March 3, 2017

Mr. Kristopher Cummings
Senior Project Manager, Used Fuel Programs
Nuclear Energy Institute
1201 F Street, NW, Suite 1100
Washington, D.C. 20004

SUBJECT: FINAL SAFETY EVALUATION FOR NUCLEAR ENERGY INSTITUTE TOPICAL REPORT NEI 16-03 - GUIDANCE FOR MONITORING OF FIXED NEUTRON ABSORBERS IN SPENT FUEL POOLS (CAC NO. MF8122)

Dear Mr. Cummings:

By letter dated May 10, 2016 (Agencywide Documents Access Management System (ADAMS) Accession No. ML16147A078), as supplemented by letter dated August 30, 2016 (ADAMS Accession No. ML16265A248), the Nuclear Energy Institute (NEI), on behalf of the nuclear industry, submitted NEI 16-03, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools," Revision 0. The NEI submittal provides guidance for monitoring programs for fixed neutron absorbers in spent fuel pools as a means to demonstrate compliance with the applicable requirements in Title 10 of the *Code of Federal Regulations* Section 50.68, "Criticality Accident Requirements," with respect to the neutron absorbing materials.

By letter dated November 9, 2016 (ADAMS Accession No. ML16280A369), an NRC draft safety evaluation (SE) was provided for your review and comment. By letter dated December 21, 2016 (ADAMS Accession No. ML16356A601), the NEI provided comments (ADAMS Accession No. ML16356A602) on the U.S. Nuclear Regulatory Commission (NRC) draft SE. The comments provided by NEI were related to clarifications and accuracy. No proprietary information was identified in the draft SE. The NRC staff dispositioned the comments as shown in the attachment to the enclosed final SE.

The NRC staff has found that NEI 16-03, Revision 0 is acceptable for referencing in licensing applications for nuclear power plants to the extent specified in the enclosed final SE. The final SE defines the basis for our acceptance of the topical report (TR).

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in licensing action requests, our review will ensure that the material presented applies to the specific plant involved. Request for licensing actions that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that NEI publish an approved version within three months of receipt of this letter. The approved version shall incorporate this letter and the enclosed final SE after the title page.

Also, it must contain historical review information, including NRC requests for additional information (RAIs) and your responses. The approved version shall include an "-A" (designating approved) following the TR identification symbol.

As an alternative to including the RAIs and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and if the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, NEI will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing. Licensees referencing this TR would be expected to justify its continued applicability or evaluate their plant using the revised TR.

Sincerely,

/RA/

Kevin Hsueh, Chief
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 689

Enclosure:
Final SE

SUBJECT: FINAL SAFETY EVALUATION FOR NUCLEAR ENERGY INSTITUTE TOPICAL REPORT NEI 16-03 - GUIDANCE FOR MONITORING OF FIXED NEUTRON ABSORBERS IN SPENT FUEL POOLS (CAC NO. MF8122).
DATED: March 3, 2017

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ADAMS Accession No.: NEI 16-03 FINAL SE Package ML16354A366; FINAL SE ML16354A486; Table to Address NEI Comments on Draft NEI 16-03 SE ML16354A487;*concurred via e-mail NRR-1043

OFFICE	NRR/DPR/PLPB/PM	NRR/DPR/PLPB/LA*	NRR/DE/ESGB/BC(A)*	NRR/DPR/PLPB/BC
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DATE	2/8/17	1/19/17	2/1/17	3/3/17

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FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

NUCLEAR ENERGY INSTITUTE TOPICAL REPORT NEI 16-03

"GUIDANCE FOR MONITORING OF FIXED NEUTRON ABSORBERS

IN SPENT FUEL POOLS"

PROJECT NO. 689

1.0 INTRODUCTION

By letter dated May 10, 2016 (Agencywide Documents Access Management System (ADAMS) Accession No. ML16147A078), as supplemented by letter dated August 30, 2016 (ADAMS Accession No. ML16265A248), the Nuclear Energy Institute (NEI), on behalf of the nuclear industry, submitted NEI 16-03, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools," Revision 0. The purpose of the document is to provide guidance for licensees to develop an acceptable fixed neutron absorber monitoring program in spent fuel pools (SFPs) as a means to demonstrate compliance with applicable regulations in Section 50.68 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Criticality Accident Requirements," 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 61, "Fuel Storage and Handling and Radioactivity Control," and 10 CFR Part 50, Appendix A, GDC 62 "Prevention of Criticality in Fuel Storage and Handling," with respect to neutron absorbing materials (NAMs).

