078% of the DOE limit of 100 mrem.

The potential dose from air releases is also modeled using a 100% exposure time assumption. A reasonable modification would be to adjust this value for a typical occupational duration (2000 hours) at the location of concern. This results in a dose of 0.0014 mrem. Doses from these two sources represent the only reasonably quantifiable exposure pathways to the public from Facility operations. If we combine the dose from these two scenarios, the maximum postulated dose from

all pathways to a member of the public from TJNAF operations in 2021 is approximately 0.079 mrem.

There is no public or private use of the shallow aquifer in the vicinity of TJNAF; thus, there is no exposure to the public via contact with or ingestion of groundwater. No accelerator-produced radioactivity was detected in any of the samples from the End Station Sump or in surface water. Considering the extremely small quantities of radioactivity that are potentially present in this effluent, the potential dose to a member of the public or biota from this pathway is insignificant. A 2013 RESRAD-based evaluation found that the total dose from pathways such as ingestion of plants, fish, meat, and milk, as well as all pathways related to surface water, was in the range of 10^{-8} mrem/year.

The total "potentially exposed population" reported herein is defined by DOE as those living within 80 km (50 miles) of the site. Population data from the 2010 Census uses an outer radius of 70 km. Population dose estimates in this report are based entirely on the NESHAP dose calculation. Dose beyond the site's boundary is so low it cannot be directly measured.

4.4 ADDRESSING RADIATION PROTECTION FOR BIOTA IN ASER

4.4.1 DOSE RATE LIMITS FOR PROTECTION OF BIOTA & METHODS FOR COMPLIANCE

TJNAF can only estimate absorbed dose to local biota (aquatic or terrestrial). The DOE has provided guidance on evaluating dose that may be received by biota. DOE-Standard-1153-2002 provides screening values for both terrestrial and aquatic organisms. The internationally recommended dose limit for terrestrial biota, 0.1 rad/day, is the lowest limit for any biota. The rad is a dose unit similar to the rem, but it does not contain any of the risk factors associated with exposure to humans. Therefore, all criteria are met if doses do not exceed 0.1 rad/day.

The best indicators of dose to biota are the passive dosimeters placed at various locations around the property. These are the same types of dosimeters used to monitor worker exposure. In 2021, 39 locations were monitored by this method for purposes of estimating environmental dose.

Earthen domes over Halls A, B, and C

During 2021, the site provided habitat for deer, foxes, raccoons, squirrels, groundhogs and other small mammals, reptiles, aquatic macroinvertebrates, and a wide variety of birds. The birds and some of the mammals roam the site, but others (like the groundhogs) live in an established burrow. The biota expected to receive the maximum dose would be ground-dwelling animals living in the earthen berms over the experimental halls.

Figure 14 – Distribution of 2021 Dose Reflected by Environmental Dosimeters - shows the frequency distribution of annual (2021) doses from the network of dosimeters. The maximum recorded dose was 33 mrad, measured at the east side of the Hall A beam dump cooling water building. Dividing this value by 365 days yields a daily dose of 0.00009 rad/day, far below the most stringent criteria. *Figure 15 – Environmental Radiation vs. Limit* - illustrates these data.

