Exelon Generation.
4300 Winfield Road
Warrenville, IL 60555
www.exeloncorp.com

RS-16-118

10 CFR 50.90

October 7, 2016

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Byron Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: License Amendment Request to Utilize the TORMIS Computer Code Methodology

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit or early site permit," and 10 CFR 50.59, "Changes, tests, and experiments," paragraph (c)(2)(viii), Exelon Generation Company, LLC, (EGC) requests amendments to Renewed Facility Operating License Nos. NPF-37 and NPF-66 for Byron Station, Units 1 and 2. This amendment request proposes to revise the Byron Station licensing basis for protection from tornado-generated missiles. Specifically, the Updated Final Safety Analysis Report (UFSAR) will be revised to identify the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of unprotected plant structures, systems and components (SSCs) and to describe the results of the Byron Station site-specific tornado hazard analysis. The results from the Byron Station TORMIS analysis will be used to credit unprotected equipment for post-tornado safe shutdown. Of particular note, the Essential Service Water Cooling Tower (SXCT) fans and cells that survive a tornado strike will be credited for Ultimate Heat Sink (UHS) cooling as opposed to the original licensing basis that assumed all the unprotected SXCT fans are damaged by tornado-generated missiles. Note that there are no Technical Specifications changes associated with this request.

The Byron Station TORMIS analysis utilizes a probabilistic approach performed in accordance with the guidance described in the NRC TORMIS Safety Evaluation Report dated October 26, 1983, as clarified by Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008.

Attachment 1 to this letter provides an evaluation of the proposed changes and a summary of the supporting analysis.

The proposed amendment has been reviewed by the Byron Station Plant Operations Review Committee in accordance with the requirements of the EGC Quality Assurance Program.

In accordance with 10 CFR 50.91, "Notice for public comment; State consultation," paragraph (b), EGC is notifying the State of Illinois of this application for license amendment by transmitting a copy of this letter and its attachments to the designated State of Illinois official.

It should be noted that Byron Station issued Event Notification Report No. 51958, dated May 25, 2016, "Discovery of Non-Conforming Conditions During Tornado Hazards Analysis." This Notification Report documents non-conforming conditions in the plant design such that specific Technical Specifications equipment on both units is considered to be inadequately protected from tornado missiles. These conditions are being addressed in accordance with Enforcement Guidance Memorandum 15-002, "Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance," dated June 10, 2015 and DSS-ISG-2016-01, "Clarification of Licensee Actions in Receipt of Enforcement Discretion Per Enforcement Guidance Memorandum EGM 15-002, "Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance."

EGC requests approval of the proposed license amendment request within one year of this submittal date; i.e., by October 7, 2017; which meets the timeframe specified in the EGM for addressing tornado missile non-compliances.

There are no regulatory commitments contained in this letter. Should you have any questions concerning this letter, please contact Joseph A. Bauer at (630) 657-2804.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 7th day of October 2016.

Respectfully,

David M. Gullott
Manager – Licensing
Exelon Generation Company, LLC

Attachments:	Attachment 1	Evaluation of Proposed Changes
	Attachment 1-1	TORMIS Results Tables 1-6
	Attachment 1-2	TORMIS Results Figures 1-10
	Attachment 1-3	Draft Markup of Updated Final Safety Analysis Pages

cc: NRC Regional Administrator, Region III
NRC Senior Resident Inspector, Byron Station
Illinois Emergency Management Agency – Division of Nuclear Safety

ATTACHMENT 1
Evaluation of Proposed Changes

Subject: License Amendment Request to Utilize the TORMIS Computer Code Methodology

ATTACHMENT 1
Evaluation of Proposed Changes

1.0 SUMMARY DESCRIPTION

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit or early site permit," and 10 CFR 50.59, "Changes, tests, and experiments," paragraph (c)(2)(viii), Exelon Generation Company, LLC, (EGC) requests amendments to Renewed Facility Operating License Nos. NPF-37 and NPF-66 for Byron Station, Units 1 and 2. This amendment request proposes to revise the Byron Station licensing basis for protection from tornado-generated missiles. Specifically, the Updated Final Safety Analysis Report (UFSAR) will be revised to identify the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of unprotected plant structures, systems and components (SSCs); and to describe the results of the Byron Station site-specific tornado hazard analysis. The results from the Byron Station TORMIS analysis will be used to credit unprotected equipment for post-tornado safe shutdown. Of particular note, the Essential Service Water Cooling Tower (SXCT) fans and cells that survive a tornado strike will be credited for Ultimate Heat Sink (UHS) cooling as opposed to the original licensing basis that assumed all the unprotected SXCT fans are damaged by tornado-generated missiles. Modifying the UHS licensing basis, and other affected UFSAR sections, will be performed in accordance with 10 CFR 50.59, "Changes, tests and experiments," only after approval of the proposed amendment. Note that there are no Technical Specifications changes associated with this request.

The Byron Station TORMIS analysis utilizes a probabilistic approach performed in accordance with the guidance described in the NRC TORMIS Safety Evaluation Report dated October 26, 1983 (Reference 1), as clarified by Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008 (Reference 2). The Byron Station TORMIS analysis was performed by Applied Research Associates, Inc. (ARA) using TORMIS_14, an updated version of the original EPRI NP-2005 (Reference 5) version of the code.

2.0 DETAILED DESCRIPTION

The proposed revision to the Byron Station tornado licensing basis is based on the NRC approved methodology as detailed in topical reports: EPRI NP-768, "Tornado Missile Risk Analysis," May 1978 (Reference 3), EPRI NP-769, "Tornado Missile Risk Analysis – Appendices," May 1978 (Reference 4) and EPRI NP-2005, "Tornado Missile Risk Evaluation Methodology," August 1981 (Reference 5). These reports address utilization of the TORMIS Computer Code. TORMIS uses a Monte Carlo simulation technique to assess, through a Probabilistic Risk Assessment (PRA) methodology, the probability of multiple missile hits causing unacceptable damage to unprotected safety-significant components at a plant. For each tornado strike, the tornado windfield is simulated, missiles are injected and flown, and missile impacts on structures and equipment are analyzed. These models are linked to form an integrated, time-history simulation methodology. By repeating these simulations, the frequencies of missiles impacting and damaging individual components (targets) and groups of targets are estimated. Statistical convergence of the results is achieved by performing multiple replications with different random number seeds. The statistical confidence bounds of the results can then be estimated using conventional methods.

Over 27.7 billion TORMIS tornado missile simulations were performed for the Byron Station analysis. Each simulation consists of sampling and flying a missile for a simulated tornado strike on the plant. A total of 2.31 million tornado strikes on the plant were simulated in the TORMIS analysis.

The TORMIS results are estimated frequencies of tornado missile hit and damage, and have the units of yr-1. They represent the modeled-output frequencies of tornado missile hit/damage to a target, or group of targets. There were 153 individual unprotected safety-significant targets modeled in TORMIS as shown in Attachment 1-1, Table 1, "TORMIS Results by Individual TORMIS Target." The average missile hit and damage frequencies were developed from 60 TORMIS replications.

In summary, the results in Table 2-1 below show that the arithmetic sum of damage frequencies for all target groups affecting the individual units (i.e., Unit 1 plus common components and Unit 2 plus common components) are lower than the acceptable threshold frequency of 1.0E-06 per year established in the Standard Review Plan, Section 2.2.3, "Evaluation of Potential Accidents." The acceptance value of 1.0E-06 per year was endorsed in Reference 8 and Reference 2.

Note that two cases (i.e., initial conditions) specific to the UHS cells were evaluated (i.e., the "1 Cell out of Service" case and "2 Cells out of Service" case). These UHS cases are discussed below in Section 3.4.3, "Boolean Logic for the Ultimate Heat Sink." The results in Table 2-1 assume that discretionary missile protection modifications will be installed for the Unit 1 and Unit 2 Refueling Water Storage Tank (RWST) Hatches (i.e., Attachment 1-1, Table 1, Target Numbers 135 and 136). None of the other unprotected safety-significant targets are assumed to have additional tornado missile protection installed.

Table 2-1
Mean Damage Frequency by Unit
(With RWST Hatches Protected)

	Damage Frequency (yr^{-1})	
	1 Cell out of Service	2 Cells out of Service
Unit 1 Damage Frequency Sum for all Target Groups	6.68E-07	6.37E-07
Unit 2 Damage Frequency Sum for all Target Groups	7.27E-07	6.97E-07

Additional information regarding the TORMIS analysis results is presented in Section 3.4.4 below.

The current tornado design basis and licensing basis for tornado missile protection is discussed in the following UFSAR sections.

UFSAR Section 3.3, "Wind and Tornado Loadings"
UFSAR Section 3.5, "Missile Protection"

As noted above, these UFSAR sections will be revised in accordance with 10 CFR 50.59 to incorporate the TORMIS analysis after approval of the proposed amendment. Draft markups of the proposed changes to these UFSAR sections are presented in Attachment 1-3 for information. Note that the UFSAR markups include the presumptive changes that will be made

to the UHS licensing basis in accordance with 10 CFR 50.59 based on implementation of the TORMIS analysis results.

Other UFSAR sections, impacted by the changes in Sections 3.3 and 3.5, will also be revised in accordance with 10 CFR 50.59 after approval of the proposed amendment; however, are not included with this submittal.

3.0 TECHNICAL EVALUATION

The evaluation and description of the Byron Station TORMIS analysis and the associated results supporting the proposed UFSAR changes, is presented below in the following sections.

Section 3.1, "Current Licensing Basis for Tornado Missile Protection," describes the current tornado missile protection licensing basis.

Section 3.2, "Ultimate Heat Sink System Overview," provides a brief description of the current UHS system description and post tornado cooldown capability.

Section 3.3, "Tornado Missile Concerns at Byron Station Prompting TORMIS Analysis," briefly describes the past issues pertaining to Byron Station missile protection which are, in part, prompting this request.

Section 3.4, "TORMIS Methodology and Analysis Results," summarizes the TORMIS methodology, including the use of Boolean Logic. This section also summarizes the analysis results and discusses how compliance with the TORMIS SER (Reference 1) and NRC RIS 2008-14 (Reference 2) requirements are met.

3.1 Current Licensing Basis for Tornado Missile Protection

The current licensing basis for tornado missile protection is presented in UFSAR Sections 3.5.3, "Barrier Design Procedures," and 3.5.4, "Analysis of Missiles Generated by a Tornado." Most safety related systems and components are located inside structures designed to protect them from tornado-generated missiles as discussed in UFSAR Section 3.5.3.

UFSAR Section 3.5.4 describes the licensing basis for safety-related components located outdoors. Section 3.5.4 states the following:

"Effects of tornado missiles have been assessed for safety-related components located outdoors. These components are the essential service water cooling towers (Byron only), the emergency diesel exhaust stacks, diesel ventilating and combustion air intake, diesel crankcase vents, the fuel handling building door, and the main steam safety and relief valve stacks."

Section 3.5.4 provides a discussion addressing how the existing missile protection (or lack of missile protection) is acceptable.

Section 3.5.4.1, "Essential Service Water Cooling Tower (Byron)," specifically addresses the tornado missile protection for the SXCTs. It is acknowledged that certain portions of the SXCTs are not tornado missile protected.

3.2 Ultimate Heat Sink System Overview

As noted above, based on the results of the Byron Station TORMIS analysis, SXCT fans and cells that survive a tornado will be credited in the UHS cooling capability as opposed to the original licensing basis that assumes all unprotected SXCT fans are damaged by tornado-generated missiles. A brief description of the UHS and associated SXCT fan configuration is provided below to assist in understanding the impact of the TORMIS analysis as it relates to the UHS.

The Byron UHS is a common system for the two Byron Station units and consists of two mechanical draft cooling towers (i.e., 0A and 0B). Each tower has four cells and each cell has a manually actuated fan (see Attachment 1-2, Figures 1 and 2. Note that Figure 1 is provided for informational purposes and is not controlled as a design document). Two fans in Tower 0A are powered from Unit 1, Division 11, and the other two fans are powered from Unit 2, Division 21. Similarly, two fans in Tower 0B are powered from Unit 1, Division 12; and the other two fans are powered from Unit 2, Division 22. Each cell is served by a riser pipe which delivers the return water to the spray header. Each tower basin contains an anti-vortex duct and trash screen for the suction intakes that supply water to the units. Byron Technical Specification 3.7.9, "Ultimate Heat Sink (UHS)," allows one or two SXCT fans to be out of service, depending on the SX pump discharge water temperature.

During a post-tornado cooldown of both units, sufficient UHS cooling capacity must be available to achieve Cold Shutdown (CSD) conditions (i.e., ≤ 200 °F) "...within a reasonable period of time following shutdown, assuming the most limiting single failure," as specified in Branch Technical Position (BTP) RSB 5-1, "Design Requirements of the Residual Heat Removal System," July 1981. UFSAR Section 5.4.7, "Residual Heat Removal System," further clarifies this time to be 72 hours.

The design of the Byron Station UHS is based on having a sufficient number of operable SXCT fans to remove the accident/transient heat load. As described in UFSAR Section 9.2.5.3.1, "Ultimate Heat Sink Design Basis," the Byron Station UHS is designed to remove the heat load from one unit experiencing a loss-of-coolant accident (LOCA) coincident with a loss-of offsite power (LOOP) in one unit and the concurrent orderly shutdown from maximum power to cold shutdown of the other unit. The LOCA analysis considers that two SXCT fans may be out of service as allowed by Byron Technical Specification 3.7.9, "Ultimate Heat Sink (UHS)," and a passive electrical failure that results in two additional fans not available to remove the accident heat load. Thus for a LOOP/LOCA event, as few as four SXCT fans have been shown to be acceptable. The peak heat input to the UHS for a post-tornado two unit shutdown event (which assumes a dual unit LOOP) is much less than the peak heat load imposed on the UHS during a LOCA; therefore, fewer SXCT fans are needed for a post-tornado cooldown of both units; i.e., either 2 or 3 SXCT fans are needed depending on the case, as discussed below in Section 3.4.3, "Boolean Logic for the Ultimate Heat Sink."

3.3 Tornado Missile Concerns at Byron Station Prompting TORMIS Analysis

In NRC Inspection Report, "Byron Station, Units 1 and 2, Integrated Inspection Report 05000454/2009004; 05000455/2009004," dated November 5, 2009, Byron Station received a non-cited violation, NCV 05000454/2009004-02; 05000455/2009004-02, for failure to protect the Emergency Diesel Generator (EDG) Diesel Oil Storage Tank (DOST) vent lines from tornado-generated missiles. During the extent of condition review to address this violation, additional safety related pipes vulnerable to tornado-generated missiles were identified (i.e., the Steam Generator Power Operated Relief Valve (PORV) tailpipes, the Main Steam Safety Valve (MSSV) tailpipes, and the Auxiliary Feedwater (AF) Diesel exhaust stacks).

Subsequently, in NRC Inspection Report, "Byron Station, Units 1 and 2, NRC Component Design Bases Inspection; Inspection Report 05000454/2015008; 05000455/2015008 and Notice of Violation," dated July 21, 2015, Byron Station received another non-cited violation, NCV 05000454/2015008-06; 05000455/2015008-06, for failure to evaluate the adverse effects of changing the SXCT Tornado Analysis as described in the UFSAR, Section 3.5.4, "Analysis of Missiles Generated by a Tornado," Revision 14. This revision changed the UFSAR to assume that two SXCT fans survive a tornado strike. As a result of this violation, the UFSAR analysis of record reverted back to the original licensing basis assumption that multiple tornado missile hits could result in the loss of all SXCT fans. An Operability Evaluation was completed and is currently in place to address the concern that CSD cannot be achieved within 72 hours with no SXCT fans available after a postulated tornado event.

On May 25, 2016, Byron Station issued Event Notification Report No. 51958, "Discovery of Non-Conforming Conditions During Tornado Hazards Analysis." This Notification Report documents non-conforming conditions in the plant design such that specific Technical Specifications equipment on both units is considered to be inadequately protected from tornado missiles. These conditions are being addressed in accordance with Enforcement Guidance Memorandum 15-002, "Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance," dated June 10, 2015 and DSS-ISG-2016-01, "Clarification of Licensee Actions in Receipt of Enforcement Discretion Per Enforcement Guidance Memorandum EGM 15-002, "Enforcement Discretion for Tornado-Generated Missile Protection Noncomplicance."

To resolve the above concerns and close out the Operability Evaluation, Byron Station has decided to pursue NRC approval to utilize the TORMIS Computer Code methodology for assessing tornado-generated missile protection of the Byron Station SSCs. Unprotected targets needed for safe shutdown after a tornado, including the unprotected UHS components, are included in the TORMIS analysis. The results of the TORMIS analysis specific to the post-tornado survival of the SXCT fans will be used to evaluate SXCT capability for safe shutdown after a tornado event. NRC approval of the TORMIS methodology will allow Byron Station to credit sufficient SXCT fans (after a tornado event) and avoid costly modifications to provide tornado missile protection to the necessary equipment. The appropriate sections of the UFSAR will then be modified under the 10 CFR 50.59 process to reflect these results. In addition, as noted in RIS 2008-14, "Once the TORMIS methodology has been approved for the plant and incorporated in the plant licensing basis, it can be used to address additional tornado missile vulnerabilities identified in the future without seeking NRC approval, provided its use is consistent with the approved licensing basis of the plant."

3.4 TORMIS Methodology and Analysis Results

As noted in Section 2.0 above, TORMIS uses a Monte Carlo simulation technique to assess, through a PRA methodology, the probability of multiple missile hits causing unacceptable damage to unprotected safety-significant components at a plant. Over 27.7 billion TORMIS tornado missile simulations were performed for the Byron Station analysis. Each simulation consists of sampling and flying a missile for a simulated tornado strike on the plant. A total of 2.31 million tornado strikes on the plant were simulated in the TORMIS analysis.

The TORMIS results are estimated frequencies of tornado missile hit and damage. They represent the modeled-output frequencies of tornado missile hit/damage to a target, or group of targets. There were 153 individual unprotected safety-significant targets modeled in TORMIS. The average missile hit and damage frequencies were developed from 60 TORMIS replications.

The TORMIS results for the 153 individual safety-significant targets are presented in Attachment 1-1, Table 1, "TORMIS Results by Individual TORMIS Target."

3.4.1 Target Hit and Damage Frequency

Target missile hit frequencies, shown in Attachment 1-1, Table 1, reflect the frequency of at least one tornado missile hitting a target over a period of one year. For very large targets, tornado-generated missiles are likely to hit the target for almost every tornado strike and hence the missile hit frequency may approximately equal the tornado strike frequency for such targets. As the target size reduces, as the target is shielded by other structures, or if only one surface of the target is exposed, the missile hit frequency reduces accordingly. In general, tornado missile hit frequencies are dependent on many geometrical factors as well as missile types, numbers, and proximity. The degree to which the elevation of the target is above the elevation of the nearby missile sources can also be a critical factor.

The damage frequencies, shown in Attachment 1-1, Table 1, reflect the modeling of damage in TORMIS. For many targets there is a notable reduction in the damage frequency from the hit frequency. The term "target damage" is used in a general sense to mean any damage (or "loss of function") criteria caused by a tornado missile hitting the target. Target damage is not necessarily the same as target hit, but hit can equal damage for fragile equipment. The accepted (i.e., built-in) TORMIS penetration, spall, and perforation equations were used to evaluate damage for selected targets. Missile impact and velocity exceedance was also used to evaluate damage for several targets.

It should be noted that the damage frequency values for the Division 1 and Division 2 MEER ventilation system exhaust openings for each unit (i.e., Attachment 1-1, Table 1, Target Numbers 137, 138, 141 and 142) assume some amount of acceptable tornado missile damage. The MEER exhaust openings were modeled in TORMIS using the pipe penetration feature to determine the missile damage frequency. When using the pipe penetration feature, exhaust system components (e.g., HELB and/or fire dampers) within the wall opening may be impacted such that the exhaust path is blocked due to physical damage or debris accumulation. Necessary equipment, such as instrument inverters and battery chargers, are contained in the MEERs; therefore, manual action is relied on to restore ventilation. The associated manual actions entail simple activities to open doors (to provide an exhaust path) and restart supply fans.

Structural response damage (i.e., velocity exceedance) can be evaluated within TORMIS using the results from offline structural response calculations. For the Byron Station TORMIS analysis, a finite element analysis was performed to provide the required missile damage threshold velocity for each missile type to cause unacceptable damage to the following targets:

- Diesel Auxiliary Feed Pump (DAFP) exhaust pipes
- DAFP exhaust cover plates
- Power Operated Relief Valve (PORV) tailpipes
- UHS riser pipes

System flow analyses were performed to determine the acceptance criteria (critical area) for crimping damage. Finite element analysis was used to determine the critical impact velocity required to crimp the pipe or cover plate to its critical area for eight of the TORMIS missiles. The results from the finite element analysis were then used to develop critical velocities for the other Byron Station TORMIS missiles. For these selected targets, damage is evaluated by comparing the missile velocity to the damage threshold velocity for the particular missile type and target group. If the missile velocity meets or exceeds the damage threshold velocity, it is scored as damage. The following conservatisms were applied when determining the damage threshold velocities:

- In general, the finite element analysis missile models were built to be conservatively strong and rigid. Conversely, target models were built to be conservatively weak to maximize the degree of potential crimping.

- The threshold velocity for missiles causing damage to the DAFP exhaust pipes, DAFP exhaust cover plates, UHS riser pipes, and PORV tailpipes were input into TORMIS as 90% of the critical velocities calculated in the finite element analysis.

Note that, if the individual target damage frequencies in Attachment 1-1, Table 1 were summed, the sum total would exceed the acceptable threshold of 1.0E-06 per year. This is primarily due to the damage frequency of a limited number of targets, individually, approaching 1.0E-06 per year. This is shown graphically in Attachment 1-2, Figure 3, "Individual Target Hit and Damage Frequencies." To address this issue, Boolean combinations of targets were developed to aid in summarizing the results and understanding the effects of system redundancies. This approach yielded acceptable results. Note that the Boolean Group Number and associated Target Group name (i.e., 38 groups), assigned to each of the 153 individual targets, are shown on Attachment 1-1, Table 1. A description of the Boolean Logic approach is provided below.

3.4.2 Boolean Logic Approach

Boolean Logic is applied to targets to account for redundancy in the structural or system design or TORMIS modeling of a component as multiple targets. With redundancy in the design, the system function could be met even with one or more individual targets damaged by postulated tornado missiles. The logic is applied to each TORMIS simulated tornado to determine if the missile damage results in a loss of function of the target group. For components/systems that have been modeled with multiple targets or with two failure modes, the Boolean Logic is used to eliminate over counting of the loss of function. For example, the unprotected PORV tailpipes are evaluated for two separate failure modes: 1) pipe penetration and 2) crimping due to

velocity exceedance. A TORMIS tornado simulation that results in either penetration of the tailpipe opening or velocity exceedance (i.e., unacceptable damage of the tailpipe) would result in loss of PORV function. For the TORMIS tornado simulations where both pipe penetration and velocity exceedance occur, the PORV function is lost when the first missile hit occurs and the second missile hit just results in additional damage. Thus, the Boolean Logic is used to count these two failures as a single loss of PORV function when determining the damage frequency for that PORV target group.

Hit and damage frequencies for groups of targets evaluated in TORMIS are commonly combined using Boolean operators (U and ∩) to aid in summarizing the results and understanding the effects of the system redundancies. The union (U) operator means that if any one of the targets is damaged in a tornado, the system is assumed to fail. The intersection (∩) operator means that all the intersected components must be damaged in a tornado strike for the system to fail. Combinations of union and intersection operators can be put together to describe multi-component system failure logic for plant systems and subsystems.

The 153 individual targets were grouped together according to target type and/or function. Attachment 1-1, Table 2, "Average Hit and Damage Frequency (per year) for Target Groups," presents the missile hit and damage frequencies for the target groups as previously defined in Attachment 1-1, Table 1 (i.e., the frequency values for each of the 38 groups in Table 2, are simply the sum of the individual target frequencies for those targets assigned to each group as shown in Table 1). These values are plotted in Attachment 1-2 Figure 4, "Target Group Hit and Damage Frequencies."

Note that the damage frequencies for each of the UHS Cell groups (i.e., Groups number 2-9) approach or exceed 1.0E-06 per year. However, these union (U) calculations do not consider any redundancy between the 8 cells that comprise the UHS. Section 3.4.3 below, discusses a more rigorous approach to the Boolean Logic developed using the TORSCR code to account for the redundancy of the cells within the UHS. TORSCR is a FORTRAN computer code that is used to post-process TORMIS output files. Its primary function is to compute Boolean combinations of target hit and damage probabilities over multiple targets. Note that the TORSCR post-processing computer code and use of the Boolean Logic approach was previously approved by the NRC for Limerick Generating Station (References 9 and 10).

3.4.3 Boolean Logic for the Ultimate Heat Sink

For the TORMIS analysis results regarding the UHS, success is defined as 3 of 8 cells surviving for the "one cell out of service" case; or 2 of 8 cells surviving for the "2 cells out of service" case. The number of cells that may be initially out of service is dependent on the outside air wet bulb temperature and number of operating units. The UHS post-tornado cool down analysis credits the surviving cells and shows that CSD is achieved within 72 hours following a unit shutdown due to a tornado. Each case also assumes a worst case single failure of an electrical bus that results in the loss of power to two additional SXCT fans. The station will establish administrative controls to ensure the assumed initial conditions in the post-tornado UHS cooldown analysis are met; i.e., the administrative controls will specify the number of SXCT fans required to be operable based on outside environmental conditions.

The Boolean Logic for the UHS was created based on minimum tower requirements. The basis for success/failure of the UHS includes the following considerations and assumptions:

1. One or two cells are assumed at random to be out of service for maintenance
   a. Use of the word "cells" includes the fan blades, fan motors, gearbox oil level gauges, inspection hatches, and personnel hatches as identified for Target Groups 2-9 in Attachment 1-1, Table 1.
   b. All cells are equally likely to be out of service.
2. Two Paired cells are assumed to have failed from a random electrical bus failure. Paired cells are as follows:
   a. Electrical Room 131Z (Division 11 power): UHS cells A and B
   b. Electrical Room 231Z (Division 21 power): UHS cells C and D
   c. Electrical Room 132Z (Division 12 power): UHS cells E and F
   d. Electrical Room 232Z (Division 22 power): UHS cells G and H
3. Assuming that considerations 1 and 2 affect different cells (e.g., cells randomly out of service are not affected by the random electrical failure) results in 4 or 5 cells available to support cooling function of the UHS. This assumption is conservative since the cells randomly out of service could also be affected by the random electrical room failure.
4. The UHS will perform its design function with at least 3 of the remaining 5 cells surviving for the 1 cell out of service case or 2 of 4 remaining cells surviving in the 2 cells out of service case based on outside air wet bulb temperature and the number of operating units.
5. The TORMIS analysis conservatively assumes that a failure of any of the 8 riser pipes results in the failure of all cells in the UHS.
6. Missile perforation to either of the anti-vortex boxes and trash screens results in failure of all cells in the UHS.

This logic was then implemented in the TORMIS post-processor TORSCR using the following procedure:

1. Conservatively, assume that the UHS cells with the lowest probability of tornado missile damage are the cells that are either out of service for maintenance or have failed from random electrical failure.
   a. From Attachment 1-1, Table 2, the 4 cells with the lowest damage frequencies in ascending order are cells E, B, F, and G. As such:
      i. For 1 cell out of service:
         1. Cell B is assumed to be randomly out of service for maintenance, and
         2. Cells E and F are assumed to be out of service because Electrical Room 132Z experienced random electrical failure.

   ii. For 2 cells out of service
      1. Cells B and G are assumed to be randomly out of service for maintenance, and
      2. Cells E and F are assumed to be out of service because Electrical Room 132Z experienced random electrical failure.

   b. The 4 cells with the highest damage frequencies are cells A, C, D, and H.

2. With the cells of highest damage frequency conservatively identified in Step 1 above (i.e., cells G, A, C, D and H), the 8 finest-grain, mutually exclusive, and collectively exhaustive listing of failure events affecting the survival of the UHS are defined as shown in Attachment 1-1, Table 3, "Individual Failure Events Considered in UHS Boolean Sample Space."

3. Based on the 8 failure events defined in Step 2, the sample space shown in Attachment 1-1, Table 4, "Space of 256 Possible Failure Combinations of UHS," was constructed to identify the possible outcomes for the UHS tornado missile events. Considering all possible combinations of the eight individual events shown in Attachment 1-1, Table 3 results in a total of 2^8 (256) total combinations to consider. The survival/failure outcome for each possible combination is given in the second and third to last columns of the table. Each of the combinations with "Survive" in the columns titled "1 Cell Out of Service" or "2 Cells Out of Service" results in that case surviving. Likewise a "Fail" value in these columns results is that condition failing.

   a. For 1 cell out of service, 24 combinations lead to 3 or more cells surviving and the remaining 232 combinations result in less than 3 cells surviving. Failure of the UHS is therefore failure of 3 of 5, 4 of 5, or 5 of 5 of the remaining cells.

   b. For 2 cells out of service, 46 combinations lead to 2 or more cells surviving and the remaining 210 combinations result in less than 2 cells surviving. Failure of the UHS is therefore failure of 3 of 4, or 4 of 4 of the remaining cells.

