UNF-ST&DARDS Enhancements for RCCA Data in As-Loaded Dual Purpose Canister Models

Spent Fuel and Waste Disposition

Prepared for
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SUMMARY

This report summarizes the work performed to enable detailed modeling of rod cluster control assembly (RCCAs) in dual purpose canisters (DPCs) in as-loaded configurations using the Used Nuclear Fuel – Storage, Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS) [1]. The goal of this project was to evaluate the reactivity impact that RCCAs have on k_{eff} of DPCs with pressurized water reactor (PWR) fuel to potentially use the additional margin in future post-closure criticality safety analysis. This preliminary evaluation determined the number of DPCs that currently require compensatory actions prior to emplacement in a repository because of their high reactivity under post-closure criticality scenarios, which could be made acceptable by including the as-loaded RCCAs as specified in the Unified Database (UDB).

This report briefly describes the modeling methods currently used within UNF-ST&DARDS and the modifications made to automate inclusion of the as-loaded RCCAs in the DPCs for post-closure criticality calculations for the loss of neutron absorber (NA) scenarios, or NA models. For the Zion site, the loss of basket scenarios, or degraded basket (DB) models, are also included. Discussion is also provided regarding the UDB data compared to available site-specific loading map data for the sites, which are specifically evaluated herein. This report compares the modifications to a similar evaluation for the Zion by site conducted by Walker [2] as an initial validation. After the partial validation, all existing PWR sites with applicable NA models within the UDB were evaluated. The results of this comprehensive evaluation are summarized in Table 1 (bolded rows indicate sites with DPCs containing RCCAs).

Table 1. Summary of analysis results

Site	DPCs	DPCs with RCCAs	Total critical DPCs	Critical DPCs with RCCAs	Critical DPCs after RCCA credit	RCCA credit criticality impact
Arkansas Nuclear ISFSI*	**79**	**22**	**0**	**0**	**0**	**0**
Braidwood ISFSI	24	0	2	0	0	0
Byron ISFSI	**26**	**7**	**1**	**0**	**0**	**0**
Catawba ISFSI	39	0	14	0	0	0
Comanche Peak ISFSI	**29**	**1**	**24**	**1**	**0**	**1 (100%)**
Cook ISFSI	**29**	**6**	**11**	**0**	**0**	**0**
Crystal River ISFSI*	**39**	**30**	**0**	**0**	**0**	**0**
Davis-Besse ISFSI*	7	0	0	0	0	0
Diablo Canyon ISFSI	49	0	32	0	0	0
Farley ISFSI	**45**	**22**	**13**	**6**	**0**	**6 (100%)**
Fort Calhoun ISFSI	10	0	0	0	0	0
Ginna ISFSI	10	0	0	0	0	0
Haddam Neck ISFSI*	**40**	**17**	**0**	**0**	**0**	**0**
Hope Creek ISFSI	**27**	**9**	**18**	**4**	**0**	**4 (100%)**
Indian Point ISFSI	**42**	**23**	**14**	**11**	**5**	**6 (55%)**
Kewaunee ISFSI	**38**	**14**	**0**	**0**	**0**	**0**
Maine Yankee ISFSI	**60**	**7**	**2**	**2**	**0**	**2 (100%)**
McGuire ISFSI*	44	0	9	0	0	0
Millstone ISFSI	**31**	**6**	**3**	**0**	**0**	**0**
North Anna ISFSI*	31	0	1	0	0	0
Palisades ISFSI*	46	0	5	0	0	0
Palo Verde ISFSI	152	0	0	0	0	0
Point Beach ISFSI*	44	0	0	0	0	0
Rancho Seco ISFSI*	**21**	**18**	**0**	**0**	**0**	**0**
San Onofre ISFSI*	**123**	**70**	**0**	**0**	**0**	**0**
Seabrook ISFSI	**22**	**4**	**2**	**0**	**0**	**0**
Sequoyah ISFSI*	**54**	**13**	**9**	**1**	**1**	**0 (0%)**
St. Lucie ISFSI	**36**	**9**	**0**	**0**	**0**	**0**
Surry ISFSI*	32	0	0	0	0	0
Trojan ISFSI	**34**	**11**	**0**	**0**	**0**	**0**
Turkey Point ISFSI	18	0	0	0	0	0
Vogtle ISFSI	**26**	**20**	**7**	**6**	**3**	**3 (50%)**
Waterford ISFSI	23	0	1	0	0	0
Yankee Rowe ISFSI	15	0	0	0	0	0
Zion ISFSI	**61**	**39**	**24**	**24**	**0**	**24 (100%)**
Totals:	1,406	348	192	55	9	46
Complete sites only	846	178	168	54	8	46

ISFSI = independent spent fuel storage installation
*Sites missing at least 1 NA-modeled cask

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ACRONYMS

AIC	silver, indium, and cadmium (control rod material)
ANS	American Nuclear Society
ANSI	American National Standards Institute
B&W	Babcock and Wilcox Enterprises, Inc.
BUC	burnup credit
BWR	boiling water reactor
CE	Combustion Engineering Corporation
C/E	calculated vs. experimental
COC	certificate of compliance
COMP	compound systems
CSAS	criticality safety analysis sequence
DB	degraded basket
DHR	decay heat ratio
DOE	US Department of Energy
DPC	dual-purpose canister
ESSM	embedded shelf-shielding method
FAST	fast neutron energy spectrum
GC	General Counsel
GE	General Electric Company
HTC	Haut Taux de Combustion
ICSBEP	International Criticality Safety Benchmark Evaluation Project
IFBA	integral fuel burnable absorber
IFP	iterated fission probability
INTER	intermediate spectrum
ISFSI	independent spent fuel storage installation
JSON	JavaScript Object Notation
LCE	laboratory critical experiment
LWR	light water reactor
MOC	method of characteristics
NA	neutron absorber
NFH	nonfuel hardware
NRC	US Nuclear Regulatory Commission
ORIGAMI	ORIGEN Assembly Isotopics
ORIGEN	Oak Ridge Isotope Generation and Depletion Code
PU	plutonium
PWR	pressurized water reactor
RCCA	rod cluster control assembly
RW	Office of Civilian Radioactive Waste Management
SDF	sensitivity data file
SKB	Swedish Nuclear Fuel and Waste Management Company
SNF	spent nuclear fuel
S/U	sensitivity/uncertainty
TRITON	Transport Rigor Implemented with Time-Dependent Operations for Neutronic depletion
TSC	transportable storage cask
TSCDF	transportable storage cask – damaged fuel
UDB	Unified Database
UNF-ST&DARDS	Used Nuclear Fuel – Storage, Transportation & Disposal Analysis Resource and Data System
VALID	Verified, Archived Library of Inputs and Data
VH	void history
W	Westinghouse Electric Corporation
WABA	wet annular burnable absorber

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UNF-ST&DARDS ENHANCEMENTS FOR RCCA DATA IN AS-LOADED DUAL-PURPOSE CANISTER MODELS

1. INTRODUCTION

This report documents work performed supporting the US Department of Energy (DOE) Nuclear Energy Spent Fuel and Waste Disposition, Integrated Waste Management under work breakdown structure element 1.08.02.04.01, "Commercial SNF Characterization." This report fulfills the M3 milestone M3SF-23OR010305075 "Modeling effect of inserts in DPCs" within work package SF-23OR01030507, "DPC Criticality Modeling and Support - ORNL."

Dual purpose canisters (DPCs) used for storage and transportation of spent nuclear fuel (SNF) are designed and evaluated for approved contents as defined in applicable storage and transportation certificates of compliance (COCs) issued by the US Nuclear Regulatory Commission (NRC). The approved content specifications provide bounding (enveloping) fuel characteristics such as fuel type, fuel dimensions, initial enrichment, discharge burnup, and cooling time. In addition to this fuel characterization, additional information related to fuel inserts is often provided and specified as nonfuel hardware (NFH). The bounding fuel characteristics for a system are developed to establish conservative values of safety analysis parameters for licensing. For certain applicants, credit is taken for NFH like rod cluster control assembly (RCCA) inserts due to their overwhelmingly black reactivity impact.

The tool Used Nuclear Fuel-Storage, Transportation, and Disposal Analysis Resource and Data System (UNF-ST&DARDS) is being developed to perform as-loaded analysis of SNF storage, transportation, and disposal systems. UNF-ST&DARDS provides a comprehensive, unified, domestic SNF system database integrated with analysis tools to perform automated analyses of nuclear safety. These analyses are performed with various depletion and criticality modules in the SCALE suite of codes described by Shaw [1], which is used by UNF-ST&DARDS. Data are collected from open literature or vendor-provided data. The data are verified and incorporated into the Unified Database (UDB) for subsequent use by integrated nuclear safety and systems analysis tools. Data and analysis tool integration is a powerful UNF-ST&DARDS feature that enables assembly- and cask-specific nuclear safety assessments based on actual assembly characteristics of as-loaded SNF (e.g., assembly inserts). All the processes are streamlined within UNF-ST&DARDS using consolidated data from the UDB and a suite of SNF analysis input templates. These data are combined to generate safety analysis code input files by template engine and computational processes tailored for SNF analysis.

The UNF-ST&DARDS post-closure criticality analysis models currently include the bounding fuel characteristics using (1) regular models with no loss of absorber and the basket intact, (2) neutron absorber (NA) models with loss of absorber and the basket intact, or (3) degraded basket (DB) models with loss of absorber and loss of basket. Models do not yet include the negative reactivity impact from as-loaded RCCAs. The DB models are only applicable to sites with basket designs considered likely to experience significant degradation resulting from material considerations. One such site is Zion, and therefore, in this report, the DB models are only applicable to Zion.

A summary of PWR site DPC results from the UDB without RCCAs in the post-closure models is provided in Table 2 which lists the DPCs available in the UDB, along with DPCs containing RCCAs.

Table 2. Summary of UDB Results for PWR sites without RCCAs included in the post-closure models

Site	DPCs	DPCs with RCCAs in UDB	DPCs with RCCAs (not credited) with $k_{eff} > 1$, NA model[a]
Arkansas Nuclear	79	22	0
Byron	26	7	0
Comanche Peak	29	1	1
Cook	29	6	0
Crystal River	39	30	0
Farley	45	22	6
Haddam Neck	40	17	0
Hope Creek (Salem)	56	9	4
Indian Point	42	23	11
Kewaunee	38	14	0
Maine Yankee	60	7	2
Millstone	31	6	0
Rancho Seco	21	18	0
San Onofre	123	70	0
Seabrook	22	4	0
Sequoyah	54	13	1
St. Lucie	36	9	0
Trojan	34	11	0
Vogtle	26	20	6
Zion	61	39	24

While UNF-ST&DARDS can model cask-specific loadings in terms of the as-loaded assembly types, initial assembly average enrichments, burnups, and cooling times given in recent work by Walker [2] demonstrate that further evaluation of the impact from as-loaded absorbers like RCCA inserts should be pursued to reduce the number of DPCs remaining above $k_{eff} > 1$ for the post-closure models. Therefore, this report presents the work completed to date to evaluate DPCs with as-loaded RCCAs.

The data used to perform the UNF-ST&DARDS analyses are taken from the General Counsel (GC) – 859 fuel inventory survey, which provides information related to various fuel assembly inserts of various types, including RCCAs. Evaluation of the impact considering the as-loaded arrangement of RCCAs in the Zion casks by Walker [2] used these data (from the GC-859 data).

The work detailed in this report expands on the approach used by Walker [2] by implementing RCCA models within the UNF-ST&DARDS database framework for select PWR sites. For this work, a Python utility was developed to automate the use of UNF-ST&DARDS, including input generation, execution, and processing. Future work aims to continue developing and testing the utility to provide the UNF-ST&DARDS platform with an automated program to use the insert data in UNF-ST&DARDS templates seamlessly within the UNF-ST&DARDS system while expanding the number of sites evaluated to fully expose the value of including the RCCAs as part of post-closure criticality evaluations.

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[a] Note that not all cases have been evaluated in the UDB and therefore the information in this column does not reflect a complete set of data.

The remainder of this report is organized as follows. Section 2 discusses UNF-ST&DARDS modeling methods and development of new detailed modeling methods, Section 0 compares the Zion inputs generated by the new automated utility and the inputs generated by Walker [2], Section 4 discusses the calculation results for the sites selected specifically for this report, Section 5 discusses the conclusions drawn from the work performed, and Section 6 provides the references cited throughout this work.

2. Feature Development for UNF-ST&NDARDS

This section discusses the modifications that were made to UNF-ST&DARDS to enable this work. The purpose of these modifications are to enable evaluation of the potential impact of fuel RCCAs in the post-closure criticality analysis. After modification, UNF-ST&DARDS has a new analysis flag that, when enabled, will extract the RCCA information from the UDB for a desired DPC evaluation and modify the resulting SCALE input to contain RCCA geometry in the locations specified in the UDB. From there, UNF-ST&DARDS can proceed as usual for criticality calculations.

For this work, a Python utility was created to drive UNF-ST&DARDS. The utility can create the JavaScript Object Notation (JSON) input files for UNF-ST&DARDS, automatically run UNF-ST&DARDS, and extract model and criticality information for table and plot creation.

The Python utility has the following features:

- Connects to the UDB directly, allowing automatic extraction of the data contained therein, which can be filtered or sorted as needed.
- Identifies DPCs containing PWR fuel in the UDB and the locations in the DPCs with RCCAs with the UDB variable *non_fuel_component_type*, which includes a string representation of any insert (e.g., "PWR – Control Rods").
- Lists the assembly types with RCCA inserts, identifying the UNF-ST&DARDS template files that needed modification for this work
- Creates JSON input files for UNF-ST&DARDS, which include the additional parameter *add_inserts*, which is used in the modified template files to selectively insert RCCA geometry into the models.
- Processes the model results across sites, casks, and parameters by forming a Pandas DataFrame containing the results.
- Creates plots, tables, and other comparisons based on the results' DataFrame.

2.1 UNF-ST&DARDS Program Flow

This section discusses the overall flow of information, codes, and methods used by UNF-ST&DARDS to perform safety analysis for SNF canisters in their as-loaded RCCA configurations to provide context for the detailed analysis in the remainder of the report. The safety analysis processes are initiated by entering a canister identifier and analysis date into UNF-ST&DARDS. The canister identifier provides UNF-ST&DARDS with the information necessary to retrieve the relevant assembly identifiers from the UDB's assembly inventory. The assembly identifiers are then used to look up the necessary Oak Ridge Isotope Generation and Depletion Code (ORIGEN) libraries, irradiation histories, and geometric information for the assemblies in the canister and form the discharge, decay, and criticality JSON parameter sets. The assembly-specific ORIGEN libraries and irradiation information from the discharge concentration JSON parameter set are used to expand the ORIGEN Assembly Isotopics (ORIGAMI) depletion template to generate axial segmented, node-wise, assembly-specific discharge concentrations. UNF-ST&DARDS then passes discharge concentrations to the ORIGAMI decay template, along with analysis-specific decay data (e.g., analysis date and assembly discharge date) from the decay JSON parameter set, to produce the necessary isotopic concentrations for criticality analysis.

The next step in the UNF-ST&DARDS analysis process is to generate as-loaded canister safety analysis models. The safety analysis models are created by pairing the base canister template—which contains the basic fuel basket geometry specification for the appropriate safety analysis code (criticality safety analysis sequence [CSAS] for criticality analysis, MAVRIC for dose assessment, or COBRA-SFS for thermal analysis)—with a safety analysis JSON that specifies the fuel materials, geometry, arrays, and decay heat or radiation sources necessary to complete the model. The safety analysis model is then executed to produce the desired safety analysis parameters (e.g., k_{eff}, peak clad temperature, dose rate). These parameters are then used to calculate the margin to the licensing basis. Figure 1 provides a diagram of the UNF-ST&DARDS safety analysis using criticality analysis as an example.

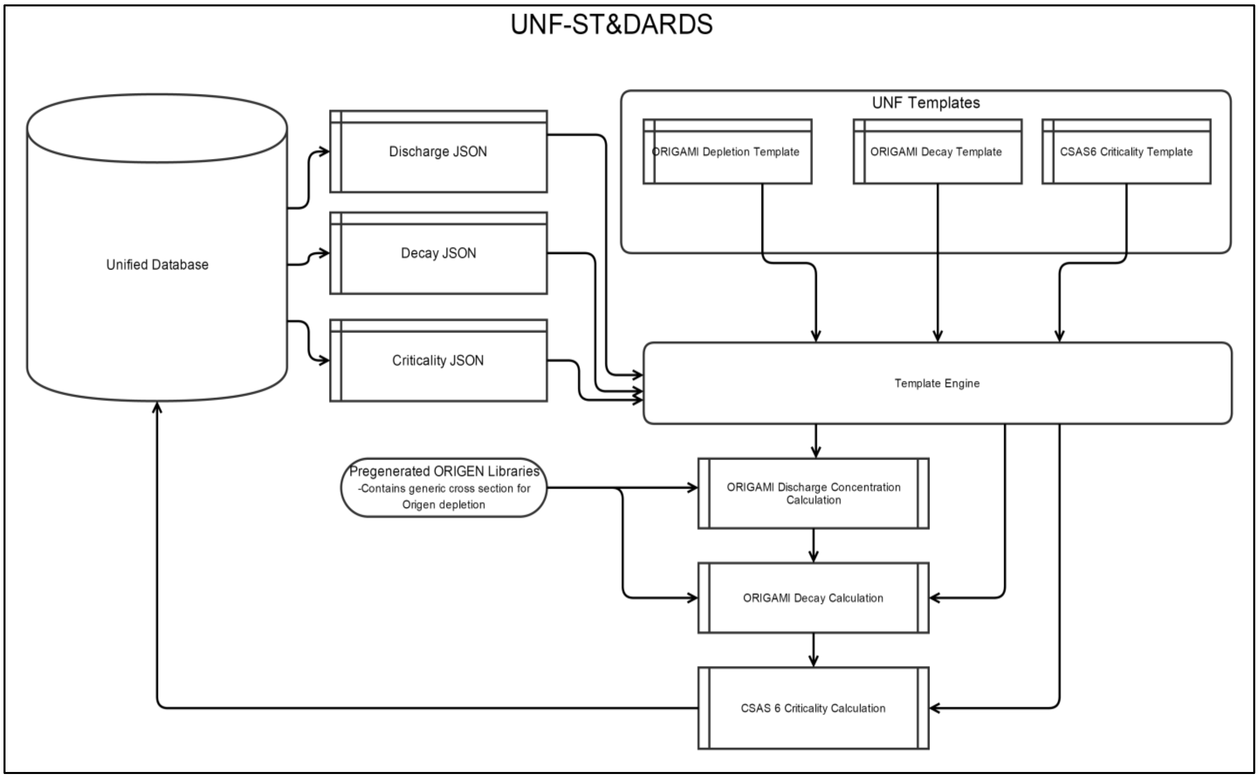

Figure 1. Safety (criticality) analysis process within UNF-ST&DARDS.

2.2 Modifications to UNF-ST&NDARDS

For this work, modifications were made to the UNF-ST&DARDS CSAS6 template files appearing in the upper right corner of Figure 1. For select assembly types, a conditional statement was implemented into the template files for the guide tubes which would switch the modeled geometry in the resulting CSAS6 input file. The templates were modified to allow setting all guide tubes within a single assembly in a DPC to either be empty (i.e., filled with water) or filled with the RCCA model discussed in Section 2.4.

Generation of the CSAS6 input files for this work was driven by the criticality JSON files shown in Figure 1. This file contains information such as the cask name, depletion date, and other parameters defining the run. Among these parameters are *additional_parameters*, which was used in this work to pass a new parameter called *add_inserts* into the template engine. If *add_inserts* were false, then the modified template files would keep the original functionality. However, if *add_inserts* were set to true, then the guide tube geometry would be switched to using a filled guide tube in an assembly within a DPC if the UDB reported RCCAs present in that assembly.