Figure 14 –Distribution of 2021 Dose Reflected by Environmental Dosimeters

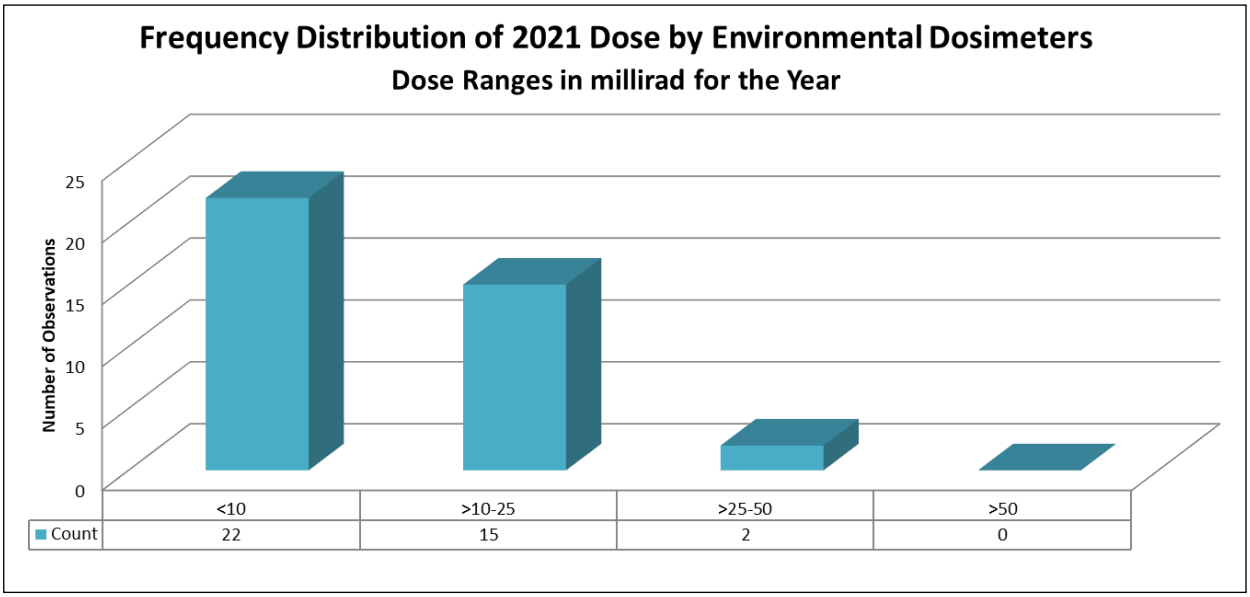


Figure 14A – Five Year Summary of Distribution of Dose in millirad/year Reflected by Environmental Dosimeters

Five Year Summary of Distribution of Dose in millirad/year Reflected by Environmental Dosimeters							
Year	**<10**	**>10-25**	**>25-50**	**>50**	**>50-75**	**>75-100**	**>100**
2021 Count	22	15	2	-	-	-	-
2020 Count	28	7	3	-	-	-	-
2019 Count	28	8	0	2	1	-	1
2018 Count	27	8	1	2	-	-	2
2017 Count	28	8	1	1	-	-	-

