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U.S. Department of Energy
Idaho Operations Office

Draft Environmental Assessment for the Molten Chloride Reactor Experiment (MCRE) Project

March 2023

Idaho National Laboratory

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INL/RPT-22-68976

Prepared for the
U.S. Department of Energy
DOE Idaho Operations Office

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ACRONYMS

AL	Analytical Laboratory
ALARA	As Low As Reasonably Achievable
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CH-LLW	Contact Handled Low-Level Waste
CPP	Chemical Processing Plant
DAF	Device Assembly Facility
dBA	Decibels
DID	Defense-in-Depth
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
EA	Environmental Assessment
EBR	Experimental Breeder Reactor
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FHS	Fuel Handling System
FMG	Fuel Manufacturing Glovebox
FSC	Fuel Salt Container
FSSL	Fuel Salt Synthesis Line
HEPA	High-Efficiency Particulate Air
HEU	Highly Enriched Uranium
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
ISC	Irradiated Salt Container
kW	Kilowatt
kWth	Kilowatt thermal
LCF	Latent Cancer Fatality
LLW	Low-Level Waste
LOTUS	Laboratory for Operation and Testing in the United States
MCFR	Molten Chloride Fast Reactor
MCRE	Molten Chloride Reactor Experiment
MEI	Maximally Exposed Individual
MFC	Materials and Fuels Complex

MFG	Multi-Function Glovebox
MLLW	Mixed Low-Level Waste
MSR	Molten Salt Reactor
MT	Metric tons
MWe	Megawatt Electric
MWth	Megawatt Thermal
NE	DOE Office of Nuclear Energy
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NIS	Nuclear Instrumentation System
NRC	Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NRIC	National Reactor Innovation Center
OSHA	Occupational Safety and Health Administration
PBF	Power Burst Facility
PIE	Post-irradiation Examination
PM	Particulate Matter
R&D	Research and Development
rem	Roentgen Equivalent Man
RH-LLW	Remote Handled Low-Level Waste
ROI	Region of Influence
SSC	Structures, Systems, and Components
TED	Total Effective Dose
USC	United States Code
WMP	Waste Management Program
ZPPR	Zero-Power Physics Reactor

HELPFUL INFORMATION FOR THE READER

SCIENTIFIC NOTATION

Scientific notation expresses numbers that are very small or very large. Negative exponents, such as 1.3×10^{-6}, express very small numbers. To convert the number to decimal notation, move the decimal point to the left by the number of places equal to the exponent, in this case six places. Thus, the number becomes 0.0000013. For large numbers, those with a positive exponent, move the decimal point to the right by the number of places equal to the exponent (e.g., the number 1.3×10^{6} becomes 1,300,000).

Units

The document uses English units with conversion to metric units given below. Occasionally, metric units are used if metric is the common usage (i.e., when discussing waste volumes or when commonly used in formula or equations).

ft	foot	Gy	Gray
in	inch	mrem	millirem
km	kilometer	ppm	Parts per million
lb	pound	yd	yard
M	meter	yr	year

Conversions

English to Metric			Metric to English		
To Convert	Multiply By	To Obtain	To Convert	Multiply By	To Obtain
ft	3.048×10^{-1}	m	m	3.28084	ft
lb	4.536×10^{2}	grams	grams	2.204×10^{-3}	lb
gallons	3.785	liters	liters	2.641×10^{-1}	gallons
mi	1.609334	km	km	6.214×10^{-1}	mi
square mi	2.590	square km	square km	3.861×10^{-1}	square mi
yd	9.144×10^{-1}	m	m	1.093613	yd

Understanding Small and Large Numbers

Number	Power	Name
1,000,000,000,000,000	10^{15}	quadrillion
1,000,000,000,000	10^{12}	trillion
1,000,000,000	10^{9}	billion
1,000,000	10^{6}	million
1,000	10^{3}	thousand
10	10^{1}	ten
0.1	10^{-1}	tenth
0.01	10^{-2}	hundredth
0.001	10^{-3}	thousandth

Number	Power	Name
0.000001	10^{-6}	millionth
0.000000001	10^{-9}	billionth
0.000000000001	10^{-12}	trillionth
0.000000000000001	10^{-15}	quadrillionth

UNDERSTANDING DOSE (MILLIREM DOSES) AND LATENT CANCER FATALITY

Relative Dose

A dose[a] is the amount of radiation energy absorbed by the body. The United States (U.S.) unit of measurement for radiation dose is the Roentgen Equivalent Man (rem). In the U.S., doses are most commonly reported in millirem (mrem). A millirem is one thousandth of a rem (1000 mrem = 1 rem). The inset diagram describes radiation doses from common radiation sources, both from natural and human sources, for comparison (Figure 1). According to the National Council on Radiation Protection and Measurements, the average annual radiation dose per person in the U.S. is 620 mrem. This information is to help the reader understand and compare dose information described in this document.

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[a] https://www.epa.gov/radiation/radiation-sources-and-doses.

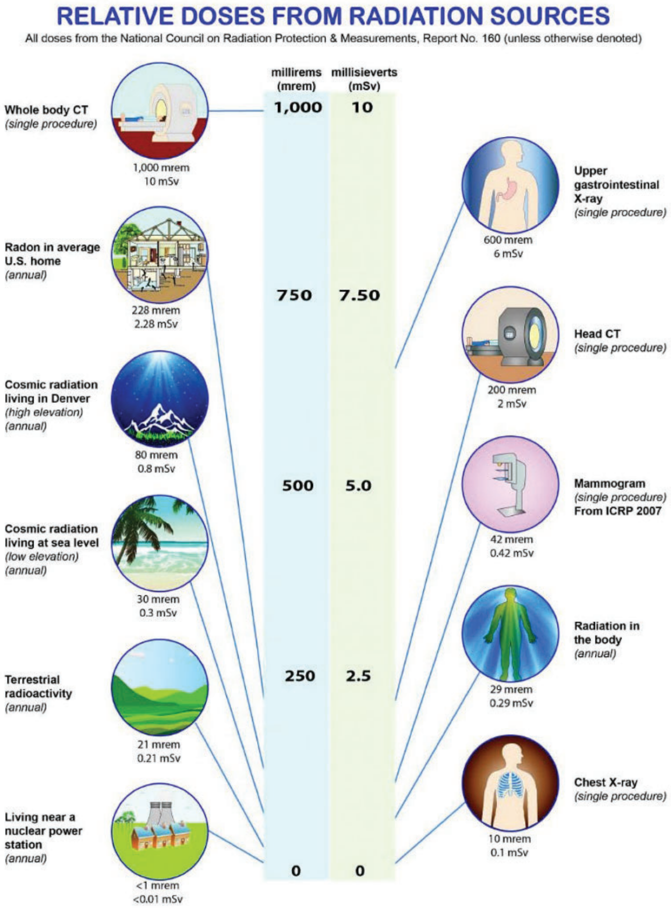

Figure 1. Diagram describes radiation doses from natural and human sources.

Latent Cancer Fatality

A latent cancer fatality is a death from a cancer that results from and occurs an appreciable time after exposure to ionizing radiation. Death from radiation-induced cancers can occur any time after the exposure. Based on a dose-to-risk conversion factor of 0.0006 latent cancer fatality (LCF) per person-rem[b] and assuming the linear no-threshold model, an exposed worker receiving a dose of 1 rem would have an estimated lifetime probability of radiation-induced fatal cancer of 0.0006 or 1 chance in 1,700.

There are questions in the scientific community regarding over estimation of LCFs by using the Linear No Threshold theory.

THE BASICS OF NUCLEAR POWER REACTORS

In some elements, the nucleus of an atom can split as a result of the nucleus absorbing an additional neutron through a process called nuclear fission. Such elements capable of nuclear fission are called fissile materials. When a nucleus fissions, it causes three important events, which result in the release of energy: (1) release of radiation, (2) release of neutrons (usually two or three), and (3) formation of two new nuclei (fission products). Some of the released neutrons collide with other atoms in the fissile materials, causing them to fission and release more neutrons. Fission also releases a large amount of heat.

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[b] Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE) ISCORS Technical Report No. 1 (DOE 2003).

Nuclear reactors contain fissile material in the nuclear fuel. A nuclear reactor achieves criticality (and is said to be critical) when each fission event releases enough neutrons to sustain a steady state or an ongoing series of reactions. This is called a chain reaction. Generally, the heat produced from fission is removed from the reactor by various methods, sometimes by a circulating fluid, and can be used to produce electricity.

Not every arrangement of fuel can be brought to criticality. A critical concentration of fissile material must be present to bring the reactor to a critical state; otherwise, neutrons can be absorbed by other reactor components, which can inhibit a sustained chain fission reaction. Similarly, even where there is a high enough concentration of fissile material for criticality, a nuclear reactor must have an appropriate volume and a prescribed geometric form or interactions between neutrons and fissile material will not be sufficient to sustain a chain reaction. This requirement imposes a limit on the minimum critical volume and critical mass within a reactor.

There are several different types of nuclear reactors, but they have many shared characteristics, including a supply of fissionable fuel in the reactor core. Some nuclear reactors also have neutron moderators. These moderators are materials that slow down neutrons to increase their probability for causing fissions or neutron absorbers, which are materials that absorb neutrons and shut down the nuclear reactions and the heat it creates. Reactor control is normally achieved using components made from neutron-absorbing material such as cadmium, hafnium, or boron. Some nuclear designs also contain a coolant, which absorbs and transports heat from the reactor for electric power production and cools the reactor core to ensure the fuel and core structures maintain their integrity. Finally, a nuclear reactor must have specifically designed shielding around it to absorb and reflect radiation to protect plant personnel from exposure.

An advanced nuclear reactor is defined in legislation enacted in 2018 as "a nuclear fission reactor with significant improvements over the most recent generation of nuclear fission reactors," meaning a reactor using nuclear fusion (P.L. 115–248, 2018). Advanced nuclear reactors include molten salt reactor (MSR) designs that are far smaller than existing nuclear reactors and use different moderators, coolants, and types of fuel. Many of these advanced designs are small, transportable, and often self-adjusting reactors capable of producing less than 20 megawatts of thermal energy, which can be used as heat to produce electricity or to scale larger commercial nuclear reactors. In contrast, existing commercial nuclear reactors generate an average of 3,000 megawatts of thermal energy.

Many advanced reactor concepts include safety, efficiency, and other improvements over existing commercial reactors. These concepts include gas-cooled reactors, liquid-metal cooled reactors, MSRs, and fusion reactors.

Draft Environmental Assessment for the Molten Chloride Reactor Experiment (MCRE) Project

1. INTRODUCTION

1.1 Introduction

Through the Advanced Reactor Demonstration Program (ARDP) Risk Reduction Pathway, the Department of Energy (DOE) announced an award, in 2020, to Southern Company Services (Southern Company), which would fund the advancement of the TerraPower, LLC (TerraPower) Molten Chloride Fast Reactor (MCFR) technology through the design, construction, and operation of the Molten Chloride Reactor Experiment (MCRE). Southern Company and TerraPower endeavor to design, construct, and operate a liquid-fueled, fast-spectrum, chloride salt-fueled experimental reactor.

The DOE Office of Nuclear Energy (NE)-sponsored National Reactor Innovation Center (NRIC) program intends to facilitate the MCRE project at Idaho National Laboratory (INL). NRIC's mission is to enable demonstration and testing of private sector reactor designs, validation of advanced nuclear reactor concepts, resolution of technical challenges of advanced nuclear reactor concepts, and provide general research and development to improve innovative nuclear energy technologies. Led by INL, the NRIC program provides private sector nuclear energy technology developers with needed infrastructure and resources to accelerate the demonstration and deployment of advanced nuclear energy. The demonstration will verify that innovative reactor concepts can be licensed and deployed by commercial entities to meet specific user requirements.

In accordance with the Council on Environmental Quality (CEQ) regulations at 40 Code of Federal Regulations (CFR) § 1500-1508[c] and with the DOE National Environmental Policy Act (NEPA) procedures at 10 CFR § 1021 (2011), DOE has prepared this environmental assessment (EA) to analyze the potential environmental impacts associated with the development, construction operation, and decommissioning of the MCRE project at the Materials and Fuels Complex (MFC) located on the INL Site (Figure 2). Depending on the results of this EA, DOE could determine either two options:

1. The potential environmental impacts of the proposed action would be significant to human health and to the environment, in which case DOE would prepare an environmental impact statement (EIS)
2. A finding of no significant impact (FONSI) is appropriate, in which case DOE could proceed with the proposed action without additional NEPA documentation.

Environmental Assessment
A primary purpose of an EA is to determine if a Proposed Action would have significant environmental impacts. If there would be none, no further NEPA documentation is required. If there would be significant environmental impacts, an EIS is required.

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[c] On December 15, 2022, the CEQ issued a final rule to update its regulations for federal agencies to implement NEPA (87 Federal Register 76578). The effective date for the new regulations is February 13, 2023. This EA has been prepared in accordance with the applicable 2022 NEPA regulations.

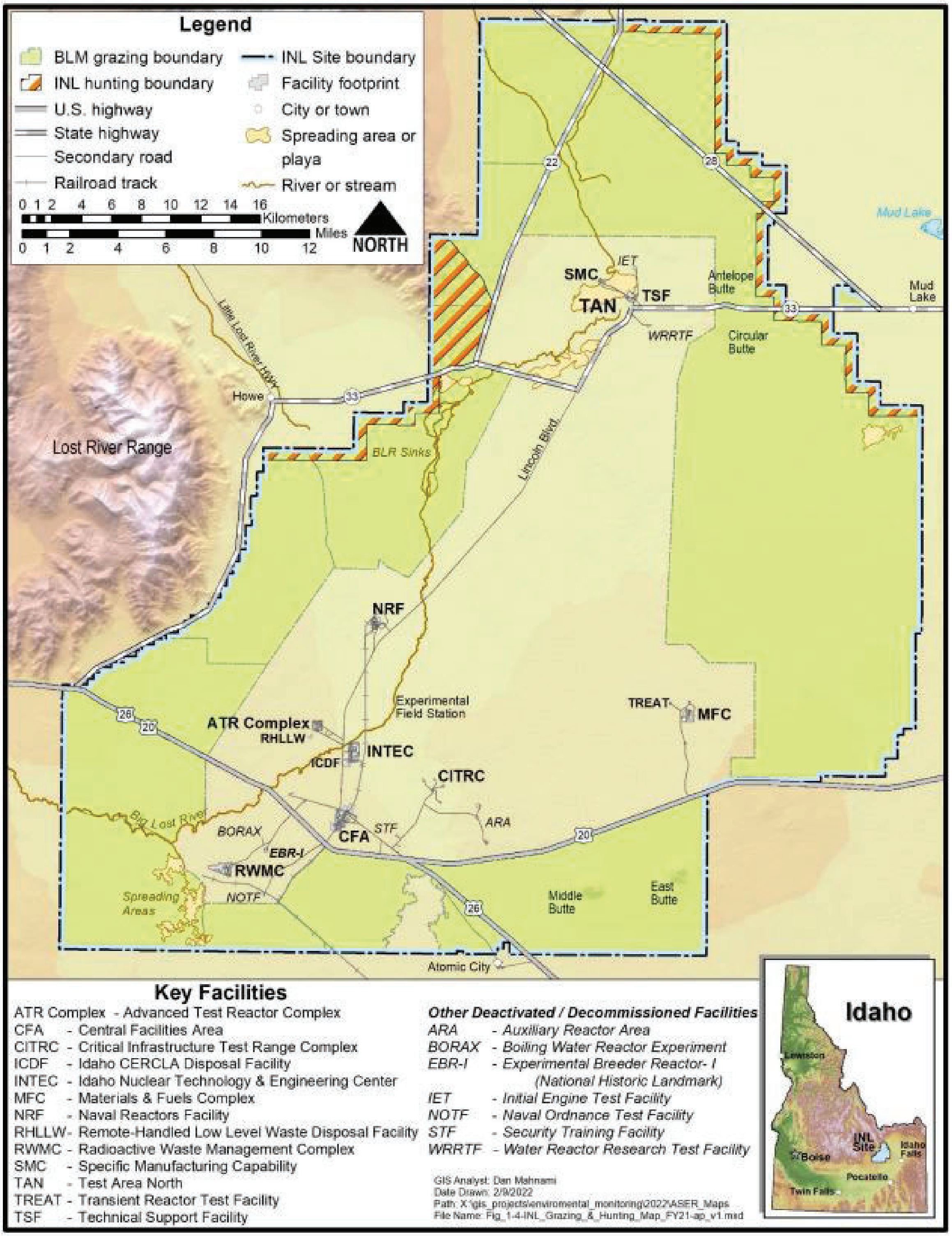

Figure 2. Site map of INL.

1.2 Background

As the nation's premier nuclear science and technology laboratory, INL supports efforts for research, development, and demonstration projects to maintain and expand nuclear energy use. The laboratory offers a unique research environment with capabilities and facilities for advancing nuclear energy. INL has dedicated facilities focused on nuclear research and development (R&D), including nuclear fuel fabrication, examination, and handling facilities.

As described by TerraPower, MCFR is an advanced nuclear reactor technology intentionally designed to combine the best aspects of homogeneous (liquid fueled) reactors, fast reactors, and molten salt reactors (MSR) to create superior performance, safety, and economic benefit when compared to conventional light-water reactors and other advanced reactor concepts. The molten chloride salt fuel of the MCFR serves as both the fuel and the coolant. MCFR technology operates at higher temperatures than conventional reactors, thus generating electricity more efficiently and without emissions.

The primary foundations of the MCFR technology date back to R&D programs that were initiated shortly after the discovery of uranium fission and to the later commercial civilian MSR programs that were originally launched in the 1950s. TerraPower has improved MSR technology to eliminate run-away reactions and meltdown scenarios, reduce refueling requirements and reactor size, and operate a reliable source of electricity.

Southern Company is an electric operating and power generation company headquartered in Birmingham, Alabama. Southern Company's mission is to provide clean, safe, reliable, and affordable energy to customers and communities they serve. To accomplish that mission, Southern Company has created an R&D organization to develop low- and no-carbon generation technologies, advance renewables, store energy, distribute generation solutions, and modernize the grid.

TerraPower is an R&D company, headquartered in Bellevue, Washington, that is focused on creating technologies that can provide safe, affordable, and abundant carbon-free energy.

Southern Company and TerraPower have partnered with CORE POWER, Orano Federal Services, and 3M to provide technical cost share support for the project.

1.3 Purpose and Need for Agency Action

The primary mission of DOE-NE is to advance nuclear power as a resource capable of meeting the nation's energy, environmental, and national security needs by resolving technical, cost, safety, security, and proliferation resistance through research, development, and demonstration. Advanced nuclear energy concepts under development in the U.S. anticipate commercial deployment as soon as the next decade. To prepare, DOE must resolve technical challenges, develop experimental infrastructure to enable testing and demonstration, and enable advanced nuclear energy concepts integration into end-user applications for broad commercial deployment and use and for public safety.