4. The sample space discussed in Step 3 above was then implemented in the TORMIS post-processor TORSCR in order to evaluate the probability of each of the 256 event combinations. All event combinations listed in the sample space are implemented in TORSCR using the Boolean intersection ($\cap$) operator, which is interpreted as "AND." For example, combination number 53 can be expressed in words as the frequency that "Event 1 fails AND Event 2 survives AND Event 3 survives AND Event 4 survives AND Event 5 fails AND Event 6 fails AND Event 7 survives AND Event 8 survives." Implementation of this logic into TORSCR required updating of the Boolean subroutine, increasing dimensions for variables related to the number of events, and recompilation of the source code.

The final column of Attachment 1-1, Table 4 shows the frequencies for each of the event combinations. This table also shows that the sum of these frequencies leading to failure in the 1 cell out of service case is 1.73E-07 per year, and the sum of these frequencies leading to failure in the 2 cells out of service case is 1.42E-07 per year. These results reflect averaging over the 60 TORMIS replications completed for the plant that considered both outage and non-outage missile scenarios.

3.4.4 TORMIS Analysis Results

The final results for the damage frequency for all Byron Station target groups, utilizing the Boolean Logic approach, are presented in Attachment 1-1, Table 5, "Mean Damage Frequency (per Year) for Byron Station Target Groups." A summary of the damage frequency results for

each unit and for all target groups (i.e., the composite site) is shown below in Table 3.4.4-1. Note that the results show the arithmetic sum of damage frequencies for targets affecting the individual units (i.e., Unit 1 plus common components and Unit 2 plus common components) and the composite site. Note that each individual unit damage frequency is lower than the acceptable threshold frequency of 1.0E-06 per year established in the Standard Review Plan, Section 2.2.3, "Evaluation of Potential Accidents," and Reference 8. However, the composite site damage frequency is slightly over this limit; i.e., 1.61E-06 per year and 1.58E-06 per year for the "1 Cell out of Service" case and "2 Cells out of Service" case, respectively.

Table 3.4.4-1
Mean Damage Frequency

	Damage Frequency (yr^{-1})	
	1 Cell out of Service	2 Cells out of Service
Unit 1 Damage Frequency Sum for all Target Groups	9.13E-07	8.83E-07
Unit 2 Damage Frequency Sum for all Target Groups	9.66E-07	9.36E-07
*Composite Site Damage Frequency for all Target Groups	1.61E-06	1.58E-06

* Composite site damage frequency values are provided for information only.

As noted, the individual units meet the acceptance criterion of 1.0E-06 per year; however, there is little margin. Note that the acceptance criterion is applied on a unit-specific basis as documented in the NRC Safety Evaluation for use of the TORMIS methodology at the Donald C. Cook Nuclear Plant; i.e., in a letter from J. F. Stang (NRC) to R. P. Powers (Indiana Michigan Power Company), "Donald C. Cook Nuclear Plant, Units 1 and 2 – Issuance of Amendments," dated November 17, 2000 (Reference 12).

Based on these results, Byron Station is considering modifications to install missile protection for the Unit 1 and Unit 2 RWST Hatches (i.e., Attachment 1-1, Table 1, Target Numbers 135 and 136). These targets were initially included in the TORMIS model; however, if missile protection is installed for these targets, margin would be improved and the final damage frequency results would be reduced as shown in Table 3.4.4-2 below. Please note that EGC assumes that NRC approval to use the TORMIS methodology at Byron Station will not be contingent on installation of the above noted modifications. The unit-specific damage frequency values noted in Table 3.4.4-1 above, meet the acceptance criteria assuming no missile protection modifications for any target groups; therefore, the subject modifications are considered discretionary and would provide additional margin.

Table 3.4.4-2
Revised Mean Damage Frequency
(With RWST Hatches Protected)

	Damage Frequency (yr^{-1})	
	1 Cell out of Service	2 Cells out of Service
Unit 1 Damage Frequency Sum for all Target Groups	6.68E-07	6.37E-07
Unit 2 Damage Frequency Sum for all Target Groups	7.27E-07	6.97E-07
*Composite Site Damage Frequency for all Target Groups	1.12E-06	1.09E-06

* Composite site damage frequency values are provided for information only.

3.4.5 Compliance with the NRC Safety Evaluation Report (SER) Acceptance Criteria

In Reference 1 (i.e., the TORMIS SER), the NRC stated that licensees using the EPRI approach (i.e., the TORMIS methodology) must consider the following points and provide the following information:

1. *Data on tornado characteristics should be employed for both broad regions and small areas around the site. The most conservative values should be used in the risk analysis or justification provided for those values selected.*

2. *The EPRI study proposes a modified tornado classification, F'-scale, for which the velocity ranges are lower by as much as 25% than the velocity ranges originally proposed in the Fujita, F-scale. Insufficient documentation was provided in the studies in support of the reduced F'-scale. The F-scale tornado classification should therefore be used in order to obtain conservative results.*

3. *Reductions in tornado wind speed near the ground due to surface friction effects are not sufficiently documented in the EPRI study. Such reductions were not consistently accounted for when estimating tornado wind speeds at 33 feet above grade on the basis of observed damage at lower elevations. Therefore, users should calculate the effect of assuming velocity profiles with ratios V_o (speed at ground level) / V_{33} (speed at 33 feet elevation) higher than that in the EPRI study. Discussion of sensitivity of the results to changes in the modeling of the tornado wind speed profile near the ground should be provided.*

4. *The assumptions concerning the locations and numbers of potential missiles presented at a specific site are not well established in the EPRI studies. However, the EPRI methodology allows site specific information on tornado missile availability to be incorporated in the risk calculation. Therefore, users should provide sufficient information to justify the assumed missile density based on site specific missile sources and dominant tornado paths of travel.*

5. *Once the EPRI [TORMIS] methodology has been chosen, justification should be provided for any deviations from the calculational approach [i.e., from the original EPRI methodology].*

The following information summarizes how the Byron Station TORMIS analysis satisfies the above criteria.

1. *Data on Tornado Characteristics Employed to Identify Byron Station Sub-Region*

   A site-specific analysis has been performed to generate a tornado hazard curve for Byron Station and a data set for the TORMIS analysis. The National Oceanic Atmospheric Administration (NOAA) Storm Prediction Center Severe Weather Database was used to identify a homogenous sub-region around the station. Tornadoes have been mapped for a large region and statistical tests have been performed to identify a suitable sub-region. The sub-region tornado occurrence rate, EF-scale intensities, path length, width, and direction variables have been analyzed for use in the TORMIS analysis.

   The analysis examines both broad and small regions around the site and provides justification for the final sub-region selected. Two Hundred Twenty-five (225) 1° latitude-

longitude blocks and 25 3° blocks were analyzed to determine a homogeneous sub-region and to assess variation of risk within the sub-region. A tornado hazard curve for Byron Station was developed and the EF-scale wind speeds were used in this analysis in accordance with NUREG/CR-4461, Revision 2 (Reference 6).

A total of 3,289 tornadoes were reported in the 64 year period (i.e., 1950-2013), producing an average of 51.4 per year. The mean unadjusted occurrence rate is:

$$\upsilon = \eta / t_0 A = 3.11\text{E-04 tornadoes / square mile / year}$$

In this equation, η = 3,289 tornadoes, t_0 = 64 years, and A = 165,059 square mile

A correction for annual reporting trend is part of the TORMIS methodology. The adjusted occurrence rate to reflect the sub-region reporting trends is 3.58E−04 tornadoes / square mile / year.

2. *Tornado Wind Speed Intensity*

The 1983 SER calls for the use of the F scale of tornado intensity in terms of assigning tornado wind speeds to each intensity category (F1-F5). However, the NRC has adopted the EF scale and confirmed in previous discussions on TORMIS that the EF scale could be used in place of the F scale. The use of the EF scale is consistent with the recently endorsed positions of NRC Regulatory Guide 1.76 that are based on NUREG/CR-4461, Revision 2 (Reference 6).

3. *Characterization of Tornado Wind Speed as a Function of Height Above Ground Elevation*

The TORMIS simulations were performed with the TORMIS rotational velocity Profile 3, which has increased near ground wind speeds over Profile 5, which was used in the 1981 EPRI TORMIS reports (see Attachment 1-2, Figure 5, "Tornado Rotational Wind Velocity Profiles"). Therefore, the Byron Station runs were made with higher near ground wind speeds than in the EPRI study. The sensitivity study was conducted by running the original EPRI profiles (i.e., Profile 5). All 60 replications that contributed to the target group results in Attachment 1-1, Table 2 were run and compared to the Profile 3 results Boolean group by Boolean group. Note that Figure 5 is a scan of Figure II-12(b) from Reference 5.

The comparison showed that differences in results were negligible for missile hit (see Attachment 1-2, Figure 6, "Plot of Frequencies with Profile 5 versus Profile 3"). Some sensitivity was observed for targets with very low damage frequencies (i.e., <1.0E-08); however, differences were negligible when aggregated over the target groups. Hence, the use of Profile 3 produces results comparable to Profile 5.

4. *Missile Characterization and Site-Structure Models*

A detailed plant survey was performed during an outage to quantify the number of potential missiles. The Byron missile survey walkdown was performed by ARA using ARA's plant walkdown procedures. The survey walkdown uses a systematic, documented process to provide input on what missiles are in each missile zone, the minimum and maximum injection heights for all missiles by missile type, the building characteristics for structures in

the missile zone, and pictures of the missiles and buildings surveyed. This information was developed into the plant modeling inputs for the TORMIS analysis. The mean number of potential missiles simulated for EF5 tornadoes was 238,874, including structural failure missile sources. This number also includes additional missiles in several zones to conservatively anticipate future conditions. The missiles consist of both zone missile and structure origin missiles. The missiles are distributed throughout the plant based on the missile survey. Tornadoes from any direction that strike the plant will interact with numerous missiles within 2500 feet of the targets.

The plant site is described by specifying the geometry, location, and material properties of the structures/components and the location of potential missile sources. Missile sources (buildings, houses, storage areas, vehicles, etc.) are modeled to a distance of approximately 2500 feet in all directions from safety-significant targets. This distance is based on a sensitivity study performed in the original TORMIS research (References 3 and 4). The sensitivity study concluded that missiles beyond 2000 feet did not need to be considered in the risk assessment. This value has been increased to 2500 feet in modern TORMIS analyses to be conservative. This process includes the development of missile origin zones around the plant (shown in Attachment 1-2, Figure 7, "Zone Layout for Byron Station TORMIS Analysis") and surveying the types and quantities of missiles in each zone. The Byron Station missiles include the standard TORMIS missiles in EPRI NP-769 (Reference 4), including structural sections, pipes, wood members, other construction materials, and an automobile category. For each set, the cross-sectional geometry and the missile aspect ratio (L/d) are deterministic.

The structure-origin missiles represent the maximum number of missiles produced given destruction of the buildings. The number of missiles produced from this total inventory depends on the wind speeds (i.e., EF scale) experienced by the building. For example, light damage might be expected in 100 mph winds, while catastrophic failure might occur in 200 mph winds. Research performed in the development of the HAZUS wind model (Reference 7) is used to determine the number of missiles available for each building type for each wind speed level considered in the TORMIS runs. When specific wind fragilities of building components are known, the calculated building fragilities are used to produce the number of available missiles in place of the HAZUS functions.

The HAZUS vulnerability models are based on detailed 3-D modeling of buildings and simulated hurricane winds. For each simulated storm, the wind pressures are estimated over the building envelope. The wind load is then computed for each component and compared to the component resistance. Component failures occur when the load exceeds the resistance. This simulation process is repeated for all components as the storm is tracked by the building for each time step. Internal pressurization of the structure is modeled when the envelope is breached by a missile or a failed opening (window or door).

Table 3.4.5-1 below summarizes the wind speed missile functions, defined at the wind speeds for which TORMIS is typically run to produce missile fragilities in support of License Amendment Requests with the Enhanced Fujita scale wind speeds from the HAZUS research. The damage state for each building type was selected based on sufficient failure to produce structural component missiles. This criteria corresponds to "Damage State 4-Destruction" for all building types except manufactured buildings, where Damage State 3 was determined to be sufficient to produce significant structural missiles.

Table 3.4.5-1
HAZUS Damage State Exceedence Probabilities for EF-Scale Mid-Point Wind Speeds

Building Type	Hazard Damage State	Enhanced Wind Speed (mph)					
		EF0	EF1	EF2	EF3	EF4	EF5
		65-85	86-110	111-135	136-165	166-200	200-230
Trailer, Manufactured Bldg	3	0.01	0.03	0.54	0.96	1.00	1.00
Wood Frame/ Modular	4	0.00	0.01	0.12	0.75	0.99	1.00
Masonry Frame	4	0.00	0.01	0.03	0.35	1.00	1.00
Pre Engr Steel Frame	4	0.00	0.00	0.02	0.32	0.85	0.98
Engineered Frame	4	0.00	0.00	0.00	0.03	0.50	0.90

A stochastic missile modeling approach was used to model the numbers of potential missiles at the plant during outage and non-outage conditions. All the postulated missiles at Byron Station were treated as minimally restrained in which each sampled missile is injected near the peak aerodynamic force, thus maximizing the transport range and impact speed and, consequently, the missile hit and damage frequency. A summary of the total missile populations used in TORMIS is given in Table 3.4.5-2 below.

Table 3.4.5-2
Number of Byron Station TORMIS Simulated Missiles (Stochastic Model)

EF Scale	Zone Origin			Structure Origin			Total Missiles (All Sources)		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
EF1	32,940	37,751	44,179	1,586	1,652	1,714	34,639	39,403	45,844
EF2	32,940	37,751	44,179	12,602	13,534	14,386	46,938	51,285	57,807
EF3	32,940	37,751	44,179	76,343	81,826	85,874	113,073	119,577	128,372
EF4	32,940	37,751	44,179	155,214	162,821	172,089	192,275	200,571	215,211
EF5	32,940	37,751	44,179	193,496	201,123	214,279	229,750	238,874	257,401

5. *Deviations from the Original EPRI Methodology:*

The Byron Station TORMIS analysis was performed by Applied Research Associates, Inc. (ARA) using TORMIS_14, an updated version of the original EPRI NP-2005 (Reference 5) version of the code.

The TORMIS code is a legacy FORTRAN computer code that has been ported to modern computers and compilers and has had bug fixes and other enhancements since 1981. The updates and enhancements made to TORMIS since 1981 are documented in ARA TORMIS reports and Code Manuals. These changes include: porting the legacy code from mainframe to minicomputer to PC computers, post processing data routines, updates to the random number generation, ensure aerodynamic function of box/beam for C/t greater than 4 to match Figure 3-8 of Reference 4 and replace the exponential tip loss function with an equivalent polynomial (i.e., replaced the exponential function in Equation 3.10 in

Reference 4 with the Hoerner suggested polynomial); enhanced output options; and addressing compiler differences and numerical round-off issues in various functions from the legacy code. All code changes have been checked and verified through comparisons to the preceding version.

Also included in the updates were the replacement of the original mainframe based random number generator with a machine-independent algorithm and re-dimensioning of the code to allow larger numbers of targets and missiles.

The TORMIS code verification includes duplications and comparison to each preceding TORMIS version as well as the original TORMIS Sample Problem in EPRI NP 2005 (Reference 5). These statistical comparisons show that the basic TORMIS code calculational approach produces comparable results to that of the original version.

An enhanced method for evaluating missiles passing through openings, such as pipe penetrations in reinforced concrete walls was used for the Byron Station analysis. This method uses a screening of missile impact conditions to screen-out missile impacts that can obviously not pass through an opening. The screening is done in the processing of the missile impact data without modifying the TORMIS physics engine in the IMPACT subroutine. This calculation approach for pipe penetration type targets was introduced as an option in previous versions of TORMIS and was used in several analyses prior to the Byron Station analysis. This approach provides an additional output option that is conservative for estimating the probabilities of missiles passing through small openings in concrete barriers. Both the TORMIS hit probability and the pipe penetration probability is reported for all such targets where the screening approach is used. The results for individual targets are given in Attachment 1-1, Table 1.

The aforementioned deviations from the original EPRI Methodology were previously discussed in a letter from J. Todd Conner (DTE Energy Company) to the NRC, "Proposed License Amendment to Revise the Fermi 2 Licensing Bases for Protection from Tornado-Generated Missiles," dated January 11, 2013. This proposed license amendment was subsequently approved by the NRC in Fermi 2 Amendment 197, dated March 10, 2014.

There was also a single change made to the code of a purely “software” nature, which was not related to the approved TORMIS physics engine and calculation approach; i.e., the dimensioned number of possible missile types was increased to 24 for evaluation of damage from missile velocity exceedance and pipe penetration pass through. This change was made, verified and exactly reproduces previous TORMIS outputs.

In addition, it should be noted that:

- TORSCR_MF was updated to accommodate up to 40,000 tornadoes (up from 15,000) to be evaluated for each TORMIS replication.
- TORSCR_MF_BNS_Union was created to implement the Boolean failure logic for the Byron Station UHS. It uses the same calculation code as TORSCR_MF, but with an updated Boolean subroutine that includes the combinations necessary to account for redundancy within the Byron Station UHS.

- TORSCR_MF_BNS_256 was created to implement the updated Boolean failure logic for the Byron Station UHS. The UHS failure logic was updated to require 3 of 5 remaining fans in the UHS to survive instead of 2 of 4 fans. It uses the same calculation code as TORSCR_MF, but with an updated Boolean subroutine that includes the 256 possible combinations of 8 mutually exclusive, collectively exhaustive events to account for redundancy within the Byron Station UHS.

3.4.6 Compliance with NRC RIS 2008-14 Criteria

Subsequent to the original NRC TORMIS SER (Reference 1), the NRC issued Regulatory Issue Summary 2008-14 (Reference 2) to inform licensees of the NRC's experience with shortcomings identified in submitted licensee TORMIS analyses. The RIS specifically identified items licensees should address to confirm the TORMIS methodology and computer code have been properly applied and implemented. This issues identified in the RIS are presented below.

1. *Licensees did not fully satisfy the first four points identified in the SER approving the TORMIS methodology. Examples include the following:*

   a. *not providing adequate justification that the analysis used the most conservative value for tornado frequency*
   b. *not including the entire TORMIS missile spectrum defined for use in the TORMIS computer code as appropriate for the plant*
   c. *not providing adequate explanation for the number and adequacy of tornado simulations and histories*
   d. *not providing sufficient information regarding the development and use of area ratios*

2. *Licensees did not fully address the fifth point identified in the SER and explain how the methodology was implemented when the parameters used differed from those specified in the TORMIS methodology. Examples include the following:*

   a. *inappropriately limiting the number of targets modeled*
   b. *failing to address missile tumbling when modeling targets*
   c. *failing to properly consider and use the variance reduction techniques and parameters specified by TORMIS*
   d. *taking credit for nonstructural members*
   e. *failing to consider risk significant, non-safety-related equipment*

3. *Licensees used the TORMIS methodology to address situations for which the methodology was not approved. Examples include the following:*

   a. *proposing the elimination of existing tornado barriers*
   b. *proposing Technical Specifications (TS) changes*
   c. *proposing plant modifications*

Byron Station considered these observations in the development of the TORMIS analysis and addressed each of them as shown below.

1.a. *Justification for Tornado Frequency:*

To meet the regulatory requirements for modeling tornado risk, TORMIS uses a statistical approach that considers both broad regions and small areas around the plant. A basic sub-region data set for Byron Station is identified and analyzed. The sub-region data is analyzed to produce the tornado input files needed in TORMIS. Tornado hazard curves are developed using a TORMIS-derived code called TORRISK. TORRISK is a specialized version of TORMIS that produces tornado hazard curves distinct from the missile risk analysis features of TORMIS. The TORRISK hazard curves provide control points to ensure that the TORMIS simulations track the Byron Station site-specific hazard curve and are conservative for missile risk analysis.

The tornado frequency value conservatively considers regions around the plant and corrects for reporting trend and tornado classification error and random encounter errors, per the TORMIS methodology (References 3, 4, and 5). The developed tornado hazard curve for Byron Station is conservative when compared to NRC Region I criteria given in NUREG/CR-4461, Revision 2 (Reference 6). A comparison of Byron Station hazard curve (i.e., the "BGS TORMIS Plant" curve) and NUREG/CR-4461 (i.e., the "BGS NUREG EF Point" curve) is shown in Attachment 1-2, Figure 8, "TORMIS Simulation of Byron Station Tornado Hazard for Plant Safety Envelope."

1.b. *Spectrum of Missile Considered:*

The Byron Station study included the missile spectrum (26 missile aerodynamic subsets) developed for use in TORMIS. A total of 24 missiles were used for Byron Station, including two plant specific missiles. The two plant specific missile types included the precast concrete roof deck panels found on several buildings and the concrete roof pavers located on top of the Turbine Building. The existing metal siding missile was also modified to be plant specific based on the characteristics of the insulated metal siding on the exterior of the Turbine Building.

1.c. *Justification for the Number and Adequacy of Tornado Simulations:*

A replication approach was used for the simulations. A total of 60 complete TORMIS replications were run with different random number seeds and missile populations. A total of 462 million missile simulations were performed for each replication, for a total of 27.72 billion missile simulations over all 60 replications. The standard deviations (σ) of these replications were computed and the standard error (ε) in the aggregate mean probability (μ) was computed from $\varepsilon = \sigma/\sqrt{n}$. The 95% confidence bounds in the mean probability were conservatively approximated by $\mu \pm 2 \cdot \varepsilon$.

Attachment 1-2, Figure 9, "Target Group Hit and Damage Frequency with Confidence Intervals," plots the two-sided 95% confidence intervals. As an example, the running 95% two-sided confidence bounds for Group 32 are illustrated in Attachment 1-2, Figure 10, "Convergence Plot for Damage Frequency for Target Group 32 (U2 MSSV 4)," to

demonstrate that reasonable statistical convergence had been obtained with 60 replications.

1.d. Use of Area Ratios:

No area ratios have been used as a method to adjust the TORMIS outputs for small targets, based on a ratio of hit probabilities from a large target or surface. A variance reduction approach is available in TORMIS and was used for Byron Station that allows for increasing the volume or size of small targets explicitly within the code. TORMIS applies the input variance reduction weight (k_a) in the TORMIS scoring equation. These adjustments are used within TORMIS for the single missile impact probability. They are not used to "ratio down" the multiple missile impact probabilities following a TORMIS simulation. Ratioing down the results at the end of TORMIS is not technically acceptable and can lead to an underestimation of the multiple missile risk.

2.a. Inappropriately Limiting of the Number of Targets Modeled:

The Byron Station TORMIS model includes plant components, identified as necessary to safely shutdown the plant and maintain a shutdown condition, located in areas not fully protected by missile barriers designed to resist impact from design basis tornado missiles. The Byron Station TORMIS analysis includes 153 potential missile targets (see Attachment 1-1, Table 1).

A number of unprotected targets were reviewed and not included in the Byron Station TORMIS model based on the following criteria:

1. Alternate protected systems or components are available to perform the required function, or

2. Analysis or evaluation to show that a postulated tornado missile impact will not result in the loss of a safe shutdown function.

The following are examples of the equipment not included in the Byron Station TORMIS model with associated justification as documented in an engineering evaluation.

- Unprotected safety related components associated with providing river makeup water to the SXCTs are not included in the TORMIS model. The essential service water (SX) makeup pumps are located in the River Screen House which is not protected against tornado missiles. For the case of a tornado impacting the river screen house, the non-safety related onsite deep well pumps are used to provide makeup water (as discussed in UFSAR Section 9.2.5.3.1, "Ultimate Heat Sink Design Basis," and Byron Station Technical Specification 3.7.9, "Ultimate Heat Sink (UHS"). Missile protected check valves are installed in the SX makeup lines to prevent back flow from the SXCT basins to the river screen house. The TORMIS model includes the deep well pump enclosures as a target.

- The unprotected non-safety related Condensate Storage Tanks (CST) and piping from the CSTs to the AF pumps located in the Turbine Building are not included in the Byron TORMIS model. The safety related essential service water system is used as

the backup suction source for the AF pumps if the CSTs or piping from the CSTs are damaged during a tornado event.

- The unprotected portion of the safety related Emergency Diesel Generator (EDG) exhaust stacks are not included in the TORMIS model. To prevent loss of diesel availability due to exhaust stack damage, a rupture disc pressure relief device is installed on each diesel exhaust line. This relief device is located inside a missile protected structure.

- Each EDG engine is provided with a crank case breather vent line that is routed to the outdoors. Where the lines penetrate the auxiliary building the vent lines could be damaged by tornado missiles blocking the crank case vent path. Design analysis has been completed and demonstrates that the crankcase vent lines can be blocked without adversely affecting the ability of the associated EDG to perform its design function.

- The Diesel Oil Storage Tanks (DOST) and EDG Day Tanks contain vent lines which provide a path to allow the tanks to fill and drain without developing excessive internal pressure or vacuum. The vent lines could be crimped by tornado missiles blocking the vent path at the point where they penetrate the auxiliary building. In the event the normal tank vent is blocked, an adequate alternate vent path for the DOSTs and EDG Day Tanks is provided by the DOST overflow lines and the piping that connects the air spaces of the DOSTs and EDG Day Tanks. These alternate vent paths are located inside the auxiliary building and are properly protected from tornado missiles.

- The normal fill path to the DOSTs is from either the 125,000-gallon or 50,000-gallon, Category II outdoor oil storage tanks utilizing gravity flow. The 125,000-gallon and 50,000-gallon oil storage tanks are not protected from tornado missiles. The outside fill connection is also not protected from tornado missiles. The DOSTs are designed to provide adequate fuel supply for 7 days of post-accident load operation.

- The AF Pump Diesel Engine Day Tanks contain vent lines which provide a path to allow the tanks to fill and drain without developing excessive internal pressure or vacuum. The vent lines could be crimped by tornado missiles blocking the vent path at the point where they penetrate the auxiliary building. For the Unit 1 AF Pump Diesel Engine Day Tank, if the normal vent path is completely blocked, an adequate alternate vent path would be provided by the tank overflow line to the 1C DOST. For the Unit 2 AF Pump Diesel Engine Day Tank, a tornado protected alternate vent path was installed. These alternate vent paths are located inside the auxiliary building and are properly protected from tornado missiles.

- As discussed in the Section 3.5.2 of the original Byron Station Safety Evaluation Report (SER), although the fuel-handling building is designed to be tornado missile resistant, the rollup freight door which is a large opening in the building is not capable of resisting tornado-missile impact. A tornado or tornado missile could destroy the door and may allow a relatively lightweight missile of large area, such as a steel panel or the door itself to travel inside the fuel-handling building. However, the spent fuel pool is sufficiently far from the door that any resulting tornado missile and debris could not enter the spent fuel pool and cause damage to the spent fuel assemblies or block

coolant flow. This is due to the low trajectory that the missile would have to follow through the door and toward the fuel pool. Further, it would then be required to turn 90° in order to enter the fuel pool.

- An unprotected six inch vent pipe runs from the top of each RWST into the Fuel Handling Building. The loss of RWST vent function (i.e., a missile hit completely crimps the vent and prevents air from entering the tank) has been analyzed to show no adverse impact on the RWST pressure boundary function. The pumps that draw suction from the RWST have been evaluated to show adequate Net Positive Suction Head is available without the vent function.

- The underground pipe tunnels from the RWSTs to the Auxiliary Building have an outdoor access shaft and hatch. The hatch cover is ¼" thick steel plate that is not designed as a missile barrier. An evaluation determined that no equipment required for safe shutdown would be damaged by tornado missiles that enter the hatch and travel down the access shaft into the pipe tunnel.

- The SXCT contains non-safety related level transmitters and local staff gauges that provide indication of the water level in the SXCT basins. SXCT basin level indication is not a required function for safe shutdown from a tornado.

- The deep well pump enclosure covers have a 2-1/2" vent pipe. Damage to the vent pipe would not impact operation of the well water pumps.

- Doors and ventilation openings between the Auxiliary Building and the Turbine Building below Elevation 451' are protected from tornado missiles by the concrete slabs, various Turbine building concrete walls, and large equipment located on elevations 426' and 401' of the Turbine Building.

It is also worthy to note that other targets were considered and include, for example, buildings that are expected to fail in a tornado and produce missiles (i.e., missile source targets) and buildings that are not assumed to fail during a tornado (such as reinforced concrete structures or heavy steel frames). Targets can be stacked on the top of one another to create, for example, a missile source on top of a safety-significant reinforced concrete building. For each target, the material type and strength are specified for each surface of the target, which is generally modeled as a prismatic box shape. These missile source targets are identified based on the site plans and aerial photos as well as plant walkdowns. Potential missiles generated by missile source buildings are estimated based on the site walkdown and building break-up models.

Missile shielding targets are buildings and other structures that are assumed to not fail in the tornado and provide missile shielding to the safety significant targets. Plant components modeled as shielding targets (also referred to as blockage) are constructed of reinforced concrete that is at least 1 foot thick, or clad with steel plate that is at least one inch thick. For example, the concrete superstructure of the UHS is modeled as a series of missile shielding targets.

TORMIS target worksheets were completed for each safety-significant target. These worksheets are used to document the location, dimensions, material properties,

references, and special modeling considerations for each of the safety-significant targets. Each worksheet also includes copies of the photos taken during the target walkdown and three-dimensional CAD representations of the targets as modeled for TORMIS.

Attachment 1-1, Table 6, "Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets," contains a list of all of the safety-significant, shielding, and missile source targets included in the Byron Station TORMIS model. Also shown in the table is the target group to which each of the safety-significant targets belongs.

2.b. *Consideration of Missile Tumbling:*

All safety-significant targets (with the exception of pipe penetrations) were modeled to allow for tumbling missile hits (i.e., offset hits) in accordance with the TORMIS technical reports (References 3, 4, and 5). Pipe penetration targets were not increased in size to reflect tumbling missiles since offset missiles cannot result in penetration of a small opening in a concrete wall.