Figure 15 – Environmental Radiation Dose vs. Limit

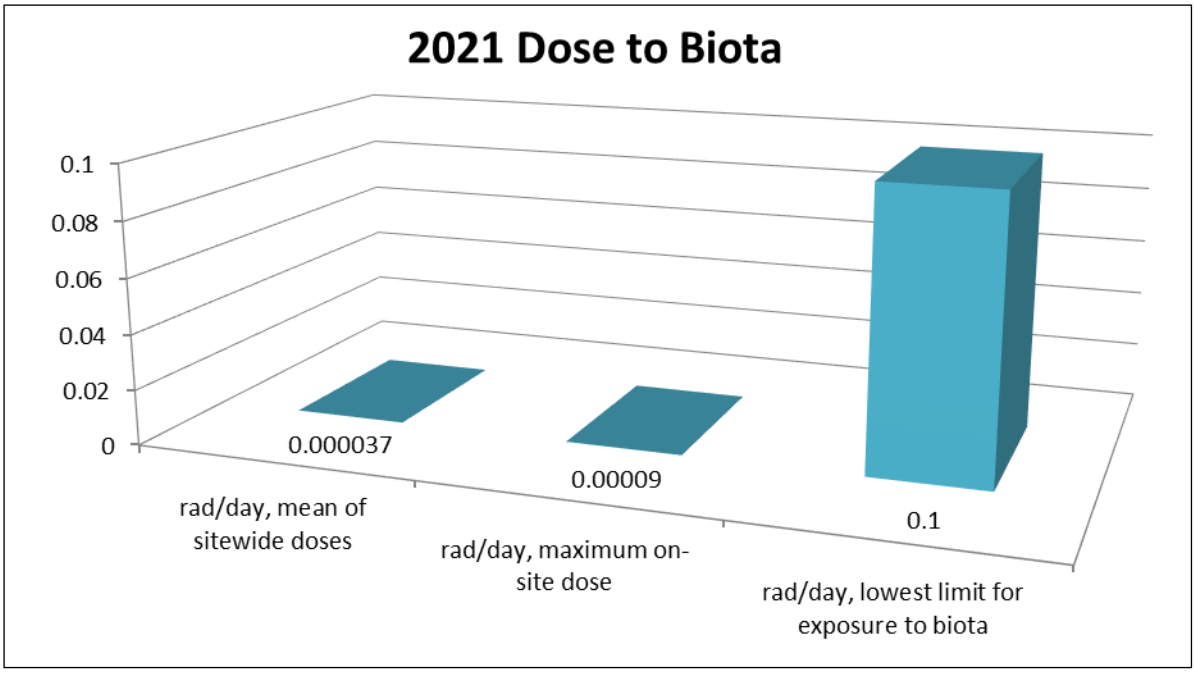


Figure 15A – Five Year Summary of Dose to Biota

Five Year Summary of Dose to Biota			
Year	**Rad/day, mean of site-wide doses**	**Rad/day, maximum on-site dose**	**Rad/day, lowest limit for exposure to biota**
2021	0.000037	0.00009	0.1
2020	0.000013	0.000082	0.1
2019	0.000029	0.00057	0.1
2018	0.000037	0.00058	0.1
2017	0.000017	0.00019	0.1

4.5 UNPLANNED RADIOLOGICAL RELEASES

TJNAF had no unplanned radiological releases in 2021.

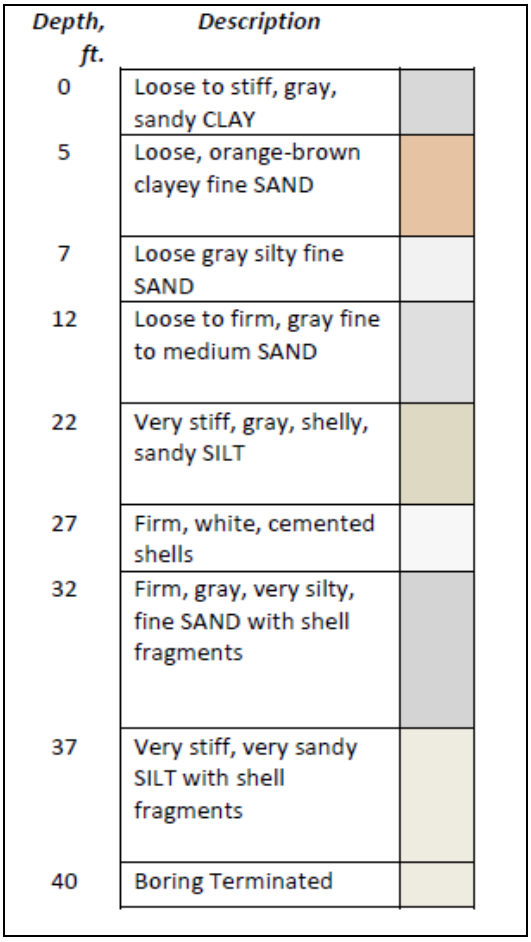
4.6 ENVIRONMENTAL RADIOLOGICAL MONITORING

Ionizing radiation and a variety of radioactive materials are by-products of research activities at TJNAF. Any potential impacts have been significantly reduced by adhering to the philosophy of "as low as reasonably achievable" (ALARA) in dealing with potential sources of radiation. The potential dose to members of the public from various pathways, such as inhalation, ingestion, and skin absorption, is evaluated by the ES&H Division to demonstrate compliance with regulatory limits (as required by DOE Order 458.1, "Radiation Protection of the Public and the Environment").