The purpose of the MCRE project is to address technical and regulatory topics associated with the MCFR technology by designing, constructing, and operating an experimental reactor in preparation for commercial deployment. The MCRE project will be used to increase the knowledge of key phenomena that are essential to successfully licensing reactors based on MCFR technology through the Nuclear Regulatory Commission (NRC).

1.4 Scope of the Environmental Assessment

This EA documents the proposed action and its alternatives, describes the existing condition or environment where the project will take place (i.e., affected environment), projected future conditions of the environment if the project is implemented (i.e., environmental consequences), and references DOE's statutory obligations and authorities[d] as required by current DOE NEPA implementing procedures described in 10 CFR Part 1021. This EA focuses on analyzing the material effects of the proposed action and describes the environmental impacts with enough detail to support the decision to either prepare an EIS or FONSI.

Considering that the development and operation of the MCRE demonstration reactor is experimental, it is anticipated that project activities described in the proposed action section may not necessarily reflect what is implemented. A bounding approach is used to ensure the EA thoroughly documents the affected environment and the environmental consequences of the MCRE project. When details about the proposed action are incomplete, a bounding approach is used to assess potential effects. When this approach is used, reasonable maximum assumptions are made regarding potential emissions, waste streams, and project activities; therefore, the analysis usually provides an overestimation of potential effects. Any proposed future action(s) exceeding the assumptions (the bounds of this effects analysis) would not be allowed until an additional NEPA review is performed. A decision to proceed or not with the action(s) would then be made.

Project segmentation can occur when a proposed activity or project is broken into smaller parts to avoid the appearance of a significant a total action. The proposed project, as described and analyzed in this document, has not been segmented into smaller parts and is not connected, nor related, to other actions with potentially significant impacts.

2. DESCRIPTION OF THE PROPOSED ACTION

The following section describes the specifics of the proposed action, no-action alternative, and alternatives not considered for further analysis. The information in the proposed action section is organized as follows: project overview, MCRE reactor overview, project siting and safety measures, operational lifecycle, fuel salt synthesis, and decommissioning.

2.1 Proposed Action

2.1.1 MCRE Project Overview

The MCRE project is a 200-kilowatt thermal (kWth) nuclear reactor experiment. The preferred location for MCRE is in the NRIC Laboratory for Operation and Testing in the United States (LOTUS) testbed which will be located in the former Zero-Power Physics Reactor (ZPPR) cell at MFC. Once operating, MCRE will be the first critical fast-spectrum circulating fuel reactor, and the first fast-spectrum MSR. The primary objective of the MCRE project is to reduce the risks of a technical, licensing, operational/human factors, and capital nature of the MCFR technology and development program, and ultimately support the MCFR Commercial Reactor design. DOE will support the MCRE project by performing the following activities: (1) supporting design and fabrication of the reactor, (2) installing the reactor in the LOTUS testbed[e] at MFC, (3) developing and synthesizing fuel salt, (4) operating the MCRE

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[d] NEPA requires that the environmental analysis (in this case an EA) be performed at the earliest reasonable time to ensure that agencies consider environmental impacts in their planning and decisions. For the MCRE project, the NEPA process has been initiated prior to the final design selection.

[e] For the purpose of this analysis, the NRIC-LOTUS testbed is assumed to be located at the former ZPPR cell at MFC. Furthermore, it is assumed that no new facilities will be constructed as a result of this project.

reactor,[f] and (5) decommissioning the MCRE reactor. The entirety of DOE-proposed activities would occur at INL; however, some MCRE project components will be developed and manufactured at Southern Company, TerraPower-, and Orano Federal Services-sponsored off-site facilities. It is assumed that these facilities would operate in accordance with all applicable federal, state, and local laws, regulations, and ordinances. INL personnel would support the development of project components by providing expertise in reactor design; inspecting components before, during, and after fabrication; and validating project plans and procedures. Southern Company, TerraPower, and Orano Federal Services will perform the transportation of equipment to the INL Site. The transportation of equipment to the INL Site would be similar to other types of equipment transports that occur at INL on a daily basis.

2.1.2 MCRE Reactor Overview

The experimental reactor will not have power conversion equipment and will not rely on traditional solid fissile material for fuel. The intention of the project is to demonstrate the operation of molten fuel salts at temperatures sufficient to drive traditional subcritical and super-critical Rankine cycles, CO_2 power cycles, or other less conventional power cycles. Figure 3 is an illustration of the pre-conceptual design for the reactor. Table 1 summarizes the individual systems that comprise the overarching reactor system. Design parameters for MCRE are shown in Table 2.

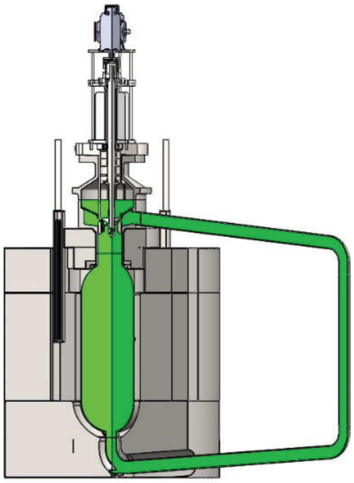

Figure 3. MCRE reactor core cross section.

Table 1. MCRE system summary description.

System	Function
Reactor Core System	Maintains fuel salt in a critical configuration, allows fuel salt to circulate, generates fission heat
Reactor Enclosure System	Encloses the reactor core system via the reactor vessel and head
Fuel Salt Pump	Pumps fuel salt through the reactor core system
Reactivity Control System	Controls reactivity during operation
Core Heating System	Heats up the reactor to fuel filling temperature and maintains temperature of reactor while fission power is less than heat losses

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[f] The operation of the MCRE reactor at INL will require the development of project specific plans, procedures, and requirements. The development of these articles will be the responsibility of INL in conjunction with the project proponents.

System	Function
Environmental Cooling System	Cools the reactor cavity (inside the shielding)
Radiation Shielding System	Reduces the amount of radiation dose to workers and equipment during operations and reduces the neutron activation of the testbed
Fuel Salt Handling System	Provides means to transfer flush and fuel salt into and out of the reactor core system, provides offload and decay heat removal method, enables insertion of additional fuel, if needed
Cover Gas System (CGS)	Provides an inert cover gas within Reactor Core System and Fuel Handling System, provides the motive force for pneumatic transfer of flush salt, and processes fission gases
Reactor Protection System	Ensures the safe operation and shutdown of the reactor in the event of an offset condition
Nuclear Instrumentation System	Monitors neutron flux to provide signals to control the reactor
Instrumentation and Controls System	Monitors, controls, and collects data
Electrical System	Provides electrical power to systems and components

Table 2. MCRE conceptual design parameters.

Parameter	Value	Units
Thermal Power	200	kW
Minimal Fuel Salt Temperature	595	°C
Nominal Fuel Salt Temperature	597.5	°C
Maximum Fuel Salt Temperature	600–700	°C
Fuel Salt Mass Flow Rate	25–100	kg/s
Design Pressure	750	kPa
Time at Temperature	6000	hours
Time at Power	1000 (out of 6000)	hours
Nominal Temperature Rise	5	°C
Max Temperature Rise	20	°C
Heat Removal	Inert Gas-cooled Vessel	–
Structural Material	SS316H	–
Cladding Materials	Inconel 600 or Inconel 625	–

2.1.3 Fuel

The fuel salt is a eutectic mixture of sodium chloride (NaCl) and uranium trichloride (UCl_3). The fuel salt will be made from highly enriched uranium (HEU) feedstock currently in storage at ZPPR.[g] This composition has a calculated melting temperature of approximately 456°C. As part of the proposed action, the fuel salt will be synthesized at INL in a Fuel Salt Synthesis Line (FSSL) established at MFC. Once synthesized, solid fuel will be stored in canisters at the Fuel Manufacturing Facility (FMF), or another appropriate location, until added to the reactor fuel cycle. It is anticipated that approximately 2.6 metric tons (MT) of fuels salt will be required for the entirety of the project.

2.1.4 MCRE Project Siting at INL

Proposed project operational activities supported by INL are planned to be located at MFC. The assumed location for the NRIC-LOTUS testbed where the MCRE reactor operational activities will take place is in the the ZPPR cell. The document *Evaluation of Site for Advanced Reactor Demonstrations at Idaho National Laboratory* (INL/EXT-20-57821) supports the assumption that the ZPPR cell structure is a suitable location for the MCRE project (INL 2020a). Per the selection criteria described in INL/EXT-20-57821, the ZPPR cell meets (1) the necessary confinement to prevent a radioactive material release, (2) the requirements to control nuclear materials, and (3) the safe operation of a nuclear reactor. Use of the ZPPR cell would not drastically interfere with existing DOE mission capabilities (INL 2020a).

The structure was originally designed to study the physics of low-power nuclear reactor designs similar to the proposed MCRE project. The ZPPR cell acts as a confinement structure capable of siting reactors that utilize molten salt material for operations.

The structure is a 50-foot inner-diameter reinforced-concrete cylinder with 16-inch thick walls (Figure 4). The cell will be reconfigured to support the demonstration of various advanced nuclear energy systems (i.e., reactors) that operate at less than 500 kilowatts (kW). The reconfigurations include installation of an access door on the side of the cell; electrical power upgrades; installation of a new heat removal system; new life safety systems (i.e., fire protection and oxygen monitoring); new electrical, instrument, and control systems; and security upgrades (Balsmeier 2020). With the reconfiguration, the capabilities will include storage of (a) material containing radionuclides and shielding against radiation that will mitigate the chances of an off-site public dose, (b) reactor experiments supplying support services (both physical and manual) for reactor experiments that enables inspections, and (c) repackaging of transuranic material and enriched uranium.

Figure 4. INL ZPPR cell. Outside view (left) and inside view (right).

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[g] HEU feedstock at INL is described in the *Environmental Assessment for Use of DOE-Owned High-Assay Low-Enriched Uranium Stored at Idaho National Laboratory* (DOE/EA-2087).

The fuel salt will be synthesized in the FSSL at FMF within MFC. FMF is a Hazard Category 2 nuclear facility, as defined by 10 CFR § 830,[h] that consists of multiple workrooms and a material storage vault. The workrooms house equipment utilized to support multiscale fuel development, including gloveboxes. The vault contains and supplies feedstock materials used for numerous programs in multiple facilities at MFC. The FSSL would be designed and operated within the Multi-Function Glovebox (MFG) within FMF. Synthesized fuel salt will be stored in the appropriate locations (i.e., FMF) until needed for fueling the reactor. Upon completion of the fuel salt synthesis, the FSSL will remain in operation for future INL R&D projects as needed.

Analytical chemistry analysis will take place within the Analytical Laboratory (AL) (MFC-752) to characterize the isotopic distribution, identify primary elemental constituents, moisture content, and fuel salt impurity. The mission of the AL is to (a) perform chemical, radiochemical, and physical measurements; (b) provide non-destructive analysis measurements; and (c) conduct applied research and engineering development activities in support of advanced nuclear fuel design, waste management, environmental, and other programs at MFC.

2.1.5 MCRE-LOTUS Integration

The NRIC-LOTUS testbed is designed to support reactor demonstration projects aligned with the NRIC and INL mission to accelerate the demonstration and deployment of advanced nuclear energy.

The MCRE project will be designed to interface with the testbed capabilities (Figure 5). Specific interfaces include (1) transfer of fuel salt into and out of the reactor system, (2) radiation shielding for worker and structure protection, (3) cell ventilation to the facility's ventilation system, (4) existing control room, and (5) facility electrical power system.

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[h] Per Table 1 in Appendix A to Subpart B of 10 CFR § 830, an HC-2 nuclear facility is defined as one that shows the potential for significant onsite consequences based on a hazard analysis. As such the facility is subject to minimum thresholds for many radionuclides and hazardous chemicals on the basis for consequences from these hazards in the immediate vicinity of the facility.

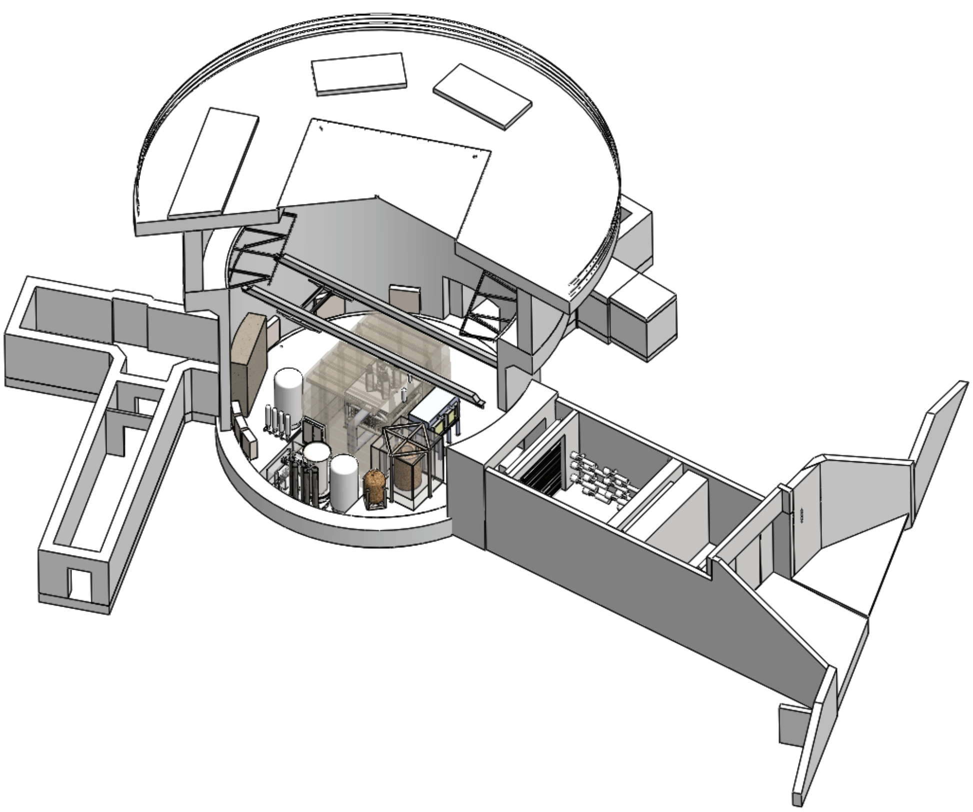

Figure 5. 3-D rendering of the MCRE reactor within a containment cell.

The NRIC-LOTUS testbed ventilation system exhaust stack would have an effluent monitoring system compliant with ANSI/HPS N13.1-2011. This standard states that sources with an unmitigated dose greater than 0.5 mrem/yr shall require continuous sampling for a record of emissions and in-line, real-time monitoring with alarm capability and consideration of separate accident monitoring system.

The MCRE project will be designed in modules, which will be shipped to MFC and assembled on site. Off-site manufacturing of the modules is considered under this EA. Modules will be staged in designated laydown areas (no greater than 6 acres each) prior to installation in the testbed (Figure 6). Laydown areas are located in previously disturbed areas. Module assembly will include the interface with the NRIC-LOTUS testbed and will be performed according to project design requirements that will incorporate INL operating plans and procedures.

The integration of the MCRE project into the NRIC-LOTUS testbed is expected to take approximately 6 months.

Figure 6. Proposed temporary laydown areas at MFC for MCRE project modules.

2.1.6 Safety

The MCRE reactor relies on passive means to ensure safety from nuclear accident events, and it incorporates active prevention and recovery controls. The most significant passive safety features of molten fuel systems are the strong and inherent temperature feedback mechanisms. The fuel density is temperature dependent, and as such, it expands upon increased temperature. The expansion is strong enough to bring the systems subcritical through negative reactivity feedback as fuel temperature increases.

Hazard evaluations, as part of the Documented Safety Analysis (DSA),[i] are performed to support each phase of the MCRE project design efforts, ensure safe operating standards, and safeguard of nuclear material (DOE 2002b). The MCRE reactor hazard evaluations are compliant with the requirements in DOE-STD-1189-2016, "Integration of Safety into the Design Process," and will follow the Licensing Modernization Project as outlined in Nuclear Energy Institute (NEI)-18-04, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light-Water Reactor Licensing Basis Development" (2019). The Licensing Modernization Project process is adapted to fit DOE reactor regulatory requirements, as applicable and appropriate, using a graded approach. The MCRE project DSA will comply with 10 CFR § 830, "Nuclear Safety Management," and DOE-STD-1189-2016. This approach provides reasonable assurance of meeting DOE-STD-1189-2016 requirements for protection of the public, worker, and environment for the MCRE project.

MCRE reactor hazard evaluations are performed for the identification and selection of the safety classification of structures, systems, and components (SSCs),[j] SSC safety functions, and design basis accidents applicable to the MCRE project. With these SSCs identified, the reactor can be built and operated safely in the NRIC-LOTUS testbed. The MCRE project safety-in-design approach implements a defense-in-depth (DID) strategy by adopting the three layers of DID: control of heat generation, control of heat removal, and retention of radionuclides. The DID layers are an integral part of the SSC classification and performance requirement determination.

MCRE is also designed to maintain reliability during a seismic event and other environmental hazards. Systems are designed to have a high confidence of low probability for failure for a seismic event of 1.66 times the safe shutdown earthquake.[k] It is also expected that the NRIC-LOTUS testbed will provide adequate protection from all other natural external hazards, including high winds, flooding, and fire.

2.1.7 MCRE Operational Lifecycle

The lifecycle of the MCRE project is broken into five phases: manufacturing/assembly, commissioning, operations, deactivation, and disposal. The manufacturing portion of the first phase is undertaken by Southern Company and TerraPower at off-site facilities. The assembly portion includes MCRE modules arriving at INL and MFC from Southern Company, TerraPower, and Orano Federal Services-affiliated manufacturing facilities. Once components are received and the testbed is ready, the modules will be installed into the facility according to project requirements.

The commissioning phase will bridge the project status from assembly to operation. Commissioning includes checking the systems for readiness by heating systems, inspecting them for leaks, pressure testing, and testing instruments and control systems to ensure they are properly functioning. It is anticipated that the commissioning phase will occur all at once. Reactor and fuel systems will be filled with a non-fuel flush salt and energized to perform commissioning tests to ensure that systems are functioning properly. In preparation for full operations, the non-fuel flush salt is removed from the

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[i] As defined by 10 CFR § 830.3, a DSA means a documented analysis of the extent to which a nuclear facility can be operated safely with respect to workers, the public, and the environment, including a description of the conditions, safe boundaries, and hazard controls that provide the basis for ensuring safety.

