



Staff Presentation to the ACRS Sub-Committee

NuScale Licensing Topical Report

Methodology for Establishing the Technical Basis for Plume Exposure Emergency Planning Zones at NuScale Small Modular Reactor Plant Sites (TR-0915-17772, Revision 3)

Open Session

SEPTEMBER 8, 2022



U.S. NRC Topical Report Review Chronology

- NuScale submitted topical report TR-0915-17772, Revision 2, “Methodology for Establishing the Technical Basis for Plume Exposure Emergency Planning Zones,” on August 4, 2020
- NRC issued requests for additional information (RAIs) 9828 and 9830 in April 2021
- Initially, TR was applicable to light-water small modular reactors (SMRs) and non-light water reactors (non-LWRs). In May 2021, in response to RAI 9830, NuScale removed applicability to non-LWRs.
- NRC performed a regulatory audit as part of its review of the methodology in Revision 2, from November 2021 to April 2022
- NuScale provided response to RAI 9828 and submitted Revision 3 of the TR on June 10, 2022, titled “Methodology for Establishing the Technical Basis for Plume Exposure Emergency Planning Zones at NuScale Small Modular Reactor Plant Sites,” applicable only to the NuScale design and its derivatives and incorporating the RAI responses
- NRC issued the advanced safety evaluation on August 8, 2022



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Outline

- Regulatory and technical basis for staff's evaluation
- Overview of TR methodology
- Dose-distance criteria and figures-of-merit (FoMs)
- Source term and consequence assessment
- Screening of Probabilistic Risk Assessment (PRA) sequences
- Treatment of uncertainty
- Conditions of use



Regulatory and Technical Basis for Staff's Evaluation

10 CFR 50.47, Appendix E to Part 50, 10 CFR Part 20

NUREG-0396 (1978)

Probabilistic Risk Assessment (PRA) Policy Statement

SRM-SECY-98-144

RG 1.174

RG 1.200

NUREG-0396 (1978)

- Identifies the purpose of the EPZ
 - Area within which prompt protective actions may be necessary to provide dose savings in the event of a radiological release
- Technical basis for current prescribed plume exposure pathway EPZ radius of 10 miles
- Based on a review of licensed design-basis events and a spectrum of accident sequences from WASH-1400

Staff's Method of Review

- Consistent with technical basis in NUREG-0396
- Consistent with risk-informed decision making and use of PRA in risk-informed applications
- Supported by regulatory audit
 - Included example calculations implementing nearly entire methodology



Staff's Review of Applicability of NuScale's EPZ TR Methodology

- Only applicable to NuScale design and its derivatives, including Standard Design Approval
- TR Section 2.5.1 provides high-level design characteristics that determine applicability
 - All characteristics must be met
- Applicability limitations are acceptable
 - High-level design characteristics capable of identifying NuScale designs with the features and risk profile considered by the staff in its review



Staff's Review Approach for Dose-Distance Criteria and FoMs

- Considered recent research efforts to re-assess current 10-mile EPZ technical bases in NUREG-0396
- Considered updated information from guidance, methods, models, and analytical tools
- Assessed TR methodology consistency with analyses, assumptions and considerations of NUREG-0396 and current information
- Important topic areas:
 - Radiological consequence assessment modeling approaches
 - Dosimetric criteria and dose-distance curves
 - Considerations derived from assessments

Dose-Distance Criteria and FoMs¹

Criterion	Description	Source Term	Figure of Merit and Acceptance Criteria
a	Encompass those areas in which projected dose from DBAs could exceed the early phase PAGs	NUREG-0800 Chapter 15 analysis	1 rem and 5 rem TEDE over 96 hours, consistent with the EPA PAG Manual early phase PAGs
b	Encompass those areas in which consequences of less severe accident (containment intact) sequences could exceed the early phase PAGs	PRA-specific accident sequences with MELCOR analyses utilizing mitigation design features and operator actions	1 rem and 5 rem TEDE over 96 hours, consistent with the EPA PAG Manual early phase PAGs
c	Sufficient size to provide for substantial reduction in early severe health effects in the event of more severe accident sequences	PRA-specific accident sequences with MELCOR analyses and separate effects models utilizing additional mitigation design features and operator actions	200 rem red marrow dose, within 24 hours, is less than the TR specified acceptance criteria, consistent with NUREG-0396

