APPENDIX B: QUAD CITIES PRA QUALITY PROCESS

PRA QUALITY

Introduction

An integral part of the Quad Cities PRA is its quality and how that quality is translated into PRA applications. The goal of PRA quality is to ensure that the PRA input to decision-making is appropriate and sufficiently accurate for the specific application. However, PRA quality is a multi-faceted attribute of the PRA and requires more than one approach to assure its adequacy. While the technical attributes of the PRA are the foundation of the PRA quality, the scope and level of detail of the PRA also represent critical elements of the PRA quality. The technical attributes are reflected in the documentation to allow a thorough and comprehensive review. Based on information in NRC risk assessment guidance documents (Regulatory Guide 1.174 and Standard Review Plan Ch. 19), the quality of a PRA is reflected by the following key attributes:

- Attribute 1: The PRA realistically reflects actual design, construction, operational practices, and operational experiences of the plant
- Attribute 2: The PRA data, methods, and assessments are well-documented and available for review
- Attribute 3: The scope and level of detail is sufficient to assess changes to plant configuration, design, procedures, and operating performance
- Attribute 4: The models and documentation are subjected to quality controls such as an independent peer review

Exelon has used multiple techniques and programs to provide a high quality PRA suitable for a wide spectrum of applications. The techniques used by Exelon to develop and maintain a quality PRA are cross referenced to these four attributes and include the following:

Technique	Key Attributes			
	1	2	3	4
• Well structured PRA program	X	X	X	
• Thorough and traceable documentation	X	X		
• Internal controls	X	X		X
• Periodic updates	X			
• Plant interface	X			
• Reasonableness check			X	
• Acceptance review	X	X	X	X
• Management oversight	X	X	X	X
• PRA Peer Review	X	X	X	X
• Highly Competent PRA Team	X	X	X	

Discussion

Each of these techniques is discussed briefly below:

Technique 1: Well Structured PRA Program

The success of a PRA is integrally dependent upon it being structured in a manner that allows the necessary inputs, reviews, and exchanges of information to occur among the technical groups. This includes feedback from the users of the PRA. Exelon has established such a structured program that includes an on-site Risk Management engineer to interface between the PRA Program and the site. Engineering procedure, ER-AA-600, discusses the process for PRA control, change tracking, and update. Qualifications of the personnel who perform and review the PRA are specified.

Technique 2: Thorough and Traceable Documentation

The PRA quality is enhanced by having a thorough and detailed set of documentation that describes the model, its inputs, its assumptions, and its limitations. This documentation allows the users to investigate and review the model and its bases in a manner that enhances critical reviews. This feature is integral to the successful application of the PRA tool.

The documentation to support the PRA Update has been compiled in a set of modularized notebooks to provide the specific information needed for the PSA Update.

Table B-1 is the list of the Quad Cities PSA supporting documents. Table B-2 summarizes the system notebooks developed as part of the Quad Cities PSA. Some supporting documents have been not developed as part of the Base PSA model. These are identified with the note, “future”, which means they are intended to be developed as part of the continuing Exelon commitment to a risk-informed approach to Quad Cities decision making.

Technique 3: Internal Controls

Exelon has placed internal controls on the development, maintenance, and use of the PRA. These controls are considered an important element in ensuring the integrity of the PRA and are similar to 10CFR50 Appendix B. The internal controls represent the first line of defense in establishing the PRA quality. Additional assurance is gained through the PRA Peer Review process using a structured approach such as NEI 00-02. The development of the PRA models and their acceptance use the following:

- Personnel qualified in the analysis approaches

- Procedures that ensure control of documentation, including revisions, and provide for both independent review and checking of calculations and information used in the analyses (an independent peer review is used as one element in this checking process).

- Documentation and records

- An independent audit function to verify quality (an independent peer review is used for this purpose).

- Guidelines that ensure appropriate attention and corrective actions are taken if assumptions, analyses, or information used in previous decision-making is changed or determined to be in error.

Technique 4: Periodic Updates

Part of the Exelon PRA program is the necessity to update the PRA periodically to ensure that the key inputs to the PRA are current. These inputs that are reviewed include (but are not limited to):

- Operational Experience
- Plant Design
- New Maintenance Policies
- Operator Training Program
- Technical Specification
- Revised Engineering Calculations
- Emergency And Abnormal Operating Procedures
- Operating Procedures
- Emergency Plan
- Accident Management Programs
- Industry Studies
- Regulatory Changes and Updates

In addition, Exelon also has an active database for commitment control that addresses items to be addressed as part of the PRA update and/or maintenance. This is the "URE" database.