[j] As required by 10 CFR § 830.3, safety SSCs are systems that perform important defense-in-depth functions; and equipment relied on for the safe operation and safe shutdown of a nuclear facility, and to maintain the facility in a safe shutdown condition as documented in the safety basis. Support systems to SSCs that are required for the safety functions are also included.

[k] Per 10 CFR § 100.23 and 110 CFR § 50 Appendix S SSE is defined as the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional. SSE are developed using guidance that satisfies 10 CFR § 100.23.

systems and stored (see Sections 2.1.8.3 and 2.1.8.5). The system is then prepared for filling with fuel salt and subsequent operations.

The operations phase is divided into subphases that include fuel salt loading, subcritical testing, approach to critical, hot zero-power, reactor start-up, and full-power operations. The fuel salt loading subphase includes melting and transferring fuel salt into the Reactor Control System using the Fuel Handling System. Subcritical testing is a host of operational testing where the instruments, control components, and reactor are checked for functionality. The approach to critical involves positioning the control elements to achieve criticality at a desired design temperature. The hot zero-power subphase withdraws the control elements to achieve criticality at temperature. The start-up subphase occurs when the control elements are withdrawn to criticality and reaches the point of adding heat to the Reactor Control System. Full-power operations are considered normal operations and when the reactor is available for testing.

The MCRE project commissioning and operational phases are expected to take approximately 1 year.

Following the operational phase, the reactor is deactivated with the termination of critical operations, cooldown, and decontamination; the systems are dismantled. Following deactivation, the reactor, components, and fuel are dispositioned to the appropriate disposal pathways (see Section 2.1.9).

No activities beyond what has been described here have been proposed. While additional activities may occur, they have not been fully developed and are not analyzed in this EA. As such activities are not fully scoped, reporting on them would be speculative. If additional activities are eventually determined to be useful and the MCRE reactor were to be used for research into the irradiated fuel salt or energy production, those efforts would need to be analyzed in separate NEPA documentation.

2.1.8 Fuel Salt Synthesis

2.1.8.1 Overview

In accordance with the terms and conditions of the ARDP Risk Reduction Award Number DE-NE0009045, DOE has agreed to provide sufficient nuclear fuel for the MCRE project with existing DOE supplies from material at INL. In support of the MCRE project, INL will synthesize approximately 2.6 MT of fuel salt. A metal chloride reaction will be used to generate the $NaCl-UCl_3$ fuel salt from a combination of NaCl, iron chloride ($FeCl_2$), and HEU feedstock from the decommissioned ZPPR.

In addition to the fuel salt, INL will receive approximately 1 MT of non-fuel flush salt from TerraPower for commissioning and decommissioning processes. The non-fuel flush salt is a non-radiological sodium chloride-magnesium chloride eutectic salt that will be used to ‘flush’ the reactor systems during commissioning testing to ensure that all systems are working appropriately. The non-fuel flush salt will then be reused during the decommissioning phase to ‘flush’ the reactor systems again to remove any remaining irradiated material. After being used for the decommissioning phase, the non-fuel flush salt will be considered radiologically contaminated and be disposed of as radiological waste.

In addition to the primary synthesis furnace, the FSSL will also have the capability to perform removal of surface oxides or other surface contaminants from the HEU feedstock, transfer fuel salt to fuel salt containers (FSCs), and test for impurities using an X-ray fluorescence spectrometer.

The FSSL will be installed in FMF. The MFG will be comprised of interconnected gloveboxes, including multiple Fuel Manufacturing Gloveboxes (FMGs), a Fuel Characterization Glovebox, and a

Transuranic Breakout Glovebox.[1] The FSSL will be integrated into the MFG ventilation, off-gas, power, and safety systems and procedures.

Equipment for the FSSL is relatively small in nature and will be delivered to the INL/MFC receipt warehouses. No laydown areas will be required.

2.1.8.2 Synthesis Process

Fuel salt synthesis begins with removing the stainless-steel cladding from the existing ZPPR plates and is followed by removing any corrosion from the HEU metal feedstock. Decontamination of the feedstock occurs in the Fuel Characterization Glovebox. Resizing the feedstock HEU may be performed either by a mechanical or chemical process to reduce the particle size and increase the surface area. Following decontamination, the NaCl and $FeCl_2$ are prepared for mixing by placing them in a synthesis crucible along with the decontaminated HEU. The crucible is then placed in a secondary container that will act as a secondary containment in the event of a spill or crucible failure. The material is then placed into a furnace within the FMG, where it will be held for a designated time and temperature, until a mixture of molten NaCl-UCl_3, eutectic salt, and solid iron metal is formed.

After the initial synthesis, the separation of the molten salt from the solid iron metal will be accomplished by mechanical filtration by passing the salt through a stainless-steel mesh filter at 600–700°C.

Following filtration, the salt will be cooled to room temperature, manually broken out of the crucible, and transferred into an FSC. Once filled, the solid fuel salt in the FSC will be stored in the FMF until transferred to the testbed to fuel the reactor.

During the transfer of the fuel salt to the FSC, salt samples will be obtained to verify that the product meets project specifications. Samples will be tested at the AL within the MFC. Samples used for analysis will be disposed of in accordance with AL disposal methods.

To maintain purity and provide a level of safety, the fuel salt will be maintained in an inert gas atmosphere during synthesis, storage, when in use in the reactor, and when removed from the reactor.

Based on the criticality safety restrictions of FMF, only 18 kg of HEU can be present in each glovebox section at any given time. Additionally, each furnace is limited to 9 kg of HEU per batch. With these restrictions, it is anticipated that a minimum of 72 batches (runs) of the synthesis process will be needed to produce the estimated 2.6 MT of fuel salt. The fuel salt synthesis portion of the project is expected to take approximately 24 months.

2.1.8.3 Fuel Salt Containers

DOE proposes that INL personnel assist Orano Federal Services and other project proponents with the design and manufacture of approximately 150 FSCs to receive fuel salt from FSSL, store salt under an inert cover gas, transport salt to/from FMF vault and the testbed, and empty the fuel salt into the MCRE reactor. The FSCs are anticipated to be cylindrical with an outside diameter of 7.5 inches and a height of 15 inches. They will be manufactured at an Orano Federal Services-sponsored off-site facility. The FSCs will be designed to secure fuel salt for temporary storage while also protecting workers and the environment from radiological contamination.

2.1.8.4 Irradiated Fuel Salt

The irradiated fuel salt, which will remain under DOE's ownership following reactor experimentation, will have significant value for future advanced reactor or advanced fuel cycle R&D

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[1] The FSSL will be connected to the Transuranic Breakout Glovebox but will not utilize the space within the glovebox to avoid any potential contamination.

programs. As such, it is proposed that these materials be managed and stored for future programmatic use at an appropriate INL storage facility.

It is anticipated that the MCRE project will generate no more than 13,000 kWh of energy through fission while completing all planned critical operations. During the entirety of operations, it is anticipated that less than 570 milligrams of fission product will be generated. A portion of the fission product, such as xenon and krypton, will be volatile and will be managed by the CGS. It is expected that any remaining fission products will be well mixed with fuel salt.

The material will be stored in a configuration that facilitates easy retrieval for programmatic reuse at an appropriate INL facility, for future uranium recovery activities, or eventual direct disposition in a future deep geologic repository without the need to repackage. The long-term management of irradiated fuel salt will depend on the future application of this material and will be comparably managed to similar materials that currently reside at INL.

The appropriate storage location for this material will be determined upon finalization of the reactor design and test plan. This information will better inform the expected characteristics of the material, enabling identification of viable storage locations based on those characteristics and other programmatic considerations.

The INL Site has existing facilities for handling this type of material, such as the Irradiated Fuels Storage Facility (facility number CPP-603), the Fluorinel Dissolution Process and Fuel Storage facility (CPP-666), the Fuel Processing Restoration Facility (CPP-691), the Remote Analytical Laboratory (CPP-684), the Material Security and Consolidation Facility (CPP-651), TREAT (MFC-720), the Fuel Conditioning Facility (MFC-765), and HFEF (MFC-785). Additionally, the NRIC-DOME testbed or a temporary hot cell facility near MFC could be used. The specific facility for this activity has not been identified nor have any procedures or plans been developed for such an activity.

2.1.8.5 Irradiated Salt Containers

DOE proposes that INL personnel will assist Orano Federal Services and other project proponents with the design and manufacture of approximately 60 safe irradiated salt containers (ISCs) to receive irradiated fuel salt from the MCRE reactor. As part of the proposed operations, INL personnel will defuel the reactor once operations cease and place the salt into these ISCs. ISCs are designed to secure irradiated fuel salt for long-term storage while also protecting workers and the environment from radiological contamination. The ISCs are anticipated to be cylindrical with an outside diameter of 9 inches and a height of 40 inches. They will have the ability to maintain an inert cover gas over the irradiated fuel salt and will be designed for compatibility with a standard DOE hazardous waste container. The ISCs will be manufactured at an Orano Federal Services-sponsored off-site facility.

2.1.9 Decommissioning

MCRE will be designed and operated to prevent contamination of the LOTUS testbed. MCRE systems, within which radiological constituents, will be present and will be designed so that radioactive material remains contained and does not contaminate the testbed. During the decommissioning of the reactor phase, which will of necessity require breaching these systems to facilitate removal and disposal of MCRE equipment, the INL Radiation Protection Program (RPP) will be followed, including requirements for contamination control.

During decommissioning, containment devices and processes will be used to ensure that the testbed is not contaminated. In the event that off-normal situations occur in which contamination is released from primary systems/containments, a DID approach will be used to ensure that the testbed does not become irretrievably contaminated:

- Secondary containments (e.g., tents, strippable coatings, Herculite surface coverings) will be used to ensure that even in off-normal situations, contamination is controlled and is not able to reach testbed structures.
- The concrete floor and walls of the testbed are painted, which facilitates effective decontamination in the unlikely event that contamination breaches primary and secondary containments.
- In the event that testbed decontamination is required, the MCRE project will require testbed decontamination be conducted to meet the RPP criteria for NOT classifying the area as a contamination area. In the event that decontamination of testbed structures is required, INL will employ decontamination techniques with proven success from many years of use at INL. Such techniques could include the use of mild decontamination solutions, physical abrasive techniques, or advanced chemical decontamination techniques.

The decommissioning of the MCRE project will include the following steps:

- Reactor cooldown. The MCRE reactor will be placed into a safe standby mode for a period of 30–90 days so that short-lived radionuclides can decay to minimize radiation dose to workers.
- Defueling. The MCRE reactor will be defueled after cooldown. The fuel salt will be heated until molten and then transferred to ISCs. After transfer, the ISCs will be cooled and transferred to a docked transfer cask. The ISCs will then be transferred to an appropriate storage facility.
- Reactor flush. The surfaces of the reactor vessel and ancillary equipment that were in contact with fuel will be flushed with non-fuel salt (flush salt) to sweep the remaining fissile material from the reactor components. The flush salt will be transferred from the reactor vessel and ancillary equipment into flush salt containers. The flush salt containers will then be transferred to an appropriate storage facility using an appropriate transfer cask.
- Removal of ancillary equipment. Following defueling and the reactor flush, project equipment will be removed from the testbed. Equipment located outside of the shielded area is expected to be un-irradiated and have little-to-no radiological contamination. Equipment located inside the shielded area is expected to be contaminated. All equipment, both inside and outside the shielded area, will be placed within appropriate waste packaging and be transferred to the appropriate waste storage location pending disposition. Equipment that is declared as waste may be stored temporarily to allow time for sufficient decay to occur in preparation for off-site shipment and final disposal.
- Removal of reactor vessel. It is yet to be determined if the vessel will be disassembled in situ or removed intact; however, the reactor vessel will be declared as waste, removed, and then placed into an appropriate waste container for transfer to an appropriate disposal facility. It may be necessary to provide interim storage for the vessel package until sufficient decay has occurred to allow for off-site transport and disposition.
- Removal of the shield and remaining equipment. Following the removal of the reactor vessel, all remaining equipment and shielding will be removed from the testbed, declared as waste, placed in appropriate waste packaging, and transported to an appropriate disposal facility. Following the removal of all remaining equipment, the NRIC-LOTUS testbed will be decontaminated and returned to pre-project condition.

2.1.10 Waste Management

All waste generated at INL during or following operation of the MCRE reactor will be permanently disposed of in accordance with all applicable environmental compliance regulations and DOE O 435.1. Waste management for MCRE project-generated waste at INL involves the ultimate disposal of post-irradiation examination (PIE) wastes, reactor components, fuel synthesis wastes, and flush salt and associated equipment, as well as the storage of the irradiated fuel salt after the MCRE project is complete.

The MCRE project will utilize existing INL Waste Management Program (WMP) processes and procedures.

Wastes generated at TerraPower, Southern Company, and Orano Federal Services-affiliated facilities would be managed in accordance with all applicable federal, state, and local laws, regulations, and ordinances.

Transuranic (TRU) waste is not anticipated to be generated during MCRE activities.[m]

The ultimate disposition of all waste generated at INL during the MCRE project will be the responsibility of DOE.

2.2 No-Action Alternative

The no-action alternative is not to develop the MCRE project for operation at INL, integrate into the NRIC-LOTUS testbed, or develop and synthesize fuel salt at MFC. The consequences of the no-action alternative serves as a baseline, enabling decisionmakers to compare the magnitude of environmental effects of the proposed action alternative (CEQ 1981).

2.3 Alternatives Considered but Eliminated from Detailed Analysis

As required by 40 CFR § 1502.14 (a), alternatives that an agency considered but eliminated from further detailed analysis should be briefly discussed and the reasoning for their elimination given. To meet that requirement, this section describes alternative actions considered but eliminated from further analysis.

DOE considered alternative site locations for the proposed MCRE project from a larger pool of potential sites across the DOE laboratory complex (INL 2020a). Selection criteria mandated that a site (1) meets requirements for DOE O 421.1C, “Facility Safety,” (2) provides the necessary confinement that will prevent a radioactive material release, (3) has the infrastructure to appropriately control nuclear materials, and (4) does not drastically interfere with existing DOE mission capabilities. This selection process considered the following sites:

- Nevada Nuclear Security Site Device Assembly Facility (DAF). The Nevada Nuclear Security Site DAF is an existing Hazard Category 2 nuclear facility that currently houses the Kilowatt Reactor using Stirling technology. The DAF is integral to the National Nuclear Security Administration Stockpile Stewardship program. Based on the facility size, configuration, and ongoing mission, DAF would not meet the needs of the MCRE project without significant facility modifications and a significant change to the existing mission requirements.
- Experimental Breeder Reactor (EBR)-II Dome. The EBR-II Dome is an existing facility at MFC that formally held the EBR-II Reactor and is scheduled for future mission use. This facility would require significant facility modifications and would interrupt future mission capabilities.
- Idaho Nuclear Technology and Engineering Center (INTEC) Chemical Processing Plant (CPP)-691. CPP-691 is a Hazard Category 2 nuclear facility at INTEC, located on the INL Site. The facility was not designed to house a reactor and would require significant modifications to provide the appropriate containment for a reactor.
- INTEC CPP-1634. CPP-1634 was originally designed as a fluorine dissolution development and support facility and designated a Hazard Category 2 nuclear facility. Currently, the facility is

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[m] Transuranic waste consists of waste containing transuranic radionuclides with a half-life >20 years in concentrations above 100 nCi/g. Final waste packaging configuration will determine the radionuclide concentrations. Because any waste from MCRE will be newly generated, it will not be subject to the Idaho Settlement Agreement.

classified as a less than Hazard Category 3 facility. This facility would require significant modifications to provide the appropriate containment for a reactor.

- Power Burst Facility (PBF)-612 and PBF-613. These facilities are located on the INL Site near the Critical Infrastructure Test Range Complex and were originally designed as Hazard Category 2 facilities. These facilities would require major upgrades and modifications to qualify for the proposed activities. Additionally, any new activity at these facilities would interfere with the mission capabilities at Critical Infrastructure Test Range Complex.
- New Facility. Design and construct new Hazard Category 2 nuclear facility on the INL Site, or on another DOE laboratory site, that can house the MCRE project. A proposed new facility would meet the selection criteria; however, the anticipated cost and time for design and construction and the potential disturbance to environmental resources would not meet the needs of the MCRE project nor the purpose and need for agency action.

Alternative sites considered for the siting of the MCRE project would require significant upgrades or modifications to existing facilities, interfere with existing DOE mission capabilities, or not meet the necessary confinement requirements to prevent a radioactive material release. To meet MCRE project requirements and the selection criteria for siting any advanced reactor demonstration project, the ZPPR cell at MFC is the preferred location for the siting of the MCRE project and is the assumed location for the purpose of this EA. Other siting alternatives were not considered further for detailed analysis. As a result, only the alternative remaining is the no-action alternative.

3. AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

This section presents the affected environment and the environmental consequences of the proposed action and the no-action alternative to that environment. The affected environment is addressed in the Proposed Action section, the Regional Setting section, and briefly described in specific resource area sections. Extensive information regarding the INL environment and resources are available in recent EAs and EISs such as the EIS for the *Construction and Operation of a Prototype Mobile Microreactor* (DoD 2022), EA for the *Microreactor Applications Research, Validation and Evaluation (MARVEL) Project* (DOE 2021a), and EA for the *Resumption of Transient Testing of Nuclear Fuels and Materials* (DOE 2014*)*.

The environmental consequences analysis builds upon the information provided in Sections 1 and 2. Compliant with DOE’s NEPA guidance, this EA applies a sliding-scale approach to the impacts analysis consistent with DOE’s *Recommendations for the Preparation of Environmental Assessments and Environmental Impacts Statements* (DOE 2004). Specifically, more information is provided regarding the resources that have a greater potential to be impacted by the proposed action and the no-action alternative while less depth and breadth of analysis is applied to resource areas having no or minor environmental impacts. This approach focuses on significant environmental issues and alternatives and discusses impacts in proportion to their significance.

Under the no-action alternative, activities at the INL Site would continue under the present-day operations, and the MCRE project would not be implemented. The no-action alternative would not result in impacts to resources at the INL Site beyond those captured in the discussion of the affected environment. The environmental impacts of future activities at the INL Site would be evaluated in project or program specific analyses in compliance with NEPA. Therefore, impacts from the no-action alternative are not discussed further in this EA.

