NWMI NORTHWEST MEDICAL ISOTOPES

ATTACHMENT 3

Northwest Medical Isotopes, LLC

Part One, Construction Permit Application

Public Version

- **General Information per 10 CFR 50.33, filing fee required by 10 CFR 50.30(e) and 10 CFR 170.21, and Classified Information Agreement in Accordance with 10 CFR 50.37**
- **Chapter 1 – The Facility**
- **Chapter 2 – Site Characteristics**
- **Chapter 3 – Design of Structures, Systems, and Components**
- **Chapter 4 – Radioisotope Production Facility Description**
- **Chapter 5 – Coolant Systems**
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- **Chapter 7 – Instrumentation and Control Systems**
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- **Chapter 9 – Auxiliary Systems**
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- **Chapter 11 – Radiation Protection and Waste Management**
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- **Chapter 16 – Other License Considerations**
- **Chapter 17 – Decommissioning and Possession-Only License Amendments**
- **Chapter 18 – Highly Enriched Uranium to Low Enriched Uranium Conversion**
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- **Integrated Safety Analysis Summary**

Information is being provided via hard copy

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GENERAL INFORMATION REQUIRED BY 10 CFR 50.33 AND FILING FEE REQUIRED BY 10 CFR 50.30(E) AND 10 CFR 170.21

1. GENERAL INFORMATION IN ACCORDANCE WITH 10 CFR 50.33

Name of Applicant [10 CFR 50.33(a)] and Address [10 CFR 50.33(b)]:

Northwest Medical Isotopes, LLC
815 NW 9th Street, Suite 256
Corvallis, Oregon 97330

Description of Business/Occupation of Applicant [10 CFR 50.33(c)]

Northwest Medical Isotopes, LLC (NWMI) was established in 2010 to ensure a domestic, secure, and reliable supply of molybdenum-99 (^{99}Mo) for medical applications.

Ownership Information [10 CFR 50.33(d)]

NWMI is a limited liability company formed under the laws of the state of Oregon. NWMI's corporate headquarters is located in Corvallis, Oregon. NWMI intends to construct and operate a Radioisotope Production Facility (RPF) to recover and purify ^{99}Mo in Columbia, Missouri, at Discovery Ridge Research Park (Discovery Ridge), an emerging research park development owned and managed by the University of Missouri (MU) System. The proposed 3 hectare (ha) (7.4-acre) RPF site is situated within Discovery Ridge, north of Discovery Ridge Drive. Discovery Ridge is located in the City of Columbia, Boone County, Missouri.

Corporate Structure, Directors and Principal Officers – NWMI is the applicant for the Construction Permit Application and will construct and operate the RPF. This application and the demonstration of financial capability are based on the current corporate structure and financial situation of NWMI. NWMI business operations are managed under the direction of a Board of Managers and through the officers of NWMI. The NWMI Board currently consists of six managing members and two executive officers (identified in Table 1). All managers and officers are U.S. citizens.

Table 1. Northwest Medical Isotopes, LLC Managing Members and Executive Officers

Managing Members	Executive Officers
Nicholas Fowler – Chairman 2260 NW Independence Hwy, Albany, OR 97321	Nicholas Fowler, President and CEO 2260 NW Independence Hwy, Albany, OR 97321
Carolyn Haass – Secretary 9011 W. John Day Ave, Kennewick, WA 99336	Carolyn Haass, Chief Operating Officer 9011 W. John Day Ave, Kennewick, WA 99336
Larry Mullins 3600 NW Samaritan Drive, Corvallis, OR 97330	
Kirk Gerner 3600 NW Samaritan Drive, Corvallis, OR 97330	
Manoja Lecamwasam, PhD 185 Berry Street, Suite 300, Lobby 2 San Francisco, CA 94107	
Milton K. Cheever 2360 SE 14th Street, Albany, OR 97322	

Ownership Information [10 CFR 50.33(d)]:

Table 2 provides the name, citizenship, and address of each partner and principal business location of the partners having a membership interest of more than two percent.

Table 2. Northwest Medical Isotopes, LLC Ownership Summary

Company/address	State/company structure	Membership interests
Samaritan Health Services, Inc. 3600 NW Samaritan Drive, Corvallis, OR 97330	Oregon Not-for-profit corporation	[Proprietary Information]
CAC IsoMed, LLC 9011 W John Day Ave, Kennewick, WA 99336	Washington Limited-liability company	[Proprietary Information]
Orion Ventures, LLC 2260 NW Independence Hwy, Albany, OR 97321	Oregon Limited-liability company	[Proprietary Information]
Oregon State University A312 Kerr Building, Corvallis, OR 97330	Oregon Institute of higher education	[Proprietary Information]
Talents Venture Fund II/Talents Isotope Fund II 2360 SE 14th Street, Albany, OR 97322	Delaware Limited-liability company	[Proprietary Information]
Dignity Health 185 Berry Street, Suite 300, San Francisco, CA 94107	California Not-for-profit corporation	[Proprietary Information]
Other[a]		[Proprietary Information]
Total		100%

[a] Membership interests are less than 2 percent.

Class of License/Duration of License [10 CFR 50.33(e)]

NWMI is applying to the U.S. Nuclear Regulatory Commission (NRC) to obtain a Class 103 license for a production facility under Title 10, *Code of Federal Regulations*, Part 50 (10 CFR 50), "Domestic Licensing of Production and Utilization Facilities." Embedded in the 10 CFR 50-licensed facility will be several activities subject to 10 CFR 70, "Domestic Licensing of Special Nuclear Material," to receive, possess, use, and transfer special nuclear material, and 10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," to process and transport ^{99}Mo for medical applications. NWMI expects to request an Operating License term of 30 years.

Financial Qualifications [10 CFR 50.33(f)]

The NRC requires that an applicant for a Construction Permit Application submit sufficient financial information to demonstrate reasonable assurance that the applicant can obtain the necessary funds to cover the estimated design, construction, and startup costs for the RPF, and the related fuel-cycle costs (e.g., low enriched uranium from the U.S. Department of Energy) pursuant to 10 CFR 50.33(f). In addition, the applicant is required to indicate the source(s) of funds to cover these costs.

The financial guidelines the applicant needs to follow are provided in 10 CFR 50, Appendix C. This appendix (1) distinguishes between applicants that are established organizations and those that are newly formed entities organized primarily for the purpose of engaging in the activity for which the permit is sought, and (2) provides a guide for the financial data and related information required to establish financial qualifications for construction permits. NWMI is considered a newly formed entity per Appendix C.

Financial Ability to Construct a Facility – NWMI is submitting information that demonstrates the company possesses or has reasonable assurance of obtaining the necessary funds to cover estimated design, construction, and startup costs and the related fuel-cycle costs.

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NWMI is submitting information demonstrating that the company possesses or has reasonable assurance of obtaining the necessary funds to cover estimated design, construction, and startup costs, and related fuel-cycle costs. The estimated NWMI costs to construct an RPF are summarized below. These estimates are based on NWMI's preliminary design of the RPF completed in May 2015. The estimated NWMI costs to construct an RPF are summarized below.

Total facility costs	[Proprietary Information]
Plant equipment	[Proprietary Information]
LEU costs for RPF startup and first year	[Proprietary Information]
Total estimated costs	[Proprietary Information]

NWMI prepared an RPF base estimate that covers all components of the project (e.g., scope, conditions, and characteristics), including engineering and construction equipment, materials, and labor. The estimate incorporates data from previous and similar projects and NWMI's preliminary RPF time-cycle logistical study that includes data for labor requirements, materials, operations, and maintenance. The base estimate also used inputs from the completed project file, project schedule, and knowledge of site conditions. The estimate was escalated to the year of construction dollars using a construction cost index and to the mid-point of construction. NWMI developed clear and concise documentation for traceability that will allow future updates, review, and validation of the estimate.

To date, NWMI has received [Proprietary Information] in equity financing and anticipates facility financing [Proprietary Information] for the final design and construction of the RPF using various sources of financing, including equity and debt to be completed in the 3rd quarter 2016. Total RPF estimated costs are [Proprietary Information]. NWMI research and development, preliminary design, regulatory, and permitting cost projections are fully funded through existing equity financing receipts and commitments. NWMI has established a wholly owned subsidiary for the RPF and expects construction to be debt-financed. The RPF site is located in the Discovery Ridge Research Park (Columbia, Missouri) and on land owned by the University of Missouri system and will be leased for [Proprietary Information].

Financial Ability to Safely Operate Facility – NWMI is providing financial information that demonstrates that the company possesses or has reasonable assurance of obtaining the funds necessary to cover estimated facility operational costs for the term of the operating license. Table 3 provides the RPF estimated operating costs and expected revenues for the first five years of the commercial operations.

Table 3. Estimated Radioisotope Production Facility Operating Costs and Expected Revenues for Years 1 – 5 ($000)

	2018	2019	2020	2021	2022
Revenue	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Cost of Goods Sold	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Gross Profit	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
% Gross Profit	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Operating Expenses	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Income from Operations	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Non-Operating Expenses	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Income Taxes	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Net Income	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Net Income % of Revenue	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

Pursuant to 10 CFR 50.33(f)(2), the sources of funds to cover these costs will be funded from the expected revenues associated with the sale of ^{99}Mo. NWMI expects that such revenue will be significantly more than the operating costs incurred.

NWMI prepared an RPF operations base estimate based on previous and similar projects, and the cost base estimating. The base estimate also used inputs from NWMI's preliminary RPF time-cycle logistical study, which includes data for labor requirements, materials, and operations and maintenance. NWMI has developed clear and concise documentation for traceability that will allow future updates, review, and validation of the estimate.

Financial Ability to Safely Decommission a Facility – NWMI will provide financial information that demonstrates reasonable assurance that funds will be available to decommission the RPF in accordance with 10 CFR 50.33(f), as part of the Operating License Application. This financial information will be submitted in accordance with 10 CFR 50.75(d), "Reporting and Recordkeeping for Decommissioning Planning."

Pursuant to 10 CFR 50.75(e), the NWMI RPF Decommissioning Plan will provide financial assurances, including a cost estimate for RPF decommissioning, identification of which method(s) will be used to provide funds for decommissioning, and a description of the means of adjusting the cost estimate and associated funding level periodically over the operational life of the RPF to account for changes in labor, energy, and waste disposal.

Based on previous experience and discussions with nuclear industry experts, NWMI's preliminary cost estimate for decommissioning the RPF is [Proprietary Information]. NWMI's current business strategy anticipates that the decommission of the RPF will be financed by an external escrow account in which deposits will be made annually, coupled with either a surety method, insurance, or some other form of guarantee. Financial projections assume that the annual escrow deposit will be approximately [Proprietary Information], and adjusted for inflation periodically, which provides reasonable assurance that decommissioning funds will be available for the RPF. NWMI's RPF Decommissioning Plan with detailed costs and associated financial assurances will be provided in the Operating License Application. The estimated costs of decommissioning will be developed using the analysis of the RPF design and the analysis of estimates and actual costs of decommissioning similar facilities.

Foreign Ownership, Control, or Domination – NWMI understands that the NRC will evaluate our application in a manner that is consistent with the guidance provided in the Standard Review Plan (SRP) regarding "Foreign Ownership, Control, or Domination of applicants for Reactor Licenses," June 1999, referred to as the "SRP on FOCD." This evaluation will determine whether NWMI is owned, controlled, or dominated by an alien, a foreign corporation, or a foreign government.

The NRC's position outlined in the SRP on FOCD states "the foreign control prohibition should be given an orientation toward safeguarding the national defense and security." Furthermore, the SRP on FOCD outlines how the effects of foreign ownership may be mitigated through implementation of a "negation action plan" to ensure that any foreign interest is effectively denied control or domination over the applicant.

NWMI fully understands that a financial analyst will review all of the information submitted by the company to determine whether there is FOCD. If it is determined that there is FOCD, additional action would be necessary to negate FOCD, and the applicant would be advised and requested to submit a Negative Action Plan.

NWMI is a limited liability company organized under the laws of the state of Oregon. NWMI is *not* owned, controlled, or dominated by alien, foreign corporation, or foreign government. In addition, NWMI is not acting as an agent or representative of another person or company in filing the Construction Permit Application.

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NWMI is governed and managed by a six-member Board of Managers, all of whom are U.S. citizens. NWMI currently has 18 members. To the best of our knowledge, all members holding more than one percent of NWMI's membership interests are U.S. citizens or entities owned or controlled by U.S. citizens.

Construction Earliest and Latest Date for Construction Completion [10 CFR 50.33(h)]

NWMI currently expects to complete construction of the facility at the earliest and latest by second quarter 2016 and fourth quarter 2017, respectively.

2. Fee Information in Accordance with 10 CFR 50.30(e) and 10 CFR 170.21

NWMI shall pay fees in accordance with 10 CFR 50.30(e) and 10 CFR 170.21, "Schedule of Fees for Production or Utilization Facilities, Review of Standard Referenced Design Approvals, Special Projects, Inspections, and Import and Export Licenses," Facility Category G, "Other Production or Utilization Facility." NWMI shall pay "Full Cost" fees for the following categories of services:

- Application for Construction Permit
- Construction Permit
- Operating License
- Amendment, Renewal, and Other Approvals
- Inspections.

Fees will be paid pursuant to 10 CFR 170.1, 170.12, and 170.20.

3. Classified Information Agreement in Accordance with 10 CFR 50.37

NWMI will not allow access to Restricted Data or classified National Security Information until the individual and/or the facility has been approved for access under provisions of 10 CFR 25, "Access Authorization," and/or 10 CFR 95, "Facility Security Clearance and Safeguarding of National Security Information and Restricted Data."