As an example of an update, the 1999 update to the Quad Cities PSA is the most recent evaluation of the risk profile at the Quad Cities Unit 1 for internal event challenges. A series of Quad Cities PRA evaluations have been performed beginning with the Individual Plant Examination (IPE) issued in 1993 as requested by the NRC in Generic Letter 88-20. These probabilistic evaluations can be summarized as follows:

Model	Date	CDF (Per Yr)
• IPE	12/93	1.2×10^{-6}/yr
• Modified IPE	8/96	2.2×10^{-6}/yr
• Updated IPE	12/96	2.2×10^{-6}/yr
• Conversion/Update (1998 – 99 Update)	4/99	4.6×10^{-6}/yr

Figure B-1 compares the CDF calculated with the various model updates.

Key changes incorporated in the latest PRA Update include the following:

- Incorporation of the latest design modifications (e.g., SBO Diesel generators)
- Reduced transient frequency based on both plant specific and generic data (i.e., Bayesian update)
- Revised offsite AC power recovery
- Increased detail in loss of DC bus initiator which was included in 1996 update.
- Revised HRA and CCF data
- Revised ATWS modeling

There has been a substantial change in the treatment of failure to scram sequences. This analysis effort is based on BWROG/GE calculations and represents the best estimate plant response to failure to scram events.

Many computer code methodology changes were performed as part of the 1999 update including the conversion to CAFTA. No substantial change in the risk profile is attributed to the differences in the methods.

However, there has been a complete update of the details within the following PSA elements:

- Event trees
- System fault trees
- Human reliability analysis
- Common cause evaluation
- Initiating event frequency
- AC power recovery probabilities
- Success criteria
- Level 2 Analysis

***Technique* 5: *Plant* Interface**

An on-site Risk Management Engineer who is knowledgeable of both the PRA and plant operations is a critical part of maintaining a PRA that accurately reflects plant design and operation. The on-site Risk Management Engineer actively participates in applying the PRA model to configuration control safety assessments and providing feedback to the PRA model.

Technique 6: Reasonableness Check

As part of the PRA development, the PRA is compared by Exelon with other comparable BWR PRAs to ensure that the inputs, models, and results are consistent in so far as the plants are similar. Where differences are noted, then the bases for these differences are explained or the models upgraded. The following qualitative summary is considered to provide a characterization of the PRA and its reasonableness:

- **Initiating Event** list has been expanded substantially from the IPE and includes support system initiators and others consistent with all current BWRs.

- **Event Trees and Event Tree Structure** have been updated to reflect the critical safety functions necessary to reach a safe stable state. The number of event tree structures is relatively large to reflect the differences among different initiators.

- **Thermal Hydraulic Analysis** using MAAP has been employed to establish success criteria and timing of events. This is similar among most BWR PSAs.

- **Human Reliability Analysis** uses accepted HRA methods and operator interviews to characterize the HEPs. This is consistent with other BWR PSAs.

- **Data:** A substantial variety of of data are required to support the quantitative evaluation of the PSA. The following is a brief summary of some of the data inputs to the quantitative model and the location of the derivation of these values. These types of data include:

  - Initiating Events
  - Component failure data
  - System/Train Unavailabilities
  - Human Error Probabilities
  - Common Cause

  Initiating Events

  The initiating event analysis includes a Bayesian update of generic data using Quad Cities specific data.

  Plant Specific Data

  The Quad Cities data development includes an extensive effort to collect and analyze plant specific data. The plant specific data used in the analysis is summarized in the Component Data Notebook (QC-PSA-010). This data collection effort consists of:

- Original effort on IPE to establish the initiating event frequency (See QC PSA-001)
- Component failure rates
- System/Train unavailabilities have been derived from various data sources including from the QC Maintenance Rule Program and individual evaluations from past data analyses supporting various PSA updates.

Risk Monitoring

Quad Cities, as other plants, have established an ongoing risk monitoring capability in response to the Maintenance Rule relative to the following:

- Equipment failures
- Equipment unavailabilities
- Configuration specific risk

This process ensures that the performance criteria used in the Maintenance Rule are consistent with the PRA. It also allows Work Control to plan on-line maintenance activities so that the risk is controlled within the best estimate calculated by the PSA by avoiding high risk configurations.