The modified template files and JSON files defining the casks were used to create a CSAS6 input file for each cask in the UDB with RCCAs. The CSAS6 files were used to evaluate the criticality impact of including RCCAs within the cask models by comparing the criticality with and without the inserts.

The only inserts considered in this work were RCCAs. In the UDB, an assembly containing RCCAs would have the variable *non_fuel_component_type.type* set to "P–WR - Control Rods." In this work, all other values for this variable were ignored, resulting in the empty (water-filled) guide tube geometry. The template modification framework used for this work can easily be adapted for other types of inserts. For example, geometry modifications for other/additional values of *non_fuel_component_type.type* such as "BWR/P–R - Burnable Absorbers" could be implemented simply by expanding the conditional within the modified template files.

2.3 PWR Fuel Assembly Template Updates

The template files modified for this work are provided in Table 3. These templates are in the *UNF-Templates/cask/assembly_types* directory, which contains subdirectories corresponding to each assembly type. Each subdirectory includes templates used for modeling that assembly type. For example, the W1515WL assembly directory contains a template for the guide tube, the node, and the pin array. In this work, only the guide tube templates were modified.

Table 3. Summary of fuel templates modified

UDB fuel type (*generic_assembly_type*) [4]
W1515WL
W1717WL
W1717WO
W1414WL
B1515B4
C1414W
XHN15WZ
XHN15B
C1414A
C1414C
C8016C
XHN15BZ
XHN15W

As mentioned in the previous section, a variable called *add_inserts* was created in the criticality JSON which triggered the change in the guide tube template file. Specifically, a conditional block such as Listing 1 was used in each modified template file to control the geometry switch.

Listing 1. Example depiction of the template modifications

```
#ifdef add_inserts
  #ifdef #eval("<non_fuel_component_type.type>" == "PWR -  Control Rods")#
    Define the RCCA insert
  #endif
  #ifndef #eval("<non_fuel_component_type.type>" == "PWR -  Control Rods")#
    Define the water-filled guide tube
  #endif
#endif
#ifndef add_inserts
  Define the water-filled guide tube
#endif
```

In addition to the modified assembly templates, a minor change was made to the *UNF-Templates/cask/general_templates/assembly_materials* file which controls the materials used in the criticality input file. This file was modified to include materials for the RCCA inserts, which included a blend of 80% silver, 15% indium, and 5% cadmium, or AIC, and type 304 stainless steel was used for the rod casing. This is consistent with the material used by Walker [2].

2.4 RCCA Data

For consistency with previous work done by Walker [2], the RCCA designs used for this effort were in the same geometry as used previously for the Zion models. The RCCA geometry used in this work is given in Table 4. For this model, the material was a mixture of silver, indium, and cadmium (AIC).

Table 4. Summary of PWR RCCA Parameters (Walker [2])

Parameter/reactor type	B&W PWR
Material	Silver-Indium-Cadmium
Silver content, wt%	80
Indium content, wt%	15
Cadmium content, wt%	5
Poison outer diameter, cm	0.9906
Clad inner diameter, cm	1.01728
Clad outer diameter, cm	1.11506
Clad material	304 SS
Poison density, g/cc	5.09

Although the UDB contains the guide tube radii for all assembly types, it does not yet contain the RCCA insert design specific to each site and fuel design. However, as shown in Table 5, all guide tube radii for the assembly types considered in this work were larger than the AIC inserts. Future work should make additional changes to the template framework to include RCCA designs specific to each fuel type for each

DPC, as it is likely that many assembly types would have inserts of different sizes and material compositions which should be evaluated.

Table 5. Summary of assembly type inner radii (IR) site [4]

UDB fuel type (*generic_assembly_type*)	**Site(s)**	**UDB guide tube IR (*guide_tube_IR*) (cm)**
W1515WL	Cook, Indian Point, Robinson, Surry, Turkey Point, Zion	0.65024
W1717WL	Beaver Valley, Catawba, Comanche Peak, Diablo Canyon, Farley, McGuire, Millstone, North Anna, Salem, Seabrook, Sequoyah, Summer, Trojan, Vogtle, Watts Bar,	0.5715
W1717WO	Beaver Valley, Braidwood, Byron, Callaway, Comanche Peak, Cook, Diablo Canyon, Farley, McGuire, North Anna, Salem, Summer, Vogtle, Watts Bar	0.56134
W1414WL	Ginna, Kewaunee, Point Beach, Prairie Island	0.62484
B1515B4	Arkansas, Crystal River, Davis-Besse, Oconee, Rancho Seco	0.63246
C1414W	Maine Yankee, Millstone	1.31445
XHN15WZ	Haddam Neck	0.63246
XHN15B	Haddam Neck	0.63246
C1414A	Maine Yankee, Millstone, St Lucie	1.31445
C1414C	Calvert Cliffs, Fort Calhoun, Maine Yankee, Millstone, St Lucie	1.31445
C8016C	Arkansas, Palo Verde, San Onofre, St Lucie, Waterford	1.143
XHN15BZ	Haddam Neck	0.63246
XHN15W	Haddam Neck	0.63246

Although many control rod materials could be considered (e.g., B_4C), AIC was chosen for this work to maintain consistency with the previous study. Criticality control rods are all strong neutron absorbers and have similar effects on criticality. Therefore, this work did not verify the type of RCCA used for a given DPC because the insert material was not included in the version of the UDB used for this work. Future studies should evaluate the impact of different insert materials which could also be added to the UDB.

3. Comparison of the Walker [2] Zion ISFSI Results

As part of the development of the utility, results for the Zion site were generated and compared to previous work completed by Walker [2]. In contrast to the previous work, the approach presented here used the UNF-ST&DARDS framework to manage model generation, including the RCCA inserts. The results from Walker [2] externally managed insert additions to UNF-ST&DARDS. Therefore, agreement with the previous study is expected for this section.

The comparison of the Walker [2] results to the utility-generated results show good agreement as seen in Figure 2 for the NA models and Figure 3 for the DB models. The slight discrepancies between the two methods likely result from the fact that the previous work included minor burnable absorbers (e.g., Pyrex) in the model, in addition to RCCAs, whereas the present work only considered RCCA inserts.

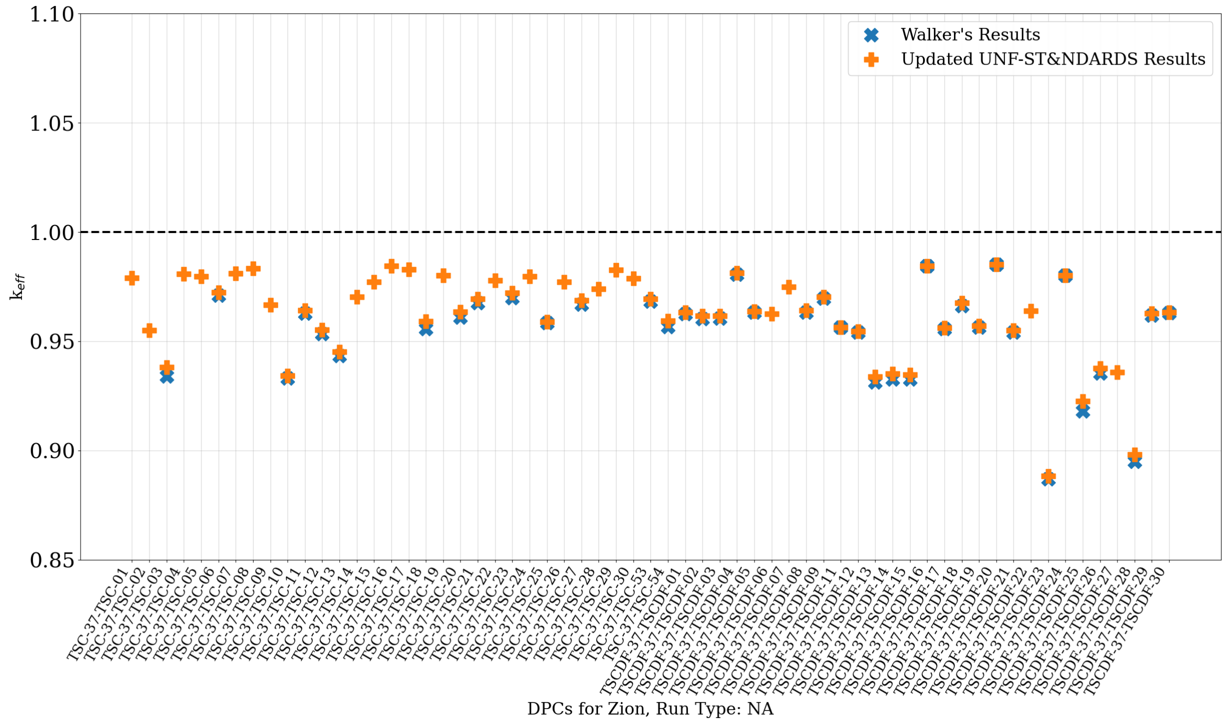

Figure 2. Comparison of the utility-generated models with the Walker [2] NA models.

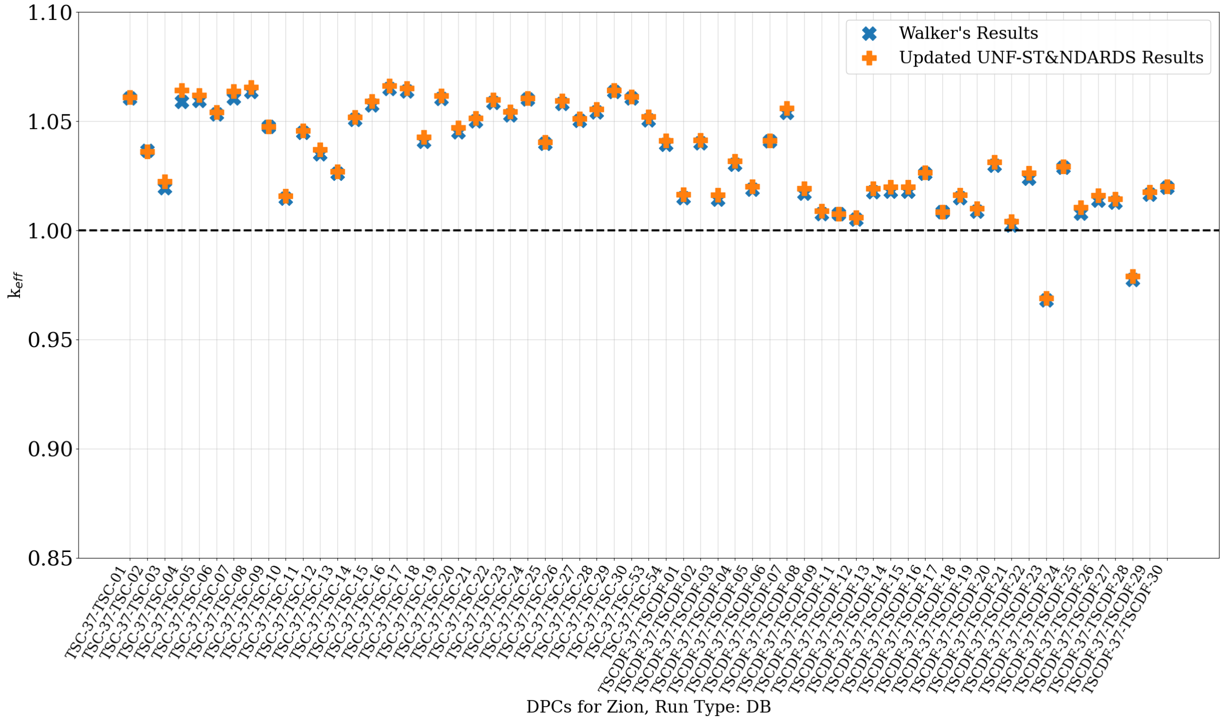

Figure 3. Comparison of the utility-generated models with the Walker [2] DB models.

The Zion site uses the NAC MAGNASTOR transportable storage cask (TSC) [5], which is listed as the TSC damaged fuel (TSCDF)-37 under *canister_type* in the UDB. The utility-generated standalone results for Zion are shown in Figure 4 and Figure 5. These figures compare the criticality of the models generated with and without inserts (i.e., *add_inserts*=True, and *add_inserts*=False). The results for the NA models show that when crediting RCCA negative reactivity, all Zion site DPC casks are subcritical for the NA case. However, for the DB case, most DPCs remain critical, albeit at a lower criticality than without the RCCA credit. Table 7 in the appendix enumerates the same data to provide easier comparison between individual Zion DPCs to determine specifically which DPCs benefit from inclusion of the RCCAs.

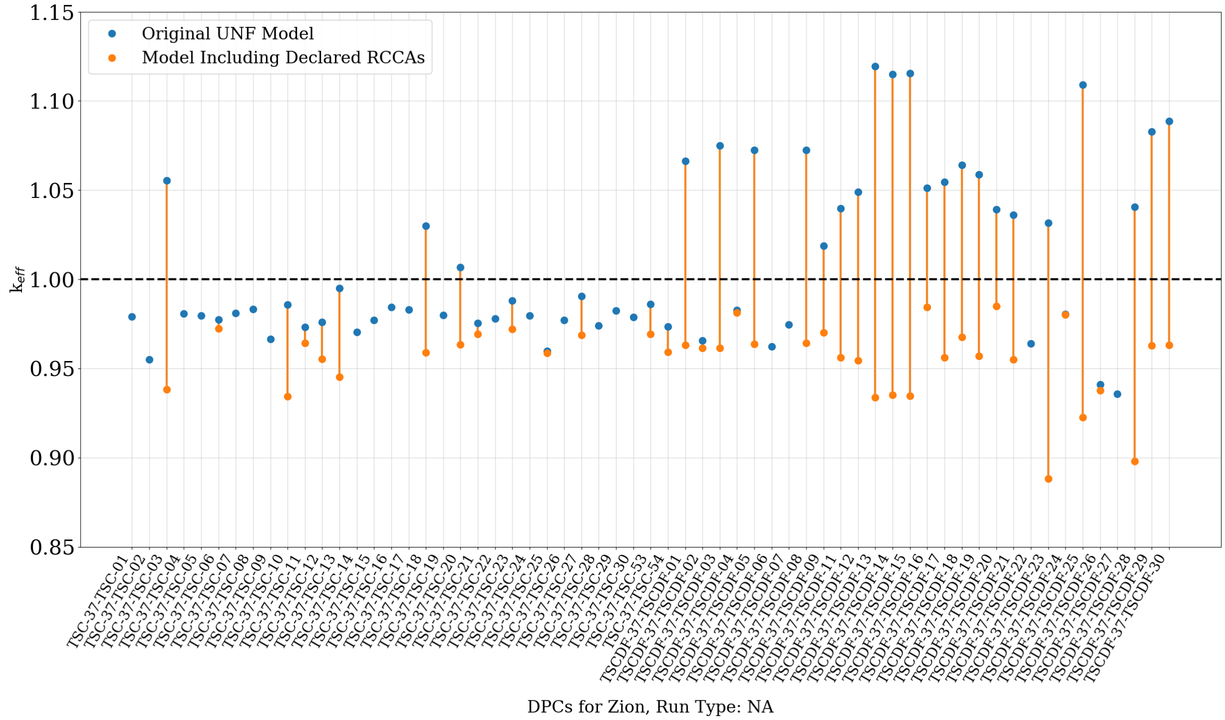

Figure 4. Criticality comparison for Zion DPCs for the NA models with and without RCCAs.

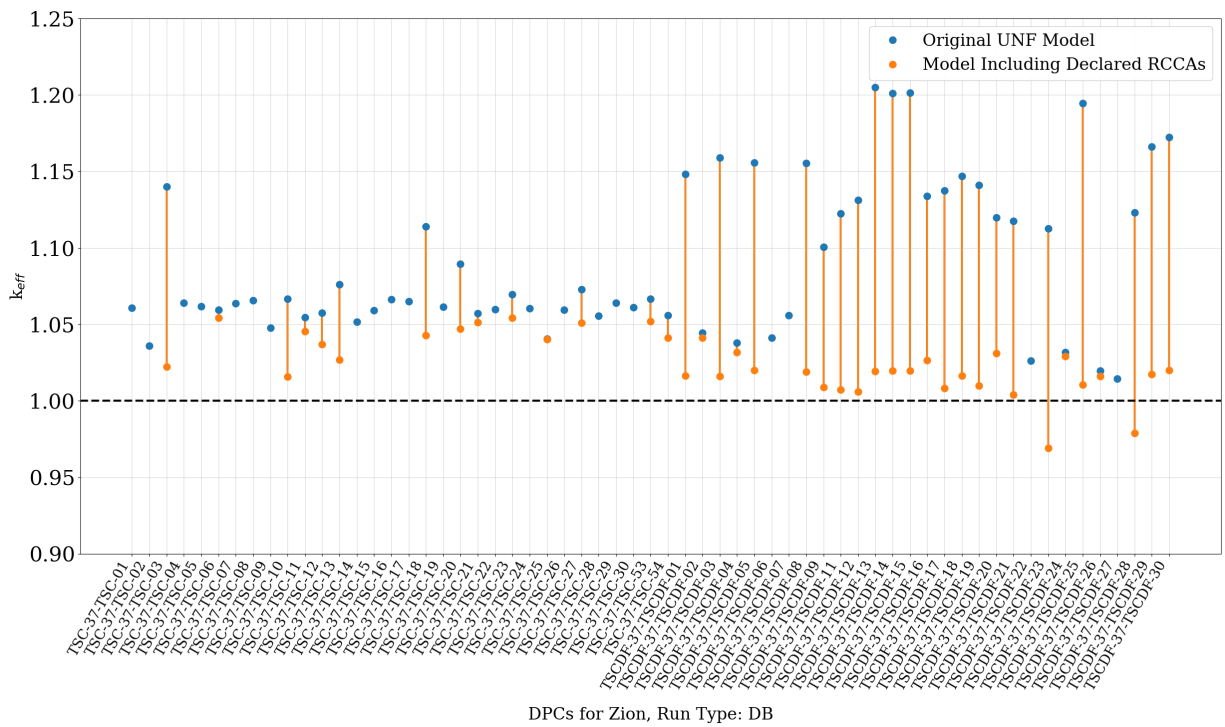

Figure 5. Criticality comparison for Zion DPCs for the DB models with and without RCCAs.

4. Additional Site Calculations and Results

This section provides calculation results performed following the approach outlined in Section 2 for template modification and utility integration with the UDB platform for additional sites. For each DPC with as-loaded RCCAs included in the UDB, the NA models were generated for selected sites utilizing the modified fuel assembly templates. The reactivity of these casks was evaluated with and without RCCA inserts within the UDB framework. All results in this section used the NA model, which is a post-closure scenario model which assumes a complete loss of neutron absorber from the DPC basket. In this section, plots representing the comparisons are presented, and tabulated data are presented in the appendix corresponding to each site. This section presents the order of sites containing the most critical DPCs; it excludes sites without RCCA inserts in their DPCs.

4.1 Seabrook ISFSI

The Seabrook site uses the TRANSNUCLEAR[b] NUHOMS 32PTH system [6]. Results for Seabrook are shown in Figure 6. Results with $k_{eff} > 1$ do not have as-loaded RCCA data in the UDB. These results are tabulated in Table 11.