5 GROUNDWATER PROTECTION PROGRAM

Figure 16 – Typical Cross Section of Boring at TJNAF Site, compiled from several on-site boring logs, depicts a typical cross section. The CEBAF tunnel and experimental end stations are located underground within the Yorktown Formation. Activation of the groundwater and soil are a potential source of groundwater contamination. Groundwater occurs site-wide at a depth of approximately 3 to 25 feet below grade. Groundwater quality in the soil surrounding the accelerator complex is the Commonwealth's greatest concern with site operations.

Figure 16 – Typical Cross Section of Boring at TJNAF Site



The monitoring of VPDES-permitted wells for groundwater quality continued in 2021, and provided much of the basis for the Groundwater Protection Program. Through a combination of engineered

controls (e.g. shielding) designed into the CEBAF and LERF facilities, and adherence to operational limits, no measurable groundwater activation was produced on or offsite.

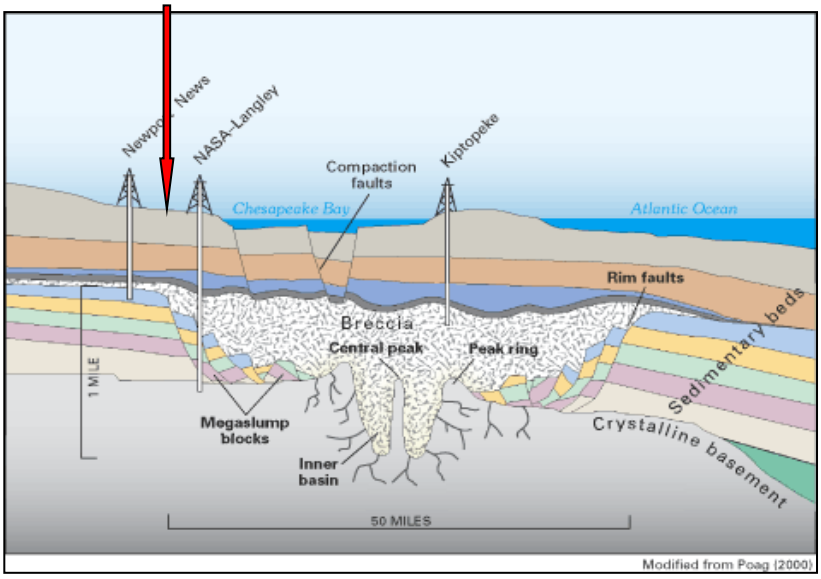
Many other programs at TJNAF contribute to groundwater protection: spill prevention and control, pollution prevention and waste minimization, materials storage, and waste management are a few.

Relatively recent information places TJNAF in a unique geologic position. Approximately 35 million years ago, a giant bolide[1] blasted a huge crater into the continental shelf. A bolide of this magnitude creates a complex crater with inner and outer rims.

As *Figure 17 – Delineation of Inner and Outer Craters* indicates, the outer rim of the crater lies across Newport News. The inner and outer rims have complex, characteristic stratigraphic features, as shown in *Figure 18 – Location of TJNAF Relative to the Outer Rim of the Chesapeake Bay Bolide Crater*.

Figure 17 – Delineation of Inner and Outer Craters

Figure 18 – Location of TJNAF Relative to the Outer Rim of the Chesapeake Bay Bolide Crater



The red arrow (*Figure 18 – Location of TJNAF Relative to the Outer Rim of the Chesapeake Bay Bolide Crater*) indicates the approximate location of TJNAF relative to the Chesapeake Bay bolide crater. Site geology could be more complex than once thought. Notably, in this area, the Yorktown-Eastover aquifer is greatly diminished. Extensive studies of the groundwater characteristics within the outer rim show that even deeper aquifers were affected by the bolide, which evaporated water more than a mile deep. That water was replaced by saline water, which remains present to this day in the Potomac aquifer and other, deeper groundwater sources.