Consideration of direct, indirect, or cumulative effects or impacts of the proposed action to the affected environment is the basis of this document. The purpose of describing direct, indirect, and cumulative effects is to ensure that the full range of reasonably foreseeable effects are considered in any decision to proceed or not with the action. The degree of potential impact includes short- and long-term effects, beneficial and adverse effects, effects on public health and safety, and effects that would violate federal, state, tribal, or local law protecting the environment. To facilitate this evaluation, the degree of potential impact is discussed in terms of *context* and *intensity*. Context is described in terms of duration, timing, and geospatial area of an impact. Intensity refers to the severity of the impact and is often referred to as the magnitude of the effects of the proposed action. When both context and intensity are used to describe an impact, the following definitions apply:

- NEGLIGIBLE. Any anticipated impact, or effect, are not detectable in the affected environment or differ from existing INL Site operations.
- LOW. Any anticipated impact or effect is so minor that it will neither destabilize nor noticeably alter any important attribute of the resource.
- MODERATE. Any anticipated impact or effect is sufficient to noticeably alter, but not destabilize, important attributes of the resource.
- HIGH. Any anticipated impact or effect is noticeable and can sufficiently destabilize important attributes of the resource. These impacts would be considered significant.

For this document, a cumulative effect is defined as an impact on the environment that results from the incremental impact of actions when added to past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such actions. The analysis of cumulative effects includes reasonably foreseeable actions that have a reasonably close causal relationship to the proposed action. Cumulative effects are discussed in the environmental consequence section for each resource area.

The discussions and analyses provided in this document are based on the most available and relevant information, current scientific evidence, and research methods generally accepted in the scientific community.

This section concludes with a description of the unavoidable adverse effects, the relationship between short-term use of resources and long-term productivity, and the irreversible or irretrievable resource commitments associated with the proposed action and no-action alternative.

3.1 Regional Setting

INL is an 890-square-mile DOE facility located on the Eastern Snake River Plain (ESRP). It is primarily located within Butte County, Idaho, but portions of INL are also in Bingham, Jefferson, Bonneville, and Clark counties. All the land within the INL Site is controlled by DOE, and public access is restricted to highways, DOE-sponsored tours, special-use permits (i.e., hunting and grazing), and the Experimental Breeder Reactor-I National Historic Landmark (INL 2020b).

Public highways U.S. 20 and 26 and Idaho 22, 28, and 33 pass through the INL Site, but off-highway travel within the INL Site and access to INL Site facilities are controlled. Currently, INL employs approximately 9,750 people (5,750 employees at BEA, 2,000 employees at Idaho Environmental Coalition, and 2,000 employees at the Naval Reactor Facility). No permanent Idaho residents reside within the INL Site boundary. Population centers in the region include large cities (more than 10,000 residents), such as Idaho Falls, Pocatello, and Blackfoot, which are located to the east and south of the INL Site, and several smaller cities (less than 10,000 residents), such as Arco, Howe, and Atomic City, which are located near the INL Site boundary (Figure 7).

Vegetation is dominated by low shrubs, such as sagebrush and rabbitbrush, and a wide variety of grass species (INL 2020b). The area is populated with animals that inhabit sagebrush grasslands. Animals include pronghorn; deer; elk; coyotes; badgers; rabbits; many bird species, including raptors, game birds, and waterfowl; a variety of small rodents; and several reptile species. Some plants and animals that live within the boundaries of INL are culturally significant to the Shoshone-Bannock Tribes.

Cultural resources are numerous on the INL Site (DOE-ID 2016). Resources that have been identified include the following:

- Pre-contact archaeological sites representing hunter-gatherer use over a span of approximately 12,000 years
- Historic archaeological sites representing settlement and agricultural development during the period from 1805 to the late 1920s
- Historic architectural properties associated with World War II and with the development of nuclear science and technology
- Other areas of cultural importance to the Shoshone-Bannock Tribes.

Many of these resources are eligible for nomination to the National Register of Historic Places (NRHP). Archaeological sites and Native American resources are generally located in undeveloped areas; however, historic architectural properties are found within facility perimeters at the INL Site. A tailored approach to manage these resources and comply with relevant federal and state law is included in DOE-ID's INL Cultural Resource Management Plan (DOE-ID 2016), which is based on a programmatic agreement among DOE-ID, the Idaho State Historic Preservation Office, and the Advisory Council on Historic Preservation as well as an Agreement in Principle between DOE-ID and the Shoshone-Bannock Tribes.

The area surrounding the INL Site is classified as a Prevention of Significant Deterioration Class II area, designated in United States Code (USC) under the Clean Air Act (42 USC 7401 et seq) as an area with reasonable or moderately good air quality while still allowing moderate industrial growth. Craters of the Moon National Monument and Preserve, located approximately 30 miles from MFC, is classified as a Prevention of Significant Deterioration Class I area and is the nearest area to the INL Site where additional degradation of local air quality is severely restricted. INL routinely monitors air quality using a network of air monitors. The monitors collect samples to measure particulate matter (PM), radioactivity, and other air pollutants.

Release of radionuclides into the environment from current INL operations can expose individuals near the INL Site to radiation. Types and quantities of radionuclides released from INL operations, including dose estimates from these releases, are listed in the National Emission Standards for Hazardous Air Pollutants annual reports (DOE-ID 2021). Historically, the dose to the maximally exposed individual (MEI) is less than 1% of the 10-mrem/yr federal standard.

INL Site workers receive the same dose as the general public from background radiation, but they may also receive an additional dose from working in facilities with nuclear materials. The average dose to the individual worker (involved worker) and the cumulative dose to all INL Site workers (total workers) fall within the radiological regulatory limits of 10 CFR § 835 (2011). According to the accepted risk estimator of 6.0×10^{-4} LCF per person-rem among workers, 0.05 LCF is the projected radiological risk for INL Site workers from normal operations[n] in 2020 (DOE-ID 2021a). Since the radiological risk is less than 0.5, no latent cancer fatalities are expected as a result of this exposure.

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[n] Normal operation is defined as the day-to-day work at INL, not including the MCRE project.

MFC is the most eastern INL facility complex (Figure 7). It is located about 38 miles west of Idaho Falls in Bingham County in the southeastern corner of INL. MFC is located on approximately 100 acres (inside the MFC fence) and is approximately 2.7 miles from the southern INL Site boundary. MFC includes a wide variety of facilities and capabilities that support INL's nuclear research missions. Activities performed at MFC include R&D for new reactor fuels and related materials and demonstration of various nuclear energy technologies. In addition, MFC supports DOE programs for space and defense radioisotope power systems. FMF is located within the MFC boundary. For the purpose of this document, it is assumed that the NRIC-LOTUS testbed will be located within the MFC boundary.

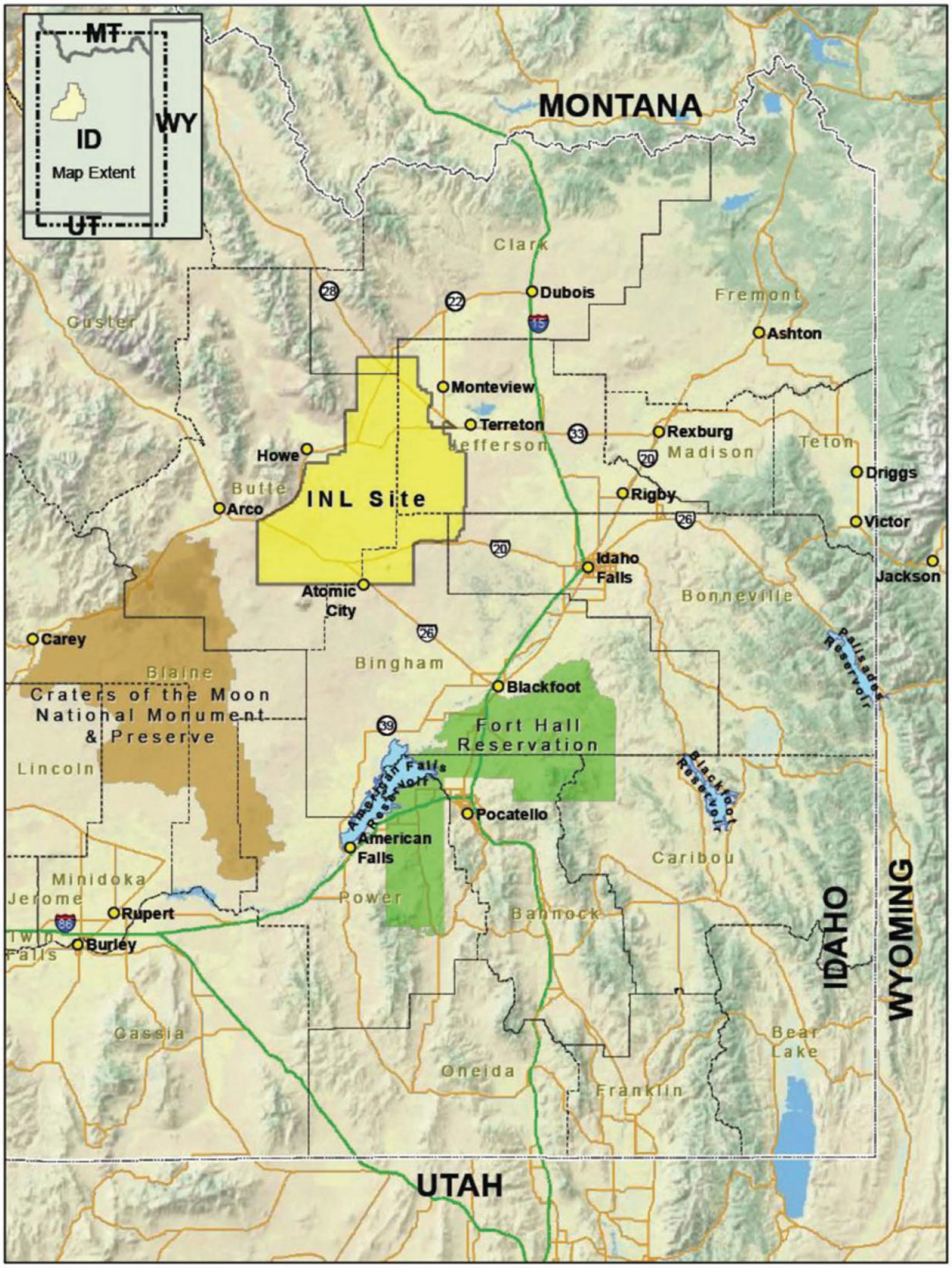

Figure 7. Location of the INL Site.

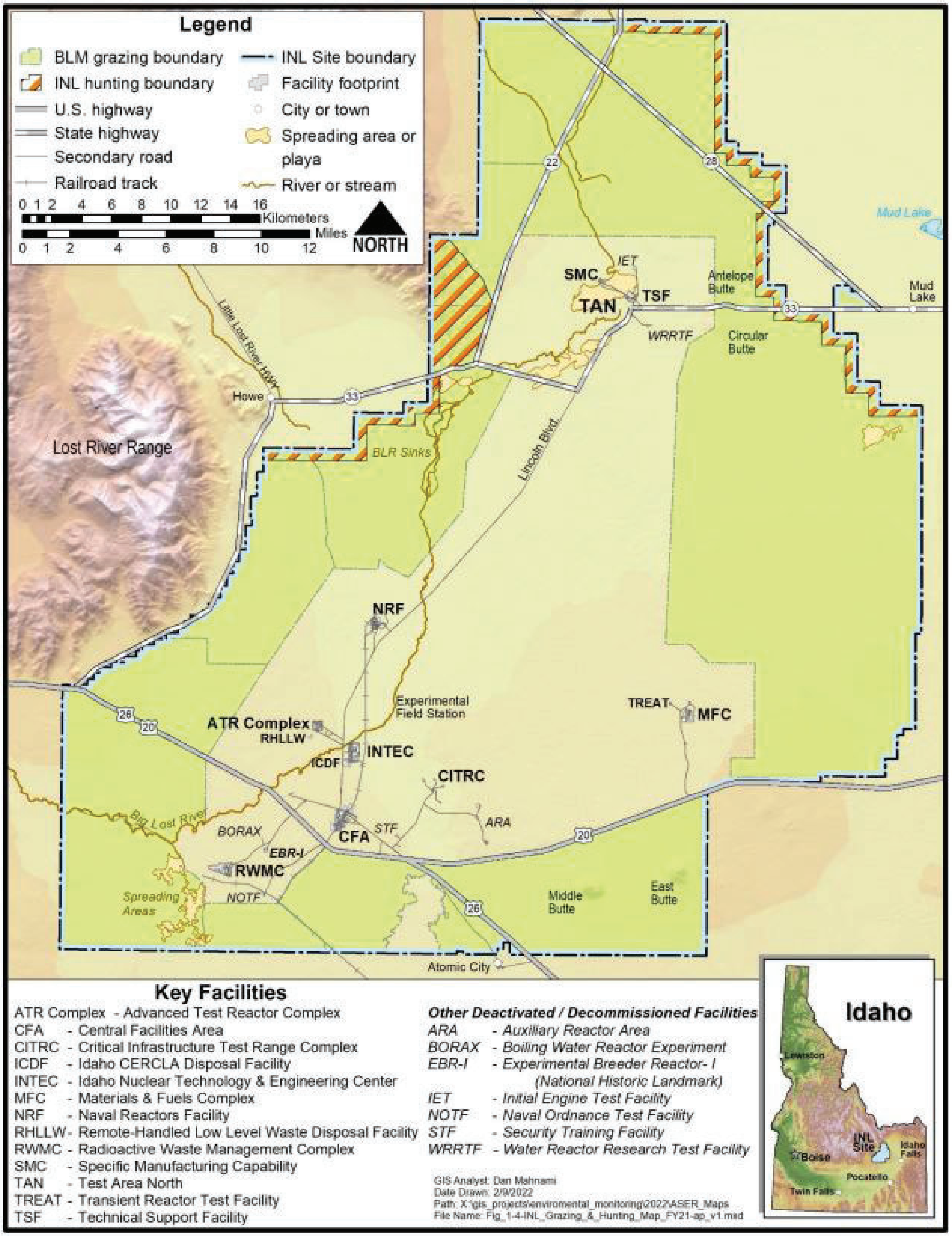

Figure 8. INL Site and facilities.

3.2 Resource Areas Eliminated from Further Analysis

Scoping and preliminary analyses indicate the MCRE project would not likely impact the following resource areas; therefore, this EA does not analyze these areas further:

- Ground and Surface Water. No perennial nor permanent surface water bodies are near MFC. All facilities within the fenced MFC area are in a single local topographically closed watershed. The MFC watershed contains natural drainage channels, which can concentrate overland flow during periods of high precipitation or heavy spring runoff. The approximate elevation of MFC is 5,130 feet above sea level and more than 7 feet above the water level predicted to occur under the probable maximum flood event corresponding to repeated rainfall events over frozen ground; therefore, the facilities described in the proposed action are not subject to flooding (Koslow 1986). The MCRE project does not include activities that physically or chemically alter ground or surface water resources. Therefore, the MCRE project does not affect ground or surface water resources.
- Land Use and Visual Resources. It is assumed that the MCRE project will not require the construction of new facilities, additional land use, or ground disturbance and will occur in existing facilities designed, or modified, for this purpose. The MCRE project would have no impacts on land use or visual resources.
- Noise. MFC is approximately 2.7 miles from the INL Site boundary. The closest noise-sensitive receptor is an agricultural homestead that is approximately 5.3 miles from MFC and 2 miles from U.S. Highway 20, which is the primary noise at this location. Discernable noise from the MCRE project is generated from the electrical equipment associated with the reactor operation. It is expected that discernable sound would range from approximately 80 to 85 decibels (dBA). To give context, a whisper registers at approximately 30 dBA, normal conversation approximately 50 to 60 dBA, a ringing phone 80 dBA, and a power mower 90 dBA (OSHA 2011). Activities associated with the MCRE project will be located in existing buildings at MFC. These buildings include a number of noise-generating sources typical of industrial activities such as industrial heating, ventilation, and air conditioning (HVAC) equipment, blowers, moving equipment, and vehicles. The noise generated from the MCRE project would be consistent with other existing industrial equipment at MFC and the potential concurrent noise would be similar to existing levels. It is anticipated that the MCRE project would not cause a change in the noise environment at MFC or the INL Site.
- Socioeconomics.[o] It is assumed that INL would hire no more than 10 full-time employees to support the MCRE project. In 2020, the total population of Bannock, Bingham, Bonneville, Butte, Clark, Jefferson, and Madison Counties was 354,598 (U.S. Census Bureau 2023). Any potential impacts to population, housing, employment, income, community services, public transportation, and public finance from an additional 10 employees would be negligible. Potential impacts to the local socioeconomic regional landscape from the MCRE project would not likely be distinguishable from current INL Site operations, and the anticipated change would not noticeably alter socioeconomic conditions in the seven-county region around the INL Site.

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[o] Economic or social impacts are not considered significant by themselves unless they are interrelated with natural or physical environmental impacts. To this end, any potential impact to the regional socioeconomic landscape would be directly related to potential impacts to other resources such as, but not limited to, land use, greenhouse gases, waste management, and/or environmental justice.

- Greenhouse Gases. A natural greenhouse effect is the warming of the earth's atmosphere due to terrestrial radiation absorbed or trapped by gases in the atmosphere. These gases primarily consist of carbon dioxide and include trace amounts of nitrous oxide, methane, sulfur hexafluoride, and chlorofluorocarbons. Emissions of greenhouse gases (carbon dioxide equivalents [CO_2e]) in 2020 at INL were estimated to be 0.1 million MT per year, which is significantly less than the total 6.457 billion MT of CO_2e produced in the U.S. in 2019 (EPA 2029). The proposed MCRE project is not projected to increase INL's greenhouse gas emissions and will adhere to INL's net-zero carbon emission initiative and goals.

3.3 Air Quality

3.3.1 Affected Environment

Sources of non-radiological air emissions at the INL Site include oil-fired boilers; diesel engines; emergency diesel generators; small gasoline, diesel, and propane combustion sources; and emissions from using chemicals and solvents. Boilers generate steam for heating facilities and are the main source of non-radiological air emissions at the INL Site. Diesel engines are mainly used to generate electricity for facility operations. Miscellaneous non-vehicle sources include small portable generators, air compressors, and welders.

Sources of non-radiological air emissions at off-site facilities include those related to the machining and manufacture of reactor components. These include the generation of PM and emissions from using chemicals and solvents.

Radionuclide emissions at INL occur from (1) point sources, such as process stacks and vents, and (2) fugitive sources, such as waste ponds, buried waste, contaminated soil areas, and decontamination and decommissioning operations. In 2021, the calculated effective dose equivalent[p] to the MEI member of the public[q] from INL Site operations was 6.7×10^{-2} millirem (mrem) per year, which is 0.67% of the 10 mrem per year regulatory standard for the INL Site (DOE-ID 2022).

Radiological air emissions from MFC occur from spent fuel treatment at the Fuel Conditioning Facility, waste characterization, fuel R&D at the Hot Fuel Examination Facility, fuel R&D at the FMF, and PIE at the Irradiated Materials Characterization Laboratory. Exhaust streams from these facilities pass through High-Efficiency Particulate Air (HEPA) filtration systems prior to being monitored via continuous emissions monitoring systems or emission sampling systems. The effective dose equivalent to the MEI member of the public from MFC operations in 2021 was calculated at 6.5×10^{-2} mrem per year, which is 97% of the effective dose equivalent to the MEI member of the public for the INL Site (DOE-ID 2022). No radiological air emissions would be produced from project activities at off-site facilities because no radiological material would be used.