EPRI TORMIS Report NP-769 (Reference 4) discusses consideration of finite missile size in modeling targets in Section 4.2.3. Since TORMIS tracks the missile as a point, missiles that just miss a target are actually likely to have hit the target by virtue of an "offset" hit. The analysis in Reference 4 shows that each safety target dimension should be increased by L/8 for each free face or direction, where L is the mean length of the missiles. Each shielding target can be increased by L/4 in each free direction. Thus, if a safety target has two free faces in the X direction, its actual X dimension, would be increased by L/8 × 2. This increase in target size accounts for the potential near misses (which are actually "offset" hits) that are not treated in TORMIS.

The determination of the appropriate offset hit dimension is an iterative process because a TORMIS model of a given plant needs to be run with its plant description and actual missile inventory. This was accomplished for Byron Station by creating a TORMIS model of the plant with an offset hit dimension of 1.5 feet per free edge.

The Byron Station TORMIS analysis conservatively did not increase the size of missile shielding targets for offset hits. This approach produces a conservative result in compliance with the RIS comment on "tumbling missiles."

2.c. *Use of Variance Reduction Techniques:*

Due to the very large simulation/replication sizes, no variance reduction techniques were used for tornado wind speed, tornado offset, tornado direction, tornado orientation, missile type, missile injection height, missile impact orientation, or trajectory termination. Variance reduction techniques were used for missile zone population and target size (k_a by target surface).

2.d. *Inappropriate Credit for Non-Structural Members:*

The Byron Station TORMIS analysis did not take credit for missile resistance for non-structural members.

2.e. *Failure to Consider Risk Significant, Non-Safety-Related Equipment:*

Plant walkdowns were performed in support of the TORMIS analysis. Risk-significant targets (both safety-related and non-safety-related) were considered. One hundred fifty-three (153) unprotected targets were ultimately identified and are included at the TORMIS analysis target set. Also see discussion under Item 2.a.

3.a. *Using TORMIS for the Elimination of Existing Tornado Barriers*

TORMIS is not being used to propose the elimination of tornado barriers.

3.b. *Using TORMIS to Propose TS Changes*

TORMIS is not being used to propose TS changes.

3.c. *Using TORMIS for Plant Modifications*

TORMIS is not being used to design new plant equipment modifications.

4.0 REGULATORY EVALUATION

4.1 Applicable Regulatory Requirements/Criteria

The TORMIS methodology was developed to estimate the probability of tornado missile impact and damage to nuclear power plant SSCs. The proposed change to utilize the TORMIS Computer Code for assessing tornado-generated missile protection of unprotected plant SSCs, is consistent with this methodology and the requirements and acceptance criteria specified in the below documents:

- Electric Power Research Institute Report – EPRI NP-768, "Tornado Missile Risk Analysis," May 1978 (Reference 3)
- Electric Power Research Institute Report – EPRI NP-769, "Tornado Missile Risk Analysis - Appendices," May 1978 (Reference 4)
- Electric Power Research Institute Report – EPRI NP-2005 Volumes, I and 2, "Tornado Missile Risk Evaluation Methodology," August 1981 (Reference 5)
- NRC Standard Review Plan (SRP) (i.e., NUREG-0800), Section 2.2.3, "Evaluation of Potential Accidents," Revision 2, July 1981

Specific information regarding TORMIS approval and acceptance criteria is contained in the following documents.

<u>NRC TORMIS Safety Evaluation Report</u>

The TORMIS methodology (References 3, 4 and 5) has been reviewed and accepted for nuclear power plant tornado missile risk analyses, as documented in the NRC Safety

Evaluation Report (SER) – Electric Power Research Institute (EPRI) Topical Reports Concerning Tornado Missile Probabilistic Risk Assessment (PRA) Methodology, dated October 26, 1983 (ML080870291) (Reference 1). The NRC SER concluded that:

> *"... the EPRI methodology can be utilized when assessing the need for positive tornado protection for specific safety-related plant features."*

The SER also states that licensees using the EPRI approach (i.e., the TORMIS methodology) must consider five specific points and provide the appropriate information. This information is provided in Section 3.4.5 above.

<u>NRC Memorandum on Use of Probabilistic Risk Assessment in Tornado Licensing Actions</u>

NRC Memorandum from Harold R. Denton to Victor Stello, "Position of Use of Probabilistic Risk Assessment in Tornado Licensing Actions," dated November 7, 1983 (ML030020331), endorsed the acceptance criteria stated in NUREG-0800, Section 2.2.3. The memorandum states:

> *"Therefore, the guidance in SRP Section 2.2.3 is applicable to tornado missiles. This guidance, which we will use in our probabilistic tornado reviews, states that an expected rate of occurrence of potential exposures in excess of the 10 CFR 100 guidelines of approximately 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the risk can be expected to be lower."*

<u>NRC Regulatory Issue Summary 2008-14</u>

The NRC subsequently issued Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008. This RIS provided additional guidance on the use of TORMIS for assessing nuclear power plant tornado missile protection. The RIS states that:

> *"The TORMIS methodology is approved for situations where (1) a licensee identifies existing plant SSCs that do not comply with the current licensing basis for positive tornado missile protection of the plant and (2) it would require costly modifications to bring the plant into compliance with the current licensing basis."*

In addition, the RIS identified specific items licensees should address to confirm the TORMIS methodology and computer code have been properly applied and implemented. This information is presented in Section 3.4.6 above. The RIS also reconfirms that the guidance in SRP Section 2.2.3 is applicable to tornado missiles.

4.2 Precedent

The NRC previously approved use of the TORMIS methodology for use at the following facilities:

Fermi 2

This amendment is documented in a letter from T. J. Wengert (NRC) to J. H. Plona (DTE Electric Company), "Fermi 2 – Issuance of Amendment Re: Revise the Fermi 2 Licensing Basis Concerning Protection from Tornado-Generated Missiles," dated March 10, 2014 (Reference 11).

In this amendment, the NRC specifically approved a number of deviations from the original EPRI methodology (see References 3, 4 and 5). These deviations are similar to the deviations utilized in the Byron Station TORMIS analysis as discussed in Section 3.4.5, Item 5, above. Of particular note, the NRC stated that following:

> *"An enhanced method was used for evaluating missiles passing through openings such as pipe penetrations in concrete walls, in addition to the standard TORMIS hit probability for such targets. This provides supplemental outputs intended to cover special cases of missiles going through wall openings."*

Donald C. Cook Nuclear Plant, Units 1 and 2

This amendment is documented in a letter from J. F. Stang (NRC) to R. P. Power (Indiana Michigan Power Company), "Donald C. Cook Nuclear Plant, Units 2 and 2 – Issuance of Amendments," dated November 17, 2000 (Reference 12).

In this amendment, the NRC explicitly acknowledged that the acceptance criterion established in SRP 2.2.3 of 10^{-6} per year is applied on a unit-specific basis.

Limerick Generating Station, Units 1 and 2

The use of TORSCR to post-process TORMIS output files and application of the Boolean Logic approach is documented in Technical Report NUS-4507, "Limerick Generating Station – Ultimate Heat Sink Extreme Wind Hazard Analysis," dated March 1984 (submitted in Reference 9). This report was accepted by the NRC in NUREG-0991, Supplement No. 3, "Safety Evaluation Report related to the operation of Limerick Generating Station, Units 1 and 2," dated October 1984.

In NUREG-0991, Supplement 3, Section 9.2.5, "Ultimate Heat Sink," the NRC documented approval of the Probabilistic Risk Assessment (PRA) analysis results addressing UHS missile protection. The details of the NRC review are contained in Supplement No. 3, Appendix O, "Technical Evaluation Report, Limerick Generating Station – Ultimate Heat Sink Extreme Wind Hazard Analysis," conducted by the National Bureau of Standards on behalf of the NRC. In summary, Appendix O concurred with the results presented in Technical Report NUS-4507.

NUS-4507 was developed by NUS Corporation and Applied Research Associates. NUS-4507, Chapter 2, "Definition of Plant Damage States," describes using TORSCR and a Boolean Logic approach to define the "plant damage states." Section 2.1, "Introduction," states the following:

> *"The purpose of this section is to define those combinations of targets for which the code TORSCR will estimate the frequency. Thus a plant damage state of interest is an identification of a specific combination of spray pond networks, feeder pipes and cooling towers such that damage to each of the elements constitutes a failure to cool ESW and RHRSW."*

In Section 2.2, "The Plant Damage States," two damage states; i.e., "T" and "V," are defined.

> *"Damage state V: At least three out of four spray networks and both cooling towers are damaged. This is failure to provide a heat sink for the ESWS and RHRSWS when both units are operational."*

> *"Damage state T: All four spray networks and the Unit 1 cooling tower is damaged. This is failure to provide a heat sink for the ESWS and RHRSWS when only Unit 1 is operational."*

Section 2.2 then notes:

> *"These two plant damage states, T and V, define the combinations of damage targets that are used as the basis for the probabilistic calculation performed using TORMIS-L and TORSCR."*

NUREG-0991, Supplement No. 3, Section 9.2.5, makes the following concluding statement:

> *"We have reviewed our consultant's TER [Technical Evaluation Report, Appendix O] and concur with the findings that the estimate of the probability of exceeding 10 CFR Part 100 limits owing to wind effects on the spray pond and the cooling towers will not exceed 1E-6 per year."*

4.3 No Significant Hazards Consideration

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit or early site permit," and 10 CFR 50.59, "Changes, tests, and experiments," paragraph (c)(2)(viii), Exelon Generation Company, LLC, (EGC) requests amendments to Renewed Facility Operating License Nos. NPF-37 and NPF-66 for Byron Station, Units 1 and 2. This amendment request proposes to revise the Byron Station licensing basis for protection from tornado-generated missiles. Specifically, the Updated Final Safety Analysis Report (UFSAR) will be revised to identify the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of unprotected plant structures, systems and components (SSCs) and to describe the results of the Byron Station site-specific tornado hazard analysis. The results from the Byron Station TORMIS analysis will be used to credit unprotected equipment for post-tornado safe shutdown. Of particular note, the Essential Service Water Cooling Tower (SXCT) fans and cells that survive a tornado strike will be credited for Ultimate Heat Sink (UHS) cooling as opposed to the original licensing basis that assumed all the unprotected SXCT fans are damaged by tornado-generated missiles. Modifying the UHS licensing basis, and other affected UFSAR sections, will be performed in accordance with 10 CFR 50.59, "Changes, tests and

experiments," upon approval of the proposed amendment. Note that there are no Technical Specifications changes associated with this request.

The Byron Station TORMIS analysis utilizes a probabilistic approach performed in accordance with the guidance described in the NRC TORMIS Safety Evaluation Report dated October 26, 1983, as clarified by Regulatory Issue Summary (RIS) 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008.

According to 10 CFR 50.92, "Issuance of amendment," paragraph (c), a proposed amendment to an operating license involves no significant hazards consideration if operation of the facility in accordance with the proposed amendment would not:

(1) Involve a significant increase in the probability or consequences of an accident previously evaluated; or

(2) Create the possibility of a new or different kind of accident from any accident previously evaluated; or

(3) Involve a significant reduction in a margin of safety.

EGC has evaluated the proposed change for Byron Station, using the criteria in 10 CFR 50.92, and has determined that the proposed change does not involve a significant hazards consideration. The following information is provided to support a finding of no significant hazards consideration.

Criteria

1. Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

   Response: No.

   The NRC TORMIS Safety Evaluation Report states the following:

   > *"The current Licensing criteria governing tornado missile protection are contained in [NUREG-0800] Standard Review Plan (SRP) Section 3.5.1.4, [Missiles Generated by Natural Phenomena] and 3.5.2 [Structures, Systems and Components to be Protected from Externally Generated Missiles]. These criteria generally specify that safety-related systems be provided positive tornado missile protection (barriers) from the maximum credible tornado threat. However, SRP Section 3.5.1.4 includes acceptance criteria permitting relaxation of the above deterministic guidance, if it can be demonstrated that the probability of damage to unprotected essential safety-related features is sufficiently small."*

   As permitted by these SRP sections, the combined probability will be maintained below an allowable level, i.e., an acceptance criterion threshold, which reflects an extremely low probability of occurrence. SRP Section 2.2.3, "Evaluation of Potential Accidents," established this threshold as approximately 1.0E-06 per year if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower. The

Byron Station analysis approach assumes that if the sum of the individual probabilities calculated for tornado missiles striking and damaging portions of safety-significant SSCs is greater than or equal to 1.0E-06 per year per unit, then installation of tornado missile protection barriers would be required for certain components to lower the total cumulative damage probability below the acceptance criterion of 1.0E-06 per year per unit. Conversely, if the total cumulative damage probability remains below the acceptance criterion of 1.0E-06 per year per unit, no additional tornado missile protection barriers would be required for any of the unprotected safety-significant components.

With respect to the probability of occurrence or the consequences of an accident previously evaluated in the UFSAR, the possibility of a tornado impacting the Byron Station site and causing damage to plant SSCs is a licensing basis event currently addressed in the UFSAR. The change being proposed (i.e., the use of the TORMIS methodology for assessing tornado-generated missile protection of unprotected plant SSCs), does not affect the probability of a tornado strike on the site; however, from a licensing basis perspective, the proposed change does affect the probability that missiles generated by a tornado will strike and damage certain safety-significant plant SSCs. There are a defined number of safety-significant components that could theoretically be struck and damaged by tornado-generated missiles. The probability of tornado-generated missile hits on these "important" systems and components is calculated using the TORMIS probabilistic methodology. The combined probability of damage for unprotected safety-significant equipment will be maintained below the acceptance criterion of 1.0E-06 per year per unit to ensure adequate equipment remains available to safely shutdown the reactors, and maintain overall plant safety, should a tornado strike occur. Consequently, the proposed change does not constitute a significant increase in the probability of occurrence or the consequences of an accident based on the extremely low probability of damage caused by tornado-generated missiles and the commensurate extremely low probability of a radiological release.

Finally, the use of the TORMIS methodology will have no impact on accident initiators or precursors; does not alter the accident analysis assumptions or the manner in which the plant is operated or maintained; and does not affect the probability of operator error.

Based on the above discussion, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No.

The impact of a tornado strike on the Byron Station site is a licensing basis event that is explicitly addressed in the UFSAR. The proposed change simply involves recognition of the acceptability of using an analysis tool (i.e., the TORMIS methodology) to perform probabilistic tornado missile damage calculations in accordance with approved regulatory guidance. The proposed change does not result in the creation of any new accident precursors; does not result in changes to any existing accident scenarios; and does not introduce any operational changes or mechanisms that would create the possibility of a new or different kind of accident.

Therefore, the proposed change will not create the possibility of a new or different kind of accident than those previously evaluated.

3. Does the proposed change involve a significant reduction in a margin of safety?

Response: No.

The existing Byron Station licensing basis regarding tornado missile protection of safety-significant SSCs assumes that missile protection barriers are provided for safety-significant SSCs; or the unprotected component is assumed to be unavailable post-tornado. The results of the Byron Station TORMIS analysis have demonstrated that there is an extremely low probability, below an established regulatory acceptance limit, that these "important" SSCs could be struck and subsequently damaged by tornado-generated missiles. The change in licensing basis from protecting safety-significant SSCs from tornado missiles, to demonstrating that there is an extremely low probability that safety-significant SSCs will be struck and damaged by tornado-generated missiles, does not constitute a significant decrease in the margin of safety.

Therefore, the proposed change to use the TORMIS methodology does not involve a significant reduction in the margin of safety.

Based on the above, EGC concludes that the proposed amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92, and accordingly, a finding of "no significant hazards consideration" is justified.

4.4 Conclusions

The conservatisms utilized in the TORMIS analysis provides high confidence that the Byron Station mean damage frequency values for each unit are conservatively high and "the risk can be expected to be lower," consistent with the acceptance criteria stated in SRP Section 2.2.3. The TORMIS methodology has been determined by the NRC (Reference 1) to be conservative with respect to missile risk analysis, provided "the tornado wind velocity ranges assumed in the calculations are defensible given the present state of the art" and "the assumptions concerning the locations and numbers of potential missiles present at the site are plausible." The first provision has been addressed by developing a site-specific tornado wind hazard curve, which considers both local and regional variations in tornado risk. A series of conservative adjustments were then made to the tornado data consistent with the TORMIS methodology. The second provision has been met by performing a detailed site survey, and conservatively applying the results of that survey to all future operating periods. The site survey was conducted during a plant outage, which increased the numbers of potential missiles at the site. There are many additional aspects of the TORMIS modeling and inputs that ensure bounding and conservative results.

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the site licensing basis and Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

5.0 ENVIRONMENTAL CONSIDERATION

EGC has evaluated this proposed operating license amendment consistent with the criteria for identification of licensing and regulatory actions requiring environmental assessment in accordance with 10 CFR 51.21, "Criteria for and identification of licensing and regulatory actions requiring environmental assessments." EGC has determined that these proposed changes to utilize the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of plant structures, systems and components (SSCs), meet the criteria for a categorical exclusion set forth in paragraph (c)(9) of 10 CFR 51.22, "Criterion for categorical exclusion; identification of licensing and regulatory actions eligible for categorical exclusion or otherwise not requiring environmental review," and as such, has determined that no irreversible consequences exist in accordance with paragraph (b) of 10 CFR 50.92, "Issuance of amendment." This determination is based on the fact that these changes are being proposed as an amendment to the license issued pursuant to 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," which changes a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, "Standards for Protection Against Radiation," or which changes an inspection or a surveillance requirement, and the amendment meets the following specific criteria:

(i) The amendment involves no significant hazards consideration.

As demonstrated in Section 4.3, "No Significant Hazards Consideration," the proposed change does not involve any significant hazards consideration.

(ii) There is no significant change in the types or significant increase in the amounts of any effluent that may be released offsite.

The proposed change does not result in an increase in power level, does not increase the production nor alter the flow path or method of disposal of radioactive waste or byproducts. It is expected that all plant equipment would operate as designed in the event of an accident to minimize the potential for any leakage of radioactive effluents. The proposed changes will have no impact on the amounts of radiological effluents released offsite during normal at-power operations or during the accident scenarios.

Based on the above evaluation, the proposed change will not result in a significant change in the types or significant increase in the amounts of any effluent released offsite.

(iii) There is no significant increase in individual or cumulative occupational radiation exposure.

There is no change in individual or cumulative occupational radiation exposure due to the proposed change. Specifically, the change to utilize the TORMIS Computer Code as the methodology used for assessing tornado-generated missile protection of plant SSCs has no impact on any radiation monitoring system setpoints. The proposed action will not change the level of controls or methodology used for processing of radioactive effluents or handling of solid radioactive waste, nor will the proposed action result in any change in the normal radiation levels within the plant.

Therefore, in accordance with 10 CFR 51.22, paragraph (b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

6.0 REFERENCES

1. NRC Safety Evaluation Report, "Electric Power Research Institute (EPRI) Topical Reports Concerning Tornado Missile Probabilistic Risk Assessment (PRA) Methodology," dated October 26, 1983 (ML080870291)

2. NRC Regulatory Issue Summary 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008 (ML080230578)

3. Electric Power Research Institute Report – EPRI NP-768, "Tornado Missile Risk Analysis," May 1978

4. Electric Power Research Institute Report – EPRI NP-769, "Tornado Missile Risk Analysis - Appendices," May 1978

5. Electric Power Research Institute Report – EPRI NP-2005 Volumes, I and 2, "Tornado Missile Risk Evaluation Methodology," August 1981

6. NUREG/CR-4461, Revision 2, "Tornado Climatology of the Contiguous United States, (PNNL-15112, Rev 2)," Ramsdell and Rishel, 2007

7. FEMA (2007), "Multi-hazard Loss Estimation – Hurricane Model, HAZUS MH MR3 Technical Manual"

8. NRC Memorandum from Harold R. Denton to Victor Stello, "Position of Use of Probabilistic Risk Assessment in Tornado Licensing Actions," dated November 7, 1983 (ML080870287)

9. Letter from J. S. Kemper (Philadelphia Electric Company) to A. S. Schwencer (NRC), "Limerick Generating Station, Analysis of Tornado Missile Effects on Ultimate Heat Sink (SSER Open Issue No 2)," dated March 22, 1984

10. NUREG-0991, Supplement No. 3, "Safety Evaluation Report related to the operation of Limerick Generating Station, Units 1 and 2," dated October 1984.

11. Letter from T. J. Wengert (NRC) to J. H. Plona (DTE Electric Company), "Fermi 2 – Issuance of Amendment Re: Revise the Fermi 2 Licensing Basis Concerning Protection from Tornado-Generated Missiles," dated March 10, 2014

12. Letter from J. F. Stang (NRC) to R. P. Powers (Indiana Michigan Power Company), "Donald C. Cook Nuclear Plant, Units 1 and 2 – Issuance of Amendments," dated November 17, 2000

ATTACHMENT 1-1

TORMIS Results
Tables 1-6

BYRON STATION
UNITS 1 AND 2

Docket Nos. 50-454 and 50-455

Renewed Facility Operating License Nos. NPF-37 and NPF-66

Table 1
TORMIS Results by Individual TORMIS Target
(Page 1 of 4)

Group Number	Target Group	Target Number	Description	Failure Mode	Crimping Type	Missile Hit	Damage
1	UHS Riser Pipes	1	UHS Riser Pipe -- Cell H -- lower	Perforation	N/A	7.37E-08	5.74E-10
		2	UHS Riser Pipe -- Cell H -- upper	V > Vdam	Riser Pipe	2.41E-08	0.00E+00
2	UHS Fan H	3	Cooling Tower Fan Motor -- Cell H	Missile Hit	N/A	1.71E-06	1.71E-06
		4	Gear Box Oil Level Gauge - Cell H	Missile Hit	N/A	7.66E-08	7.66E-08
		5	Personnel Hatch -- Cell H	Perforation	N/A	1.71E-07	5.68E-10
		6	Fan Inspection Hatch - Cell H	Perforation	N/A	9.66E-08	1.12E-09
		7	Fan - Cell H	Missile Hit	N/A	4.88E-08	4.88E-08
1	UHS Riser Pipes	8	UHS Riser Pipe -- Cell G -- lower	Perforation	N/A	1.28E-07	5.45E-09
		9	UHS Riser Pipe -- Cell G -- upper	V > Vdam	Riser Pipe	5.64E-08	0.00E+00
3	UHS Fan G	10	Cooling Tower Fan Motor -- Cell G	Missile Hit	N/A	3.82E-07	3.82E-07
		11	Gear Box Oil Level Gauge - Cell G	Missile Hit	N/A	8.98E-08	8.98E-08
		12	Personnel Hatch -- Cell G	Perforation	N/A	4.32E-08	4.78E-10
		13	Fan Inspection Hatch - Cell G	Perforation	N/A	2.21E-08	4.09E-10
		14	Fan - Cell G	Missile Hit	N/A	5.01E-08	5.01E-08
1	UHS Riser Pipes	15	UHS Riser Pipe -- Cell F - Lower	Perforation	N/A	1.53E-07	4.77E-09
		16	UHS Riser Pipe -- Cell F - Upper	V > Vdam	Riser Pipe	7.28E-08	0.00E+00
4	UHS Fan F	17	Cooling Tower Fan Motor -- Cell F	Missile Hit	N/A	4.03E-07	4.03E-07
		18	Gear Box Oil Level Gauge - Cell F	Missile Hit	N/A	5.75E-08	5.75E-08
		19	Personnel Hatch -- Cell F	Perforation	N/A	2.95E-08	3.01E-09
		20	Fan Inspection Hatch - Cell F	Perforation	N/A	9.57E-09	3.52E-10
		21	Fan - Cell F	Missile Hit	N/A	4.25E-08	4.25E-08
1	UHS Riser Pipes	22	UHS Riser Pipe -- Cell E -- Lower	Perforation	N/A	4.22E-08	3.26E-09
		23	UHS Riser Pipe -- Cell E -- Upper	V > Vdam	Riser Pipe	2.78E-08	0.00E+00
5	UHS Fan E	24	Cooling Tower Fan Motor -- Cell E	Missile Hit	N/A	2.52E-07	2.52E-07
		25	Gear Box Oil Level Gauge - Cell E	Missile Hit	N/A	6.65E-08	6.65E-08
		26	Personnel Hatch -- Cell E	Perforation	N/A	3.62E-08	4.36E-09
		27	Fan Inspection Hatch - Cell E	Perforation	N/A	7.69E-09	6.08E-10
		28	Fan - Cell E	Missile Hit	N/A	4.54E-08	4.54E-08
1	UHS Riser Pipes	29	UHS Riser Pipe -- Cell D - Lower	Perforation	N/A	1.21E-07	8.89E-09
		30	UHS Riser Pipe -- Cell D -- Upper	V > Vdam	Riser Pipe	6.07E-08	0.00E+00
6	UHS Fan D	31	Cooling Tower Fan Motor -- Cell D	Missile Hit	N/A	7.38E-07	7.38E-07
		32	Gear Box Oil Level Gauge - Cell D	Missile Hit	N/A	5.82E-08	5.82E-08
		33	Personnel Hatch -- Cell D	Perforation	N/A	1.99E-08	1.29E-09
		34	Fan Inspection Hatch - Cell D	Perforation	N/A	7.93E-08	1.78E-08
		35	Fan - Cell D	Missile Hit	N/A	6.23E-08	6.23E-08
1	UHS Riser Pipes	36	UHS Riser Pipe -- Cell C -- Lower	Perforation	N/A	1.19E-07	7.72E-09
		37	UHS Riser Pipe -- Cell C -- Upper	V > Vdam	Riser Pipe	6.51E-08	0.00E+00

Table 1
TORMIS Results by Individual TORMIS Target
(Page 2 of 4)

Group Number	*Target Group*	*Target Number*	*Description*	*Failure Mode*	*Crimping Type*	*Missile Hit*	*Damage*
7	UHS Fan C	38	Cooling Tower Fan Motor -- Cell C	Missile Hit	N/A	8.65E-07	8.65E-07
		39	Gear Box Oil Level Gauge - Cell C	Missile Hit	N/A	6.44E-08	6.44E-08
		40	Personnel Hatch -- Cell C	Perforation	N/A	1.25E-08	1.97E-09
		41	Fan Inspection Hatch - Cell C	Perforation	N/A	9.91E-08	1.90E-08
		42	Fan - Cell C	Missile Hit	N/A	5.78E-08	5.78E-08
1	UHS Riser Pipes	43	UHS Riser Pipe -- Cell B -- Lower	Perforation	N/A	1.81E-07	1.16E-08
		44	UHS Riser Pipe -- Cell B -- Upper	V > Vdam	Riser Pipe	7.39E-08	0.00E+00
8	UHS Fan B	45	Cooling Tower Fan Motor -- Cell B	Missile Hit	N/A	3.04E-07	3.04E-07
		46	Gear Box Oil Level Gauge - Cell B	Missile Hit	N/A	3.11E-08	3.11E-08
		47	Personnel Hatch -- Cell B	Perforation	N/A	7.31E-08	5.83E-09
		48	Fan Inspection Hatch - Cell B	Perforation	N/A	1.09E-07	2.29E-08
		49	Fan - Cell B	Missile Hit	N/A	6.27E-08	6.27E-08
1	UHS Riser Pipes	50	UHS Riser Pipe -- Cell A --Lower	Perforation	N/A	2.16E-07	1.38E-08
		51	UHS Riser Pipe -- Cell A -- Upper	V > Vdam	Riser Pipe	9.62E-08	0.00E+00
9	UHS Fan A	52	Cooling Tower Fan Motor -- Cell A	Missile Hit	N/A	9.90E-07	9.90E-07
		53	Gear Box Oil Level Gauge - Cell A	Missile Hit	N/A	4.52E-08	4.52E-08
		54	Personnel Hatch -- Cell A	Perforation	N/A	9.22E-08	6.36E-09
		55	Fan Inspection Hatch - Cell A	Perforation	N/A	1.36E-07	2.39E-08
		56	Fan - Cell A	Missile Hit	N/A	8.04E-08	8.04E-08
10	UHS Anti Vortex Screen	57	Anti-Vortex Trash Screen -- South Side	Perforation	N/A	4.43E-07	2.25E-08
		58	Anti-Vortex Trash Screen -- North Side	Perforation	N/A	5.10E-07	2.11E-08
11	UHS Room 232Z	59	Air Intake Louver on UHS Electrical Room -- SouthWest	Perforation	N/A	1.17E-08	3.08E-09
12	UHS Room 132Z	60	Air Intake Louver on UHS Electrical Room -- SouthEast	Perforation	N/A	4.24E-07	4.93E-08
13	UHS Room 231Z	61	Air Intake Louver on UHS Electrical Room -- NorthWest	Perforation	N/A	5.24E-08	8.96E-09
14	UHS Room 131Z	62	Air Intake Louver on UHS Electrical Room -- NorthEast	Perforation	N/A	2.38E-09	9.75E-11
15	U1 DAFP	63	Diesel Auxiary Feed Pump Exhaust U1 -- Pipe	V > Vdam	DAFP Pipe	4.91E-06	3.62E-10
		64	Diesel Auxiary Feed Pump Exhaust U1 -- Cover Plate	V > Vdam	DAFP Cover Plate	4.13E-06	3.15E-07
16	U2 DAFP	65	Diesel Auxiary Feed Pump Exhaust U2 -- Pipe	V > Vdam	DAFP Pipe	5.29E-06	2.19E-10
		66	Diesel Auxiary Feed Pump Exhaust U2 -- Cover Plate	V > Vdam	DAFP Cover Plate	4.59E-06	3.76E-07
17	U1 PORV	67	U1 - SE PORV Tailpipe - crush	V > Vdam	PORV	5.98E-07	3.56E-10
		68	U1 - SE PORV Tailpipe -PP	Pipe Penetration	N/A	4.90E-07	3.05E-10
18	U1 PORV	69	U1 - SE PORV Tailpipe - crush	V > Vdam	PORV	2.04E-07	1.57E-11
		70	U1 - SE PORV Tailpipe -PP	Pipe Penetration	N/A	2.25E-07	1.99E-10
19	U1 PORV	71	U1 - SW PORV Tailpipe - crush	V > Vdam	PORV	4.03E-07	8.64E-11
		72	U1 - SW PORV Tailpipe - PP	Pipe Penetration	N/A	1.92E-07	8.07E-10
20	U1 PORV	73	U1 - SW PORV Tailpipe - crush	V > Vdam	PORV	1.41E-06	1.34E-10
		74	U1 - SW PORV Tailpipe - PP	Pipe Penetration	N/A	1.66E-07	1.72E-10
21	U2 PORV	75	U2 - NE PORV Tailpipe - crush	V > Vdam	PORV	3.87E-07	9.58E-11
		76	U2 - NE PORV Tailpipe - PP	Pipe Penetration	N/A	2.77E-07	5.07E-11
22	U2 PORV	77	U2 - NE PORV Tailpipe - crush	V > Vdam	PORV	1.25E-06	3.90E-10
		78	U2 - NE PORV Tailpipe - PP	Pipe Penetration	N/A	6.31E-07	6.61E-11