1 – See staff report, *Use of MACCS Dose Coefficient Files to Compute Total Effective Dose Equivalent*, which provides information on how to compute TEDE and red marrow FOMs using the MACCS computer code. (ADAMS Accession No. ML21211A584)



Staff's Review of Source Term and Radiological Consequence Analysis

- For source term and radiological consequence analyses, the TR:
 - Recommends computational codes such as MELCOR and RELAP to develop design-specific source terms
 - Requires the MACCS code to perform radiological consequence analyses
- The staff finds these computer codes to be appropriate to perform these analyses



Fundamentals of Event Selection for EPZ Sizing Consistent with NUREG-0396

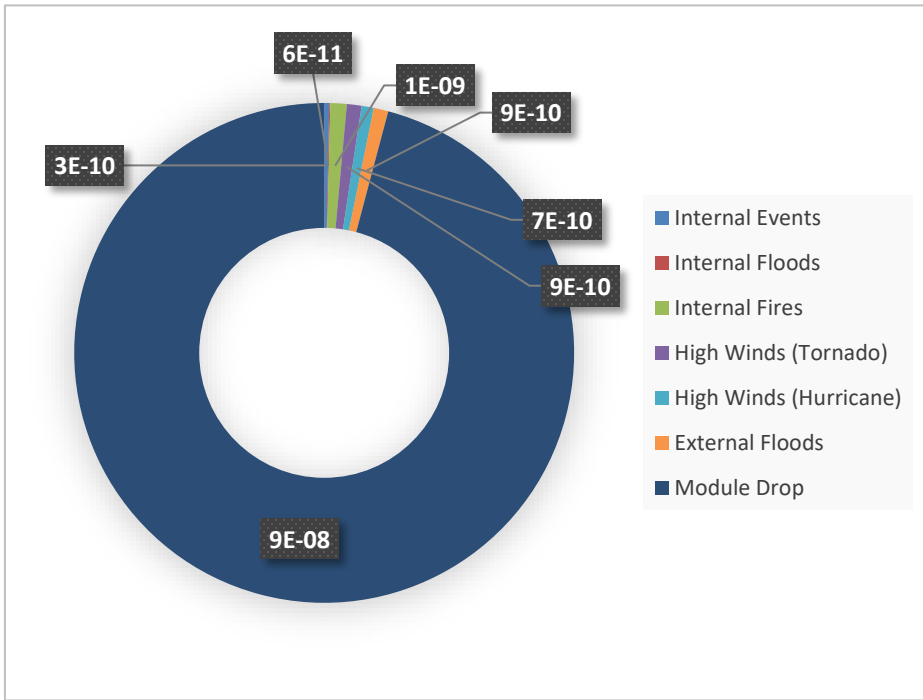
- Spectrum of accidents \neq licensing and design against QHOs
- Spectrum of accidents for EPZ sizing includes characteristics of radiological consequences from DBAs and BDBAs
 - Includes some of the key characteristics of more severe accidents (with large releases)
 - Ensures capability to reduce early severe health effects (injuries or deaths) in the event of the most severe BDBAs
- Selection of spectrum of accidents for EPZ sizing does not alter the design or operation