2.0 REGULATORY EVALUATION

The effectiveness of the NAM installed in SFP storage racks ensures that the effective neutron multiplication factor (k_{eff}) does not exceed the values and assumptions used in the criticality analysis of record (AOR) and other licensing basis documents. The AOR is the basis, in part, for demonstrating compliance with plant technical specifications and with applicable the U.S. Nuclear Regulatory Commission (NRC) regulations. Degradation or deformation of the credited NAM may reduce safety margin and potentially challenge the subcriticality requirement. NAMs utilized in SFP racks exposed to treated water or treated borated water may be susceptible to reduction of neutron absorbing capacity, changes in dimension, and/or loss of material that increases k_{eff}. A monitoring program is implemented to ensure that degradation of the NAM used in SFPs, which could compromise the ability of the NAM to perform its safety function as assumed in the AOR, will be detected. NRC's regulatory requirements and corresponding staff review criteria and guidance for NAM monitoring programs are contained in the following documents:

- 10 CFR 50.68(b)(4), "Criticality accident requirements," states that if the licensee does not credit soluble boron in the SFP criticality AOR, the k_{eff} of the SFP storage racks must not exceed 0.95 at a 95 percent probability, 95 percent confidence level. If the licensee does take credit for soluble boron, the k_{eff} of the SFP storage racks must not exceed 0.95 at a 95 percent probability, 95 percent confidence level, if flooded with borated water, and if flooded with unborated water, the k_{eff} must remain below 1.0 at a 95 percent probability, 95 percent confidence level.

- GDC 61, "Fuel storage and handling and radioactivity control," states that "The fuel storage and handling, radioactive waste, and other systems which may contain radioactivity shall be designed to assure adequate safety under normal and postulated accident conditions. These systems shall be designed (1) with a capability to permit appropriate periodic inspection and testing of components important to safety…"

- GDC 62, "Prevention of Criticality in Fuel Storage and Handling," states that "Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations."

- NUREG-0800, "Standard Review Plan [(SRP)]," Section 9.1.1, Revision 3, "Criticality Safety of Fresh and Spent Fuel Storage and Handling" (ADAMS Accession No. ML070570006) provides guidance regarding the acceptance criteria and review procedures to ensure that the proposed changes satisfy the requirements in 10 CFR 50.68.

- NUREG-0800, "Standard Review Plan," Section 9.1.2, Revision 4, "New and Spent Fuel Storage" (ADAMS Accession No. ML070550057) provides guidance regarding the acceptance criteria and review procedures to ensure that the proposed changes satisfy the requirements in 10 CFR 50.68.

- NUREG-1801, "Generic Aging Lessons Learned (GALL) Report," Revision 2 (ADAMS Accession No. ML103490041) provides guidance on what constitutes an acceptable monitoring program for NAMs providing criticality control in the SFP.

