
REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 434-8352
SRP Section: SRP 19
Application Section: 19.1
Date of RAI Issue: 03/08/2016

Question No. 19-92

10 CFR 52.47(a)(27) states that a design certification (DC) application must contain an FSAR that includes a description of the design-specific PRA and its results. In addition, SRP Chapter 19.0, draft Revision 3, Section II "Acceptance Criteria," Item 4 on Page 19.0-13 states "The staff will determine that the applicant has identified risk-informed safety insights based on systematic evaluations of the risk associated with the design such that the applicant can identify and describe the following: A. The design's robustness, levels of defense-in-depth, and tolerance of severe accidents initiated by either internal or external events and B. The risk significance of potential human errors associated with the design." In addition, Item 13 on Page 19.0-16 states "The staff will determine that the assumptions made in the applicant's PRA during design development and certification, in which a specific site may not have been identified or all aspects of the design (e.g., balance of plant) may not have been fully developed, are identified in the DC application and either remain valid or are adequately addressed within the COL application." Furthermore, Item 14 on Page 19.0-16 states that "The staff will determine that FSAR Chapter 19 includes PRA qualitative results, including the identification of key PRA assumptions, the identification of PRA-based insights, and discussion of the results and insights from importance, sensitivity, and uncertainty analyses."

Thus, in this context, the staff reviewed APR1400 DCD Table 19.1-4 "Risk Insights and Key Assumptions" and found this table is not comprehensive in identifying the APR1400 PRA-related key assumptions and insights. Therefore, in order for the staff to reach a reasonable assurance finding, please enhance Table 19.1-4 of the DCD to identify all PRA key assumptions and PRA-based insights, and also the insights from the importance, sensitivity, and uncertainty analyses.

Response – (Rev.3)

The DCD Table 19.1-4 "Risk Insights and Key Assumptions" provides risk insights that are based on key design features, severe accident design features, and PRA that includes key assumptions, importance, and sensitivity analyses. There were total of fifty-eight (58) specific

items listed in Table 19.1-4, and ten (10) additional items, mostly related to LPSD conditions, were added during the DCD review.

Table 19.1-4 was reviewed during the PRA update, and incorporated the changes to several key PRA assumptions, to ensure that risk insights listed in the table are consistent with the risk insights and the key assumptions, and also the insights from the importance, sensitivity, and uncertainty analyses. The detailed sensitivity and uncertainty analysis will be documented in APR1400-K-P-NR-01308-P, "APR1400 PRA Sensitivity and Uncertainty Analysis," which will be made available in the Electronic Reading Room.

- a) A comprehensive assessment of the impact of uncertainties in key assumptions will be performed with considerations of risk insights and risk quantifications of CDF and LRF using the PRA update, and the assessment will be documented in APR1400-K-P-NR-01308-P, "APR1400 PRA Sensitivity and Uncertainty Analysis."

Some example assumptions (not limited to these examples) that were evaluated for uncertainty are as follows:

- fire ignition frequencies (e.g., consideration of more recent fire ignition frequency estimates)
 - RCP seal failure probability and model (e.g., based on new technical bases), Assumption No. 1 in DCD Table 19.1-4.
 - Room heat-up calculations (e.g., based on new calculations) , Assumption No. 5 in DCD Table 19.1-4
- b) The uncertainty assessment will consider all PRA models included in the APR1400 DC PRA (i.e., all operating modes, hazards, and PRA levels) using the PRA update.
- c) The uncertainty and key assumptions related to the PRA update were identified in DCD Table 19.1-4, see Assumptions 1, 5, 7, 11, 14, 15, 21, and 66.

The DCD markups from the PRA update results and insights are provided in Attachments 1 and 2 of [RAI 434-8352 Question 19-92 Rev.1](#). The Table 1 to this RAI response shows the update status of the DCD Section 19.1 tables from 2017 PRA update.

The Table 2 to this RAI response shows the update status of the DCD Section 19.1 table to add basic event probability in CDF and LRF cutsets in table in [Attachment of RAI 434-8352 Question 19-92 Rev.2](#).

Information provided to address NRC observations identified as Punch List Items No. 23, (a) - (f) and No. 32 (c):**Observation 23 (a)**

In the top 100 internal events cutsets, cutsets 55 and 73 include only one basic event indicating a potential fundamental issue relevant to the single failure requirement described in GDC 21. The staff reviewed the DCD markups and finds no discussion, justification, nor technical basis behind these cutsets. The staff is unable to draw any conclusions on these scenarios. Such results restrict staff's ability to make an adequate safety determination.

Response 23 (a)

Components can be impacted or unavailable depending on LLOCA location. For example, if a LLOCA occurs on hot leg connected with SI pump from train D, only one hot leg injection flow path connected with a SI pump from train C can be possible. To consider the different effects by LOCA location, the LLOCA initiator was divided into three areas: (1) cold leg, (2) hot leg and (3) direct vessel injection line (DVI).

However, the recent thermal-hydraulic (T/H) analysis in DCD Chapter.15 shows that boron precipitation is not expected under the condition that there is no hot leg injection during a hot leg LLOCA, and thus no core damage should occur in the accident sequence that hot leg injection fails in a hot leg LLOCA (see APR1400-F-A-NR-14003-P, Rev.1 "Post-LOCA Long Term Cooling Evaluation Model", see ML17143A428).

Cutsets #55, #73 appear in table 19.1-19 since hot leg injection in a hot leg LLOCA is assumed and modeled in APR 1400 PRA. The history of this modeling is as follows:

- a. To perform realistic analysis for system availability (mitigation capacity) for a LLOCA, KHNP divided three types LLOCAs, i.e. cold leg break, DVI break and hot leg break.
- b. When APR1400 PRA model was docketed, T/H analysis results in DCD Chapter 15 were not finalized, and it had not yet been determined whether hot leg injection was required during a LLOCA in the hot leg or not.
- c. Consequently, hot leg injection during a LLOCA in hot leg was considered in the PRA model based on the APR 1400 Emergency Operating Guidelines (EOG).

The cutsets (#55 and #73) describes that failure of hot leg injection due to a single failure of the SI pump leads to core damage when a hot leg LLOCA occurs. It does not correspond with the single failure requirement described in GDC 21, however, those cutsets appeared due to the modeling of hot leg injection in a hot leg LLOCA compared to the Chapter 15 analysis. A single failure of the SI pump would not lead to core damage when the COL applicant reviews modeling of hot leg injection in the APR 1400 PRA to decide if the modeling of hot leg injection should be considered in a hot leg LLOCA.

A sensitivity analysis for not modeling hot leg injection during a LLOCA in hot leg shows that the core damage frequency (CDF) is estimated to be 1.1E-06/yr. This is the same as the base model CDF, and therefore, there is no impact even if hot leg injection is modeled.

Other chapters within the DCD would not be affected since the CDF changes are negligible.

Therefore, KHNP believes that hot leg injection in a hot leg LLOCA, for the purposes of risk analysis in Chapter 19, is modeled in APR 1400 PRA. KHNP proposes adding the issue of hot leg injection modeling as a COL item and providing additional information in the DCD as follows:

- 1) Add assumption "I" in the DCD section 19.1.4.1.2.5.
 - i) It is assumed for the purpose of analysis that hot leg injection during a hot leg LLOCA is required and modeled in the APR 1400 PRA. This assumption is less restrained compared to T/H analysis results in DCD Chapter 15.

The mark-up is provided in Attachment 1.

- 2) Add COL item "19.1(27)" in the DCD section 19.1.9 and Table 1.8-2.

COL 19.1(27) The COL applicant will ensure the APR1400 thermal-hydraulic (T/H) analysis supporting the application is reflected in the updated PRA model including those design and operational features for mitigation of a hot leg LLOCA.

The mark-up is provided in Attachment 2.

- 3) Add Modeling history for hot leg injection in a hot leg LLOCA and explanation for cutsets (#55, #73) in the DCD section 19.1.4.1.2.3.

To perform realistic analysis for system availability (mitigation capacity) for a LLOCA, the PRA analysis evaluated three types of LLOCAs, i.e. cold leg break, DVI break and hot leg break. Consequently, hot leg injection during a LLOCA in hot leg was modeled in the PRA since the guidance in the APR 1400 Emergency Operating Guidelines (EOG) requires the initiation of hot leg injection during a potential LLOCA scenario. For the purposes of the APR 1400 PRA analysis, a failure of hot leg injection due to a single failure of the SI pump resulted in two cutsets within the top 100 which reflected that the modeling could lead core damage when a hot leg LLOCA occurs. However, the recent thermal-hydraulic (T/H) analysis in DCD Chapter.15 shows that boron precipitation is not expected under the condition that there is no hot leg injection during a hot leg LLOCA, and thus no core damage should occur in the accident sequence that hot leg injection fails in a hot leg LLOCA (see APR1400-F-A-NR-14003-P, Rev.1 "Post-LOCA Long Term Cooling Evaluation Model", Therefore, based on the T/H analysis performed to support Chapter 15 of the APR1400 design, no single failure will result in core damage or the loss of safety or protection function. To assess this relative to design criteria and T/H analysis performed for deterministic purposes, e.g. Chapter 15, a sensitivity analysis for not modeling hot leg injection during a LLOCA in hot leg shows that the core damage frequency (CDF) is estimated to be 1.1E-06/yr. This is the same as the full power internal base model CDF, and therefore, there is no impact even if hot leg injection is modeled (COL 19.1(27)).