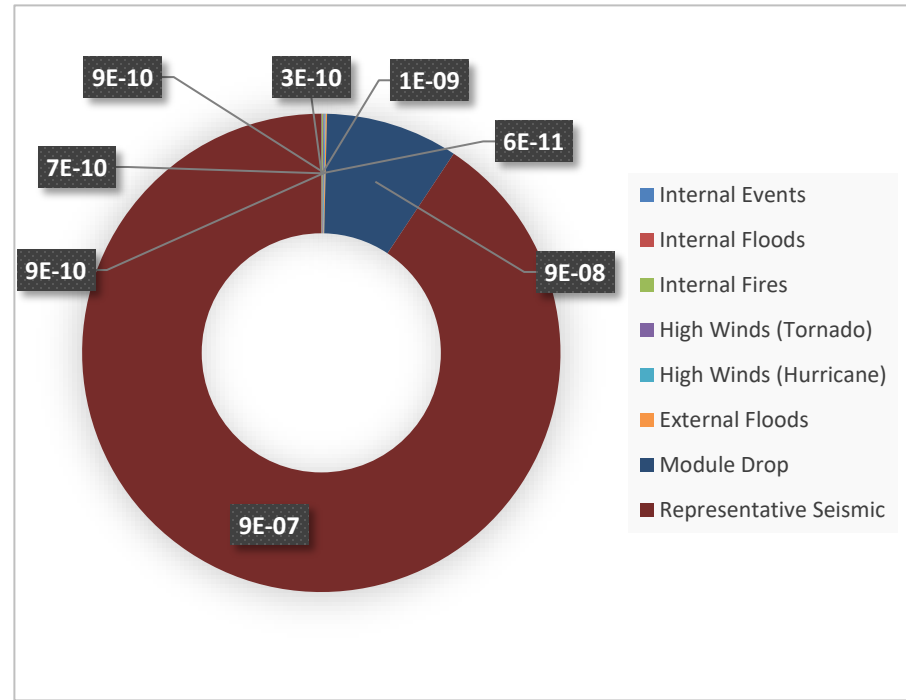
Fundamentals of Event Selection for EPZ Sizing Consistent with NUREG-0396 (cont'd)

- Purpose of EPZ is dose savings and not dose avoidance
 - NUREG 0396: “...while the EPZ should not be solely dependent on the most severe and most improbable BDBEs, the determination of the EPZ size needs to include some of the key characteristics of very large releases.”
- Seismic risk expected to dominate NuScale risk profile and EPZ sizing
 - Design reduces the risk from internal events
 - Timing of seismically-initiated sequences different compared to non-seismic events
 - Inclusion in spectrum of accidents maintains consistency with NUREG-0396

Seismic Risk – Potential Dominant Contributor for the NuScale Design



NuScale Core Damage Frequency (per year) Profile Without Seismic Contribution



Estimated NuScale Core Damage Frequency (per year) Profile for Site Within NuScale Certified Design Response Spectrum

Staff Review of Non-Seismic Single Module Sequence Screening

- TR sequence screening of $1E-7$ per reactor year CDF would have screened in all the WASH-1400 release sequences
 - None of these release sequences had a frequency less than $1E-7$ per reactor year



Staff Review of Consideration of Multi-Module Impacts for Non-Seismic Hazards

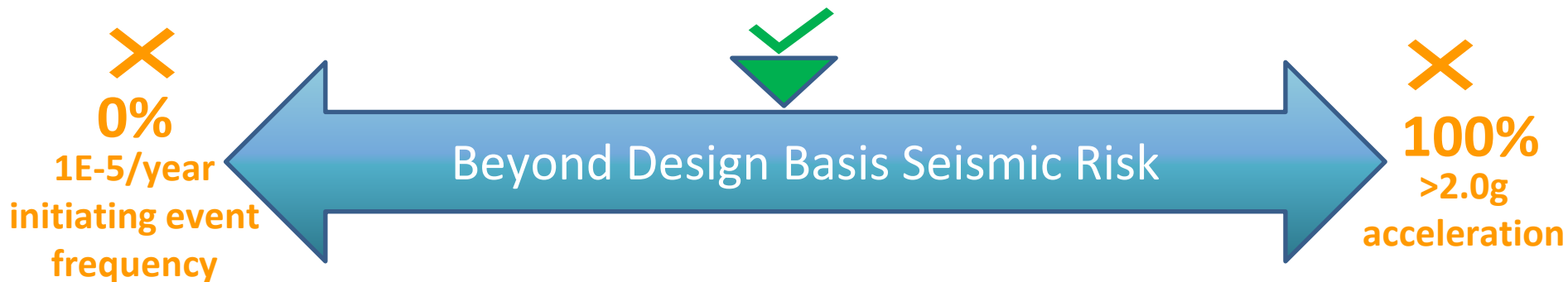
- WASH 1400 did not explicitly model “common mode mechanisms” such as fire, flood, and tornadoes (which have the potential to impact multiple modules) in the event trees and fault trees
- Appendix IV of WASH 1400: “common mode mechanisms” were assessed as impacts on the system fault trees
- Core damage sequence screening of $1E-7$ per reactor year was also applied to multi-module core damage sequences
 - None of WASH 1400 release sequences had a frequency less than $1E-7$ per reactor year