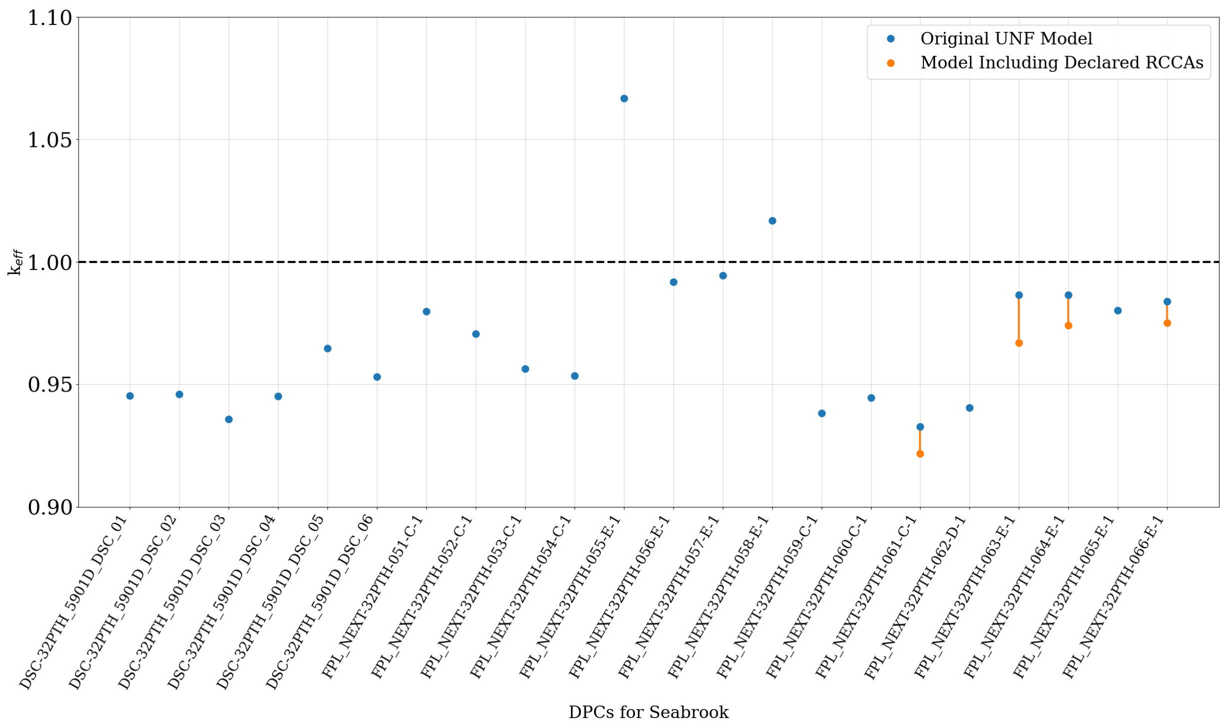

Figure 6. Criticality comparison for Seabrook DPCs for the NA models with and without RCCAs.

[b] Now Orano TN.

4.2 Indian Point ISFSI

The Indian Point ISFSI uses the Holtec International HI-STORM 100 MCP-32 system [7]. Results for Indian Point are shown in Figure 7. There is a total of 14 critical DPCs, with 11 of them containing RCCAs, and 6 of the 11 were brought to a subcritical level. These results are tabulated in Table 12 and Table 13.

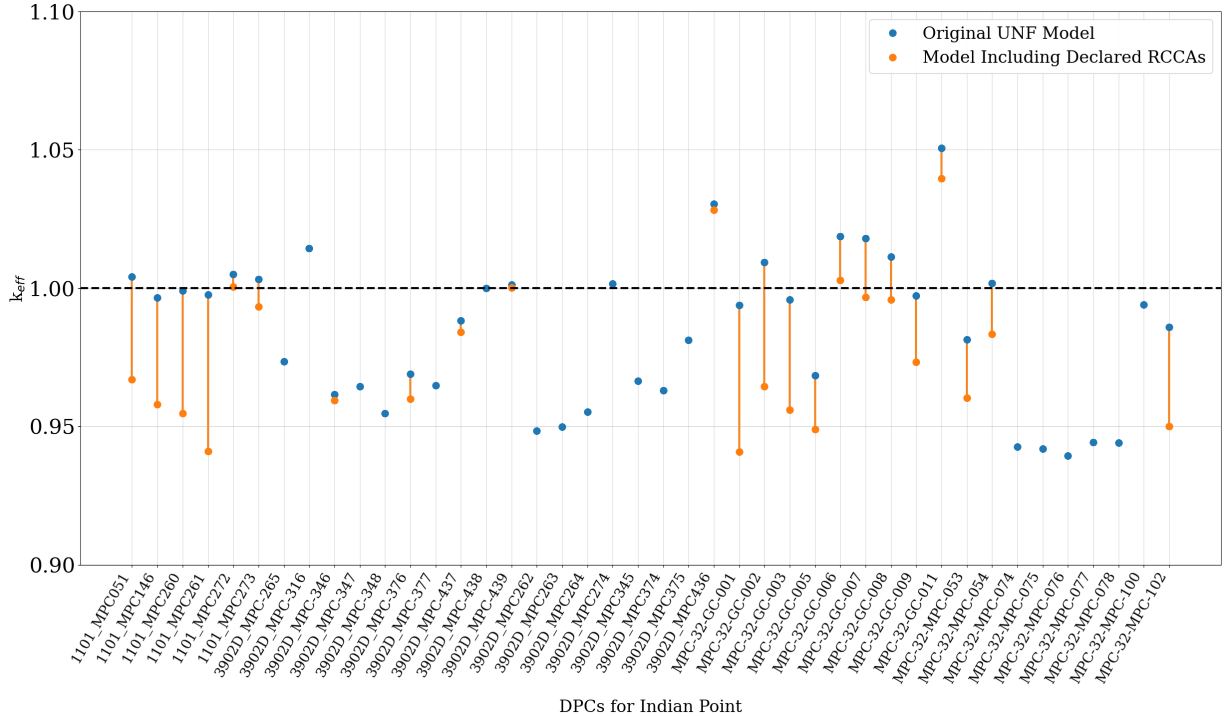

Figure 7. Criticality comparison of Indian Point DPCs for NA models with and without RCCAs.

4.3 Comanche Peak ISFSI

The Comanche Peak ISFSI uses the Holtec International HI-STORM 100 MCP-32 system [7] . Results for Comanche Peak are shown in Figure 8. 24 DPCs are supercritical, but only one has RCCA inserts, and this one was brought subcritical. These results are tabulated in Table 14.

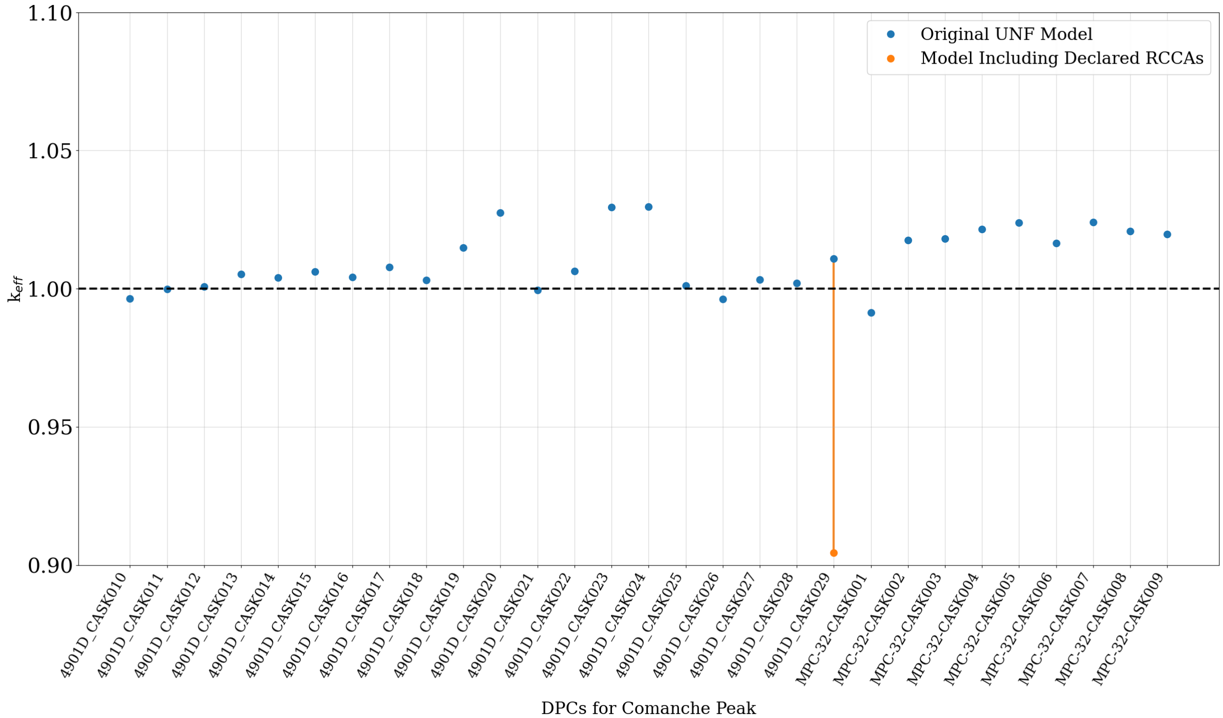

Figure 8. Criticality comparison of Comanche Peak DPCs for NA models with and without RCCAs.

4.4 Farley ISFSI

The Farley site uses the Holtec International HI-STORM 100 MPC-32 System [7]. Results for Farley are presented in Figure 9. Results for the NA models show that many of these DPCs have k_{eff} less <1 when the RCCAs are not included in the models. Results with k_{eff} >1 do not have RCCAs. These results are also tabulated in Table 15 and Table 16.

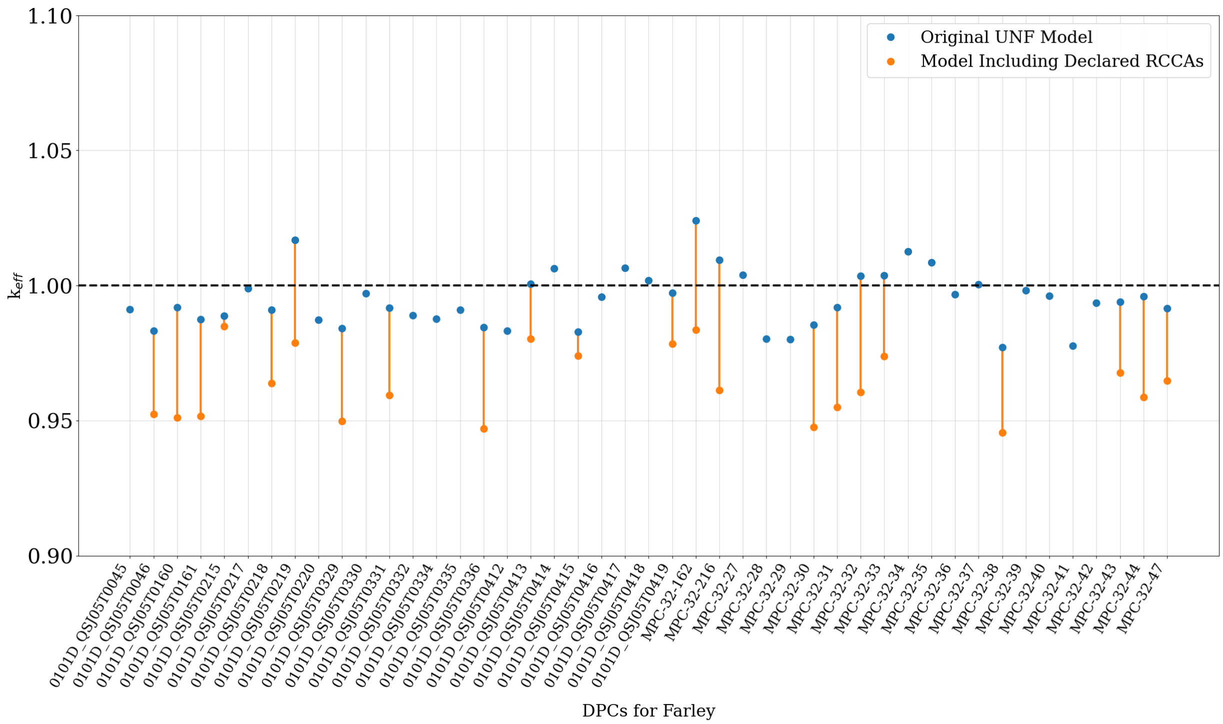

Figure 9. Criticality comparison of Farley DPCs for NA models with and without RCCAs.

4.5 Sequoyah ISFSI

The Sequoyah ISFSI uses two cask systems, the Holtec International HI-STORM 100 MCP-32 system and HI-STORM FW MCP-37 system [7] but only MPC-32 system results are shown in Figure 10. Only one supercritical DPC contains an RCCA, and it was not brought to a k_{eff} <1. These results are tabulated in Table 17 and Table 18.

For the Sequoyah ISFSI, UNF-ST&DARDS was unable to create a SCALE input for 10 DPCs because of the missing NA model templates. These were all the DPCs with *canister_type* MPC-37 and *canister_id* 4808D_MPCFW-11, in which the ID numbers—the last two numbers of the *canister_id*—range from -11 to -16 and -39 to -42.

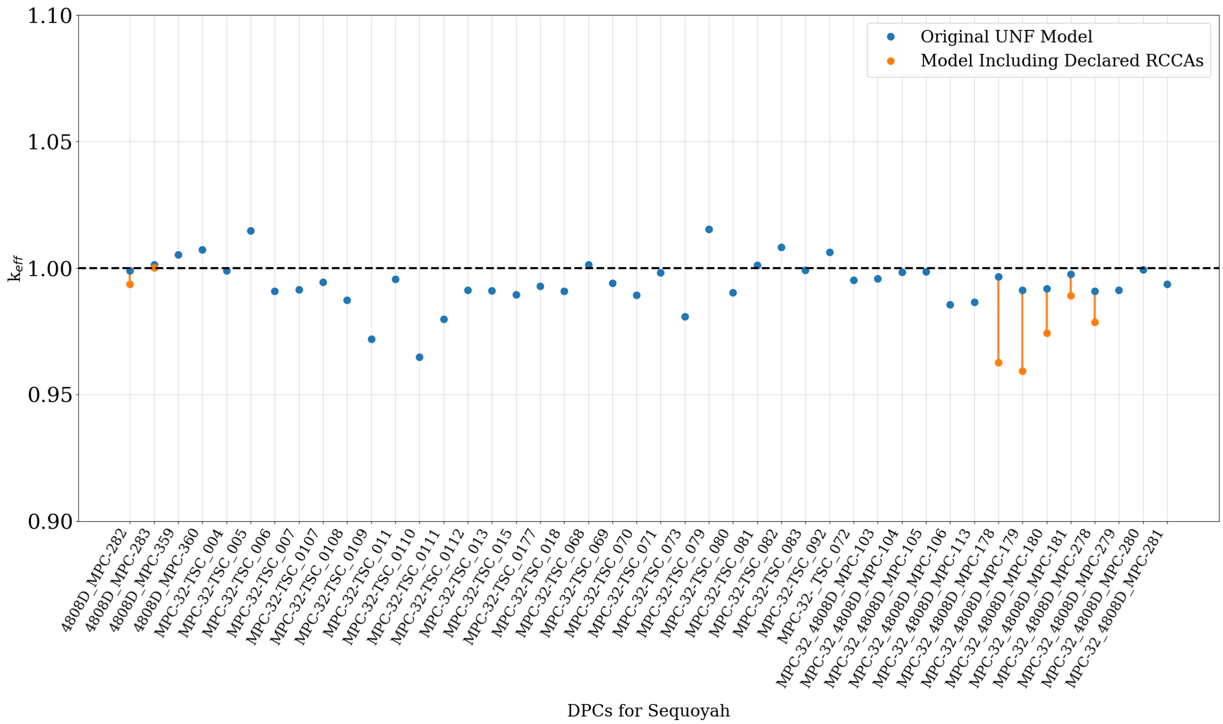

Figure 10. Criticality comparison of Sequoyah DPCs for NA models with and without RCCAs.

4.6 Vogtle ISFSI

The Vogtle site uses the Holtec International HI-STORM 100 MPC-32 system [7]. Results for Vogtle are shown in Figure 11. The results for the NA models show that there are 7 sites with a k_{eff} greater >1, 6 of which contain as-loaded RCCAs, and 3 which were subcritical when the RCCAs were credited. These results are also tabulated in Table 19.

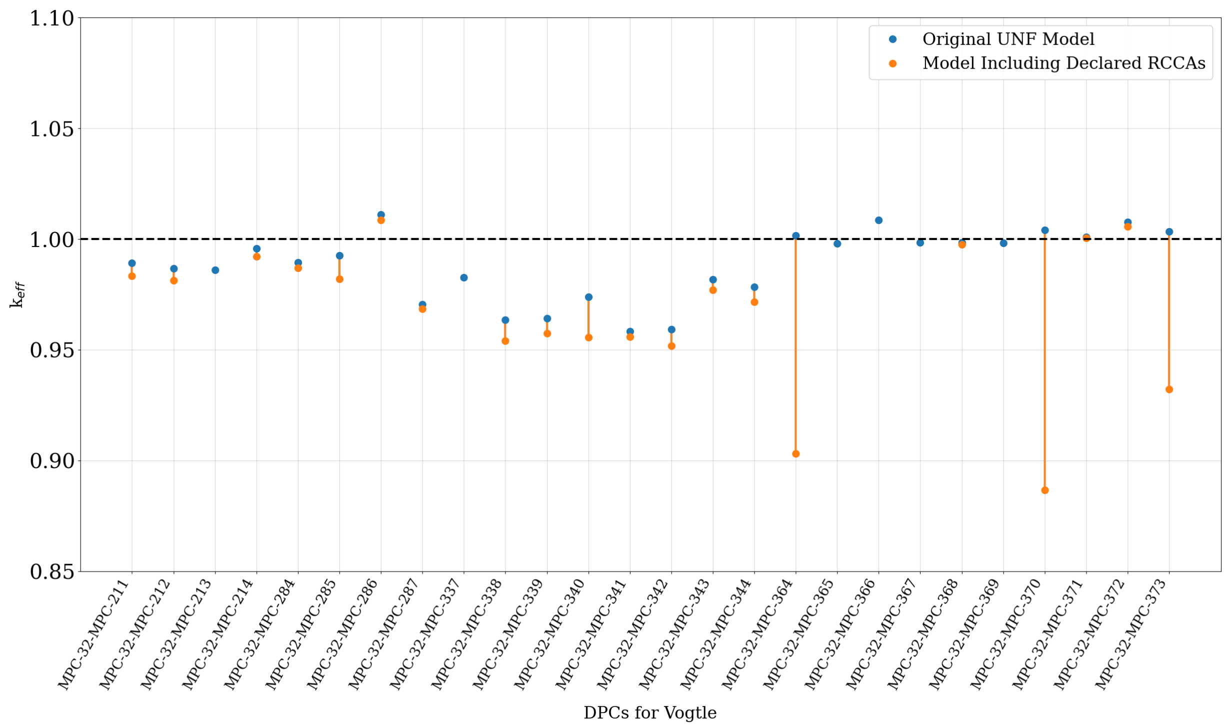

Figure 11. Criticality comparison of Vogtle DPCs for the NA models with and without RCCAs.

4.7 Maine Yankee ISFSI

The Maine Yankee ISFSI uses the NAC-UMS UMS-PWR system [7. Results for Maine Yankee are shown in Figure 12. The two supercritical sites with as-loaded RCCAs were both brought to subcritical levels. These results are tabulated in Table 20 and Table 21.