TJNAF activities to date have involved only the Yorktown-Eastover aquifer; that aquifer is the focus of our Groundwater Protection Program. The Yorktown-Eastover aquifer is represented in the above figure by the blue layer between the orange-tan (Yorktown) and dark gray (Eastover) formations.

Semiannual monitoring of wells installed around the Hall D complex was initiated in the Fall of 2016, as a result of the reissuance of VPDES Permit VAR0089320. Groundwater data from wells around Hall D for 2021 is consistent in quality with the remainder of the TJNAF site.

6 QUALITY ASSURANCE (QA)

Extensive QA activities ensure that TJNAF's environmental monitoring program continually performs in accordance with the principles of the QA Program (DOE Order 414.1D) and the requirements of DOE Order 458.1. The QA Program includes:

- Qualification of the laboratories that provide analytical services.
- Verification of certification to perform analytical work.
- Review of performance test results.
- Assessment of the adequacy of each subcontractor's internal quality control (QC) practices, recordkeeping, chain of custody, etc.

In addition to the internal QA performed by TJNAF's Environment, Safety, and Health Division, independent assessments are performed by Performance Assurance, the DOE Site Office, regulatory agencies such as the EPA and Virginia Department of Environmental Quality, and oversight groups within DOE. No QA concerns regarding environmental sampling protocols or results were noted in 2021.

An independent laboratory (James R. Reed & Associates) collected most of 2021's VPDES and HRSD permit-required water samples. Other samples that involve radionuclide analysis, including some required by the HRSD permit, are collected by the ES&H Division and analyzed in TJNAF's radiological analysis facility (RAL). Eberline Services performed all subcontracted radiological analyses. James R. Reed is a Virginia Environmental Laboratory Accreditation Program (VELAP) certified facility as administered by the Virginia Division of Consolidated Laboratory Services (DCLS). The DCLS administers the certification/accreditation program and conducts inspections of environmental laboratories to ensure consistency with the National Environmental Facilityoratory Accreditation Program (NELAP).

Samples collected by external analytical laboratories are analyzed for radiological (and non-radiological) attributes using standard EPA-approved analytical procedures. Both external facilities and TJNAF have a continuing program of analytical laboratory QC. Participation in inter-laboratory crosschecks, analysis of various blanks, and replicate sampling and analysis verify data quality. ES&H Division staff and other responsible TJNAF personnel review all analytical data for the samples analyzed under their subcontracts. The analytical results are reviewed relative to the accompanying QA/QC results and compared with regulatory limits for acceptability. These reviews include inspection of chain-of-custodies, sample stewardship, sample handling and transport, and sampling protocols. When applicable to the analysis requested, analytical labs must be appropriately certified.

On-going precision and accuracy are monitored by analysis of the following with each batch of samples taken under Permit VA0089320: laboratory standards, duplicate determinations, matrix spikes, and matrix spike duplicates. These data are used to calculate the relative standard deviation on all applicable parameters. The quality of the data is then evaluated and compared to regulatory