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[p] Dose equivalent is a measure of the biological damage to living tissue as a result of radiation exposure. The dose equivalent is calculated as the product of absorbed dose in tissue multiplied by a quality factor. Effective dose equivalent is the sum of the products of the dose equivalent and the weighting factors applicable to each of the body organs or tissues that are irradiated. Refer to the "Helpful Information for the Reader" section at the beginning of this document or Nuclear Regulatory Commission publication Dose in Our Daily Lives and Measuring Radiation for more information (NRC 2021).

[q] A maximally exposed individual member of the public is a hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible dose of radiation or of a hazardous chemical from a given event or process.

3.3.2 Environmental Consequences

The MCRE project activities have the potential to generate minor amounts of toxic air pollutants and radionuclide air emissions.

Off-site activities would occur in facilities that are designed and operated for performing the machining and manufacturing of project components and include all pollution prevention measures as required by all applicable federal, state, and local laws, regulations, and ordinances. It is anticipated that any non-radiological emissions from these facilities would be similar to existing emissions as the manufacturing processes would be similar to what these facilities currently produce.

The integration of MCRE systems and components into the testbed are minimal and are typical activities performed at INL. It is expected that integration activities would have no radiological impacts on the general public.

Combustion equipment, such as generators, portable heaters, ventilation equipment, and heavy equipment fueled with diesel fuel, may be used during project activities. In general, emissions during construction type activities are exempt from Prevention of Significant Deterioration[r] review because these requirements are primarily for major stationary sources and specifically exempt temporary increases in emissions. Emissions from mobile generators are exempt from regulation since the generators are temporary in that they will be in place for less than 1 year.

Combustion of fossil fuel in construction type equipment, trucks, and worker commuter vehicles would emit non-radiological criteria air pollutants and hazardous air pollutants. Temporary emissions include reactive organic gases, nitrogen oxides, and respirable PM with an aerodynamic diameter of 10 micrometer or less (referred to as PM_{10}). PM_{10} consists of PM emitted directly into the air (e.g., fugitive dust, soot, and smoke) from mobile and stationary sources and construction operations.

The mobile and intermittent operation of equipment emission sources combined with the integration of the MCRE project into the ZPPR cell occurring indoors would result in dispersed concentrations of these pollutants adjacent to proposed activities. The substantial transport distance of emissions from MFC to the nearest locations of the INL Site boundary (approximately 3 miles south) would produce greater dispersion and negligible concentrations of hazardous air pollutants beyond the INL Site boundary. The use of worker commuter vehicles on public roads would result in low concentrations of pollutants. Concentrations generated by integrating the MCRE project into the ZPPR cell and by worker transportation activities would not result in adverse conditions beyond the existing baseline. Any potential impact would be considered low.

The synthesis of fuel salt in the FSSL could potentially emit a minimal amount of radiological emissions. Any radiological emissions would be managed by the FMF cell ventilation system. The cell ventilation system exhaust stack has an effluent monitoring system compliant with ANSI/HPS N13.1-2011.

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[r] Prevention of Significant Deterioration applies to new major sources or major modifications at existing sources for pollutants where the source is located in attainment or unclassifiable with National Ambient Air Quality Standards as defined by the Clean Air Act.

The MCRE project is designed to operate with minimal risk to the health and safety of the public. The fuel salt is contained under an inert cover gas to limit the possibility of fuel salt and any emissions from migrating from the reactor. By nature of the proposed activities, the expected fuel burn-up will be low, thereby further reducing the risk of a release of fission products to the environment. The integration of MCRE project components inside the ZPPR cell provides the needed confinement necessary (e.g., walls, floor, and ceiling) to prevent unintended toxic air pollutants and radiological emissions from entering the environment. The integration includes incorporating project components with the LOTUS testbed ventilation system that includes HEPA filtration and negative air pressure to prevent contaminated exhaust air.

The inert cover gas, as part of the CGS, acts as a barrier by retaining fission products and limiting the release of toxic air pollutants and radiological emissions to the environment. When integrated with the ZPPR cell, any off gases from the CGS will be emitted through the ventilation system and exhaust stack.

Under the MCRE project, there are no direct emissions from the fission process during normal reactor operations because of the inert cover gas. Any indirect emission would be abated through the ventilation system. The ventilation system would vent to a stack that would operate with a continuous emission monitoring system and HEPA filters or series of HEPA filters that would each have a control efficiency of at least 99.97%.

The impact of unabated radioactive air emissions from fuel salt synthesis to an off-site member of the public and co-located worker were assessed and determined to be extremely low when compared to the regulatory limits (INL 2022). Doses were calculated with CAP88-PC, a set of computer programs, databases, and associated utility programs for estimation of dose and risk from radionuclide emissions to the air. CAP88-PC is both a mature and EPA-recommended model for demonstration of compliance with the applicable performance objective (40 CFR 61, Subpart H). The potential dose to an off-site member of the public (INL Site MEI[s]) is 2.4×10^{-3} mrem/year and the dose to a co-located worker is estimated to be 7.62×10^{-2} mrem/year. The estimated 2.4×10^{-3} mrem/year dose to a member of the public is significantly less than both the 10 mrem/year regulatory standard and the minor source threshold of 0.1 mrem/yr. The estimated potential dose to a co-located worker of 7.62×10^{-2} mrem/year is significantly less than the 5,000 mrem/year regulatory dose standard.

The dose estimates are calculated without accounting for abatement via HEPA filtration system. Assuming that radiological emissions are abated, it is anticipated that the actual dose to a member of the public and a co-located worker would be significantly less than estimated. Because the estimated dose is significantly less than the regulatory limits, the normal operation of the MCRE project would not result in adverse conditions beyond the existing baseline, and any potential impact would be considered low.

During decommissioning, hazardous and radioactive materials will be removed to ensure the protection of workers, public health and safety, and the environment. Activities associated with decommissioning of the MCRE project reactor, FSSL, and associated equipment will be performed in existing INL facilities. The actual emissions would be determined when more definite operational conditions have been defined. Decommissioning operations will comply with all regulatory requirements of the Clean Air Act; therefore, the operations are bound by the regulatory limits.

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[s] The INL Site MEI for CY 2020 is a farmhouse and cattle operation located 3.1 km south of Highway 20, 3 km from INL's east entrance. It is also the location of the highest potential dose for a residence, school, business, or office for MCRE project emissions.

INL will develop an air permitting and applicability determination for each applicable source of radiological air emissions associated with the project to ensure compliance with the National Emission Standards for Hazardous Air Pollutants, Subpart H (40 CFR § 61). The air permitting and applicability determination will also demonstrate compliance with the facility emissions cap sitewide permit (P-2020.0045) for any non-radiological emissions. In the event a Permit to Construct is required, an application for the Permit to Construct will be submitted to the Idaho Department of Environmental Quality, pursuant to IDAPA 58.01.01, “Rules for the Control of Air Pollution in Idaho,” and an Approval to Construct application will be submitted to EPA, pursuant to 40 CFR § 61.96.

As described above, the MCRE project (including the manufacturing of components, reactor operation, fuel salt synthesis, and decommissioning) would produce minor amounts of air emissions. Transport of these emissions would produce negligible ambient air pollutant concentrations at off-site locations. Therefore, any minor increase in off-site air pollutant concentrations produced from the MCRE project, in combination with emissions from other past, present, and reasonably foreseeable future actions, including future demonstration reactor projects (VTR, Project Pele, MARVEL, etc.), would result in air pollutants concentrations that would not exceed the state and National Ambient Air Quality Standards and would not substantially contribute to cumulative air quality impacts. Similarly, any radioactive air emissions would result in negligible dose impacts to co-located workers and off-site members of the public. Any potential direct, indirect, or cumulative impacts to air quality from the MCRE project would be considered low.

3.4 Ecological Resources

3.4.1 Affected Environment

Ecological resources include the plant and animal species, habitats, and ecological relationships between the land and water within the area of interest, as described in the 2021 ASER, which is the area directly or indirectly affected by the proposed MCRE project (VNS Federal Services 2022). Consideration is given to sensitive species, which are those species protected under the Endangered Species Act, Idaho Rules Governing Classification and Protection of Wildlife (IDAPA 13.01.06.000), Migratory Bird Treaty Act of 1918, and Bald and Golden Eagle Protection Act (INL 2020b). For this document, sensitive and protected ecological resources include plant and animal species that are federally or state-listed for protection.

3.4.2 Environmental Consequences

An impact to ecological resources is considered significant if they result in a loss of protected or sensitive species or a loss of local populations from direct mortality or diminished survivorship.

As stated in the proposed action section, activities associated with the MCRE project are anticipated to occur within or near existing facilities. Ground disturbing activities, additional land use, or additional exterior night-time lighting are not anticipated. The expected noise from project activities is not likely to exceed existing industrial noise levels. As such, it is not expected that activities associated with the manufacturing of project components at off-site facilities or the integration of the MCRE project into the testbed, operation, or decommissioning would impact ecological resources.

Trucks transporting project equipment to and from INL and increased motor activity from additional commuting employees have the potential to impact wildlife from inadvertent vehicle strikes. Vehicle noise also disturbs wildlife, causing some animals to relocate. While large ungulates, such as elk and deer, adapt to busy highways, roads with continuous, slow-moving traffic can cause displacement and change in range use. Smaller animals are less noticeable and slower moving; direct strikes from motorized vehicles may occur.

It is expected that the MCRE project would not result in major disruptions to wildlife or increases in wildlife mortality because MFC is located where vehicle use regularly occurs. Any increase in traffic from transport or commuter vehicles would not be discernable from current INL operations. The loss of protected or sensitive species or loss of local populations or their respective habitats from direct mortality or diminished survivorship is not anticipated. Therefore, impacts to ecological resources from project traffic would be negligible.

Radiological activities that cause direct radiation to the environment or that discharge or otherwise release radioactive material into the environment must comply with DOE-STD-1153-2019, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," to show that dose rates to representative biota populations do not exceed the dose rate criteria DOE Order 458.1 (DOE 2019). The impact of potential radioactive air emissions on terrestrial biota were assessed using an approach that compares the potential maximum concentration of each radionuclide in the soil to an INL Site-specific ecologically based screening level. Based on this analysis, it is expected that potential radiological air emissions from fuel salt synthesis and from the operation of the MCRE reactor would not exceed the dose rate criteria for the protection of populations of aquatic and terrestrial biotic. Therefore, any potential impact to ecological resources from radiological air emissions would be low to negligible (INL 2022).

As described above, the potential impacts to ecological resources from air emissions and traffic associated with the MCRE project is considered low to negligible and may not be discernable from existing INL activities. Therefore, these potential direct and indirect impacts in combination with other impacts to ecological resources from other past, present, and reasonably foreseeable future actions would not result in a long-term loss of protected or sensitive species or loss of local populations from direct mortality, diminished survivorship, or habitat loss.

3.5 Cultural Resources

3.5.1 Affected Environment

The portion of the MCRE project occurring at INL was reviewed under Section 106 of the National Historic Preservation Act (NHPA) per 36 CFR § 800 through processes identified in the INL Cultural Resource Management Plan (CRMP) and supporting documents by the INL Cultural Resource Management Office (CRMO) (DOE-ID 2016). CRMO personnel meet the appropriate Secretary of the Interior's Professional Qualifications Standards for cultural resource management under 36 CFR Appendix A § 61.

Installation of the MCRE reactor into the NRIC-LOTUS testbed is consistent with the purpose and mission for which LOTUS was designed. Assuming that the LOTUS testbed is installed into the interior of the ZPPR cell which is a historic property eligible for inclusion in the National Register of Historic Places (NRHP). In this event, the LOTUS testbed will become a permanent component of ZPPR and allows the facility to continue to function as it was initially designed.

Synthesizing the fuel salt in the FSSL is consistent with the standard operating activities conducted at FMF, MFC-704, as is the fuel salt's analytical chemistry analysis that would be conducted in the AL, MFC-752. Standard operating activities and procedures that take place inside buildings that utilize existing infrastructure do not meet the threshold of federal undertakings with the potential to affect historic properties and do not require Section 106 review and are not considered when defining the APE.

Several activities within the proposed action were excluded from further Section 106 review due to the nature of the activities aligning with excluded actions, as defined in the INL CRMP (DOE-ID 2016). These activities have little-to-no potential to affect historic properties and are excluded from further cultural review or consideration when defining the area of potential effects (APE). Therefore, the APE[t] was determined to include the proposed construction laydown areas located outside the MFC fence, which encompasses approximately 5.4 acres and the interior of ZPPR..

The installation of MCRE is consistent with the standard operation procedures for which the LOTUS testbed was designed and will use the LOTUS test bed infrastructure. As the LOTUS testbed continues the original function of ZPPR and no modifications to APPR will be required to install MCRE into the LOTUS testbed, there will be no effect to the characteristics that qualify ZPPR as a historic property. In the event of an off-normal situation, containment measures have been developed to ensure that contamination is controlled and is not allowed to reach testbed infrastructure. Therefore, there would be no impacts to ZPPR.

Previous Class III surveys were conducted within the 5.4 acres of secondary construction laydown area and no historic properties were identified. Use of the construction laydown area would have no effect on any historic properties.

Off-site project activities would occur in existing facilities where proposed activities regularly occur and any disturbance to cultural resources are not expected.

3.5.2 Environmental Consequences

The integration of the MCRE project into the NRIC-LOTUS testbed would require a few modifications that have been identified to have little-to-no potential to affect historic properties within the interior of the facility. Furthermore, these modifications would be temporary in nature (less than two years) and would be required during the integration into the test bed, operational lifecycle, and decommissioning process. At decommissioning, MCRE project components would be removed, and the testbed would be returned to pre-project conditions. No modifications to the exterior of the NRIC-LOTUS testbed would be necessary to accommodate the MCRE project. The use of the secondary construction laydown area was evaluated under Section 106 of the NHPA per 36 CFR § 800. The result of the Section 106 review recommends the MCRE project would result in no historic properties affected. DOE concurred with the recommendation and determined the undertaking would have no effect to historic properties on February 14, 2023. As such, it is expected that the MCRE project would have no impact to historic properties within the APE. In addition, the project would not contribute to cumulative impacts to any historic properties.

3.6 Geological and Soil Resource

3.6.1 Affected Environment

MFC is located on the ESRP, part of the Snake River Plain, a large physiographic region (~90 km [56 mi] wide and 560 km [348 mi] long) within low-relief and is covered by basaltic lava flows and sediment. The Snake River Plain extends in a broad arc across southern Idaho from the Yellowstone Plateau, to Wyoming on the east, and into eastern Oregon on the west (Figure 8). Surface elevations on the Snake River Plain decrease continually and gradually from approximately 2,000 m (6,562 ft) near Yellowstone to approximately 650 m (2,132 ft) near the Idaho-Oregon border.

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[t] APE is the geographic area (or areas) within which a federal undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist.

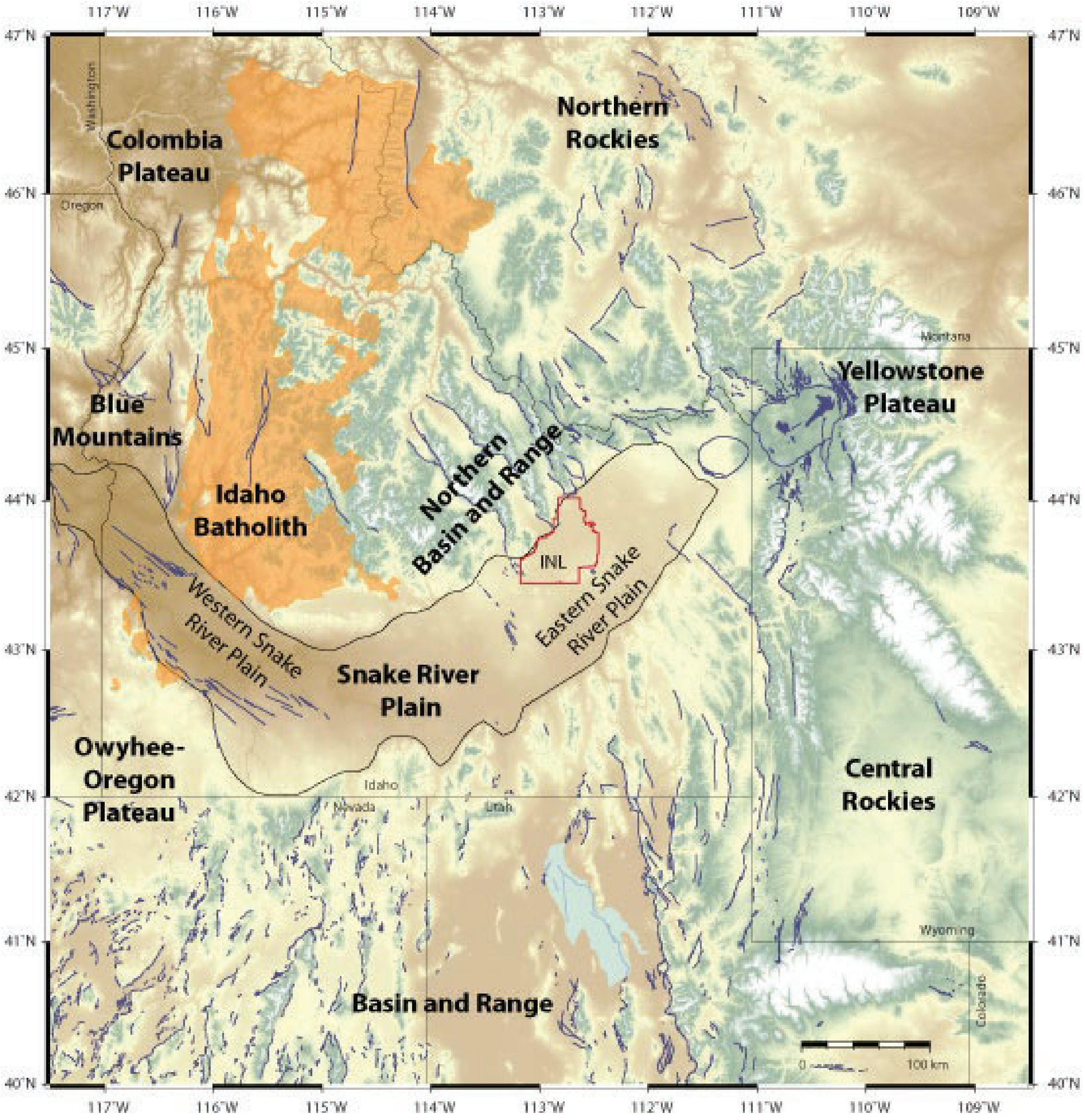

Figure 9. Snake River Plain in relation to regional geographic features.