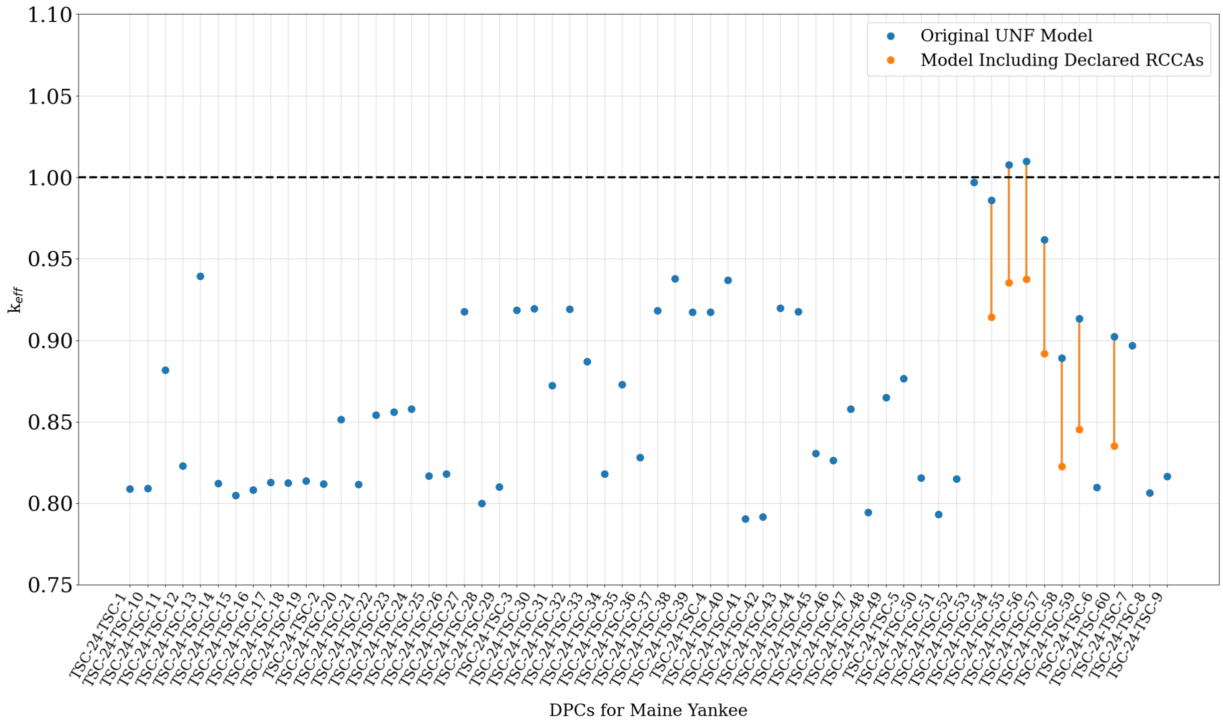

Figure 12. Criticality comparison of Maine Yankee DPCs for the NA models with and without RCCAs.

4.8 Haddam Neck ISFSI

The Haddam Neck[c] ISFSI uses two cask systems, but only the results for the NAC-MPC CY-MPC 26 Assy [7] system are shown in Figure 13. There are no sites with a k_{eff} greater than 1. These results are tabulated in Table 22.

For the Haddam Neck ISFSI, UNF-ST&DARDS was unable to create a SCALE input for three DPCs because of missing NA model templates. These were all DPCs with *canister_type* CY-MPC24 and *canister_id* CY-MPC24-TSC-38 in which the ID numbers—the last two numbers of the *canister_id*—range from -38 to -40.

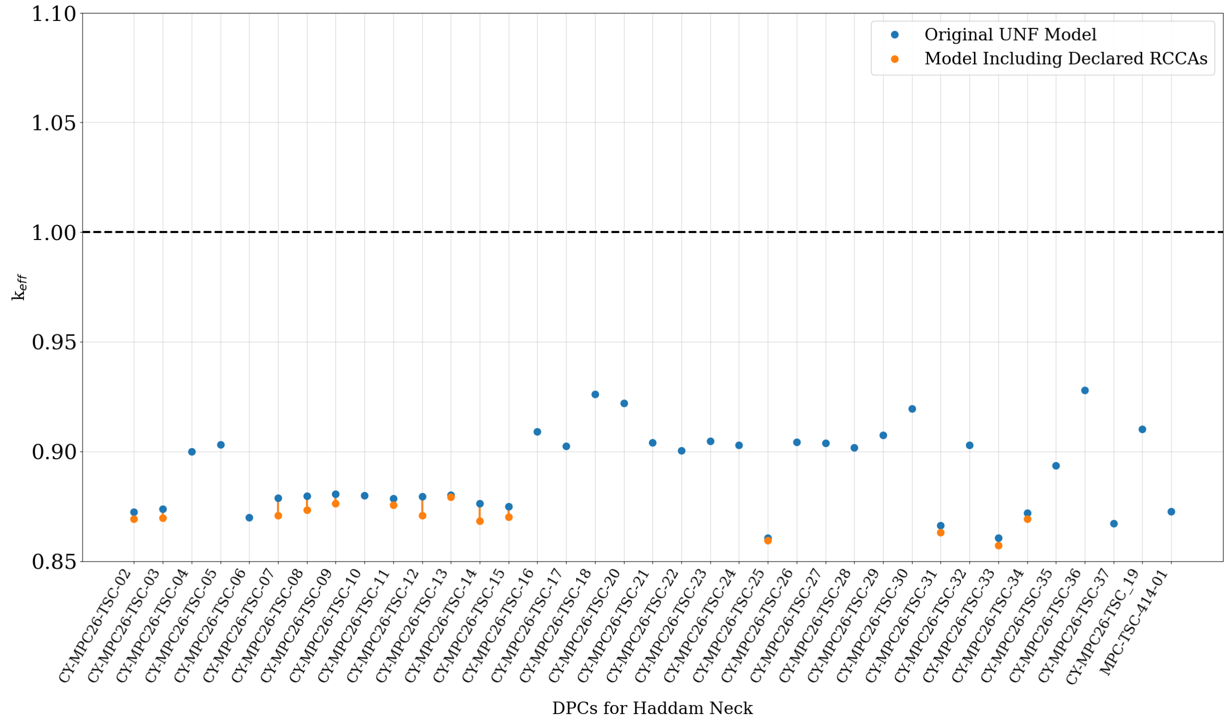

Figure 13. Criticality comparison of Haddam Neck DPCs for NA models with and without RCCAs.

[c] Connecticut Yankee [7].

4.9 Cook ISFSI

The Cook site uses the Holtec International HI-STORM 100 MPC-32 system [7]. Results for Cook are shown in Figure 14. Results from the NA models show that 11 DPCs are supercritical, but none of these contain RCCAs. The 6 DPCs that do have as-loaded RCCAs are all subcritical. These results are also tabulated in Table 23.

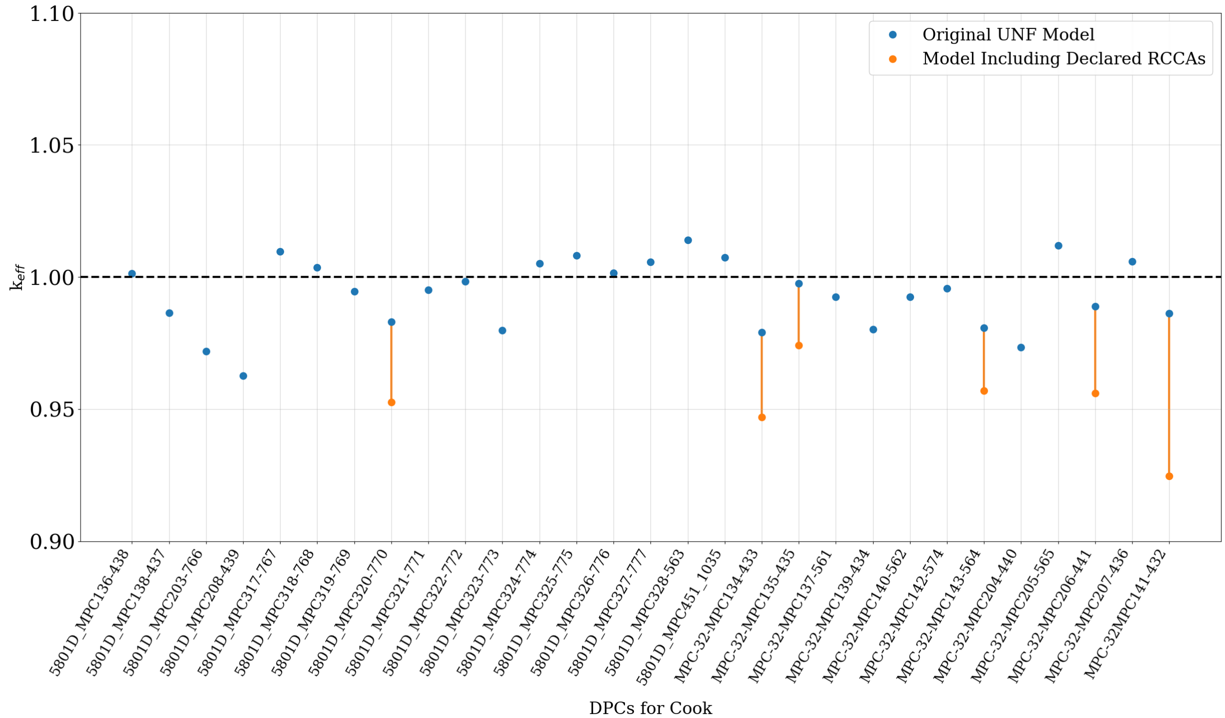

Figure 14. Criticality comparison of Cook DPCs for NA models with and without RCCAs.

4.10 Byron ISFSI

The Byron ISFSI uses the Holtec International HI-STORM 100 MPC-32 system [7]. Results for Byron are shown in Figure 15. Results from the NA models show that one DPC is supercritical and has no as-loaded RCCAs. The 7 DPCs that do have as-loaded RCCAs are all subcritical. These results are tabulated in Table 24.

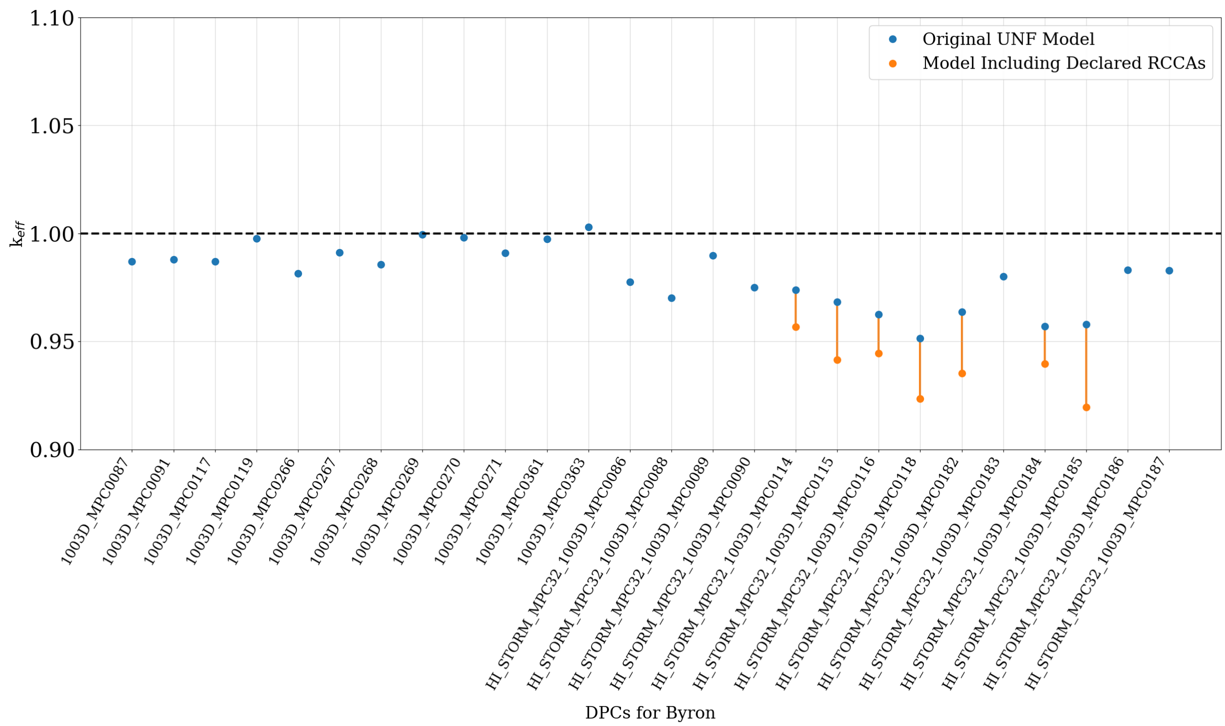

Figure 15. Criticality comparison of Byron DPCs for NA models with and without RCCAs.

4.11 Crystal River ISFSI

The Crystal River ISFSI uses the NUHOMS 32PTH1-L system [6]. Results for Crystal River are shown in Figure 16. All DPCs on site are subcritical. These results are tabulated in Table 25.

For the Crystal River ISFSI, UNF-ST&DARDS was unable to create a SCALE input for one DPC, CR3-32PTH1-L-2C-W-30, because there was no NA model template available.

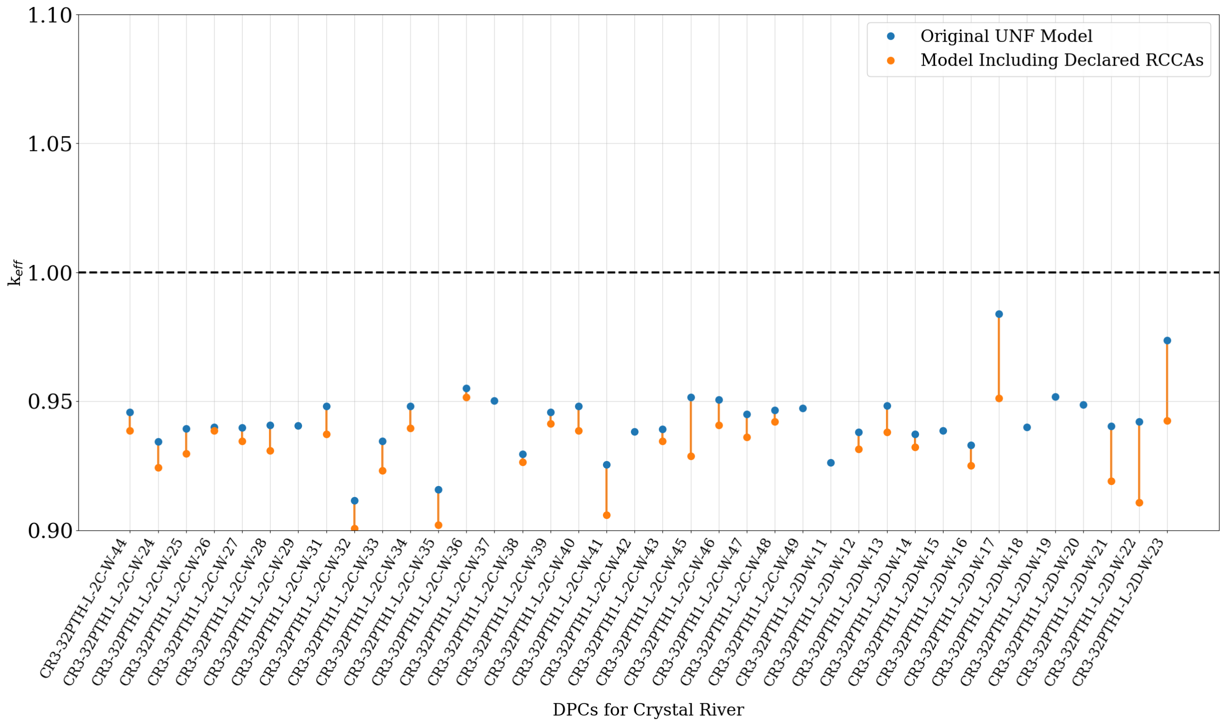

Figure 16. Criticality comparison of Crystal River DPCs for NA models with and without RCCAs.

4.12 Kewaunee ISFSI

The Kewaunee ISFSI uses three NUHOMS systems [6, 7]**:** NUHOMS 32PT-S100, TSC-37, and TSCDF-37. Results for Kewaunee are shown in Figure 17. All DPCs on site are subcritical. These results are tabulated in Table 26.

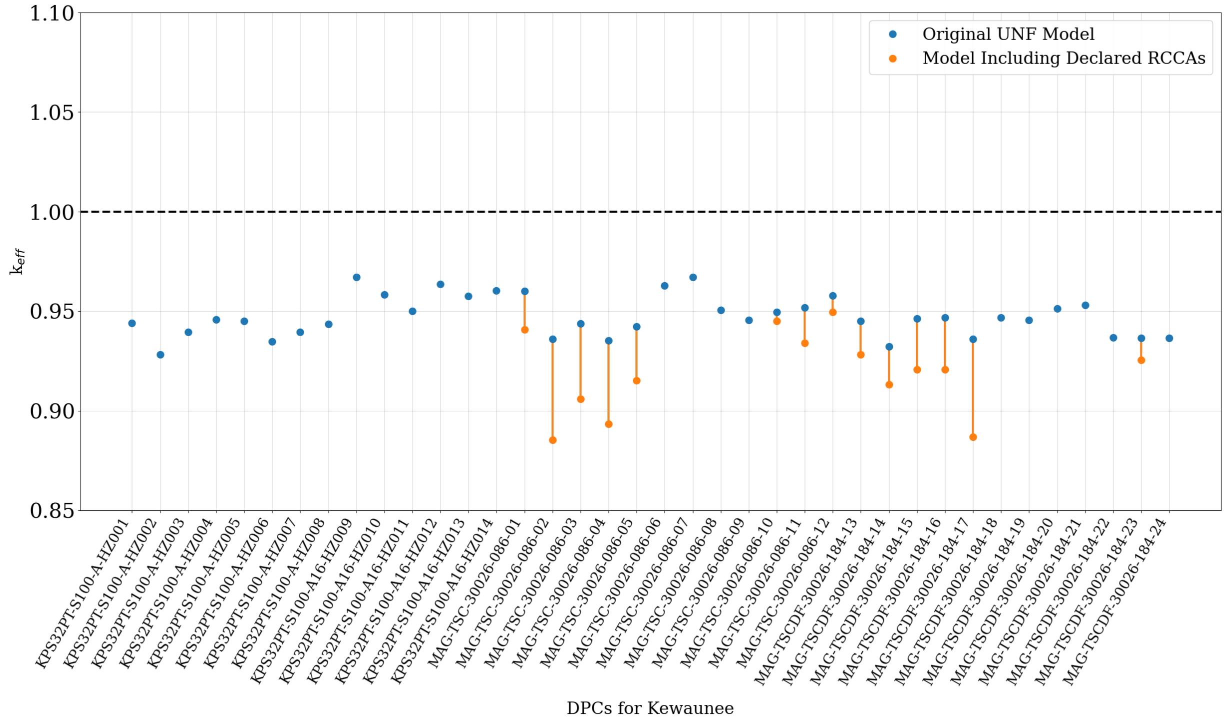

Figure 17. Criticality comparison of Kewaunee DPCs for NA models with and without RCCAs.

4.13 Arkansas Nuclear ISFSI

The Arkansas Nuclear ISFSI uses three cask systems [7] the EnergySolutions Spent Fuel Division MSB-Long system, the Holtec International HI_STORM MPC-24 system, and the Holtec International HI_STORM MPC-32 system. Results for Arkansas Nuclear ISFSI are shown in Figure 18. All DPCs on site are subcritical. These results are tabulated in Table 27 and Table 28.

For the Arkansas Nuclear ISFSI, UNF-ST&DARDS was unable to create a SCALE input for 24 DPCs because the NA model templates were missing. These were all the DPCs with *canister_type* MSB-Long, *canister_id* VSC-24-MSB-01, in which the ID—the last two numbers of the *canister_id*—ranges from -01 to -24.