The mark-up is provided in Attachment 3.

Observations 23 (b) and (e)

- (b) CCF higher in the data notebook than Random Failures. CCF appears to have not been included in the dominant cutsets, e.g. EDG, T-D Pump, etc., explain.
- (e) Cutsets #10, #11, and #12 include the combination of individual failures of similar components such as the AFW TDPs or the 2 of the 4 EDGs. However, the CCF of the similar components does not show up in the cutsets, e.g. a CCF of the 'C' and 'D' EDGs would result in a higher cutset probability. This has implications for the CCF combinations omitted and the total plant CDF.

Response 23 (b) and (e)

As shown in the table below, running failure probability for one AF TDP is 3.52E-02, and therefore, running failure probability for two AF TDPs can be calculated to be 1.24E-03 ($3.52\text{E-}02 \times 3.52\text{E-}02 = 1.24\text{E-}03$). This means that the running failure probability for two AF TDPs (1.24E-03) is higher than that of 2/2 running CCF (6.89E-04), and thus, running failure events for AF TDPs can appear in a higher cutset than 2/2 running CCF event. The 2/2 running CCF event for AF TDPs, AFTPKD2-TDP01A/B, appears in a cutset #26.

Basic Event	Description	Failure Probability
AFTPR1A-TDP01A	FAILS TO RUN AFW TDP PP01A	3.52E-02
AFTPR1B-TDP01B	FAILS TO RUN AFW TDP PP01B	3.52E-02
AFTPKD2-TDP01A/B	2/2 CCF OF FOR AFW TDP PP01A/B FAIL TO RUN	6.89E-04

The issue for running failure and 2/4 running CCF for EDGs can also be interpreted in the same context.

In other cases, CCF probability could be higher than that of random failure probability. For instance, as shown in the table below, 4/4 running CCF probability for EDGs (5.95E-05) is higher than that of random failure combination for EDGs ($2.50\text{E-}02 \times 2.50\text{E-}02 \times 2.50\text{E-}02 \times 2.50\text{E-}02 = 3.91\text{E-}07$). The 4/4 running CCF event for EDGs appears in a cutset #14 while random failure combination for EDGs appears in a cutset #2151.

Basic Event	Description	Failure Probability
DGDGR-A-DGA	FAILS TO RUN OF EMERGENCY DIESEL GENERATOR DG01A	2.50E-02
DGDGR-B-DGB	FAILS TO RUN OF EMERGENCY DIESEL GENERATOR DG01B	2.50E-02
DGDGR-C-DGC	FAILS TO RUN OF EMERGENCY DIESEL GENERATOR DG01C	2.50E-02
DGDGR-D-DGD	FAILS TO RUN OF EMERGENCY DIESEL GENERATOR DG01D	2.50E-02
DGDGKQ4-DG01ABCD	4/4 CCF OF EDG 01A/01B/01C/01D FAIL TO RUN	5.95E-05

In conclusion, the random failures (e.g., start failure and running failure) and the CCFs for EDGs and AF TDPs are modeled as basic events in the APR 1400 PRA model. CCF probability could

be higher and lower than that of random failure probability, and therefore, the cutset level would be different based on event's failure probability.

Observation 23 (c)

The cutsets 28, 51 and 100 include the unavailability due to test and maintenance of two of the same type of component that would not be allowed by Tech Specs, e.g. Containment Spray Heat exchanger, EDGs, and DC Batteries.

Response 23 (c)

Cutsets 28, 51 and 100 should not be presented as a PRA result. For example, cutset 28 is that combination of test and maintenance (T&M) for CS heat exchangers of all of CS Trains. This test and maintenance configuration is not allowed by APR1400 Technical Specifications. Therefore, KHNP reviewed mutually exclusive cutsets (MUX) in the scope of at power and LPSD conditions (for both internal Level 1/Level2 and external Level 1/Level 2), to assess the effects on CDF and LRF. Recovery rules were made and reviewed for deleting MUX. The MUX rule file consists of 91 combinations of T&M cutset. The MUX rules are based on Technical Specifications provided in Chapter 16 of DCD (Rev.1), and are included in the Attachment 8.

The MUX rule file is applied for the PRA results and the effects on other chapters are provided in Attachment 9. The total CDF/LRF slightly decreases about 1.75% and 0.66% respectively. KHNP has reviewed the impact on the DCD other chapters, and it has been identified that the change of results does not have the impact on the DCD other chapters. However, there is small impact on the DCD related document for chapter 18, Human Factor Engineering. It is limited to editorial issue of the human factors engineering program element technical report, APR1400-E-I-NR-14006, "Treatment of Important Human Actions Implementation Plan."

Considering the results of applying the MUX rule file and their limited impact on the DCD other chapters, KHNP proposes to provide additional information in the DCD as follows:

In Chapter 19, section 19.1.4.1.1.4, "Systems Analysis", subsection b. "Conditions concerning level of detail", add assumption (6):

- 6) The APR1400 PRA model currently contains some "test and maintenance" configurations which are not permissible by APR1400 Technical Specifications. While these configurations are outside current Technical Specifications for operations, inclusion of these maintenance configurations in the current PRA is conservative with respect to CDF and LRF. The improper cutsets will be excluded from the cutsets resulting from the plant specific PRA, maintenance programs and Technical Specifications developed by the COL applicant (COL 19.1(28)).

The mark-up is provided in Attachment 4.

In Chapter 19, section 19.1.9, add the following COL item:

- COL 19.1(28) The COL applicant will review the Technical Specifications and incorporate logic into the PRA model to ensure cutsets reflect permissible maintenance configurations.

The mark-up is provided in Attachment 2.

In addition, KHNP notices that APR 1400 PRA model does not meet QU-B7 and QU-B8 in the ASME standard due to the improper cutsets that would not be allowed by Tech Specs of APR1400 PRA. Therefore, KHNP proposes to revise the DCD in Chapter 19, Table 19.1-1, "Characterization of PRA Relative to Supporting Requirements in ASME PRA Standard", to change "Quantification (QU)" characteristics to read as follows:

The quantification was performed by solving the overall core damage model using the linked fault-tree approach. The quantification satisfies at least Category I for each of the supporting requirements except for two (2) supporting requirements, QU-B7 and QU-B8. The logic of mutually exclusive events (MUX) did not cover all MUX, thus, some improper test and maintenance events appeared in the PRA results.

The mark-up is provided in Attachment 5.

Observation 23 (d)

The list of cutsets does not include the asymmetric equivalent of Cutset 55, such that the unavailability of the "A" SI pump in combination with a LLOCA would be in a similar and equivalent cutset.

Response 23 (d)

In section 19.1.4.1.1.4 "Systems Analysis", in subsection b. "Conditions concerning level of detail", add assumption 7):

- 7) The APR1400 PRA model is an asymmetric model. Therefore, location specific initiating events are assigned to a single location, e.g., SGTR is assumed to occur in SG #2, DVI line Large LOCA is assumed to occur in DVI line 1B, etc. System models reflect these locational initiating events, e.g., DVI large LOCA is assumed to result in the direct failure of SI pump PP02D and SIT TK01D since the injection flow from these components would be lost via the break in DVI line 1B. In addition, normally operating systems whose trains are operated on a rotational basis (e.g., CC, SX, etc.) have an assumed configuration with one train assumed to be the operating train, and the other train is assumed to be the standby train. Note that for the purposes of determining the CDF and LRF risk metrics, model asymmetry has no impact. The main impact is that the importance of equipment in those systems can differ on a train basis; however, for risk applications related to risk ranking, this can be compensated for by assigning the highest importance measure of a component within a group to all members within the group (COL 19.1(23)).

The mark-up is provided in Attachment 4.

Observation 23 (f)

Cutset 55 assumes a LLOCA and Hot Leg Injection using an SI Pump. It is not clear what is the specific SI Pump success criteria for injecting into the core and to prevent boron precipitation by hot leg injection.

Response 23 (f)

Since RCS inventory makeup and hot leg injection by safety injection pumps are required in response to a large break LOCA (LLOCA), components can be impacted or unavailable depending on the LLOCA locations. For example, if a LLOCA occurs on hot leg connected with SI pump from train D, only one hot leg injection flow path connected with SI pump from train C can be possible. To consider the different effects by LOCA location, the LLOCA initiator was divided into three areas: (1) cold leg, (2) hot leg and (3) direct vessel injection line (DVI). As a result, SI Pump success criteria for injecting into the core and to prevent boron precipitation by hot leg injection (HLI) were identified as follows:

	Cold Leg Break	DVI Leg Break	Hot Leg Break
SI Pump success criteria for safety injection	DVI : 2/4	DVI : 2/3	DVI : 2/4
SI Pump success criteria for hot leg injection	HLI : 1/2 DVI : 1/2	HLI : 1/2 DVI : 1/2	HLI : 1/1 DVI : 1/2

Observation 32 (c)

DCD, Risk Insights table, Item 25, on the C & D Batteries, it should say “no load shedding” instead of “not dc loading”

Response 32 (c)

The mark-up addressing this observation relating to the risk insights, Table 19.1-4, item No. 25 is provided in Attachment 6, and an editorial change to the same table, item Nos. 40, 41, and 43 is provided in Attachment 7.