Table 1
TORMIS Results by Individual TORMIS Target
(Page 3 of 4)

Group Number	*Target Group*	*Target Number*	*Description*	*Failure Mode*	*Crimping Type*	*Missile Hit*	*Damage*
23	U2 PORV	79	U2 - NW PORV Tailpipe - crush	V > Vdam	PORV	5.37E-07	1.06E-10
		80	U2 - NW PORV Tailpipe - PP	Pipe Penetration	N/A	1.58E-07	3.22E-10
24	U2 PORV	81	U2 - NW PORV Tailpipe - crush	V > Vdam	PORV	7.47E-07	2.79E-10
		82	U2 - NW PORV Tailpipe - PP	Pipe Penetration	N/A	2.23E-07	1.96E-10
25	U1 MSSV	83	U1 - SE MSSV Tailpipe Group - PP 1	Pipe Penetration	N/A	6.66E-07	5.11E-10
		84	U1 - SE MSSV Tailpipe Group - PP 2	Pipe Penetration	N/A	5.50E-07	2.29E-10
		85	U1 - SE MSSV Tailpipe Group - PP 3	Pipe Penetration	N/A	5.23E-07	2.03E-10
		86	U1 - SE MSSV Tailpipe Group - PP 4	Pipe Penetration	N/A	7.35E-07	4.89E-10
		87	U1 - SE MSSV Tailpipe Group - PP 5	Pipe Penetration	N/A	6.36E-07	4.71E-11
26	U1 MSSV	88	U1 - SE MSSV Tailpipe Group - PP 1	Pipe Penetration	N/A	3.48E-07	2.03E-10
		89	U1 - SE MSSV Tailpipe Group - PP 2	Pipe Penetration	N/A	3.61E-07	2.78E-11
		90	U1 - SE MSSV Tailpipe Group - PP 3	Pipe Penetration	N/A	3.34E-07	3.51E-11
		91	U1 - SE MSSV Tailpipe Group - PP 4	Pipe Penetration	N/A	2.89E-07	3.01E-11
		92	U1 - SE MSSV Tailpipe Group - PP 5	Pipe Penetration	N/A	3.02E-07	1.08E-11
27	U1 MSSV	93	U1 - SW MSSV Tailpipe Group - PP 1	Pipe Penetration	N/A	1.69E-07	2.72E-10
		94	U1 - SW MSSV Tailpipe Group - PP 2	Pipe Penetration	N/A	1.69E-07	2.26E-09
		95	U1 - SW MSSV Tailpipe Group - PP 3	Pipe Penetration	N/A	1.97E-07	2.46E-09
		96	U1 - SW MSSV Tailpipe Group - PP 4	Pipe Penetration	N/A	1.68E-07	2.46E-10
		97	U1 - SW MSSV Tailpipe Group - PP 5	Pipe Penetration	N/A	1.71E-07	5.52E-10
28	U1 MSSV	98	U1 - SW MSSV Tailpipe Group - PP 1	Pipe Penetration	N/A	1.68E-07	9.86E-11
		99	U1 - SW MSSV Tailpipe Group - PP 2	Pipe Penetration	N/A	1.53E-07	2.20E-10
		100	U1 - SW MSSV Tailpipe Group - PP 3	Pipe Penetration	N/A	1.67E-07	1.48E-10
		101	U1 - SW MSSV Tailpipe Group - PP 4	Pipe Penetration	N/A	1.58E-07	1.20E-10
		102	U1 - SW MSSV Tailpipe Group - PP 5	Pipe Penetration	N/A	1.80E-07	1.72E-10
29	U2 MSSV	103	U2 - NE MSSV Tailpipe Group - PP 1	Pipe Penetration	N/A	3.46E-07	8.57E-11
		104	U2 - NE MSSV Tailpipe Group - PP 2	Pipe Penetration	N/A	3.68E-07	1.99E-10
		105	U2 - NE MSSV Tailpipe Group - PP 3	Pipe Penetration	N/A	3.72E-07	7.89E-11
		106	U2 - NE MSSV Tailpipe Group - PP 4	Pipe Penetration	N/A	2.87E-07	3.14E-11
		107	U2 - NE MSSV Tailpipe Group - PP 5	Pipe Penetration	N/A	2.78E-07	1.68E-10
30	U2 MSSV	108	U2 - NE MSSV Tailpipe Group - PP 1	Pipe Penetration	N/A	5.63E-07	1.22E-10
		109	U2 - NE MSSV Tailpipe Group - PP 2	Pipe Penetration	N/A	6.64E-07	5.36E-10
		110	U2 - NE MSSV Tailpipe Group - PP 3	Pipe Penetration	N/A	7.83E-07	1.58E-10
		111	U2 - NE MSSV Tailpipe Group - PP 4	Pipe Penetration	N/A	6.98E-07	7.10E-11
		112	U2 - NE MSSV Tailpipe Group - PP 5	Pipe Penetration	N/A	8.35E-07	2.58E-10
31	U2 MSSV	113	U2 - NW MSSV Tailpipe Group - PP 1	Pipe Penetration	N/A	1.52E-07	3.15E-10
		114	U2 - NW MSSV Tailpipe Group - PP 2	Pipe Penetration	N/A	1.65E-07	1.98E-10
		115	U2 - NW MSSV Tailpipe Group - PP 3	Pipe Penetration	N/A	1.72E-07	9.65E-11
		116	U2 - NW MSSV Tailpipe Group - PP 4	Pipe Penetration	N/A	1.56E-07	7.61E-11
		117	U2 - NW MSSV Tailpipe Group - PP 5	Pipe Penetration	N/A	1.60E-07	9.04E-11

Table 1
TORMIS Results by Individual TORMIS Target
(Page 4 of 4)

Group Number	*Target Group*	*Target Number*	*Description*	*Failure Mode*	*Crimping Type*	*Missile Hit*	*Damage*
32	U2 MSSV	118	U2 - NW MSSV Tailpipe Group - PP 1	Pipe Penetration	N/A	2.01E-07	4.32E-10
		119	U2 - NW MSSV Tailpipe Group - PP 2	Pipe Penetration	N/A	1.97E-07	1.68E-10
		120	U2 - NW MSSV Tailpipe Group - PP 3	Pipe Penetration	N/A	2.03E-07	1.13E-10
		121	U2 - NW MSSV Tailpipe Group - PP 4	Pipe Penetration	N/A	2.14E-07	1.46E-10
		122	U2 - NW MSSV Tailpipe Group - PP 5	Pipe Penetration	N/A	2.20E-07	5.06E-10
33	Deepwell Enclosures	123	Deepwell Enclosure #1	Spall	N/A	1.46E-05	4.09E-09
		124	Deepwell Enclosure #2	Spall	N/A	1.11E-05	2.16E-08
14	UHS Room 131Z	125	Div 11 Embedded Conduits in South Wall of Aux Bldg	Perforation	N/A	3.33E-05	3.22E-09
13	UHS Room 231Z	126	Div 21 Embedded Conduits in South Wall of Aux Bldg	Perforation	N/A	3.00E-05	2.45E-09
12	UHS Room 132Z	127	Div 12 Embedded Conduits in South Wall of Aux Bldg	Perforation	N/A	1.20E-05	1.57E-09
11	UHS Room 232Z	128	Div 22 Embedded Conduits in South Wall of Aux Bldg	Perforation	N/A	1.64E-05	2.90E-09
		129	Cable Vault 2H2 -- Div 22	Spall	N/A	3.60E-06	1.16E-08
12	UHS Room 132Z	130	Cable Vault 1H2 -- Div 12	Spall	N/A	3.05E-06	3.59E-09
13	UHS Room 231Z	131	Cable Vault 2G1 -- Div 21	Spall	N/A	3.04E-06	5.08E-09
14	UHS Room 131Z	132	Cable Vault 1G1 -- Div 11	Spall	N/A	3.14E-06	1.08E-08
11	UHS Room 232Z	133	Cable Vault 2J2 -- Div 22	Spall	N/A	1.70E-06	5.44E-10
12	UHS Room 132Z	134	Cable Vault 1J2 -- Div 12	Spall	N/A	1.18E-06	6.64E-10
34	U1 RWST Hatch	135	Unit 1 RWST Hatch	Missile Hit	N/A	2.45E-07	2.45E-07
35	U2 RWST Hatch	136	Unit 2 RWST Hatch	Missile Hit	N/A	2.39E-07	2.39E-07
36	U1 L-Line Wall Targets	137	U1 Division 2 MEER Opening	Pipe Penetration	N/A	1.60E-06	3.48E-09
		138	U1 Division 1 MEER Opening	Pipe Penetration	N/A	1.56E-06	6.43E-08
		139	U1 Control Room HVAC Intake Opening	Pipe Penetration	N/A	7.22E-07	4.00E-10
37	U2 L-Line Wall Targets	140	U2 Control Room HVAC Intake Opening	Pipe Penetration	N/A	7.30E-07	1.50E-09
		141	U2 Division 1 MEER Opening	Pipe Penetration	N/A	1.64E-06	6.00E-08
		142	U2 Division 2 MEER Opening	Pipe Penetration	N/A	1.67E-06	8.87E-09
38	Div 11 and 21 Conduits in Non-ESF Room	143	Conduits in Non-ESF Switchgear Room - Segment 1	Perforation	N/A	1.63E-09	1.71E-11
		144	Conduits in Non-ESF Switchgear Room - Segment 2	Perforation	N/A	3.18E-09	9.92E-12
		145	Conduits in Non-ESF Switchgear Room - Segment 3	Perforation	N/A	4.28E-08	3.64E-10
		146	Conduits in Non-ESF Switchgear Room - Segment 4	Perforation	N/A	3.13E-07	4.62E-10
		147	Conduits in Non-ESF Switchgear Room - Segment 5	Perforation	N/A	2.24E-06	1.21E-10
		148	Pipe East of Non-ESF Room Opening - Segment 1	Perforation	N/A	1.56E-05	1.80E-10
		149	Pipe East of Non-ESF Room Opening - Segment 2	Perforation	N/A	1.95E-05	4.42E-10
36	U1 L-Line Wall Targets	150	Pipe East of U1 Division 2 MEER Opening	Perforation	N/A	4.94E-05	1.63E-09
		151	Pipe East of U1 Division 1 MEER Opening	Perforation	N/A	3.85E-05	1.03E-09
37	U2 L-Line Wall Targets	152	Pipe East of U2 Division 1 MEER Opening	Perforation	N/A	3.87E-05	1.62E-09
		153	Pipe East of U2 Division 2 MEER Opening	Perforation	N/A	4.99E-05	2.30E-09

1. Zero entries mean no successful hits or damages in the simulations.

Table 2
Average Hit and Damage Frequency (per year) for Target Groups

Group Number	*Target Group*	*Failure Logic*	*Missile Hit*	*Damage*
1	UHS Riser Pipes	1 U 2 U 8 U 9 U 15 U 16 U 22 U 23 U 29 U 30 U 36 U 37 U 43 U 44 U 50 U 51	1.41E-06	5.60E-08
2	UHS Cell H	3 U 4 U 5 U 6 U 7	2.07E-06	1.83E-06
3	UHS Cell G	10 U 11 U 12 U 13 U 14	5.79E-07	5.15E-07
4	UHS Cell F	17 U 18 U 19 U 20 U 21	5.39E-07	5.04E-07
5	UHS Cell E	24 U 25 U 26 U 27 U 28	4.06E-07	3.68E-07
6	UHS Cell D	31 U 32 U 33 U 34 U 35	9.42E-07	8.67E-07
7	UHS Cell C	38 U 39 U 40 U 41 U 42	1.08E-06	9.96E-07
8	UHS Cell B	45 U 46 U 47 U 48 U 49	5.73E-07	4.25E-07
9	UHS Cell A	52 U 53 U 54 U 55 U 56	1.31E-06	1.13E-06
10	UHS Anti Vortex Screen	57 U 58	9.40E-07	4.36E-08
11	UHS Room 232Z	59 U 128 U 129 U 133	2.13E-05	1.81E-08
12	UHS Room 132Z	60 U 127 U 130 U 134	1.64E-05	5.51E-08
13	UHS Room 231Z	61 U 126 U 131	3.27E-05	1.65E-08
14	UHS Room 131Z	62 U 125 U 132	3.62E-05	1.41E-08
15	U1 DAFP	63 U 64	8.55E-06	3.16E-07
16	U2 DAFP	65 U 66	9.33E-06	3.77E-07
17	U1 PORV1	67 U 68	1.08E-06	6.61E-10
18	U1 PORV2	69 U 70	4.28E-07	2.14E-10
19	U1 PORV3	71 U 72	5.95E-07	8.93E-10
20	U1 PORV4	73 U 74	1.57E-06	3.06E-10
21	U2 PORV1	75 U 76	6.61E-07	1.46E-10
22	U2 PORV2	77 U 78	1.87E-06	4.57E-10
23	U2 PORV3	79 U 80	6.94E-07	4.29E-10
24	U2 PORV4	81 U 82	9.64E-07	4.75E-10
25	U1 MSSV1	83 U 84 U 85 U 86 U 87	3.00E-06	1.48E-09
26	U1 MSSV2	88 U 89 U 90 U 91 U 92	1.62E-06	3.07E-10
27	U1 MSSV3	93 U 94 U 95 U 96 U 97	8.70E-07	5.79E-09
28	U1 MSSV4	98 U 99 U 100 U 101 U 102	8.23E-07	7.59E-10
29	U2 MSSV1	103 U 104 U 105 U 106 U 107	1.63E-06	5.63E-10
30	U2 MSSV2	108 U 109 U 110 U 111 U 112	3.39E-06	1.15E-09
31	U2 MSSV3	113 U 114 U 115 U 116 U 117	7.97E-07	7.76E-10
32	U2 MSSV4	118 U 119 U 120 U 121 U 122	1.02E-06	1.36E-09
33	Deepwell Enclosures and Associated Conduits	60 U 62 U 123 U 124 U 125 U 127 U 130 U 132 U 134 U 143 U 144 U 145 U 146 U 147 U 148 U 149	1.00E-04	9.64E-08
34	U1 RWST Hatch	135	2.45E-07	2.45E-07
35	U2 RWST Hatch	136	2.39E-07	2.39E-07
36	U1 L-Line Wall Targets	137 U 138 U 139 U 150 U 151	8.57E-05	7.08E-08
37	U2 L-Line Wall Targets	140 U 141 U 142 U 152 U 153	8.63E-05	7.42E-08
38	Div 11 and 21 Conduits in Non-ESF Room	143 U 144 U 145 U 146 U 147 U 148 U 149	3.65E-05	1.60E-09

Table 3
Individual Failure Events Considered in UHS Boolean Sample Space

Event #	*Description*	*Failure Logic*
1	One or more unique components of Cell H fails by wind missile. Note that failure of electrical room 232Z is a separate event as its failure affects Cells G and H.	3 U 4 U 5 U 6 U 7
2	One or more unique components of Cell D fails by wind missile. Note that failure of electrical room 231Z is a separate event as its failure affects Cells C and D.	31 U 32 U 33 U 34 U 35
3	One or more unique components of Cell C fails by wind missile. Note that failure of electrical room 231Z is a separate event as its failure affects Cells C and D.	38 U 39 U 40 U 41 U 42
4	Electrical room 231Z (including embedded conduits and cable vaults), fails by wind missile – leads to failure of Cells C and D.	61 U 126 U 131
5	One or more unique components of Cell A, including electrical room 131Z (including embedded conduits and cable vaults), fails by wind missile.	52 U 53 U 54 U 55 U 56 U 62 U 125 U 132
6	Either anti-vortex box or any of the 8 riser pipes fails by wind missile.	1 U 2 U 8 U 9 U 15 U 16 U 22 U 23 U 29 U 30 U 36 U 37 U 43 U 44 U 50 U 51 U 57 U 58
7	Electrical room 232Z (including embedded conduits and cable vaults), fails by wind missile – leads to failure of Cells G and H.	59 U 128 U 129 U 133
8	One or more unique components of Cell G fails by wind missile. Note that failure of electrical room 232Z is a separate event as its failure affects Cells G and H.	10 U 11 U 12 U 13 U 14

Table 4
Space of 256 Possible Failure Combinations of UHS
(Page 1 of 6)

Combination Number	Fan H	Fan D	Fan C	Room 231Z (Fails C & D)	Fan A (with Room 131Z)	8 Risers and 2 Anti Vortex	Room 232Z (Fails G & H)	Fan G	1 Cell Out of Service Case	2 Cells Out of Service Case	Frequency (yr^{-1})
1	0	0	0	0	0	0	0	0	Survive	Survive	7.24E-04
2	1	0	0	0	0	0	0	0	Survive	Survive	1.66E-06
3	0	1	0	0	0	0	0	0	Survive	Survive	6.36E-07
4	0	0	1	0	0	0	0	0	Survive	Survive	7.49E-07
5	0	0	0	1	0	0	0	0	Survive	Survive	9.42E-09
6	0	0	0	0	1	0	0	0	Survive	Survive	8.70E-07
7	0	0	0	0	0	1	0	0	Fail	Fail	6.23E-08
8	0	0	0	0	0	0	1	0	Survive	Survive	6.07E-09
9	0	0	0	0	0	0	0	1	Survive	Survive	3.74E-07
10	1	1	0	0	0	0	0	0	Survive	Survive	3.27E-08
11	1	0	1	0	0	0	0	0	Survive	Survive	2.95E-08
12	1	0	0	1	0	0	0	0	Fail	Fail	4.21E-10
13	1	0	0	0	1	0	0	0	Survive	Survive	3.56E-08
14	1	0	0	0	0	1	0	0	Fail	Fail	7.08E-09
15	1	0	0	0	0	0	1	0	Survive	Survive	3.13E-10

Table 4
Space of 256 Possible Failure Combinations of UHS
(Page 2 of 6)

Combination Number	Fan H	Fan D	Fan C	Room 2312 (Fails C & D)	Fan A (with Room 1312)	8 Risers and 2 Anti Vortex	Room 2322 (Fails G & H)	Fan G	1 Cell Out of Service Case	2 Cells Out of Service Case	Frequency (yr^{-1})
16	1	0	0	0	0	0	0	1	Survive	Survive	2.50E-08
17	0	1	1	0	0	0	0	0	Survive	Survive	5.49E-08
18	0	1	0	1	0	0	0	0	Survive	Survive	7.62E-10
19	0	1	0	0	1	0	0	0	Survive	Survive	6.13E-08
20	0	1	0	0	0	1	0	0	Fail	Fail	5.02E-09
21	0	1	0	0	0	0	1	0	Fail	Survive	5.26E-11
22	0	1	0	0	0	0	0	1	Survive	Survive	2.17E-08
23	0	0	1	1	0	0	0	0	Survive	Survive	3.51E-10
24	0	0	1	0	1	0	0	0	Survive	Survive	7.53E-08
25	0	0	1	0	0	1	0	0	Fail	Fail	4.38E-09
26	0	0	1	0	0	0	1	0	Fail	Survive	2.49E-10
27	0	0	1	0	0	0	0	1	Survive	Survive	2.63E-08
28	0	0	0	1	1	0	0	0	Fail	Fail	6.55E-10
29	0	0	0	1	0	1	0	0	Fail	Fail	1.01E-10
30	0	0	0	1	0	0	1	0	Fail	Fail	0.00E+00
31	0	0	0	1	0	0	0	1	Fail	Survive	5.96E-10
32	0	0	0	0	1	1	0	0	Fail	Fail	7.20E-09
33	0	0	0	0	1	0	1	0	Fail	Survive	1.43E-10
34	0	0	0	0	1	0	0	1	Survive	Survive	2.54E-08
35	0	0	0	0	0	1	1	0	Fail	Fail	4.89E-12
36	0	0	0	0	0	1	0	1	Fail	Fail	4.21E-09
37	0	0	0	0	0	0	1	1	Survive	Survive	3.29E-10
38	1	1	1	0	0	0	0	0	Fail	Fail	4.88E-09
39	1	1	0	1	0	0	0	0	Fail	Fail	3.10E-17
40	1	1	0	0	1	0	0	0	Fail	Fail	5.94E-09
41	1	1	0	0	0	1	0	0	Fail	Fail	9.28E-10
42	1	1	0	0	0	0	1	0	Fail	Survive	9.93E-12
43	1	1	0	0	0	0	0	1	Fail	Survive	3.46E-09
44	1	0	1	1	0	0	0	0	Fail	Fail	0.00E+00
45	1	0	1	0	1	0	0	0	Fail	Fail	6.81E-09
46	1	0	1	0	0	1	0	0	Fail	Fail	2.22E-10
47	1	0	1	0	0	0	1	0	Fail	Survive	2.83E-12
48	1	0	1	0	0	0	0	1	Fail	Survive	3.86E-09
49	1	0	0	1	1	0	0	0	Fail	Fail	2.29E-12
50	1	0	0	1	0	1	0	0	Fail	Fail	0.00E+00
51	1	0	0	1	0	0	1	0	Fail	Fail	0.00E+00
52	1	0	0	1	0	0	0	1	Fail	Fail	0.00E+00
53	1	0	0	0	1	1	0	0	Fail	Fail	7.35E-10
54	1	0	0	0	1	0	1	0	Fail	Survive	7.62E-12
55	1	0	0	0	1	0	0	1	Fail	Survive	3.35E-09
56	1	0	0	0	0	1	1	0	Fail	Fail	8.32E-12
57	1	0	0	0	0	1	0	1	Fail	Fail	3.08E-10
58	1	0	0	0	0	0	1	1	Survive	Survive	2.40E-12
59	0	1	1	1	0	0	0	0	Survive	Survive	2.17E-11
60	0	1	1	0	1	0	0	0	Fail	Fail	1.67E-08
61	0	1	1	0	0	1	0	0	Fail	Fail	1.29E-09
62	0	1	1	0	0	0	1	0	Fail	Fail	3.80E-14
63	0	1	1	0	0	0	0	1	Fail	Survive	6.22E-09
64	0	1	0	1	1	0	0	0	Fail	Fail	4.50E-11
65	0	1	0	1	0	1	0	0	Fail	Fail	6.46E-11

Table 4
Space of 256 Possible Failure Combinations of UHS
(Page 3 of 6)

Combination Number	Fan H	Fan D	Fan C	Room 2312 (Fails C & D)	Fan A (with Room 1312)	8 Risers and 2 Anti Vortex	Room 2322 (Fails G & H)	Fan G	1 Cell Out of Service Case	2 Cells Out of Service Case	Frequency (yr^{-1})
66	0	1	0	1	0	0	1	0	Fail	Fail	0.00E+00
67	0	1	0	1	0	0	0	1	Fail	Survive	9.10E-12
68	0	1	0	0	1	1	0	0	Fail	Fail	1.41E-09
69	0	1	0	0	1	0	1	0	Fail	Fail	2.38E-11
70	0	1	0	0	1	0	0	1	Fail	Survive	5.34E-09
71	0	1	0	0	0	1	1	0	Fail	Fail	0.00E+00
72	0	1	0	0	0	1	0	1	Fail	Fail	3.00E-10
73	0	1	0	0	0	0	1	1	Fail	Survive	0.00E+00
74	0	0	1	1	1	0	0	0	Fail	Fail	9.85E-11
75	0	0	1	1	0	1	0	0	Fail	Fail	0.00E+00
76	0	0	1	1	0	0	1	0	Fail	Fail	0.00E+00
77	0	0	1	1	0	0	0	1	Fail	Survive	1.42E-11
78	0	0	1	0	1	1	0	0	Fail	Fail	6.03E-10
79	0	0	1	0	1	0	1	0	Fail	Fail	6.90E-13
80	0	0	1	0	1	0	0	1	Fail	Survive	6.94E-09
81	0	0	1	0	0	1	1	0	Fail	Fail	0.00E+00
82	0	0	1	0	0	1	0	1	Fail	Fail	6.40E-10
83	0	0	1	0	0	0	1	1	Fail	Survive	7.98E-11
84	0	0	0	1	1	1	0	0	Fail	Fail	3.36E-11
85	0	0	0	1	1	0	1	0	Fail	Fail	0.00E+00
86	0	0	0	1	1	0	0	1	Fail	Fail	1.45E-11
87	0	0	0	1	0	1	1	0	Fail	Fail	0.00E+00
88	0	0	0	1	0	1	0	1	Fail	Fail	7.54E-14
89	0	0	0	1	0	0	1	1	Fail	Fail	0.00E+00
90	0	0	0	0	1	1	1	0	Fail	Fail	0.00E+00
91	0	0	0	0	1	1	0	1	Fail	Fail	5.83E-10
92	0	0	0	0	1	0	1	1	Fail	Survive	0.00E+00
93	0	0	0	0	0	1	1	1	Fail	Fail	0.00E+00
94	1	1	1	1	0	0	0	0	Fail	Fail	0.00E+00
95	1	1	1	0	1	0	0	0	Fail	Fail	2.08E-09
96	1	1	1	0	0	1	0	0	Fail	Fail	8.79E-11
97	1	1	1	0	0	0	1	0	Fail	Fail	1.16E-12
98	1	1	1	0	0	0	0	1	Fail	Fail	9.34E-10
99	1	1	0	1	1	0	0	0	Fail	Fail	1.69E-12
100	1	1	0	1	0	1	0	0	Fail	Fail	0.00E+00
101	1	1	0	1	0	0	1	0	Fail	Fail	0.00E+00
102	1	1	0	1	0	0	0	1	Fail	Fail	2.00E-15
103	1	1	0	0	1	1	0	0	Fail	Fail	1.01E-10
104	1	1	0	0	1	0	1	0	Fail	Fail	0.00E+00
105	1	1	0	0	1	0	0	1	Fail	Fail	6.79E-10
106	1	1	0	0	0	1	1	0	Fail	Fail	0.00E+00
107	1	1	0	0	0	1	0	1	Fail	Fail	7.99E-11
108	1	1	0	0	0	0	1	1	Fail	Survive	0.00E+00
109	1	0	1	1	1	0	0	0	Fail	Fail	1.25E-12
110	1	0	1	1	0	1	0	0	Fail	Fail	0.00E+00
111	1	0	1	1	0	0	1	0	Fail	Fail	0.00E+00
112	1	0	1	1	0	0	0	1	Fail	Fail	0.00E+00
113	1	0	1	0	1	1	0	0	Fail	Fail	2.13E-10
114	1	0	1	0	1	0	1	0	Fail	Fail	0.00E+00
115	1	0	1	0	1	0	0	1	Fail	Fail	1.09E-09

Table 4
Space of 256 Possible Failure Combinations of UHS (continued)
(Page 4 of 6)