I declare under penalty of perjury that the foregoing is true and correct. Executed on July 6, 2015.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
Chief Operating Officer
Northwest Medical Isotopes, LLC
Project No.: Project No. 0803

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Public
Chapter 1

NWMI

NORTHWEST MEDICAL ISOTOPES

Chapter 1.0 – The Facility

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 0

June 2015

Prepared for:
Northwest Medical Isotopes, LLC
815 NW 9th Ave, Suite 256
Corvallis, Oregon 97330

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Chapter 1.0 – The Facility

Construction Permit Application for Radioisotope Production Facility

NWMI-2013-021, Rev. 0

Date Published:
June 29, 2015

***Document Number*: NWMI-2013-021**	***Revision Number*: 0**
***Title*: Chapter 1.0 – The Facility Construction Permit Application for Radioisotope Production Facility**	
***Approved by*: Carolyn Haass**	***Signature*:** Carolyn C Haass

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REVISION HISTORY

Rev	Date	Reason for Revision	Revised By
0	6/29/2015	Initial Application	Not required

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CONTENTS

FIGURES

TABLES

TERMS

Acronyms and Abbreviations

^{99}Mo	molybdenum-99
^{235}U	uranium-235
^{238}U	uranium-238
ADUN	acid deficient uranyl nitrate
ALARA	as low as reasonably achievable
BMS	building management system
CFR	Code of Federal Regulations
CSA	criticality safety analysis
Discovery Ridge	Discovery Ridge Research Park
DOE	U.S. Department of Energy
EF scale	enhanced Fujita tornado intensity scale
EOI	end of irradiation
ESF	engineered safety feature
F scale	Fujita tornado intensity scale
FEMA	Federal Emergency Management Agency
FPC	facility process control
H_2	hydrogen gas
HAZOP	hazards and operability
HEPA	high-efficiency particulate air
HMTA	hexamethylenetetramine
HVAC	heating ventilation and air conditioning
I&C	instrumentation and control
IBC	International Building Code
IROFS	item relied on for safety
ISA	integrated safety analysis
ISG	interim staff guidance
IX	ion exchange
LEU	low-enriched uranium
MMI	Modified Mercalli Intensity
Mo	molybdenum
MU	University of Missouri
MURR	University of Missouri Research Reactor
NO_x	nitrogen oxide
NMSZ	New Madrid Seismic Zone
NRC	U.S. Nuclear Regulatory Commission
NWMI	Northwest Medical Isotopes, LLC
OSTR	Oregon State University TRIGA Reactor
OSU	Oregon State University
PHA	preliminary hazards analysis
PUREX	plutonium-uranium extraction
QRA	quantitative risk assessment
R&D	research and development
RPF	radioisotope production facility
SNM	special nuclear material
SSC	structures, systems, and components
TBP	tributyl phosphate
TCE	trichloroethylene
[Proprietary Information]	[Proprietary Information]

U	uranium
U.S.	United States
UN	uranyl nitrate
UNH	uranyl nitrate hexahydrate
[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]
USGS	U.S. Geological Survey

Units

Ci	curie
cm	centimeter
ft	feet
ft^2	square feet
g	gram
gal	gallon
ha	hectare
hr	hour
in.	inch
kg	kilogram
km	kilometer
L	liter
lb	pound
m	meter
m^2	square meter
mi	mile
sec	second
wt%	weight percent

1.0 THE FACILITY

1.1 INTRODUCTION

Northwest Medical Isotopes, LLC (NWMI) is applying to the U.S. Nuclear Regulatory Commission (NRC) to obtain a license for a production facility under Title 10, *Code of Federal Regulations* (CFR) Part 50 (10 CFR 50), "Domestic Licensing of Production and Utilization Facilities." Embedded in the 10 CFR 50-licensed facility will be several activities subject to 10 CFR 70, "Domestic Licensing of Special Nuclear Material," to receive, possess, use, and transfer special nuclear material (SNM) and 10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," to process and transport molybdenum-99 (^{99}Mo) for medical applications.

NWMI intends to submit a single 10 CFR 50 license application for the Radioisotope Production Facility (RPF) following the guidance in NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, that encompasses activities regulated under different NRC requirements (e.g., 10 CFR 70 and 10 CFR 30), in accordance with 10 CFR 50.31, "Combining Applications," and 10 CFR 50.32, "Elimination of Repetition."

The NRC has determined that a radioisotope separation and processing facility, which also conducts separation of SNM, will be considered a production facility and as such, will be subject to licensing under 10 CFR 50. A significant portion of the NWMI RPF is focused on the disassembly of irradiated low-enriched uranium (LEU) targets, separation and purification of fission product ^{99}Mo, and the recycle of LEU that is licensed under 10 CFR 50. The RPF will also include the fabrication of LEU targets, which will be licensed under 10 CFR 70. These targets will be shipped to NWMI's network of research or test reactors for irradiation (considered a connected action) and returned to the RPF for processing. The LEU used for the production of the LEU target materials will be obtained from the U.S. Department of Energy (DOE) and from LEU reclaimed from processing the irradiated targets.

NWMI's licensing approach for the RPF defines the following unit processes and areas that fall under the following NRC regulations:

- 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities"
  - Irradiated LEU target receipt (from network of university research or test reactors)
  - Irradiated LEU target disassembly and dissolution
  - ^{99}Mo recovery and purification
  - Uranium recovery and recycle
  - Waste management
  - Associated laboratory and support areas
- 10 CFR 70, "Domestic Licensing of Special Nuclear Material"
  - Receipt of fresh LEU (from DOE)
  - LEU target fabrication
  - Associated laboratory and support areas

Any byproduct materials produced or extracted in the RPF will be licensed under 10 CFR 30.

The proposed action is the issuance of an NRC license under 10 CFR 50 and provisions of 10 CFR 70 and 10 CFR 30 that would authorize NWMI to construct and operate a ^{99}Mo RPF at a site located in Columbia, Missouri.

Proposed RPF activities will include:

- Receiving LEU from the DOE
- Producing LEU target materials and fabrication of targets
- Packaging and shipping LEU targets to the university reactor network for irradiation
- Returning irradiated LEU targets for dissolution, recovery, and purification of ^{99}Mo
- Recovering and recycling LEU to minimize radioactive, mixed, and hazardous waste generation
- Treating/packaging wastes generated by RPF process steps to enable transport to a disposal site

The schedule for proposed RPF construction, operation, and decommissioning is as follows:

- Start date of site preparation/construction: First quarter 2016
- End date of construction: First quarter 2017
- Start date of facility startup and cold commissioning (pre-operational): Second quarter 2017
- Date of hot commissioning and commercial operations: Third quarter 2017
- Date of decommissioning: 2047

1.2 SUMMARY AND CONCLUSIONS ON PRINCIPAL SAFETY CONSIDERATIONS

This section identifies safety criteria, principal safety considerations, and conclusions for the RPF structures, systems, and components (SSC).

1.2.1 Radioisotope Production Facility Special Nuclear Material Inventory

The RPF SNM inventory is summarized below based on material accountability areas. The RPF target fabrication area is governed by 10 CFR 70 and summarized in Table 1-1. Some locations may contain SNM in multiple forms. For example, the LEU can rack may include some containers of uranium metal pieces, while others may contain LEU target material [Proprietary Information]. The material physical form will affect the SNM mass that may be present in the storage location. The dissolver process enclosure will include uranium metal that is being dissolved to produce uranyl nitrate (UN) solution. Composition ranges indicate the variation of solution compositions present in different vessels at a particular location.

Table 1-1. Special Nuclear Material Inventory of Target Fabrication Area

Location[a]	Form	Concentration	Volume	SNM mass[b]	
				Bounding[c, d]	Nominal[c, d]
[Proprietary Information]	Solid U-metal pieces/LEU target material in sealed containers	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Dissolver process enclosure	U-metal/UNH	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Recycled uranium process enclosures	UNH	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
ADUN concentration and storage process enclosures	ADUN	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Wash column and drying tray enclosures	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] All process enclosures and storage systems are located in the target fabrication process area.
[b] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤19.95 wt% ^{235}U).
[c] [Proprietary Information]
[d] The indicated masses are not additive to describe the total 10 CFR 70 area inventory because material is transferred from one location to another during a processing week.
[Proprietary Information].

ADUN = acid deficient uranyl nitrate.
LEU = low-enriched uranium.
N/A = not applicable.
SNM = special nuclear material.
U = uranium.
UNH = uranyl nitrate hexahydrate.
[Proprietary Information]

Bounding and nominal SNM inventories are indicated on Table 1-1 and shown in terms of the equivalent mass of uranium, independent of the physical form. The bounding inventory in each location is based on the full vessel capacity and composition of in-process solution. The nominal inventory is based on the assumption that storage areas are generally operated at half capacity to provide a buffer for potential variations in process throughput during normal operation. Summation of the location inventories does not necessarily provide an accurate description of the total target fabrication area inventory due to the batch

processing operation. Material from one process location is used as input to a subsequent location so that material cannot be present in all locations at the indicated inventories under normal operating conditions.

Irradiated material areas are governed by 10 CFR 50 and summarized in Table 1-2. Equipment and vessels containing SNM will be located in a variety of hot cells within the RPF. Multiple forms are shown for the target dissolution hot cell because material entering as [Proprietary Information] is dissolved to produce UN solution.

Table 1-2. Special Nuclear Material Inventory of Irradiated Material Areas

Location	Form	Concentration	Volume	SNM mass[a]	
				Bounding[b, c]	Nominal[c, d]
Target receipt hot cell	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target disassembly hot cells[e]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Target dissolution hot cells[e]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Mo recovery and purification hot cells	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Tank hot cell					
Mo recovery tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Impure U collection tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
IX columns and support tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Uranium concentrator #1	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Uranium concentrator #2	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
U decay tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
U IX waste tanks	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
High dose liquid accumulation[g]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]
Solid waste vessels[h]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]	[Proprietary Information]

[a] SNM concentration and mass represent total amount of LEU (combined ^{235}U and ^{238}U at ≤ 19.95 wt% ^{235}U)
[b] [Proprietary Information]
[c] The indicated masses are not additive to describe the total 10 CFR 50 area inventory, as the material is transferred from one location to another during a processing week.
[Proprietary Information].
[e] [Proprietary Information].
[f] [Proprietary Information].
[g] [Proprietary Information].
[h] [Proprietary Information]..

IX = ion exchange.
LEU = low-enriched uranium.
Mo = molybdenum.
MURR = University of Missouri Research Reactor.
N/A = not applicable.
OSTR = Oregon State University TRIGA Reactor.
SNM = special nuclear material.
U = uranium.
UNH = uranyl nitrate hexahydrate solution.
[Proprietary Information]

Bounding and nominal SNM inventories are indicated on Table 1-2 and shown in terms of the equivalent mass of uranium, independent of the physical form. The bounding inventory in each location is based on operation at the weekly maximum system capacity and approximates the condition where most vessels are filled to capacity with material at a composition of the in-process solution.

The nominal inventory in each location is based on operation at the weekly system throughput when processing the dominant annual target load. Multiple locations indicate a range for solution concentrations and volumes describing the variations over bounding and nominal conditions.

Summation of the location inventories does not necessarily provide an accurate description of the total irradiated material area inventory due to the batch processing operation. Material from one process location is used as input to a subsequent location such that material cannot be present in all locations at the indicated inventories under normal operating conditions.

1.2.2 Consequences from the Operation and Use of the Facility

The primary consequences resulting from the operation of the RPF operations are radiological. The RPF will produce LEU target material that will then be irradiated in a network of university reactors. After the LEU target material is irradiated, the material will transported back to the RPF and processed in the RPF to extract and purify the ^{99}Mo. Radioactive waste materials will be processed and/or converted to solid wastes for shipment to off-site disposal facilities. The RPF is designed to be a zero radioactive liquid effluent discharge facility.

The anticipated radionuclide inventory in the RPF is based on a weekly throughput [Proprietary Information]. The maximum radionuclide inventory is based on the accumulation in the various systems dependent on the process material decay times, as noted in Table 1-3. Table 1-3 provides the calculated radionuclide inventory (curies [Ci]) for the different process streams in the RPF. The radionuclide inventory values are discussed further in the Radiological Hazards subsections (Chapter 4.0, "Radioisotope Production Facility Description," Section 4.3.x.5) of each RPF process area.

Table 1-3. Radionuclide Inventory for Radioisotope Production Facility Process Streams

System	Ci	Time (hr EOI)
Target dissolution	[Proprietary Information]	[Proprietary Information]
Mo feed tanks	[Proprietary Information]	[Proprietary Information]
U system	[Proprietary Information]	[Proprietary Information]
Mo system	[Proprietary Information]	[Proprietary Information]
Mo waste tank	[Proprietary Information]	[Proprietary Information]
Offgas system[a]	[Proprietary Information]	[Proprietary Information]
High-dose waste tanks[c]	[Proprietary Information]	[Proprietary Information]
Uranium recycle[d]	[Proprietary Information]	[Proprietary Information]

[a] Offgas system radionuclide inventory is based on NWMI-2013-CALC-011[b] to account for accumulation of isotope buildup in the offgas system[Proprietary Information].

[b] Material decay time is based on the total equilibrium in-process inventory, as described in NWMI-2013-CALC-011, *Source Term Calculations*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, February, 2015.

[c] [Proprietary Information].

[Proprietary Information].

EOI = end of irradiation.
IX = ion exchange.
Mo = molybdenum.
U = uranium.

Figure 1-1 shows the anticipated radionuclide inventory and provides a color key indicating the amount of curies for the different process areas depending on the EOI.

[Proprietary Information]

Figure 1-1. Radioisotope Processing Facility at 0 to 40 Hours End of Irradiation

Figure 1-2 shows the anticipated maximum radionuclide inventory in the RPF at the completion of processing [Proprietary Information] at an operation time greater than 40 hr EOI.

[Proprietary Information]

Figure 1-2. Radioisotope Processing Facility at Greater than 40 Hours End of Irradiation

As a result of working with radioactive materials, the RPF workers will receive occupational exposures, and members of the public will receive some exposure from the release and shipment of the produced materials. Doses to workers and the public during normal operation are within the limits of 10 CFR 20.1201, "Occupational Dose Limits for Adults," and 10 CFR 20.1301, "Dose Limits for Individual Members of the Public," respectively. In addition, there are potential exposures to the public from postulated accidents. Potential doses to workers and the public from postulated accident are within the limits of 10 CFR 20.1201 and 10 CFR 20.1301, respectively.

1.2.3 Radioisotope Production Facility Integrated Safety Analysis

NWMI evaluated the safety of the facility using an integrated safety analysis (ISA) process. The ISA process comprises a preliminary hazards analysis (PHA) and the follow-on development and completion of quantitative risk assessments (QRA) to address events and hazards identified in the PHA as requiring further evaluation.

The ISA process flow diagram is provided Figure 1-3. The ISA process (being adapted for this application) consists of conducting a PHA of a system using a combination of written process descriptions, process flow diagrams, process and instrumentation diagrams, and supporting calculations to identify events that could lead to adverse consequences. Those adverse consequences are evaluated qualitatively by the ISA team members to identify the likelihood and severity of consequences using guidance on event frequencies and consequence categories consistent with the regulatory guidelines.

Each event with an adverse consequence that involves licensed material or its byproducts is evaluated for risk using a risk matrix that enables the user to identify unacceptable intermediate- and high-consequence risks. For these unacceptable intermediate- and high-consequence risks events, items relied on for safety (IROFS) are developed to prevent or mitigate the consequences of the events, and an event tree analysis is used to demonstrate that the risk can be reduced to acceptable frequencies through preventative or mitigative IROFS.

Fault trees and failure mode and effects analysis can be used to (1) provide quantitative failure analysis data (failure frequencies) for use in the event tree analysis of the IROFS, as necessary, or (2) quantitatively analyze an event from its basic initiators to demonstrate that the quantitative failure frequency is already highly unlikely under normal standard industrial conditions, thus not needing the application of IROFS. Once the IROFS are developed, management measures are identified to ensure that the IROFS failure frequency used in the analysis is preserved and the IROFS are able to perform the intended functions when needed.

Additional detailed information is provided in Chapter 13.0, "Accident Analysis" and NWMI-2015-SAFETY-002, *Radioisotope Production Facility Integrated Safety Analysis Summary*.

