May 2, 2001

Mr. Oliver D. Kingsley, President
Exelon Nuclear
Exelon Generation Company, LLC
200 Exelon Way, KSA 3-E
Kennett Square, PA 19348

SUBJECT: LIMERICK GENERATING STATION, UNITS 1 AND 2, SITE-SPECIFIC WORKSHEETS FOR USE IN THE NUCLEAR REGULATORY COMMISSION'S SIGNIFICANCE DETERMINATION PROCESS (TAC NO. MA6544)

Dear Mr. Kingsley:

Enclosed please find the "Risk-Informed Inspection Notebook" which incorporates the updated Significance Determination Process (SDP) Phase 2 Worksheets that inspectors will be using to characterize and risk-inform inspection findings. This document is one of the key implementation tools of the reactor safety SDP in the reactor oversight process and will also be publicly available through the Nuclear Regulatory Commission's (NRC's) external website at http://www.nrc.gov/NRC/IM/index.html.

The 1999 Pilot Plant review effort clearly indicated that significant site-specific design and risk information was not captured in the Phase 2 worksheets forwarded to you last spring. Subsequently a site visit was conducted by the NRC to verify and update plant equipment configuration data and to collect site-specific risk information from your staff. The enclosed document reflects the results of this visit.

The enclosed Phase 2 Worksheets have incorporated much of the information we obtained during our site visits. The staff encourages further licensee comments where it is identified that the Worksheets give inaccurately low significance determinations. Any comments should be provided to the Document Control Desk, with a copy to the Chief, Probabilistic Safety Assessment Branch, Division of Systems Safety and Analysis, Office of Nuclear Reactor Regulation.

While the enclosed Phase 2 Worksheets have been verified by our staff to include the site-specific data, we will continue to assess its accuracy throughout implementation and update the document based on comments by our inspectors and your staff.

Sincerely,

/RA/

Christopher Gratton, Sr. Project Manager, Section 2
Project Directorate I
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-352 and 50-353

Enclosure: Risk-Informed Inspection Notebook

cc w/encl: See next page

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May 2, 2001

Limerick Generating Station, Units 1 & 2

cc:

Mr. Edward Cullen
Vice President & General Counsel
Exelon Generation Company, LLC
300 Exelon Way
Kennett Square, PA 19348

Manager-Limerick Licensing
Exelon Generation Company, LLC
Nuclear Group Headquarters
Correspondence Control
P.O. Box 160
Kennett Square, PA 19348

Mr. William Levis, Site Vice President
Limerick Generating Station
P.O. Box 2300
Sanatoga, PA 19464

Mr. R. Braun
Plant Manager
Limerick Generating Station
P.O. Box 2300
Sanatoga, PA 19464

Regional Administrator, Region I
U.S. Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, PA 19406

Senior Resident Inspector
U.S. Nuclear Regulatory Commission
Limerick Generating Station
P.O. Box 596
Pottstown, PA 19464

Chairman
Board of Supervisors
of Limerick Township
646 West Ridge Pike
Linfield, PA 19468

Chief-Division of Nuclear Safety
PA Dept. of Environmental Resources
P.O. Box 8469
Harrisburg, PA 17105-8469

Library
U.S. Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, PA 19406

Dr. Judith Johnsrud
National Energy Committee
Sierra Club
433 Orlando Avenue
State College, PA 16803

Mr. Jeffrey A. Benjamin
Licensing - Vice President
Exelon Corporation
1400 Opus Place, Suite 900
Downers Grove, IL 60515

Mr. James A. Hutton
Director-Licensing
Exelon Generation Company, LLC
Nuclear Group Headquarters
Correspondence Control
P. O. Box 160
Kennett Square, PA 19348

Correspondence Control Desk
Exelon Generation Company, LLC
200 Exelon Way, KSA 1-N-1
Kennett Square, PA 19348

Mr. John Skolds
Chief Operating Officer
Exelon Generation Company, LLC
1400 Opus Place, Suite 900
Downers Grove, IL 60515

Mr. William Bohlke
Senior Vice President, Nuclear Services
Exelon Generation Company, LLC
1400 Opus Place, Suite 900
Downers Grove, IL 60515