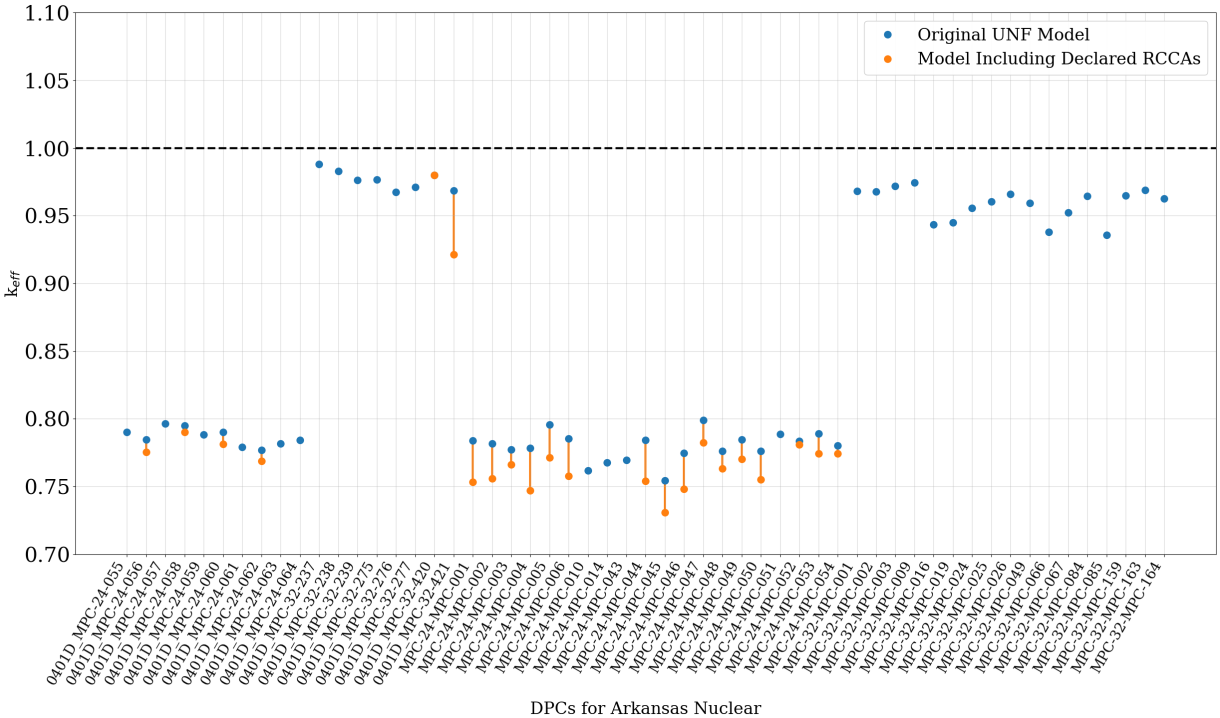

Figure 18. Criticality comparison of Arkansas Nuclear DPCs for NA models with and without RCCAs.

4.14 Millstone ISFSI

The Millstone site uses two standardized NUHOMS systems [7], the NUHOMS 32PT-S100 and the NUHOMS 32PT-L125. Results for Millstone are shown in Figure 19. Results for the NA models show that all but three of these DPCs are subcritical. The DPCs with k_{eff} >1 do not have as-loaded DPCs. These results are tabulated in Table 29.

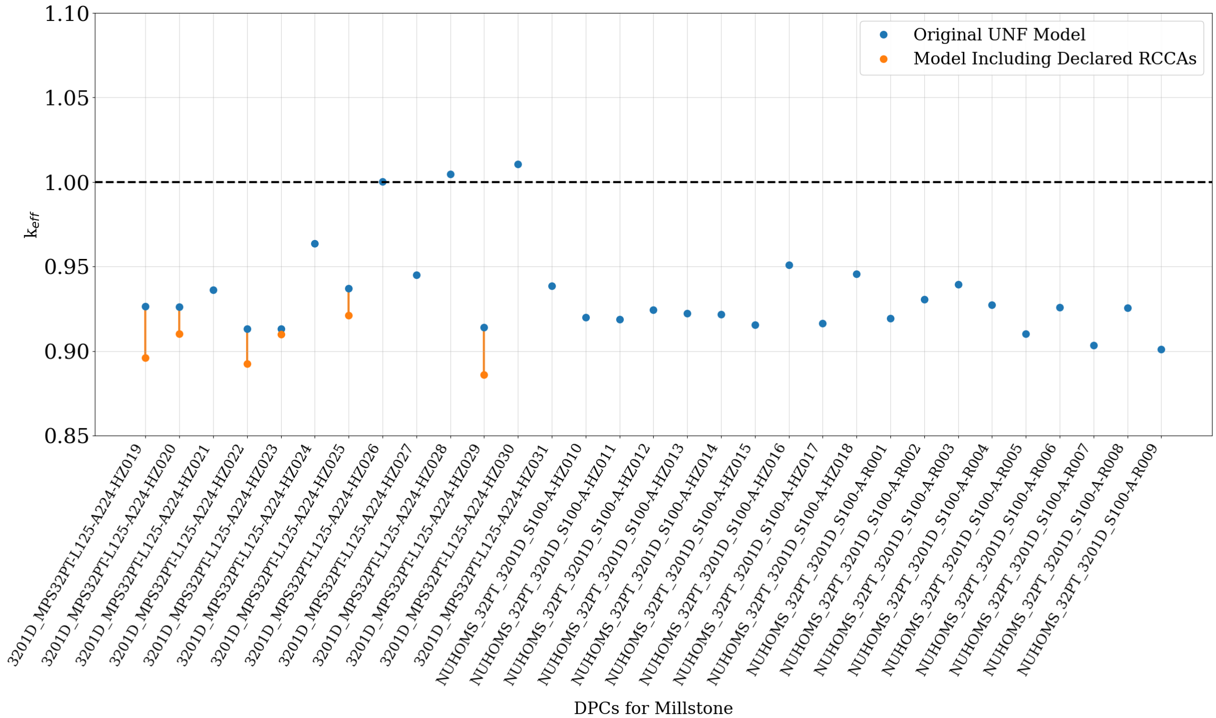

Figure 19. Criticality comparison of Millstone DPCs for NA models with and without RCCAs.

4.15 Rancho Seco ISFSI

The Rancho Seco ISFSI uses three standardized NUHOMS systems [7]: the FC-DSC system, the FO-DSC system, and the FF-DSC system. Results for Rancho Seco are shown in Figure 20. All DPCs on site are subcritical. These results are tabulated in Table 30.

For the Rancho Seco ISFSI, UNF-ST&DARDS was unable to create a SCALE input for one DPC, FF-DSC-FF13P-R21, because NA model template was available. This was the only FF-DSC *canister_type* for the site.

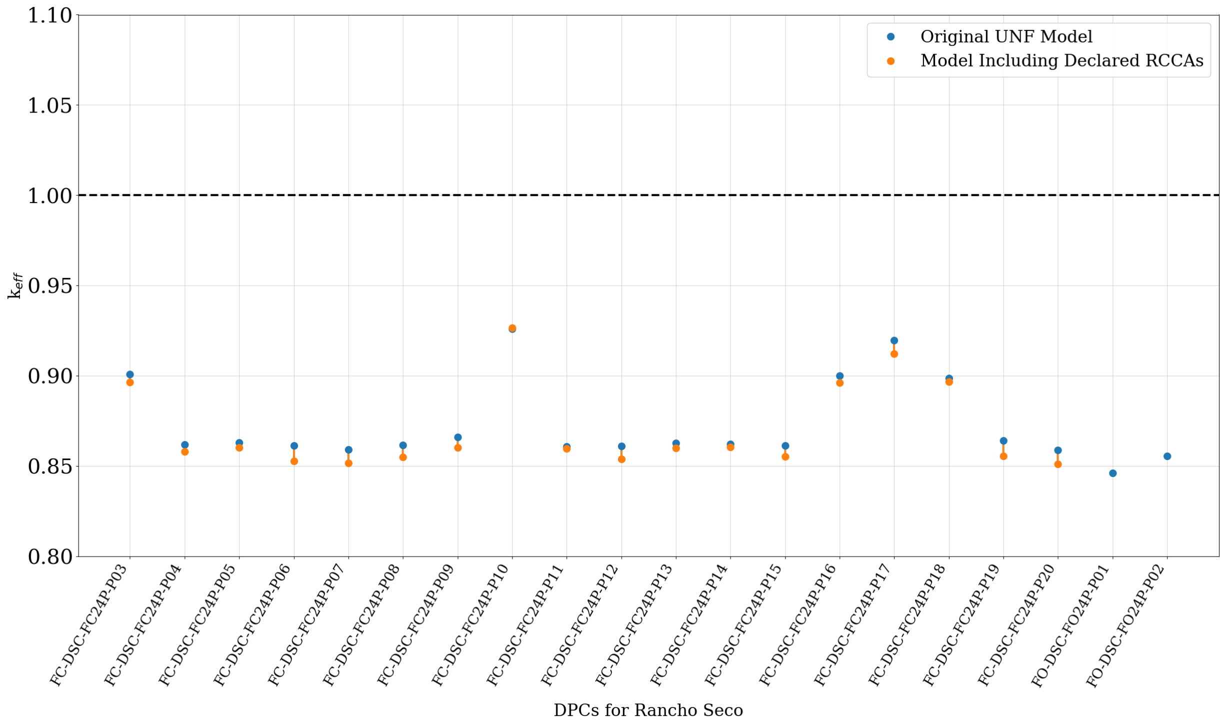

Figure 20. Criticality comparison of Rancho Seco DPCs for NA models with and without RCCAs.

4.16 St. Lucie ISFSI

The St. Lucie ISFSI uses the NUHOMS HD 32PTH system [7]. Results for St. Lucie are shown in Figure 21. All the DPCs on site are subcritical. These results are tabulated in Table 31.

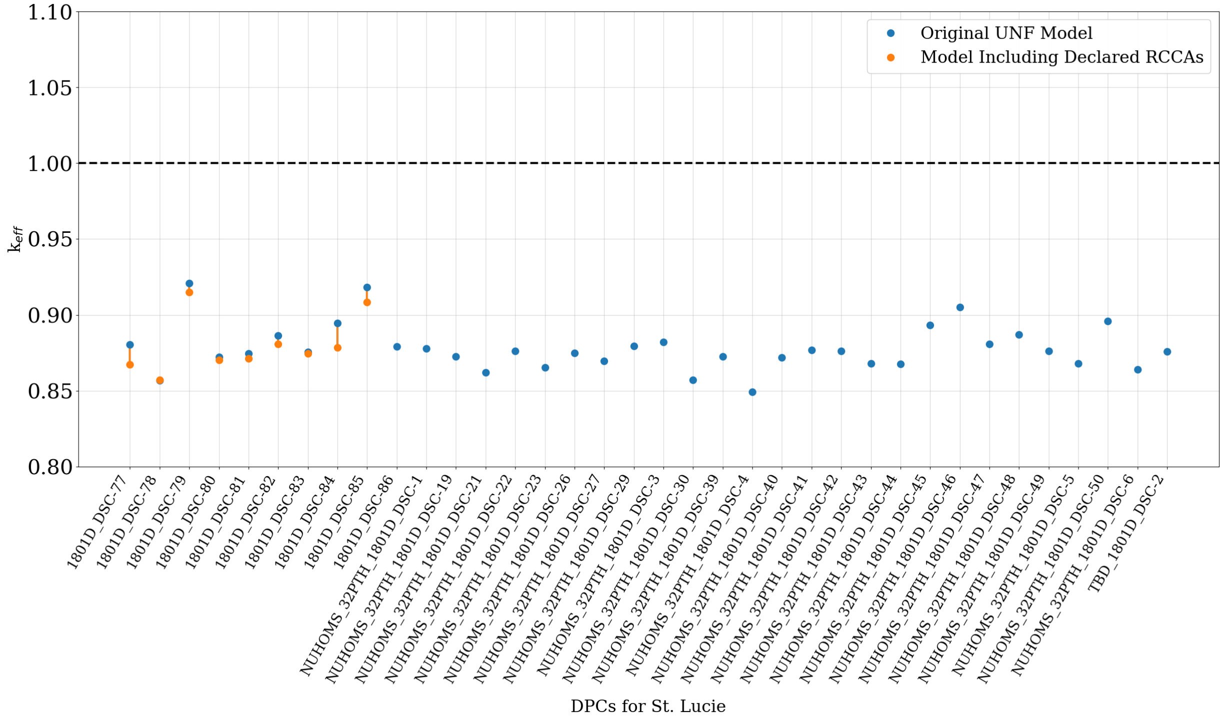

Figure 21. Criticality comparison of St. Lucie DPCs for NA models with and without RCCAs.

4.17 Trojan ISFSI

The Trojan ISFSI uses the Holtec International HI-STORM TranStor MPC-24EF[d] system [7]. Results for Trojan are shown in Figure 22. All the DPCs on site are subcritical. These results are tabulated in Table 32.

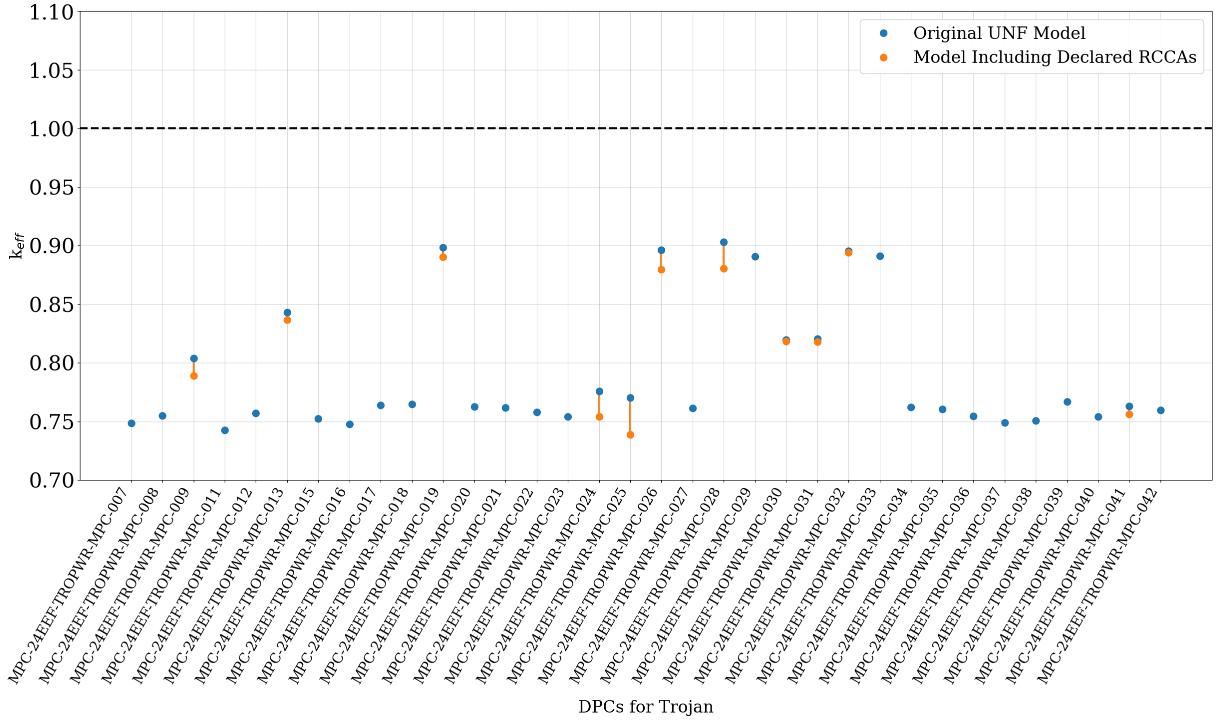

Figure 22. Criticality comparison of Trojan DPCs for NA models with and without RCCAs.

[d] MPC-24E and MPC-24EF [7].

4.18 Hope Creek ISFSI

The Hope Creek ISFSI uses two cask systems. One is for BWR spent fuel and is not considered in this report. The PWR fuel uses the Holtec International HI-STORM 100 MPC-32. Results for Hope Creek are shown in Figure 23. There are 27 DPCs on site, 9 of which have as-loaded RCCAs. After crediting RCCAs, all RCCA-containing DPCs are subcritical. However, there are still 14 DPCs that have a k_{eff} >1. These results are tabulated in Table 33.

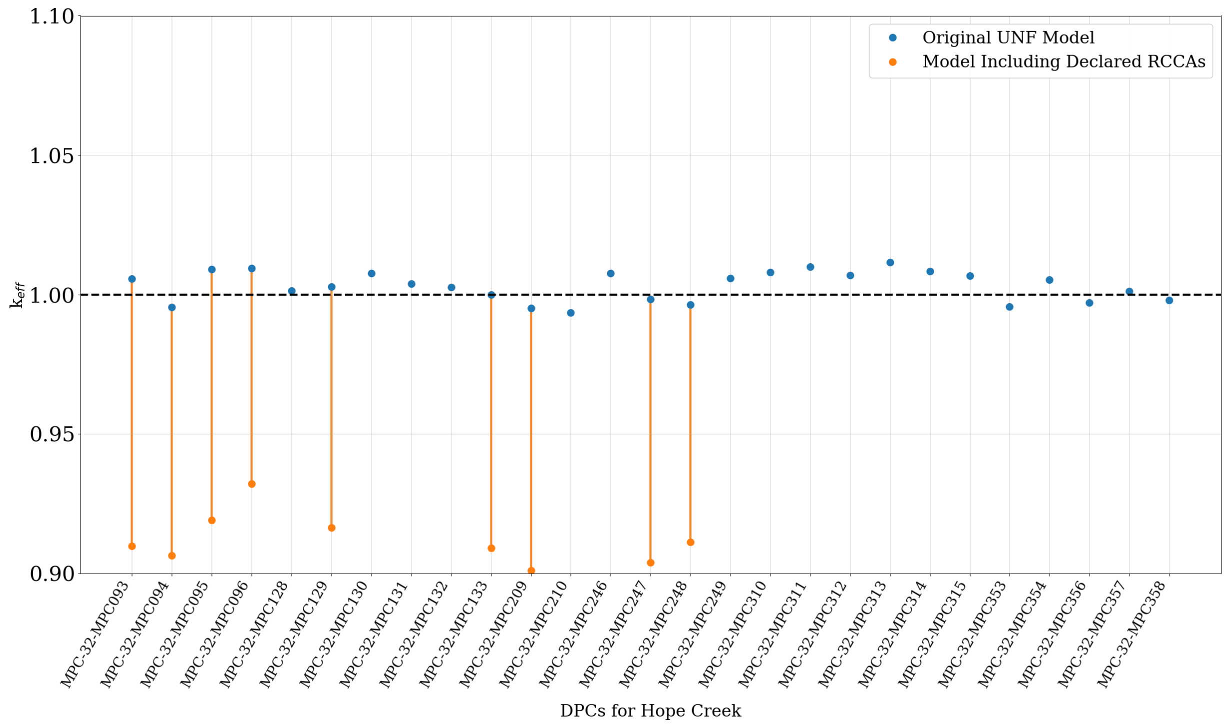

Figure 23. Criticality comparison of Hope Creek DPCs for NA models with and without RCCAs.