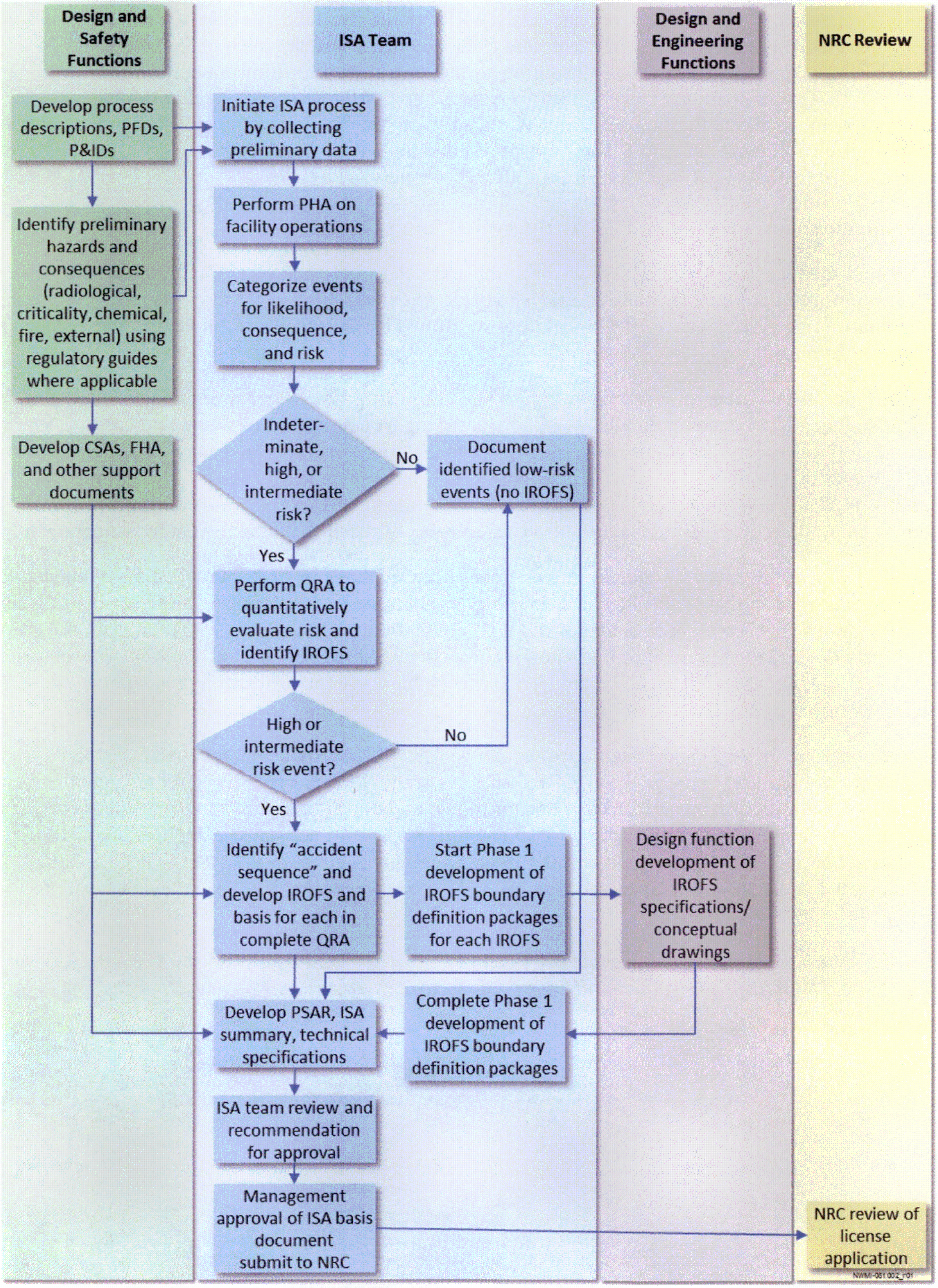

Figure 1-3. Integrated Safety Analysis Process Flow Diagram

1.2.3.1 Items Relied on for Safety Boundary Definition Package and Technical Specifications Development

One of the outcomes of the ISA process is the development of ISA baseline documents that will be used to develop the preliminary safety analysis report, license application, and technical specifications (and following construction, the final safety analysis report). These ISA baseline documents will include process descriptions, process flow diagrams, process and instrumentation diagrams, supporting calculations (e.g., release consequences, dose consequences, shielding calculations, etc.), PHAs, criticality safety evaluations, fire hazards analysis, QRAs, and other evaluations of specific topics (e.g., natural phenomenon strengths, man-made accident frequencies, support structure evaluations, etc.) supporting conclusions in the ISA not covered in the above documents. Where IROFS are developed from the ISA process, an IROFS boundary definition package will be developed to incorporate relevant information from all of these documents into one place for each IROFS.

These IROFS boundary definition packages are living documents that will be updated throughout the construction phase and operating life of the facility as changes to the implementation of IROFS and their management measures evolve. Using the IROFS boundary definition package, an ISA team member will prepare the technical specifications and the IROFS summary. During the NRC licensing review, operational readiness review, and periodic NRC inspections, the NRC staff will review the IROFS boundary definition packages to ensure that the IROFS are maintained, reliable, and available when needed.

1.2.3.1.1 Items Relied on for Safety Boundary Definition Package Development

As living documents, the IROFS boundary definition packages will be developed in the following phases.

Phase 1: Initial development phase – During initial development of the IROFS during conceptual and preliminary design, the safety function (including safety limits, limiting safety system settings, human factors engineering and human-system interface requirements, design standards, and initial management measures) will be documented. This level of completion will provide the designers with the information needed to create the final design of the IROFS. This level of completion will also provide support for the technical specifications and NRC review of the initial construction license.

Phase 2: Final design phase – All sections of the IROFS boundary definition package will be completed, including drawings approved for construction or fabrication. Exceptions include reference to the actual versions of the training program and procedures. This level of completion is required before construction, fabrication, and testing of passive engineered controls, active engineered controls, and augmented administrative controls-type IROFS. For augmented administrative controls and simple administrative controls-type IROFS, this level is required to proceed with training and procedure completion and approval. At this level of completion, NWMI should have a basis for any license amendments that need to be approved before implementation. NRC license amendments must be approved before initiation of construction, fabrication, and testing.

Phase 3: Implementation phase – Applicable training and procedures (operating and maintenance/ surveillance) will be referenced and logs of NRC inspection reports, audit findings, and event notifications made against each IROFS will be maintained. This level of completion will support the initial testing and operations of the facility and the NRC operational readiness review.

1.2.3.1.2 Technical Specification Development

The technical specifications will be developed from the IROFS boundary definition packages. The ISA team will review the completed document, and the ISA Manager and RPF Operations Manager will approve the changes to the technical specifications. The NRC must review and approve any changes to the technical specifications.

A PHA was performed to support the RPF Construction Permit Application and is documented in NWMI-2015-SAFETY-001, *Radioisotope Production Facility Preliminary Hazards Analysis*. The following sections summarize the PHA results. Additional detailed information is provided in Chapter 13.0.

1.2.3.2 Hazard and Accident Analysis

1.2.3.2.1 Description of Processes Analyzed

Process descriptions used by the PHA are provided in Section 1.3.2.2. The PHA evaluated the system hazards using the eight nodes in Table 1-4 to describe the RPF primary processes and systems. The target fabrication process is represented by Node 1.0.0. The target disassembly and target dissolution processes are represented by Nodes 6.0.0 and 2.0.0, respectively. The molybdenum (Mo) recovery and purification process is represented by Node 3.0.0, and the uranium (U) recovery and recycle process is represented by Node 4.0.0. The waste handling system process is represented by Node 5.0.0. Ventilation systems are represented by Node 7.0.0. Node 8.0.0 represents other facility hazards, including natural phenomena, man-made external events, and other facility operations not specifically covered by the process systems.

Table 1-4. Preliminary Hazard Analysis Nodes

Node	System/Process
1.0.0	Target fabrication process
2.0.0	Target dissolution process
3.0.0	Mo recovery and purification process
4.0.0	U recovery and recycle process
5.0.0	Waste handling system process
6.0.0	Target disassembly
7.0.0	Ventilation system
8.0.0	Natural phenomena, man-made external events, and other facility operations

Mo = molybdenum.
U = uranium.

1.2.3.2.2 Identification of Hazards

Initial hazards identified by preliminary reviews included:

- High radiation dose to workers and the public from irradiated target material during processing
- High radiation dose due to accidental nuclear criticality
- Toxic uptake of licensed material by workers or the public during processing or accidents
- Fires and explosions associated with chemical reactions and use of combustible materials and flammable gases
- Chemical exposures associated with chemicals used in processing the irradiated target material
- External events (both natural and man-made) that impact the facility operations

The primary nodes shown in Table 1-4 were further subdivided to describe subsystems or subprocess elements and basic design functions for hazards identification. A methodology was selected from the alternate techniques described in Chapter 13.0 and NWMI-2015-SAFETY-002 for analysis of the hazards at each lower-tier node based on the status of the current design maturity.

In general, the design status available for the RPF Construction Permit Application basis resulted in selection of what-if, structured what-if, or hazards and operability (HAZOP) analysis methodologies for the identification of hazards and determination of whether a hazard would pose an unacceptable risk. Hazards that posed an unacceptable risk were used as input to define accident sequences for further evaluation.

Chapter 13.0 and NWMI-2015-SAFETY-002 provide summary descriptions of the PHA hazard identification results described in NWMI-2015-SAFETY-001 for each of the upper-tier nodes.

1.2.3.3 Description of Accident Sequences

Each of the following accident initiating events were included in the PHA.

- Criticality accident
- Loss of electrical power
- External events (meteorological, seismic, fire, flood)
- Critical equipment malfunction
- Operator error
- Facility fire (explosion is included in this category)
- Any other event potentially related to unique facility operations

The PHA identifies and categorizes accident sequences that require further evaluation. Table 1-5 defines the top-level accident sequence notation used in the RPF PHA.

Table 1-6 provides a crosswalk between the PHA top-level accident sequence categories and the NUREG-1537, Part 1 Interim Staff Guidance (ISG) accident initiating events (NRC, 2012). As noted at the bottom of Table 1-6, PHA accident sequences involve one or more of the NUREG-1537 Part 1 ISG accident initiating event categories, as noted by ✓ in the corresponding table cell, but the PHA accident sequences themselves are not necessarily initiated by the ISG accident initiating event. Table 1-6 shows how PHA accident sequences correspond with ISG accident initiating events, and demonstrates that the PHA considers the full range of accident events identified in the ISG.

Table 1-5. Radioisotope Production Facility Preliminary Hazard Analysis Accident Sequence Category Designator Definitions

PHA top-level accident sequence category[a]	Definition
S.C.	Criticality
S.F.	Fire or explosion
S.R.	Radiological
S.M.	Man-made
S.N.	Natural phenomena
S.CS.	Chemical safety

[a] The alpha category designator is followed in the PHA by a two-digit number "XX" that refers to the specific accident sequence (e.g., S.C.01, S.F.07, etc.).

PHA = preliminary hazard analysis.

Table 1-6. Crosswalk of NUREG-1537 Part 1 Interim Staff Guidance Accident Initiating Events versus Radioisotope Production Facility Preliminary Hazards Analysis Top-Level Accident Sequence Categories (2 pages)

NUREG-1537[a] Part 1 ISG accident initiating event category	PHA top-level accident sequence category[b]					
	S.C. (criticality)	S.F. (fire)	S.R. (radiological)	S.M. (man-made)	S.N. (natural phenomena)	S.CS. (chemical safety)
Criticality accident	✓	✓			✓	
Loss of electrical power			✓		✓	
External events (meteorological, seismic, fire, flood)	✓	✓		✓	✓	✓
Critical equipment malfunction	✓	✓	✓	✓		✓
Operator error	✓		✓	✓		✓
Facility fire (explosion is included in this category)		✓	✓			
Any other event potentially related to unique facility operations	✓		✓	✓		

[a] NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, Part 1, U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C., February 1996.

[b] PHA accident sequences involve one or more of the NUREG-1537 Part 1 ISG accident initiating event categories, as noted by an ✓ in the corresponding table cell, but the PHA sequences themselves are not necessarily initiated by the ISG accident initiating event.

ISG = Interim Staff Guidance. PHA = preliminary hazard analysis.

Table 1-7 provides a crosswalk that identifies the applicability of RPF PHA top-level accident sequence categories to the primary process nodes. The information in this table is referenceable to Table 1-6 and ultimately shows the relationship between the PHA process nodes and the NUREG-1537 Part 1 ISG accident initiating event categories via the PHA top-level accident scenario categories.

All process system nodes were analyzed, as described in Section 1.2.3.2.2, with special emphasis on criticality, radiological, and chemical safety hazards. Fire safety issues are addressed in every node and addressed generally in Node 8.0.0. Fire safety issues include the explosive hazard associated with hydrogen gas generation via radiolytic decomposition of water in process solutions and due to certain chemical reactions encountered during dissolution processes. Most hot cell processing areas contain very few combustible materials, both transient and fixed.

The RPF PHA identified adverse events described in NWMI-2015-SAFETY-002, Sections 4.3.1.1 through 4.3.1.7. Adverse events are identified as:

- Standard industrial events that do not involve licensed material
- Acceptable accident sequences that satisfy performance criteria by being low consequence and/or low frequency
- Unacceptable accident sequences that require further evaluation via the QRA process

Table 1-7. Crosswalk of Radioisotope Production Facility Preliminary Hazards Analysis Process Nodes and Top-Level Accident Sequence Categories

Primary process node	PHA top-level accident sequence category					
	S.C. (criticality)	S.F. (fire)	S.R. (radiological)	S.M. (man-made)	S.N. (natural phenomena)	S.CS. (chemical safety)
Target fabrication (Node 1.0.0)	✓	✓	✓			
Target dissolution (Node 2.0.0)	✓	✓	✓			
Mo recovery and purification (Node 3.0.0)	✓	✓	✓			
U recovery and recycle (Node 4.0.0)	✓	✓	✓			
Waste handling system (Node 5.0.0)	✓	✓	✓			
Target receipt and disassembly (Node 6.0.0)	✓		✓			
Ventilation system (Node 7.0.0)	✓	✓	✓			
Natural phenomena, man-made external events, and other facility operations (Node 8.0.0)	✓	✓	✓	✓	✓	✓

Note: The ✓ in a table cell indicates that the accident sequence category applies to the process node. If it does not, the cell is blank.

Mo = molybdenum.
PHA = preliminary hazards analysis.
U = uranium.

An accident sequence number is assigned to each accident initiator that results in the same, or similar, bounding accident sequence results and consequences. The same accident sequence designator can appear in multiple nodes. (Table 1-5 provides definitions of accident sequence category designators.)