Impact on DCD

DCD Section 19.1 & DCD Table 1.8-2 will be revised as indicated in the Attachment 1 & 2.

In the previous revised response (Rev.2), the Attachment only includes the tables changed from RAI 434-8352 Question 19-92 Rev.1.

In this revised response (Rev.3), the Attachments 1, 2, 3, 4, 5, 6 and 7 includes mark-ups changed from RAI 434-8352 Question 19-92 Rev.1 & Rev.2.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

Table 1 - Section 19.1 Table Update Status from 2017 PRA Update

Table Number	Table Title	Update Status
Table 19.1-1	Characterization of PRA Relative to Supporting Requirements in ASME PRA Standard	Unchanged
Table 19.1-2	Key Design Features in APR1400	Unchanged
Table 19.1-3	Design Features Addressing Potential Risk Challenges	Unchanged
Table 19.1-4	Risk Insights and Key Assumptions	Partial Update
Table 19.1-5	Relation of the Plant Safety Functions and the Initiating Events Types	Unchanged
Table 19.1-6	Internal Events PRA Initiating Event Frequencies	Table Replaced
Table 19.1-7	Level 1 Internal Events PRA Event Tree List	Unchanged
Table 19.1-8	Event Tree Top Events and Success Criteria	Unchanged
Table 19.1-9	PRA Modeled Systems	Unchanged
Table 19.1-10a	Dependency between Initiating Events and Front Line Systems	Unchanged
Table 19.1-10b	Dependency between Initiating Events and Support Systems	Unchanged
Table 19.1-11a	Front Line System Dependencies on Support Systems	Unchanged
Table 19.1-11b	Support System Dependencies on Other Support Systems	Unchanged
Table 19.1-12	RELAP Thermal-Hydraulic Run Summaries	Unchanged
Table 19.1-13	MAAP Thermal-Hydraulic Run Summaries	Unchanged
Table 19.1-14	Component Failure Rate Data	Table Replaced
Table 19.1-14a	Component Unavailability Data	New Table
Table 19.1-15	Component Boundaries	Unchanged
Table 19.1-16	Special Basic Events	Table Replaced
Table 19.1-17	Level 1 Internal Events CDF Contribution by Initiating Events	Table Replaced
Table 19.1-18	Level 1 Internal Events Top Accident Sequences	Table Replaced
Table 19.1-19	Level 1 Internal Events Top 100 CDF Cutsets	Table Replaced
Table 19.1-20	Level 1 Internal Events Key Basic Events RAW (CDF)	Table Replaced
Table 19.1-21	Level 1 Internal Events Key Basic Events by FV (CDF)	Table Replaced
Table 19.1-22	Level 1 Internal Events Key CCF Events by RAW (CDF)	Table Replaced
Table 19.1-23	Level 1 Internal Events Key CCF Events by FV (CDF)	Table Replaced
Table 19.1-24	Level 1 Internal Events Key Operator Actions by RAW (CDF)	Table Replaced
Table 19.1-25	Level 1 Internal Events Key Operator Actions by FV (CDF)	Table Replaced
Table 19.1-26	PDS Grouping Parameters	Unchanged
Table 19.1-27	Frequency of Dominant PDSs	Table Replaced
Table 19.1-28	Containment Failure Modes and Results	Unchanged

Table 1 - Section 19.1 Table Update Status from 2017 PRA Update

Table Number	Table Title	Update Status
Table 19.1-28a	Comparison of Containment Pressure Between 19.1, 19.2 and 19.3	Unchanged
Table 19.1-29	Summary of Source Term Evaluation	Unchanged
Table 19.1-30	Source Term Category Frequencies and Contributions to LRF for Internal Events	Table Replaced
Table 19.1-30a	Source Term Category Frequencies and Contributions to LRF for Internal Fire Events	Table Replaced
Table 19.1-30b	Source Term Category Frequencies and Contributions to LRF for Internal Flooding Events	Table Replaced
Table 19.1-31	Level 2 Internal Events Top 100 LRF Cutsets	Table Replaced
Table 19.1-32	Level 2 Internal Events LRF Contributions by Initiating Events	Table Replaced
Table 19.1-33	Significant PDS Contributors to LRF	Table Deleted
Table 19.1-34	Level 2 Internal Events Key Basic Events by RAW (LRF)	Table Replaced
Table 19.1-35	Level 2 Internal Events Key Basic Events by FV (LRF)	Table Replaced
Table 19.1-36	Level 2 Internal Events Key CCF Events by RAW (LRF)	Table Replaced
Table 19.1-37	Level 2 Internal Events Key CCF Events by FV (LRF)	Table Replaced
Table 19.1-38	Level 2 Internal Events Key Operator Actions by RAW (LRF)	Table Replaced
Table 19.1-39	Level 2 Internal Events Key Operator Actions by FV (LRF)	Table Replaced
Table 19.1-40	Results of LRF Sensitivity Analyses	Table Replaced
Table 19.1-41	Systems Considered for Seismic Equipment List	See RAI 19-10 Response
Table 19.1-42	Seismic Equipment List	See RAI 19-10 Response
Table 19.1-43	Seismic Fragility Analysis Results Summary	See RAI 19-10 Response
Table 19.1-44	Dominant Contributors to the Plant HCLPF	Table Replaced
Table 19.1-45	Fire Compartment Initiator Development and Screening	Unchanged
Table 19.1-46a	Internal Fire PRA Fire – Induced Initiators IEF	Table Replaced
Table 19.1-46b	Internal Fire PRA CDF Contribution by Top Fire Induced Initiators	Table Replaced
Table 19.1-46c	Internal Fire PRA LRF Contribution by Top Fire Induced Initiators	Table Replaced
Table 19.1-47	Internal Fire PRA CDF Contribution by Top Fire Scenario	Table Replaced
Table 19.1-48	Internal Fire PRA LRF Contribution by Top Fire Scenario	Table Replaced
Table 19.1-49	Internal Fire PRA Top 100 CDF Cutsets	Table Replaced
Table 19.1-50	Internal Fire PRA Top 100 LRF Cutsets	Table Replaced

Table 1 - Section 19.1 Table Update Status from 2017 PRA Update

Table Number	Table Title	Update Status
Table 19.1-51	Internal Fire PRA Key Basic Events by RAW (CDF)	Table Replaced
Table 19.1-52	Internal Fire PRA Key Basic Events by FV (CDF)	Table Replaced
Table 19.1-53	Internal Fire PRA Key CCF Events by RAW (CDF)	Table Replaced
Table 19.1-54	Internal Fire PRA Key CCF Events by FV (CDF)	Table Replaced
Table 19.1-55	Internal Fire PRA Key Operator Actions by RAW (CDF)	Table Replaced
Table 19.1-56	Internal Fire PRA Key Operator Actions by FV (CDF)	Table Replaced
Table 19.1-57	Internal Fire PRA Key Basic Events by RAW (LRF)	Table Replaced
Table 19.1-58	Internal Fire PRA Key Basic Events by FV (LRF)	Table Replaced
Table 19.1-59	Internal Fire PRA Key CCF Events by RAW (LRF)	Table Replaced
Table 19.1-60	Internal Fire PRA Key CCF Events by FV (LRF)	Table Replaced
Table 19.1-61	Internal Fire PRA Key Operator Actions by RAW (LRF)	Table Replaced
Table 19.1-62	Internal Fire PRA Key Operator Actions by FV (LRF)	Table Replaced
Table 19.1-62a	Flood Sources by Flood Area	Unchanged
Table 19.1-63	Internal Flooding Initiating Event Summary	Table Replaced
Table 19.1-64	Internal Flooding PRA CDF Contribution by Top Flooding Induced Initiators	Table Replaced
Table 19.1-65	Internal Flooding PRA LRF Contribution by Top Flooding Induced Initiators	Table Replaced
Table 19.1-66	Internal Flooding PRA Top 100 CDF Cutsets	Table Replaced
Table 19.1-67	Internal Flooding PRA Top 100 LRF Cutsets	Table Replaced
Table 19.1-68	Internal Flooding PRA Key Basic Events by RAW (CDF)	Table Replaced
Table 19.1-69	Internal Flooding PRA Key Basic Events by FV (CDF)	Table Replaced
Table 19.1-70	Internal Flooding PRA Key CCF Events by RAW (CDF)	Table Replaced
Table 19.1-71	Internal Flooding PRA Key CCF Events by FV (CDF)	Table Replaced
Table 19.1-72	Internal Flooding PRA Key Operator Actions by RAW (CDF)	Table Replaced
Table 19.1-73	Internal Flooding PRA Key Operator Actions by FV (CDF)	Table Replaced
Table 19.1-74	Internal Flooding PRA Key Basic Events by RAW (LRF)	Table Replaced
Table 19.1-75	Internal Flooding PRA Key Basic Events by FV (LRF)	Table Replaced
Table 19.1-76	Internal Flooding PRA Key CCF Events by RAW (LRF)	Table Replaced
Table 19.1-77	Internal Flooding PRA Key CCF Events by FV (LRF)	Table Replaced
Table 19.1-78	Internal Flooding PRA Key Operator Actions by RAW (LRF)	Table Replaced
Table 19.1-79	Internal Flooding PRA Key Operator Actions by FV (LRF)	Table Replaced
Table 19.1-80	Summary of External Hazard Dispositions	See RAI 19-14 Response