3.0 TECHNICAL EVALUATION

Guidance for developing a NAM monitoring program for NAM in the SFP is provided in NEI 16-03. The purpose of a NAM monitoring program is to verify that the NAM installed in SFPs continues to provide the criticality control relied upon in the AOR, and help to maintain the subcriticality margin in accordance with 10 CFR 50.68 requirements. The guidance provided in NEI 16-03 for a NAM monitoring program, relies on periodic inspection, testing, monitoring, and analysis of the NAM. To accomplish this purpose, the guidance document states that a monitoring program must be capable of identifying unanticipated changes in the absorber material and determining whether anticipated changes can be verified. The guidance recommends the use of coupon testing, in-situ measurement, and/or SFP water chemistry monitoring as a means to monitor potential changes in characteristics of the NAM. The NRC staff reviewed the proposed guidance for what constitutes an acceptable monitoring program and its ability to ensure that potential degradation of SFP NAM will be detected, monitored, and mitigated. The staff determined that an appropriate combination of the three methods listed above (coupon testing, in-situ measurement, and/or SFP water chemistry monitoring) can comprise an effective NAM monitoring program. During the course of the NRC staff's review, there were several topics identified in the guidance that required clarification. A Category 2 public meeting was held with NEI on August 10, 2016, to seek clarification on these topics. The NRC staff and NEI representatives discussed these topics and NEI subsequently submitted a revision to NEI 16-03.

A meeting summary is included as a reference (ADAMS Accession No. ML16209A375) in this safety evaluation (SE) that describes the topics that were discussed at the public meeting, as well as the changes that were made to the guidance document as a result of the discussion.

3.1 Coupon Testing Program

3.1.1 Description of NEI 16-03

The guidance document states that the use of a coupon testing program is the preferred method for a neutron absorber monitoring program. This program consists of small sections (coupons) of the same NAM installed in the SFP, which are attached to a structure (coupon tree) in the SFP. The coupon tree is placed near freshly discharged fuel assemblies in an attempt to accelerate potential degradation mechanisms. The document provides the following criteria for an acceptable coupon program:

- The number of coupons needs to be adequate to allow for sampling at interval for the intended life of the absorbers.
- The sampling intervals are based on the expected rate of material change.
- Performance of coupon testing
    - Basic testing: visual observations, dimensional measurements, and weight
    - Full testing: density measurements, Boron-10 (^{10}B) areal density (AD) measurements, microscopic analysis, and characterization of changes, in addition to the basic testing parameters

The guidance document states that the coupons will be located in the SFP "such that their exposure to parameters controlling change mechanisms is conservative or similar to the in-service neutron absorbers." For neutron attenuation testing, NEI 16-03 provides acceptance criteria for the NAM depending on if there is, or is not, an anticipated loss of ^{10}B AD. The acceptable result for NAMs with expected ^{10}B AD loss is the ^{10}B AD of the test coupon is greater than the ^{10}B AD assumed in the licensee's SFP criticality AOR. For NAM without an expected loss of ^{10}B AD, the acceptable result is the ^{10}B AD of the test coupon is equal to the original ^{10}B AD of the coupon (within measurement uncertainty). Furthermore, the guidance states that the acceptable initial sampling interval for testing of new material (i.e., with a limited, or no, operating history) is up to 5 years, with subsequent intervals up to 10 years. For those materials that have well documented operating experience, do not have a history of degradation or degradation mechanisms, and information on stability of the material condition is well developed, the document states initial and subsequent test intervals up to 10 years are acceptable. The document states that for materials with known degradation mechanisms, or a history of known degradation (e.g., Boraflex, Carborundum, Tetrabor, etc.), the acceptable interval for neutron attenuation testing is at least once every five years. In addition, NEI 16-03 includes neutron attenuation testing in the full testing approach for any NAMs used, as a component of a satisfactory NAM monitoring program.

3.1.2 NRC Staff Evaluation

The NRC staff has evaluated the guidance for the basic and full portions of a coupon testing program. The basic portion of the testing includes methods to monitor the physical condition of the NAM so that signs of potential degradation may be observed. The full portion of the testing includes neutron attenuation testing for all NAMs that are credited in the SFP criticality analysis that will allow the licensee to detect a potential loss in ^{10}B AD. The staff finds the coupon testing program to be acceptable because it includes measurements of ^{10}B AD and of dimensional changes in the material that can impact the ability of the NAM to perform its function as assumed in the licensee's SFP criticality AOR.