Combination Number	Fan H	Fan D	Fan C	Room 231Z (Fails C & D)	Fan A (with Room 131Z)	8 Risers and 2 Anti Vortex	Room 232Z (Fails G & H)	Fan G	1 Cell Out of Service Case	2 Cells Out of Service Case	Frequency (yr^{-1})
116	1	0	1	0	0	1	1	0	Fail	Fail	0.00E+00
117	1	0	1	0	0	1	0	1	Fail	Fail	9.45E-11
118	1	0	1	0	0	0	1	1	Fail	Survive	1.01E-11
119	1	0	0	1	1	1	0	0	Fail	Fail	0.00E+00
120	1	0	0	1	1	0	1	0	Fail	Fail	0.00E+00
121	1	0	0	1	1	0	0	1	Fail	Fail	0.00E+00
122	1	0	0	1	0	1	1	0	Fail	Fail	0.00E+00
123	1	0	0	1	0	1	0	1	Fail	Fail	0.00E+00
124	1	0	0	1	0	0	1	1	Fail	Fail	0.00E+00
125	1	0	0	0	1	1	1	0	Fail	Fail	0.00E+00
126	1	0	0	0	1	1	0	1	Fail	Fail	4.60E-11
127	1	0	0	0	1	0	1	1	Fail	Survive	0.00E+00
128	1	0	0	0	0	1	1	1	Fail	Fail	0.00E+00
129	0	1	1	1	1	0	0	0	Fail	Fail	1.76E-12
130	0	1	1	1	0	1	0	0	Fail	Fail	0.00E+00
131	0	1	1	1	0	0	1	0	Fail	Fail	0.00E+00
132	0	1	1	1	0	0	0	1	Fail	Survive	3.28E-12
133	0	1	1	0	1	1	0	0	Fail	Fail	3.59E-10
134	0	1	1	0	1	0	1	0	Fail	Fail	1.76E-11
135	0	1	1	0	1	0	0	1	Fail	Fail	2.15E-09
136	0	1	1	0	0	1	1	0	Fail	Fail	0.00E+00
137	0	1	1	0	0	1	0	1	Fail	Fail	1.60E-10
138	0	1	1	0	0	0	1	1	Fail	Fail	0.00E+00
139	0	1	0	1	1	1	0	0	Fail	Fail	1.12E-11
140	0	1	0	1	1	0	1	0	Fail	Fail	0.00E+00
141	0	1	0	1	1	0	0	1	Fail	Fail	1.68E-13
142	0	1	0	1	0	1	1	0	Fail	Fail	0.00E+00
143	0	1	0	1	0	1	0	1	Fail	Fail	3.37E-11
144	0	1	0	1	0	0	1	1	Fail	Fail	0.00E+00
145	0	1	0	0	1	1	1	0	Fail	Fail	0.00E+00
146	0	1	0	0	1	1	0	1	Fail	Fail	5.41E-10
147	0	1	0	0	1	0	1	1	Fail	Fail	0.00E+00
148	0	1	0	0	0	1	1	1	Fail	Fail	0.00E+00
149	0	0	1	1	1	1	0	0	Fail	Fail	0.00E+00
150	0	0	1	1	1	0	1	0	Fail	Fail	0.00E+00
151	0	0	1	1	1	0	0	1	Fail	Fail	0.00E+00
152	0	0	1	1	0	1	1	0	Fail	Fail	0.00E+00
153	0	0	1	1	0	1	0	1	Fail	Fail	0.00E+00
154	0	0	1	1	0	0	1	1	Fail	Fail	0.00E+00
155	0	0	1	0	1	1	1	0	Fail	Fail	0.00E+00
156	0	0	1	0	1	1	0	1	Fail	Fail	1.37E-10
157	0	0	1	0	1	0	1	1	Fail	Fail	0.00E+00
158	0	0	1	0	0	1	1	1	Fail	Fail	0.00E+00
159	0	0	0	1	1	1	1	0	Fail	Fail	0.00E+00
160	0	0	0	1	1	1	0	1	Fail	Fail	0.00E+00
161	0	0	0	1	1	0	1	1	Fail	Fail	0.00E+00
162	0	0	0	1	0	1	1	1	Fail	Fail	0.00E+00
163	0	0	0	0	1	1	1	1	Fail	Fail	0.00E+00
164	1	1	1	1	1	0	0	0	Fail	Fail	0.00E+00
165	1	1	1	1	0	1	0	0	Fail	Fail	0.00E+00

Table 4
Space of 256 Possible Failure Combinations of UHS
(Page 5 of 6)

Combination Number	Fan H	Fan D	Fan C	Room 231Z (Fails C & D)	Fan A (with Room 131Z)	8 Risers and 2 Anti Vortex	Room 232Z (Fails G & H)	Fan G	1 Cell Out of Service Case	2 Cells Out of Service Case	Frequency (yr^{-1})
166	1	1	1	1	0	0	1	0	Fail	Fail	0.00E+00
167	1	1	1	1	0	0	0	1	Fail	Fail	0.00E+00
168	1	1	1	0	1	1	0	0	Fail	Fail	1.67E-12
169	1	1	1	0	1	0	1	0	Fail	Fail	0.00E+00
170	1	1	1	0	1	0	0	1	Fail	Fail	4.37E-10
171	1	1	1	0	0	1	1	0	Fail	Fail	0.00E+00
172	1	1	1	0	0	1	0	1	Fail	Fail	1.80E-11
173	1	1	1	0	0	0	1	1	Fail	Fail	0.00E+00
174	1	1	0	1	1	1	0	0	Fail	Fail	0.00E+00
175	1	1	0	1	1	0	1	0	Fail	Fail	0.00E+00
176	1	1	0	1	1	0	0	1	Fail	Fail	2.50E-11
177	1	1	0	1	0	1	1	0	Fail	Fail	0.00E+00
178	1	1	0	1	0	1	0	1	Fail	Fail	0.00E+00
179	1	1	0	1	0	0	1	1	Fail	Fail	0.00E+00
180	1	1	0	0	1	1	1	0	Fail	Fail	0.00E+00
181	1	1	0	0	1	1	0	1	Fail	Fail	0.00E+00
182	1	1	0	0	1	0	1	1	Fail	Fail	0.00E+00
183	1	1	0	0	0	1	1	1	Fail	Fail	0.00E+00
184	1	0	1	1	1	1	0	0	Fail	Fail	0.00E+00
185	1	0	1	1	1	0	1	0	Fail	Fail	0.00E+00
186	1	0	1	1	1	0	0	1	Fail	Fail	0.00E+00
187	1	0	1	1	0	1	1	0	Fail	Fail	0.00E+00
188	1	0	1	1	0	1	0	1	Fail	Fail	0.00E+00
189	1	0	1	1	0	0	1	1	Fail	Fail	0.00E+00
190	1	0	1	0	1	1	1	0	Fail	Fail	0.00E+00
191	1	0	1	0	1	1	0	1	Fail	Fail	1.07E-11
192	1	0	1	0	1	0	1	1	Fail	Fail	0.00E+00
193	1	0	1	0	0	1	1	1	Fail	Fail	0.00E+00
194	1	0	0	1	1	1	1	0	Fail	Fail	0.00E+00
195	1	0	0	1	1	1	0	1	Fail	Fail	0.00E+00
196	1	0	0	1	1	0	1	1	Fail	Fail	0.00E+00
197	1	0	0	1	0	1	1	1	Fail	Fail	0.00E+00
198	1	0	0	0	1	1	1	1	Fail	Fail	0.00E+00
199	0	1	1	1	1	1	0	0	Fail	Fail	0.00E+00
200	0	1	1	1	1	0	1	0	Fail	Fail	0.00E+00
201	0	1	1	1	1	0	0	1	Fail	Fail	4.46E-11
202	0	1	1	1	0	1	1	0	Fail	Fail	0.00E+00
203	0	1	1	1	0	1	0	1	Fail	Fail	0.00E+00
204	0	1	1	1	0	0	1	1	Fail	Fail	0.00E+00
205	0	1	1	0	1	1	1	0	Fail	Fail	0.00E+00
206	0	1	1	0	1	1	0	1	Fail	Fail	8.59E-17
207	0	1	1	0	1	0	1	1	Fail	Fail	0.00E+00
208	0	1	1	0	0	1	1	1	Fail	Fail	0.00E+00
209	0	1	0	1	1	1	1	0	Fail	Fail	0.00E+00
210	0	1	0	1	1	1	0	1	Fail	Fail	0.00E+00
211	0	1	0	1	1	0	1	1	Fail	Fail	0.00E+00
212	0	1	0	1	0	1	1	1	Fail	Fail	0.00E+00
213	0	1	0	0	1	1	1	1	Fail	Fail	0.00E+00
214	0	0	1	1	1	1	1	0	Fail	Fail	0.00E+00
215	0	0	1	1	1	1	0	1	Fail	Fail	0.00E+00

Table 4
Space of 256 Possible Failure Combinations of UHS
(Page 6 of 6)

Combination Number	Fan H	Fan D	Fan C	Room 231Z (Fails C & D)	Fan A (with Room 131Z)	8 Risers and 2 Anti Vortex	Room 232Z (Fails G & H)	Fan G	1 Cell Out of Service Case	2 Cells Out of Service Case	Frequency (yr^{-1})
216	0	0	1	1	1	0	1	1	Fail	Fail	0.00E+00
217	0	0	1	1	0	1	1	1	Fail	Fail	0.00E+00
218	0	0	1	0	1	1	1	1	Fail	Fail	0.00E+00
219	0	0	0	1	1	1	1	1	Fail	Fail	0.00E+00
220	1	1	1	1	1	1	0	0	Fail	Fail	0.00E+00
221	1	1	1	1	1	0	1	0	Fail	Fail	0.00E+00
222	1	1	1	1	1	0	0	1	Fail	Fail	0.00E+00
223	1	1	1	1	0	1	1	0	Fail	Fail	0.00E+00
224	1	1	1	1	0	1	0	1	Fail	Fail	0.00E+00
225	1	1	1	1	0	0	1	1	Fail	Fail	0.00E+00
226	1	1	1	0	1	1	1	0	Fail	Fail	0.00E+00
227	1	1	1	0	1	1	0	1	Fail	Fail	6.17E-14
228	1	1	1	0	1	0	1	1	Fail	Fail	0.00E+00
229	1	1	1	0	0	1	1	1	Fail	Fail	0.00E+00
230	1	1	0	1	1	1	1	0	Fail	Fail	0.00E+00
231	1	1	0	1	1	1	0	1	Fail	Fail	0.00E+00
232	1	1	0	1	1	0	1	1	Fail	Fail	0.00E+00
233	1	1	0	1	0	1	1	1	Fail	Fail	0.00E+00
234	1	1	0	0	1	1	1	1	Fail	Fail	0.00E+00
235	1	0	1	1	1	1	1	0	Fail	Fail	0.00E+00
236	1	0	1	1	1	1	0	1	Fail	Fail	0.00E+00
237	1	0	1	1	1	0	1	1	Fail	Fail	0.00E+00
238	1	0	1	1	0	1	1	1	Fail	Fail	0.00E+00
239	1	0	1	0	1	1	1	1	Fail	Fail	0.00E+00
240	1	0	0	1	1	1	1	1	Fail	Fail	0.00E+00
241	0	1	1	1	1	1	1	0	Fail	Fail	0.00E+00
242	0	1	1	1	1	1	0	1	Fail	Fail	0.00E+00
243	0	1	1	1	1	0	1	1	Fail	Fail	0.00E+00
244	0	1	1	1	0	1	1	1	Fail	Fail	0.00E+00
245	0	1	1	0	1	1	1	1	Fail	Fail	0.00E+00
246	0	1	0	1	1	1	1	1	Fail	Fail	0.00E+00
247	0	0	1	1	1	1	1	1	Fail	Fail	0.00E+00
248	1	1	1	1	1	1	1	0	Fail	Fail	0.00E+00
249	1	1	1	1	1	1	0	1	Fail	Fail	0.00E+00
250	1	1	1	1	1	0	1	1	Fail	Fail	0.00E+00
251	1	1	1	1	0	1	1	1	Fail	Fail	0.00E+00
252	1	1	1	0	1	1	1	1	Fail	Fail	0.00E+00
253	1	1	0	1	1	1	1	1	Fail	Fail	0.00E+00
254	1	0	1	1	1	1	1	1	Fail	Fail	0.00E+00
255	0	1	1	1	1	1	1	1	Fail	Fail	0.00E+00
256	1	1	1	1	1	1	1	1	Fail	Fail	0.00E+00
Annual Frequency of Failure for 1 Cell Out of Service Case (3, 4, or 5 of 5 Fans Failing)									Fail		1.73E-07
Annual Frequency of Failure for 2 Cells Out of Service Case (3 or 4 of 4 Fans Failing)										Fail	1.42E-07

Table 5
Mean Damage Frequency (per Year) for Byron Station Target Groups

Target Identified by BGS	*Corresponding Target Groups*	*Target Group Approach*	*Source Table for Damage Frequency*	*Damage Frequency (yr^{-1}) by Case* 1 Cell Out of Service	*Damage Frequency (yr^{-1}) by Case* 2 Cells Out of Service
UHS Riser Pipes UHS Anti Vortex Boxes & Trash Screens UHS Fan Motor and Power Feeds UHS Fan Gear Box Oil Gauges UHS Personnel Hatches UHS Inspection Hatches UHS Fan Blades UHS Electrical Room Louvers Embedded Conduits in South Wall of Auxiliary Building Underground Cable Vaults	Ultimate Heat Sink (UHS)	3 or 4 of 8 cells assumed to be out of service. 2 are out of service for random electrical failure and 1 or 2 are out of service for maintenance. With 1 fan out of service for maintenance, 3 of the remaining 5 fans need to survive to ensure success of UHS. UHS failure based on >= 3 of 5 remaining fans damaged by tornado missiles. With 2 fans out of service for maintenance, 2 of the remaining 4 fans need to survive to ensure success of UHS. UHS failure based on >= 2 of 4 remaining fans damaged by tornado missiles. Details of approach documented in Section 2.3.2.	Table 2-6	1.73E-07	1.42E-07
Diesel AuxFW Pump Exhausts	U1 DAFP	Boolean Union over separate targets for exhaust pipe and cover plate. Separate damage frequencies computed for each unit.	Table 2-4	3.16E-07	
Diesel AuxFW Pump Exhausts	U2 DAFP	Boolean Union over separate targets for exhaust pipe and cover plate. Separate damage frequencies computed for each unit.	Table 2-4	3.77E-07	
PORV Tailpipes	U1 PORV1	Boolean Union over separate targets modeled for pipe crimping and pipe penetration pass through. Separate damage frequencies computed for each PORV on each unit.	Table 2-4	6.61E-10	
PORV Tailpipes	U1 PORV2			2.14E-10	
PORV Tailpipes	U1 PORV3			8.93E-10	
PORV Tailpipes	U1 PORV4			3.06E-10	
PORV Tailpipes	U2 PORV1			1.46E-10	
PORV Tailpipes	U2 PORV2			4.57E-10	
PORV Tailpipes	U2 PORV3			4.29E-10	
PORV Tailpipes	U2 PORV4			4.75E-10	
MSSV Tailpipes	U1 MSSV1	Boolean Union over 5 MSSVs on each respective Main Steam line. Separate damage frequencies computed for each set of 5 MSSVs on each unit.	Table 2-4	1.48E-09	
MSSV Tailpipes	U1 MSSV2			3.07E-10	
MSSV Tailpipes	U1 MSSV3			5.79E-09	
MSSV Tailpipes	U1 MSSV4			7.59E-10	
MSSV Tailpipes	U2 MSSV1			5.63E-10	
MSSV Tailpipes	U2 MSSV2			1.15E-09	
MSSV Tailpipes	U2 MSSV3			7.76E-10	
MSSV Tailpipes	U2 MSSV4			1.36E-09	
Deepwell Enclosures	Deepwell Enclosures, Electrical Rooms 131Z and 132Z, and related conduits	Boolean union of Deepwell Pump 0A and Deepwell Pump 0B	Table 2-4	9.64E-08	
RWST Hatches	U1 RWST Hatch	Missile hit probability on single target representing the RWST hatch for each unit.	Table 2-3	2.45E-07	
RWST Hatches	U2 RWST Hatch			2.39E-07	
U1 New Targets	U1 MEER Div 2 Opening	Arithmetic sum of missiles passing through equivalent pipe penetration and perforating the pipe blocking the opening	Table 2-3	5.11E-09	
U1 New Targets	U1 MEER Div 1 Opening			6.53E-08	
U1 New Targets	U1 CR HVAC Intake Opening	Missiles passing through equivalent pipe penetration		4.00E-10	
U2 New Targets	U2 CR HVAC Intake Opening	Missiles passing through equivalent pipe penetration	Table 2-3	1.50E-09	
U2 New Targets	U2 MEER Div 1 Opening	Arithmetic sum of missiles passing through equivalent pipe penetration and perforating the pipe blocking the opening		6.16E-08	
U2 New Targets	U2 MEER Div 2 Opening			1.12E-08	
Conduits in Non-ESF Room	Div 11 and 21 Conduit behind Opening	Boolean union over all conduit segments behind opening	Table 2-4	1.60E-09	
Arithmetic Sum over all Unit 1 Target Groups (includes UHS)				**9.13E-07**	**8.83E-07**
Arithmetic Sum over all Unit 2 Target Groups (includes UHS)				**9.66E-07**	**9.36E-07**
Arithmetic Sum over all Target Groups				**1.61E-06**	**1.58E-06**

Table 6
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 1 of 7)

TORMIS Target #	BGS Target Group	TORMIS Target Description	I_{safety}	I_{shield}	I_{source}
1	UHS Cell H Riser Pipes	UHS Riser Pipe -- Cell H -- lower	1		
2		UHS Riser Pipe -- Cell H -- upper	2		
3	UHS Cell H Fan and Associated	Cooling Tower Fan Motor -- Cell H	3		
4	Components	Gear Box Oil Level Gauge - Cell H	4		
5		Personnel Hatch -- Cell H	5		
6		Fan Inspection Hatch - Cell H	6		
7		Fan - Cell H	7		
8	UHS Cell G Riser Pipes	UHS Riser Pipe -- Cell G -- lower	8		
9		UHS Riser Pipe -- Cell G -- upper	9		
10	UHS Cell G Fan and Associated	Cooling Tower Fan Motor -- Cell G	10		
11	Components	Gear Box Oil Level Gauge - Cell G	11		
12		Personnel Hatch -- Cell G	12		
13		Fan Inspection Hatch - Cell G	13		
14		Fan - Cell G	14		
15	UHS Cell F Riser Pipes	UHS Riser Pipe -- Cell F - Lower	15		
16		UHS Riser Pipe -- Cell F - Upper	16		
17	UHS Cell F Fan and Associated	Cooling Tower Fan Motor -- Cell F	17		
18	Components	Gear Box Oil Level Gauge - Cell F	18		
19		Personnel Hatch -- Cell F	19		
20		Fan Inspection Hatch - Cell F	20		
21		Fan - Cell F	21		
22	UHS Cell E Riser Pipes	UHS Riser Pipe -- Cell E -- Lower	22		
23		UHS Riser Pipe -- Cell E -- Upper	23		
24	UHS Cell E Fan and Associated	Cooling Tower Fan Motor -- Cell E	24		
25	Components	Gear Box Oil Level Gauge - Cell E	25		
26		Personnel Hatch -- Cell E	26		
27		Fan Inspection Hatch - Cell E	27		
28		Fan - Cell E	28		
29	UHS Cell D Riser Pipes	UHS Riser Pipe -- Cell D - Lower	29		
30		UHS Riser Pipe -- Cell D -- Upper	30		
31	UHS Cell D Fan and Associated	Cooling Tower Fan Motor -- Cell D	31		
32	Components	Gear Box Oil Level Gauge - Cell D	32		
33		Personnel Hatch -- Cell D	33		
34		Fan Inspection Hatch - Cell D	34		
35		Fan - Cell D	35		
36	UHS Cell C Riser Pipes	UHS Riser Pipe -- Cell C -- Lower	36		
37		UHS Riser Pipe -- Cell C -- Upper	37		
38	UHS Cell C Fan and Associated	Cooling Tower Fan Motor -- Cell C	38		
39	Components	Gear Box Oil Level Gauge - Cell C	39		
40		Personnel Hatch -- Cell C	40		
41		Fan Inspection Hatch - Cell C	41		
42		Fan - Cell C	42		

Table 6
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets

TORMIS Target #	BGS Target Group	TORMIS Target Description	I_{safety}	I_{shield}	I_{source}
43	UHS Cell B Riser Pipes	UHS Riser Pipe – Cell B – Lower	43		
44		UHS Riser Pipe – Cell B – Upper	44		
45	UHS Cell B Fan and Associated Components	Cooling Tower Fan Motor – Cell B	45		
46		Gear Box Oil Level Gauge - Cell B	46		
47		Personnel Hatch – Cell B	47		
48		Fan Inspection Hatch - Cell B	48		
49		Fan - Cell B	49		
50	UHS Cell A Riser Pipes	UHS Riser Pipe – Cell A –Lower	50		
51		UHS Riser Pipe – Cell A – Upper	51		
52	UHS Cell A Fan and Associated Components	Cooling Tower Fan Motor – Cell A	52		
53		Gear Box Oil Level Gauge - Cell A	53		
54		Personnel Hatch – Cell A	54		
55		Fan Inspection Hatch - Cell A	55		
56		Fan - Cell A	56		
57	Anti-Vortex Box / Trash Screens	Anti-Vortex Trash Screen – South Side	57		
58		Anti-Vortex Trash Screen – North Side	58		
59	UHS Electrical Room 232Z	Air Intake Louver on UHS Electrical Room – South - West Opening	59		
60	UHS Electrical Room 132Z	Air Intake Louver on UHS Electrical Room – South - East Opening	60		
61	UHS Electrical Room 231Z	Air Intake Louver on UHS Electrical Room – North - West Opening	61		
62	UHS Electrical Room 131Z	Air Intake Louver on UHS Electrical Room – North - East Opening	62		
63	U1 Diesel Auxiliary Feed Pump Exhausts	Diesel Auxiary Feed Pump Exhaust U1 – Lower portion	63		
64		Diesel Auxiary Feed Pump Exhaust U1 – Upper portion	64		
65	U2 Diesel Auxiliary Feed Pump Exhausts	Diesel Auxiary Feed Pump Exhaust U2 – Lower portion	65		
66		Diesel Auxiary Feed Pump Exhaust U2 – Upper portion	66		
67	U1 PORV 1 (SE)	U1 - SE PORV Tailpipe 1 - crush	67		
68		U1 - SE PORV Tailpipe 1 -PP	68		
69	U1 PORV 2 (SE)	U1 - SE PORV Tailpipe 2 - crush	69		
70		U1 - SE PORV Tailpipe 2 -PP	70		
71	U1 PORV 3 (SW)	U1 - SW PORV Tailpipe 1 - crush	71		
72		U1 - SW PORV Tailpipe 1 - PP	72		
73	U1 PORV 4 (SW)	U1 - SW PORV Tailpipe 2 - crush	73		
74		U1 - SW PORV Tailpipe 2 - PP	74		
75	U2 PORV 1 (NE)	U2 - NE PORV Tailpipe 1 - crush	75		
76		U2 - NE PORV Tailpipe 1 - PP	76		
77	U2 PORV 2 (NE)	U2 - NE PORV Tailpipe 2 - crush	77		
78		U2 - NE PORV Tailpipe 2 - PP	78		
79	U2 PORV 3 (NW)	U2 - NW PORV Tailpipe 1 - crush	79		
80		U2 - NW PORV Tailpipe 1 - PP	80		
81	U2 PORV 4 (NW)	U2 - NW PORV Tailpipe 2 - crush	81		
82		U2 - NW PORV Tailpipe 2 - PP	82		
83	U1 MSSV Group 1 (SE)	U1 - SE MSSV Tailpipe Group 1 - PP 1	83		
84		U1 - SE MSSV Tailpipe Group 1 - PP 2	84		
85		U1 - SE MSSV Tailpipe Group 1 - PP 3	85		
86		U1 - SE MSSV Tailpipe Group 1 - PP 4	86		
87		U1 - SE MSSV Tailpipe Group 1 - PP 5	87		
88	U1 MSSV Group 2 (SE)	U1 - SE MSSV Tailpipe Group 2 - PP 1	88		
89		U1 - SE MSSV Tailpipe Group 2 - PP 2	89		
90		U1 - SE MSSV Tailpipe Group 2 - PP 3	90		
91		U1 - SE MSSV Tailpipe Group 2 - PP 4	91		
92		U1 - SE MSSV Tailpipe Group 2 - PP 5	92		
93	U1 MSSV Group 3 (SW)	U1 - SW MSSV Tailpipe Group 1 - PP 1	93		
94		U1 - SW MSSV Tailpipe Group 1 - PP 2	94		
95		U1 - SW MSSV Tailpipe Group 1 - PP 3	95		
96		U1 - SW MSSV Tailpipe Group 1 - PP 4	96		
97		U1 - SW MSSV Tailpipe Group 1 - PP 5	97		

Table 6
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 3 of 7)

TORMIS Target #	BGS Target Group	TORMIS Target Description	I_{safety}	I_{shield}	$I_{missile}$
98	U1 MSSV Group 4 (SW)	U1 - SW MSSV Tailpipe Group 2 - PP 1	98		
99		U1 - SW MSSV Tailpipe Group 2 - PP 2	99		
100		U1 - SW MSSV Tailpipe Group 2 - PP 3	100		
101		U1 - SW MSSV Tailpipe Group 2 - PP 4	101		
102		U1 - SW MSSV Tailpipe Group 2 - PP 5	102		
103	U2 MSSV Group 1 (NE)	U2 - NE MSSV Tailpipe Group 1 - PP 1	103		
104		U2 - NE MSSV Tailpipe Group 1 - PP 2	104		
105		U2 - NE MSSV Tailpipe Group 1 - PP 3	105		
106		U2 - NE MSSV Tailpipe Group 1 - PP 4	106		
107		U2 - NE MSSV Tailpipe Group 1 - PP 5	107		
108	U2 MSSV Group 2 (NE)	U2 - NE MSSV Tailpipe Group 2 - PP 1	108		
109		U2 - NE MSSV Tailpipe Group 2 - PP 2	109		
110		U2 - NE MSSV Tailpipe Group 2 - PP 3	110		
111		U2 - NE MSSV Tailpipe Group 2 - PP 4	111		
112		U2 - NE MSSV Tailpipe Group 2 - PP 5	112		
113	U2 MSSV Group 3 (NW)	U2 - NW MSSV Tailpipe Group 1 - PP 1	113		
114		U2 - NW MSSV Tailpipe Group 1 - PP 2	114		
115		U2 - NW MSSV Tailpipe Group 1 - PP 3	115		
116		U2 - NW MSSV Tailpipe Group 1 - PP 4	116		
117		U2 - NW MSSV Tailpipe Group 1 - PP 5	117		
118	U2 MSSV Group 4 (NW)	U2 - NW MSSV Tailpipe Group 2 - PP 1	118		
119		U2 - NW MSSV Tailpipe Group 2 - PP 2	119		
120		U2 - NW MSSV Tailpipe Group 2 - PP 3	120		
121		U2 - NW MSSV Tailpipe Group 2 - PP 4	121		
122		U2 - NW MSSV Tailpipe Group 2 - PP 5	122		
123	Deepwell Enclosures	Deepwell Enclosure #1	123		
124		Deepwell Enclosure #2	124		
125	Embedded Conduits	Div 11 Embedded Conduits in South Wall of Aux Bldg	125		
126		Div 21 Embedded Conduits in South Wall of Aux Bldg	126		
127		Div 12 Embedded Conduits in South Wall of Aux Bldg	127		
128		Div 22 Embedded Conduits in South Wall of Aux Bldg	128		
129	Cable Vaults	Cable Vault 2H2 -- Div 22	129		
130		Cable Vault 1H2 -- Div 12	130		
131		Cable Vault 2G1 -- Div 21	131		
132		Cable Vault 1G1 -- Div 11	132		
133		Cable Vault 2J2 -- Div 22	133		
134		Cable Vault 1J2 -- Div 12	134		
135	RWST Hatches	Unit 1 RWST Hatch	135		
136		Unit 2 RWST Hatch	136		
137	Div 12 MEER	U1 Division 2 MEER Opening	137		
138	Div 11 MEER	U1 Division 1 MEER Opening	138		
139	MCR Makeup Air Intake U1	U1 Control Room HVAC Intake Opening	139		
140	MCR Makeup Air Intake U2	U2 Control Room HVAC Intake Opening	140		
141	Div 21 MEER	U2 Division 1 MEER Opening	141		
142	Div 22 MEER	U2 Division 2 MEER Opening	142		
143	Non-ESF Switchgear Room	Conduits in Non-ESF Switchgear Room - Segment 1	143		
144		Conduits in Non-ESF Switchgear Room - Segment 2	144		
145		Conduits in Non-ESF Switchgear Room - Segment 3	145		
146		Conduits in Non-ESF Switchgear Room - Segment 4	146		
147		Conduits in Non-ESF Switchgear Room - Segment 5	147		
148		Pipe East of Non-ESF Room Opening - Segment 1	148		
149		Pipe East of Non-ESF Room Opening - Segment 2	149		
150	Div 12 MEER	Pipe East of U1 Division 2 MEER Opening	150		
151	Div 11 MEER	Pipe East of U1 Division 1 MEER Opening	151		
152	Div 21 MEER	Pipe East of U2 Division 1 MEER Opening	152		
153	Div 22 MEER	Pipe East of U2 Division 2 MEER Opening	153		

Table 6
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 4 of 7)