The ESRP represents the track of buried and extinct volcanic centers associated with passage of the North American plate over the relatively stationary "Yellowstone" hotspot (Pierce and Morgan 1992; 2009; Smith et al. 2009). Between approximately 6.3 and 8.4 million years ago, the crust beneath the ESRP at and near INL's location was impacted by volcanism associated with the Yellowstone hotspot (McCurry et al. 2016; Anders et al. 2014; Schusler et al. 2020). Volcanism within the last 2.1 million years associated with the Yellowstone hotspot is now centered beneath the Yellowstone Plateau (Christensen et al. 2007), 160 to 230 km (99 to 143 mi) northeast of INL. Since about 4 million to 2,100 years ago, in the ESRP at and around INL basaltic magma has continued to periodically erupt, producing volcanic vents and lava flows (Kuntz et al. 1994; Kuntz et al. 2002; Kuntz et al. 2007). Surface basalt flows at INL range in age from 13,000 years to 1.2 million years ago (Kuntz et al. 1994). Along the southern INL Site border, basaltic magma stagnated in the crust and eventually evolved in composition to erupt between 300,000 years and 1.4 million years ago producing rhyolitic domes, which formed five buttes with heights between 120 and 750 m (394 to 2,460 ft) (McCurry et al. 2008).

MFC is located in the eastern part of the INL Site and on thin surficial sediments of primarily eolian origin overlying basaltic lava flows. MFC is within a closed basin and outside of the Big Lost River drainage basin, thus sediments are deposited primarily by the wind and localized drainage during precipitation events. The surface sediment thicknesses near the ZPPR cell range from approximately 2 m (6.5 ft) to 8 m (26.5 ft). The surface sediment thickness of two nearby locations of the ZPPR cell are as deep as 9.6 m (31.5 ft) and 14 m (46 ft) and are composed of silty, sandy layers containing varying amounts of basalt rock fragments. Basaltic lava flows at MFC erupted as pahoehoe flow types and generally have rubbly zones from the top of the flow to more massive interiors at the center (Northern Testing Laboratories 1978). The ZPPR cell is underlain by basalt lava flows that erupted from nearby vents south and east of MFC, which have been dated to be less than 358,000 years to over 1.4 million years old (Champion et al. 2011). The closest basaltic vents are more than 7 km (4.3 mi) east and south of the ZPPR cell. No mapped faults are at or near MCRE nor are volcanically induced features such as ground cracks or fractures (Kuntz et al. 1994).

The Snake River Plain transects and sharply contrasts with the surrounding mountainous country of the Northern Basin and Range Province. Summits of mountains surrounding the Snake River reach elevations of up to 3,660 m (12,000 ft), producing a maximum elevation contrast of 2,150 m (7,050 ft). North and northwest trending mountain ranges, up to 200 km (124 mi) long and 30 km (19 mi) wide, are separated by intervening basins filled with terrestrial sediments and volcanic rocks. Extension of the Earth's crust over the last 16 million years formed normal faults, including the three closest range-bounding faults northwest of INL (northern Basin and Range) and those east and south of the ESRP in the Basin and Range (Figure 9).

From 1850 to 2020, 22,870 earthquakes with magnitudes of >2.0 compiled from nearby seismic networks and INL's networks show a parabolic distribution of epicenters located predominantly in the Basin and Range regions outside of the ESRP (Payne and Falero 2022) (Figure 9). The two largest earthquakes, the 1959 momentous magnitude (M) 7.3 Hebgen Lake, Montana, and 1983 M 6.9 Borah Peak, Idaho, produced normal faulting surface ruptures with maximum lengths of 36 km (22 mi) (Crone et al. 1987) and 37 km (23 mi) (Myers and Hamilton 1964), respectively. Three earthquakes have caused ground shaking at INL, but no damage occurred due to the large distances of their epicenters from INL. Infrequent small magnitude earthquakes occur within the ESRP. From 1972 to 2020, INL's seismic network has located 103 microearthquakes with magnitudes of <2.4 in the ESRP (Bockholt, et al. 2022). Of these, 15 occurred within INL Site boundaries, and none were located near MFC.

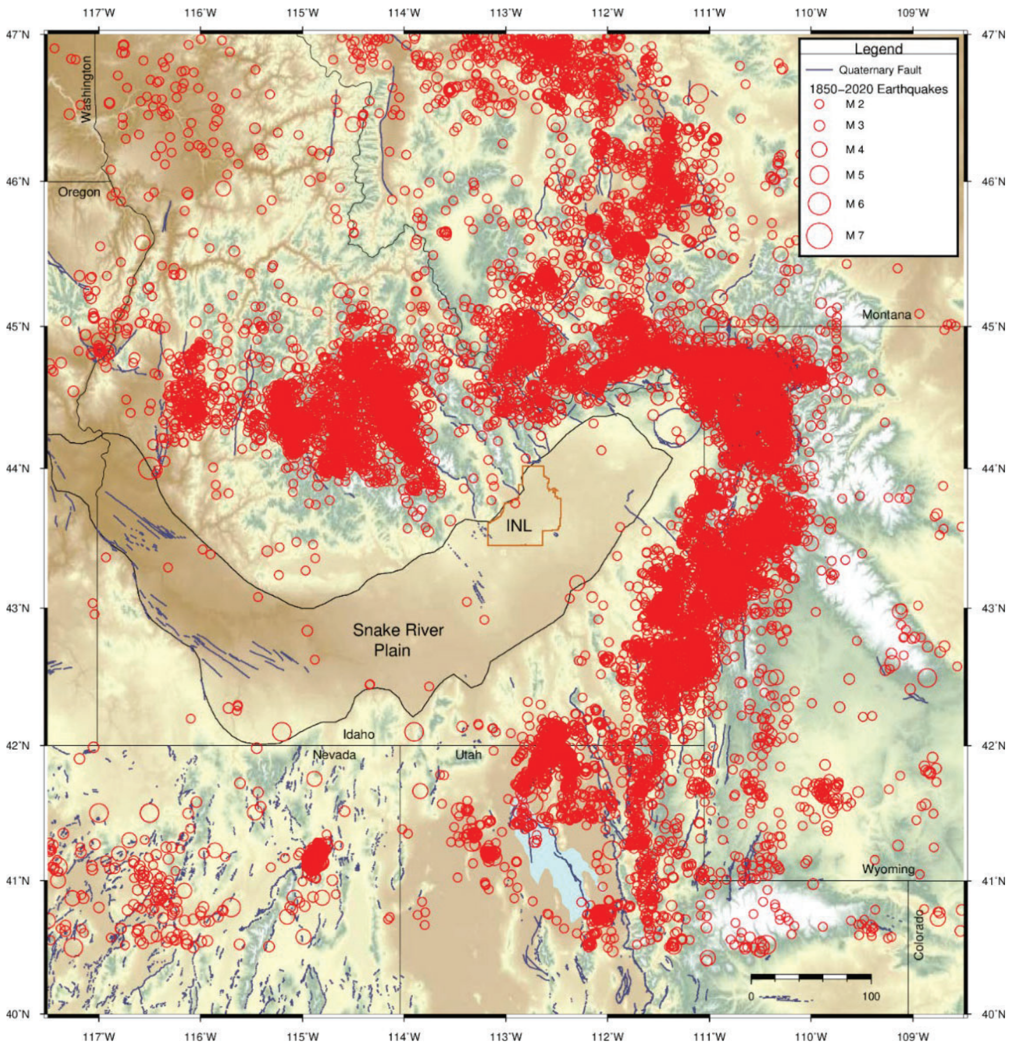

Figure 10. Earthquakes occurring from 1850 to 2020 with magnitudes greater than 2.0.

Soils beneath MFC generally consist of light brown-gray, well-drained, silty loams to brown, extremely stony loams. Soils are highly disturbed within the developed areas of MFC (DOE 2002). The thickness of surficial soils and sediment range from 0.5 to 26 ft, with deposits at two locations that are 31.5 and 46 ft thick (Payne 2006). Two primary types of soils at MFC are classified as Bondfarm-Rock outcrop-Grassy Butte complex and Maim-Bondfarm-Matheson complex (DOE 1998). The permeability of these soils is moderately rapid to rapid, and their erosion hazard is slight or moderate.

Off-site project activities would occur in existing facilities where proposed activities regularly occur and any disturbance to geological or soil resources are not expected.

3.6.2 Environmental Consequences

The MCRE project will be located in existing facilities. No ground disturbance or change to existing land use at MFC is expected; therefore, there are no anticipated impacts to geological or soil resources.

No environmental impacts are assessed from the MCRE project as a result of potential future earthquakes. The ZPPR cell is classified as Seismic Design Category (SDC), SDC-3, facility per DOE Order 420.1C, "Facility Safety" (DOE 2012), implemented through DOE Standard, DOE-STD-1020, "Natural Phenomena Hazards Design and Evaluation Criteria" (DOE 2016). Seismic design criteria were developed from site-specific, seismic hazard analyses of soil and rock conditions at the ZPPR cell (Payne 2006). The evaluation of the ZPPR cell under seismic loads is currently being performed. MCRE and its installation in the ZPPR cell will be designed to withstand vibratory ground motions (or ground shaking) as specified by American Society of Civil Engineers, (ASCE 2017) Standard 4-16, "Seismic Design of Safety-Related Nuclear Structures." Ground shaking levels are obtained from the U.S. National Seismic Hazard Maps available online from the U.S. Geological Survey (https://earthquake.usgs.gov/hazards/interactive/) for peak ground acceleration data.

As described above, potential impacts due to seismic activity are not expected. Therefore, no cumulative impacts to geologic or soil resources from other past, present, and reasonably foreseeable future actions are expected.

3.7 Infrastructure

3.7.1 Affected Environment

INL Site infrastructure includes basic resources and services required to support planned construction, operation activities, and continued operations of existing facilities. For the purpose of this document, infrastructure is defined as electricity, fuel (for equipment), water, and municipal wastewater. Table 3 summarizes INL's 2020 infrastructure usage and capacity.

Table 3. INL 2020 infrastructure usage and capacity.

Resource	Site Usage	Site Capacity
Electricity from INL Power Infrastructure		
Energy Consumption (megawatt-hours per year)	186,255	481,800[a]
Peak Load (megawatts)	36	55[a]
Fuel		
Natural Gas (cubic feet per year)	3,149,227	Not limited[b]
Fuel Oil for Heating (gallons per year)	902,001	Not limited[b]
Diesel Fuel (gallons per year)	571,028	Not limited[b]
Gasoline (gallons per year)	262,909	Not limited[b]
Propane (gallons per year)	627,007	Not limited[b]
Water		
Water (gallons per year)	754,699,070	11,400,000,000[c]

Resource	Site Usage	Site Capacity
Municipal Wastewater		
MFC Sewage Effluent (gallons per day)	10,512	14,950[d]

Source (DOE 2021)

a. Limited by contract with the Idaho Power Company
b. Capacity is limited only by the ability to ship resources to the INL Site
c. Water right allocation
d. MFC wastewater lagoons design capacity.

Off-site project activities would occur in existing facilities where proposed activities regularly occur. Because the exact location is not known, projections for infrastructure use cannot be ascertained. However, it is anticipated that infrastructure and utility use would not be greater than what the existing facilities would be capable of accommodating.

3.7.2 Environmental Consequences

Project activities at INL would use approximately 350 kWh of electricity per year, which would be supplied by the INL Site power infrastructure. This is an anticipated increase of 0.2% from the annual site usage. Any potential impacts to electrical energy consumption at the INL Site would be low and nearly indiscernible from current consumption rates.

The MCRE reactor is a molten salt reactor (MSR) and does not require water for its operation. Water usage for reactor operation is not required. It is anticipated that 10 employees would be added to the existing workforce at INL, resulting in an increase of 34,470 gallons per year of water consumption. This is an anticipated increase of 0.0046% of total gallons of water used at INL per year. The small increase in water consumption would not affect the ability of the system to provide an adequate supply to meet the requirements for personnel, process, and fire protection purposes. Any potential impacts to water consumption at the INL Site would be negligible.

The MFC sanitary sewer system collects and treats domestic wastewater from its facilities. The 10 new employees would result in the addition of approximately 100 to 250 gallons of wastewater per day to the MFC sanitary sewer system. The small increase in effluent to the sanitary sewer system would not affect the ability of the system to perform as currently designed. Any potential impacts to the sanitary sewer system at MFC would be low.

INL employs approximately 9,750 people (5,750 employees at BEA, 2,000 employees at Idaho Environmental Coalition, and 2,000 employees at the Naval Reactor Facility). During a typical workweek, the majority of employees take buses to various work areas at the INL Site, covering about 70 bus routes. About 1,200 private vehicles also travel to and from the INL Site daily. Adding 10 new commuter trips per day under the MCRE project would not result in discernable impacts to traffic at the INL Site or on public roads.

It is anticipated that the MCRE project would have low-to-negligible impact on the current INL Site infrastructure. Direct and indirect impacts would be nearly indiscernible from current operations when combined with past, present, and reasonably foreseeable future actions. Cumulative impacts would be low.

3.8 Waste Management

3.8.1 Affected Environment

The INL WMP provides the processes and procedures for compliant management of radioactive waste, hazardous waste, mixed waste, universal waste, and hazardous recyclables at INL. The INL WMP facilitates management of containerized radioactive waste, hazardous waste, mixed waste, universal waste, and hazardous recyclables from characterization through disposal ensures long-term waste storage prior to disposition is minimized, exposures are below allowable levels and as low as reasonably achievable (ALARA), and comply with DOE Order 435.1, “Radioactive Waste Management,” (2021) and the accompanying DOE Manual 435.1-1, “Radioactive Waste Management Manual” (2021).

Construction and demolition debris that are not hazardous may be recycled or disposed of at on-site facilities or sent off-site, but would be recycled to the greatest extent possible regardless of the facility. From Fiscal Year (FY) 2018 through FY 2021, MFC generated and disposed of an average of 17.3 m^3 of recyclable[u] and industrial[v] wastes per year. During the same time period, the volume of non-radiological hazardous wastes generated at MFC and disposed of at an off-site facility averaged 88.9 m^3 of hazardous[w] and universal[x] wastes per year (Table 4) (INL 2022).

Project activities at off-site facilities would likely produce construction type debris from machining and fabrication operations. It is anticipated that this waste would be managed in accordance with all applicable federal, state, and local laws, regulations, and ordinances. Furthermore, any waste generation would be acceptable to all disposal facilities.

Radioactive wastes generated at INL are generally divided into the following categories: low-level waste (LLW),[y] mixed low-level waste (MLLW),[z] and TRU. Waste quantities vary with different operations, construction activities, and implementation of waste minimization activities. Radioactive wastes are typically disposed of at off-site or on-site waste disposal facilities. From FY 2018 through FY 2021, MFC generated and disposed of an average of 1136.9 m^3 of LLW and MLLW per year (Table 4) (INL 2022).

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[u] Recyclable means material or objects that may be reclaimed and/or processed and used in the production of raw materials or products.

[v] Industrial waste means the solid waste generated by manufacturing and industrial and research and development processes and operations, including contaminated soil, non-hazardous oil spill cleanup waste and dry nonhazardous pesticides and chemical waste, but does not include hazardous waste regulated under Subtitle C of the Solid Waste Disposal Act (42 U.S.C. 6921 et seq.), mining or oil and gas waste.

[w] Hazardous waste is waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment as defined by the Resource Conservation and Recovery Act (40 CFR § 239–282).

[x] Universal wastes are considered hazardous wastes that are subject to the universal waste requirements of 40 CFR § 273. These wastes include, but are not limited to, batteries, pesticides, mercury-containing equipment, light bulbs or lamps, and aerosol cans.

[y] Low-level radioactive waste is radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct (as defined in Section 11e. (2) of the Atomic Energy Act, as amended), or naturally occurring radioactive material.

[z] Mixed low-level radioactive waste contains source, special nuclear, or byproduct material subject to the Atomic Energy Act, as amended, and a hazardous component subject to the Resource Conservation and Recovery Act.

Table 4. Summary of generated waste from MFC from FY 2018 through FY 2021.

Waste Type	Four Year Annual Average	
	Gross Volume (m^3)	Gross Mass (kg)
LLW		
CH-LLW	9.88E+02	1.09E+06
RH-LLW	1.08E+01	1.05E+04
CH-MLLW	1.35E+02	6.01E+04
CH-MLLW	3.13E+00	3.74E+03
Totals	1.14E+03	1.16E+06
Non-Radioactive Waste		
Recyclable	1.24E+01	8.04E+03
Universal	1.08E+00	3.56E+02
Hazardous	8.78E+01	2.65E+04
Industrial	4.91E+00	5.14E+03
TSCA[a]	3.72E-01	2.53E+02
Totals	1.07E+02	4.03E+04

[a] TSCA wastes include mercury, PCBs, lead, and other chemicals described in the Toxic Substances Control Act. These wastes are considered hazardous wastes

3.8.2 Environmental Consequences

Potential impacts associated with the implementation of the MCRE project include the generation of waste from the integration of the MCRE project into the testbed, fuel salt synthesis, reactor operations, PIE, and decommissioning.

During the integration phase the MCRE project is expected to generate a minimum quantity of installation waste ranging from small tools and packaging material used to transport and assemble the reactor components. This waste will consist of industrial, recyclable, and hazardous wastes (e.g., lead, brass, and circuit boards). Much of the construction waste will be recycled to the greatest extent possible. LLW and MLLW are not expected to be generated during construction activities.

Waste from the fuel salt synthesis process that is contaminated with process chemicals are expected to be designated as CH-LLW.[aa] Waste will include stainless-steel crucibles, stainless-steel mesh, iron metal particles contaminated with process and residual chemical waste, uranium-containing concentrated process scrap material and metal slag, and containers. CH-LLW will be disposed of as routine glovebox waste per INL Waste Generator Services direction. Based on the estimated 2.6 MT of fuel salt, it is projected that 8.16 m^3 of CH-LLW will be produced during the synthesis process (Table 5).

Most of the radioactive waste generated associated with the routine operations of the reactor are anticipated to be to CH-LLW. Routine operations are expected to include sampling activities, PPE, scrap metal, filters, wipes, rags, and radiological control supplies. It is expected that these wastes would be designated as CH-LLW. The projected radioactive waste generated during the MCRE project operations is approximately 0.91 m^3 of CH-LLW (Table 5).

[aa] CH-LLW is low-level radioactive waste that can be handled directly by workers using appropriate PPE.