The NRC staff also determined the acceptance criteria for the coupon testing program provided in NEI 16-03 is acceptable. The acceptance criteria provides reasonable assurance that the assumptions regarding the AD of the NAM in the licensee's SFP criticality AOR will be maintained, because the acceptance criteria show that the material is either not losing ^{10}B AD (for materials not expected to lose ^{10}B AD), or the ^{10}B AD is still above the ^{10}B AD assumed in the licensee's SFP criticality AOR (for NAM anticipated to lose ^{10}B AD). In addition, the NRC staff recognizes that if a coupon being tested approaches the ^{10}B AD value used in the licensee's SFP criticality AOR, the licensee would likely need to perform further evaluations and/or take additional corrective actions to provide reasonable assurance that the in-service NAM will not degrade below the ^{10}B AD assumed in the licensee's SFP criticality AOR. Guidance on additional corrective actions that may be necessary is given in Section 2.3, "Evaluating Neutron Absorber Test Results," of NEI 16-03, and this guidance is evaluated in Section 3.3 of this SE.

3.2 In-Situ Measurement Program

3.2.1 Description of NEI 16-03

The NEI guidance document states that in-situ measurement is another method that can be used to confirm ^{10}B AD of NAM. It further states that this method can be used to supplement coupon monitoring to extend the coupon testing interval, permit greater reliance on basic testing, or in lieu of coupon testing for plants that may no longer have coupons in the SFP. It also states that in-situ measurement can be used instead of coupon testing if coupons do not exist.

The guidance states that all in-situ measurement campaigns are to be performed at an acceptable interval and on an adequate number of panels. The guidance gives two options for determining what constitutes an adequate number of panels. The first option uses the methodology of NUREG-6698 (ADAMS Accession No. ML050250061) to measure a minimum of 59 panels to provide 95/95 confidence limits. The second option selects the panels with the greatest exposure (top 5%) to parameters that influence degradation (e.g., neutron fluence, temperature, time). The amount of panels will be no less than one percent of the total panels in the SFP, although more panels can be tested from other areas of the SFP to gain a more representative sampling. The guidance also states sources of uncertainty in the in-situ measurement will be identified and quantified.

The sampling interval will be based upon the NAM credited in the SFP. New materials with minimal operating experience will have an initial test interval that does not exceed 5 years, with subsequent intervals up to 10 years (with appropriate operating experience). For materials with known histories of degradation and known degradation mechanisms, test intervals do not exceed 5 years. For other materials that do not have known histories of degradation or known degradation mechanisms test intervals will not exceed 10 years. The guidance also states that if used in conjunction with a coupon monitoring program, the in-situ sampling interval can be longer.

The NEI document also provides acceptance criteria for in-situ measurements. It states that for NAMs that do not have potential degradation mechanisms for loss of ^{10}B AD, results of the in-situ measurements are acceptable if the nominal measured ^{10}B AD is greater than or equal to the value assumed in the licensee's criticality AOR (within measurement uncertainties). For materials that have potential degradation mechanisms that result in loss of ^{10}B AD, results are considered acceptable if the nominal measured ^{10}B AD minus measurement uncertainty is greater than the ^{10}B AD in the licensee's criticality AOR.

3.2.2 NRC Staff Evaluation

The NRC staff has reviewed the guidance for performing in-situ measurement testing and finds it to be acceptable, because it allows for detection of degradation mechanisms, potential loss of neutron absorption capacity (e.g. loss of ^{10}B), and ensure the NAM will continue to provide the criticality control relied upon in the AOR. The NRC staff reviewed the methodology recommended for determining the number of panels that may be selected for in-situ inspection and finds it to be acceptable because it is based in part on guidance provided in NUREG-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," or on selecting panels that have experienced the greatest exposure to the SFP environment. The NRC staff also finds that depending on the population of NAM panels in the SFP, a licensee may need to measure more than the minimum of 59 panels in order to produce 95/95 confidence limits. The method used for selecting the panels for in-situ testing is used to obtain data that is bounding or representative of the entire NAM in the SFP.