4.19 Other ISFSI

All ISFSI's that are not shown in the report meet one of the following criteria:

1. The ISFSI has no DPCs that contain declared RCCA inserts.
    a. Sites: Braidwood ISFSI, Catawba ISFSI, Davis-Besse ISFSI, Diablo Canyon ISFSI, Fort Calhoun ISFSI, Ginna ISFSI, McGuire ISFSI, North Anna ISFSI, Palisades ISFSI, Palo Verde ISFSI, Point Beach ISFSI, Surry ISFSI, Turkey Point ISFSI, Waterford ISFSI, Yankee Rowe ISFSI
2. The ISFSI had no SCALE inputs produced because NA model templates were not available.
    a. Sites: Beaver Valley ISFSI, Callaway ISFSI, Calvert Cliffs ISFSI, Oconee ISFSI, Prairie Island ISFSI, Robinson ISFSI, Summer ISFSI, Watts Bar ISFSI

The only exception is the San Onofre ISFSI. The results for that site are presented in Figure 24 and Table 34 in the appendix to this report. The site was not discussed in Section 4 because, of the 123 DPCs on that site, only 17 had the necessary NA model template to create SCALE inputs, and those sites were all subcritical and contained no RCCAs. The omitted sites are tabulated in Table 35.

5. Conclusions

The data being used to perform the UNF-ST&DARDS analyses, which are taken from the General Counsel (GC) – 859 fuel inventory survey, provide information related to various fuel assembly inserts of various types, including RCCAs. In the current format, the data that the GC-859 fuel inventory survey contains are entered individually by each site, without any common guidance for common language structure. Therefore, the data can lack uniformity or completeness, although recent UDB revisions have rectified many of these differences. Because the work presented in this report explores incorporation of at least the RCCA data, it is of interest to compare the UDB insert data to that found in additional references. Site-specific insert information for various DPCs from Clarity [3] was compared to loading maps generated from the UDB for RCCAs.

This report primarily documents the FY23 efforts contributing to an assessment of the UNF-ST&DARDS PWR DPCs with RCCAs included in the NA post-closure criticality models. In FY22, Walker [2] began performing this work for the Zion site; calculations were performed external to the UDB framework. The current work was accomplished by creating a new automated Python utility to assess, modify, and execute new JSON templates within the UDB framework. This work was tested using the Zion models in comparison to results by Walker [2] and was implemented for all PWR sites with existing NA models in the UDB framework. This work used the same RCCA geometry and material composition as those used by Walker [2]. Future work should implement site- and DPC-specific RCCA data. The results tabulated within this report and summarized in Table 6 demonstrate that taking credit for RCCAs usually has a substantial impact on k_{eff}, often enough to make the DPC subcritical or to significantly increase the subcritical margin. The results are tabulated according to DPC ID in the appendix.

Table 6. Summary of site-specific insert data

Site	DPCs	DPC with RCCAs	Total critical DPCs	Critical DPCs with RCCAs	Critical DPCs after RCCA credit	RCCA credit criticality impact
Arkansas Nuclear ISFSI*	**79**	**22**	**0**	**0**	**0**	**0**
Braidwood ISFSI	24	0	2	0	0	0
Byron ISFSI	**26**	**7**	**1**	**0**	**0**	**0**
Catawba ISFSI	39	0	14	0	0	0
Comanche Peak ISFSI	**29**	**1**	**24**	**1**	**0**	**1 (100%)**
Cook ISFSI	**29**	**6**	**11**	**0**	**0**	**0**
Crystal River ISFSI*	**39**	**30**	**0**	**0**	**0**	**0**
Davis-Besse ISFSI*	7	0	0	0	0	0
Diablo Canyon ISFSI	49	0	32	0	0	0
Farley ISFSI	**45**	**22**	**13**	**6**	**0**	**6 (100%)**
Fort Calhoun ISFSI	10	0	0	0	0	0
Ginna ISFSI	10	0	0	0	0	0
Haddam Neck ISFSI*	**40**	**17**	**0**	**0**	**0**	**0**
Hope Creek ISFSI	**27**	**9**	**18**	**4**	**0**	**4 (100%)**
Indian Point ISFSI	**42**	**23**	**14**	**11**	**5**	**6 (55%)**
Kewaunee ISFSI	**38**	**14**	**0**	**0**	**0**	**0**
Maine Yankee ISFSI	**60**	**7**	**2**	**2**	**0**	**2 (100%)**
McGuire ISFSI*	44	0	9	0	0	0
Millstone ISFSI	**31**	**6**	**3**	**0**	**0**	**0**
North Anna ISFSI*	31	0	1	0	0	0
Palisades ISFSI*	46	0	5	0	0	0
Palo Verde ISFSI	152	0	0	0	0	0
Point Beach ISFSI*	44	0	0	0	0	0
Rancho Seco ISFSI*	**21**	**18**	**0**	**0**	**0**	**0**
San Onofre ISFSI*	**123**	**70**	**0**	**0**	**0**	**0**
Seabrook ISFSI	**22**	**4**	**2**	**0**	**0**	**0**
Sequoyah ISFSI*	**54**	**13**	**9**	**1**	**1**	**0 (0%)**
St. Lucie ISFSI	**36**	**9**	**0**	**0**	**0**	**0**
Surry ISFSI*	32	0	0	0	0	0
Trojan ISFSI	**34**	**11**	**0**	**0**	**0**	**0**
Turkey Point ISFSI	18	0	0	0	0	0
Vogtle ISFSI	**26**	**20**	**7**	**6**	**3**	**3 (50%)**
Waterford ISFSI	23	0	1	0	0	0
Yankee Rowe ISFSI	15	0	0	0	0	0
Zion ISFSI	**61**	**39**	**24**	**24**	**0**	**24 (100%)**
Totals:	1406	348	192	55	9	46
Complete Sites Only:	846	178	168	54	8	46

*Sites missing at least 1 NA-modeled cask

6. REFERENCES

1. A. M. Shaw et al., *Dual Purpose Canister Reactivity and Groundwater Absorption Analyses, Revision 8*, ORNL/SPR-2022/2609, September 2022.
2. E. Walker, *Insert Modeling in UNF ST&DARDS*, ORNL/SPR-2022/2616, 2022.
3. J. B. Clarity, "Loading Maps 1/5", 1/10/2023.
4. J. B. Clarity et al., *Fuel Assembly Characterization for GC-859 Incorporation into the Unified Database*, Revision 9, ORNL/SPR/2015/32
5. NAC COC 9356 Docket 71-9356 package USA/9356/B(U)F-96
6. TN Americas LLC NUHOMS COC Docket 72-1004, package USA/72-1004.
7. R. H. Jones, Dry Storage Cask Inventory Assessment, FCRD-NFST-2014-00602, Revision 2, 2016.

A-1. Tabulated Zion Results

This appendix tabulates the data presented graphically in Figure 4 and Figure 5 above. Table 7 and Table 8 present the Zion NA cases for the TSC-type and TSCDF-type DPCs, respectively. Table 9 and Table 10 present the corresponding DB data for the TSC-type and TSCDF-type DPCs, respectively.

Table 7. Zion NA model criticality results for TSC-type DPCs

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
TSC-37-TSC-01	0	0.97898	
TSC-37-TSC-02	0	0.95509	
TSC-37-TSC-03	8	1.05532	0.93816
TSC-37-TSC-04	0	0.9808	
TSC-37-TSC-05	0	0.97974	
TSC-37-TSC-06	1	0.97752	0.9724
TSC-37-TSC-07	0	0.98091	
TSC-37-TSC-08	0	0.98336	
TSC-37-TSC-09	0	0.96657	
TSC-37-TSC-10	5	0.98591	0.93432
TSC-37-TSC-11	1	0.9731	0.96419
TSC-37-TSC-12	1	0.97609	0.95524
TSC-37-TSC-13	5	0.99501	0.94521
TSC-37-TSC-14	0	0.97032	
TSC-37-TSC-15	0	0.97719	
TSC-37-TSC-16	0	0.98446	
TSC-37-TSC-17	0	0.98293	
TSC-37-TSC-18	4	1.02982	0.95901
TSC-37-TSC-19	0	0.97998	
TSC-37-TSC-20	2	1.00672	0.96348
TSC-37-TSC-21	1	0.97533	0.96938
TSC-37-TSC-22	0	0.97785	
TSC-37-TSC-23	1	0.988	0.97209
TSC-37-TSC-24	0	0.97953	
TSC-37-TSC-25	1	0.95988	0.95876
TSC-37-TSC-26	0	0.97704	
TSC-37-TSC-27	2	0.99041	0.96862
TSC-37-TSC-28	0	0.97402	
TSC-37-TSC-29	0	0.9825	
TSC-37-TSC-30	0	0.9788	
TSC-37-TSC-53	1	0.98614	0.9693
TSC-37-TSC-54	2	0.97343	0.95937

Table 8. Zion NA model criticality results for TSCDF-type DPCs

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
TSCDF-37-TSCDF-01	9	1.06628	0.96328
TSCDF-37-TSCDF-02	1	0.96558	0.96159
TSCDF-37-TSCDF-03	9	1.07494	0.9616
TSCDF-37-TSCDF-04	3	0.98259	0.98124
TSCDF-37-TSCDF-05	9	1.07241	0.96377
TSCDF-37-TSCDF-06	0	0.96241	
TSCDF-37-TSCDF-07	0	0.97475	
TSCDF-37-TSCDF-08	9	1.07246	0.9642
TSCDF-37-TSCDF-09	9	1.01871	0.97018
TSCDF-37-TSCDF-11	9	1.03967	0.95631
TSCDF-37-TSCDF-12	9	1.0489	0.95456
TSCDF-37-TSCDF-13	9	1.11949	0.93369
TSCDF-37-TSCDF-14	9	1.11501	0.93513
TSCDF-37-TSCDF-15	9	1.1154	0.93459
TSCDF-37-TSCDF-16	9	1.0512	0.98438
TSCDF-37-TSCDF-17	9	1.05448	0.95605
TSCDF-37-TSCDF-18	9	1.06411	0.96753
TSCDF-37-TSCDF-19	9	1.05884	0.95714
TSCDF-37-TSCDF-20	9	1.03924	0.98509
TSCDF-37-TSCDF-21	9	1.03599	0.95501
TSCDF-37-TSCDF-22	0	0.964	
TSCDF-37-TSCDF-23	9	1.03171	0.88827
TSCDF-37-TSCDF-24	2	0.98053	0.98016
TSCDF-37-TSCDF-25	9	1.10903	0.92261
TSCDF-37-TSCDF-26	1	0.94115	0.93762
TSCDF-37-TSCDF-27	0	0.93587	
TSCDF-37-TSCDF-28	9	1.04066	0.89812
TSCDF-37-TSCDF-29	9	1.0829	0.96279
TSCDF-37-TSCDF-30	9	1.08855	0.96316

Table 9. Zion DB model criticality results for TSC-type DPCs

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
TSC-37-TSC-01	0	1.0608	
TSC-37-TSC-02	0	1.03592	
TSC-37-TSC-03	8	1.13991	1.02222
TSC-37-TSC-04	0	1.06402	
TSC-37-TSC-05	0	1.06167	
TSC-37-TSC-06	1	1.05951	1.05405
TSC-37-TSC-07	0	1.0635	
TSC-37-TSC-08	0	1.06547	
TSC-37-TSC-09	0	1.04751	
TSC-37-TSC-10	5	1.06663	1.01564
TSC-37-TSC-11	1	1.05454	1.04555
TSC-37-TSC-12	1	1.05759	1.03701
TSC-37-TSC-13	5	1.0759	1.02683
TSC-37-TSC-14	0	1.05164	
TSC-37-TSC-15	0	1.05915	
TSC-37-TSC-16	0	1.06611	
TSC-37-TSC-17	0	1.065	
TSC-37-TSC-18	4	1.11382	1.04266
TSC-37-TSC-19	0	1.06146	
TSC-37-TSC-20	2	1.08938	1.04686
TSC-37-TSC-21	1	1.05703	1.05131
TSC-37-TSC-22	0	1.05965	
TSC-37-TSC-23	1	1.06946	1.05418
TSC-37-TSC-24	0	1.06049	
TSC-37-TSC-25	1	1.04065	1.04023
TSC-37-TSC-26	0	1.05936	
TSC-37-TSC-27	2	1.07273	1.05104
TSC-37-TSC-28	0	1.05537	
TSC-37-TSC-29	0	1.06412	
TSC-37-TSC-30	0	1.06106	
TSC-37-TSC-53	1	1.06673	1.0519
TSC-37-TSC-54	2	1.05582	1.04112

Table 10. Zion DB model criticality results for TSCDF-type DPCs

DPC	Num	k_{eff}	k_{eff} with RCCAs credited
TSCDF-37-TSCDF-01	9	1.14825	1.01629
TSCDF-37-TSCDF-02	1	1.04452	1.04118
TSCDF-37-TSCDF-03	9	1.15877	1.01603
TSCDF-37-TSCDF-04	3	1.03773	1.03159
TSCDF-37-TSCDF-05	9	1.15545	1.01991
TSCDF-37-TSCDF-06	0	1.04106	
TSCDF-37-TSCDF-07	0	1.05581	
TSCDF-37-TSCDF-08	9	1.15533	1.01902
TSCDF-37-TSCDF-09	9	1.10059	1.00886
TSCDF-37-TSCDF-11	9	1.12226	1.00737
TSCDF-37-TSCDF-12	9	1.1313	1.00577
TSCDF-37-TSCDF-13	9	1.20472	1.01915
TSCDF-37-TSCDF-14	9	1.20094	1.01973
TSCDF-37-TSCDF-15	9	1.20127	1.01971
TSCDF-37-TSCDF-16	9	1.13378	1.02645
TSCDF-37-TSCDF-17	9	1.13738	1.00827
TSCDF-37-TSCDF-18	9	1.14667	1.01622
TSCDF-37-TSCDF-19	9	1.14079	1.00992
TSCDF-37-TSCDF-20	9	1.11979	1.0311
TSCDF-37-TSCDF-21	9	1.11741	1.00407
TSCDF-37-TSCDF-22	0	1.02616	
TSCDF-37-TSCDF-23	9	1.11271	0.96899
TSCDF-37-TSCDF-24	2	1.03168	1.02909
TSCDF-37-TSCDF-25	9	1.19437	1.01054
TSCDF-37-TSCDF-26	1	1.01973	1.01593
TSCDF-37-TSCDF-27	0	1.01431	
TSCDF-37-TSCDF-28	9	1.12286	0.97886
TSCDF-37-TSCDF-29	9	1.16614	1.01748
TSCDF-37-TSCDF-30	9	1.17231	1.01991

A-2. Tabulated Seabrook Results

Table 11. Seabrook NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
DSC-32PTH_5901D_DSC_01	0	0.94531	
DSC-32PTH_5901D_DSC_02	0	0.94607	
DSC-32PTH_5901D_DSC_03	0	0.93586	
DSC-32PTH_5901D_DSC_04	0	0.94517	
DSC-32PTH_5901D_DSC_05	0	0.9648	
DSC-32PTH_5901D_DSC_06	0	0.95304	
FPL_NEXT-32PTH-051-C-1	0	0.97981	
FPL_NEXT-32PTH-052-C-1	0	0.97071	
FPL_NEXT-32PTH-053-C-1	0	0.95646	
FPL_NEXT-32PTH-054-C-1	0	0.95345	
FPL_NEXT-32PTH-055-E-1	0	1.06665	
FPL_NEXT-32PTH-056-E-1	0	0.99175	
FPL_NEXT-32PTH-057-E-1	0	0.99451	
FPL_NEXT-32PTH-058-E-1	0	1.01674	
FPL_NEXT-32PTH-059-C-1	0	0.93816	
FPL_NEXT-32PTH-060-C-1	0	0.94448	
FPL_NEXT-32PTH-061-C-1	2	0.93283	0.92179
FPL_NEXT-32PTH-062-D-1	0	0.94053	
FPL_NEXT-32PTH-063-E-1	2	0.9865	0.96694
FPL_NEXT-32PTH-064-E-1	1	0.9865	0.97411
FPL_NEXT-32PTH-065-E-1	0	0.98015	
FPL_NEXT-32PTH-066-E-1	2	0.98389	0.97511

A-3. Tabulated Indian Point Results

Table 12. Indian Point NA model criticality results, non–MPC-32 type

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
1101_MPC051	4	1.00404	0.96701
1101_MPC146	3	0.99655	0.95801
1101_MPC260	4	0.99896	0.95465
1101_MPC261	6	0.99756	0.94105
1101_MPC272	1	1.00499	1.00046
1101_MPC273	1	1.00318	0.99336
3902D_MPC-265	0	0.97345	
3902D_MPC-316	0	1.01435	
3902D_MPC-346	1	0.96165	0.95944
3902D_MPC-347	0	0.96445	
3902D_MPC-348	0	0.95468	
3902D_MPC-376	1	0.96902	0.95993
3902D_MPC-377	0	0.9648	
3902D_MPC-437	4	0.98817	0.98417
3902D_MPC-438	0	1.00001	
3902D_MPC-439	1	1.00114	1.00011
3902D_MPC262	0	0.9485	
3902D_MPC263	0	0.94978	
3902D_MPC264	0	0.95534	
3902D_MPC274	0	1.00163	
3902D_MPC345	0	0.96641	
3902D_MPC374	0	0.96309	
3902D_MPC375	0	0.98122	
3902D_MPC436	1	1.0304	1.02829

Table 13. Indian Point NA model criticality results, MPC-32 type

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
MPC-32-GC-001	4	0.99386	0.94091
MPC-32-GC-002	4	1.00934	0.96442
MPC-32-GC-003	4	0.99573	0.95605
MPC-32-GC-005	4	0.96836	0.94904
MPC-32-GC-006	4	1.01872	1.00284
MPC-32-GC-007	4	1.01797	0.99664
MPC-32-GC-008	4	1.01137	0.99575
MPC-32-GC-009	4	0.99723	0.97319
MPC-32-GC-011	4	1.05056	1.03949
MPC-32-MPC-053	4	0.98146	0.9603
MPC-32-MPC-054	4	1.0017	0.98329
MPC-32-MPC-074	0	0.94264	
MPC-32-MPC-075	0	0.94194	
MPC-32-MPC-076	0	0.93936	
MPC-32-MPC-077	0	0.94429	
MPC-32-MPC-078	0	0.94408	
MPC-32-MPC-100	0	0.99408	
MPC-32-MPC-102	4	0.98592	0.94998

A-4. Tabulated Comanche Peak Results

Table 14. Comanche Peak NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
MPC-32-CASK001	0	0.99135	
MPC-32-CASK002	0	1.01761	
MPC-32-CASK003	0	1.01809	
MPC-32-CASK004	0	1.02152	
MPC-32-CASK005	0	1.02391	
MPC-32-CASK006	0	1.01645	
MPC-32-CASK007	0	1.02407	
MPC-32-CASK008	0	1.02088	
MPC-32-CASK009	0	1.01976	
4901D_CASK010	0	0.99642	
4901D_CASK011	0	0.99982	
4901D_CASK012	0	1.00079	
4901D_CASK013	0	1.00525	
4901D_CASK014	0	1.00398	
4901D_CASK015	0	1.0061	
4901D_CASK016	0	1.0042	
4901D_CASK017	0	1.00784	
4901D_CASK018	0	1.00305	
4901D_CASK019	0	1.01484	
4901D_CASK020	0	1.02753	
4901D_CASK021	0	0.99951	
4901D_CASK022	0	1.00636	
4901D_CASK023	0	1.02947	
4901D_CASK024	0	1.02959	
4901D_CASK025	0	1.00115	
4901D_CASK026	0	0.99618	
4901D_CASK027	0	1.00337	
4901D_CASK028	0	1.002	
4901D_CASK029	12	1.01083	0.90451