TORMIS Target #	BGS Target Group	TORMIS Target Description	L_{safety}	L_{shield}	L_{source}
154	Missile Shielding Targets	Reserved 1		1	
155		Reserved 2		2	
156		Reserved 3		3	
157		Reserved 4		4	
158		Reserved 5		5	
159		Reserved 6		6	
160		Reserved 7		7	
161		Reserved 8		8	
162		Unit 1 RWST		9	
163		Unit 2 RWST		10	
164		DAFP North		11	
165		DAFP East		12	
166		DAFP South		13	
167		DAFP North2		14	
168		DAFP East2		15	
169		DAFP South2		16	
170		UHS South Shield Wall Low		17	
171		UHS North Shield Wall low		18	
172		Cell H West Column blockage		19	
173		Cell G West Column blockage		20	
174		Cell F West Column blockage		21	
175		Cell E West Column blockage		22	
176		Cell D East Column bockage		23	
177		Cell C East Column bockage		24	
178		Cell B East Column bockage		25	
179		Cell A East Column bockage		26	
180		Turbine Bldg		27	
181		Heater Bay		28	
182		Aux Bldg Center		29	
183		Fuel Bldg		30	
184		U1 Aux Bldg E		31	
185		U1 Aux Bldg W		32	
186		U2 Aux Bldg E		33	
187		U2 Aux Bldg W		34	
188		U1 Reactor Bldg		35	
189		U2 Reactor Bldg		36	
190		U1 Safety Valve Room SE		37	
191		U1 Safety Valve Room SE Upper		38	
192		U1 Safety Valve Room SW		39	
193		U1 Safety Valve Room SW Upper		40	
194		U2 Safety Valve Room NE		41	
195		U2 Safety Valve Room NE Upper		42	
196		U2 Safety Valve Room NW		43	
197		U2 Safety Valve Room NW Upper		44	
198		UHS Upper Fill South		45	
199		UHS Upper Fill North		46	
200		UHS Electrical Area South		47	
201		UHS Electrical Area North		48	
202		UHS Riser Barrier N1		49	
203		UHS Riser Barrier N2		50	
204		UHS Riser Barrier N3		51	
205		UHS Riser Barrier N4		52	
206		UHS Riser Barrier S1		53	
207		UHS Riser Barrier S2		54	
208		UHS Riser Barrier S3		55	
209		UHS Riser Barrier S4		56	
210		UHS Interior Wall 1		57	
211		UHS Interior Wall 2		58	

Table 6
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets

TORMIS Target #	BGS Target Group	TORMIS Target Description	I [illegible]	I [illegible]	I [illegible]
212	Missile Shielding Targets *continued*	UHS Interior Wall 3		59	
213		UHS Interior Wall 4		60	
214		UHS Interior Wall 5		61	
215		UHS Interior Wall 6		62	
216		UHS Interior Wall 7		63	
217		UHS Interior Wall 8		64	
218		UHS Fan Barrier 1		65	
219		UHS Fan Barrier 2		66	
220		UHS Fan Barrier 3		67	
221		UHS Fan Barrier 4		68	
222		UHS Fan Barrier 5		69	
223		UHS Fan Barrier 6		70	
224		UHS Fan Barrier 7		71	
225		UHS Fan Barrier 8		72	
226		UHS South Barrier S wall		73	
227		UHS South Barrier N wall		74	
228		UHS South Barrier Roof		75	
229		UHS South Barrier Inner wall		76	
230		UHS North Barrier S wall		77	
231		UHS North Barrier N wall		78	
232		UHS North Barrier Roof		79	
233		UHS North Barrier Inner wall		80	
234		UHS West Wall Low		81	
235		UHS East Wall Low		82	
236		MS Pipe near conduit room		83	
237		MS Pipe between conduit room and HELB 1		84	
238		MS Pipe after HELB 2		85	
239		MS Pipe before HELB 5		86	
240		MS Pipe After HELB 6		87	
241		In front of cable room		88	
242		In front of HELB 2 and 3		89	
243		Gap between HELB targets		90	
244		In front of U2 airintake and HELB and 6		91	
245	Missile Source Targets	Z1 Trailer Group 1			1
246		Z1 Trailer Group 2			2
247		New Service Building			3
248		Gatehouse (MAF)			4
249		Old Service Building			5
250		Radwaste Building			6
251		Receiving Building			7
252		Receiving Building Warehouse			8
253		Bottled Gas Storage			9
254		Z4 Pumphouse 1			10
255		Z4 Pumphouse 2			11
256		Z4 Pumphouse 3			12
257		Waste Treatment Building			13
258		Substation			14
259		Z5 Eyewash Station			15
260		Abandoned Facility Maintenance Storage			16
261		U1 CAF			17
262		UHS Guard Walkway Structure/top of stairway			18
263		ISFSI Building			19
264		NSWP Training Building			20
265		Z12 Warehouse 1			21
266		Z12 Warehouse 2			22
267		Switchyard Maintenance Building			23
268		Switchyard Relay House			24
269		Vehicle Storage and Warehouse			25
270		EPA Waste Storage			26

Table 6
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 6 of 7)

TORMIS Target #	BGS Target Group	TORMIS Target Description	I_{safety}	I_{shield}	I_{source}
271	Missile Source Targets *continued*	Chlorine Shack			27
272		Z15 Warehouse 3			28
273		Sewage Treatment			29
274		Z16 Warehouse 4			30
275		Z16 Warehouse 5			31
276		Pre-Entry Facility			32
277		Mower Shed			33
278		Training Building			34
279		Z18 Shed			35
280		Z18 Trailer			36
281		Z18 Canopy			37
282		Training Building Section 1			38
283		Training Building Section 2			39
284		Training Building Maintenance Lab			40
285		Z20 Shed			41
286		Z21 Rail Car Shed			42
287		Microwave Tower Building			43
288		Z27 Guard Shack			44
289		Z28 Barn			45
290		Z28 Shed			46
291		Z28 House			47
292		Z30 Trailer			48
293		Z31 Guard Shack			49
294		Z31 Canopy			50
295		Z32 Trailer			51
296		Circ Water Pumphouse			52
297		U1 Cooling Tower Stairs			53
298		U2 Cooling Tower Stairs			54
299		Z34 Barn and Shed Structures			55
300		Z34 House			56
301		IEMA Building			57
302		Train Shed			58
303		U2 CAF			59
304		Unit 1 Turbine Deck			60
305		Unit 2 Turbine Deck			61
306		Turbine Bldg West Wall 1			62
307		Turbine Bldg East Wall			63
308		Turbine Bldg South Wall			64
309		Turbine Building North Wall			65
310		TB Roof Deck			66
311		U1 RB Cladding			67
312		U2 RB Cladding			68
313		U1 CAF Transition			69
314		U2 CAF Transition			70
315		Contractors Facility			71
316		IM EM Shop			72
317		Heater Bay Roof			73
318		TSC			74
319		TB Roof Pavers Section 1			75
320		TSC Roof Pavers			76
321		EM Shop Roof Pavers			77
322		TB Roof Pavers Section 2			78
323		TB Roof Pavers Section 3			79
324		TB Roof Pavers Section 4			80
325		TB Roof Pavers Section 5			81
326		TB Roof Pavers Section 6			82
327		TB Roof Pavers Section 7			83
328		TB Roof Pavers Section 8			84
329		TB Roof Pavers Section 9			85
330		TB Roof Pavers Section 10			86

Table 6
Sequential Numbering of Safety-Significant, Shielding and Missile Source Targets
(Page 7 of 7)

TORMIS Target #	BGS Target Group	TORMIS Target Description	I_{safety}	I_{shield}	I_{source}
331	Missile Source Targets *continued*	**Commercial Flex Bldg**			**87**
332		**Break and Ready Room**			**88**
333		**Unit 2 Testing Office**			**89**
334		**Cooling Tower 1 Framing**			**90**
335		**Cooling Tower 2 Framing**			**91**
336		**Cooling Tower 1 Top**			**92**
337		**Cooling Tower Top 2**			**93**
338		**Cooling Tower 1 Stairs**			**94**
339		**Cooling Tower 2 Stairs**			**95**
340		**Acid Tank Room**			**96**
341		**Turbine Building West Wall 2**			**97**
342		**Turbine Building West Wall 3**			**98**
343		**UHS Guard Lower Stairway**			**99**

ATTACHMENT 1-2

TORMIS Results
Figures 1-10

BYRON STATION
UNITS 1 AND 2

Docket Nos. 50-454 and 50-455

Renewed Facility Operating License Nos. NPF-37 and NPF-66

Figure 1
SX System Diagram

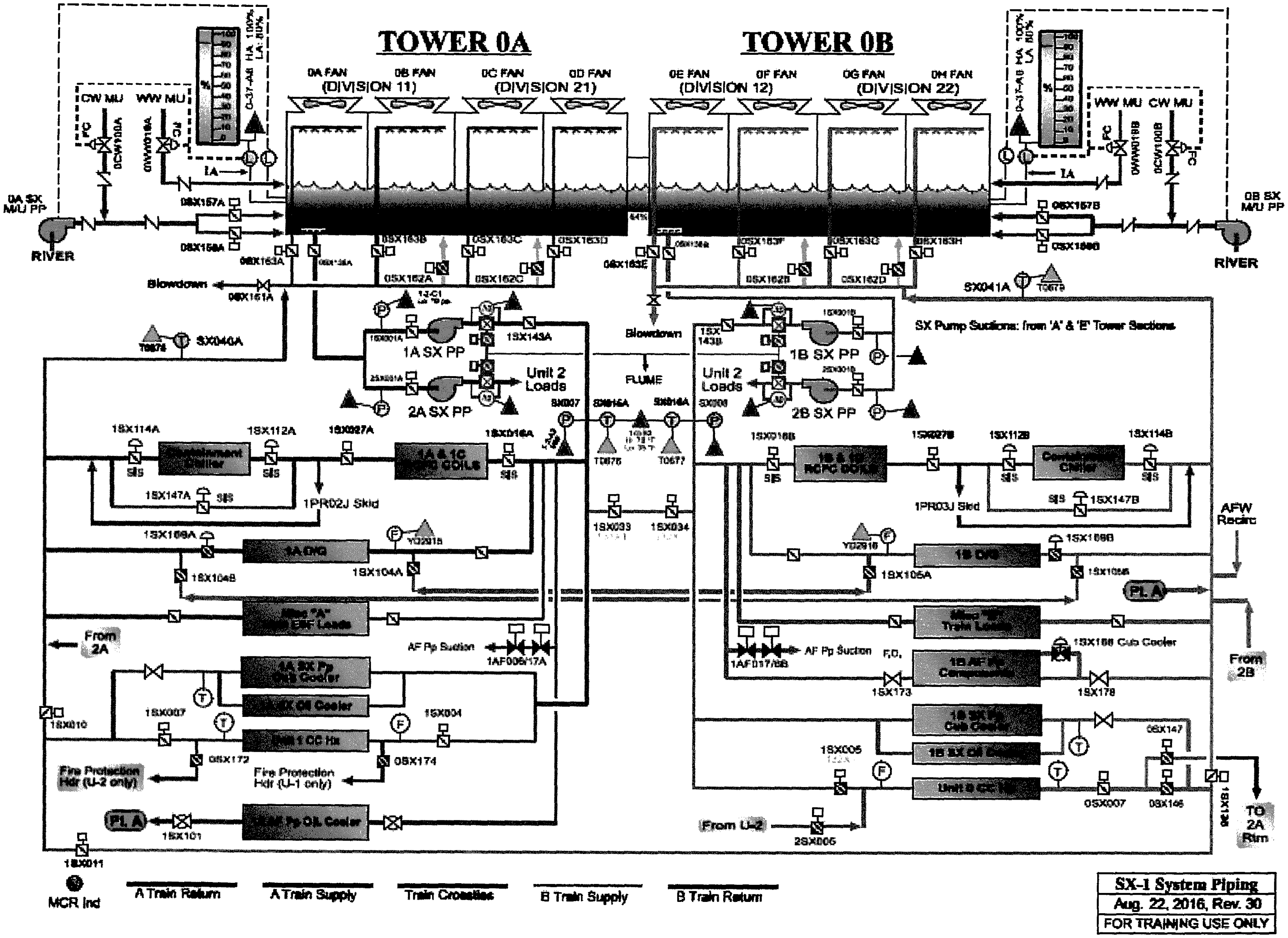


Figure 2
Aerial Photograph of the Byron Station UHS Physical Layout

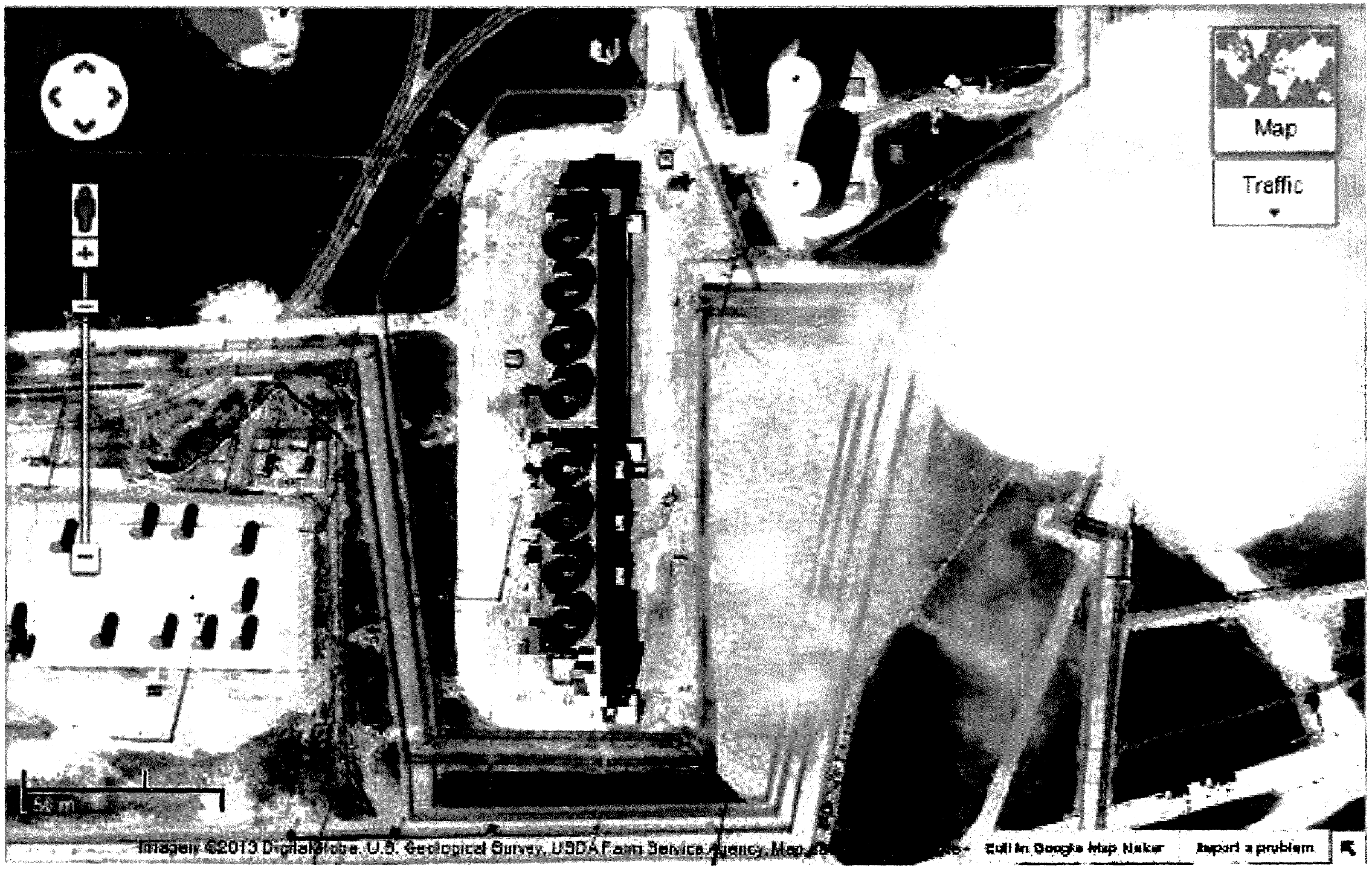


Figure 3
Individual Target Hit and Damage Frequencies

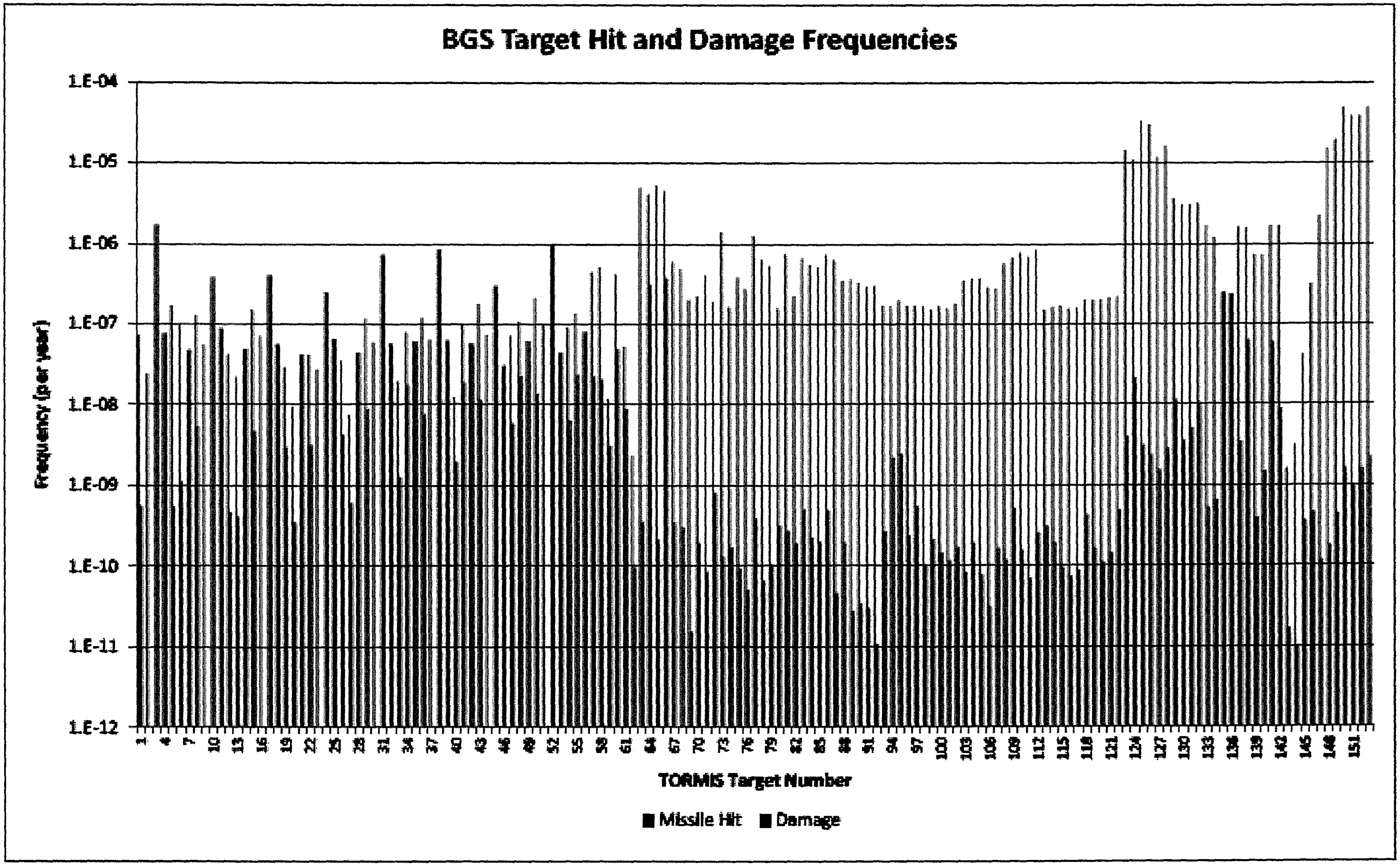


Figure 4
Target Group Hit and Damage Frequencies

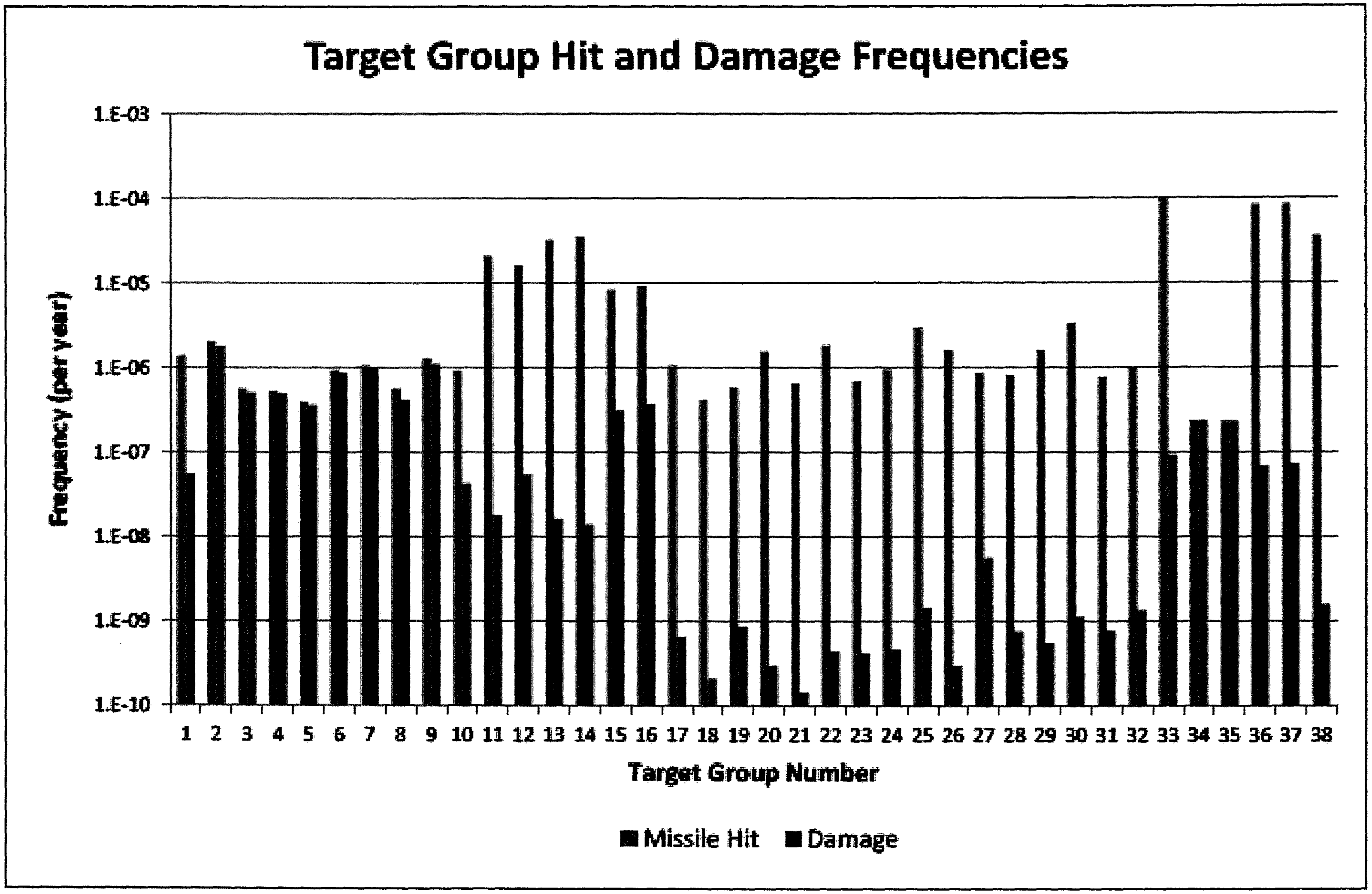
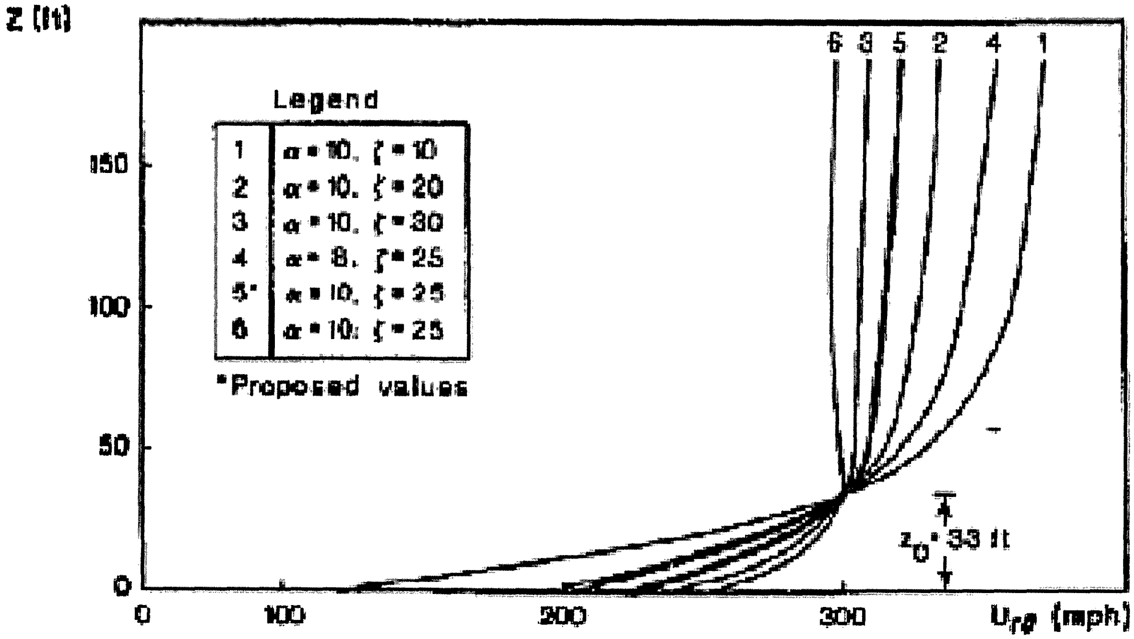
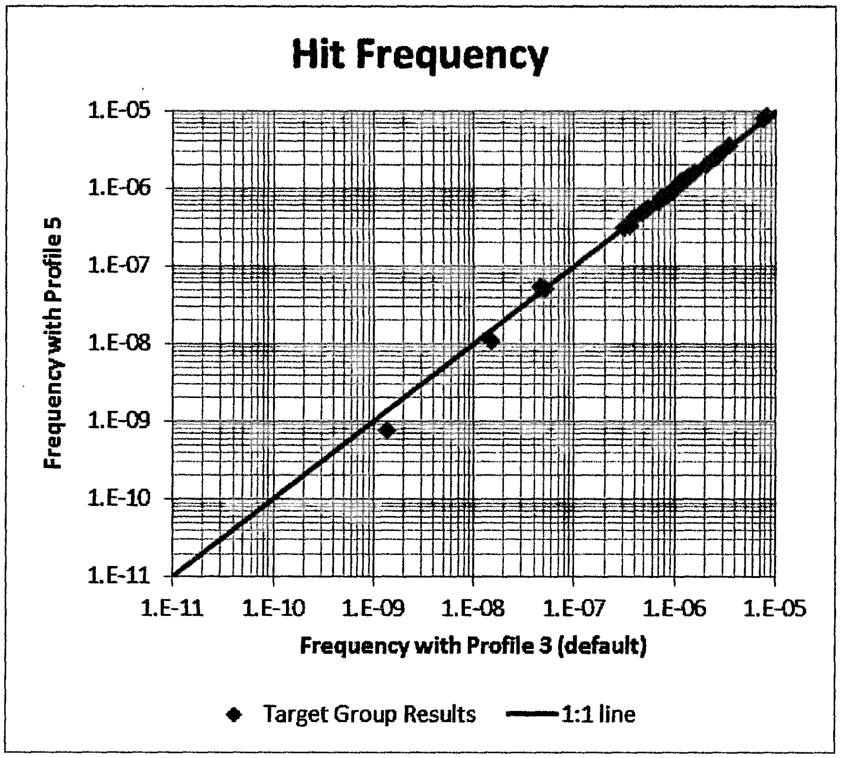