In addition, the NRC staff has determined that the proposed testing intervals (intervals not to exceed 10 years for materials with no known history of degradation/degradation mechanisms, and 5 years for materials with a known history of degradation/degradation mechanisms or for new materials (i.e., no operating history)) are acceptable and consistent with NRC guidance in the GALL Report, Revision 2. The neutron attenuation testing must be performed on the intervals as described in the document, regardless of how the licensee uses the in-situ monitoring program (e.g., in conjunction with coupons, without coupon program, or other reasons as described in NEI 16-03). The statement in the guidance that the in-situ sampling interval can be longer if used in conjunction with a coupon program does not obviate the need to perform neutron attenuation testing on intervals not to exceed 5 or 10 years (depending on the NAM used and associated operating experience).

In addition, the NRC staff finds it to be acceptable to identify and evaluate sources of uncertainty in order to assess the reliability of the instruments and methodology used to the collect the data. Sources of uncertainty can greatly impact results and confidence in the data collected, especially as it relates to the subcriticality margin.

3.3 Evaluating Neutron Absorber Test Results

3.3.1 Description of NEI 16-03

The guidance document states that the test results from neutron absorber monitoring may fall within the following categories:

1) Confirmation that no material changes are occurring,
2) Confirmation that anticipated changes are occurring, and/or
3) Identification that unanticipated changes are occurring.

Furthermore, the guidance document states that the testing results will be compared to the AOR input (i.e., ^{10}B AD assumed in criticality AOR). If no changes, or if anticipated changes are occurring, then the guidance assumes that the material continues to be adequately represented in the AOR.

The guidance document also describes the additional actions that may be necessary when unanticipated changes in the NAM are identified. It states that there are certain technical evaluations that may be necessary in addition to any required regulatory or licensing processes. The technical evaluations include a determination if these changes may result in a loss of ^{10}B AD. Any potential impacts of a loss of ^{10}B AD on the SFP criticality AOR will be evaluated and addressed through licensee processes. In addition, the results of monitoring and testing are to be evaluated and trended, regardless of potential impact on the SFP criticality AOR. If the unanticipated changes do not appear to result in the loss of ^{10}B AD, the changes will still be evaluated for impacts on the SFP criticality AOR. The effects on the SFP criticality AOR due to potential dimensional changes of the NAM, or other material in the SFP, are evaluated and addressed in accordance with licensee processes.

3.3.2 NRC Staff Evaluation

The NRC staff has reviewed the actions described in the guidance for when potential degradation is detected in the neutron absorbing material as potential degradation of the NAM may impact ^{10}B AD assumptions in the SFP criticality AOR. The NRC staff finds the actions described in the guidance acceptable because they will be able to identify anticipated, and unanticipated changes in order to provide information that will allow a licensee to determine whether or not the neutron absorbing material is performing its safety function as assumed in the AOR.

The NRC staff has also determined that it is necessary to evaluate and trend the results of ^{10}B AD measurements from neutron attenuation testing in the NAM as described in NEI 16-03. The NRC staff finds the methods, and requirement, to trend data acceptable because it will provide information regarding the potential degradation mechanism(s) and rate for the NAM in the SFP. This information will also help to provide reasonable assurance that the ^{10}B AD of the NAM will not decrease below the value assumed in the SFP criticality AOR between the specified test intervals for neutron attenuation testing. In addition, this data can identify previously un-evaluated degradation mechanisms that may have an impact on the SFP criticality AOR.

The actions described above ensure, in part, that the ability of the NAM to provide the criticality control relied upon in the AOR, is maintained.