1.2.3.4 Characterization of High and Intermediate Consequence Accident Sequences

A total of 75 accident sequences identified for further evaluation by the PHA were analyzed for the Construction Permit Application. The accidents are analyzed in nine separate QRAs, including:

- NWMI-2015-SAFETY-003, *Quantitative Risk Analysis of Chemical Safety Process Upsets*
- NWMI-2015-SAFETY-004, *Quantitative Risk Analysis of Process Upsets Associated with Passive Engineering Controls Leading to Accident Criticality Accident Sequences*
- NWMI-2015-SAFETY-005, *Quantitative Risk Analysis of Criticality Accident Sequences that Involve Uranium Entering a System Not Intended for Uranium Service*
- NWMI-2015-SAFETY-006, *Quantitative Risk Analysis of Criticality Accident Sequences that Involve High Uranium Content in Side Waste Streams*
- NWMI-2015-SAFETY-007, *Quantitative Risk Analysis of Facility Fires and Explosions Leading to Uncontrolled Release of Fissile Material, High and Low Dose Radionuclides*

- NWMI-2015-SAFETY-008, *Quantitative Risk Analysis of Radiological Accident Sequences in the Confinement Boundaries (Including Ventilation Systems) for the NWMI Radioisotope Production Facility*
- NWMI-2015-SAFETY-009, *Quantitative Risk Analysis of Administratively Controlled Enrichment, Mass, Container Volume, and Interaction Limit Process Upsets leading to Accidental Criticality Accident Sequences*
- NWMI-2015-SAFETY-010, *Quantitative Risk Analysis of Receipt and Shipping Events*
- NWMI-2015-SAFETY-011, *Evaluation of Natural Phenomenon and Man-made Events on Safety Features and IROFS*

A summary of the accidents analyzed is provided in in Chapter 13.0 and includes each accident sequence number, a descriptive title of the accident, and IROFS identified (if needed) to prevent or mitigate the consequences of the accident sequence. The preliminary IROFS selected to meet the performance criteria of 10 CFR 70.61, "Performance Requirements," are provided in Chapter 13.0 and NWMI-2015-SAFETY-002.

IROFS are identified using the following designator naming convention:

- RS-XX Radiation safety IROFS
- CS-XX Criticality safety IROFS
- FS-XX Facility safety IROFS (protecting from external events)
- FP-XX Fire protection IROFS
- CE-XX Chemical exposure IROFS

1.2.3.5 Radioisotope Production Facility Items Relied on For Safety

Table 1-8 provides a summary of the IROFSs identified by the accident analyses in Chapter 13.0, and a crosswalk to where the IROFSs are described in this Construction Permit Application. Chapter 13.0 also provides the associated detailed descriptions. Table 1-8 also identifies whether the IROFS are considered engineered safety feature (ESF) or administrative controls. Additional IROFS may be identified (or the current IROFS modified) during the RPF final design and development of the Operating License Application.

Table 1-8. Summary of Items Relied on for Safety Identified by Accident Analyses (3 pages)

IROFS designator	Descriptor	ESF	AC	Construction Permit Application crosswalk (primary references)
RS-01	Hot cell liquid confinement boundary	✓		Chapter 6.0, Sections 6.2.1.1 – 6.2.1.6 Chapter 13.0, Section 13.2.2.8
RS-02	Reserved[a]			
RS-03	Hot cell secondary confinement boundary	✓		Chapter 6.0, Sections 6.2.1.1 – 6.2.1.6 Chapter 13.0, Sections 13.2.2.8, 13.2.3.8
RS-04	Hot cell shielding boundary	✓		Chapter 6.0, Sections 6.2.1.1 – 6.2.1.6 Chapter 13.0, Sections 13.2.2.8, 13.2.4.8
RS-05	Reserved[a]			
RS-06	Reserved[a]			

Table 1-8. Summary of Items Relied on for Safety Identified by Accident Analyses (3 pages)

IROFS designator	Descriptor	ESF	AC	Construction Permit Application crosswalk (primary references)
RS-07	Reserved[a]			
RS-08	Sample and analysis of low-dose waste tank dose rate prior to transfer outside the hot cell shielded boundary		✓	Chapter 13.0, Section 13.2.7.1
RS-09	Primary offgas relief system	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.3.8
RS-10	Active radiation monitoring and isolation of low-dose waste transfer	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.1
RS-11	Reserved[a]			
RS-12	Cask containment sampling prior to closure lid removal		✓	Chapter 13.0, Section 13.2.7.1
RS-13	Cask local ventilation during closure lid removal and docking preparations	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.1
RS-14	Reserved[a]			
RS-15	Cask docking port enabling sensor	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.1
CS-01	Reserved[a]			
CS-02	Mass and batch handling limits for uranium metal, uranium oxides, targets, and laboratory sample outside process systems		✓	Chapter 13.0, Section 13.2.7.2
CS-03	Interaction control spacing provided by administrative control		✓	Chapter 13.0, Section 13.2.7.2
CS-04	Interaction control spacing provided by passively designed fixtures and workstation placement	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-05	Container batch volume limit		✓	Chapter 13.0, Section 13.2.7.2
CS-06	Pencil tank, vessel, or piping safe geometry confinement using the diameter of tanks, vessels, or piping	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-07	Pencil tank and vessel spacing control using fixed interaction spacing of individual tanks or vessels	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.2.8
CS-08	Floor and sump geometry control of slab depth, sump diameter or depth for floor spill containment berms	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.2.8
CS-09	Double-wall piping	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.2.8
CS-10	Closed safe geometry heating or cooling loop with monitoring and alarm	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-11	Simple overflow to normally empty safe geometry tank with level alarm	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2

Table 1-8. Summary of Items Relied on for Safety Identified by Accident Analyses (3 pages)

IROFS designator	Descriptor	ESF	AC	Construction Permit Application crosswalk (primary references)
CS-12	Condensing pot or seal pot in ventilation vent line	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-13	Simple overflow to normally empty safe geometry floor with level alarm in the hot cell containment boundary	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-14	Active discharge monitoring and isolation	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-15	Independent active discharge monitoring and isolation	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-16	Sampling and analysis of uranium mass or concentration prior to discharge or disposal		✓	Chapter 13.0, Section 13.2.7.2
CS-17	Independent sampling/analysis of uranium concentration prior to discharge or disposal		✓	Chapter 13.0, Section 13.2.7.2
CS-18	Backflow prevention device	✓		Chapter 6.0, Sections 6.2.1.7 and 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-19	Safe-geometry day tanks	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-20	Evaporator or concentrator condensate monitoring	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
CS-21	Visual inspection of accessible surfaces for foreign debris		✓	Chapter 13.0, Section 13.2.7.2
CS-22	Gram estimator survey of accessible surfaces for gamma activity		✓	Chapter 13.0, Section 13.2.7.2
CS-23	Nondestructive assay of items with inaccessible surfaces		✓	Chapter 13.0, Section 13.2.7.2
CS-24	Independent nondestructive assay of items with inaccessible surfaces		✓	Chapter 13.0, Section 13.2.7.2
CS-25	Target housing weighing prior to disposal		✓	Chapter 13.0, Section 13.2.7.2
CS-26	Processing component safe volume confinement	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.7.2
CS-27	Closed heating or cooling loop with monitoring and alarm	✓		Chapter 6.0, Section 6.3.1.2 Chapter 13.0, Section 13.2.4.8
FS-01	Enhanced lift procedure (duplicate designator)		✓	Chapter 13.0, Section 13.2.2.8, 13.2.7.1
FS-02	Overhead cranes		✓	Chapter 13.0, Section 13.2.7.3
FS-03	Process vessel emergency purge system	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.3
FS-04	Irradiated target cask lifting fixture	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.6.5
FS-05	Exhaust stack height	✓		Chapter 6.0, Section 6.2.1.7 Chapter 13.0, Section 13.2.7.3

[a] Reserved – IROFS designator currently unassigned.

AC = administrative control.
ESF = engineered safety feature.
IROFS = items relied on for safety.

1.3 GENERAL DESCRIPTION OF THE FACILITY

1.3.1 Location and Characteristics of the Site

Site location – The proposed 3.0 hectare (ha) (7.4-acre) site of the RPF is situated in Boone County, within the University of Missouri (MU) Discovery Ridge Research Park (Discovery Ridge) in Columbia, Missouri, north of Discovery Ridge Drive. The site is situated in central Missouri approximately 201 kilometers (km) (125 miles [mi]) east of Kansas City and 201 km (125 mi) west of St. Louis. The site is 7.2 km (4.5 mi) south of United States (U.S.) Interstate Highway 70 just to the north of U.S. Highway 63. The Missouri River lies 15.3 km (9.5 mi) to the west of the site. Figure 1-7 (on page 1-20) provides the 8 km (5-mi) radius from the center of the facility and shows highways, rivers, and other local bodies of water.

Figure 1-4 shows the layout of the NWMI site, including the RPF.

Figure 1-4. Radioisotope Production Facility Site Layout

Figure 1-5 provides a building model view of the RPF. The building will be divided into material accountability areas that are regulated by 10 CFR 50 and 10 CFR 70, as shown in Figure 1-6. The target fabrication area will be governed by 10 CFR 70, and the remainder of the production areas (irradiated target receipt bay, hot cells, waste management, laboratory, and utilities) will be governed by 10 CFR 50. The administration and support area will provide the main personnel access to the RPF and include personnel support areas such as access control, change rooms, and office spaces.

The first level (excluding the tank pit area) and second levels of the RPF are currently estimated to contain approximately 4,282 square meters (m^2) (46,088 square feet [ft^2]) and 1,569 m^2 (16,884 ft^2) of floor space, respectively. The processing hot cell and waste management temporary storage floor space area is approximately 544 m^2 (5,857 ft^2). The maximum height of the building is 19.8 meter (m) (65 ft), with a maximum stack height of 22.9 m (75 ft). The depth of the processing hot cell below-grade, without footers, is 4.6 m (15 ft) of enclosure height in rooms containing process equipment. The site is enclosed by perimeter fencing to satisfy safeguards and security and other regulatory requirements.

Figure 1-6 is first level general layout of the RPF and presents the seven major areas, including the target fabrication area, irradiated target receipt area, tank hot cell area, laboratory area, waste management area, utility area, and administrative support area

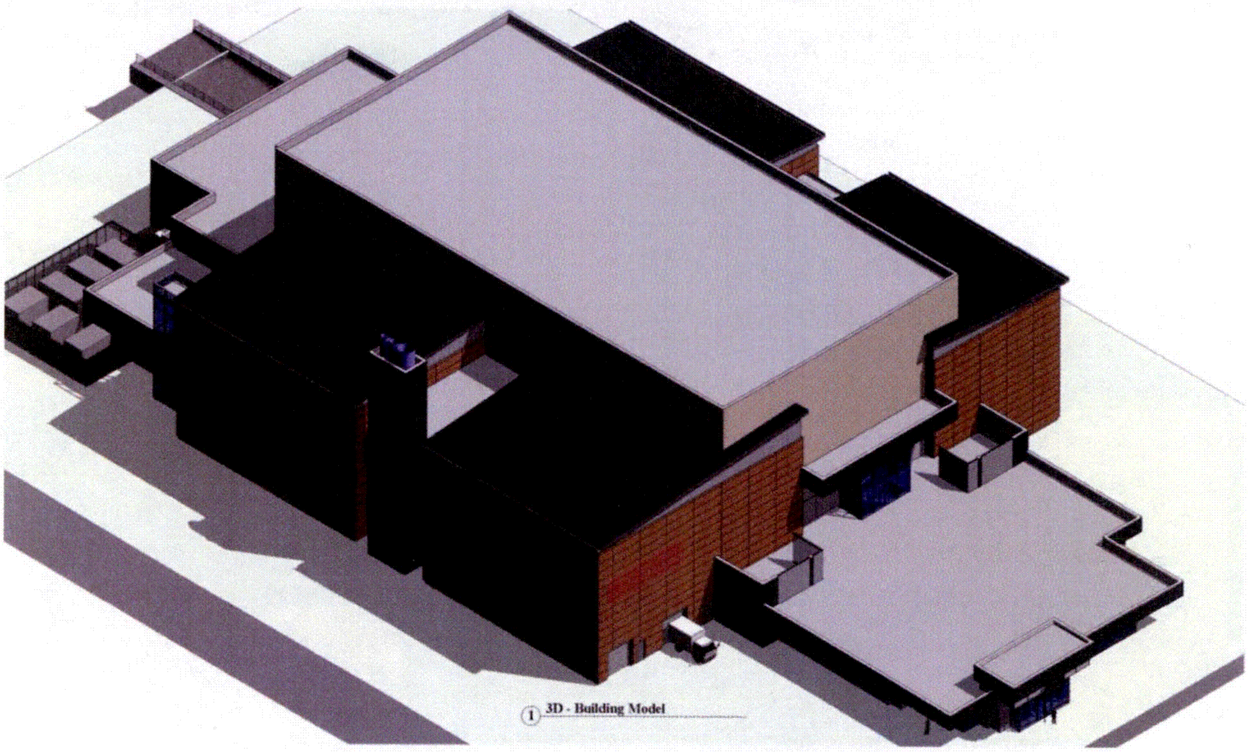

Figure 1-5. Building Model of the Radioisotope Production Facility

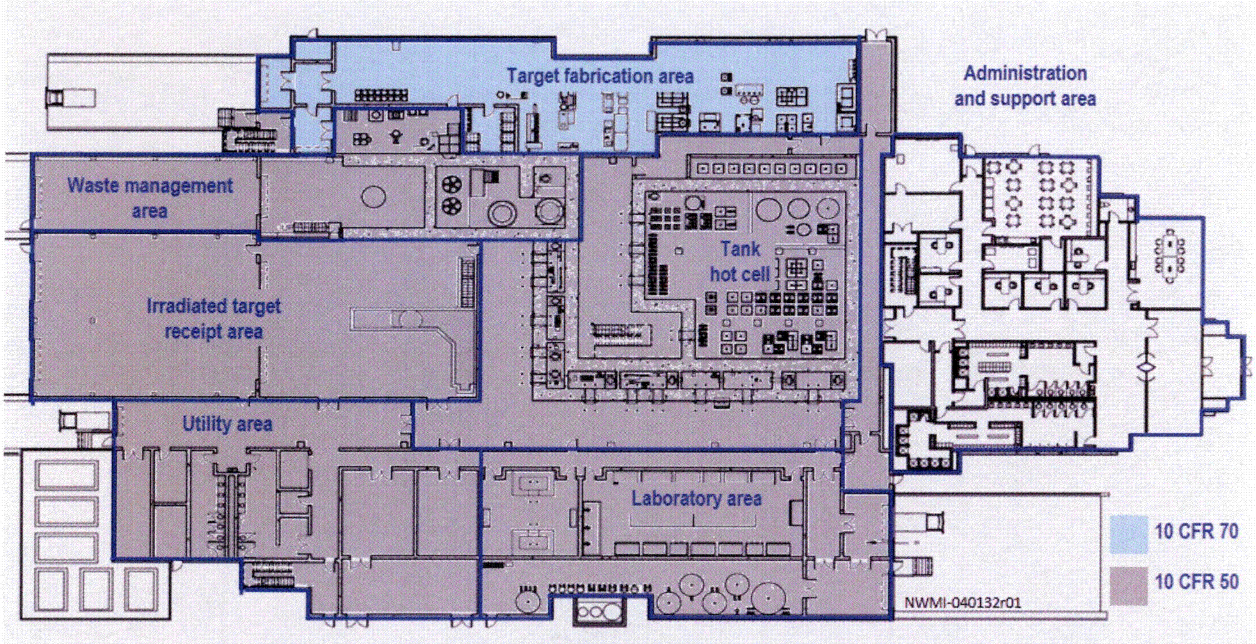

Figure 1-6. General Layout of the Radioisotope Production Facility

Additional detailed facility information is provided in Chapter 4.0.