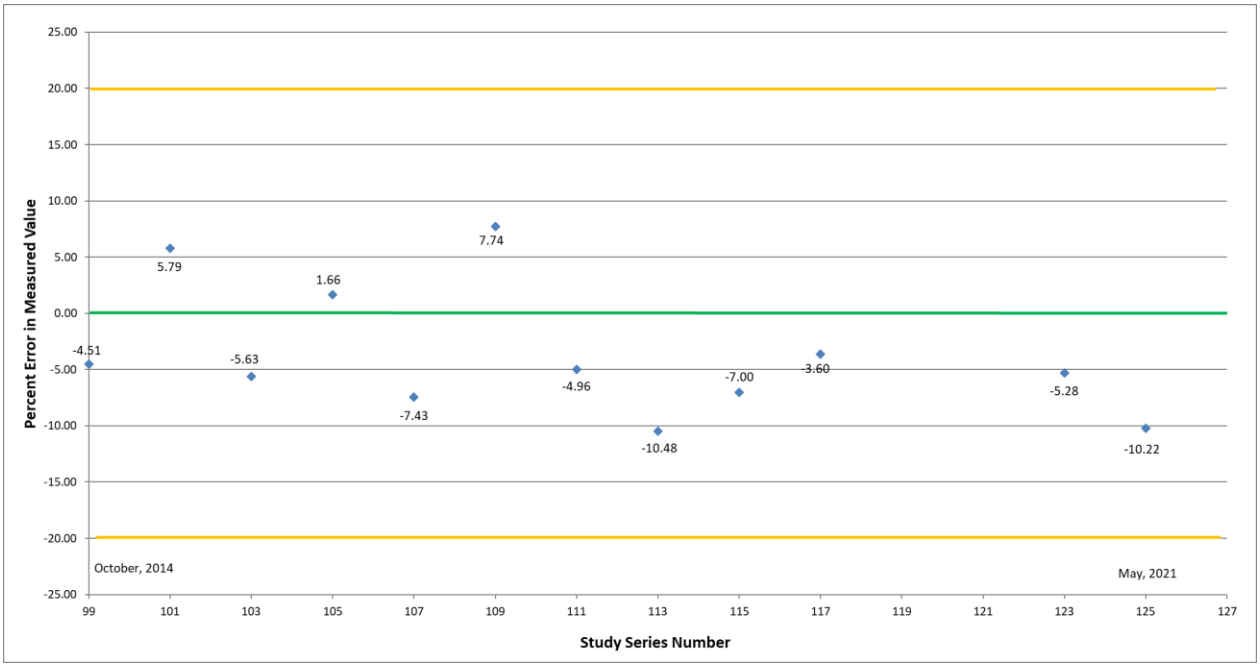
limits to determine acceptability. Satisfactory results from the vendors enable TJNAF to validate compliance with the QA requirements in the permit.

TJNAF and Eberline Services participate in the Mixed Analyte Performance Evaluation Program (MAPEP) conducted by DOE's Radiological and Environmental Services Laboratory, which is available to all DOE subcontractors. This program tests the quality of environmental radiological and non-radiological measurements and provides DOE with complex-wide comparability of measurement performance. In the two rounds of MAPEP QA testing in 2021, overall performance by both TJNAF and Eberline was acceptable, with only minor potential quality concerns associated with false positive results or results for constituents that are not of concern at TJNAF. In one round, Eberline significantly over-reported tritium results (a conservative result). Results of the MAPEP testing can be found at:

http://www.id.energy.gov/resl/mapep/mapepreports.html.

TJNAF also participates in an additional annualquality test for analysis of tritium. *Figure 19 – Environmental Resource Association (ERA) Quality Control Program for Tritium Analysis* - demonstrates the agreement between the control samples and the values reported by our radioanalytical laboratory over time (note: two rounds of testing – late 2019 and early 2020 – were not conducted due to the COVID pandemic).

Figure 19 – ERA Quality Control Program for Tritium Analysis



7 ACRONYMS LIST

ALARA	As Low As Reasonably Achievable
AFV	Alternative Fuel Vehicles
ASHRAE	American Society of Heating, Refrigerating, and Air-conditioning Engineers
BAT	Best Available Technology
BDX	Beam Dump Experiment
Be-7	Beryllium-7
BMP	Best Management Practices
BOMARC	Boeing and Michigan Aerospace Research Center
BTU	British Thermal Unit
CASA	Center for Advanced Studies of Accelerators
CD	Critical Decision
CEBAF	Continuous Electron Beam Accelerator Facility
CFR	Code of Federal Regulations
CHL	Central Helium Liquifier
Ci	Curie
CLAS12	CEBAF Large Acceptance Spectrometer for 12 GeV Upgrade
CMSA	Central Material Storage Area
CRAD/LOI	Criteria Review and Approach Document/Lines of Inquiry
CRE	CEBAF Center Renovation & Expansion
CTF	Chiller Treatment Facility
DCLS	Virginia Division of Consolidated Laboratory Services
DEQ	Virginia Department of Environmental Quality
DOD	Department of Defense
DOE	Department of Energy