Figure 5
Tornado Rotational Wind Velocity Profiles



(b) Rotational Velocity

Figure 6
Plot of Frequencies with Profile 5 versus Profile 3



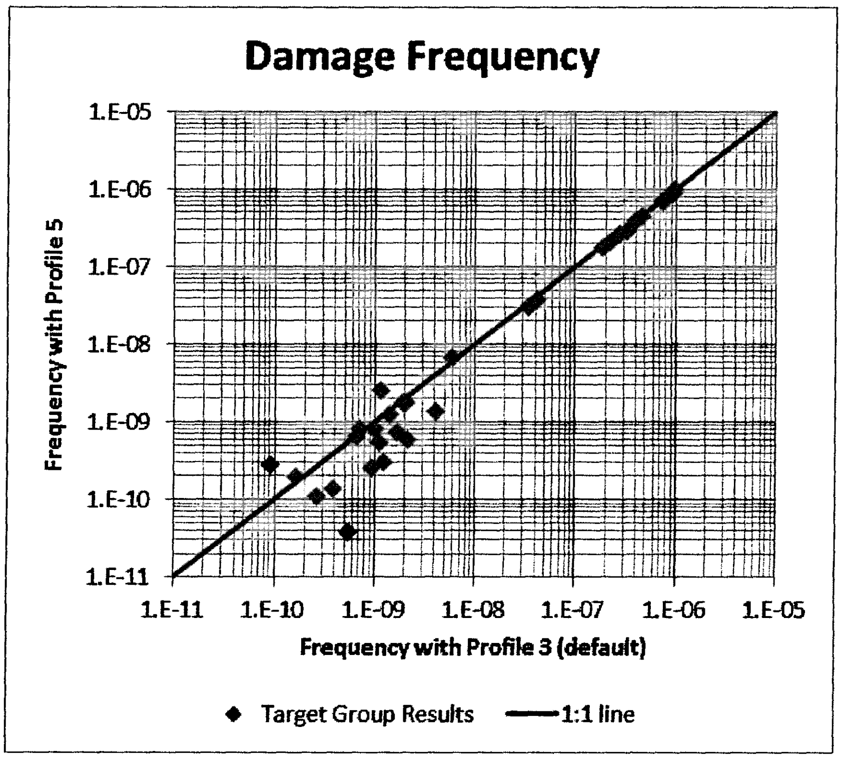


Figure 7
Zone Layout for Byron Station TORMIS Analysis

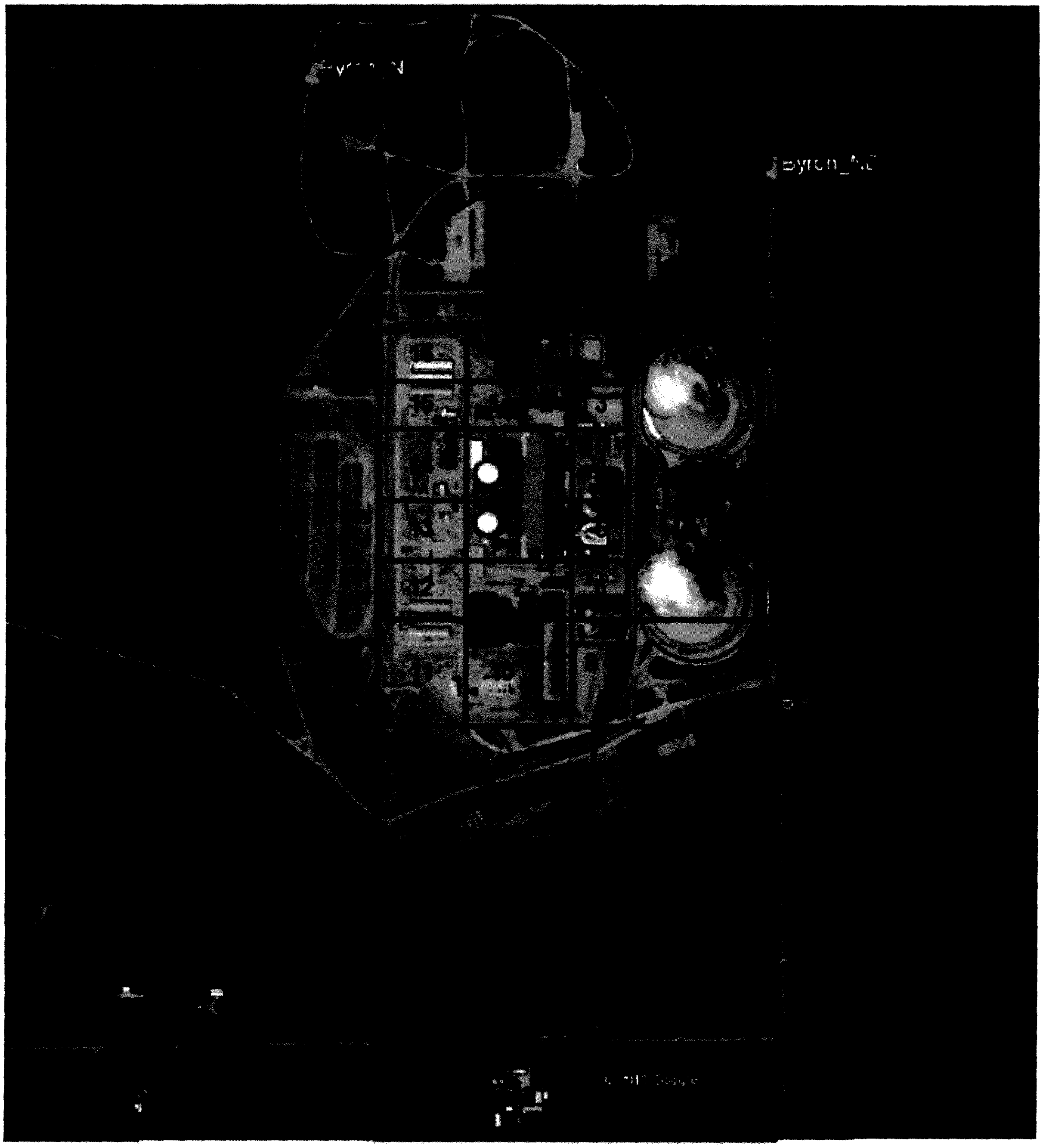


Figure 8
TORMIS Simulation of Byron Station Tornado Hazard for Plant Safety Envelope

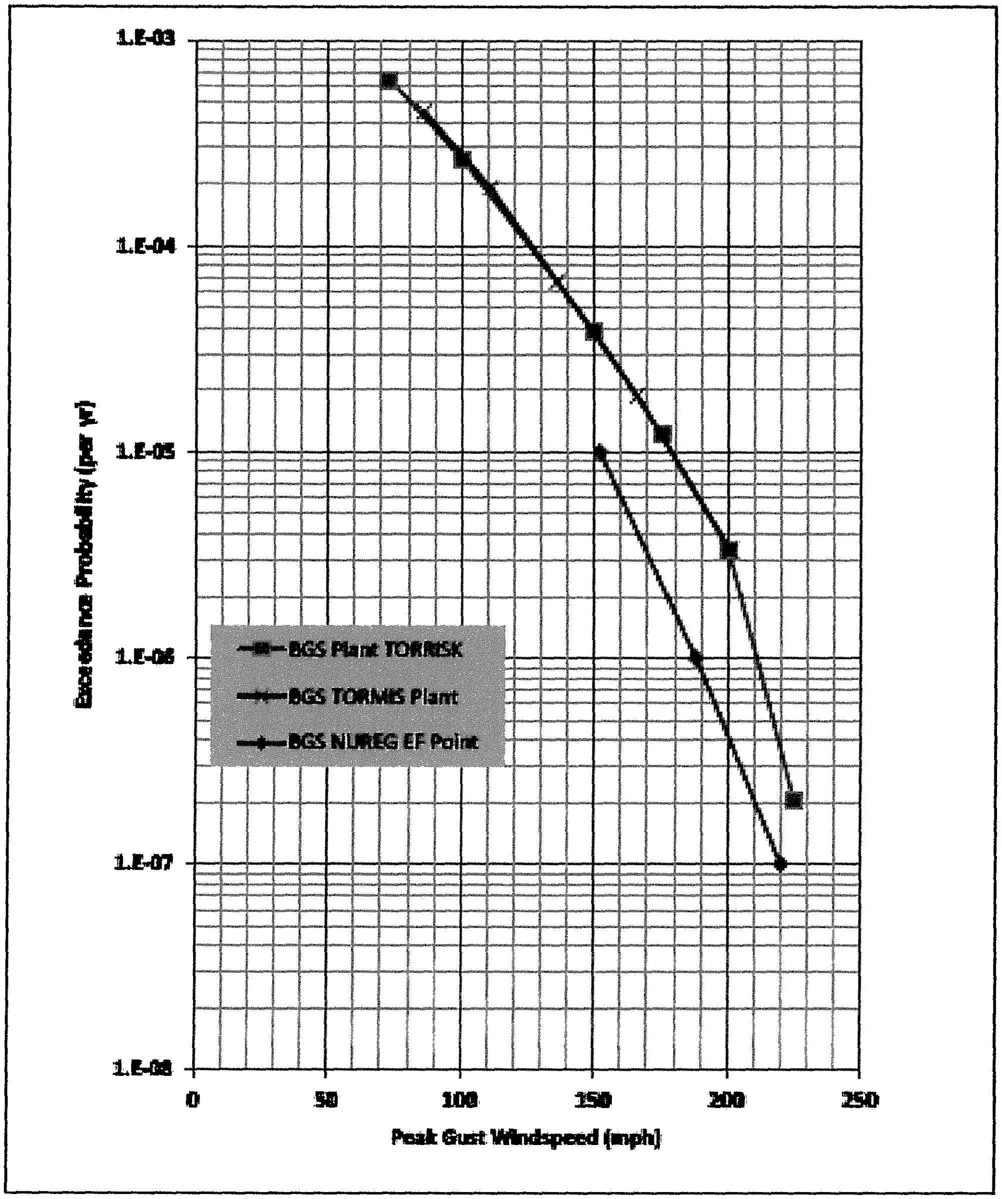
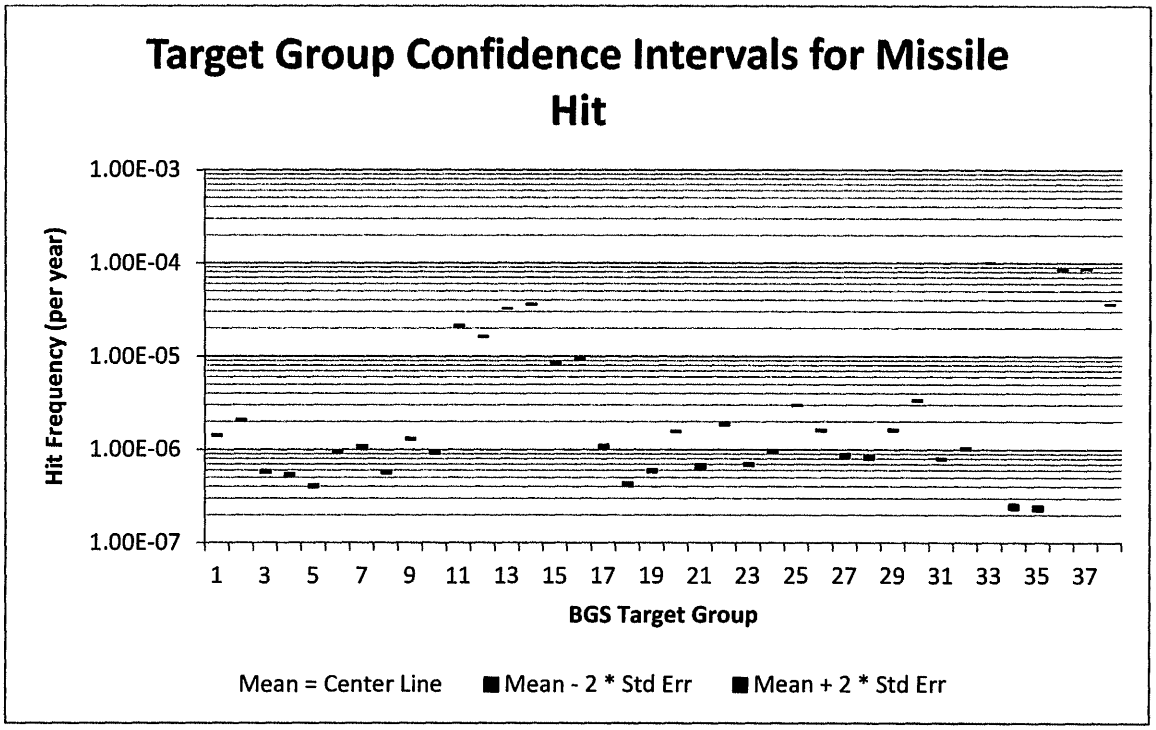


Figure 9
Target Group Hit and Damage Frequency with Confidence Intervals



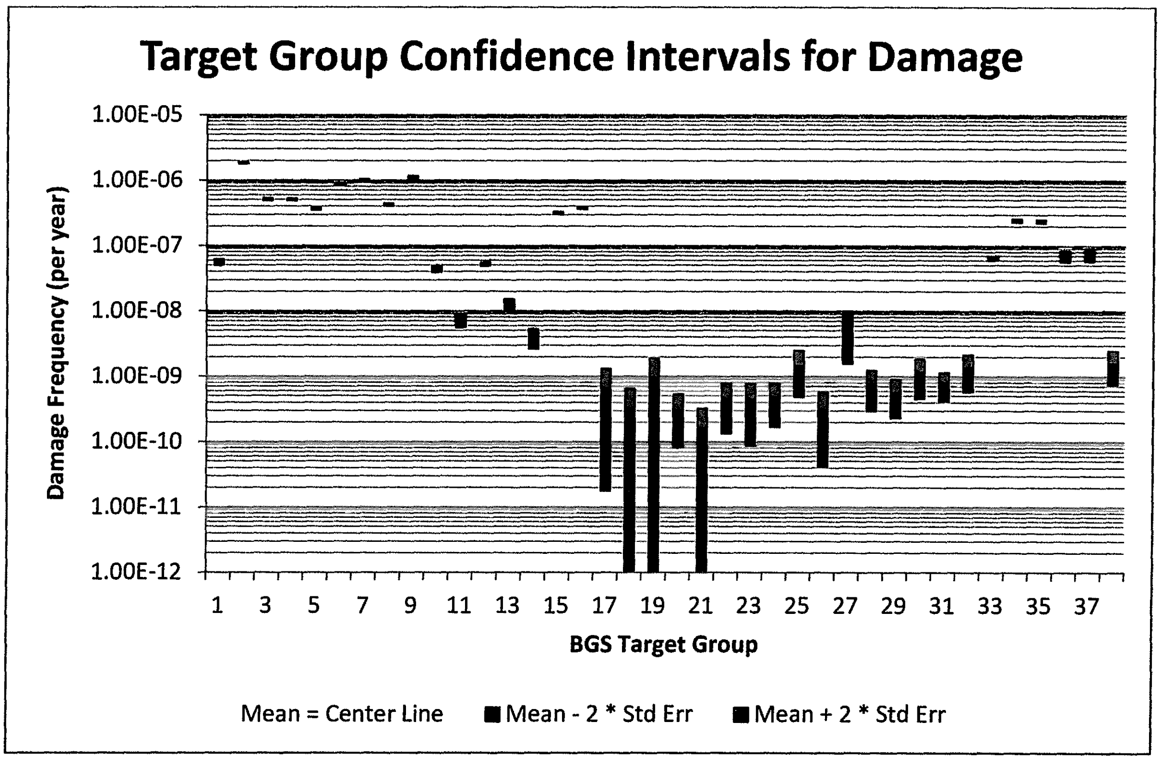
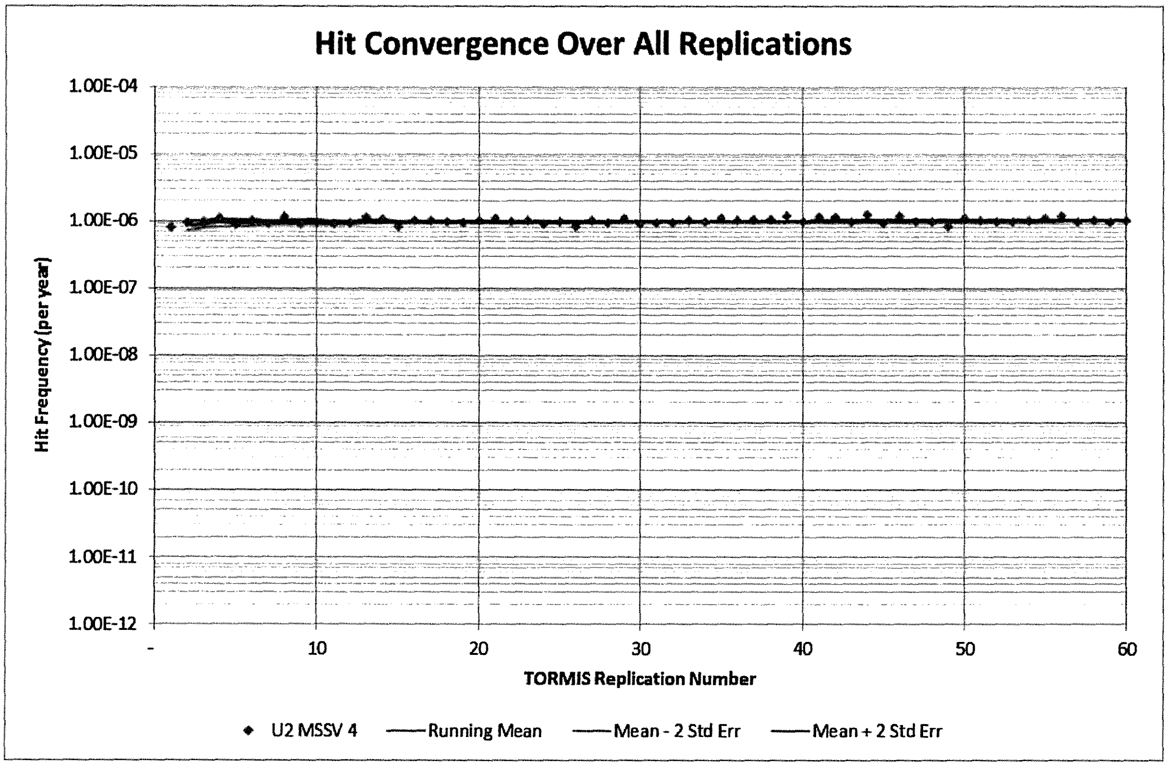
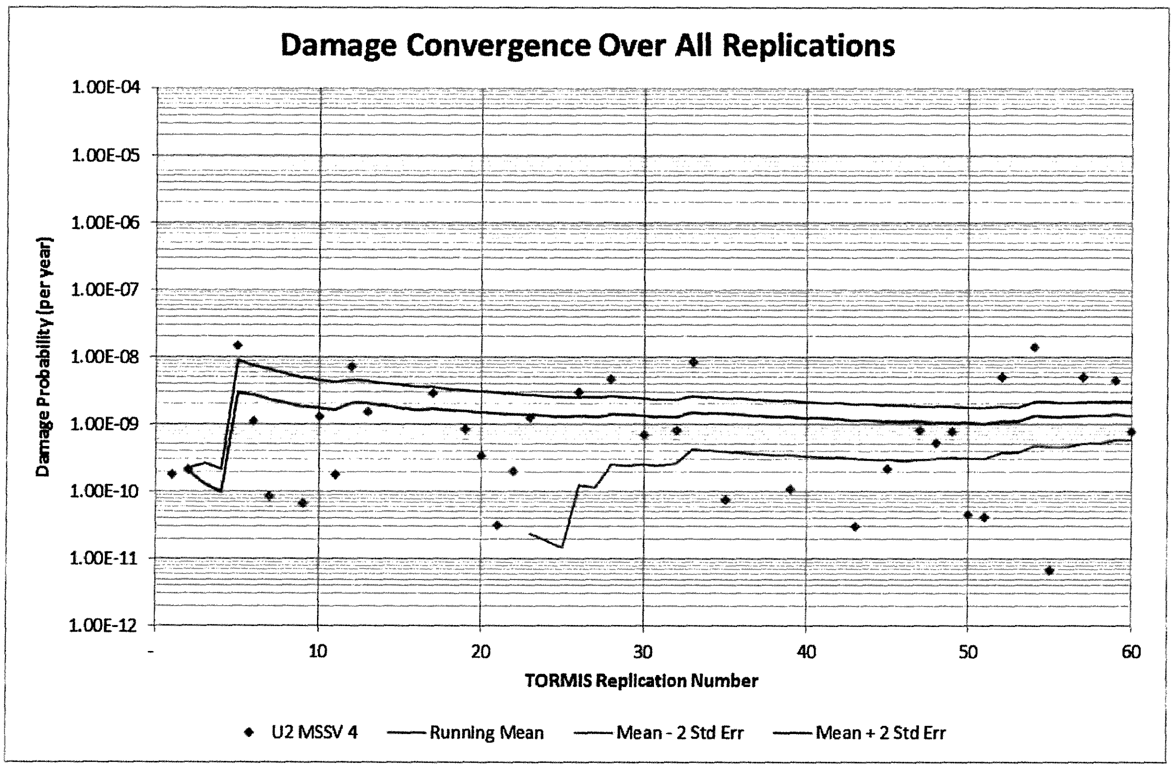


Figure 10
Convergence Plot for Damage Frequency for Target Group 32 (U2 MSSV 4)





ATTACHMENT 1-3

Draft Markup of Updated Final Safety Analysis Report Pages

BYRON STATION
UNITS 1 AND 2

Docket Nos. 50-454 and 50-455

Renewed Facility Operating License Nos. NPF-37 and NPF-66

REVISED UFSAR PAGES

3.3-1 through 3.3-5
3.5-11
3.5-21 through 3.5-28
3.5-33
3.5-34
3.5-48
3.5-49

3.3 WIND AND TORNADO LOADINGS

3.3.1 Wind Loadings

3.3.1.1 Design Wind Velocity

A design wind velocity of 85 mph, based upon a 100-year mean recurrence interval, is used in the design of Seismic Category I structures.

For Category II structures a design wind velocity of 75 mph is used, based upon a 50-year mean recurrence interval.

The vertical velocity distribution and gust factors employed for the wind velocities are based on Table 5 of Reference 1 for exposure Type C.

3.3.1.2 Determination of Applied Forces

The dynamic wind pressures are converted to an equivalent static force by considering appropriate pressure coefficients. The applied forces were derived in accordance with the provisions of Table 7, Reference 1, using external pressure coefficients, Cp of 0.8 and -0.5 for windward and leeward walls respectively, and -0.7 for side walls and roofs.

For structural shapes other than rectangular appropriate pressure coefficients are used in accordance with Reference 2.

3.3.2 Tornado Loadings

3.3.2.1 Applicable Design Parameters

The following are the parameters for the design-basis tornado (Reference 3):

Tangential velocity: 290 mph

Translational velocity: 70 mph

Radius of maximum rotational velocity from center of tornado: 150 feet

Pressure drop at the center of vortex: 3 psi

Rate of pressure drop: 2 psi/sec.

~~The characteristics and spectrum of tornado-generated missiles are found in Subsection 3.5.1.4.~~

The tornado parameters used in the probabilistic tornado missile risk analysis (TORMIS) described in Byron only Section 3.5.5 are found in Reference 5.

Load Factor

Since the postulated tornado loading is an extreme environmental

condition with a very low probability of occurrence, a load factor of 1.0 is used.

3.3.2.2 Determination of Forces on Structures

The Category I structures which have wind tornado loads, design-basis tornado generated missiles, and/or combination of these loads addressed in their design are as follows:

a. containment building,

b. auxiliary building,

c. fuel handling building,

d. main steam tunnel,

e. auxiliary feedwater tunnel,

f. essential service water cooling tower (Byron),

g. essential cooling pond (Braidwood),

h. deep well enclosures (Byron),

i. lake screen house substructure (Braidwood),

j. isolation valve room, and

k. essential service water discharge (Braidwood).

Several individual essential service water cooling tower components (Byron) not fully protected from tornado generated missiles are addressed in the probabilistic tornado missile risk analysis (TORMIS) described in Byron only Section 3.5.5.

3.3.2.2.1 Transformation of Tornado Winds Into Effective Pressure

All tornado wind pressure and differential pressure effects are considered as static loads since the natural period of building structures and their exposed structural elements is very short compared to the rate of variation of the applied loads.

The effects of the design-basis tornado are translated into forces on structures with the use of a tornado model (Reference 4) that incorporates parameters defined in Subsection 3.3.2.1.

The tornado model considers a velocity distribution based on the following equations:

$$v(r) = V_c \frac{r}{R_c} + V_t, \text{ for } \frac{r}{R_c} \leq 1 \quad (3.3\text{-}1)$$

$$v(r) = V_c \frac{R_c}{r} + V_t, \text{ for } \frac{r}{R_c} \geq 1 \quad (3.3\text{-}2)$$

where:

$v(r)$ = wind velocity at radius r,

r = distance from the center of the tornado,

V_c = maximum tangential velocity,

R_c = distance from the center of the tornado, to the locus of the maximum wind velocity, and

V_t = translational velocity.

The distribution of the pressure drop with the radius from the tornado is as follows:

$$p(r) = 3.0\,[1 - 0.5\,(r/R_c)^2],\ \text{for } \frac{r}{R_c} < 1 \qquad (3.3\text{-}3)$$

$$p(r) = 1.5\,(R_c/r)^2,\ \text{for } \frac{r}{R_c} \geq 1 \qquad (3.3\text{-}4)$$

where:

$p(r)$ = pressure drop in psi.

The tornado velocity is converted into an equivalent static pressure using equations given in ANSI A–58.1-1972 (Reference 1). Neither a "gust factor" nor any change in velocity with height is considered. Figure 3.3-1 shows the variation in wind velocity and differential pressure as per Equations 3.3-1, 3.3-2, 3.3-3, and 3.3-4. Figure 3.3-2 shows the windward and leeward wind pressure components of the tornado.

The load combination equation used for tornado load and tornado generated missiles is W_t = 448 psf + W_m. Figure 3.3-3 shows the resulting surface pressure when the effect of tornado wind and pressure drop components are added together.

The load combination equations as per SRP Section 3.3.2 using load parameters of UFSAR Section 3.3 are as follows:

1. $W_t = W_w$ i.e., W_t = 265 psf
2. $W_t = W_p$ i.e., W_t = 432 psf
3. $W_t = W_p = W_m$
4. $W_t = W_w + .5\ W_p$ i.e., W_t = 340.1 psf

5. $W_t = W_w + W_m$ i.e., $W_t = 265$ psf + W_m

6. $W_t = W_w + .5\ W_p + W_m$ i.e., $W_t = 340.1$ psf + W_m.

The equation ($W_t = 448$ psf + W_m) used in design is more conservative than the SRP equations above.

3.3.2.2.2 Venting of the Structure

Venting of concrete structures is not relied upon to reduce the differential pressure loadings. However, all siding and roof decking of the Turbine Building above the floor at elevation 451 feet 0 inch is designed and detailed to blow off at tornado pressures exceeding 105 psf. Above this pressure only bare framework is considered to be exposed to design-basis tornado loads.

3.3.2.2.3 Tornado Generated Missiles

The characteristics and spectrum of tornado generated missiles for the design-basis tornado are found in Subsection 3.5.1.4. The characteristics and spectrum of tornado generated missiles considered in the probabilistic tornado missile risk analysis (TORMIS) described in Byron only Section 3.5.5 are found in Reference 5. The procedures used for designing for the impactive dynamic effects of a point load resulting from tornado generated missiles are found in Subsection 3.5.3.

3.3.2.2.4 Tornado Loading Combinations

Refer to Tables 3.8-3 through 3.8-9 for the load factors and load combinations associated with tornado loading. In designing for the postulated design-basis tornado, the structure in consideration is placed in various locations of the pressure field to determine the maximum critical effects of shear, overturning moment, and torsional moment on the structure.

3.3.2.3 Effect of Failure of Structures or Components Not Designed for Tornado Loadings

All non-safety-related structures which are connected to safety-related structures are designed to prevent collapse under the design tornado loading. The only exceptions are the fuel handling building train shed, the Essential Service Water Cooling Tower Security Booth Tower Walkway (applicable to Byron only) and Walkway Access Stair Tower (applicable to Byron only) and the equipment staging structures installed adjacent to the emergency hatches. The collapse of these structures under tornado loading does not affect the structural integrity of any safety-related structures.

All other non-safety-related structures are separated from safety-related structures by a distance exceeding the height of the non-safety-related structure. This ensures that the failure of non-safety-related structures will not affect safety-related structures. Missiles generated by the collapse of non-safety-

related structures were evaluated to be less critical than those considered in Subsection 3.5.1.4. or were evaluated in Byron only Section 3.5.5.

3.3.3 References

1. ANSI A58.1-1972, "Building Code Requirements for Minimum Design Loads in Buildings and oOther Structures," American National Standards Institute, Inc., New York, New York.ANSI A 58.1-1972.

2. "Task Committee on Wind Forces, Committee on Loads and Stresses, Wind Forces on Structures, Final Report," Paper No. 3269, Transactions, ASCE, Vol. 26.rg 1961.

3. USNRC Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plant," April 1974.

4. J. D. Stevenson, "Tornado Design of Class I Structures for Nuclear Power Plants," Proceedings of Symposium on Structural Design of Nuclear Power Plant Facilities, University of Pittsburgh, December 1972.

5. Design Analysis ARA-002116, "Tornado Missile TORMIS Analysis of [Byron Generating Station] BGS," Revision 3.

the piping pressure element assemblies are less severe than those of Table 3.5-2b.

The missile characteristics of the reactor coolant pump temperature sensor, the instrumentation well of the pressurizer, and the pressurizer heaters are given in Table 3.5-2c. A 10 degree expansion half angle water jet has been assumed.

3.5.1.3 Turbine Missiles

The turbine-generators at the Byron/Braidwood Stations are manufactured by the Westinghouse Electric Corporation. Each unit consists of four double-flow turbine cylinders: one high pressure, and three low pressure. The low pressure stages employ 40-inch last row blades. The rated speed of the turbine-generator is 1800 rpm.

The current approach to evaluating turbine missile protection focuses on the probability of turbine failure resulting in the ejection of turbine disc (or internal structure) fragments through the turbine casing (P_1). A risk assessment will be performed each refueling outage to ensure that the probability of a turbine missile, P_1, remains at an acceptably low value. Based on this low probability, the turbine missile hazard is not considered a design-basis event for these stations. The details of the approach to ensure turbine missile protection are provided in Section 10.2.3.

For details on turbine overspeed protection, valve testing, and turbine characteristics, refer to Subsection 10.2.2.

3.5.1.4 Missiles Generated By Natural Phenomena

Tornadoes are the only natural phenomenon occurring in the vicinity of the Byron/Braidwood Stations that can generate missiles. The characteristics of postulated design-basis tornado-generated missiles are given in Table 3.5-3. The impact velocities of these missiles resulting from the design-basis tornado (Subsection 3.3.2) are shown in Table 3.5-4. Missiles A, B, C, D, and E are considered at all elevations, and missiles F and G are postulated at elevations up to 30 feet above grade level. These missiles are assumed to be capable of striking in all directions.

The characteristics of tornado-generated missiles considered in the probabilistic tornado missile risk analysis (TORMIS) described in Byron only Section 3.5.5 are found in Reference 15.

3.5.2 Systems to be Protected

All systems and equipment which may require protection are listed in Table 3.2-1. Onsite storage locations for compressed gases are provided in Table 3.5-10. Table 15.1-2 must be evaluated for protection against missiles postulated in Section 3.5.