Table 1 - Section 19.1 Table Update Status from 2017 PRA Update

Table Number	Table Title	Update Status
Table 19.1-81	LPSD Plant Operating States	Unchanged
Table 19.1-82	LPSD PRA Loss of SCS Initiators	Unchanged
Table 19.1-83	LPSD PRA General LOCA Initiators	Table Replaced
Table 19.1-84	LPSD PRA Shutdown-Specific LOCA Initiators	Unchanged
Table 19.1-85	LPSD PRA (LOOP)(SBO) Initiators	Table Replaced
Table 19.1-86	LPSD PRA Loss of Supporting System Initiators	Table Replaced
Table 19.1-87	LPSD PRA Transient Events Initiators	Table Replaced
Table 19.1-88	LPSD PRA Accident Sequences Summary	Unchanged
Table 19.1-89	LPSD PRA Success Criteria Summary for Events Involving Loss of Operating SCS Train	Unchanged
Table 19.1-90	LPSD PRA Success Criteria Summary for Events Involving RCS Inventory	Unchanged
Table 19.1-91	LPSD PRA Success Criteria Summary for SBO Events	Unchanged
Table 19.1-92	LPSD PRA Success Criteria Summary for TLOCCW/TLOESW Events	Unchanged
Table 19.1-92a	The Results of Thermal-Hydraulic Analyses for POS 12B	Unchanged
Table 19.1-92b	Summary of Analysis Results for Plant Operating States	Unchanged
Table 19.1-93	LPSD PRA Internal Events CDF Contributions for Initiating Event - All POS	Table Replaced
Table 19.1-94	LPSD PRA Internal Events CDF Contributions for Initiating Event – Reduced Inventory	Table Replaced
Table 19.1-95	LPSD Internal Events PRA CDF Contributions by Plant Operating State	Table Replaced
Table 19.1-96	LPSD Internal Events PRA Top 100 CDF Cutsets - All POS	Table Replaced
Table 19.1-97	LPSD Internal Events PRA Top 100 CDF Cutsets - Reduced Inventory	Table Replaced
Table 19.1-98	LPSD Internal Events PRA Key Basic Events by RAW (CDF) - All POS	Table Replaced
Table 19.1-99	LPSD Internal Events PRA Key Basic Events by RAW (CDF) - Reduced Inventory	Table Replaced
Table 19.1-100	LPSD Internal Events PRA Key Basic Events by FV (CDF) - All POS	Table Replaced
Table 19.1-101	LPSD Internal Events PRA Key Basic Events by FV (CDF) - Reduced Inventory	Table Replaced
Table 19.1-102	LPSD Internal Events PRA Key CCF Events by RAW (CDF)	Table Replaced
Table 19.1-103	LPSD Internal Events PRA Key CCF Events by FV (CDF)	Table Replaced
Table 19.1-104	LPSD Internal Events PRA Key Operator Actions by	Table Replaced

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Table Number	Table Title	Update Status
	RAW (CDF)	
Table 19.1-105	LPSD Internal Events PRA Key Operator Actions by FV (CDF)	Table Replaced
Table 19.1-105a	LPSD Internal Events PRA Key Initiating Events by FV (CDF)	Table Replaced
Table 19.1-105b	LPSD Internal Events PRA Key Initiating Events by RAW (CDF)	Table Replaced
Table 19.1-105c	LPSD Internal Events PRA Key Initiating Events by RRW (CDF)	Table Replaced
Table 19.1-106	LPSD Internal Flooding PRA CDF Contributions for Initiating Events - All POS	Table Replaced
Table 19.1-107	LPSD Internal Flooding PRA CDF Contributions for Initiating Events - Reduced Inventory	Table Replaced
Table 19.1-107a	LPSD Internal Events PRA Key Initiating Events by RAW (CDF)	See Table 19.1-105b
Table 19.1-108	LPSD Internal Flooding PRA CDF Contributions by Plant Operating State	Table Replaced
Table 19.1-108a	LPSD Internal Events PRA Key Initiating Events by RRW (CDF)	See Table 19.1-105c
Table 19.1-109	LPSD Internal Flooding PRA CDF Top 100 Cutsets – All POS	Table Replaced
Table 19.1-110	LPSD Internal Flooding PRA CDF Top 100 Cutsets – Reduced Inventory	Table Replaced
Table 19.1-111	LPSD Internal Flooding PRA Key Basic Events by RAW (CDF) – All POS	Table Replaced
Table 19.1-112	LPSD Internal Flooding PRA Key Basic Events by RAW (CDF) – Reduce Inventory	Table Replaced
Table 19.1-113	LPSD Internal Flooding PRA Key Basic Events by FV (CDF) – All POS	Table Replaced
Table 19.1-114	LPSD Internal Flooding PRA Key Basic Events by FV (CDF) – Reduced Inventory	Table Replaced
Table 19.1-115	LPSD Internal Flooding PRA Key CCF by RAW (CDF)	Table Replaced
Table 19.1-116	LPSD Internal Flooding PRA Key CCF by FV (CDF)	Table Replaced
Table 19.1-117	LPSD Internal Flooding PRA Key Operator Actions by RAW (CDF)	Table Replaced
Table 19.1-118	LPSD Internal Flooding PRA Key Operator Actions by FV (CDF)	Table Replaced
Table 19.1-119	LPSD Fire PRA CDF Contributions by Plant Operating State	Table Replaced
Table 19.1-120	LPSD PRA CDF Contributions for Internal Fire Initiating Events - All POS	Table Replaced

Table 1 - Section 19.1 Table Update Status from 2017 PRA Update

Table Number	Table Title	Update Status
Table 19.1-121	LPSD PRA CDF Contributions for Internal Fire Initiating Events – Reduced Inventory	Table Replaced
Table 19.1-122	LPSD PRA CDF Internal Fire Top 100 Cutsets – All POS	Table Replaced
Table 19.1-123	LPSD PRA CDF Internal Fire Top 100 Cutsets – Reduced Inventory	Table Replaced
Table 19.1-124	LPSD Internal Fire PRA Key Basic Events by RAW (CDF) – All POS	Table Replaced
Table 19.1-125	LPSD Internal Fire PRA Key Basic Events by RAW (CDF) – Reduced Inventory	Table Replaced
Table 19.1-126	LPSD Internal Fire PRA Key Basic Events by FV (CDF) – All POS	Table Replaced
Table 19.1-127	LPSD Internal Fire PRA Key Basic Events by FV (CDF) – Reduced Inventory	Table Replaced
Table 19.1-128	LPSD Internal Fire PRA Key CCF by RAW (CDF)	Table Replaced
Table 19.1-129	LPSD Internal Fire PRA Key CCF by FV (CDF)	Unchanged
Table 19.1-130	LPSD Internal Fire PRA Key PRA Operator Actions by RAW (CDF)	Table Replaced
Table 19.1-131	LPSD Internal Fire PRA Key PRA Operator Actions by FV (CDF)	Table Replaced
Table 19.1-132	APR1400 Shutdown LRF Screening Methodology	Table Replaced
Table 19.1-133	APR1400 LPSD Internal Events Release Fractions	Table Replaced
Table 19.1-134	Internal Events LPSD LRF by POS	Table Replaced
Table 19.1-135	LPSD Internal Events PRA Top 100 Cutsets (LRF) – All POS	Table Replaced
Table 19.1-136	LPSD Internal Events PRA Top 100 Cutsets (LRF) – Reduced Inventory	Table Replaced
Table 19.1-137	LPSD Internal Events PRA LRF Contribution by Initiating Events – POS 4B to 12A	Table Replaced
Table 19.1-138	LPSD Internal Events PRA LRF Contribution by Initiating Events – Reduced Inventory POS	Table Replaced
Table 19.1-139	LPSD Internal Events PRA Key Basic Events by RAW (LRF) – POS 4B to 12A	Table Replaced
Table 19.1-140	LPSD Internal Events PRA Key Basic Events by RAW (LRF) – Reduced Inventory	Table Replaced
Table 19.1-141	LPSD Internal Events PRA Key Basic Events by FV (LRF) – POS 4B to 12A	Table Replaced
Table 19.1-142	LPSD Internal Events PRA Key Basic Events by RAW (LRF) – Reduced Inventory	Table Replaced
Table 19.1-143	LPSD Internal Events PRA Key CCF Events by RAW (LRF)	Table Replaced
Table 19.1-144	LPSD Internal Events PRA Key CCF Events by FV	Table Replaced