PIE waste includes, but is not limited to, laboratory samples of fuel salt, activated foils, filters, scrap metal, cellulosics, plastics, and rubber. Waste generated during PIE activities is expected to be CH-LLW or Remote Handled (RH)-LLW.[bb] The projected PIE waste generated during the MCRE project is approximately 5.33 m^3 of CH-LLW 0.57 m^3 of RH-LLW (Table 5).

Wastes generated during MCRE project decommissioning will include the reactor, flush salt, and all ancillary equipment. Based on an evaluation of the equipment inside and outside of the radiation shield, it is anticipated that CH-LLW and RH-LLW will be generated (INL 2022). Approximately 59 m^3 will be disposed of as RH-LLW, and 258 m^3 will disposed of as CH-LLW (Table 5).

Table 5. Summary of projected radioactive waste generated from the MCRE project.

Project Phase	Waste Type	Total Waste Volume (m^3)	Percentage of MFC Generated Annual Waste
Fuel Synthesis	CH-LLW	8.16	0.64
Operations	CH-LLW	0.91	0.07
PIE	CH-LLW	5.33	0.41
	RH-LLW	0.57	0.044
Decommissioning	CH-LLW	257.54	19.97
	RH-LLW	59.41	4.61

Based on the projected radioactive waste quantities from the MCRE project, the majority of the MCRE project radioactive waste will occur during the decommissioning phase of the project (24.6%). It is anticipated that the waste generated during the decommissioning phase would cause a temporary increase in the overall waste generated at MFC. Radioactive waste generated during other project phases would be indiscernible from the annual radioactive waste generated at MFC.

Based on the projected amount of waste generated, is not expected that storage capacities of either on-site or off-site waste storage facilities will be permanently impacted (see Section 3.9, Transportation). LLW has a clear and accepted disposition pathway with little uncertainty, and the additional amounts contributed from the MCRE project would have a negligible direct or indirect impact on the aggregate LLW inventory. Any potential impacts would be temporary and minor in nature from current operations when combined with past, present, and reasonably foreseeable future actions.

3.9 Transportation

3.9.1 Affected Environment

Truck shipments and commuters from Bonneville, Bingham, Bannock, Madison, Butte, Jefferson, and Clark counties access the INL Site on U.S. Highway 20, U.S. Highway 26, or Idaho State Highway 33 (Figure 7). Highway 20 is the closest public road and the only access to MFC. The closest interstate highway to the INL Site is Interstate 15 (I-15), east of the INL Site and is the major transportation route from the local area to places beyond eastern Idaho. Truck shipments to and from the INL Site primarily enter the region on the I-15 and reach the Site along either U.S. Highway 26 from Blackfoot, Idaho, or U.S. Highway 20 from Idaho Falls, Idaho.

[bb] RH-LLW is low-level radioactive waste that emits radiation that can penetrate container walls and human skin, making it unsafe for workers to handle directly and requires remote-handling equipment to protect workers.

3.9.2 Environmental Consequences

The MCRE project at INL would involve non-radiological shipments from off-site manufacturing facilities. These shipments will consist of MCRE project equipment, including the reactor and other material necessary for successful integration of the project into the testbed. No radiological shipments to INL are expected because the radiological material is already located at MFC. It is anticipated that the normal transport of this material would not adversely affect the public as all shipments would adhere to Department of Transportation requirements and would be similar to other non-hazardous material shipments received on the INL Site.

It is anticipated that the MCRE project will add an additional 41 INL Industrial Waste Landfill radiological shipments of LLW. The transportation of other types of hazardous waste from INL are also expected to be minimal. Shipments of LLW and other hazardous waste from INL are a regular occurrence and are described in DOE/EIS-0200, ''Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste" (1997). The packaging and transportation of hazardous waste is strictly regulated and is conducted in accordance with the U.S. Department of Transportation regulation (49 CFR § 100–185) and DOE Order 460.1D, "Hazardous Materials Packaging and Transportation Safety" (2016). It is anticipated that the normal transport of LLW and other hazardous waste from INL would not adversely affect the public and any potential impact would be low.[cc]

On-site shipments containing radiological materials undergo an extensive safety analysis and review process to ensure proper safety plans are developed and implemented. Accidents are not likely to occur more than once in every 100,000 miles on public roadways (NRC 2012). Minor accidents are even less likely to occur on the INL Site because of the low transport speeds and because access along the INL transportation route will be restricted. The total number of miles traveled on the INL Site per year is expected to be less than 1,000. Based on mileage alone, the likelihood of a minor accident would be small.

A small increase in worker commuter traffic is not anticipated to adversely affect the existing level of roadway service that services the INL Site. The addition of approximately 10 new staff members to support the MCRE project would not cause a major increase in traffic, and it is anticipated that traffic will generally flow at the posted speed limits to and from the INL Site.

It is anticipated that the MCRE project would have low-to-negligible impact on the transportation network that serves the INL Site. These impacts would be nearly indiscernible from current operations when combined with past, present, and reasonably foreseeable future actions. Cumulative impacts would be low.

[cc] Annually, about three million radioactive materials packages are shipped in the United States by highway, rail, air, and water. DOE successfully completes thousands of shipments each year. The shipments have included a variety of waste types, such as low-level radioactive waste, primarily by highway and rail (DOE 2020).

3.10 Worker and Public Health and Safety

3.10.1 Radiation Exposure and Risk

3.10.1.1 Affected Environment

DOE monitors radiation in the environment and the exposure of workers and calculates the radiation doses of members of the off-site general public and workers on the INL Site. Historically, the dose to the MEI has been in the range of hundredths of an mrem/year and less than 1% of the 10-mrem/yr, federal standard (40 CFR § 61 Subpart H) for radionuclide emissions from DOE facilities. For calendar year 2022, the dose to the public MEI from INL Site operations was 6.7×10^{-2} mrem/yr. The risk of developing an LCF from this dose is less than 1 in 1 million.[dd]

The annual dose to an individual from INL Site operations is several orders of magnitude less than the average dose of 381 mrem/year from exposure to natural background radiation for someone living on the Snake River Plain (VNS Federal Services 2022). Potential impacts from radiological air emissions are discussed in Section 3.3.1.

To protect workers from impacts from radiological exposure, 10 CFR § 835 imposes an individual dose limit of 5,000 mrem (5 rem) per year. Additionally, worker doses must be monitored and controlled below the regulatory limit to ensure that individual doses are less than a DOE administrative limit of 2,000 mrem (2 rem) per year, as detailed in DOE-STD-1098-2017, “Radiological Control,” and maintained ALARA (2017). INL imposes further ALARA considerations through a 700 mrem/yr administrative limit for worker dose.

To protect the public against undue risk from radiation associated with radiological activities conducted under the control of DOE, DOE O 458.1, “Radiation Protection of the Public and the Environment,” establishes the public dose limit at a total effective dose not to exceed 100 mrem/yr above background radiation levels.

3.10.1.2 Environmental Consequences

As described in Section 3.3, the potential dose to an off-site member of the public from unabated emissions associated with the MCRE project is estimated to be approximately 2.4×10^{-3} mrem/yr. This is less than 4% of the 2020 dose to the public MEI from all INL Site operations, and significantly less than the 10 mrem/year regulatory standard for all sources. Therefore, the MCRE project dose contribution to the cumulative off-site dose from other INL Site operations would be low.

Fuel salt synthesis at the FMF will use existing processes in compliance with the limitations set in 10 CFR § 835 and DOE-STD-1098-2017. Gloveboxes used during fuel salt synthesis will use shielding and radiological designs adequate to limit operator radiological exposure. Regulations require that all activities are conducted following the ALARA dose principle.

[dd] For comparison, the American Cancer Society estimated in 2021, that from the U.S. population of about 330 million, about 1.9 million new cancer cases would be diagnosed and about 608,570 cancer deaths would occur. About 30% of U.S. cancer deaths are estimated to be caused by tobacco use. The average U.S. resident has about 4 chances in 10 of developing an invasive cancer over his or her lifetime (41% probability for males, 39% for females) (American Cancer Society 2021).

INL Site workers receive the same dose as the general public from background radiation. Some workers may receive an additional dose from working in facilities with nuclear materials. The MCRE project would require an estimated total 40 operation workers that could receive a measurable dose over the life of the project. Each MCRE project operation worker would be expected to receive a total effective dose of approximately 62.27 mrem per year (INL 2022). During fuel fabrication, the MCRE project would require about 20 workers who could receive a total effective dose of approximately 174.0 mrem per year (INL 2022). During operations and defueling, the MCRE project would require about eight workers who could receive a total effective dose of approximately 69.4 mrem per year each (INL 2022). During decommissioning, the MCRE project would require approximately 22 workers who could receive a total effective dose of approximately 30.4 mrem per year each (INL 2022). All potential doses are well within the administrative control level for INL workers (700 mrem per year). During all operations, DOE would implement measures to minimize worker exposures and maintain doses ALARA, including the use of shielding, personal protective equipment, and training mock-ups to improve the efficiency of operations and reduce exposure times.

For comparison, the average collective total effective dose (TED)[ee] for INL employees from 2014 to 2019 was 84.7 person-rem as shown in Table 6 (DOE 2021b). Operating the MCRE project is anticipated to add approximately 2.1 person-rem to the INL Site's average worker occupational exposure (collective TED).

Table 6. Annual radiation dose to INL workers during operations 2014 to 2019.

Year	Collective TED (person-rem)	Number with Measurable Dose	Ave. Measured TED (rem)	Radiological Risk[a]
2014	61.292	1257	0.049	0 (0.04)
2015	71.814	1437	0.05	0 (0.04)
2016	92.67	1273	0.073	0 (0.06)
2017	123.232	1331	0.093	0 (0.07)
2018	82.66	1368	0.060	0 (0.05)
2019	76.511	1203	0.064	0 (0.04)
AVERAGE	84.70	1311.5	0.065	0 (0.05)

A Represents the probability of the occurrence of an LCF for an individual or a population group from exposure to ionizing radiation or other carcinogens when the number of latent cancer fatalities is less than one. Calculated using a dose conversion factor of 6×10^{-4} LCF per rem (6×10^{-7} per mrem). Values in parentheses are calculated values. A value of less than 0.5 is considered to result in no LCFs. There are questions in the scientific community regarding over estimation of LCFs by using the Linear No Threshold theory.

Activities associated with the MCRE project decommissioning will be performed in existing INL facilities. INL would monitor worker dose and take appropriate action to limit the individual worker dose to be below the INL 700 mrem annual administrative control level. DOE-STD-1098-2017 identifies an effective ALARA process as including implementation of both engineered and administrative controls to manage worker dose. All equipment and operations would be designed and implemented following this principle. Further worker protection would be incorporated into the final decommissioning process to ensure worker doses are ALARA. The dose received by workers would be monitored and limited for decommissioning activities at any facility in accordance with regulatory limits.

[ee] TED is the sum of the effective dose (for external exposures). An effective dose is the summation of the products of the equivalent dose received by specified tissues or organs of the body and the appropriate tissue weighting factor. It includes the dose from radiation sources internal and/or external to the body.

The average dose to the individual worker (involved worker) and the cumulative dose to all INL Site workers (total workers) are significantly below the radiological regulatory limits of 10 CFR § 835. The MCRE project potential impact to worker and public health and safety from direct radiation and radiological emissions are expected to be low and will provide a low contribution to the existing baseline doses.

3.10.2 Non-radiological Health and Safety

3.10.2.1 Affected Environment

Non-radiological exposures are controlled through programs intended to protect workers from normal industrial hazards. Activities at INL are controlled by the safety and health regulations for DOE contractor workers governed by 10 CFR § 851, which established requirements for worker safety and health programs to ensure DOE-contracted workers have a safe work environment. Provisions are included to protect against occupational injuries and illnesses, accidents, and hazardous chemicals.

Project activities occurring at off-site facilities would be subject to Occupational Safety and Health Administration standards for those specific industries. Considering that these activities would occur in facilities that operated under these industry-specific standards, workers are expected to have a safe work environment and be protected against occupational injuries and illnesses, accidents, and hazardous chemicals. Furthermore, considering these facilities are established in their respective areas, it is also anticipated that there would be controls in place to prevent accidents or injuries to the public at large.

3.10.2.2 Environmental Consequences

Potential impacts from noise, chemical exposure, and occupational injuries are and would continue to be regulated to protect human health. Per 10 CFR § 851, employee exposures to hazardous agents are maintained below the American Conference of Governmental Industrial Hygienists threshold limit values, the Occupational Safety and Health Administration permissible exposure limits, and other applicable standards as defined by DOE. When exposure limits defined by the various agencies conflict, INL policy is to comply with the most stringent limit.

Hazardous materials (radiological and chemical) at the INL Site are minimized to those necessary to accomplish the mission. The MCRE project will follow site-wide and facility/project-specific plans and procedures for handling and storing hazardous materials.

Standard industrial hazards are hazards that are routinely encountered in general industry and construction. For these hazards, national consensus codes and standards (e.g., OSHA standards and DOE-prescribed occupational safety and health standards) guide safe design and operation of the MCRE project. In accordance with the guidelines in DOE-STD-1027-2018, “Hazard Categorization of DOE Nuclear Facilities” (2019), and DOE-STD-3009-2014, “Preparation of Nonreactor Nuclear Facility Documented Safety Analysis” (2014), no special analysis is required for these occupational hazards unless they are possible initiators for an uncontrolled release of radioactive or hazardous material.

The level of exposure to non-radiological hazards, the regulatory requirements for managing those hazards, and the existing exposures are not anticipated to change. Therefore, the potential impacts from exposure to normal industrial hazards at INL would be low.

3.10.3 Facility Accidents

A safety basis describes the nuclear facility hazards and the risks to the workers, the public, and the environment and defines the safety-related equipment, procedures, and practices used to adequately control those hazards. To support the development of a DSA[ff] for the MCRE project, hypothetical events are identified that are evaluated to determine the potential accident consequences and identify appropriate safety SSCs necessary to ensure the prevention and mitigation of functions. Furthermore, per the recommendations from "Recommendations for Analyzing Accidents under the National Environmental Policy Act" (DOE 2002), the collective impact to a population is determined. The DSA development for the MCRE project is ongoing and will include a set of safety SSCs and their associated, required safety functions to avoid unacceptable consequences. The safety SSCs for the MCRE project are assigned a safety classification based on whether they perform a required safety function, provide environmental conditions for the performance of safety functions, or provide significant DID protection.

The MCRE reactor is a relatively small, low-power density, low burn-up reactor that is fueled with a molten uranium chloride salt. The reactor is designed to survive a wide variety of off-normal, upset, or accident conditions. The typical safety response for the reactor is to shut down, and after an in-vessel shut-down period, the reactor response is to offload the reactor fuel to the drain tank. Following the fuel offload, the system is passively safe with no further actions necessary.

The primary hazard for a facility release is the irradiated fuel. In the event of a release of irradiated fuel, the LOTUS testbed will perform the confinement function for non-gaseous fission products, and the MCRE CGS will contain a portion of the gaseous fission products.

A theoretical possibility is that a severe accident could occur that challenges the plant design basis. Thus, a maximum, reasonably foreseeable accident assumed to be initiated by operator error, equipment failure, or a severe natural phenomena hazard is evaluated for this project (INL 2022). The hypothetical accident scenario includes a reactor boundary breach that results in a portion of fuel leaks into the reactor cell.

If this type of event were to occur, it is assumed that a plume of fission products would disperse from the testbed. Under this scenario, it is assumed that some hypothetical receptors would be unaware of the accident and no emergency actions would be taken for protection and the receptors would be susceptible to the entire potential dose. By way of the calculated TED, the evaluation estimates the collective impact to the population of co-located workers and a member of the public at the nearest INL Site boundary, the nearest population zone, and the city of Idaho Falls (INL 2022) (Table 7).

Table 7. Summary of dose impacts for the highest postulated accident consequences for the MCRE project (INL 2022).

Receptor (distance)	Dose (TED) person-rem	LCF Risk[a]
Co-located worker (100 meters)	9.04	0 (5.42×10^{-2})
Nearest Site Boundary (4700 meters)	1.36×10^{-2}	0 (8.16×10^{-6})
Nearest Low-Population Zone (~32,000 meters)	1.78×10^{-2}	0 (1.07×10^{-5})
Idaho Falls (~48,000 meters)	7.51×10^{-3}	0 (4.51×10^{-6})

[a] Calculated using a dose conversion factor of 6×10^{-4} LCF per rem. Values in parenthesis are calculated values. A value of less than 0.5 is considered to result in no LCFs

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[ff] A DSA is the formal document that is required by 10 CFR 830.294. A DSA includes a systematic identification of the hazards, analyses of potential accidents, and analyses of measures to eliminate, reduce, control, and mitigate the hazards. A DSA is a living document that must change as the facility configuration or operations are modified or change.

Adverse consequences from significant releases of radioactive or hazardous materials are limited by the MCRE reactor size, fuel type, and fission product inventory. However, DOE requirements for emergency planning, as described in DOE Order 151.D, “Comprehensive Emergency Management System” (2016), state that distances to site boundaries on DOE facilities and additional safety management programs, including the MCRE project DID strategy, are used to mitigate consequences from extremely low probability events. In all cases, the release of fission products during normal operations, as described here, is within guidelines for public exposure under severe accident conditions (see Section 3.3, Air Quality). Existing low-population exposures to humans from radiation resulting from a hypothetical accident with the MCRE project would remain low. When combined with past, present, and reasonably foreseeable actions at INL, the cumulative effects of the evaluated hypothetical accident (i.e., any accidental release of radioactive material) is anticipated to be low.

3.10.4 Emergency Preparedness

DOE Order 151.D, “Comprehensive Emergency Management System,” describes detailed requirements for emergency management DOE must implement (2016). Each DOE site, facility, and activity, including the INL Site, establishes and maintains a documented emergency management program that implements the requirements of applicable federal, state, and local laws, regulations, and ordinances for fundamental worker safety programs (e.g., fire, safety, and security). In addition, each DOE site, facility, and activity containing hazardous materials (e.g., radioactive materials or certain chemicals that do not fall under the purview of fundamental worker safety programs) establishes and maintains an Emergency Management Hazardous Materials program. Finally, each site that receives or initiates shipments managed by the Office of Secure Transportation must be prepared to manage an emergency involving such a shipment, should that emergency occur onsite.

The emergency management system at INL includes emergency response facilities and equipment, trained staff, and effective interface and integration with off-site emergency response authorities and organizations. INL maintains the necessary apparatus, equipment, and a state-of-the-art Emergency Operations Center in Idaho Falls to respond to emergencies, not only at INL but throughout the local communities.

A readiness assessment will be completed prior to the integration of the MCRE project into NRIC-LOTUS, fuel synthesis at FMF, and MCRE reactor operation to demonstrate that there is a reasonable assurance that operations are performed safely and provide adequate protection for workers, the public, and the environment. The readiness assessment includes, but is not limited to, an evaluation of safety management programs; operational interfaces, selection, training, and qualification of operations and support personnel; implementation of facility safety documentation; programs to conform and periodically reconfirm the condition and operability of all safety and support systems; procedures; emergency management; and conduct of operation processes.