Generic Data

When plant specific data is unavailable, generic sources are used. The primary generic data source chosen for use is the EPRI ALWR data base. Appendix D of QC-PSA-010 includes the generic data source information used in the Quad Cities PSA.

Human Error Probabilities (HEP)

- Pre-Initiators

  Pre-initiator human error events are identified as part of the system analysis and quantified using THERP. These errors primarily include the following:

  -- Operator misalignment

  -- Miscalibration of logic sensors and systems.

- Post-Initiators

Post-initiator human errors (e.g., Failure to Initiate Suppression Pool Cooling) are also addressed in the Human Reliability Analysis document using the following HRA techniques:

--- THERP

--- Cause Based Method

--- Time reliability correlaton

Common Cause Failures (CCF)

"Common Cause" describes multiple failures of functionally identical components due to a single, shared cause. Common cause analysis evaluates the effects of these dependencies that may affect the ability of a system to prevent or mitigate a severe accident.

Quad Cities modeled common cause failures at the basic event level, employing the Multiple Greek Letter (MGL) method as defined in NUREG/CR-4780, "Procedures for Treating Common Cause Failure in Safety and Reliability Studies." The latest industry data evaluated by the NRC contractors in INEL 94/0064 are used. (The NRC contractor report was subsequently published as NUREG/CR-5497 with some minor changes.)

- **Systems analysis** includes the fault tree evaluation of 23 systems. The number and types of systems are similar among BWR PSAs.

- **Dependency Analysis** considers influences from:

  a) Support Systems
  b) Initiating Events
  c) Functional Dependencies
  d) Common Cause Influences
  e) Spatial Effects

There are a substantial number of techniques used in the Quad Cities PSA to ensure that dependencies are accurately reflected in the model. These include the following:

- A detailed set of dependency matrices are developed as part of the PSA process (QC-PSA-006)

- The linked fault tree process provides the method of implementing the system dependency matrices

- The functional dependencies have been treated explicitly in the event tree development. The Event Tree Notebook provides the basis for these functional dependency determinations.

- Common cause failures among similar redundant systems, structures, or components is also a key dependency included in the PSA. The common cause groups and their quantification are included in Volume 2 of QC-PSA-010

- Human error analysis included in the PRA may also exhibit a number of dependencies. These include:

  - Sequence dependencies due to timing, adverse conditions, or lack of symptoms

  - Multiple crew errors that may indicate a lack of recognition of a symptom or a general break down in the procedures, symptom recognition, or crew performance.

  - These dependencies are explicitly addressed in the development of the HEPs in the PSA model. The analysis is documented in QC-PSA-004, the HRA Notebook.

  - Spatial or environmental dependencies are incorporated in each of the crew actions as appropriate with the accident sequence -- see QC-PSA-004.

The dependency approach is at the state-of-the-technology.

- **Structural Analysis** is based on a comparison with the BWROG generic CB&I Mark I analysis performed on Peach Bottom and provides a reasonable estimate of containment failure pressure and failure locations.

- **Level 2 assessments** have been performed in a simplified manner to examine LERF. The analysis has been performed in a conservative manner. It has used an approach based on the NRC sponsored research on simplification of the CET structure to address LERF issues only (NUREG/CR-6595).

Technique 7: Acceptance Review

Exelon performs a detailed acceptance review of the PRA to ensure that the model scope, level of detail, and results are accurate.

Technique 8: Management Oversight

Senior Vice President of Exelon (D.R. Helwig) review of each of the MWROG Exelon PRAs including Quad Cities was performed to ensure the PRAs were of high quality and that potential lessons learned are reflected in actions that can be taken at the plant.

Dr. William E. Burchill holds the PRA management and oversight role for all Exelon plants. In this position, he oversees the PRA development and PRA process such that there is a single standard approach to PRA quality.

Technique 9: PRA Peer Review

One of the finishing steps in the quality process is the performance of an independent audit by a PRA Peer Review team to investigate the technical attributes, the scope, level of detail, and results of the PRA model. The Quad Cities PRA was peer reviewed by three groups:

- First, an independent contractor reviewed the PRA and provided comments, clarifications, and additions to the PRA.