A-5. Tabulated Farley Results

Table 15. Farley NA model criticality results, 0101D type

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
0101D_QSJ05T0045	0	0.99112	
0101D_QSJ05T0046	4	0.98333	0.95254
0101D_QSJ05T0160	4	0.99197	0.95113
0101D_QSJ05T0161	4	0.98752	0.95164
0101D_QSJ05T0215	2	0.98872	0.98500
0101D_QSJ05T0217	0	0.99897	
0101D_QSJ05T0218	4	0.99096	0.96397
0101D_QSJ05T0219	5	1.01695	0.97884
0101D_QSJ05T0220	0	0.98729	
0101D_QSJ05T0329	4	0.98415	0.94993
0101D_QSJ05T0330	0	0.99704	
0101D_QSJ05T0331	3	0.99172	0.95955
0101D_QSJ05T0332	0	0.98896	
0101D_QSJ05T0334	0	0.98767	
0101D_QSJ05T0335	0	0.99111	
0101D_QSJ05T0336	4	0.98453	0.94704
0101D_QSJ05T0412	0	0.98331	
0101D_QSJ05T0413	3	1.0006	0.98025
0101D_QSJ05T0414	0	1.00643	
0101D_QSJ05T0415	3	0.98283	0.97408
0101D_QSJ05T0416	0	0.99575	
0101D_QSJ05T0417	0	1.00654	
0101D_QSJ05T0418	0	1.00193	
0101D_QSJ05T0419	3	0.99739	0.97848

Table 16. Farley NA model criticality results, MPC-32 type

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
MPC-32-162	4	1.02398	0.98356
MPC-32-216	4	1.00939	0.96133
MPC-32-27	0	1.00386	
MPC-32-28	0	0.98024	
MPC-32-29	0	0.98018	
MPC-32-30	4	0.98558	0.94759
MPC-32-31	4	0.992	0.95502
MPC-32-32	4	1.00363	0.96061
MPC-32-33	4	1.00384	0.97384
MPC-32-34	0	1.01263	
MPC-32-35	0	1.00855	
MPC-32-36	0	0.99667	
MPC-32-37	0	1.00047	
MPC-32-38	4	0.97713	0.94563
MPC-32-39	0	0.99815	
MPC-32-40	0	0.9962	
MPC-32-41	0	0.97769	
MPC-32-42	0	0.99354	
MPC-32-43	4	0.99395	0.96770
MPC-32-44	4	0.99593	0.95869
MPC-32-47	4	0.99166	0.96477

A-6. Tabulated Sequoyah Results

Table 17. Sequoyah NA model criticality results, type TSC

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
MPC-32-TSC_004	0	0.99892	
MPC-32-TSC_005	0	1.01478	
MPC-32-TSC_006	0	0.99075	
MPC-32-TSC_007	0	0.99149	
MPC-32-TSC_011	0	0.99554	
MPC-32-TSC_013	0	0.991	
MPC-32-TSC_015	0	0.98939	
MPC-32-TSC_018	0	0.99081	
MPC-32-TSC_068	0	1.00122	
MPC-32-TSC_069	0	0.99407	
MPC-32-TSC_070	0	0.98923	
MPC-32-TSC_071	0	0.99804	
MPC-32-_TSC_072	0	0.99525	
MPC-32-TSC_073	0	0.9808	
MPC-32-TSC_079	0	1.0152	
MPC-32-TSC_080	0	0.99033	
MPC-32-TSC_081	0	1.00107	
MPC-32-TSC_082	0	1.00823	
MPC-32-TSC_083	0	0.9992	
MPC-32-TSC_092	0	1.00613	
MPC-32-TSC_0107	0	0.99435	
MPC-32-TSC_0108	0	0.98728	
MPC-32-TSC_0109	0	0.97188	
MPC-32-TSC_0110	0	0.96473	
MPC-32-TSC_0111	0	0.97983	
MPC-32-TSC_0112	0	0.99121	
MPC-32-TSC_0177	0	0.99279	

Table 18. Sequoyah NA model criticality results, type 4808D

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
4808D_MPC-282	2	0.99891	0.99352
4808D_MPC-283	1	1.00133	1.00001
4808D_MPC-359	0	1.00522	
4808D_MPC-360	0	1.00717	
MPC-32_4808D_MPC-103	0	0.99575	
MPC-32_4808D_MPC-104	0	0.99842	
MPC-32_4808D_MPC-105	0	0.99857	
MPC-32_4808D_MPC-106	0	0.98547	
MPC-32_4808D_MPC-113	0	0.98643	
MPC-32_4808D_MPC-178	6	0.99661	0.96268
MPC-32_4808D_MPC-179	3	0.99116	0.95918
MPC-32_4808D_MPC-180	3	0.99172	0.97425
MPC-32_4808D_MPC-181	2	0.99752	0.98905
MPC-32_4808D_MPC-278	2	0.99082	0.9787
MPC-32_4808D_MPC-279	0	0.99129	
MPC-32_4808D_MPC-280	0	0.99939	
MPC-32_4808D_MPC-281	0	0.99355	

A-7. Tabulated Vogtle Results

Table 19. Vogtle NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
MPC-32-MPC-211	5	0.98908	0.98323
MPC-32-MPC-212	2	0.98674	0.9813
MPC-32-MPC-213	0	0.98602	
MPC-32-MPC-214	5	0.99564	0.99206
MPC-32-MPC-284	2	0.98938	0.98687
MPC-32-MPC-285	12	0.9925	0.98189
MPC-32-MPC-286	2	1.01092	1.00846
MPC-32-MPC-287	1	0.97033	0.9684
MPC-32-MPC-337	0	0.98261	
MPC-32-MPC-338	6	0.96335	0.95399
MPC-32-MPC-339	6	0.9642	0.95727
MPC-32-MPC-340	12	0.97376	0.95555
MPC-32-MPC-341	2	0.95823	0.9558
MPC-32-MPC-342	3	0.95925	0.95177
MPC-32-MPC-343	2	0.98173	0.97702
MPC-32-MPC-344	1	0.97822	0.97164
MPC-32-MPC-364	12	1.00156	0.9032
MPC-32-MPC-365	0	0.99789	
MPC-32-MPC-366	0	1.00837	
MPC-32-MPC-367	0	0.99841	
MPC-32-MPC-368	1	0.99836	0.99748
MPC-32-MPC-369	0	0.99807	
MPC-32-MPC-370	17	1.00386	0.8867
MPC-32-MPC-371	1	1.00092	1.00037
MPC-32-MPC-372	3	1.00762	1.00554
MPC-32-MPC-373	9	1.00335	0.93205

A-8. Tabulated Maine Yankee Results

Table 20. Maine Yankee NA model criticality results, DPCs 1–30

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
TSC-24-TSC-1	0	0.80882	
TSC-24-TSC-2	0	0.81189	
TSC-24-TSC-3	0	0.91857	
TSC-24-TSC-4	0	0.91725	
TSC-24-TSC-5	0	0.8765	
TSC-24-TSC-6	0	0.80972	
TSC-24-TSC-7	0	0.89687	
TSC-24-TSC-8	0	0.80643	
TSC-24-TSC-9	0	0.81666	
TSC-24-TSC-10	0	0.80932	
TSC-24-TSC-11	0	0.88187	
TSC-24-TSC-12	0	0.82288	
TSC-24-TSC-13	0	0.93927	
TSC-24-TSC-14	0	0.81233	
TSC-24-TSC-15	0	0.80493	
TSC-24-TSC-16	0	0.80828	
TSC-24-TSC-17	0	0.81282	
TSC-24-TSC-18	0	0.81249	
TSC-24-TSC-19	0	0.81378	
TSC-24-TSC-20	0	0.8514	
TSC-24-TSC-21	0	0.8116	
TSC-24-TSC-22	0	0.85438	
TSC-24-TSC-23	0	0.85596	
TSC-24-TSC-24	0	0.85802	
TSC-24-TSC-25	0	0.81679	
TSC-24-TSC-26	0	0.81825	
TSC-24-TSC-27	0	0.91772	
TSC-24-TSC-28	0	0.80004	
TSC-24-TSC-29	0	0.81026	
TSC-24-TSC-30	0	0.91951	

Table 21. Maine Yankee NA model criticality results, DPCs 31-60

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
TSC-24-TSC-31	0	0.87234	
TSC-24-TSC-32	0	0.91919	
TSC-24-TSC-33	0	0.88705	
TSC-24-TSC-34	0	0.8181	
TSC-24-TSC-35	0	0.87297	
TSC-24-TSC-36	0	0.82833	
TSC-24-TSC-37	0	0.9181	
TSC-24-TSC-38	0	0.93782	
TSC-24-TSC-39	0	0.91732	
TSC-24-TSC-40	0	0.937	
TSC-24-TSC-41	0	0.79039	
TSC-24-TSC-42	0	0.79188	
TSC-24-TSC-43	0	0.91968	
TSC-24-TSC-44	0	0.91773	
TSC-24-TSC-45	0	0.83055	
TSC-24-TSC-46	0	0.82634	
TSC-24-TSC-47	0	0.8578	
TSC-24-TSC-48	0	0.79443	
TSC-24-TSC-49	0	0.86495	
TSC-24-TSC-50	0	0.81554	
TSC-24-TSC-51	0	0.79322	
TSC-24-TSC-52	0	0.81505	
TSC-24-TSC-53	0	0.99696	
TSC-24-TSC-54	24	0.98584	0.91439
TSC-24-TSC-55	24	1.00781	0.93539
TSC-24-TSC-56	24	1.00974	0.93763
TSC-24-TSC-57	24	0.96173	0.89193
TSC-24-TSC-58	24	0.88912	0.82255
TSC-24-TSC-59	24	0.91331	0.8454
TSC-24-TSC-60	22	0.90241	0.8352

A-9. Tabulated Haddam Neck Results

Table 22. Haddam Neck NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
CY-MPC26-TSC-02	1	0.87251	0.86927
CY-MPC26-TSC-03	1	0.87379	0.86971
CY-MPC26-TSC-04	0	0.89999	
CY-MPC26-TSC-05	0	0.90323	
CY-MPC26-TSC-06	0	0.86991	
CY-MPC26-TSC-07	2	0.87879	0.87082
CY-MPC26-TSC-08	1	0.87977	0.87325
CY-MPC26-TSC-09	2	0.88069	0.87622
CY-MPC26-TSC-10	0	0.87983	
CY-MPC26-TSC-11	3	0.87849	0.87555
CY-MPC26-TSC-12	3	0.87944	0.87083
CY-MPC26-TSC-13	1	0.88022	0.87919
CY-MPC26-TSC-14	2	0.87619	0.86828
CY-MPC26-TSC-15	2	0.8748	0.87011
CY-MPC26-TSC-16	0	0.90901	
CY-MPC26-TSC-17	0	0.90241	
CY-MPC26-TSC-18	0	0.9262	
CY-MPC26-TSC-20	0	0.92199	
CY-MPC26-TSC-21	0	0.90405	
CY-MPC26-TSC-22	0	0.90045	
CY-MPC26-TSC-23	0	0.90477	
CY-MPC26-TSC-24	0	0.903	
CY-MPC26-TSC-25	1	0.86052	0.85941
CY-MPC26-TSC-26	0	0.90421	
CY-MPC26-TSC-27	0	0.9038	
CY-MPC26-TSC-28	0	0.90168	
CY-MPC26-TSC-29	0	0.90749	
CY-MPC26-TSC-30	0	0.91944	
CY-MPC26-TSC-31	1	0.86617	0.8631
CY-MPC26-TSC-32	0	0.903	
CY-MPC26-TSC-33	1	0.86059	0.85707
CY-MPC26-TSC-34	1	0.87186	0.86925
CY-MPC26-TSC-35	0	0.89352	
CY-MPC26-TSC-36	0	0.92781	
CY-MPC26-TSC-37	0	0.86709	
CY-MPC26-TSC_19	0	0.91008	
MPC-TSC-414-01	0	0.87263	

A-10. Tabulated Cook Results

Table 23. Cook NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
5801D_MPC136-438	0	1.00135	
5801D_MPC138-437	0	0.98638	
5801D_MPC203-766	0	0.97184	
5801D_MPC208-439	0	0.96259	
5801D_MPC317-767	0	1.00967	
5801D_MPC318-768	0	1.00366	
5801D_MPC319-769	0	0.99448	
5801D_MPC320-770	4	0.98304	0.95256
5801D_MPC321-771	0	0.99516	
5801D_MPC322-772	0	0.99838	
5801D_MPC323-773	0	0.97975	
5801D_MPC324-774	0	1.00516	
5801D_MPC325-775	0	1.00804	
5801D_MPC326-776	0	1.0016	
5801D_MPC327-777	0	1.00569	
5801D_MPC328-563	0	1.01391	
5801D_MPC451_1035	0	1.00731	
MPC-32-MPC134-433	4	0.97909	0.94692
MPC-32-MPC135-435	4	0.99757	0.9741
MPC-32-MPC137-561	0	0.99236	
MPC-32-MPC139-434	0	0.9802	
MPC-32-MPC140-562	0	0.99249	
MPC-32-MPC142-574	0	0.99563	
MPC-32-MPC143-564	2	0.98068	0.95686
MPC-32-MPC204-440	0	0.97337	
MPC-32-MPC205-565	0	1.01194	
MPC-32-MPC206-441	3	0.98882	0.95609
MPC-32-MPC207-436	0	1.00583	
MPC-32MPC141-432	8	0.98622	0.92457

A-11. Tabulated Byron Results

Table 24. Byron NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
1003D_MPC0087	0	0.98689	
1003D_MPC0091	0	0.9878	
1003D_MPC0117	0	0.98701	
1003D_MPC0119	0	0.99751	
1003D_MPC0266	0	0.98137	
1003D_MPC0267	0	0.99104	
1003D_MPC0268	0	0.98563	
1003D_MPC0269	0	0.99934	
1003D_MPC0270	0	0.99808	
1003D_MPC0271	0	0.99087	
1003D_MPC0361	0	0.99735	
1003D_MPC0363	0	1.00279	
HI_STORM_MPC32_1003D_MPC0086	0	0.97759	
HI_STORM_MPC32_1003D_MPC0088	0	0.97013	
HI_STORM_MPC32_1003D_MPC0089	0	0.98968	
HI_STORM_MPC32_1003D_MPC0090	0	0.97506	
HI_STORM_MPC32_1003D_MPC0114	4	0.97372	0.95659
HI_STORM_MPC32_1003D_MPC0115	12	0.96817	0.94146
HI_STORM_MPC32_1003D_MPC0116	4	0.96242	0.94447
HI_STORM_MPC32_1003D_MPC0118	12	0.95144	0.92353
HI_STORM_MPC32_1003D_MPC0182	12	0.96355	0.93528
HI_STORM_MPC32_1003D_MPC0183	0	0.97994	
HI_STORM_MPC32_1003D_MPC0184	12	0.95702	0.93972
HI_STORM_MPC32_1003D_MPC0185	12	0.95778	0.91942
HI_STORM_MPC32_1003D_MPC0186	0	0.98293	
HI_STORM_MPC32_1003D_MPC0187	0	0.98276	

A-12. Tabulated Crystal River Results

Table 25. Crystal River NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
CR3-32PTH-L-2C-W-44	4	0.94577	0.93865
CR3-32PTH1-L-2C-W-24	4	0.93441	0.92431
CR3-32PTH1-L-2C-W-25	3	0.9395	0.9297
CR3-32PTH1-L-2C-W-26	1	0.94003	0.93862
CR3-32PTH1-L-2C-W-27	2	0.93975	0.9346
CR3-32PTH1-L-2C-W-28	4	0.94086	0.931
CR3-32PTH1-L-2C-W-29	0	0.94063	
CR3-32PTH1-L-2C-W-31	6	0.94811	0.93735
CR3-32PTH1-L-2C-W-32	3	0.91168	0.90082
CR3-32PTH1-L-2C-W-33	5	0.93454	0.92321
CR3-32PTH1-L-2C-W-34	4	0.94808	0.93964
CR3-32PTH1-L-2C-W-35	6	0.91584	0.90212
CR3-32PTH1-L-2C-W-36	1	0.95509	0.95158
CR3-32PTH1-L-2C-W-37	0	0.95022	
CR3-32PTH1-L-2C-W-38	3	0.92966	0.92646
CR3-32PTH1-L-2C-W-39	3	0.94574	0.94135
CR3-32PTH1-L-2C-W-40	6	0.94812	0.93862
CR3-32PTH1-L-2C-W-41	2	0.92549	0.90597
CR3-32PTH1-L-2C-W-42	0	0.93821	
CR3-32PTH1-L-2C-W-43	2	0.93925	0.9346
CR3-32PTH1-L-2C-W-45	3	0.95169	0.92881
CR3-32PTH1-L-2C-W-46	5	0.95068	0.94082
CR3-32PTH1-L-2C-W-47	2	0.94509	0.93623
CR3-32PTH1-L-2C-W-48	1	0.94657	0.9422
CR3-32PTH1-L-2C-W-49	0	0.9473	
CR3-32PTH1-L-2D-W-11	0	0.92637	
CR3-32PTH1-L-2D-W-12	3	0.93801	0.93161
CR3-32PTH1-L-2D-W-13	2	0.94831	0.93813
CR3-32PTH1-L-2D-W-14	3	0.93739	0.93235
CR3-32PTH1-L-2D-W-15	0	0.9387	
CR3-32PTH1-L-2D-W-16	2	0.93314	0.92523
CR3-32PTH1-L-2D-W-17	11	0.98381	0.95124
CR3-32PTH1-L-2D-W-18	0	0.94011	
CR3-32PTH1-L-2D-W-19	0	0.95174	
CR3-32PTH1-L-2D-W-20	0	0.94868	
CR3-32PTH1-L-2D-W-21	4	0.94039	0.91909
CR3-32PTH1-L-2D-W-22	6	0.94219	0.91092
CR3-32PTH1-L-2D-W-23	12	0.97367	0.9426

A-13. Tabulated Kewaunee Results

Table 26. Kewaunee NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
KPS32PT-S100-A-HZ001	0	0.94405	
KPS32PT-S100-A-HZ002	0	0.9282	
KPS32PT-S100-A-HZ003	0	0.93958	
KPS32PT-S100-A-HZ004	0	0.94565	
KPS32PT-S100-A-HZ005	0	0.94491	
KPS32PT-S100-A-HZ006	0	0.93478	
KPS32PT-S100-A-HZ007	0	0.93952	
KPS32PT-S100-A-HZ008	0	0.94354	
KPS32PT-S100-A16-HZ009	0	0.96694	
KPS32PT-S100-A16-HZ010	0	0.95832	
KPS32PT-S100-A16-HZ011	0	0.95006	
KPS32PT-S100-A16-HZ012	0	0.96356	
KPS32PT-S100-A16-HZ013	0	0.95755	
KPS32PT-S100-A16-HZ014	0	0.96023	
MAG-TSC-30026-086-01	7	0.96012	0.94075
MAG-TSC-30026-086-02	9	0.9359	0.88545
MAG-TSC-30026-086-03	8	0.94367	0.90582
MAG-TSC-30026-086-04	8	0.93512	0.89342
MAG-TSC-30026-086-05	4	0.94216	0.91508
MAG-TSC-30026-086-06	0	0.96289	
MAG-TSC-30026-086-07	0	0.96704	
MAG-TSC-30026-086-08	0	0.95052	
MAG-TSC-30026-086-09	0	0.94539	
MAG-TSC-30026-086-10	1	0.94956	0.9451
MAG-TSC-30026-086-11	6	0.95181	0.93401
MAG-TSC-30026-086-12	2	0.95774	0.94963
MAG-TSCDF-30026-184-13	4	0.9449	0.92814
MAG-TSCDF-30026-184-14	5	0.93215	0.91321
MAG-TSCDF-30026-184-15	6	0.94621	0.92073
MAG-TSCDF-30026-184-16	7	0.9467	0.92063
MAG-TSCDF-30026-184-17	9	0.93606	0.88676
MAG-TSCDF-30026-184-18	0	0.94678	
MAG-TSCDF-30026-184-19	0	0.94538	
MAG-TSCDF-30026-184-20	0	0.95119	
MAG-TSCDF-30026-184-21	0	0.95297	
MAG-TSCDF-30026-184-22	0	0.93661	
MAG-TSCDF-30026-184-23	1	0.93641	0.92537
MAG-TSCDF-30026-184-24	0	0.93638	