3.11 Environmental Justice

3.11.1 Affected Environment

Consideration of environmental justice in NEPA analysis is driven by Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” and is further supported by Executive Order 14008, “Tackling the Climate Crisis at Home and Abroad,” and accompanying guidance (CEQ 1997; IWG 2017). The executive orders effectively direct federal agencies to identify disproportionately high and adverse human health or environmental effects of federal programs, policies, and activities on minority, low-income, and minority and low-income populations and to take action to address such impacts. The definitions used for minority, low-income, and minority and low-income populations in this document are consistent with the definitions within the executive orders and guidance.

In evaluating potential impacts on populations in closer proximity to MFC, radial distances of 15, 25, and 50 miles were analyzed at the Census block-group level (which is the smallest geographic area that the U.S. Census Bureau provides data). Minority and low-income populations are evaluated using an absolute 50% and a relative meaningfully greater[gg] percentage criteria for potentially affected block groups in the identified radial distances. If a block group's percentage of minority or low-income individuals exceeds 50% of the potentially affected populations or is more than 1.2 times the percentage of the total minority population, then the block group is identified as having a minority or low-income population. Table 8 describes the minority and low-income composition of the potentially affected area surrounding MFC at each of the radial distances.

The radial distance of 50 miles of INL's MFC is considered the Region of Influence (ROI). A 50-mile ROI was selected as the ROI for environmental justice because it focuses on the resource areas where an impact could potentially occur (e.g., radiological air emissions, transportation issues, and socioeconomic influences). The potentially affected area for environmental justice includes parts of 14 counties throughout Idaho.

The total population residing within the 50-mile ROI is approximately 253,454, of which 44,780 people (17.7% of the population) are considered a minority population (U.S. Census Bureau 2022) (Table 8). The meaningfully greater criterion for minority populations is 21.2%. The overall composition of the projected populations within every radial distance is predominantly nonminority. Minority populations within the 50-mile ROI are predominantly White Hispanic or other minority. The concentration of minority populations is greatest within the 25-mile radial distance. American Indian and Alaska Native populations comprise approximately 2% of the population within the 50-mile radial distance because the Fort Hall Reservation of the Shoshone-Bannock Tribes lies largely within the ROI (Table 8). In total, minority populations represent less than 50% of the total population of the ROI at radial distances.

Table 8. Minority and low-income populations within the 50-mile radius of MFC.

Population Group	Within 15 Miles		Within 25 Miles		Within 50 Miles	
	Population	Percent of Total	Population	Percent of Total	Population	Percent of Total
Total Population	1,496	100	4,154	100	259,367	100
Nonminority	908	60.8	2,911	70.1	214,095	82.5
Total Minority	588	39.2	1,243	29.9	45,272	17.5
White – Hispanic/Latino	541	36.1	1,147	27.6	31,932	12.3
Black/African American	0	0	0	0	956	0.4
American Indian or Alaska Native	5	0.3	18	0.4	4,192	1.6

[gg] Meaningfully greater is defined as a minority or low-income population percentage in a block group within the ROI that is 1.2 times the percentage of the total minority or low-income population within the comparison population.

Population Group	Within 15 Miles		Within 25 Miles		Within 50 Miles	
	Population	Percent of Total	Population	Percent of Total	Population	Percent of Total
Other Minority[1,2]	42	2.8	78	1.9	8,192	3.2
Low Income[3]	133	8.9	332	8.0	20,497	7.9

Source (U.S. Census Bureau 2022)

Includes persons who also indicated Hispanic or Latino origin.

Other Minority includes all combined individuals of Asian, Native Hawaiian and Other Pacific Islanders, Some Other Race, or Two Races.

Low-income is defined as a household income between $25,000–$50,000 annually (U.S. Census Bureau 2022). The U.S poverty rate for a family of five individuals for 2022 is less than or equal to an annual income of $32,470 (HHS 2022).

On the total population living within the ROI, approximately 7.9% are identified as living below the U.S. poverty rate. Therefore, the meaningfully greater criterion of low-income populations is 9.5%. Of the total population identified, no block groups have a low-income population that exceeds the 50% criterion (Figure 11).

3.11.2 Environmental Consequences

When determining whether environmental effects from the MCRE project on minority or low-income populations are disproportionately high and adverse, DOE considered the following three factors:

1. Whether there is, or may be, an impact on the natural or physical environment that significantly and adversely affects minority or low-income populations.
2. Whether environmental effects are significant (as defined by 40 CFR § 1500–1508) and are, or may, adversely impact minority or low-income populations that appreciably exceeds, or is likely to exceed, the general population or another appropriate comparison group.
3. Whether the environmental effects occur, or may occur, in a minority or low-income population affected by cumulative or multiple adverse exposures from environmental hazards.

Under the proposed activities and the analysis provided in their respective sections, the potential impacts attributed to the MCRE project are anticipated to be low to negligible for factors of socioeconomics, worker and public health and safety, transportation, waste management, and air quality. Any potential impact to these resources from proposed activities are not anticipated to significantly and adversely affect minority or low-income populations more than the population at large within the ROI.

The potential radiological dose to the MEI (i.e., a member of the public located approximately 2 miles south of MFC outside of the INL Site boundary), regardless of minority or low-income status, was estimated to be 2.4×10^{-3} mrem/year. This number represents no appreciable change in dose exposure over natural background levels at the INL Site (i.e., 381 mrem/year) and is significantly less than both the 10 mrem/year regulatory standard and the minor source threshold of 0.1 mrem/year. Therefore, all other average individual doses at each radial distance from the project location would be smaller than this estimated amount and similarly would not represent an appreciable change in dose exposure over baseline levels.

Regarding potential impacts to communities who rely on subsistence consumption, ongoing monitoring from the entirety of INL operations does not indicate any health risks from radiation exposure directly or through subsistence consumption (VNS Federal Services 2022). The total annual dose (via air and ingestion) estimated to be received by an MEI during 2019 was 0.06 mrem, which is below the regulatory limit of 100 mrem per year for a public dose (VNS Federal Services 2022). When considering the estimated dose from the proposed activities, the overall levels of exposure would remain low and well below DOE and regulatory limits. Furthermore, as described in Sections 3.3 and 3.4 there would be low-to-negligible impacts to these resource areas that may affect off-site populations (including Native American populations) or subsistence resources. Land disturbance at the INL Site from the proposed activities would be negligible as the project would occur within an existing facility. Therefore, any potential impact to communities that rely on subsistence consumption (including Native American populations) would be negligible, and there would be no change to an individual's ability to continue to hunt and gather for various purposes throughout their traditional range.

Considering the low levels of risk exposure from project activities and the location of minority and low-income populations in relation to the project site (Figure 11 and Figure 12), the overall levels of exposure from the MCRE project is not expected to (1) significantly impact or adversely affect the natural or physical environment, (2) adversely impact a minority or low-income population in a manner that would exceed any impact on the general population, or (3) expose a minority or low-income population group to an environmental hazard more than the general population when considering cumulative impacts. In total, when considering any direct or indirect impacts in conjunction with past, present, and reasonably foreseeable future actions, any impact as a result of the proposed action would be considered low to negligible as it relates to any potential disproportionately high, adverse impacts on minority or low-income populations.

In accordance with DOE Order 458.1 and DOE-HDBK-1216-2015, environmental sampling would continue to be performed at several locations on the INL Site, at the INL Site boundary, and at various distances from the INL Site, including locations at the Fort Hall Reservation of the Shoshone-Bannock Tribes (DOE 2008). These efforts would ensure that any potential adverse effects on the populations surrounding the INL Site would be limited. The status of environmental sampling can be reviewed in the latest *Idaho National Laboratory Site Environmental Report* (VNS Federal Services 2022).

Any potential impact to the Fort Hall Reservation of the Shoshone-Bannock Tribes, members, or their use of sacred and traditional-use areas, natural landscapes, water, and ecological resources on or near the INL Site that are significant to them would be limited. The MCRE project would not limit access to these resources as all proposed activities would occur in existing facilities. It is not expected that radiological activities would significantly affect terrestrial or aquatic biota populations, thus subsistence resources available to them would not be impacted.

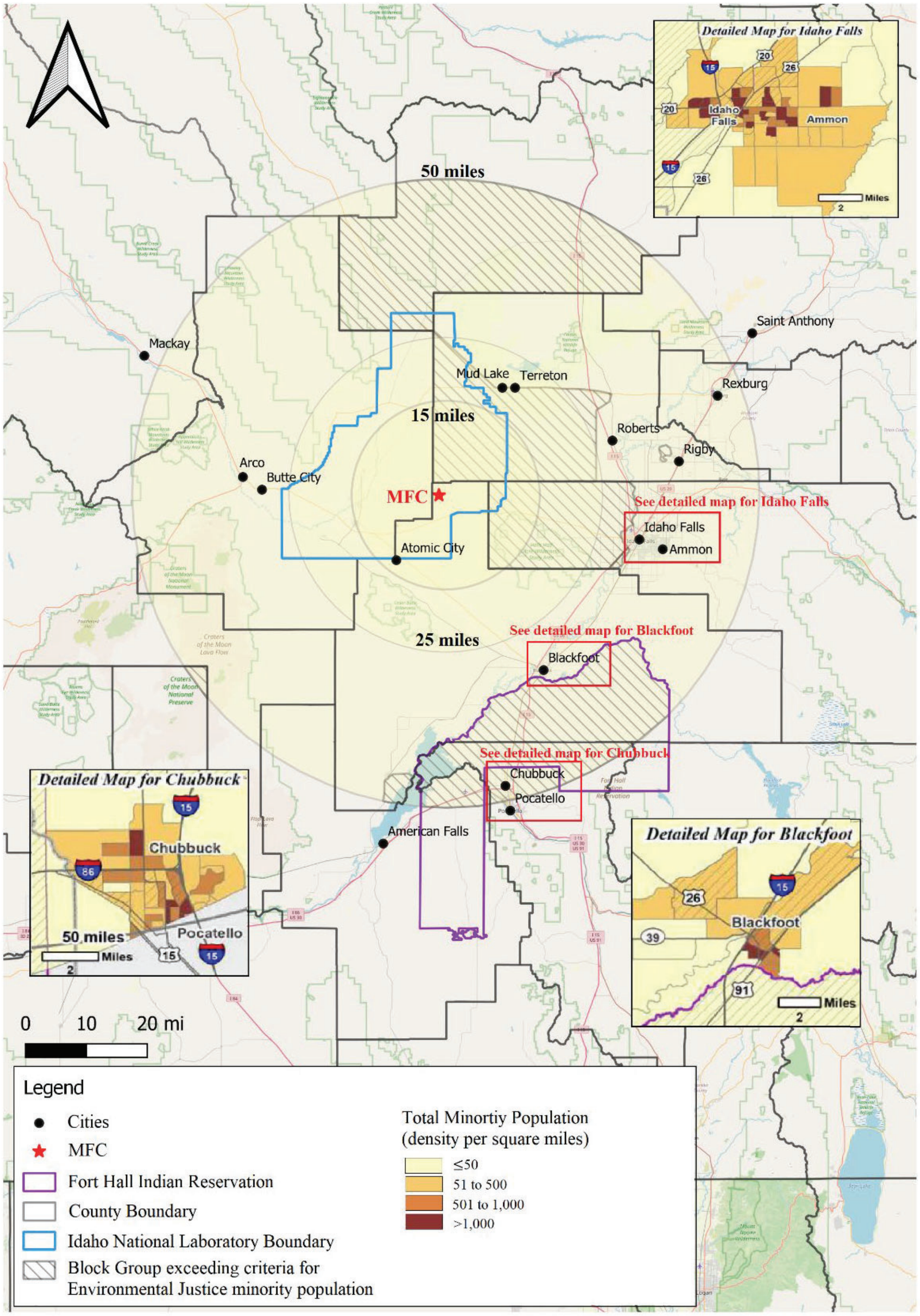

Figure 11. Locations of Census block-groups meeting the criteria for environmental justice minority populations. Note: There are no minority populations residing within the INL boundary although the Census block-groups identifies minority populations. The Census block group does cross into the INL boundary.

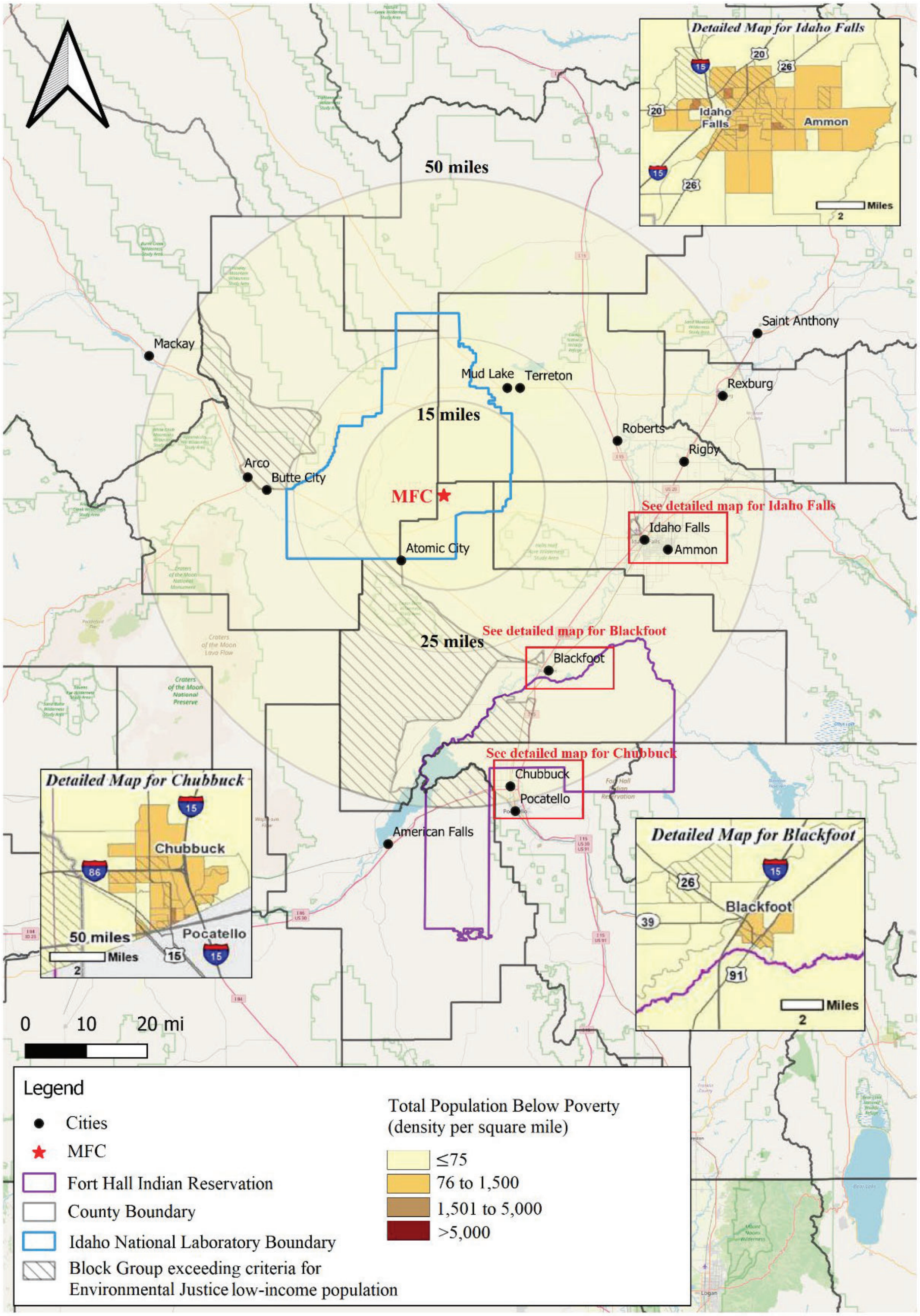

Figure 12. Locations of Census block groups meeting the criteria for environmental justice low-income populations.

3.12 Intentional Destructive Acts

INL routinely uses a variety of measures to mitigate the likelihood and consequences of intentional destructive acts. DOE maintains a highly trained and equipped Protective Force intended to prevent attacks against and entry into facilities and to mitigate the potential for an act of sabotage to occur onsite.

Whether an intentional destructive act were to occur —including its exact nature, location, and consequential magnitude—is inherently uncertain. However, MCRE project activities would be performed within the highly secure ZPPR cell and FMF protected area, under a high level of security at MFC. If an intentional destructive act involving the ZPPR cell or FMF occurred, the potential consequences would be dependent on the amount of fissile material in those facilities at the time of the event and could potentially be similar to the maximum reasonably foreseeable accident as described Section 3.10.3.

3.13 Irreversible and Irretrievable Commitment of Resources

Irreversible commitment of resources refers to the loss of future options for resource development or management, especially of nonrenewable resources such as cultural resources. The implementation of the MCRE project would not require the disturbance of soil, conversion of current land uses, or disturbance of habitat. All activities would occur in existing facilities designed to support the proposed activities. The MCRE project would require the irretrievable commitment of non-recyclable materials for the fabrication of project equipment, fuel consumed by equipment and vehicles, and the energy consumed by the project.

3.14 Relationship Between Short-term Use of Resources and Long-term Productivity

The proposed action or no-action alternatives would not result in a substantial change to the existing condition. Therefore, there would be no impact from the short-term use versus long-term productivity due to the MCRE project. The results of the MCRE project will contribute to the commercialization of the MCFR technology and be beneficial in the long-term productivity of non-carbon sources of energy production.

3.15 Conclusion

The selection of any alternative would not result in the exceedance of a regulatory limit or standard (e.g., air emissions), capacity of a specific resource (e.g., ecological resources), or infrastructure and utilities capability to provide services (e.g., waste treatment) for the MCRE project. Based on the impact analysis associated with the proposed action implementation, no potential adverse impacts were identified that would require additional mitigation measures beyond those required by regulations, permits, and agreements or achieved through design features and best management practices. Any adverse impact is considered to be minor and will neither destabilize any important attribute of the resource or the environment as described in the ASER (VNS Federal Services 2022). Many potential impacts will be indistinguishable from the existing environment of INL Site operations. However, these potential impacts, in conjunction with other past, present, and reasonably foreseeable future actions, would not result in long-term cumulative impacts. Finally, based on the analysis provided in this document, it is anticipated that any potential impact would not significantly affect the quality of the human environment.

4. COORDINATION AND CONSULTATION

4.1 State of Idaho

DOE briefed staff from the Idaho Office of Energy and Mineral Resources on the MCRE project on March 8, 2023.

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