Table 1 - Section 19.1 Table Update Status from 2017 PRA Update

Table Number	Table Title	Update Status
	(LRF)	
Table 19.1-145	LPSD Internal Events PRA Key Operator Actions by RAW (LRF)	Table Replaced
Table 19.1-146	LPSD Internal Events PRA Key Operator Actions by FV (LRF)	Table Replaced
Table 19.1-147	LPSD Internal Events Source Term Category Frequencies and Contributions to LRF (POS 4B-12A)	Table Replaced
Table 19.1-148	LPSD Fire LRF by POS	Table Replaced
Table 19.1-149	LPSD Internal Fire PRA Top 100 Cutsets (LRF) – All POS	Table Replaced
Table 19.1-150	LPSD Internal Fire PRA Top 100 Cutsets (LRF) – Reduced Inventory	Table Replaced
Table 19.1-151	LPSD Internal Fire PRA LRF Contribution by Initiating Events – All POS	Table Replaced
Table 19.1-152	LPSD Internal Fire PRA LRF Contribution by Initiating Events – Reduced Inventory POS	Table Replaced
Table 19.1-153	LPSD Internal Fire PRA Key Basic Events by RAW (LRF) –All POS	Table Replaced
Table 19.1-154	LPSD Internal Fire PRA Key Basic Events by RAW (LRF) –Reduced Inventory	Table Replaced
Table 19.1-155	LPSD Internal Fire PRA Key Basic Events by FV (LRF) – All POS	Table Replaced
Table 19.1-156	LPSD Internal Fire PRA Key Basic Events by FV (LRF) – Reduced Inventory	Table Replaced
Table 19.1-157	LPSD Internal Fire PRA Key CCF Events by RAW (LRF)	Table Replaced
Table 19.1-158	LPSD Internal Fire PRA Key CCF Events by FV (LRF)	Table Replaced
Table 19.1-159	LPSD Internal Fire PRA Key Operator Actions by RAW (LRF)	Table Replaced
Table 19.1-160	LPSD Internal Events PRA Key Operator Actions by FV (LRF)	Table Replaced
Table 19.1-161	LPSD FPRA Source Term Category Frequencies and Contributions to LRF (POS 4B-12A)	Table Replaced
Table 19.1-162	AFWS Unreliability Results	See RAI 19-45

Table 2 - Section 19.1 Revised Table Update Status

Table Number	Table Title	Update Status
Table 19.1-31	Level 2 Internal Events Top 100 LRF Cutsets	Table Modified
Table 19.1-66	Internal Flooding PRA Top 100 CDF Cutsets	Table Modified
Table 19.1-67	Internal Flooding PRA Top 100 LRF Cutsets	Table Modified
Table 19.1-96	LPSD Internal Events PRA Top 100 CDF Cutsets - All POS	Table Modified
Table 19.1-97	LPSD Internal Events PRA Top 100 CDF Cutsets - Reduced Inventory	Table Modified
Table 19.1-109	LPSD Internal Flooding PRA CDF Top 100 Cutsets – All POS	Table Modified
Table 19.1-110	LPSD Internal Flooding PRA CDF Top 100 Cutsets – Reduced Inventory	Table Modified
Table 19.1-135	LPSD Internal Events PRA Top 100 Cutsets (LRF) – All POS	Table Modified
Table 19.1-136	LPSD Internal Events PRA Top 100 Cutsets (LRF) – Reduced Inventory	Table Modified

~~models. The digital I&C model is retained as is with a single event representing the software/communication links as a black box event. The event probability in the fault tree model is based on engineering judgment. The dependency between hardware and software/communication links is not evaluated, but will be evaluated when design details are finalized.~~ assumptions are described in Section 19.1.4.1.1.4 general assumption c.8.

Add A

19.1.4.1.2.6

Uncertainty Analysis

Uncertainty in the Level 1 internal events PRA results is quantified using the SAREXUNCERT code to run Monte Carlo simulations (5,000 samples). The results of the parametric uncertainty analysis for the Level 1 internal events CDF are summarized below:

- 5 percent value: ~~4.53.5~~ 4.53.5 $\times 10^{-7}$ /year
- Mean value: ~~1.9.3~~ 1.9.3 $\times 10^{-6}$ /year
- 95 percent value: ~~3.83.4~~ 3.83.4 $\times 10^{-6}$ /year

This 95th percentile CDF value is more than an order of magnitude below the NRC goal of 1×10^{-4} /year.

The results for parametric uncertainty, the mean value from Monte Carlo simulation, is larger than the point estimate. This is due to the “state of knowledge correlation” as defined in the ASME/ANS PRA Standards, which is important for cutsets that contain multiple basic events whose probabilities are based on the same data, particularly when the uncertainty of the parameter value is large. In the Monte Carlo sampling approach, the same value is used for each basic event probability, since the “state of knowledge” about the parameter value is the same for each event. This results in a mean value for the joint probability that is larger than the product of the mean values of the event probabilities.

Importance of the redundant equipment and the state-of-knowledge dependencies is limited for the equipment where CCFs dominate the results. The impact of the redundant equipment is more important in the case where equipment single failures are also significant contributors to the results.

More detailed discussion on parametric and modeling uncertainty is as follows:

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- i) It is assumed for the purpose of analysis that hot leg injection during a hot leg LLOCA is required and modeled in the APR 1400 PRA. This assumption is less restrained when compared to T/H analysis results in DCD Chapter 15.

- COL 19.1(20) The COL applicant is to perform the seismic-fire interactions walkdown to confirm a qualitative seismic-fire interaction assessment.
- COL 19.1(21) The COL applicant is to develop outage procedures to ensure that in fire compartments containing post-seismic or post-fire safe shutdown equipment that: 1) the seismic ruggedness of temporary ignition sources is adequate, or that the duration that these temporary ignition sources are in these areas is minimized, 2) the seismic ruggedness of temporary equipment such as scaffolding in fire compartments containing potential seismic-fire ignition sources, or near fire protection equipment is adequate, and 3) either the duration of activities which could impact manual firefighting is minimized, or alternative firefighting equipment (e.g., pre-stage portable smoke removal equipment, prestage additional firefighting equipment, etc.) is supplied.
- COL 19.1(22) The COL applicant is to demonstrate that failure of buildings that are not seismic Category I (e.g., turbine building and compound building) does not impact SSCs designed to be seismic Category I.
- COL 19.1(23) The COL applicant is to ensure that asymmetric conditions due to modeling simplicity will be addressed or properly accounted for when the PRA is used for decision making.
- COL 19.1(24) The COL applicant will demonstrate that maintenance-induced floods are negligible contributors to flood risk when the plant specific data are available.

Add A

19.1.10

References

1. ASME/ANS RA-S-2008, "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications" (Revision 1 RA-S-2002), American Society of Mechanical Engineers, April 2008.
2. ASME/ANS RA-Sa-2009, "Addenda to ASME/ANS RA-S-2008," American Society of Mechanical Engineers, February 2009.

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COL 19.1(27) The COL applicant will ensure the APR1400 thermal-hydraulic (T/H) analysis supporting the application is reflected in the updated PRA model including those design and operational features for mitigation of a hot leg LLOCA.

COL 19.1(28) The COL applicant will review the Technical Specifications and incorporate logic into the PRA model to ensure cutsets reflect permissible maintenance configurations.

Table 1.8-2 (36 of 38)

Item No.	Description
COL 19.1(21)	The COL applicant is to develop outage procedures to ensure that in fire compartments containing post-seismic or post-fire safe shutdown equipment that: 1) the seismic ruggedness of temporary ignition sources is adequate, or that the duration that these temporary ignition sources are in these areas is minimized, 2) the seismic ruggedness of temporary equipment such as scaffolding in fire compartments containing potential seismic-fire ignition sources, or near fire protection equipment is adequate, and 3) either the duration of activities which could impact manual firefighting is minimized, or alternative firefighting equipment (e.g., pre-stage portable smoke removal equipment, prestage additional firefighting equipment, etc.) is supplied.
COL 19.1(22)	The COL applicant is to demonstrate that failure of buildings that are not seismic Category I (e.g., turbine building and compound building) does not impact SSCs designed to be seismic Category I.
COL 19.1(23)	The COL applicant is to ensure that asymmetric conditions due to modeling simplicity will be addressed or properly accounted for when the PRA is used for decision making.
COL 19.1(24)	The COL applicant will demonstrate that maintenance-induced floods are negligible contributors to flood risk when the plant specific data are available.
COL 19.2(1)	The COL applicant is to perform and submit site-specific equipment survivability assessment in accordance with 10 CFR 50.34(f) and 10 CFR 50.44 which reflects the equipment identified and the containment atmospheric assessments of temperature, pressure and radiation described in Subsection 19.2.3.3.7.
COL 19.2(2)	The COL applicant will demonstrate that the covers for large penetrations such as equipment hatch and personnel airlocks meet the Service Level C requirements in Subsection NE-3220 of the ASME code and explain how the consideration of containment leakage is accounted for when modeling local regions of containment.
COL 19.2(3)	The COL applicant is to develop and submit an accident management plan.
COL 19.3(1)	The COL applicant is to perform site-specific seismic hazard evaluation and seismic risk evaluation as applicable in accordance with NTTF Recommendation 2.1 as outlined in the NRC RFI.
COL 19.3(2)	The COL applicant is to address the flood requirements for wet sites
COL 19.3(3)	The COL applicant is to develop the details for offsite resources.
COL 19.3(4)	The COL applicant is to address the details of selecting suitable storage locations for FLEX equipment that provide reasonable protection during specific external events as provided in NEI 12-06 guidance Sections 5 through 9, and the details of the guidance for storage of FLEX equipment provided in the Technical Report (Reference 5) Section 6.2.9.
COL 19.3(5)	The COL applicant is to confirm, satisfy, or fulfill the specific design functional requirements of raw water tank including the associated instrument, capacity, location, flow path to on-site, the valve pit connected to FLEX equipment, and any other design features as described in Section 19.3 in support of BDBEE mitigation strategies.
COL 19.3(6)	The COL applicant is to confirm and ensure that the raw water tank and flow path to the FLEX equipment (structures, piping, components, and connections) are designed to be robust with respect to applicable hazards (e.g., seismic events, floods, high winds, and associated missiles).