- Second, a comprehensive self-assessment of the at-power Level 1 and Level 2 PRA models was performed.
- Third, a team from the BWROG, using NEI 00-02 as the structural basis for the review, performed a PRA Peer Review and issued a report identifying the relative quality of the PRA which was supplemented by specific Facts and Observations to improve the PRA.

The self-assessment was performed prior to the PRA Peer Review.

The general scope of the implementation of the PRA Peer Review included a review of eleven main technical elements, using checklist tables (to cover the elements and sub-elements), for an at-power PRA including internal events, internal flooding, and containment performance, with focus on large early release frequency (LERF).

The comments from the PRA Peer Review were prioritized into four categories A-D based upon importance to the completeness of the model. All comments in Categories A and B (recommended actions and items for consideration) have been identified to Quad Cities as priority items to be resolved by the next model update. The comments in Categories C and D (good practices and editorial) are potential enhancements and remain for consideration in future updates of the Level 1 and 2 PRA models.

Technique 10: Highly Competent PRA Team

The PRA Team is well qualified, experienced, and highly competent. The team brings experience from operation, licensing, design, and PRA. This experience provides the Team with the ability to provide the questioning attitude necessary to develop the PRA and make use of the PRA in an effective and realistic manner.

PRA Quality Summary

The quality of the Quad Cities PRA models used in performing the risk assessment is manifested by the following:

- Fidelity of the PRA
- Scope and level of detail in PRA
- Maintenance of the PRA
- Comprehensive Critical Reviews

The techniques used to ensure that these attributes are incorporated in the PRA include the following:

- Well structured PRA Program
- Thorough and traceable documentation
- Internal Controls
- Periodic Updates
- Plant Interface
- Reasonableness Check
- Acceptance Review
- Management Oversight
- PRA Peer Review
- Highly Competent PRA Team

All of these techniques are used to ensure that the PRA scope and level of detail are adequate to support a spectrum of applications. In addition, the more important critiques of the PRA ("A" and "B" Facts and Observations) are evaluated for each application to ensure that those items would not alter the conclusions of the PRA for the specific application being considered.

These multiple techniques form the basis for assuring the quality of the Quad Cities PRA for use in risk-informed applications.

Table B-1

PSA SUPPORTING DOCUMENTS

Document Title	Document No.
Living PSA Policy Document (ComEd Guideline on PSA Update is Surrogate for this NEP-1704.)	NEP-1704
Initiating Events Analysis	QC PSA-001
Event Tree Notebook	QC PSA-002
Level 1 Success Criteria	QC PSA-003
Human Reliability Analysis	QC PSA-004
System Notebooks	QC PSA-005
Dependency Matrix Notebook	QC PSA-006
Level 1 MAAP Thermal Hydraulic Calculations	QC PSA-007
Level 2 MAAP Thermal Hydraulic Calculations	QC PSA-008
AC Power Recovery	QC PSA-009
Component Data Notebook	QC PSA-010
ISLOCA Evaluation (See Appendix A of QC-PSA-001)	QC PSA-011
Internal Flooding Evaluation (Future)	QC PSA-012
PSA Revision Summary Document	QC PSA-013
Quantification Notebook	QC PSA-014
Level 2 PSA Analysis (LERF)	QC PSA-015
Project Development Guidelines (Future)	QC PSA-016
PSA Application Document (Future)	QC PSA-017
Containment Structural Analysis (Future)	QC PSA-018
Walkdown Summary Notebook (Future)	QC PSA-019
Fire Evaluation (Future)	QC PSA-020

Document Title	Document No.
External Events (Future) • Fire Evaluation • Seismic • Others • Shutdown Risk	QC PSA-021