Staff Review of Screening Threshold for Seismic Hazard in TR, Revision 2

- Proposed threshold was 1E-5 per year initiating event frequency
- Proposed threshold did not provide spectrum of accidents consistent with NUREG-0396
 - Negligible beyond design basis seismic risk
 - Excluded key characteristics of more severe seismic accidents
 - Risk gap in EPZ sizing insights
- Proposed threshold was inconsistent with technical basis in NUREG-0396 and consideration of seismic events in WASH-1400

Staff Review of Screening Threshold for Seismic Hazard in TR, Revision 3

- TR identified a proprietary screening threshold for seismic hazard
- “Risk gap” approach developed by staff for evaluation
 - Determine appropriateness of screening threshold for seismic hazard consistent with basis in NUREG-0396



Staff Review of Screening Threshold for Seismic Hazard in TR, Revision 3 (cont'd)

- Overview of “risk gap” approach
 - Step 1: Collect ensemble of hazard curves representing different sites within the certified seismic design response spectrum
 - Step 2: Identify plant-level fragility and spectral ratios
 - Step 3: Convolve hazard curves with plant-level fragility
 - Step 4: Calculate simple average absolute and relative “risk gap” below screening threshold value

Staff Review of Screening Threshold for Seismic Hazard in TR, Revision 3 (cont'd)

- Staff evaluation used “risk gap” approach with 9 operating reactor sites
 - Within NuScale Certified Seismic Design Response Spectra
 - Using NuScale high confidence of low probability of failure (HCLPF) plant-level fragility
 - Threshold captures 20% – 50% of seismic risk for the NuScale design across majority of 9 sites

Staff Review of Screening Threshold for Seismic Hazard in TR, Revision 3 (cont'd)