B

COL 19.1(27)

The COL applicant will ensure the APR1400 thermal-hydraulic (T/H) analysis supporting the application is reflected in the updated PRA model including those design and operational features for mitigation of a hot leg LLOCA.

COL 19.1(28)

The COL applicant will review the Technical Specifications and incorporate logic into the PRA model to ensure cutsets reflect permissible maintenance configurations.

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remaining 43%. ~~Only one~~ Two accident sequence contributes over 10 percent of the CDF, LOOP_005 and MLOCA_002; ~~these is~~ sequences involves the following elements:

a. LOOP_005

- LOOP initiating event
- ~~b.~~ Success of reactor trip (i.e., not an ATWS event)
- ~~e.~~ No POSRV challenge (i.e., not an induced LOCA event)
- ~~d.~~ Success of one or more EDGs (i.e., not an SBO event)
- ~~e.~~ Failure of secondary heat removal
- ~~f.~~ Failure of bleed for feed and bleed operation

a. MLOCA_002

- MLOCA initiating event
- Success of reactor trip (i.e., not an ATWS event)
- Success of Safety Injection
- Failure of containment heat removal via CS

•

The ~~significant~~ top 100 cutsets for the internal events are ~~provided~~ illustrated in Table 19.1-19. The top 100 cutsets contribute approximately ~~39-37~~ percent of the total CDF. Cutset contribution to the internal events CDF is equally distributed. Only ~~eight~~ three of the top cutsets contribute more than 1 percent to the total CDF. The number of top cutsets that cumulatively contribute to 95 percent of the CDF is over ~~200~~ 293,000. These results show that there are no significant cutset outliers in the APR1400 internal events CDF.

Add A

19.1.4.1.2.4

Significant SSCs, Common Cause Events, and Operator Actions

Table 19.1-20 shows the risk-significant SSCs based on the RAW importance measure. The most important pieces of equipment are ~~DC-MC01A/1B~~ (the Class 1E 125 Vdc ~~bus~~ 1A

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To perform realistic analysis for system availability (mitigation capacity) for a LLOCA, the PRA analysis evaluated three types of LLOCAs, i.e. cold leg break, DVI break and hot leg break. Consequently, hot leg injection during a LLOCA in hot leg was modeled in the PRA since the guidance in the APR 1400 Emergency Operating Guidelines (EOG) requires the initiation of hot leg injection during a potential LLOCA scenario. For the purposes of the APR 1400 PRA analysis, a failure of hot leg injection due to a single failure of the SI pump resulted in two cutsets within the top 100 which reflected that the modeling could lead core damage when a hot leg LLOCA occurs. However, the recent thermal-hydraulic (T/H) analysis in DCD Chapter.15 shows that boron precipitation is not expected under the condition that there is no hot leg injection during a hot leg LLOCA, and thus no core damage should occur in the accident sequence that hot leg injection fails in a hot leg LLOCA (see APR1400-F-A-NR-14003-P, Rev.1 "Post-LOCA Long Term Cooling Evaluation Model", Therefore, based on the T/H analysis performed to support Chapter 15 of the APR1400 design, no single failure will result in core damage or the loss of safety or protection function. To assess this relative to design criteria and T/H analysis performed for deterministic purposes, e.g. Chapter 15, a sensitivity analysis for not modeling hot leg injection during a LLOCA in hot leg shows that the core damage frequency (CDF) is estimated to be 1.1E-06/yr. This is the same as the full power internal base model CDF, and therefore, there is no impact even if hot leg injection is modeled (COL 19.1(27)).

General assumptions and conditions applied to system analysis are summarized below.

a. General modeling conditions:

- 1) Models reflect the design as-designed and as-to-be-built to the extent possible.
- 2) Systems that participate in the necessary response to events or that provide critical support to such systems are modeled.
- 3) Models reflect the success criteria for the systems to mitigate each identified accident sequence.
- 4) Models capture the impact of dependencies, including support systems and harsh environmental impacts.
- 5) Operator errors of commission are not included in the system model.

b. Conditions concerning level of detail

- 1) The level of detail in the model matches one for one the simplified diagrams and includes key active components and potential misaligned components based upon data availability.
- 2) Models include contributions due to random component failures, outages for maintenance and test, support system failures, CCFs, initiating events which affect the system, human errors to restore equipment to its operable state, and human errors involving failure to perform procedural actions.
- 3) Models include both failure modes of active and passive components that impact the function of the system.
- 4) A thorough treatment of CCFs, intra-system dependencies, and selected intersystem dependencies is provided.

Add A

- 5) The fault tree is developed to the level of detail that existing data can support.

c. Failure modes of components modeled are as follows:

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- 6) The APR1400 PRA model currently contains some “test and maintenance” configurations which are not permissible by APR1400 Technical Specifications. While these configurations are outside current Technical Specifications for operations, inclusion of these maintenance configurations in the current PRA is conservative with respect to CDF and LRF. The improper cutsets will be excluded from the cutsets resulting from the plant specific PRA, maintenance programs and Technical Specifications developed by the COL applicant (COL 19.1(28)).
- 7) The APR1400 PRA model is an asymmetric model. Therefore, location specific initiating events are assigned to a single location, e.g., SGTR is assumed to occur in SG #2, DVI line Large LOCA is assumed to occur in DVI line 1B, etc. System models reflect these locational initiating events, e.g., DVI large LOCA is assumed to result in the direct failure of SI pump PP02D and SIT TK01D since the injection flow from these components would be lost via the break in DVI line 1B. In addition, normally operating systems whose trains are operated on a rotational basis (e.g., CC, SX, etc.) have an assumed configuration with one train assumed to be the operating train, and the other train is assumed to be the standby train. Note that for the purposes of determining the CDF and LRF risk metrics, model asymmetry has no impact. The main impact is that the importance of equipment in those systems can differ on a train basis; however, for risk applications related to risk ranking, this can be compensated for by assigning the highest importance measure of a component within a group to all members within the group (COL 19.1(23)).

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Table 19.1-1 (3 of 3)

Technical Area	APR1400 PRA Characteristics
Internal Flooding (IF)	<p>Some aspects of the internal flooding analysis are limited by the lack of plant-specific details. Specific areas in which the internal flooding analysis does not meet at least Category I include the following:</p> <ul style="list-style-type: none"> Plant information reflecting as-built, as-operated conditions does not yet exist. Walkdowns cannot be conducted until the plant is constructed. Some sources of flooding will account for plant/site-specific features not yet available. Conservative assumptions were made with respect to propagation pathways and areas that could be affected.
Quantification (QU)	<p>The quantification was performed by solving the overall core damage model using the linked fault tree approach. The quantification satisfies at least Category I for each of the supporting requirements.</p>
LERF (LE)	<p>A detailed assessment of containment response and release frequency was conducted. The assessment satisfies at least Capability Category I for the supporting requirements, except for such aspects as system failure analysis and human reliability analysis. A detailed assessment of containment response and release frequency was conducted. The assessment satisfies at least Capability Category I for the supporting requirements, except for such aspects as system failure analysis and human reliability analysis, as addressed for technical areas SY, HF, and DA above.</p>

The quantification was performed by solving the overall core damage model using the linked fault-tree approach. The quantification satisfies at least Category I for each of the supporting requirements except for two (2) supporting requirements, QU-B7 and QU-B8. The logic of mutually exclusive events (MUX) did not cover all MUX, thus, some improper test and maintenance events appeared in the PRA results.