Population distribution – Estimates and projections of resident and transient populations around the proposed project site are divided into five distance bands—concentric circles at 0-1 km (0-0.6 mi), 1-2 km (0.6-1.2 mi), 2-4 km (1.2-2.5 mi), 4-6 km (2.5-3.7 mi), and 6-8 km (3.7-5.0 mi) from the center point of the RPF—and 16 directional sectors (with each direction sector centered on one of the 16 compass points). For each segment formed by the distance bands and directional sectors, the resident population was estimated using U.S. Census Bureau 2010 census data (USCB, 2010). The extrapolated population data for 2014 is also shown on Figure 1-7.

The permanent residences nearest to the proposed RPF site were identified through an examination of aerial photographs and geographic information system data files using ArcGIS 10.1 (ESRI, 2011). There are two permanent residences located approximately 0.48 km (0.3 mi) from the center point, one to the south and the other to the northeast. These two houses are the closest residences to the center point of the safety-related area.

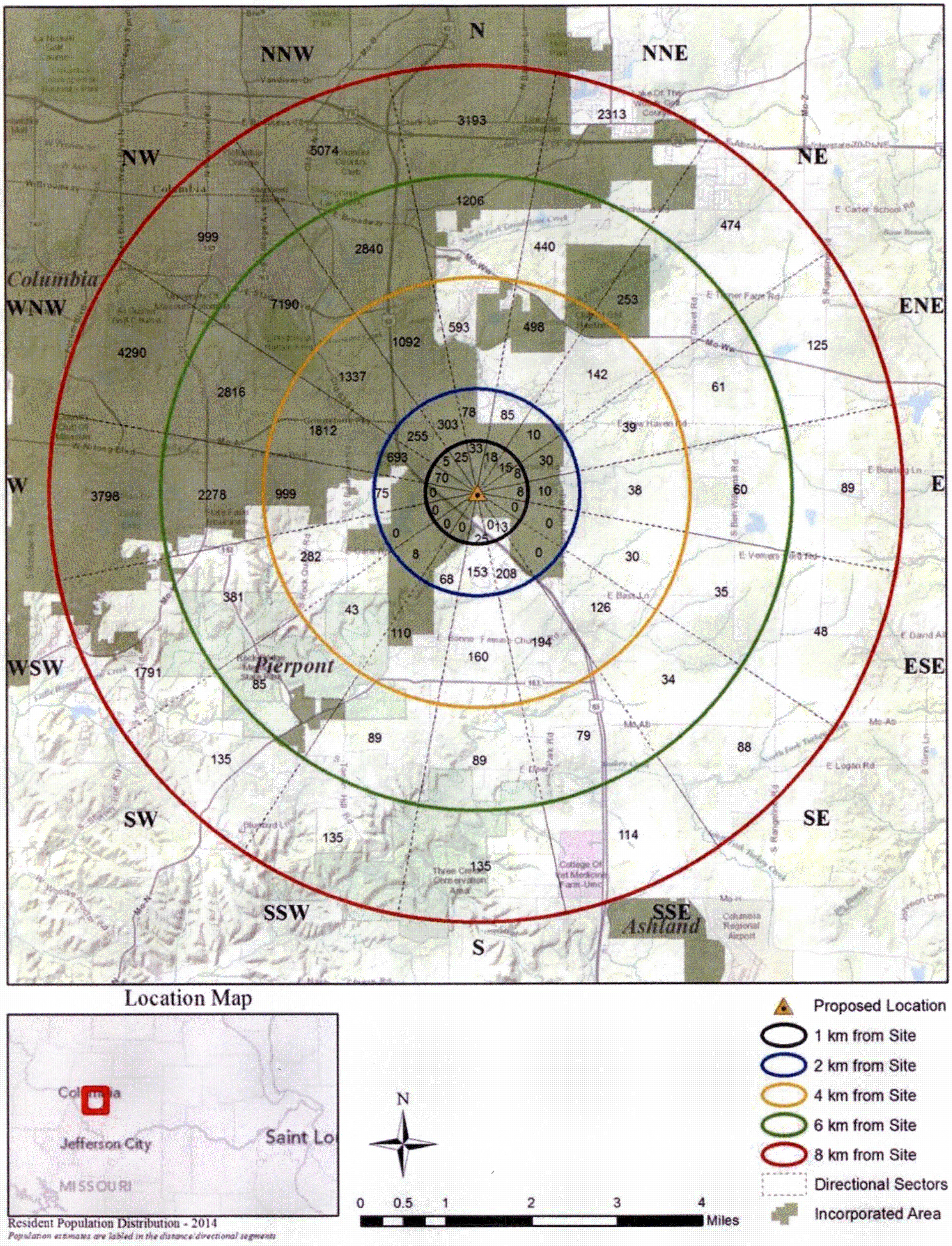

Figure 1-7. 8 km (5-mi) Radius from the Center of the Facility and Resident Population Distribution – 2014

Nearby industrial, transportation, and military facilities – An investigation of industrial, transportation and military facilities within 8 km (5 mi) of the proposed site was performed. The U.S. Environmental Protection Agency's Envirofacts Database was initially used to identify potential facilities within 8 km (5 mi). The Missouri Emergency Management Agency supplied Tier II chemical inventory reports for all of the facilities in Boone County. The following facilities were identified for further evaluation.

Industrial Facilities

- Analytical Bio Chemistry Laboratories, Inc.
- Radil Discovery Ridge
- Gates Power Transmissions Materials Center
- MU South Farm
- MU Woman's and Children's Hospital
- Ryder Transportation
- Truegreen
- Schwan's Home Service
- Petro Mart #44

Pipelines

- South Star Central Gas Pipeline
- Magellan Pipeline Company Non-HLV product Hazardous Pipeline
- Ameren Natural Gas Transmission Pipeline

Fuel Storage Facilities

- Magellan Pipeline Company Breakout Tank

Mining and Quarrying Operations

None

Transportation Routes/Facilities

- Air
  - State University Hospitals and Clinics Heliport
  - University of Missouri Heliport
  - Boone Hospital Center Heliport
- Land
  - U.S. Highway 63
  - U.S. Interstate 70
  - State Route 163
  - State Route 740
  - State Route 763
- Waterways – None
- Railroads – COLT Transload

Military Bases

- None

There are three airports and three helicopter ports located within 16 km (10 mi) of the proposed RPF site. The nearest airport is the Columbia Regional Airport approximately 10.5 km (6.5 mi) south of the RPF site. The Columbia Regional Airport is used by commercial and privately owned aircraft. The airport is situated on approximately 0.532 ha (1,314 acre) and is owned and operated by the City of Columbia. This airport is the only public use airport located in Boone County for which records are kept.

Based on NUREG-1537, sites located between 8 km (5 mi) and 16 km (10 mi) from an existing or projected commercial or military airport with more than approximately 200 d^2 (where d is the distance in kilometers from the airport to the RPF site) commercial or military aircraft movements per year. The number of aircraft movements per year for the three heliports are not recorded. However, if it is assumed that on average these heliports support five operations or less a day (1,825/year), they are under the 200 d^2 (7,200) limit.

For the Columbia Regional Airport:

$$200\ d^2 = 200(10.4)^2 = 21,632$$

Based on this requirement, the Columbia Regional Airport does not need to be further evaluated.

Meteorology – The RPF location places it in the Humid Continental-Warm Summer climatic zone. This type of climate has a characteristic long, warm summer with moderate relative humidity. The winters are cool to cold and mark a period of lower precipitation than during the remainder of the year. Because of its geographical location far inland, the region is subject to significant seasonal and daily temperature variations. Air masses moving over the state during the year include cold continental polar air from Canada, warm and humid maritime tropical air from the Gulf of Mexico and the Caribbean Sea, and dry eastward flowing air masses from the Rocky Mountains located to the west. Prolonged periods of extreme hot or cold temperatures are unusual (MU, 2006).

Spring, summer, and early fall precipitation occurs in the form of rain and thunderstorms. Severe thunderstorms typically occur during the period from mid- to late-spring through early summer. Hail may be expected as a product of these storms. Wind speeds of up to 97 km/hr (60 mi/hr) or more may be experienced once or twice a year during a severe thunderstorm (MU, 2006).

NUREG-1537, Part 1, Section 2.3.1, states that the snow load should be based on the 100-year return period snow accumulation. For MU facilities, the 2012 International Building Code (IBC) (IBC, 2012) has been levied as the required building code. The ground snow load is 20 pounds (lb)/ft^2. To modify the snow load to be based on a 100-year return period, an importance factor of 1.2 is applied to the load determined using the nominal snow load (ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, Section C7.3.3). The nominal ice thickness is 2.54 centimeters (cm) (1 inch [in.]) concurrent with a 64.4 km/hr (40-mi/hr), 3-second (sec) wind gust. To modify the ice load based on a 100-year return period, an importance factor of 1.25 is applied to the load determined using the nominal ice load (ASCE 7, Section C10.4.4).

Wind – Extreme wind speeds are uncommon in central Missouri. Wind that does occur is usually caused by pressure gradients and temperature contrasts present in the mid-latitude cyclones that pass through the state. These cyclones may spawn storms that produce high winds from gust fronts, microbursts, and tornadoes. Non-storm-related extreme winds are rare. Occasionally, cold high-pressure air filling in behind a front will cause high wind, especially in the winter when temperature contrasts are large.

Figure 1-8 shows the wind patterns recorded at the Remote Automatic Weather Station in Columbia. Wind roses show that the prevailing surface wind direction is from the south, with a total average speed of 14.16 km/hr (8.8 mi/hr). The average frequency of higher speed winds falls into the 24 to 40 km/hr (15 to 25-mi/hr) range.

NUREG-1537, Part 1, Section 2.3.1, states that the wind load should be based on the 100-year return period wind speed. For MU facilities, IBC (2012) has been levied as the required building code. The basic wind speed for Category III and IV facilities is 193.1 km/hr (120 mi/hr). An evaluation of the effective return period for the basic wind speeds for Category III and IV facilities determined that the effective return period is 1,700 years (3 percent in 50 years, or 5.7 percent in 100 years) (ASCE 7, Section C26.5.1). Note that an event with a 100-year return period has a 63 percent chance of occurring at least once in a 100-year period.

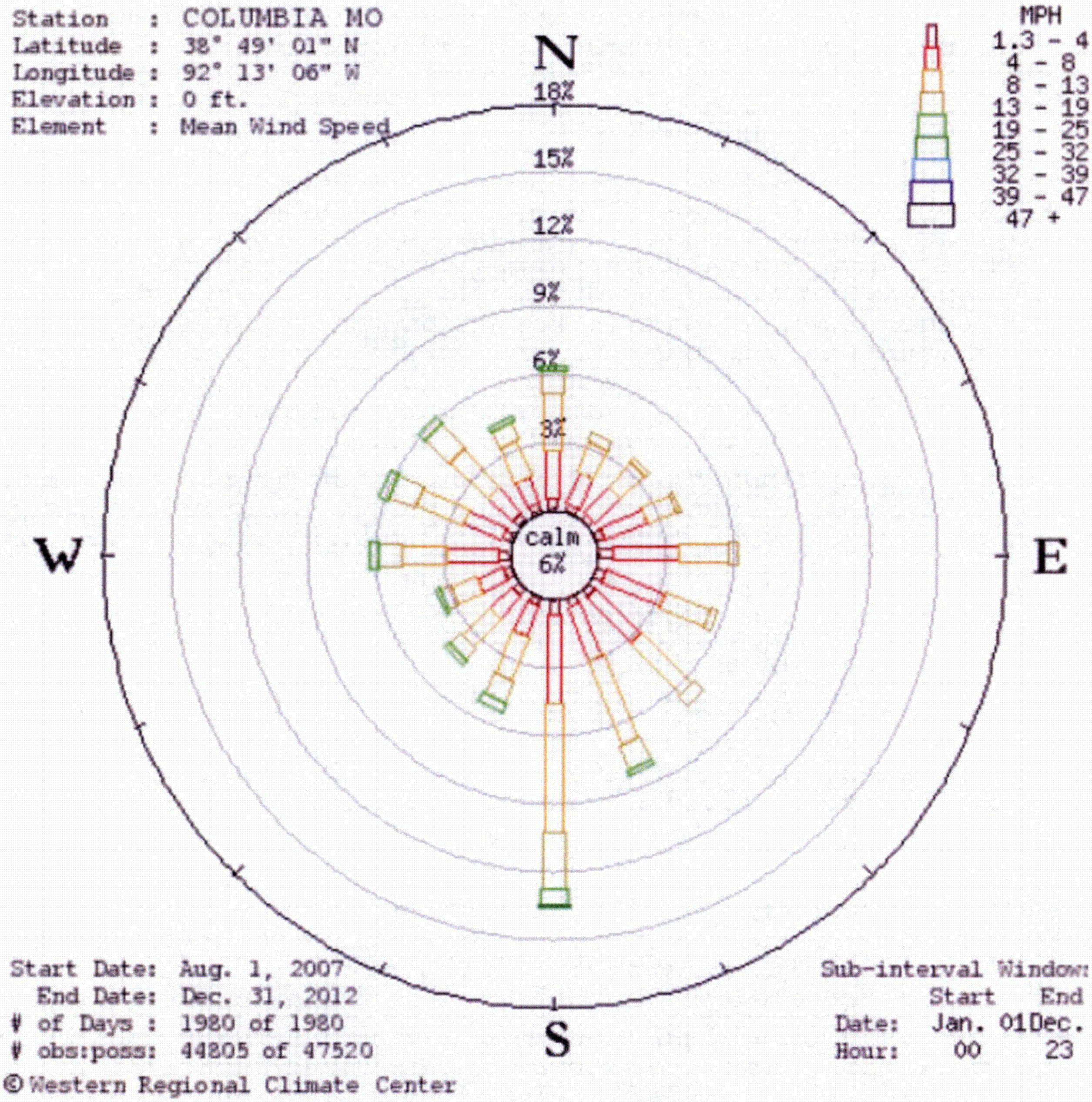

Figure 1-8. Wind Rose from Automatic Weather Station, Columbia, Missouri, 2007-2012 (Western Regional Climate Center)

Tornado – The heartland of the country has the distinction of also being known as "tornado alley," a non-meteorological term that references the area where 90 percent of tornadoes have occurred as a result of the mixing of cold, dry air from Canada and the Rocky Mountains, with warm, moist air from the Gulf of Mexico and hot, dry air from the Sonoran Desert. This area typically exhibits atmospheric instability, heavy precipitation, and many intense thunderstorms.