Limerick Generating Station, Units 1 & 2

cc:

Mr. John Cotton
Senior Vice President, Operations Support
Exelon Generation Company, LLC
1400 Opus Place, Suite 900
Downers Grove, IL 60515

Mr. Joseph Hagan
Senior Vice President
Mid-Atlantic Regional Operating Group
Exelon Generation Company, LLC
200 Exelon Way, KSA 3-N
Kennett Square, PA 19348

Ms. K. Gallogly
Regulatory Assurance Manager
Limerick Generating Station
P.O. Box 2300
Sanatoga, PA 19464

May 2, 2001

RISK-INFORMED INSPECTION NOTEBOOK FOR LIMERICK GENERATING STATION

Units 1 & 2

BWR-4, GE, WITH MARK II CONTAINMENT

Prepared by

Brookhaven National Laboratory
Energy Sciences and Technology Department

Contributors

M. A. Azarm
T. L. Chu
A. Fresco
J. Higgins
G. Martinez-Guridi
P. K. Samanta

NRC Technical Review Team

John Flack	RES
Jose Ibarra	RES
Doug Coe	NRR
Gareth Parry	NRR
Peter Wilson	NRR
See Meng Wong	NRR
Jim Trapp	Region I
Michael Parker	Region III
William B. Jones	Region IV

Prepared for

U. S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Division of Systems Analysis and Regulatory Effectiveness

Enclosure

May 2, 2001

NOTICE

This notebook was developed for the NRC's inspection teams to support risk-informed inspections. The "Reactor Oversight Process Improvement," SECY-99-007A, March 1999 discusses the activities involved in these inspections. The user of this notebook is assumed to be an inspector with an extensive understanding of plant-specific design features and operation. Therefore, the notebook is not a stand-alone document, and may not be suitable for use by non-specialists. It will be periodically updated with new or replacement pages incorporating additional information on this plant. All recommendations for improvement of this document should be forwarded to the Chief, Probabilistic Safety Assessment Branch, NRR, with a copy to the Chief, Inspection Program Branch, NRR.

U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

ABSTRACT

This notebook contains summary information to support the Significance Determination Process (SDP) in risk-informed inspections for the Limerick Generating Station, Units 1 and 2.

The information includes the following: Categories of Initiating Events Table, Initiators and System Dependency Table, SDP Worksheets, and SDP Event Trees. This information is used by the NRC's inspectors to identify the significance of their findings, i.e., in screening risk-significant findings, consistent with Phase-2 screening in SECY-99-007A. The Categories of Initiating Event Table is used to determine the likelihood rating for the applicable initiating events. The SDP worksheets are used to assess the remaining mitigation capability rating for the applicable initiating event likelihood ratings in identifying the significance of the inspector's findings. The Initiators and System Dependency Table and the SDP Event Trees (the simplified event trees developed in preparing the SDP worksheets) provide additional information supporting the use of SDP worksheets.

The information contained herein is based on the licensee's Individual Plant Examination (IPE) submittal, the updated Probabilistic Risk Assessment (PRA), and system information obtained from the licensee during site visits as part of the review of earlier versions of this notebook. Approaches used to maintain consistency within the SDP, specifically within similar plant types, resulted in sacrificing some plant-specific modeling approaches and details. Such generic considerations, along with changes made in response to plant-specific comments, are summarized.

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1. INFORMATION SUPPORTING SIGNIFICANCE DETERMINATION PROCESS (SDP)

SECY-99-007A (NRC, March 1999) describes the process for making a Phase-2 evaluation of the inspection findings. In Phase 2, the first step is to identify the pertinent core damage scenarios that require further evaluation consistent with the specifics of the inspection findings. To aid in this process, this notebook provides the following information:

1. Estimated Likelihood Rating for Initiating Events Categories
2. Initiator and System Dependency Table
3. Significance Determination Process (SDP) Worksheets
4. SDP Event Trees.