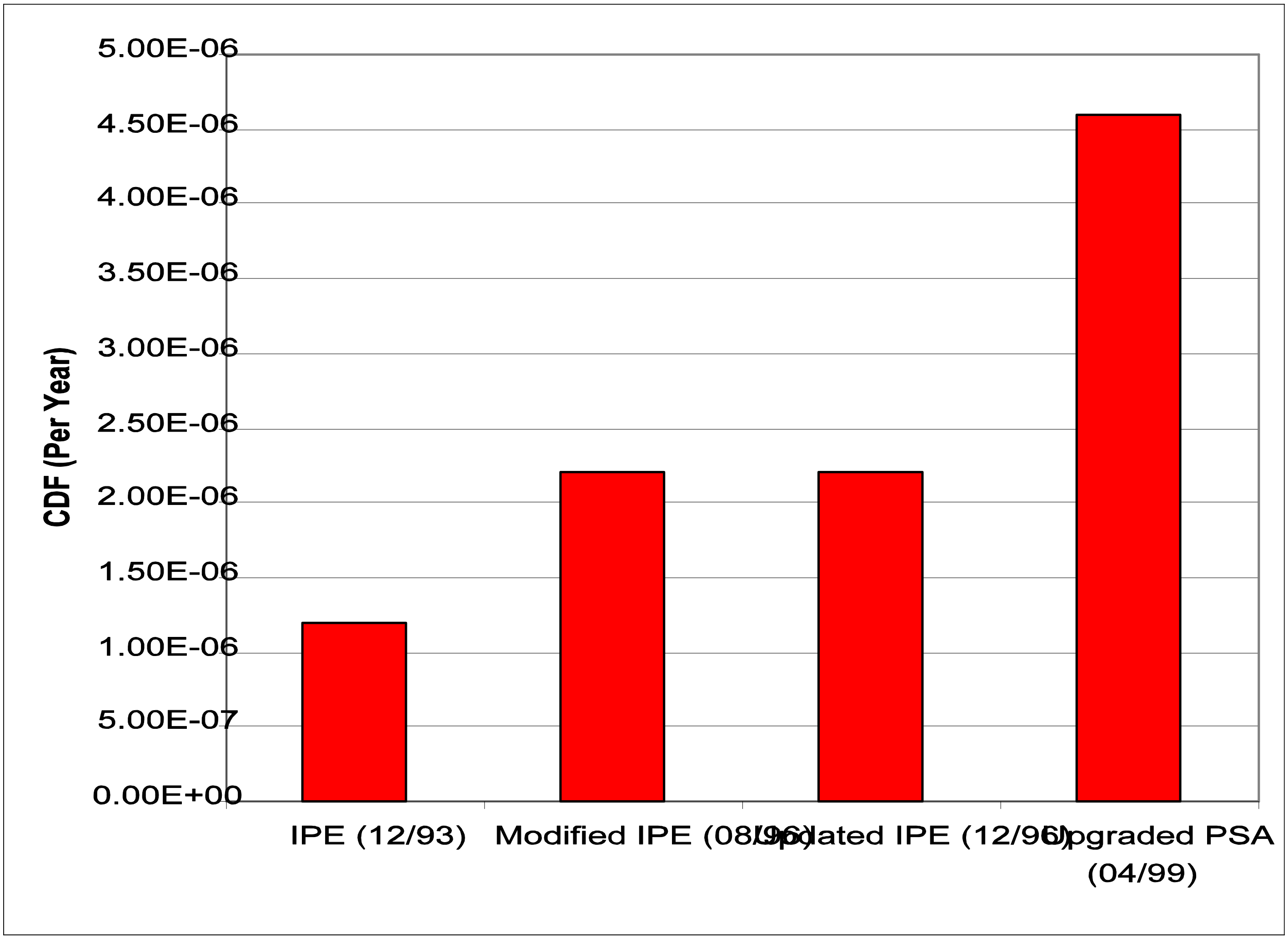
Table B-2

SYSTEM NOTEBOOK LISTING

Document No.	System
QC PSA-005.01	RPS
QC PSA-005.02	RPT & ARI
QC PSA-005.03	SLC
QC PSA-005.04	CRD
QC PSA-005.05	FW/COND
QC PSA-005.06	HPCI
QC PSA-005.07	RCIC
QC PSA-005.08	SSMP
QC PSA-005.09	ERV, SRV, ADS
QC PSA-005.10	Air
QC PSA-005.11	RHR/RHRSW
QC PSA-005.12	Fire Protection
QC PSA-005.13	CS
QC PSA-005.14	SW
QC PSA-005.15	Main Condenser
QC PSA-005.16	TDV
QC PSA-005.17	TBCCW
QC PSA-005.18 (Future)	RBCCW
QC PSA-005.19	Vapor Suppression
QC PSA-005.20	Electric Power (D/G, DC, AC)
QC PSA-005.21	CCST
QC PSA-005.22	CAS
QCPSA-005.23	Containment Isolation

Figure B-1

Quad Cities Results Comparison



(Internal Events)