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Table 19.1-4 (13 of 27)

No.	Insight	Disposition
Risk Insights from Key Design Features		
24	<p>The Class 1E onsite power system has four trains with two trains per division. Each train is connected to one EDG. The two EDGs of a single division (i.e., Trains A and C, or Trains B and D) are sufficient to meet the emergency load requirements for a safe shutdown during a LOOP.</p> <p>Each EDG train and its associated auxiliaries are installed in a separate room within physically separate seismic Category I structures that provide protection against tornadoes, hurricanes, external missiles and seismic phenomena, and are electrically isolated from the circuits of other EDG trains and non-Class 1E circuits. Each EDG room is a separate fire area with 3-hour fire-rated walls, floors, and ceilings. Each EDG room is provided with its own independent ventilation system that automatically maintains the design room temperature for proper equipment operation and personnel access. The EDG room HVAC system and other EDG support auxiliaries are powered from the same electrical train as the EDG.</p> <p>Per the Technical Specifications, two EDGs on the same division (i.e., EDG A and C, or EDG B and D) can be out-of-service (OOS) together during an online maintenance. This allows two EDG maintenance cases to be retained in the PRA results, as compared to allowing only one EDG maintenance case.</p>	<p>Subsection 8.3.1.1.3</p> <p>Subsection 16.3.8.1</p>
25	<p>The onsite Class 1E 125 Vdc power system is composed of four independent subsystems (Trains A, B, C, and D) and supplies reliable power to the plant safety system dc loads and essential I&C system loads. Each dc power subsystem consists of a battery, two battery chargers (normal and standby), a dc control center, and distribution panels.</p> <p>The station batteries A and B will last up to 2 hours without dc load shedding and 8 hours with load shedding. The station batteries C and D will last up to 16 hours without dc loading. The operator action to perform the load shedding is included in the PRA model.</p>	<p>Subsection 8.3.2.1.2</p> <p>Subsection 8.3.2.1.2</p>

load shedding

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Table 19.1-4 (18 of 27)

No.	Insight	Disposition
Risk Insights from Key Design Features		
36	Flood protection is integrated into the auxiliary building floor drainage systems. The flood drainage systems are separated by quadrants with no common drain lines between the quadrants. The floor drainage systems are separated by division and Safety Class 3, seismic Category I valves that prevent backflow of water to areas containing safety-related equipment. Each quadrant contains its own separate sump equipped with redundant Safety Class 3, seismic Category I sump pumps and associated instrumentation.	Subsection 3.4.1.3 Subsection 9.3.3.1 Subsection 9.3.3.2
37	The potential for consequential flooding of safety-related SSCs due to flooding in the turbine building is prevented by the following design features: (a) no openings to safety-related structures exist below grade, (b) openings to safety-related structures above the maximum design basis flood level for the turbine building are sealed, (c) very large openings to allow flow out of the turbine building once level exceeds plant grade, and (d) site grade moves water away from structures where safety-related equipment is located.	Subsection 10.4.1.3
38	No water lines are routed above or through the MCR and the computer room. HVAC water lines contained in rooms around the MCR are located in rooms with raised curbs to prevent leakage from entering the MCR.	Subsection 3.4.1.5.2
39	All fire barriers that provide separation between the two divisions are rated for at least 3 hours.	Subsection 9.5.1.1
40	<p>The emergency containment spray backup subsystem (ECSBS) for severe accident management is provided. The ECSBS is used as an alternate means of providing containment spray in the event of a beyond design basis accident in which all CSPs/SCPs or the IRWST are unavailable. The ECSBS is to be placed in service 24 hours after a severe accident to prevent a catastrophic failure of the containment. The fire engine truck as ECSBS pumping device is used to deliver water from external water sources to the ECSBS containment spray header after the initiation of a severe accident.</p> <p>The operating procedure(s) for use of the ECSBS is to be developed by the COL applicant.</p>	<p>Subsection 6.2.2.2</p> <p>COL 19.2(3) COL 19.2(2)</p>

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Table 19.1-4 (19 of 27)

No.	Insight	Disposition
Risk Insights from Severe Accident Design Features		
41	<p>The reactor cavity is configured to promote retention of and heat removal from the postulated core debris during a severe accident, thus serving roles in accident mitigation. The reactor cavity is designed to prevent or mitigate the effect of severe accident phenomena such as HPME/DCH, EVSE and MCCI. The reactor cavity design characteristics include a core debris chamber inside a reactor cavity, a convoluted gas vent path, large floor area, and the CFS.</p> <p>The cavity flooding system consists of two independent divisions and is supplied, via gravity, from the IRWST via the HVT.</p> <p>Procedures for use of the cavity flood system during a severe accident are to be developed by the COL applicant as part of its plant-specific severe accident management guidelines (SAMG).</p>	<p>Subsection 19.2.3.3</p> <p>Subsection 6.8.3.1</p> <p>COL 19.2(3)</p> <p>COL 19.2(2)</p>
42	<p>In-vessel retention of core debris as result of external RV cooling is a potential means to mitigate a severe accident. The goal of external cooling is to retain the molten core debris in the RV lower plenum and thus prevent vessel failure. In-vessel retention precludes the possible ex-vessel physical phenomena related to debris relocation such as steam explosions and molten core-concrete interaction (MCCI).</p> <p>The plant is designed to allow operators to fill the reactor cavity with water and thereby submerge the RV in coolant. This can achieve ex-vessel cooling and in-vessel retention. However, in-vessel retention is not credited as a mitigation feature due to uncertainty surrounding the associated phenomena along with the need for operators to take additional manual actions.</p>	<p>Subsection 19.2.3.3.1</p>
43	<p>The hydrogen mitigation system (HMS) consists of igniters and passive autocatalytic recombiners (PARs) to control hydrogen concentration during a severe accident. HMS consists of eight igniters and 30 passive autocatalytic recombiners (PARs), which are strategically located inside the containment.</p> <p>The SAMG will address use of the HMS.</p>	<p>Subsection 6.2.5.1</p> <p>Subsection 6.2.5.2</p> <p>COL 19.2(3)</p> <p>COL 19.2(2)</p>

Attachment 5. Recovery rules for delete MUX

RECOVERY RULES

DELETE

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; LCO 3.5.2

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SIMPM1A-PP02A	SIMPM1B-PP02B
SIMPM1A-PP02A	SIMPM2A-PP02C
SIMPM1A-PP02A	SIMPM2B-PP02D
SIMPM1B-PP02B	SIMPM2A-PP02C
SIMPM1B-PP02B	SIMPM2B-PP02D
SIMPM2A-PP02C	SIMPM2B-PP02D

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; LCO 3.6.6

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CSMPM2A-PP01A	CSMPM2B-PP01B
CSHEM2A-HE01A	CSMPM2B-PP01B
CSHEM2B-HE01B	CSMPM2A-PP01A
CSHEM2A-HE01A	CSHEM2B-HE01B

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; LCO 3.7.5

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AFMPM2A-MDP02A	AFMPM2B-MDP02B	AFTPM1A-TDP01A	AFTPM1B-TDP01B
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; LCO 3.7.12

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VKAHM1A-AH01A	VKAHM1B-AH01B	VKAHM1C-AH01C
VKAHM1A-AH01A	VKAHM1B-AH01B	VKAHM1D-AH01D
VKAHM1A-AH01A	VKAHM1C-AH01C	VKAHM1D-AH01D
VKAHM1B-AH01B	VKAHM1C-AH01C	VKAHM1D-AH01D

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; LCO 3.8.1

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DGDGM-A-DGA	DGDGM-B-DGB
DGDGM-A-DGA	DGDGM-D-DGD
DGDGM-B-DGB	DGDGM-C-DGC
DGDGM-C-DGC	DGDGM-D-DGD
DGDGM-A-DGA	VDHVM-B-HV12B
DGDGM-A-DGA	VDHVM-B-HV13B
DGDGM-A-DGA	VDHVM-D-HV12D
DGDGM-A-DGA	VDHVM-D-HV13D
DGDGM-B-DGB	VDHVM-A-HV12A
DGDGM-B-DGB	VDHVM-A-HV13A
DGDGM-B-DGB	VDHVM-C-HV12C
DGDGM-B-DGB	VDHVM-C-HV13C
DGDGM-C-DGC	VDHVM-B-HV12B
DGDGM-C-DGC	VDHVM-B-HV13B
DGDGM-C-DGC	VDHVM-D-HV12D
DGDGM-C-DGC	VDHVM-D-HV13D
DGDGM-D-DGD	VDHVM-A-HV12A
DGDGM-D-DGD	VDHVM-A-HV13A
DGDGM-D-DGD	VDHVM-C-HV12C
DGDGM-D-DGD	VDHVM-C-HV13C
VDHVM-A-HV12A	VDHVM-B-HV12B
VDHVM-A-HV12A	VDHVM-B-HV13B
VDHVM-A-HV12A	VDHVM-D-HV12D
VDHVM-A-HV12A	VDHVM-D-HV13D
VDHVM-A-HV13A	VDHVM-B-HV12B
VDHVM-A-HV13A	VDHVM-B-HV13B
VDHVM-A-HV13A	VDHVM-D-HV12D