Tornados are extreme wind speed events that are classified according to the Enhanced Fujita Tornado Intensity Scale (EF scale). The scale matches wind speeds to the severity of damaged caused by a tornado. The process involves determining the degree of damage according to a predefined damage scale of 28 indicators. The observed damage is associated with estimated wind speeds during the storm, and an EF scale number is assigned. Measuring tornadoes from EF-1 to EF-5, the scale uses more specific structural damage guidelines than the original Fujita scale (F scale), which was established in 1971. Table 1-9 shows the F and EF scales.

Table 1-9. Fujita Scale and Enhanced Fujita Scales Used to Determine Tornado Intensity

F number	F scale				EF number	EF scale	
	Fastest 1/4-mi		3-sec gust			3-sec gust	
	(km/hr)	(mi/hr)	(km/hr)	(mi/hr)		(km/hr)	(mi/hr)
0	64 -116	40–72	72-126	45–78	0	105-137	65-85
1	117 – 180	73–112	127-188	79–117	1	138-177	86–110
2	182- 253	113–157	189-259	118–161	2	178-217	111–135
3	254- 333	158–207	260-336	162–209	3	218-265	136–165
4	334- 418	208–260	337-420	210–261	4	266-322	166–200
5	419 – 512	261–318	421-510	262–317	5	Over 322	Over 200

EF scale = enhanced Fujita tornado intensity scale.
F scale = Fujita tornado intensity scale.

Flooding – The proposed RPF site is located outside of the 500-year flood plain. The nearest Federal Emergency Management Agency (FEMA) flood zone A is located along Gans Creek, which is southeast of the site. The elevation of this zone is 242 m (795 ft). The RPF site elevation is 248 m (815 ft). There are no water impoundments or dams upstream of the RPF site on Gans Creek that could affect the facility.

There are also two ponds located near the RPF site within Discovery Ridge. These ponds include the 7.9 ha (19.6-acre) common grounds stormwater management pond located to the northwest of the site. The top of the dam for this pond is 246 m (807 ft), with the spillway at 245 m (804 ft). The second pond, currently approximately 4 ha (10 acres), is located to the northeast of the site. The elevation of the dam is approximately 244 m (801 ft). Failure of either of these two ponds would not likely affect the RPF because the elevation of the dams is lower than the elevation of the RPF.

Seismic – The most significant seismological feature in Missouri is the New Madrid Seismic Zone (NMSZ), located in the southeastern corner of the state and extending into parts of the contiguous states of Arkansas, Tennessee, Kentucky, and Illinois. The NMSZ is the most seismically active region in the U.S. east of the Rocky Mountains and is located approximately 483 km (300 mi) southeast of the proposed RPF site. During the winter of 1811–1812, the NMSZ was the location of some of the highest intensity seismic events ever noted in U.S. history. Hundreds of aftershocks, some severely damaging, continued for years.

Records show that since 1900, moderately damaging earthquakes have struck the NMSZ every few decades. Prehistoric earthquakes similar in size to those of 1811–1812 occurred in the middle 1400s and around 900 A.D. Strong, damaging earthquakes struck the southwestern end of the NMSZ near Marked Tree, Arkansas, in 1843 (magnitude 6.0), and the northeastern end near Charleston, Missouri, in 1895 (magnitude 6.6) (USGS, 2011a).

The NMSZ is made up of reactivated faults that formed when what is now North America began to split or rift apart approximately 500 million years ago. The resulting rift system died out before an ocean basin was formed, but a deep zone of weakness was created, referred to as the Reelfoot rift (USGS, 2011b). This fault system extends 241 km (150 mi) southward from Cairo, Illinois, through New Madrid and Caruthersville, Missouri, down through Blytheville, Arkansas, to Marked Tree, Arkansas. The Reelfoot rift dips into Kentucky near Fulton and into Tennessee near Reelfoot Lake, extending southeast into Dyersburg, Tennessee. The rift then crosses five state lines and crosses the Mississippi River in at least three places. The fault system is buried beneath as much as 8 km (5 mi) of sediment for much of the fault length and typically cannot be seen at the surface (USGS, 2011b).

Four of the largest faults are recognized as alignments of abundant small earthquakes, and movements along two of these faults dammed rivers and created lakes during the earthquakes of 1811–1812. A few more deeply buried faults were detected during oil and gas exploration, and a few small faults are known from geologic mapping (USGS, 2011b).

The remainder of the state, including the proposed RPF site located in central Missouri, is typical of the stable midcontinent U.S.

Earthquakes occur on faults within bedrock, usually several miles deep. According to the U.S. Geological Survey (USGS), earthquakes in the central and eastern U.S. typically are felt over a much broader region than in the western U.S. East of the Rocky Mountains, an earthquake can be felt over an area ten times larger than a similar magnitude earthquake on the west coast.

According to information from Missouri's State Emergency Management Agency Earthquake Program, some of the earthquakes measure at least 7.6 in magnitude and five of them measured 8.0 or greater. The 1811–1812 series changed the course of the Missouri River, and some shocks were felt as far away as Washington D.C. and Boston (MMRPC, 2010). The NMSZ has experienced numerous earthquakes since the 1811–1812 series, and at least 35 aftershocks of intensity V or greater that have been recorded in the state of Missouri since 1811. Numerous earthquakes originating outside of the state's boundaries have also affected Missouri.

In 2002, the USGS released the following projected hazards for Boone County, if an earthquake occurred along the NMSZ in the following 50 years (MMRPC, 2010):

- 25 to 40 percent chance of a magnitude 6.0 and greater earthquake
- 7 to 10 percent chance of a magnitude 7.5 to 8.0 earthquake

According to the USGS, Boone County is one of the 47 counties in Missouri that would be severely impacted by a 7.6 magnitude earthquake with an epicenter on or near the NMSZ.

According to the *Boone County Hazard Mitigation Plan for 2010* (MMRPC, 2010), the Missouri State Emergency Management Agency has made projections of the highest earthquake intensities that would be experienced throughout the state of Missouri if various magnitude earthquakes occur along the NMSZ as measured by the Modified Mercalli Intensity (MMI) scale. The pertinent information for Boone County is summarized in Table 1-10.

Table 1-10. Projected Earthquake Hazards for Boone County

Magnitude at NMSZ	Probability of occurrence (2002–2052)	Intensity in Boone County (MMI)	Expected damage
6.7	25–40%	VI, strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
7.6	7–10%	VII, very strong	Difficult to stand; significant damage to poorly or badly designed buildings, adobe houses, old walls, spires, and other; damage would be slight to moderate in well-built buildings; numerous broken windows; weak chimneys break at roof lines; cornices from towers and high buildings fall; loose bricks fall from buildings; heavy furniture is overturned and damaged; and some sand and gravel stream banks cave in.

Source: MMRPC, 2010, *Boone County Hazard Mitigation Plan*, www.mmrpc.org/the-region/boone-county, Mid-Missouri Regional Planning Commission, State of Missouri Emergency Management Agency, Ashland, Missouri, July 15, 2010.

MMI = Modified Mercalli Intensity.
NMSZ = New Madrid Seismic Zone.

Additional detailed site information is provided in Chapter 2.0, "Site Characteristics."

1.3.2 Principal Design Criteria, Operating Characteristics, and Safety Systems

NWMI's RPF design is based on applicable standards, guides, codes, and criteria and provides reasonable assurance that the RPF SSCs, including electromechanical systems:

- Are built and will function as designed and required by the analyses in Chapter 13.0, "Accident Analysis"
- Ensure acceptable protection of the public health and safety and environment from radiological risks (e.g., radioactive materials, exposure) resulting from operations
- Protect against potential hydrological (water) damage
- Protect against seismic damage
- Provide surveillance activities and technical specifications required to respond to or mitigate consequences of seismic damage
- Have technical specifications developed to ensure that safety-related functions of electromechanical systems and components will be operable and protect the health and safety of workers, the public, and environment

Defense-in-depth is a design philosophy, applied from the outset and through completion of the design that is based on providing successive levels of protection such that health and safety are not wholly dependent on any single element of the design, construction, maintenance, or operation of the facility. The net effect of incorporating defense-in-depth practices is a conservatively designed facility and systems that exhibit higher tolerances to failures and external challenges. The risk insights obtained through performance of accident analysis can then be used to supplement the final design by focusing attention on the prevention and mitigation of the higher risk potential accidents.

The design basis and facility SSCs for the RPF are based on defense-in-depth practices. Defense-in-depth is a design philosophy, applied from the beginning and through completion of the design, which is based on providing successive levels of protection such that health and safety are not wholly dependent on any single element of the design, construction, maintenance, or operation of the facility. The net effect of incorporating defense-in-depth practices is a conservatively designed facility and systems that exhibit a higher tolerance to failures and external challenges. The risk insights obtained through the performance of accident analysis can then be used to supplement the final design by focusing attention on the prevention and mitigation of the higher risk potential accidents.

1.3.2.1 Principal Design Criteria

NWMI addresses the following baseline design criteria for the RPF.

- **Quality standards and records** – Design is being developed and implemented in accordance with management measures to provide adequate assurance that IROFS will be available and reliable to perform the intended functions when needed. Appropriate records of these items must be maintained by or under the control of the licensee throughout the life of the facility.
- **Natural phenomena hazards** – Design will provide for adequate protection against natural phenomena with consideration of the most severe documented historical events for the site.
- **Fire protection** – Design will provide for adequate protection against fires and explosions.
- **Environmental and dynamic effects** – Design will provide for adequate protection from environmental conditions and dynamic effects associated with normal operations, maintenance, testing, and postulated accidents that could lead to loss of safety functions.
- **Chemical protection** – Design will provide for adequate protection against chemical risks produced from licensed material, facility conditions that affect the safety of licensed material, and hazardous chemicals produced from licensed material.
- **Emergency capability** – Design will provide for emergency capability to maintain control of:
  - Material and hazardous chemicals produced from licensed material
  - Evacuation of on-site personnel
  - On-site emergency facilities and services that facilitate the use of available off-site services
- **Utility services** – Design will provide for continued operation of essential utility services.
- **Inspection, testing, and maintenance** – Design of IROFS will provide for adequate inspection, testing, and maintenance to ensure availability and reliability to perform intended function when needed.
- **Criticality control** – Design will provide for criticality control, including adherence to the double-contingency principle.
- **Instrumentation and controls** – Design will provide for inclusion of instrumentation and control (I&C) systems to monitor and control the behavior of IROFS.
- Facility and system design and facility layout will be based on defense-in-depth practices. Design will incorporate, to the extent practicable:
  - Preference for the selection of engineered controls over administrative controls to increase overall system reliability
  - Features that enhance safety by reducing challenges to IROFS

The principal design criteria for a production facility establish the necessary design, fabrication, construction, testing, and performance requirements for SSCs important to safety (i.e., those that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of workers and the public). The systems associated with the RPF are identified below, and the associated IROFS are identified in Chapter 6.0, "Engineered Safety Features," and Chapter 13.0. Requirements are derived from:

- Code of Federal Regulations
- U.S. Nuclear Regulatory Commission
- Federal regulations, guidelines, and standards
- Local government regulations and requirements
- Discovery Ridge covenants
- MU System requirements
- Other codes and standards

Table 1-11 lists the RPF systems, and identifies the RPF material accountability area and the Construction Permit Application reference chapter that provides the associated detailed system descriptions.

Table 1-11. List of System and Associated Systems and Construction Permit Application Crosswalk (2 pages)

Primary structure and associated systems	Construction Permit Application reference (primary references)
Radioisotope Production Facility (RPF – primary structure)	
10 CFR 70[a]	
Target fabrication	Chapter 4.0, Sections 4.1.3.1 and 4.4
10 CFR 50[b]	
Target receipt and disassembly	Chapter 4.0, Section 4.1.3.2, 4.3.2, and 4.3.3
Target dissolution	Chapter 4.0, Sections 4.1.3.3 and 4.3.4
Molybdenum recovery and purification	Chapter 4.0, Sections 4.1.3.4 and 4.3.5
Uranium recovery and recycle	Chapter 4.0, Sections 4.1.3.5 and 4.3.6
Waste handling	Chapter 4.0, Section 4.1.3.6; Chapter 9.0, Section 9.7.2
Criticality accident alarm	Chapter 6.0, Section 6.3.3.1; Chapter 7.0, Section 7.3.7
Radiation monitoring	Chapter 7.0, Section 7.6; Chapter 11.0, Section 11.1.4
Normal electrical power	Chapter 8.0, Section 8.1
Standby electrical power	Chapter 8.0, Section 8.2
Process vessel ventilation	Chapter 9.0, Section 9.1
Facility ventilation	Chapter 9.0, Section 9.1
Fire protection	Chapter 9.0, Section 9.3
Plant and instrument air	Chapter 9.0, Section 9.7.1
Purge gas	Chapter 9.0, Section 9.7.1
Gas supply	Chapter 9.0, Section 9.7.1
Process chilled water	Chapter 9.0, Section 9.7.1
Facility chilled water	Chapter 9.0, Section 9.7.1
Facility heated water	Chapter 9.0, Section 9.7.1
Process stream – boiler	Chapter 9.0, Section 9.7.1
Process stream – hot cell secondary loops	Chapter 9.0, Section 9.7.1
Demineralized water	Chapter 9.0, Section 9.7.1

Table 1-11. List of System and Associated Systems and Construction Permit Application Crosswalk (2 pages)

Primary structure and associated systems	Construction Permit Application reference (primary references)
Supply air	Chapter 9.0, Section 9.1.2
Chemical supply	Chapter 9.0, Section 9.7.4
Biological shield	Chapter 4.0, Section 4.2
Facility process control	Chapter 7.0, Section 7.2.3

[a] 10 CFR 70, "Domestic Licensing of Special Nuclear Material," *Code of Federal Regulations*, Office of the Federal Register, as amended.

[b] 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," *Code of Federal Regulations*, Office of the Federal Register, as amended.

Detailed design standards and codes for the RPF SSCs are listed in Chapter 3.0, "Design of Structures, Systems, and Components."

1.3.2.2 Operating Characteristics

A flow diagram of the primary process to be performed at the RPF is provided in Figure 1-9. The primary purpose of these RPF operations is to provide ^{99}Mo product in a safe, economic, and environmentally protective manner.