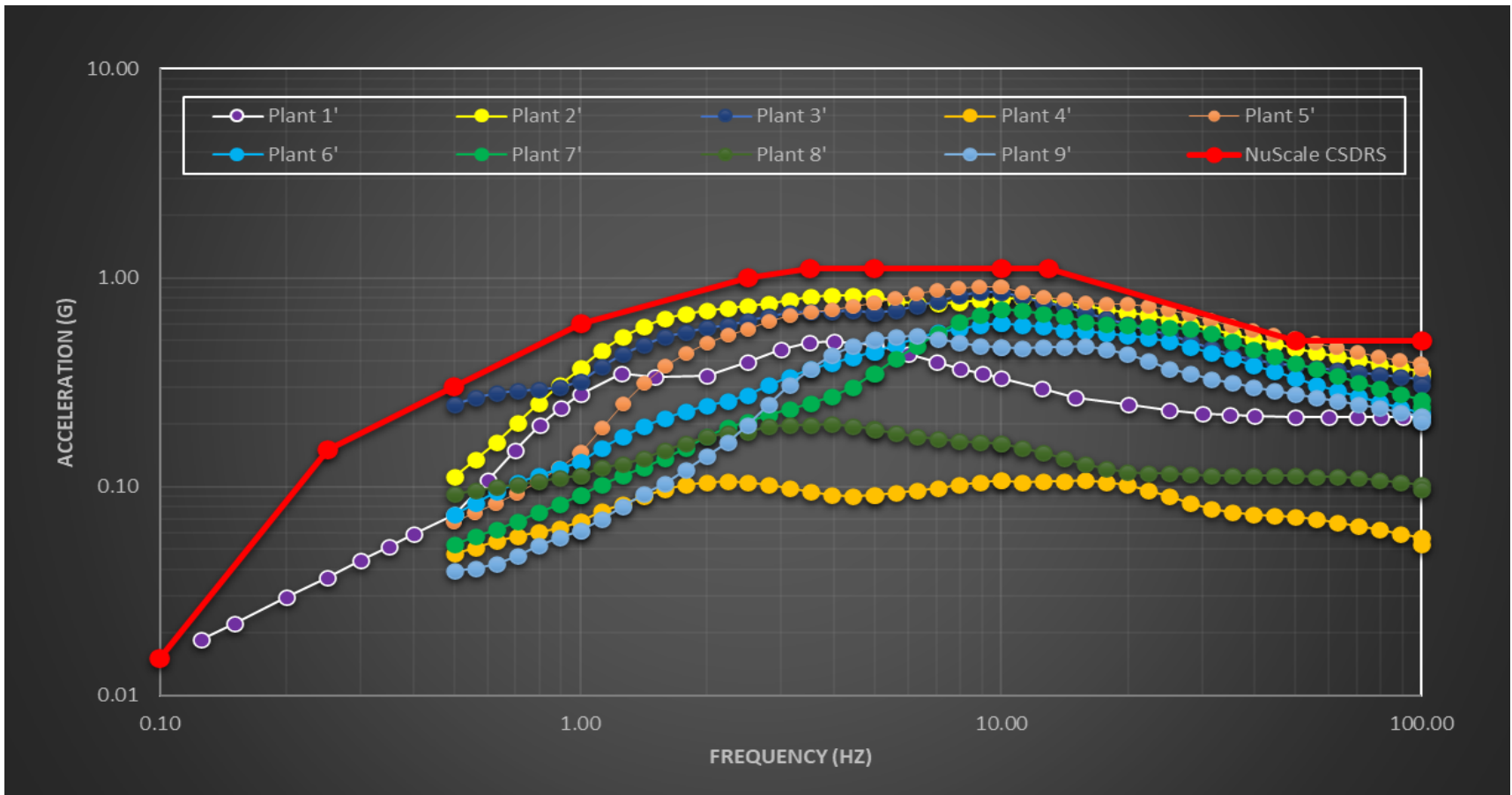


Figure 1 in NRC staff's safety evaluation (ML22118A760)



Staff Review of Screening Threshold for Seismic Hazard in TR, Revision 3 (cont'd)

- Achieves consistency with NUREG-0396 and WASH-1400 for seismic events
 - Results in a complete spectrum of accidents
 - Avoids extremely unlikely seismic accelerations
 - Does not ‘penalize’ NuScale for its risk profile
- Addresses multi-module risk (details in subsequent slide)
- Uses quantified seismic sequences because they can be dominant contributor to plant risk and EPZ sizing



Technology-Inclusive Applicability of “Risk Gap” Approach for Risk- Informed EPZ Sizing

- Provides design- and site-specific screening threshold value(s) consistent with technical basis in NUREG-0396
 - Single value across technologies and sites is difficult to defend
- Uses accessible design-specific information
- Compatible with risk metrics other than CDF or LERF
- This approach provides regulatory stability

Staff Review of Treatment of Uncertainty in Screening Threshold for Seismic Hazard

- Sufficient to identify new insights
 - Addresses uncertainty in context of identification of spectrum of accidents for EPZ sizing
 - Addresses potential for cliff edge effect (i.e., large change in EPZ size decision with small change in event screening)
- New sequences included in remaining steps of methodology

Staff Review of Consideration of Multi-Module Impacts for Seismic Hazard

- Methodology appropriately identifies and includes multi-module impacts from seismic events
- Considerations in staff evaluation:
 - Seismic events are a common-mode initiator
 - Screening threshold results in inclusion of accelerations with potential multi-module impacts
 - Dominant contributors to NuScale's seismic large release frequency impact multiple modules
 - Impact of multi-module sequences reflected in source term for those sequences

Information at Various Licensing Stages Under 10 CFR 52



Part 52:	PRA Based Seismic Margins Analysis (SMA) Allowed	PRA Based SMA Allowed	Site-Specific Seismic PRA
EPZ TR:	Not Applicable	Site-Specific Seismic PRA	Site-Specific Seismic PRA





Staff's Review of Treatment of Modeling Uncertainty for Seismic and Non-Seismic Hazards and Staff Review