3.4 Technical Evaluation Conclusion

The NRC staff has determined that in order for a NAM monitoring program to be acceptable, the licensee must perform neutron attenuation testing at the intervals stated in NEI 16-03. The NRC staff finds the interval for inspection and testing acceptable because the frequency is determined based on the neutron absorbing material credited, and operating experience of that material. Depending on the material used, the interval for neutron attenuation testing will not exceed 5 years (for materials with a history of known degradation or a known degradation mechanism, and new materials), or 10 years (for other materials that do not have a history of degradation, or a known degradation mechanism). Periodic neutron attenuation testing, and the intervals described in NEI 16-03 are consistent with staff guidance (i.e., the GALL Report, Revision 2). Licensees must request site-specific NRC review and approval to extend the interval of any neutron attenuation testing past the approved intervals, as described in NEI 16-03.

The NRC staff also finds that it would not meet the acceptance criteria in a NAM monitoring program for the measurement uncertainty to result in a ^{10}B AD value that is lower than the assumed value in the SFP criticality AOR. The staff expects that if a given test result shows a ^{10}B AD value lower than the value assumed in the SFP criticality AOR, the licensee will take the appropriate corrective actions in accordance with licensee programs and processes.

Based on its review of NEI 16-03, the NRC staff has determined that a NAM monitoring program meeting the provisions in NEI 16-03 will allow a licensee to reasonably ensure that the ability of the NAM to provide the criticality control relied upon in the AOR, is maintained, thus demonstrating compliance with the subcriticality requirements of 10 CFR 50.68.

4.0 CONCLUSION

The NRC staff has reviewed NEI 16-03, and the proposed methods for developing a NAM monitoring program. A NAM monitoring program implementing the proposed guidance provides reasonable assurance that such program will be able to detect degradation of neutron absorbing material, and provides assurance that the ability of the NAM to provide the criticality control relied upon in the AOR, is maintained. The NRC staff finds that the requirements of 10 CFR 50.68(b)(4), GDC 61, and GDC 62, as well as the guidance provided in SRP 9.1.1, SRP 9.1.2, and the GALL, Revision 2, with respect to NAMs and the NAM monitoring program, are satisfied. Therefore, the NRC staff finds the proposed guidance in NEI 16-03 acceptable for developing a NAM monitoring program.

5.0 REFERENCES

1. Letter from Kristopher W. Cummings to Timothy J. McGinty, “Submittal of NEI 16-03, Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools, Draft A, dated May 2016,” May 10, 2016 (ADAMS Accession No. ML16147A078).

2. Letter from Kristopher W. Cummings to Brian J. Benney, "Submittal of NEI 16-03, Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools, Revision 0, dated August 2016," August 30, 2016 (ADAMS Accession No. ML16265A248).

3. U.S. Code of Federal Regulations, "Criticality accident requirements," Title 10 of the *Code of Federal Regulations*, Section 50.68(b)(4).

4. U.S. Code of Federal Regulations, "Domestic Licensing of Production and Utilization Facilities – Proposed General Design Criteria for Nuclear Power Plants," Part 50, Appendix A.

5. U.S. Nuclear Regulatory Commission, "Standard Review Plan, Section 9.1.1, Criticality Safety of Fresh and Spent Fuel Storage and Handling," NUREG-0800, Revision 3, March 2007 (ADAMS Accession No. ML070570006).

6. U.S. Nuclear Regulatory Commission, "Standard Review Plan, Section 9.1.2, New and Spent Fuel Storage," NUREG-0800, Revision 4, March 2007 (ADAMS Accession No. ML070550057).

7. U.S. Nuclear Regulatory Commission, "Generic Aging Lessons Learned (GALL) Report," NUREG-1801, Revision 2, December 2010 (ADAMS Accession No. ML103490041).

8. U.S. Nuclear Regulatory Commission Category 2 Public Meeting, 'Summary of August 10, 2016, Meeting with the Nuclear Energy Institute to Discuss NEI 16-03, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools,"' September 27, 2016 (ADAMS Accession No. ML16209A375).

9. U.S. Nuclear Regulatory Commission, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," NUREG/CR-6698, January 2001 (ADAMS Accession No. ML050250061).

Principle Contributor: Alex Chereskin, NRR/DE/ESGB

Date: March 3, 2017