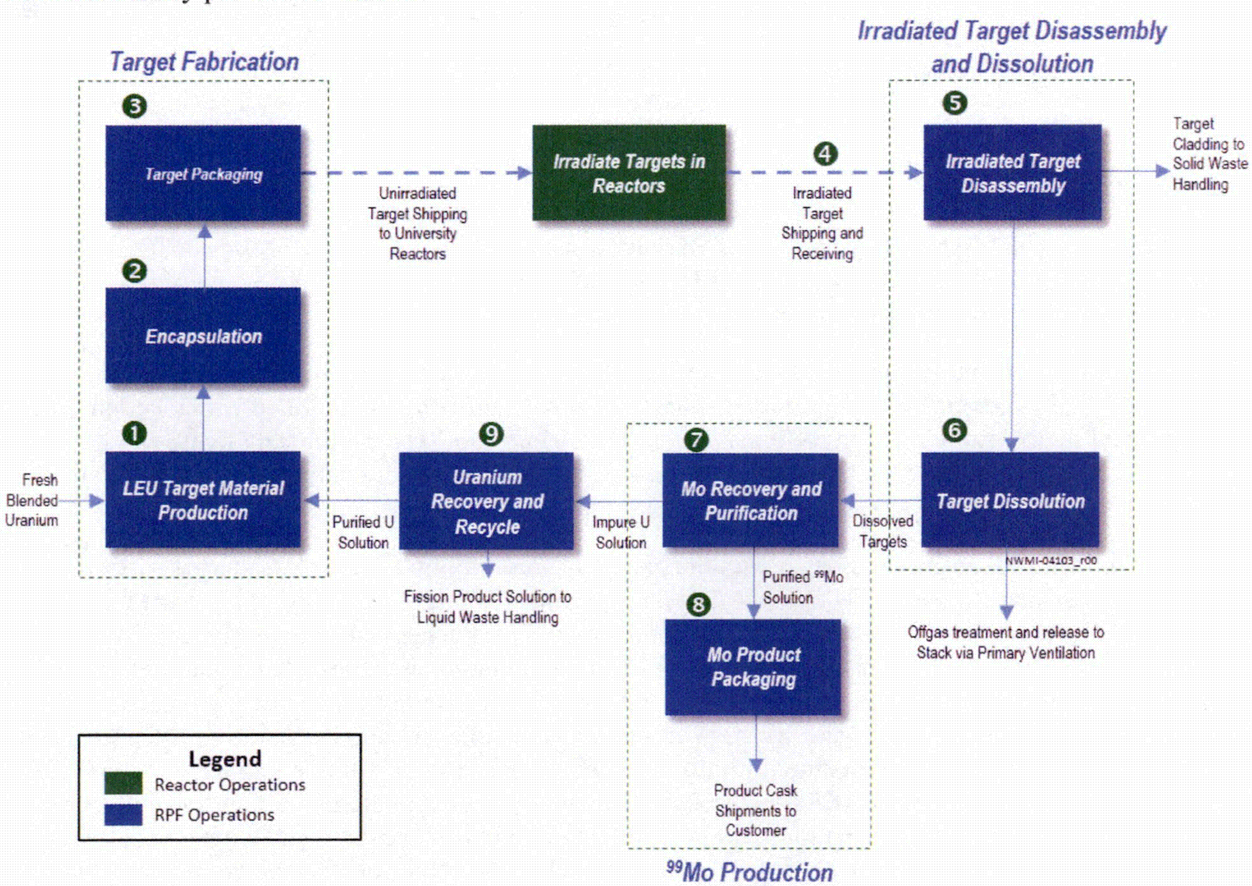

Figure 1-9. Radioisotope Production Facility Block Flow Diagram

Facility operation has the following general process steps (which correspond with Figure 1-9).

Target Fabrication

❶ LEU target material is fabricated using a combination of fresh LEU and recycled uranium.

❷ Target material is encapsulated using metal cladding to contain the LEU and fission products produced during irradiation.

❸ Fabricated targets are packaged and shipped to university reactors for irradiation.

Target Receipt, Disassembly, and Dissolution

❹ After irradiation, targets are shipped back to the RPF.

❺ Irradiated targets are disassembled and metal cladding is removed.

❻ Targets are then dissolved into a solution for processing.

Molybdenum Recovery and Purification

❼ Dissolved LEU solution is processed to recover and purify ^{99}Mo.

❽ Purified ^{99}Mo is packaged in certified shipping containers and shipped to a radiopharmaceutical distributor.

Uranium Recovery and Recycle

❾ LEU solution is treated to recover uranium and remove trace contaminants and is recycled back to Step 1 to be made into new targets via the target fabrication system.

The RPF operating and process characteristics are described in more detail in Chapter 4.0.

1.3.2.2.1 Target Fabrication Process Description

The target fabrication process will center on the production of LEU target material that are generated through an [Proprietary Information]; the LEU target material will subsequently be loaded into aluminum target elements. The LEU feed for the [Proprietary Information] will be chilled UN and consist of a combination of fresh LEU, recovered scrap LEU, and LEU recovered from the processing of irradiated targets. [Proprietary Information].

The aluminum target components will be cleaned, and then a target subassembly will be welded and loaded with LEU target material. This target subassembly will subsequently be filled with a helium or air cover gas and sealed by welding on the remaining hardware end cap. The completed targets will be inspected and quality checked using a process similar to that performed for commercial nuclear fuel. The targets will then be shipped back to the reactor sites for irradiation.

The target fabrication process will begin with the receipt of fresh uranium from DOE, target hardware, and chemicals associated with LEU target material production and target assembly. The target fabrication process will center on the production of LEU target material that is generated through [Proprietary Information], which will subsequently be loaded into aluminum target elements. The uranium feed for the [Proprietary Information] acid deficient uranyl nitrate (ADUN) solution. This feed will consist of a combination of fresh uranium, off-specification uranium recovered from target fabrication processes, and uranium recovered from the processing of irradiated targets. The fresh uranium, enriched to 19.75 weight percent (wt%) uranium-235 (^{235}U), will be received as uranium metal and dissolved in nitric acid. The reactant for the [Proprietary Information] will be a chilled mixture of hexamethylenetetramine (HMTA) and urea, and the uranium [Proprietary Information]. The HMTA will decompose on contact with the heated silicone oil, releasing ammonia for [Proprietary Information]. The uranium-gel particles will then be filtered, washed, dried, calcined, and reduced to high-density LEU target material.

The target hardware components will be cleaned, and a target subassembly will be welded and loaded [Proprietary Information] by means of a [Proprietary Information]. This target subassembly will subsequently be filled with helium or air cover gas and sealed by welding on the remaining hardware end cap. The completed targets will then be inspected and quality checked.

1.3.2.2.2 Target Disassembly and Dissolution Process Description

The target receipt and disassembly process will be operated in a batch mode, starting with receipt of a batch of targets inside a shipping cask. The targets will be disassembled one at a time, and the irradiated LEU target material will be transferred to a dissolver.

The target dissolution hot cells operations will start with the transfer of the collection containers containing irradiated LEU target material from the target disassembly hot cells. A dissolver basket will then be filled with the contents of the collection container. Multiple containers may be loaded into the dissolver basket. The dissolver Basket will be lowered into place in the dissolver assembly via the open valve. After loading the dissolver basket into the dissolver assembly, the valves will be closed in preparation for the start of dissolution. The LEU target material will be dissolved in hot nitric acid.

The offgas containing the fission product gases will go through a series of cleanup columns. The nitrogen oxide (NO_x) will be removed by a reflux condenser and several NO_x absorbers, the fission product gases (noble and iodine) will be captured on absorbers, and the remaining gas will be filtered and discharged into the process ventilation header. The dissolver solution will be diluted, cooled, filtered, and pumped to the ^{99}Mo system feed tank. Only one of the two dissolvers is planned to be actively dissolving LEU target material at a time.

1.3.2.2.3 Molybdenum Recovery and Purification Process Description

Acidified dissolver solution from the target dissolution operation will be processed by the Mo recovery and purification system to recover the ^{99}Mo. The Mo recovery and separation process primarily consists of a series of chemical adjustments and ion exchange (IX) columns to remove unwanted isotopes from the Mo product solution. Product solution will be sampled to verify compliance with acceptance criteria after a final chemical adjustment. The product solution will then be placed into shipping containers that are sequentially loaded into shipping casks for transfer to the customer.

Waste solutions from the IX columns will contain the LEU present in the incoming dissolver solution and will be transferred to the LEU recovery system. The remaining waste solutions will be sent to low-or high-dose waste storage tanks.

1.3.2.2.4 Uranium Recycle and Recovery Process Description

The uranium recovery and recycle system will process aqueous LEU solutions generated in the Mo recovery and purification system to separate unwanted radioisotopes from uranium. Uranium will be separated from the unwanted radioisotopes using two cycles of IX. A concentrator will be provided for the uranium-bearing solution as part of each IX cycle to adjust the LEU solution uranium concentration. Vent gases from process vessels will be treated by the process vessel ventilation system prior to merging with the main facility ventilation system and release to the environment. Recycled uranium product will be an aqueous LEU solution that is transferred to the target fabrication system for use as a source to fabricate new reactor targets. Waste generated by the uranium recovery and recycle system operation will be transferred to the waste handling system for solidification, packaging, and shipping to a disposal site.

1.3.2.2.5 Liquid Waste Handling Process Description

The waste handling system is divided into three subsystems: (1) liquid waste system, (2) solid waste system, and (3) specialty waste system. The liquid waste disposal system will consist of a group of storage tanks for accumulating waste liquids and adjusting the waste composition. Liquid waste will be split into high-dose and low-dose streams by concentration. The high-dose fraction composition will be adjusted and mixed with adsorbent material. A portion of the low-dose fraction is expected to be suitable for recycle to selected systems as process water. Water that is not recycled will be adjusted and then mixed with an adsorbent material.

The solid waste disposal system will consist of an area for collection, size reduction, and staging of solid wastes. The solids will be placed in a 208 liter (L) (55-gallon [gal]) waste drum and encapsulated by adding a cement material to fill voids remaining within the drum. Encapsulated waste will be stored until the drums are loaded into a shipping cask and transported to a disposal site.

A specialty waste disposal system will address small quantities of unique wastes generated by other processes. The following are examples of these processes:

- A reclamation process to recycle organic solvent
- [Proprietary Information]
- Operation of a trichloroethylene (TCE) reclamation unit

The waste streams will be containerized, stabilized as appropriate, and shipped offsite for treatment and disposal.

1.3.2.3 Facility Ventilation System

The facility ventilation system, or RPF heating ventilation and air conditioning (HVAC) system, will be divided into four zones (Zone I, Zone II, Zone III, and Zone IV) with airflow directed from lowest to highest potential for contamination. The Zone I ventilation system will be the initial confinement barrier and will include gloveboxes, vessels, tanks, piping, hot cells, and the Zone I exhaust subsystem. The process vessel ventilation system exhausts to the Zone I exhaust subsystem, which will include two 100 percent capacity exhaust fans and filter trains for complete redundancy. Each filter train will consist of prefilters, two stages of high-efficiency particulate air (HEPA) filters, carbon adsorbers (for iodine removal), and isolation dampers. A separate stack with a monitoring and sampling system will be provided for the Zone I exhaust.

1.3.2.4 Biological Shield

The RPF biological shield will provide an integrated system of features that protects workers from the high-dose radiation generated during the radioisotope processing to recover ^{99}Mo. The primary function of the biological shield will be to reduce the radiation dose rates and accumulated doses in occupied areas to not exceed the limits of 10 CFR 20 and the guidelines of the facility ALARA (as low as reasonably achievable) program. The shielding and its components will withstand seismic and other concurrent loads, while maintaining containment and shielding during a design basis event.

Additional detailed process information is provided in Chapter 4.0.

1.3.3 Engineered Safety Features

ESFs are active or passive features designed to mitigate the consequences of accidents and to keep radiological exposures to workers, the public, and environment within acceptable values. The ESFs associated with confinement of the process radionuclides and hazardous chemicals for the RPF are summarized in Table 1-12, including the accidents mitigated, SSCs used to provide the ESFs, and references to subsequent sections providing a more detailed ESF description.

Confinement is a general ESF that is credited as being in place as part of the PHA described in Chapter 13.0. Additional IROFS associated with the confinement system were derived from the accident analyses in Chapter 13.0. The derived IROFS are also listed in Chapter 6.0, Table 6-1, with reference to more detailed descriptions in Section 6.2.1.

Table 1-12. Summary of Confinement Engineered Safety Features (2 pages)

Engineered safety feature	IROFS	Accident(s) mitigated	SSCs providing engineered safety features	Detailed description section
Confinement includes: • Hot cell liquid confinement boundary • Hot cell secondary confinement boundary • Hot cell shielding boundary	 RS-01 RS-03 RS-04	• Equipment malfunction and/or maintenance • Hazardous chemical spills	• Confinement enclosures including penetration seals • Zone I exhaust ventilation system, including ducting, filters, and exhaust stack • Zone I inlet ventilation system, including ducting, filters, and bubble-tight isolation dampers • Ventilation control system • Secondary iodine removal bed • Berms	6.2.1.1 through 6.2.1.6
Confinement IROFS Derived from Accident Analyses and Potential Technical Specifications				
Primary offgas relief system	RS-09	Dissolver offgas failure during dissolution operation	• Pressure relief device • Pressure relief tank	6.2.1.7.1
Active radiation monitoring and isolation of low-dose waste transfer	RS-10	Transfer of high-dose process liquid outside the hot cell shielding boundary	Radiation monitoring and isolation system for low-dose liquid transfers	6.2.1.7.2
Cask local ventilation during closure lid removal and docking preparations	RS-13	Target cladding leakage during shipment	Local capture ventilation system over closure lid during lid removal	6.2.1.7.3
Cask docking port enabler	RS-15	Cask not engaged in cask docking port prior to opening docking port door	Sensor system controlling cask docking port door operation	6.2.1.7.4

Table 1-12. Summary of Confinement Engineered Safety Features (2 pages)

Engineered safety feature	IROFS	Accident(s) mitigated	SSCs providing engineered safety features	Detailed description section
Process vessel emergency purge system	FS-03	SSC damage due to hydrogen deflagration or detonation	Backup bottled nitrogen gas supply	6.2.1.7.5
Irradiated target cask lifting fixture	FS-04	Dislodging the target cask shield plug while workers present during target unloading activities	• Cask lifting fixture design that prevents cask tipping • Cask lifting fixture design that prevents lift from toppling during a seismic event	6.2.1.7.6
Exhaust stack height	FS-05	• Equipment malfunction resulting in liquid spill or spray • Carbon bed fire	• Zone I exhaust stack	6.2.1.7.7
Double-wall piping	CS-09	Solution spill in facility area where spill containment berm is neither practical nor desirable for personnel chemical protection purposes	Double-wall piping for selected transfer lines	6.2.1.7.7
Backflow prevention devices Safe geometry day tanks	CS-18 CS-19	High worker exposure from backflow of high-dose solution	Backflow prevention devices located on process lines crossing the hot cell shielding boundary	6.2.1.7.9
Dissolver offgas iodine removal unit[a]	–	• Potential limiting control for operation • Primary iodine control system during normal operation	Dissolver offgas iodine removal units (DS-SB-600A/B/C)	6.2.1.8.2
Dissolver offgas primary adsorber[a]	–	• Potential limiting control for operation • Primary noble gas control system during normal operation	Dissolver offgas primary adsorber units (DS-SB-620A/B/C)	6.2.1.7.
Dissolver offgas vacuum receiver or vacuum pump[a]	–	• Potential limiting control for operation • Motive force for dissolver offgas	• Dissolver offgas vacuum receiver tanks (DS-TK-700A/B) • Dissolver offgas vacuum pumps (DS-P-710A/B)	6.2.1.8.3

[a] Examples of candidate technical specification rather than engineered safety feature.