The following safety-related components are located outdoors, away from the main building complex, installed above grade and have missile protection to the extent indicated:

Byron Station

a. At the river screen house, the essential service water makeup pumps, and associated diesel-engine drives and fuel oil storage tanks are installed at elevation 702 feet 0 inch. The building does not protect the components from tornado missiles. Refer to Subsection 9.2.5.2 and Drawing M-20.

b. The mechanical draft fans and their respective electric motor drives are located at the essential service water cooling towers (SXCTs) (refer to Drawings NCT-683-4H and -14H). The fans and motors are not fully protected from ~~vertical or near vertical~~ missiles and are evaluated in Section 3.5.5. A combination of TORMIS analysis and t~~T~~ornado protection was used ~~has been provided~~ for the exposed supply piping to the SXCTs.

c. The outside air intake openings for the SXCT~~Essential Service Water Cooling Tower~~ ESF Switchgear rooms are not protected from a tornado missile and are evaluated in Section 3.5.5.

d. The onsite wells and pumps at Byron, although not safety-related, are each protected by missile-proof walls and roofs. The onsite wells supply makeup water to the ~~essential service water cooling towers~~ SXCTs in the event that a tornado missile renders the essential service water makeup pumps inoperative. Missile protected check valves (0SX284A/B) are installed in the essential service water makeup lines to prevent back flow from the SXCT basins to the river screen house.

Braidwood

There are no safety-related components located outdoors at Braidwood Station.

All safety-related electrical components which are located outdoors are listed in Subsection 8.3.1.4.4 (Class 1E Equipment in Remote Structures). Safety-related electrical cables are adequately protected against tornado-generated missiles by the reinforced concrete ducts around them. Embedded conduits in the auxiliary building south wall and associated cable vaults

supporting operation of the SXCTs and deep well pumps at Byron are evaluated in Byron only Section 3.5.5.

All Category I buried pipes on Byron/Braidwood sites and the Category II (Non-Safety Related) Well Water (WW) piping from the onsite wells and pumps to the SXCTsessential service water cooling towers at Byron have adequate soil cover for protection from tornado-generated missiles. These pipes are buried to depths greater than the

required minimum depth of 4 feet 1 inch, determined using Young's method.

Safety-related HVAC system air intakes and exhausts are indicated on the plant arrangement Drawings M-5, M-6, M-14, M-15 and M-22-2.

Auxiliary Building and Containment Purge (VA, VQ)

Intakes

Intake louvers are shown as listed above. Protection is provided by missile walls.

Exhaust

The exhaust stacks are shown as listed above. Vertical stack connected to horizontal exhaust tunnel affords missile protection.

Diesel-Generator Room Intake (VD)

The diesel-generator room intake is shown as listed above. Protection is provided by missile walls.

~~Safety-related electrical cables are adequately protected against tornado-generated missiles by the reinforced concrete ducts around them.~~

Control Room Intake (VC)

The control room outside air intake is shown as listed above. Protection is provided by missile walls. The Byron control room turbine building makeup air intakes are evaluated in Byron only Section 3.5.5.

3.5.3 Barrier Design Procedures

Two types of structural response to missile impact have been investigated for the design-basis tornado-generated missiles in Section 3.5.1.4:

a. local effect in the impacted area which includes estimation of the depth of penetration and, in the case of concrete barriers, the potential for secondary missiles by spalling or scabbing; and

b. overall response of the barrier which includes the calculation of deflection due to missile impact.

The design-basis tornado-generated missile velocities presented in Table 3.5-4 are based on TVA Topical Report TVA-TR74-1. Commonwealth Edison committed to design to these velocities during the PSAR review. The staff had accepted these velocities as indicated in Revision 0 of the Standard Review Plan 3.5.1.4.

Draft Rev. 1 of SRP 3.5.1.4 states: "At the operating license

stage, applicants who were not required at the construction

permit stage to design to the missile spectrum of Rev. 0 of this SRP and the corresponding velocity set, should show the capability of the existing structures and components to withstand at least missiles C and F of the Rev. 0 to this SRP." It can be noted from Table 3.5-4 that the horizontal velocity of the missile F, utility pole - used in the Byron/Braidwood design is larger than the velocity of 211 fps (i.e., 0.4 times the total tornado velocity) specified in Revision 0 missile spectrum. The velocity for the steel rod is however lower than the Revision 0 spectrum velocity of 317 fps.

The walls and roofs of structures protecting the safety-related systems and components from design-basis tornado-generated missiles are of reinforced concrete with minimum thickness of 2~~4~~0 and 14 inches respectively. The concrete used has a minimum cylinder strength of 3500 psi at 91 days.

The roof and wall thickness required to prevent back-face scabbing as a result of impact from the steel rod missile have been calculated using the modified National Defense Research council formula as 5.5 and 6.5 inches respectively. Since the minimum barrier thicknesses provided at Byron/Braidwood are much larger than the above values, it is concluded that the plant structures, systems and components are adequately protected against the Revision 0 spectrum of design-basis tornado-generated missiles.

Generally, all missiles (internal or external) are considered as impacting instantaneously with a very short rise time relative to the natural period of the impacting structure. Types of barriers designed to resist missile impact are:

a. Reinforced Concrete Barriers - The depth of penetration into a concrete barrier is calculated using the modified Petry equation (Reference 6). Concrete barriers are designed such that the missile penetrates no more than two-thirds of the thickness of the barrier thus preventing spalling or scabbing (Reference 6). The overall deformation of the panel is investigated using methods presented in Reference 7. Reference 7 presents an equation of motion which enables one to calculate an impact force time-history consistent with the calculated penetration depth. To establish the capacity of the barrier to absorb energy, the deflection due to static loads are first calculated, then the deflection due to missile impact is determined by integrating the equation of motion or by using a simplified expression adopted from the equation of motion. This is compared with the maximum allowable deflection (or allowable ductility ratio), in accordance with ACI-349 (Reference 10).

   The design of concrete members under impactive loads from design-basis tornado missiles is in compliance with Appendix A to SRP Section 3.5.3. Those members which see

impactive and impulsive loads due to pipe breaks have been designed using a nonlinear analysis assuming hinge rotations not exceeding 0.07 radians. The experimental data on which this method is based is in Reference 13 (a PCA Bulletin).

b. Steel Plate Barriers - The thickness of steel plate required to resist the impacting design-basis missile is calculated using the Stanford Formula (Reference 8). The overall structural response, including structural stability and deformation is investigated using concepts and methods presented in Reference 9.

c. Control Rod Drive Missile Shield - A missile shield structure is provided over the control rod drive mechanisms to block missiles which might be associated with a fracture of the pressure housing of any mechanism. This missile shield is a reinforced steel structure attached to the reactor vessel head and located above the CRDMs. Each CRDM housing is terminated with a small tapered pin which penetrated the missile shield through a slightly larger diameter hole to direct the ejected CRDM missile into the shield. This prevents any missile from missing or ricocheting from the shield to strike the containment liner or other CRDM housings.

   The walls of the refueling cavity protect the CRDMs from missiles originating from the horizontal direction.

   Missile shield penetrations are given in Table 3.5-1 using the Ballistic Research Laboratories (BRL) formula for steel. The steel missile shield has an effective thickness of approximately 3 inches.

   For the case of housing plug and drive shaft impact, which is the design case, it is assumed that the plug partially perforates the missile shield. The drive shaft then hits the plug and further penetrates the steel missile shield. The resultant penetration into the shield is 0.773 inches. Therefore, the effective thickness of the steel missile shield is more than three times the combined penetration value for the design case.

   The CRDM missile shield is also designed to withstand the dynamic impact loads due to the missile and the water jet.

It is to be noted that the location of the secondary shield wall inside the containment structure is such that no potential missile will strike the containment liner.

3.5.4 Analysis of Missiles Generated by a Tornado

Effects of tornado missiles have been assessed for safety-related components located outdoors. These components are the SXCTsessential service water cooling towers (Byron only), the emergency diesel generator exhaust stacks, the emergency diesel generator ventilatingon and combustion air intakes, the emergency diesel generator crankcase vents, the fuel handling building door, and the main steam safety and power operated relief valve stacks tailpipes (Braidwood only).

3.5.4.1 Essential Service Water Cooling Towers (Byron)

The following components of the essential service water cooling towers are unprotected from tornado missiles:

a. fans,

b. fan motors,

c. fan drives, and

d. ESF switchgear room outside air intake openings.

An analysis of the UHS cooling capability for a tornado missile event has been made. The analysis was performed using service water cooling tower performance curves generated using the method described in UFSAR Section 9.2.5.3.1.1.2 and the time dependent two cooling tower model described in UFSAR Section 9.2.5.3.1.1.3. The following inputs and assumptions were used in the analysis:

a. A single tornado generated missile is assumed to disable two essential service water cooling tower (SXCT) fans. Concurrent with the missile impact, a LOOP and an electrical failure is assumed to occur that results in the loss of power to two additional SXCT fans. Additionally up to two SXCT fans are assumed to be initially out of service.

b. A maximum outside air wet bulb temperature of 78°F is assumed and is conservatively held constant throughout the transient.

c. The analysis assumes operator action will be taken to delay RH initiation until an adequate number of SXCT fans are available for shutdown cooling. Additionally, RH initiation for the two units may need to be staggered so RH cool down is not occurring simultaneously for both units and operator action may be needed to control the cool down rate. The RH initiation delay time and the cool down rate are dependent on the number of SXCT fans available and the outside air wet bulb temperature. For the worst case design conditions the first unit is assumed to be placed on RH cooling 24 hours after the event and the second unit at 30 hours after the event.

d. For failed fans that have open riser valves, the SXCT cells operating in the natural draft mode are assumed to

~~provide 10 percent of the heat removal of a cell with the fan running in high speed.~~

~~The calculated maximum temperature of the service water supplied to the plant is less than 110°F. Although this exceeds the normal maximum temperature of 100°F, no adverse impact on safety equipment will result.~~

~~The Essential Service Water Cooling Tower (SXCT) ESF Switchgear rooms are orientated such that a single tornado missile strike on the UHS would only impact the air intake of one of the rooms. Based on the physical layout of the intake opening a tornado missile could potentially damage the air intake control damper and cause a loss of function of the SXCT switchgear room ventilation system for one switchgear room. With a loss of ventilation the switchgear room temperature could exceed the normal room design temperature. Analysis of the room heat-up event determined that the room temperature remains below the thermal endurance limit of the safety related electrical equipment in the room for at least 2 hours. This provides time for operator action to mitigate the room heat-up event. If the electrical equipment in one of the SXCT switchgear rooms fails, the electrical equipment in the remaining three switchgear rooms will support the operation of the redundant equipment needed for safe shutdown.~~

~~Tornado protection has been provided for the exposed supply piping to the cooling towers.~~

A temperature and inventory analysis of the UHS after the loss of SXCT fans due to tornado-generated missiles was performed. The analysis also considers out of service fans and postulated single failures. The number of fans lost due to tornado missiles is based on the results of the TORMIS analysis described in Section 3.5.5.

The analysis was performed using SXCT performance curves generated using the method described in Section 9.2.5.3.1.1.2. Various outside air wet bulb temperatures were considered in the analysis. The results of the analysis are used to establish operating limits on the number of SXCT fans required to be operable based on the outside air wet bulb temperature and number of units operating. The analysis credits the following operator actions:

a. Manual initiation of the deep well pump(s) is assumed to occur 1.5 hours into the event,

b. Isolation of essential service water blowdown within two hours,

c. Isolation of the auxiliary feedwater telltale drains within two hours, and

d. Isolation of the SXCT riser leakoff drains within two hours

The analyses determined the SXCTs are capable of providing

adequate heat removal and timely safe shutdown of both units.

3.5.4.2 Emergency Diesel Generator Exhaust Stacks

The diesel generator exhausts are completely protected up to the point where they penetrate the tornado proof concrete enclosure on the auxiliary building roof. Above this point, they are exposed for about 35 feet as they travel vertically. ~~Analysis has established that the stacks can be damaged to the extent that the flow area is reduced to 50% of the original flow area without reducing the diesel power output.~~

To prevent loss of diesel availability due to the exhaust stack damage, a rupture disc pressure relief device is installed on each diesel exhaust line. This relief device is located downstream of the silencer and inside the missile protection structure on the roof of the auxiliary building. Upon blockage of the stack, the rupture disc will open prior to backpressure increasing to the point that required diesel power is not available. The emergency diesel generators will therefore remain functional following any postulated tornado missile impact.

3.5.4.3 Emergency Diesel Generator Ventilation and Combustion Air Intakes and Crankcase Vents

Ventilation and combustion air for the emergency diesels is inducted through tornado proof intakes in the auxiliary building roof. The emergency diesel engine crankcase vents are exposed to tornado missiles. Reference 14 demonstrates that the crankcase vent lines can be blocked without adversely affecting the ability of the associated diesel to perform its design function.

~~3.5.4.4 Fuel Handling Building Railroad Freight Door~~

~~The railroad freight door is not designed to be tornado proof. In the event the door is missing or open, missiles would potentially enter the tunnel to the fuel handling building. To reach the fuel handling area, missiles would have to travel over 100 feet down the tunnel which is approximately 25 feet square. The two most vulnerable areas are the fuel pool heat exchangers on the lower level and fuel storage area on the upper level. After negotiating the tunnel, the missile would have to make a 90 degree turn and penetrate a wall to damage either of the heat exchangers (which are redundant) or make two 90 degree turns (up and right) to reach the fuel storage area. Based on this assessment, it is concluded that tornado missiles pose no hazard to the fuel handling building.~~

3.5.4.~~5~~4 Main Steam Safety and Power Operated Relief Valve ~~Stacks~~ Tailpipes (Braidwood only)

The Braidwood Unit 2 main steam safety and relief valve ~~stacks~~ tailpipes penetrate the valve room roof slightly over 25 feet above grade. The ~~stacks~~ tailpipes extend 7 feet above the roof. The exhaust of the power operated relief valve is in a recessed area between the valve room roof and the containment wall, and is, therefore, protected from horizontal missiles. The ~~stacks~~ tailpipes are 16 inch diameter pipe with 1/2 inch thick walls. All are located near the containment. Bending or breaking of the pipe would not seriously affect the function of the safety and relief valves. Because of the relatively short height of the pipes and the thickness of the walls, no significant denting or crimping of the pipes is expected.

~~For~~ The Braidwood Unit 1 ~~and Byron Units 1 and 2, the~~ main steam safety valve 16 inch diameter 1/2 inch thick ~~vent pipes~~tailpipes extend approximately 1 foot above the MSSV roof and a maximum of 1.5 inches above a guard pipe. The guard pipe is a 20 inch diameter, 1/2 inch thick pipe. The combination of a short height above the roof and the installed guard pipe practically eliminates the possibility of a horizontal missile denting or crimping the MSSV ~~vent pipes~~tailpipes. The exhaust of the power operated relief valve is in a recessed area between the valve room upper roof and the containment wall, and is, therefore, protected from horizontal missiles.

The Byron main steam safety and power operated relief valve

tailpipes are evaluated in Byron only Section 3.5.5.

3.5.4.5 Fuel Handling Building Railroad Freight Door

The non-safety related railroad freight door is not designed to be tornado proof. In the event the door is missing or open, missiles would potentially enter the tunnel to the fuel handling building. To reach the fuel handling area, missiles would have to travel over 100 feet down the tunnel which is approximately 25 feet square. The two most vulnerable areas are the fuel pool heat exchangers on the lower level and fuel storage area on the upper level. After negotiating the tunnel, the missile would have to make a 90 degree turn and penetrate a wall to damage either of the heat exchangers (which are redundant) or make two 90 degree turns (up and right) to reach the fuel storage area. Based on this assessment, it is concluded that tornado missiles pose no hazard to the fuel handling building.

3.5.4.6 Essential Service Water Discharge Extension Lines (Braidwood only)

The Non-Safety Related portions of the Essential Service Water (SX) discharge extension lines extend approximately 3 feet above lake level and they are attached to the safety related portion of the SX discharge piping at the discharge structure via a flanged connection. Analysis has demonstrated that the flange connection will fail and separate before the SX extension pipe stress reaches the yield stress of the pipe material, i.e. the extension pipe section will remain in the elastic behavior zone without plastic deformation due to a force generated by a horizontal missile. Therefore, the SX discharge flow path is not adversely impacted by a Tornado generated horizontal missile striking the exposed SX discharge extension lines.

3.5.5 Probabilistic Tornado Missile Risk Analysis

A probabilistic tornado missile risk analysis (Reference 15) was completed for Byron using the TORMIS computer code which is based on the NRC approved methodology detailed in References 16, 17 and 18. The TORMIS analysis was performed in accordance with the guidance described in the NRC TORMIS Safety Evaluation Report (Reference 19) and as clarified by Regulatory Issue Summary (RIS) 2008-14 (Reference 20).

3.5.5.1 Scope

The TORMIS analysis (Reference 15) includes plant components, identified as necessary to safely shutdown the plant and maintain a shutdown condition, located in areas not fully protected by missile barriers designed to resist impact from design-basis tornado missiles. The targets included in the TORMIS analysis are listed in Table 3.5-17 and additional details regarding targets (i.e., specific location and identification) are included in Reference 15, Volume 3.

3.5.5.2 Computer Codes

3.5.5.2.1 TORMIS

TORMIS (TORnado MISsile Risk Analysis Methodology Computer Code) uses a Monte Carlo simulation method that simulates tornado strikes on a plant. For each tornado strike, the tornado wind field is simulated, missiles are injected and flown, and missile impacts on structures and equipment are analyzed. These models are linked to form an integrated, time-history simulation methodology. By repeating these simulations, the frequencies of missiles impacting and damaging individual components (targets) and groups of targets are estimated. Statistical convergence of the results is achieved by performing multiple replications with different random number seeds.

3.5.5.2.2 TORRISK

TORRISK (TORnado RISK Analysis Methodology Computer Code) is a specialized version of TORMIS that produces tornado hazard curves distinct from the missile risk analysis features of TORMIS. TORRISK is a fast-running version of TORMIS and was spun-off in 1983 specifically for the purpose of tornado wind probability analysis for the different types of geometrical targets, like points, buildings, sites and transmission lines. TORRISK uses the same tornado input data as TORMIS and produces tornado wind hazard risks only. TORRISK produces a more accurate wind hazard curve than TORMIS since it is not encumbered with all of the TORMIS missile simulation variance reduction methods.

3.5.5.2.3 TORSCR

TORSCR is a FORTRAN computer code that is used to post-process TORMIS output files. Its primary function is to compute Boolean combinations of target hit and damage probabilities over multiple targets.

3.5.5.2.4 LS-DYNA

LS-DYNA is a nonlinear explicit finite element code for the dynamic analysis of structures. Since 1987, the LS-DYNA code has been extensively developed and supported by the Livermore Software Technology Corporation and is used for a wide variety of crash, blast and impact applications. LS-DYNA was used to develop missile threshold damage velocities for selected targets which are used as an input in the TORMIS model.

3.5.5.3 Analysis

The Byron TORMIS tornado missile risk analysis results show that the arithmetic sum of damage frequencies for all target groups affecting the individual units (i.e., Unit 1 plus common components and Unit 2 plus common components) are lower than the acceptable threshold frequency of 1.0E-06 per year established in SRP Section 2.2.3 and Reference 21.

The following limiting inputs and assumptions were used in the analysis (refer to Reference 15 for additional assumptions and engineering judgments used in the analysis):

a. A site specific tornado hazard curve and data set for Byron was developed using statistical analysis of the NOAA/National Weather Service Storm Prediction Center tornado data for the years 1950 thru 2013.

b. The missile characteristics and locations are based on a plant walk down survey and plant drawings. The plant walk down survey was performed during a unit outage to capture both non-outage and outage conditions during the survey. A stochastic (time-dependent) model of the missile population is implemented in TORMIS. The stochastic approach to the missile population varies the missile populations in each of the TORMIS replications to account for predictable changes in plant conditions (i.e., increased missiles during outages) and the randomness inherent in the total number of missiles present at the plant at any given time.

c. Finite element calculations were performed to provide the missile damage threshold velocity for each missile type to cause unacceptable crimping damage for the SXCT riser pipes, diesel driven auxiliary feedwater pump exhaust pipes and cover plates and the main steam power operated relief valve tailpipes.

d. For the UHS, one or two SXCT cells are assumed to be randomly out of service for maintenance. A postulated single failure of an electrical bus is assumed resulting in the loss of power to two additional SXCT cells. For the TORMIS analysis, success is defined as at least 3 of the remaining 5 cells surviving when one cell is out of service or 2 of the remaining 4 cells surviving when two cells are out of service.

The arithmetic sum of damage frequencies for all target groups affecting the individual units would exceed the acceptance criteria of 1.0E-06 per year per unit. Boolean combinations of targets were developed to aid in summarizing the results and understanding the effects of system redundancies. This approach yielded acceptable results. Boolean Logic is applied to target groups to account for redundancy in the structural or system design or TORMIS modeling of a component as multiple targets. With redundancy in the design, the system function could be met even with one or more individual targets damaged by postulated tornado missiles. The logic is applied to each TORMIS simulated tornado to determine if the missile damage results in a loss of function of the target group.

There was a single change made to the TORMIS code of a purely "software" nature which was not related to the approved TORMIS physics engine and calculation approach; i.e., the dimensioned number of possible missile types was increased to 24 for evaluation of damage from missile velocity exceedance and pipe penetration pass through.

3.5.~~5~~6 References

1. J. M. Vallance, A Study of the Probability of an Aircraft Using Waukegan Memorial Airport Hitting the Zion Station, Pickard, Lowe and Associates, Inc., Washington, D.C., 1972.

2. Clair Billington, FAA, Telephone conversations with H. H. Hitzeman, Senior Engineering Analyst, Sargent & Lundy, August 5, 1977 and August 9, 1977.

3. John W. Ryan, FAA, Telephone conversation with H. H. Hitzeman, Senior Engineering Analyst, Sargent & Lundy, September 7, 1977.

4. Annual Review of Aircraft Accident Data - U.S. General Aviation - Calendar Year 1970. National Transportation Safety Board, Washington, D.C., Report Number NTSB-ARG-74-1, April 18, 1974.

5. Annual Review of Aircraft Accident Data - U.S. General Aviation - Calendar Year 1969, National Transportation Safety Board, Washington, D.C., Report Number NTSB-ARG-71-1, April 28, 1971.

6. A. Amirikian, "Design of Protective Structures," Bureau of Yards and Docks, Publication No. NAVDOCKS P-51, Department of the Navy, Washington, D.C., August 1950.

7. J. M. Doyle, H. J. Klein, and H. Shah, "Design of Missile Restraint Concrete Panels," Second International Conference on Structural Mechanical in Reactor Technology, Berlin, Germany, September 1973.

8. W. B. Cottrell and A. W. Savolainen, "U.S. Reactor Containment Technology," ORNL-NSIC-5, Vol. 1, Chapter 6, Oak Ridge National Laboratory, August 1965.

9. R. A. Williamson and R. R. Alvy, "Impact Effect of Fragments Striking Structural Elements," Holmes and Naver, Inc., Revised November 1973.

10. ACI 349, Code Requirements for Nuclear Safety Related Concrete Structures, 1976.

11. P. Gottlieb, "Estimation of Nuclear Power Plant Aircraft Hazards," Probabilistic Analysis of Nuclear Reactor Safety, Proceedings of the American Nuclear Society Topical Meeting (May 8-10, 1978, Los Angeles, California), p. VIII.8, 1 to 8.

12. "A Manual for the Prediction of Blast and Fragment Loadings On Structures," DOE/TIC-11268, U.S. Department of Energy, November 1980.

13. A. H. Motloch, "Rotational Capacity of Hinging Regions in Reinforced Concrete Beams," from Proceedings of the International Symposium on Flexural Mechanics of Reinforced Concrete, American Society of Civil Engineers, 1965.

14. Design Analysis 3101-0039-01, "Calculation of EDG (Emergency Diesel Generator) Crankcase Pressure Assuming the Crankcase Vent Line is Blocked."

15. Design Analysis ARA-002116, "Tornado Missile TORMIS Analysis of [Byron Generating Station] BGS," Revision 3.

16. Electric Power Research Institute Report - EPRI NP-768, "Tornado Missile Risk Analysis," May 1978.

17. Electric Power Research Institute Report - EPRI NP-769, "Tornado Missile Risk Analysis - Appendices," May 1978.

18. Electric Power Research Institute Report - EPRI NP-2005 Volumes 1 and 2, "Tornado Missile Risk Evaluation Methodology," August 1981.

19. NRC Safety Evaluation Report - "Electric Power Research Institute (EPRI) Topical Reports Concerning Tornado Missile Probabilistic Risk Assessment (PRA) Methodology," dated October 26, 1983 (ML080870291).

20. NRC Regulatory Issue Summary 2008-14, "Use of TORMIS Computer Code for Assessment of Tornado Missile Protection," dated June 16, 2008 (ML080230578).

21. Memorandum from Harold Denton, NRR Director to Victor Stello, Deputy Executive Director for Regional Operations and Generic Requirements, "Position of Use of Probabilistic Risk Assessment in Tornado Licensing Actions," dated November 7, 1983 (ML030020331).

TABLE 3.5-3

DESIGN-BASIS TORNADO-GENERATED MISSILES AND THEIR PROPERTIES

	MISSILE	WEIGHT (lb)	CROSS SECTION	LENGTH (ft)	HEAD ON CONTACT AREA (in^2)
A.	Wood	200	4 in. x 12 in.	12	48.00
B.	3-inch Schedule 40 steel pipe	78	3.5 in. OD	10	9.62
C.	Steel rod	8	1-in. diameter	3	0.79
D.	6-inch Schedule 40 steel pipe	285	6.625 in. OD	15	34.50
E.	12-inch Schedule 40 steel pipe	743	12.75 in. OD	15	127.70
F.	Utility pole	1,490	13.5 in. diameter	35	143.10
G.	Automobile	4,000	--	--	2,880.00

TABLE 3.5-4

IMPACT VELOCITIES OF DESIGN-BASIS TORNADO-GENERATED MISSILES

MISSILE	HORIZONTAL IMPACT VELOCITY* (fps)
A. Wood plank (4 in. x 12 in. x 12 ft, weight 200 lb)	368
B. Steel pipe (3 in. diameter, Schedule 40, 10 ft long, weight 78 lb)	268
C. Steel rod (1 in. diameter x 3 ft long, weight 8 lb)	259
D. Steel pipe (6 in. diameter, Schedule 40, 15 ft long, weight 285 lb)	230
E. Steel pipe (12 in. diameter, Schedule 40, 15 ft long, weight 743 lb)	205
F. Utility pole (13.5 in. diameter, 35 ft long, weight 1490 lb)	241
G. Automobile (frontal area 20 ft^2, weight 4000 lb)	100

* Vertical impact velocities are taken equal to 80% of the horizontal impact velocities.

TABLE 3.5-17

TARGETS EVALUATED IN TORMIS ANALYSIS

TARGET	NUMBER OF TARGETS	FAILURE MODE(S)	NOTES
SXCT Riser Pipes	8	Perforation and Crimping	SXCT Cells A-H
SXCT Fan Motors and Power Feeds	8	Missile Hit	SXCT Cells A-H
SXCT Fan Gear Box Oil Level Gauges	8	Missile Hit	SXCT Cells A-H
SXCT Personnel Hatches	8	Perforation	SXCT Cells A-H
SXCT Fan Inspection Hatches	8	Perforation	SXCT Cells A-H
SXCT Fan Blades	8	Missile Hit	SXCT Cells A-H
SXCT Anti-Vortex Boxes and Trash Screens	2	Perforation	North and South
SXCT Switchgear Room Ventilation Louvers	4	Perforation	Division 11 (Bus 131Z), 12 (Bus 132Z), 21 (Bus 231Z) and 22 (Bus 232Z)
Diesel Driven Auxiliary Feedwater Pump Exhaust Pipes	2	Crimping	Unit 1 and Unit 2
Diesel Driven Auxiliary Feedwater Pump Exhaust Cover Plates	2	Crimping	Unit 1 and Unit 2
Steam Generator Power Operated Relief Valve Tailpipes	8	Pipe Penetration and Crimping	Unit 1 (4) and Unit 2 (4)

TABLE 3.5-17 (cont'd)

TARGET	NUMBER OF TARGETS	FAILURE MODE(S)	NOTES
Main Steam Safety Valve Tailpipes	40	Pipe Penetration	Unit 1 (20) and Unit 2 (20)
Deep Well Pump Enclosures	2	Spall	Pumps 0A and 0B
Embedded Conduits (Auxiliary Building South Wall)	4	Perforation	Division 11 (Bus 131Z), 12 (Bus 132Z, 21 (Bus 231Z) and 22 (Bus 232Z)
Cable Vaults - Division 11 (Bus 131Z), 12 (Bus 132Z), 21 (Bus 231Z) and 22 (Bus 232Z)	6	Spall	Division 11 (1G1), 12 (1H2 and 1J2), 21 (2G1) and 22 (2H2 and 2J2)
Auxiliary Building L Line Openings	2	Pipe Penetration	0A and 0B Main Control Room Turbine Building Makeup Air Intakes
Auxiliary Building L Line Openings	4	Pipe Penetration	Division 11, 12, 21 and 22, Miscellaneous Electrical Equipment Room Exhaust*
Non-ESF Switchgear Room Conduits	5	Perforation	Division 11 and 21 SXCT Power and Control Cables (Evaluated in Segments)

*In a limited number of cases, the exhaust path may be impacted. Therefore, manual action is relied on to restore ventilation. These manual actions entail simple activities to open doors (to provide an exhaust path) and restart supply fans.