EA	Environmental Assessment
ECM	Energy Conservation Measures
EEL	Experimental Equipment Facility
EISA	Energy Independence and Security Act
EIU	Energy Intensity Utilization
EMS	Environmental Management System
E.O.	Executive Order
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act of 1986
EPEAT	Electronic Product Environmental Assessment Tool
ERA	Environmental Resource Association
ES&H	Environment, Safety and Health
ES&H	Environment, Safety, and Health
FAR	Federal Acquisition Regulation
FEL	Free Electron Laser
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FML	Facilities Management & Logistics
FONSI	Finding of No Significant Impact
FY	Fiscal Year
GeV	Billion (Giga)-electron Volts
GHG	Greenhouse gas
GP	Guiding Principles
GSF	Gross Square Foot
H-3	Tritium
HEMSF	High Energy Mission Specific Facility
HPSB	High Performance and Sustainable Building

HRSD	Hampton Roads Sanitation District
ILA	Industrial, Landscaping, and Agricultural
ISM	Integrated Safety Management
ISO	International Organization for Standardization
TJNAF	Thomas Jefferson National Accelerator Facility
JSA	Jefferson Science Associates, LLC
kg	Kilogram
kW	Kilowatt
LED	Light-Emitting Diode
LEEDS	Leadership in Energy and Environmental Design
LERF	Low Energy Recirculator Facility
LQG	Large Quantity Generator
LID/GI	Low Impact Development/Green Infrastructure
LLW	Low Level Radioactive Waste
Mn-54	Manganese-54
MAPEP	Mixed Analytic Performance Evaluation Program
MBTU	One Million British Thermal Units
MDA	Minimum Detectable Activity
MEI	Maximum Exposed Individual
METF	Maximum Extent Technically Feasible
MOLLER	Measurement of Lepton-Lepton Electroweak Reaction
mrem	millirem
mSv	millisievert
MS4	Municipal Separate Storm Sewer Systems
Na-22	Sodium-22
NAAQS	National Ambient Air Quality Standards

NASA	National Aeronautics and Space Administration
NELAP	National Environmental Laboratory Accreditation Program
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOV	Notice of Violation
ODS	Ozone-Depleting Substance
QA	Quality Assurance
QC	Quality Control
PC	Personal Computer
PUE	Power Utilization Effectiveness
PV	Photo Voltaic
Radcon	Radiation Control
RAL	Radiological Analysis Laboratory
RBM	Radiation Boundary Monitor
RCRA	Resource Conservation and Recovery Act
REC	Renewable Energy Credit
REM	Roentgen equivalent man
RESRAD	Residual Radiation
SARA	Superfund Amendments and Reauthorization Act
SPCC	Spill Prevention, Control, and Countermeasure
SqFt	Square Feet
SQG	Small Quantity Generator
SRF	Superconducting Radiofrequency
SARA	Superfund Amendments and Reauthorization Act
TEDF	Technology Engineering and Development Facility
TJNAF	Thomas Jefferson National Accelerator Facility

TJSO	Thomas Jefferson Site Office
TMDL	Total Maximum Daily Load
UESC	Utility Energy Service Contract
UIM	Utility Infrastructure Modernization
UITF	Upgrade Injector Test Facility
VELAP	Virginia Environmental Laboratory Accreditation Program
VPDES	Virginia Pollutant Discharge Elimination System
VSMP	Virginia Stormwater Management Program
W	Watt

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