VDHVM-A-HV13A	VDHVM-D-HV13D		
VDHVM-B-HV12B	VDHVM-C-HV12C		
VDHVM-B-HV12B	VDHVM-C-HV13C		
VDHVM-B-HV13B	VDHVM-C-HV12C		
VDHVM-B-HV13B	VDHVM-C-HV13C		
VDHVM-C-HV12C	VDHVM-D-HV12D		
VDHVM-C-HV12C	VDHVM-D-HV13D		
VDHVM-C-HV13C	VDHVM-D-HV12D		
VDHVM-C-HV13C	VDHVM-D-HV13D		
DGDGM-A-DGA	DOMPM-B-PP01B	DOMPM-B-PP02B	
DGDGM-A-DGA	DOMPM-D-PP01D	DOMPM-D-PP02D	
DGDGM-B-DGB	DOMPM-A-PP01A	DOMPM-A-PP02A	
DGDGM-B-DGB	DOMPM-C-PP01C	DOMPM-C-PP02C	
DGDGM-C-DGC	DOMPM-B-PP01B	DOMPM-B-PP02B	
DGDGM-C-DGC	DOMPM-D-PP01D	DOMPM-D-PP02D	
DGDGM-D-DGD	DOMPM-A-PP01A	DOMPM-A-PP02A	
DGDGM-D-DGD	DOMPM-C-PP01C	DOMPM-C-PP02C	
DOMPM-A-PP01A	DOMPM-A-PP02A	VDHVM-B-HV12B	
DOMPM-A-PP01A	DOMPM-A-PP02A	VDHVM-B-HV13B	
DOMPM-A-PP01A	DOMPM-A-PP02A	VDHVM-D-HV12D	
DOMPM-A-PP01A	DOMPM-A-PP02A	VDHVM-D-HV13D	
DOMPM-B-PP01B	DOMPM-B-PP02B	VDHVM-A-HV12A	
DOMPM-B-PP01B	DOMPM-B-PP02B	VDHVM-A-HV13A	
DOMPM-B-PP01B	DOMPM-B-PP02B	VDHVM-C-HV12C	
DOMPM-B-PP01B	DOMPM-B-PP02B	VDHVM-C-HV13C	
DOMPM-C-PP01C	DOMPM-C-PP02C	VDHVM-B-HV12B	
DOMPM-C-PP01C	DOMPM-C-PP02C	VDHVM-B-HV13B	
DOMPM-C-PP01C	DOMPM-C-PP02C	VDHVM-D-HV12D	
DOMPM-C-PP01C	DOMPM-C-PP02C	VDHVM-D-HV13D	
DOMPM-D-PP01D	DOMPM-D-PP02D	VDHVM-A-HV12A	
DOMPM-D-PP01D	DOMPM-D-PP02D	VDHVM-A-HV13A	
DOMPM-D-PP01D	DOMPM-D-PP02D	VDHVM-C-HV12C	
DOMPM-D-PP01D	DOMPM-D-PP02D	VDHVM-C-HV13C	
DOMPM-A-PP01A	DOMPM-A-PP02A	DOMPM-B-PP01B	DOMPM-B-PP02B
DOMPM-A-PP01A	DOMPM-A-PP02A	DOMPM-D-PP01D	DOMPM-D-PP02D
DOMPM-B-PP01B	DOMPM-B-PP02B	DOMPM-C-PP01C	DOMPM-C-PP02c
DOMPM-C-PP01C	DOMPM-C-PP02C	DOMPM-D-PP01D	DOMPM-D-PP02D
; LCO 3.8.4			
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DCBTM-A-BT01A	DCBTM-B-BT01B		
DCBTM-A-BT01A	DCBTM-C-BT01C		
DCBTM-A-BT01A	DCBTM-D-BT01D		
DCBTM-B-BT01B	DCBTM-C-BT01C		
DCBTM-B-BT01B	DCBTM-D-BT01D		
DCBTM-C-BT01C	DCBTM-D-BT01D		
;			
; LCO 3.8.7			
;			
IPINM-A-IN01A	IPINM-B-IN01B		
IPINM-A-IN01A	IPINM-C-IN01C		
IPINM-A-IN01A	IPINM-D-IN01D		
IPINM-B-IN01B	IPINM-C-IN01C		
IPINM-B-IN01B	IPINM-D-IN01D		
IPINM-C-IN01C	IPINM-D-IN01D		

Attachment 6. The sensitivity Analysis Results for Applying MUX Rule File

1. The MUX rule file is applied for all parts of PRA and the results are introduced below.

a. At-Power

1) At-Power Level 1 Internal Event

	CDF	Decrease CDF	MCS
Rev.1 model	1.10E-06	-	655,609
Delete MUX	1.01E-06	9.00E-08 (8.18%)	591,841

2) At-Power Level 1 Internal Fire

	CDF	Decrease CDF	MCS
Rev.1 model	2.22E-06	-	620,856
Delete MUX	2.20E-06	2.00E-08 (0.90%)	594,235

3) At-Power Level 1 Internal Flooding

	CDF	Decrease CDF	MCS
Rev.1 model	4.00E-07	-	190,960
Delete MUX	4.00E-07	0.00E-00 (0.00%)	189,374

4) At-Power Level 2 Internal Event

	LRF	Decrease LRF	MCS
Rev.1 model	1.00E-07	-	52,966
Delete MUX	9.65E-08	3.50E-09 (3.50%)	44,764

5) At-Power Level 2 Internal Fire

	LRF	Decrease LRF	MCS
Rev.1 model	1.85E-07	-	93,971
Delete MUX	1.85E-07	0.00E-00 (0.00%)	92,751

6) At-Power Level 2 Internal Flooding

	LRF	Decrease LRF	MCS
Rev.1 model	2.54E-08	-	226,874
Delete MUX	2.54E-08	0.00E-00 (0.00%)	226,106

b. Low Power and Shutdown

1) LPSD Level 1 Internal Event

	CDF	Decrease CDF	MCS
Rev.1 model	1.80E-06	-	80,843
Delete MUX	1.80E-06	0.00E-00 (0.00%)	79,914

2) LPSD Level 1 Internal Fire

	CDF	Decrease CDF	MCS
Rev.1 model	1.25E-06	-	39,639
Delete MUX	1.25E-06	0.00E-00 (0.00%)	39,639

3) LPSD Level 1 Internal Flooding

	CDF	Decrease CDF	MCS
Rev.1 model	8.02E-08	-	10,923
Delete MUX	8.02E-08	0.00E-00 (0.00%)	10,923

4) LPSD Level 2 Internal Event

	LRF	Decrease LRF	MCS
Rev.1 model	7.02E-08	-	129,683
Delete MUX	7.02E-08	0.00E-00 (0.00%)	129,679

5) LPSD Level 2 Internal Fire

	LRF	Decrease LRF	MCS
Rev.1 model	6.68E-08	-	56474
Delete MUX	6.68E-08	0.00E-00 (0.00%)	56474

6) LPSD Level 2 Internal Flooding

	CDF	Decrease CDF	MCS
Rev.1 model	8.02E-08	-	10,923
Delete MUX	8.02E-08	0.00E-00 (0.00%)	10,923

Note: The CDF for LPSD level 1 internal flooding is 8.02E-08/y. This value is very low compared with LPSD level 1 internal event and internal fire, both of which are 1.8E-06/year and 1.2E-06/y respectively. Thus, LPSD internal flooding CDF is conservatively assigned to the LRF. In other words, there is no separate cutsets for LRF and it is bounded by level 1 LPSD flooding.

c. Summary of Results

The table below summarizes the results above. As shown in the table, there is a CDF decrease 9.00E-08 (8.18%) by deleting MUX for at-power Level 1 internal events PRA. Overall, the total CDF and LRF are decreased by 1.75% and 0.66% respectively. With deletion of MUX, it has no effect on the LPSD PRA. This is due to the configuration of each system and the maintenance of equipment are analyzed separately during shutdown cooling operation (POS 3A through 13). Therefore, the results of CDF and LRF are not changed.

	At-Power			LPSP			Total CDF
	Level 1			Level 1			
	IE	Fire	Flood	IE	Fire	Flood	
Rev.1 model	1.10E-06	2.22E-06	4.00E-07	1.80E-06	1.25E-06	8.02E-08	6.85E-06
Delete MUX	1.01E-06	2.19E-06	4.00E-07	1.80E-06	1.25E-06	8.02E-08	6.73E-06
Decrease	9.00E-08	2.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E-07
Decrease (%)	8.18%	0.90%	0.00%	0.00%	0.00%	0.00%	1.75%
	At-Power			LPSP			Total LRF
	Level 2			Level 2			
	IE	Fire	Flood	IE	Fire	Flood	
Rev.1 model	1.00E-07	1.85E-07	2.54E-08	7.02E-08	6.68E-08	8.02E-08	5.28E-07
Delete MUX	9.65E-08	1.85E-07	2.54E-08	7.02E-08	6.68E-08	8.02E-08	5.24E-07
Decrease	3.50E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-09
Decrease (%)	3.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.66%

2) The impact of DCD Other Chapters by Applying MUX Rule File

KHNP has reviewed the impact on DCD other chapters resulted from applying MUX rule file. With respect to Physical Security (Ch. 13.6), ITAAC (Ch. 14.3), Technical Specifications (Ch. 16), Reliability Assurance Program (Ch. 17.4) and Severe Accidents (Ch. 19.2) are not affected by deleting cutsets in the PRA results. With respect to Human Factor Engineering (Ch. 18), two (2) human failure events were identified and added as a RIHA by deleting MUX. However, Most of specific human factors designs in the APR1400 are COL items.

PRA Scope	Additional RIHA	Remark
Internal Events at power Level 1 & Level 2	CVOPH-S-BORATION	added by FV in at power Level 1 internal events
	VKOPH-S-ECCS	added by FV in at power Level 2 internal events
Internal Fire at Power Level 1 & Level 2	-	No Change
Internal Flood at Power Level 1 & Level 2	-	No Change
Internal Events for LPSD Level 1 & Level 2	-	No Change
Internal Fire for LPSD Level 1 & Level 2	-	No Change
Internal Flood for LPSD Level 1 & Level 2	-	No Change

Thus, it is expected that the change of RIHAs has no effect on human factors design, but only one document, APR1400-E-I-NR-14006 "Treatment of Important Human Actions Implementation Plan", is required for revising RIHAs list.