IROFS = item relied on for safety. SSC = structures, systems, and components.

The current design approach does not anticipate requiring containment or an emergency cooling system as ESFs, as discussed in Chapter 6.0, Sections 6.2.2 and 6.2.3.

Nuclear criticality safety and associated controls are discussed in Chapter 6.0, Section 6.3. The currently defined criticality safety controls are derived from a combination of preliminary criticality safety evaluations and accident analyses, which are described in Chapter 13.0. The criticality safety analyses produce a set of features needed to satisfy the double-contingency requirements for nuclear criticality control. These features are evaluated by major systems within the RPF and listed by major system in Chapter 6.0, Section 6.3.1.1, Table 6-6 through Table 6-13. The accident analyses in Chapter 13.0 identify IROFS for the prevention of nuclear criticality, which are summarized in Chapter 6.0, Table 6-2, with reference to more detailed descriptions in Section 6.3.1.2.

Instrumentation and Control System

The RPF preliminary I&C configuration includes the SNM preparation and handling processes (e.g., target fabrication, and uranium recovery and recycle), radioisotope extraction and purification processes (e.g., target receipt and disassembly, target dissolution, Mo recovery and purification, and waste handling), process utility systems, criticality accident alarm system, and systems associated with radiation monitoring.

The SNM processes will be enclosed predominately by hot cells and gloveboxes except in the target fabrication area. The facility process control (FPC) system will provide monitoring and control of the process systems within the RPF. The FPC system will also provide monitoring of safety-related components within the RPF. The process strategy for the RPF involves the use of batch or semi-batch processes with relatively simple control steps.

The building management system (BMS) (a subset of the FPC system) will monitor the RPF ventilation system and mechanical utility systems. The BMS primary functions will be to monitor the facility ventilation system and monitor and control (turn on and off) the mechanical utility systems.

ESF systems will operate independently from the FPC system or BMS. Each ESF safety function will use hard-wired analog controls/interlocks to protect workers, the public, and environment. The ESF parameters and alarm functions will be integrated into and monitored by the FPC system or BMS.

The fire protection system will report the status of the fire protection equipment to the central alarm station and the RPF control room.

Cooling Water System

Cooling water systems are used to control the temperature of process solutions in the RPF from process activities and the heat load resulting from radioactive decay of the fission product inventory. The RPF is located at a separate site, independent from the reactors used to irradiate the targets. Therefore, the RPF cooling system does not influence operation of a reactor primary core cooling system.

Chilled water is used as the primary cooling fluid to process vessels. A central process chilled-water loop is used to cool three secondary loops: one large geometry secondary loop in the hot cell, one criticality-safe geometry secondary loop in the hot cell, and one criticality-safe geometry secondary loop in the target fabrication area. The central process chilled-water loop relies on air-cooled chillers, while the secondary loops are cooled by the central chilled-water system through plate-and-frame heat exchangers. Selected process demands require cooling at less than the freezing point of water. These demands are met with water-cooled refrigerant chiller packages, cooled by the secondary chilled water loops.

Electrical Power Systems

The RPF design uses high-quality, commercially available components and wiring in accordance with applicable code. Electrical power circuits will be isolated sufficiently to avoid electromagnetic interference with safety-related I&C functions. The facility is designed for passive, safe shutdown and to prevent uncontrolled release of radioactive material if normal electric power is interrupted or lost. Uninterruptable power supplies automatically provide power to systems that support the safety functions protecting workers and the public.

The normal electric power system is designed to provide reasonable assurance that use or malfunction of electrical power systems could not damage the RPF or prevent safe RPF shutdown. The RPF also has a non-safety standby electrical power system to reduce or eliminate process downtime due to electrical outages. A combination of uninterruptable power supplies and the standby electrical power system will provide emergency electrical power to the RPF.

Additional information on the electrical power systems is provided in Chapter 8.0, "Electrical Power Systems."

Other Auxiliary Systems

The RPF has the following auxiliary systems:

- Fire protection systems
- Communication systems
- Possession and use of byproduct, source, and SNM
- Cover gas control in the closed primary coolant system
- Other auxiliary systems, including utility systems, analytical laboratory, and chemical supply

Radiation Protection and Radioactive Waste Management

The NWMI RPF has a radiation protection program to protect the radiological health and safety of its workers. The program complies with the regulatory requirements of 10 CFR 19, "Notices, Instructions and Reports to Workers: Inspection and Investigations," 10 CFR 20, and 10 CFR 70. This program includes the elements of an ALARA program, radiation monitoring and surveying, exposure control, dosimetry, contamination control, and environmental monitoring. Additional details are provided in Chapter 11.0, "Radiation Protection and Waste Management," Section 11.1.2.

The radiation protection program provides a complete list of expected radiation and radioactive sources, including airborne, liquid, and solid sources. The radiation protection program also requires the development and implementation of procedures, identifies monitoring instrumentation and techniques, and specifies practices to be employed to verify compliance with the radiation dose limits and other applicable requirements. The basis and plans used to develop procedures for assessing and controlling radioactive wastes and the ALARA program are included.

Control of gaseous, liquid, and solid radioactive wastes in the RPF is described in Chapter 9.0, "Auxiliary Systems," Sections 9.6 and 9.7. NWMI's waste management program for radioactive wastes resulting from normal operations and maintenance of the RPF, including the required procedures, ensure that radiation exposures and releases of radioactive materials are adequately assessed and controlled. The waste management program addresses the following elements:

- Philosophy and approach to waste management
- Basis of procedures and technical specifications
- Organization, staffing, and associated training

- Document control and records management
- Review and audit committees for radioactive waste management activities
- Plans for shipping, disposal, and long-term waste storage

1.3.4 Experimental Facilities and Capabilities

The RPF does not include experimental facility SSCs that require research and development (R&D) to:

- Confirm adequacy of the facility design
- Identify and describe the R&D program that will completed to resolve any safety questions associated with such SSCs
- Schedule the R&D program to show that such safety questions will be resolved at or before the latest date stated in the application for completion of construction of the facility.

NWMI has and will continue to perform testing to validate the acceptable operating conditions for material and target solution compatibility at MURR and the DOE national laboratories prior to completion of RPF construction. Selected materials will be examined following irradiation testing at fluence levels expected in the operation of the target solution vessel for a 30-year lifetime. The testing will include specific work involving irradiation in a corrosive environment to examine the effects on the properties of selected raw materials and welded samples in an as-received and as-fabricated state. This work will be completed no later than December 31, 2016.

1.4 SHARED FACILITIES AND EQUIPMENT

The NWMI RPF does not share any systems or equipment with facilities not covered by this Construction Permit Application. The primary structure is the RPF. Three adjacent, separate buildings will be located on the site: an Administrative Building (outside of the protected area), a Waste Staging and Shipping Building for additional Class A waste storage (inside the protected area), and a Diesel Generator Building. These major facilities also receive, store/hold, or process chemicals, oil, diesel fuel, and other hazardous and radioactive materials.

1.5 COMPARISON WITH SIMILAR FACILITIES

As stated in Section 1.1, the NWMI RPF will produce ^{99}Mo through a fission-based process. NWMI has established a network of domestic university research reactors to irradiate LEU targets. Nearly all of the ^{99}Mo in the supply chain today is produced by irradiating ^{235}U with neutrons. Referred to as a fission reaction, six percent of collisions result in the formation of ^{99}Mo, as depicted in Figure 1-10. The process is well understood, reliable, predictable, and once extracted and purified, produces high-specific activity, ^{99}Mo. Radiopharmaceutical distributors in the U.S. use U.S. Food and Drug Administration-approved generators for ^{99}Mo produced by this method.

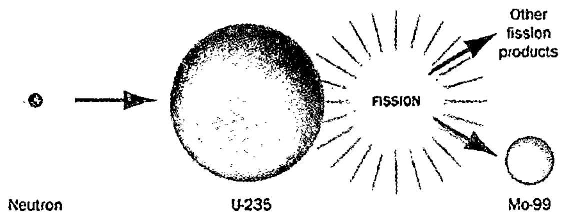

Figure 1-10. Irradiating Uranium-235 with Neutrons to Form Molybdenum-99

On a weekly basis, targets will be loaded around the reactor core and irradiated for approximately [Proprietary Information]. After irradiation, the targets will be mechanically removed from the core and placed in a cask or cooling tank. The targets will then be transported to the RPF using NRC-certified casks. Once the targets are received, the casks will be delidded and the targets poured into a nitric acid solution for dissolution. Any gases produced from the dissolution step will be trapped and held until no longer an environmental concern and will then be vented through an offgas treatment system. The resulting solution will be separated into liquids containing unused uranium and ^{99}Mo. During the second stage, the ^{99}Mo liquid will be passed through several exchange columns to extract purified ^{99}Mo and rinse out the majority of other by-products.

The RPF is a conventional design, similar to the design used in other nuclear processing facilities. A detailed RPF description is provided in Chapter 4.0.

1.5.1 Comparison of Physical Plant and Equipment

NWMI has developed extraction and purification chemistries, is designing and plans to construct an RPF to extract and purify ^{99}Mo, and intends to sell ^{99}Mo assuring a reliable, securable and domestic supply of this critical medical isotope. In addition, NWMI will recover and recycle the LEU.

The RPF will have design features for processing irradiated targets (i.e. hot cells, robust ventilation systems) and the ability to perform remote operations and maintenance. Parts of the process will be behind shielding walls, and decontaminated solutions will be processed or analyzed in gloveboxes, enclosures, or hoods. The process equipment is typical of that used in a DOE facility, with geometrically favorable tanks, IX columns, centrifugal contactors, evaporators, and batch solidification systems.

1.5.2 Comparison of Chemical Processes

The dissolution of target material uses a standard hot nitric acid process. The offgas treatment unit operations are well known and commercially available. The RPF Mo recovery and purification system will use [Proprietary Information] to selectively adsorb Mo from the irradiated target solution. The Mo purification process is very similar to the Cintichem process developed in the 1950s and 1960s by Union Carbide. Cintichem, Inc. used the process until 1990 as a means of purifying ^{99}Mo for use as a medical isotope. There are no NRC or DOE licensed facilities currently using this technology.

The uranium recovery process is a modification of a widely used uranium separation and purification process known as plutonium-uranium extraction (PUREX). The PUREX process was developed in the late 1940s and uses tributyl phosphate (TBP) to selectively remove uranium from a nitric acid solution typically containing a host of fission product and other actinide contaminants. The NWMI process uses similar chemistry but instead of a solvent process, the active agent is attached to a solid substrate.

The target fabrication processes and techniques are used in uranium processing and fuel fabrication facilities in the U.S., with standard nitric acid dissolution, small solvent extraction system, concentrator, and [Proprietary Information], and filling and sealing of the target hardware.

1.5.3 Comparison of Support Systems

Supporting systems, including ventilation, cooling water, waste processing, electrical power, and I&C, are conventional and generally require no unique features for the operation of the RPF.

1.6 SUMMARY OF OPERATIONS

The proposed action is the issuance of an NRC license under 10 CFR 50 and provisions of 10 CFR 70 and 10 CFR 30 that would authorize NWMI to construct and operate a ^{99}Mo RPF at a site located in Columbia, Missouri. RPF process activities will include:

- Receiving LEU from the DOE
- Producing LEU target materials and fabrication of targets
- Packaging and shipping LEU targets to the university reactor network for irradiation
- Returning irradiated LEU targets for dissolution, recovery, and purification of ^{99}Mo
- Recovering and recycling LEU to minimize radioactive, mixed, and hazardous waste generation
- Treating/packaging wastes generated by RPF process steps to enable transport to a disposal site.

The process design requirements are identified in NMWI-2013-049, *Process System Functional Specification*. [Proprietary Information]. The following summarizes key requirements for the RPF and the primary process systems:

- [Proprietary Information]
- [Proprietary Information]
- [Proprietary Information]
- Control/prevent flammable gas from reaching lower flammability limit conditions of 5 percent hydrogen gas (H_2); design for 25 percent of lower flammability limit
- Ensure that ^{235}U processing and storage meet security and criticality safety requirements

The RPF operating and process characteristics are provided in more detail in Chapter 4.0.

1.7 COMPLIANCE WITH THE NUCLEAR WASTE POLICY ACT OF 1982

The RPF does not produce high-level nuclear wastes or spent nuclear fuel. Therefore, the Nuclear Waste Policy Act of 1982 is not applicable to the RPF.

1.8 FACILITY MODIFICATIONS AND HISTORY

This Construction Permit and Operating License Applications are for the construction and operation of the NWMI RPF. There are no existing facilities at the proposed NWMI Discovery Ridge site, thus, no facilities modifications have occurred. This section is not applicable to the NWMI RPF.

1.9 REFERENCES

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10 CFR 20.1201, "Occupational Dose Limits for Adults," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 20.1301, "Dose Limits for Individual Members of the Public," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 50.31, "Combining Applications," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 50.32, "Elimination of Repetition," *Code of Federal Regulations*, Office of the Federal Register, as amended.

10 CFR 70, "Domestic Licensing of Special Nuclear Material," *Code of Federal Regulations*, Office of the Federal Register, as amended.

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NWMI-2015-SAFETY-002, *Radioisotope Production Facility Integrated Safety Analysis Summary*, Rev. 0, Northwest Medical Isotopes, Corvallis, Oregon, June 2015.

NWMI-2015-SAFETY-003, *Quantitative Risk Analysis of Chemical Safety Process Upsets*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

NWMI-2015-SAFETY-004, *Quantitative Risk Analysis of Process Upsets Associated with Passive Engineering Controls Leading to Accident Criticality Accident Sequences*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

NWMI-2015-SAFETY-005, *Quantitative Risk Analysis of Criticality Accident Sequences that Involve Uranium Entering a System Not Intended for Uranium Service*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

NWMI-2015-SAFETY-006, *Quantitative Risk Analysis of Criticality Accident Sequences that Involve High Uranium Content in Side Waste Streams*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

NWMI-2015-SAFETY-007, *Quantitative Risk Analysis of Facility Fires and Explosions Leading to Uncontrolled Release of Fissile Material, High and Low Dose Radionuclides*, Rev. A, Northwest Medical Isotopes, LLC, Corvallis, Oregon, 2015.

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