A-14. Tabulated Arkansas Nuclear Results

Table 27. Arkansas Nuclear NA model criticality results, type 0401D

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
0401D_MPC-24-055	0	0.79024	
0401D_MPC-24-056	4	0.78477	0.77545
0401D_MPC-24-057	0	0.79656	
0401D_MPC-24-058	2	0.7948	0.79035
0401D_MPC-24-059	0	0.78838	
0401D_MPC-24-060	3	0.79034	0.78136
0401D_MPC-24-061	0	0.77902	
0401D_MPC-24-062	5	0.77705	0.76889
0401D_MPC-24-063	0	0.78167	
0401D_MPC-24-064	0	0.78433	
0401D_MPC-32-237	0	0.98814	
0401D_MPC-32-238	0	0.9829	
0401D_MPC-32-239	0	0.97642	
0401D_MPC-32-275	0	0.97685	
0401D_MPC-32-276	0	0.96732	
0401D_MPC-32-277	0	0.97102	
0401D_MPC-32-420	1	0.98009	0.97988
0401D_MPC-32-421	20	0.9687	0.92143

Table 28. Arkansas Nuclear NA model criticality results, type MPC-24

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
MPC-24-MPC-001	4	0.78378	0.75345
MPC-24-MPC-002	4	0.78157	0.75581
MPC-24-MPC-003	2	0.77737	0.76631
MPC-24-MPC-004	4	0.77833	0.74715
MPC-24-MPC-005	4	0.79569	0.77127
MPC-24-MPC-006	4	0.78525	0.75778
MPC-24-MPC-010	0	0.76175	
MPC-24-MPC-014	0	0.76763	
MPC-24-MPC-043	0	0.7696	
MPC-24-MPC-044	4	0.78423	0.75416
MPC-24-MPC-045	4	0.75452	0.73089
MPC-24-MPC-046	3	0.77473	0.74816
MPC-24-MPC-047	1	0.79911	0.78261
MPC-24-MPC-048	2	0.77603	0.76341
MPC-24-MPC-049	3	0.78477	0.77016
MPC-24-MPC-050	2	0.77601	0.75524
MPC-24-MPC-051	0	0.78875	
MPC-24-MPC-052	1	0.78345	0.78095
MPC-24-MPC-053	3	0.78896	0.77435
MPC-24-MPC-054	1	0.78026	0.77433
MPC-32-MPC-001	0	0.96836	
MPC-32-MPC-002	0	0.96777	
MPC-32-MPC-003	0	0.97197	
MPC-32-MPC-009	0	0.97453	
MPC-32-MPC-016	0	0.94358	
MPC-32-MPC-019	0	0.945	
MPC-32-MPC-024	0	0.95563	
MPC-32-MPC-025	0	0.96034	
MPC-32-MPC-026	0	0.96601	
MPC-32-MPC-049	0	0.95948	
MPC-32-MPC-066	0	0.93802	
MPC-32-MPC-067	0	0.95249	
MPC-32-MPC-084	0	0.96468	
MPC-32-MPC-085	0	0.9359	
MPC-32-MPC-159	0	0.96488	
MPC-32-MPC-163	0	0.96888	
MPC-32-MPC-164	0	0.96266	

A-15. Tabulated Millstone Results

Table 29. Millstone NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
3201D_MPS32PT-L125-A224-HZ019	12	0.92636	0.896
3201D_MPS32PT-L125-A224-HZ020	12	0.92624	0.91025
3201D_MPS32PT-L125-A224-HZ021	0	0.93627	
3201D_MPS32PT-L125-A224-HZ022	12	0.91331	0.8925
3201D_MPS32PT-L125-A224-HZ023	8	0.91329	0.90992
3201D_MPS32PT-L125-A224-HZ024	0	0.96364	
3201D_MPS32PT-L125-A224-HZ025	8	0.93702	0.92112
3201D_MPS32PT-L125-A224-HZ026	0	1.00021	
3201D_MPS32PT-L125-A224-HZ027	0	0.94495	
3201D_MPS32PT-L125-A224-HZ028	0	1.00453	
3201D_MPS32PT-L125-A224-HZ029	13	0.91415	0.88598
3201D_MPS32PT-L125-A224-HZ030	0	1.01040	
3201D_MPS32PT-L125-A224-HZ031	0	0.93843	
NUHOMS_32PT_3201D_S100-A-HZ010	0	0.91992	
NUHOMS_32PT_3201D_S100-A-HZ011	0	0.91883	
NUHOMS_32PT_3201D_S100-A-HZ012	0	0.92429	
NUHOMS_32PT_3201D_S100-A-HZ013	0	0.92237	
NUHOMS_32PT_3201D_S100-A-HZ014	0	0.92171	
NUHOMS_32PT_3201D_S100-A-HZ015	0	0.91547	
NUHOMS_32PT_3201D_S100-A-HZ016	0	0.95088	
NUHOMS_32PT_3201D_S100-A-HZ017	0	0.91646	
NUHOMS_32PT_3201D_S100-A-HZ018	0	0.94573	
NUHOMS_32PT_3201D_S100-A-R001	0	0.91942	
NUHOMS_32PT_3201D_S100-A-R002	0	0.93048	
NUHOMS_32PT_3201D_S100-A-R003	0	0.93955	
NUHOMS_32PT_3201D_S100-A-R004	0	0.92724	
NUHOMS_32PT_3201D_S100-A-R005	0	0.91022	
NUHOMS_32PT_3201D_S100-A-R006	0	0.92594	
NUHOMS_32PT_3201D_S100-A-R007	0	0.90349	
NUHOMS_32PT_3201D_S100-A-R008	0	0.92559	
NUHOMS_32PT_3201D_S100-A-R009	0	0.90100	

A-16. Tabulated Rancho Seco Results

Table 30. Rancho Seco NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
FC-DSC-FC24P-P03	2	0.90077	0.89652
FC-DSC-FC24P-P04	5	0.86203	0.85813
FC-DSC-FC24P-P05	2	0.86303	0.86017
FC-DSC-FC24P-P06	4	0.86143	0.85272
FC-DSC-FC24P-P07	5	0.85909	0.85168
FC-DSC-FC24P-P08	4	0.86162	0.85505
FC-DSC-FC24P-P09	4	0.86612	0.8603
FC-DSC-FC24P-P10	1	0.92594	0.92647
FC-DSC-FC24P-P11	1	0.86086	0.8598
FC-DSC-FC24P-P12	3	0.86119	0.85394
FC-DSC-FC24P-P13	2	0.86282	0.85997
FC-DSC-FC24P-P14	3	0.8623	0.86044
FC-DSC-FC24P-P15	3	0.86141	0.85535
FC-DSC-FC24P-P16	6	0.90016	0.8963
FC-DSC-FC24P-P17	5	0.91963	0.91219
FC-DSC-FC24P-P18	4	0.89869	0.89683
FC-DSC-FC24P-P19	4	0.86398	0.85565
FC-DSC-FC24P-P20	3	0.85883	0.85115
FO-DSC-FO24P-P01	0	0.8462	
FO-DSC-FO24P-P02	0	0.85543	

A-17. Tabulated St. Lucie Results

Table 31. St. Lucie NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
1801D_DSC-77	7	0.8804	0.86746
1801D_DSC-78	1	0.85697	0.85705
1801D_DSC-79	4	0.92083	0.91511
1801D_DSC-80	2	0.87223	0.87043
1801D_DSC-81	3	0.87469	0.87141
1801D_DSC-82	4	0.88635	0.88075
1801D_DSC-83	2	0.87555	0.87456
1801D_DSC-84	8	0.89473	0.87866
1801D_DSC-85	9	0.91818	0.90834
1801D_DSC-86	0	0.87909	
NUHOMS_32PTH_1801D_DSC-1	0	0.8779	
NUHOMS_32PTH_1801D_DSC-19	0	0.87272	
NUHOMS_32PTH_1801D_DSC-21	0	0.86197	
NUHOMS_32PTH_1801D_DSC-22	0	0.87613	
NUHOMS_32PTH_1801D_DSC-23	0	0.86547	
NUHOMS_32PTH_1801D_DSC-26	0	0.87508	
NUHOMS_32PTH_1801D_DSC-27	0	0.86968	
NUHOMS_32PTH_1801D_DSC-29	0	0.87957	
NUHOMS_32PTH_1801D_DSC-3	0	0.88226	
NUHOMS_32PTH_1801D_DSC-30	0	0.85721	
NUHOMS_32PTH_1801D_DSC-39	0	0.8725	
NUHOMS_32PTH_1801D_DSC-4	0	0.84918	
NUHOMS_32PTH_1801D_DSC-40	0	0.8721	
NUHOMS_32PTH_1801D_DSC-41	0	0.87686	
NUHOMS_32PTH_1801D_DSC-42	0	0.87616	
NUHOMS_32PTH_1801D_DSC-43	0	0.86801	
NUHOMS_32PTH_1801D_DSC-44	0	0.86785	
NUHOMS_32PTH_1801D_DSC-45	0	0.89324	
NUHOMS_32PTH_1801D_DSC-46	0	0.90517	
NUHOMS_32PTH_1801D_DSC-47	0	0.88077	
NUHOMS_32PTH_1801D_DSC-48	0	0.88701	
NUHOMS_32PTH_1801D_DSC-49	0	0.87625	
NUHOMS_32PTH_1801D_DSC-5	0	0.86791	
NUHOMS_32PTH_1801D_DSC-50	0	0.89608	
NUHOMS_32PTH_1801D_DSC-6	0	0.8641	
TBD_1801D_DSC-2	0	0.87586	

A-18. Tabulated Trojan Results

Table 32. Trojan NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
MPC-24EEF-TROPWR-MPC-007	0	0.74865	
MPC-24EEF-TROPWR-MPC-008	0	0.75488	
MPC-24EEF-TROPWR-MPC-009	6	0.80394	0.78915
MPC-24EEF-TROPWR-MPC-011	0	0.74255	
MPC-24EEF-TROPWR-MPC-012	0	0.75711	
MPC-24EEF-TROPWR-MPC-013	3	0.84317	0.83671
MPC-24EEF-TROPWR-MPC-015	0	0.75254	
MPC-24EEF-TROPWR-MPC-016	0	0.74767	
MPC-24EEF-TROPWR-MPC-017	0	0.76394	
MPC-24EEF-TROPWR-MPC-018	0	0.76453	
MPC-24EEF-TROPWR-MPC-019	9	0.89829	0.89037
MPC-24EEF-TROPWR-MPC-020	0	0.76278	
MPC-24EEF-TROPWR-MPC-021	0	0.76165	
MPC-24EEF-TROPWR-MPC-022	0	0.7578	
MPC-24EEF-TROPWR-MPC-023	0	0.75411	
MPC-24EEF-TROPWR-MPC-024	9	0.77594	0.75394
MPC-24EEF-TROPWR-MPC-025	5	0.7702	0.73884
MPC-24EEF-TROPWR-MPC-026	9	0.89634	0.87977
MPC-24EEF-TROPWR-MPC-027	0	0.76134	
MPC-24EEF-TROPWR-MPC-028	8	0.90296	0.88069
MPC-24EEF-TROPWR-MPC-029	0	0.89086	
MPC-24EEF-TROPWR-MPC-030	2	0.81958	0.8184
MPC-24EEF-TROPWR-MPC-031	5	0.82028	0.81813
MPC-24EEF-TROPWR-MPC-032	2	0.89549	0.8943
MPC-24EEF-TROPWR-MPC-033	0	0.89106	
MPC-24EEF-TROPWR-MPC-034	0	0.76219	
MPC-24EEF-TROPWR-MPC-035	0	0.76031	
MPC-24EEF-TROPWR-MPC-036	0	0.75466	
MPC-24EEF-TROPWR-MPC-037	0	0.74902	
MPC-24EEF-TROPWR-MPC-038	0	0.75067	
MPC-24EEF-TROPWR-MPC-039	0	0.76685	
MPC-24EEF-TROPWR-MPC-040	0	0.75398	
MPC-24EEF-TROPWR-MPC-041	3	0.76283	0.75638
MPC-24EEF-TROPWR-MPC-042	0	0.75958	

A-19. Tabulated Hope Creek Results

Table 33. Hope Creek NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
MPC-32-MPC093	12	1.00564	0.90979
MPC-32-MPC094	12	0.99545	0.90639
MPC-32-MPC095	12	1.00905	0.91906
MPC-32-MPC096	12	1.00946	0.93227
MPC-32-MPC128	0	1.00145	
MPC-32-MPC129	12	1.00286	0.91654
MPC-32-MPC130	0	1.00771	
MPC-32-MPC131	0	1.00381	
MPC-32-MPC132	0	1.00271	
MPC-32-MPC133	12	0.99997	0.90913
MPC-32-MPC209	12	0.99508	0.90099
MPC-32-MPC210	0	0.99359	
MPC-32-MPC246	0	1.0077	
MPC-32-MPC247	12	0.99842	0.90389
MPC-32-MPC248	12	0.99645	0.91118
MPC-32-MPC249	0	1.00577	
MPC-32-MPC310	0	1.00807	
MPC-32-MPC311	0	1.00996	
MPC-32-MPC312	0	1.00689	
MPC-32-MPC313	0	1.01164	
MPC-32-MPC314	0	1.00832	
MPC-32-MPC315	0	1.0068	
MPC-32-MPC353	0	0.99559	
MPC-32-MPC354	0	1.00526	
MPC-32-MPC356	0	0.9971	
MPC-32-MPC357	0	1.00112	
MPC-32-MPC358	0	0.99796	

A-20. Tabulated San Onofre Results

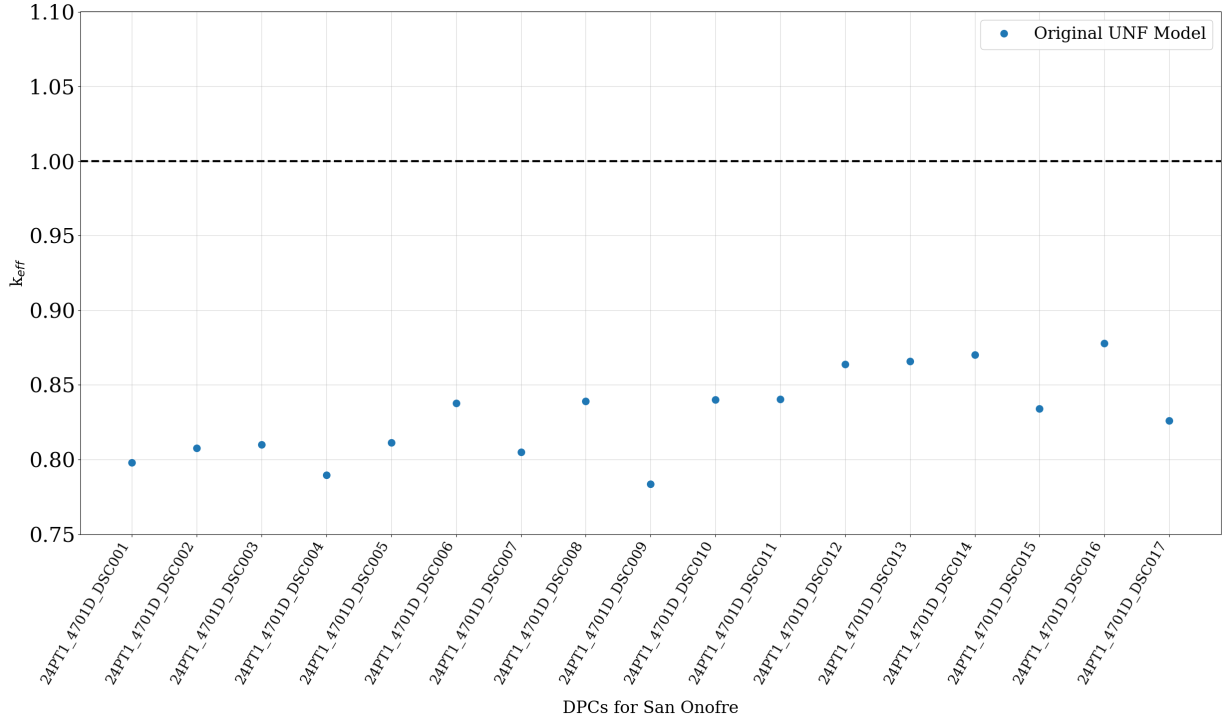

Figure 24. Criticality comparison of San Onofre DPCs for NA models with and without RCCAs.

Table 34. San Onofre NA model criticality results

DPC	Num RCCAs	k_{eff}	k_{eff} with RCCAs credited
24PT1_4701D_DSC001	0	0.79791	
24PT1_4701D_DSC002	0	0.80758	
24PT1_4701D_DSC003	0	0.81016	
24PT1_4701D_DSC004	0	0.78965	
24PT1_4701D_DSC005	0	0.81149	
24PT1_4701D_DSC006	0	0.83779	
24PT1_4701D_DSC007	0	0.8052	
24PT1_4701D_DSC008	0	0.83903	
24PT1_4701D_DSC009	0	0.78372	
24PT1_4701D_DSC010	0	0.84029	
24PT1_4701D_DSC011	0	0.84031	
24PT1_4701D_DSC012	0	0.86398	
24PT1_4701D_DSC013	0	0.86576	
24PT1_4701D_DSC014	0	0.87021	
24PT1_4701D_DSC015	0	0.83398	
24PT1_4701D_DSC016	0	0.87789	
24PT1_4701D_DSC017	0	0.82624	

Table 35. San Onofre DPCs not modeled

4701_DSC026	MPC044	MPC081
4701_DSC027	MPC045	MPC082
4701_DSC028	MPC046	MPC083
4701_DSC029	MPC047	MPC084
4701_DSC030	MPC048	MPC085
4701_DSC031	MPC049	MPC086
4701_DSC037	MPC050	MPC087
4701_DSC038	MPC051	MPC088
4701_DSC039	MPC052	MPC089
4701_DSC040	MPC053	MPC090
4701_DSC041	MPC054	MPC091
4701_DSC042	MPC055	MPC092
4701_DSC048	MPC056	MPC093
4701_DSC049	MPC057	MPC094
4701_DSC050	MPC058	MPC095
4701_DSC051	MPC059	MPC096
DSC-24PT4_4701D_DSC019	MPC060	MPC097
DSC-24PT4_4701D_DSC020	MPC061	MPC098
DSC-24PT4_4701D_DSC021	MPC062	MPC099
DSC-24PT4_4701D_DSC022	MPC063	MPC100
DSC-24PT4_4701D_DSC023	MPC064	MPC101
DSC-24PT4_4701D_DSC024	MPC065	MPC102
DSC-24PT4_4701D_DSC025	MPC066	MPC103
DSC-24PT4_4701D_DSC032	MPC067	MPC104
DSC-24PT4_4701D_DSC033	MPC068	MPC105
DSC-24PT4_4701D_DSC034	MPC069	MPC106
DSC-24PT4_4701D_DSC035	MPC070	MPC107
DSC-24PT4_4701D_DSC036	MPC071	MPC108
DSC-24PT4_4701D_DSC043	MPC072	MPC109
DSC-24PT4_4701D_DSC044	MPC073	MPC110
DSC-24PT4_4701D_DSC045	MPC074	MPC111
DSC-24PT4_4701D_DSC046	MPC075	MPC112
DSC-24PT4_4701D_DSC047	MPC076	MPC113
	MPC077	MPC114
	MPC078	MPC115
	MPC079	MPC116
	MPC080	