- TR contains broad discussion of consideration of assumptions and sources of uncertainty in the underlying PRA
- Staff determined that consistency with established guidance applied for voluntary risk-informed applications is important
 - RG 1.200, Revision 3 and NUREG-1855, Revision 1
- Includes a corresponding Condition of Use

Staff Review of Consideration of Defense-In-Depth

- Methodology identifies key plant design and operational characteristics necessary for achieving defense-in-depth
 - Includes consideration of severe accident management strategies and diverse and flexible coping strategies
- Consistent with PRA Policy Statement and RG 1.174, Revision 3
- Five levels of defense in INSAG-10 adds confidence in consideration of defense-in-depth

Staff's Conditions of Use

- Ensure user addresses key inputs for methodology and staff findings
- Eight (8) conditions of use:
 - A. Consistency in use between applicant for operating license application under Part 50 and COL under Part 52
 - B. Consistency of PRA technical acceptability with established guidance
 - C. Treatment of PRA key assumptions and sources of uncertainty consistent with established guidance
 - D. Limit seismic event screening threshold to sites with GMRS bounded by NuScale's CSDRS
 - E. Limit seismic event screening threshold to NuScale's HCLPF plant-level fragility
 - F. Demonstration of GMRS and HCLPF plant-level fragility at application and prior to fuel-load
 - G. Monotonic decrease of {{ }}
 - H. Periodic evaluation to ensure (1) E is met AND (2) conclusion on EPZ size remain valid. Periodicity consistent with 10 CFR 50.71(h)(2)

Staff's Conclusion

- TR methodology is generally consistent with technical basis of current 10-mile EPZ prescribed in 10 CFR 50.47 (i.e., NUREG-0396)
- Reasonable assurance that methodology is adequate for assessing plume exposure pathway EPZ sizing
- Applicants using the methodology as the technical basis for assessing plume exposure pathway EPZ sizing need to meet :
 - Scope of applicability in Section 2.5 of the TR
 - Conditions of Use listed in Section 5.0 of staff's SE

Staff's Conclusion (cont'd)

- NuScale EPZ TR is risk-informed and reflective of NUREG-0396 approach
 - Uses risk information from design- and site-specific PRAs, with explicit consideration of uncertainty
 - Explicitly addresses defense-in-depth
 - Staff evaluated impact on safety margins
 - Includes performance monitoring (based on corresponding Condition of Use)

Caveats on Scope of Staff's Findings

- Only applicable to this TR for EPZ sizing
 - Not extended to design and operation for licensing
 - Quantitative Health Objectives applicable for design and operation for licensing
- Screening threshold, especially for the seismic hazard, not applicable to PRA development
 - Follow applicable endorsed PRA Standard
- Does not define “credible” events for any hazard

Acronyms

BDBA/E	beyond design basis accident/event
CDF	core damage frequency
CSDRS	certified seismic design response spectrum
DBA	design basis accident
EPZ	emergency planning zone
GMRS	ground motion response spectrum
HCLPF	high confidence of low probability of failure
LERF	large early release frequency
LRF	large release frequency
LWR	light water reactor
Non-LWR	non-light water reactor
ONT	other nuclear technology
PRA	probabilistic risk assessment
QHO	quantitative health objective
RG	regulatory guide
SMR	small modular reactor
WASH-1400	Nuclear Regulatory Commission Reactor Safety Study, 1975

References

10 CFR 50.47 “Emergency Plans”

10 CFR Part 50 Appendix E “Emergency Planning and Preparedness”

10 CFR Part 20 “Standards for Protection Against Radiation”

NUREG-0396, “*Planning Basis For The Development Of State And Local Government Radiological Emergency Response Plans In Support Of Light Water Nuclear Power Plants*” (ML051390356)

Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory, 60 FR 42622

SRM-SECY 98-144, “*White Paper Risk Informed and Performance-Based Regulation*” (ML003753601)

Regulatory Guide (RG) 1.174, “*An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis*,” Revision 3 (ML17317A256)

RG 1.200, “*Acceptability of Probabilistic Risk Assessment Results for Risk-Informed Activities*,” Revision 3 (ML20238B871)