Table 1, Categories of Initiating Events, is used to obtain the estimated likelihood rating for applicable initiating events for the plant for different exposures times for degraded conditions. This Table follows the format of the Table 1 contained in SECY-99-007A. Initiating events are grouped in frequency bins covering one order of magnitude. The table includes the initiating events that should be considered for the plant and for which SDP worksheets are provided. Categorization of the following initiating events is based on industry-average frequency: transients (Reactor Trip) (TRANS); transients without power conversion system (TPCS); large, medium, and small loss of coolant accidents (LLOCA, MLOCA, and SLOCA); inadvertent or stuck open relief valve (IORV or SORV); anticipated transients without scram (ATWS); interfacing systems LOCA (ISLOCA) and LOCA outside containment (LOC). The frequency of the remaining initiating events vary significantly from plant to plant, and accordingly, they are categorized using the plant-specific frequency obtained from the licensee. These initiating events include loss of offsite power (LOOP) and special initiators caused by loss of support systems.

The Initiator and System Dependency Table shows the major dependencies between frontline and support systems, and identifies their involvement in different types of initiators. This table identifies the most risk-significant systems; it is not an exhaustive nor comprehensive compilation of the dependency matrix, as shown in Probabilistic Risk Assessments (PRAs). This table is used to identify the SDP worksheets to be evaluated, corresponding to inspection findings on systems and components.

To evaluate the impact of an inspection finding on the core-damage scenarios, we developed the SDP worksheets. They contain two parts. The first part identifies the functions, the systems, and the combinations thereof that can perform mitigating functions, the number of trains in each system, and the number of trains required (success criteria) for each the initiator. It also characterizes the mitigation capability in terms of the available hardware (e.g., 1 train, 1 multi-train system) and the operator action involved. The second part of the SDP worksheet contains the core-damage accident sequences associated with each initiator; these sequences are based on SDP event trees. In the parentheses next to each of the sequences the corresponding event tree branch number(s) representing the sequence is included. Multiple branch numbers indicate that the different accident sequences identified by the event tree are merged into one through the Boolean reduction.

SDP worksheets are developed for each initiating event, including “Special Initiators,” which are typically caused by complete or partial loss of support systems. A special initiator typically leads to a reactor scram and degrades some front-line or support systems (e.g., Loss of Service water in BWRs). The SDP worksheets for initiating events that directly lead to core damage are different. Of this type of initiating events, only the interfacing system LOCA (ISLOCA) and LOCA outside containment (LOC) are included. This worksheet identifies the major consequential leak paths and the number of barriers that may fail to cause the initiator to occur.

For the special initiators, we considered those plant-specific initiators whose contribution to the plant’s core damage frequency (CDF) is non-negligible and/or have the potential to be a significant contributor to CDF given an inspection finding on system trains and components. We defined a set of criteria for their inclusion to maintain some consistency across the plants. These conditions are as follows:

1. The special initiator should degrade at least one of the mitigating safety functions changing its mitigation capability in the worksheet. For example, a safety function with two redundant trains, classified as a multi-train system, degrades to an one-train system, to be classified as 1 Train, due to the loss of one of the trains as a result of the special initiator.

2. The special initiators, which degrade the mitigation capability of the accident sequences associated with the initiator from comparable transient sequences by two and higher orders of magnitude, must be considered.

Following the above considerations, the classes of initiators that we consider in this notebook are:

1. Transients with power conversion system (PCS)available, called Transients (Reactor trip) (TRANS),
2. Transients without PCS available, called Transients w/o PCS (TPCS),
3. Small Loss of Coolant Accident (SLOCA),
4. Inadvertent or Stuck-open Power Operated Relief Valve (IORV or SORV),
5. Medium LOCA (MLOCA),
6. Large LOCA (LLOCA),
7. Loss of Offsite Power (LOOP)
8. Anticipated Transients Without Scram (ATWS).

Section 1.3 lists the plant-specific special initiators addressed in this notebook. Examples of special initiators are as follows:

1. LOOP with failure of 1 Emergency AC (LEAC) bus or associated EDG (LEAC),

2. LOOP with stuck open SORV (LORV),

3. Loss of one DC Bus (LDC),
4. Loss of component cooling water (LCCW),
5. Loss of instrument air (LOIA),
6. Loss of service water (LSW).

The worksheet for the LOOP may include LOOP with emergency AC power (EAC) available and LOOP without EAC, i.e., Station Blackout (SBO). LOOP with partial availability of EAC, i.e., LOOP with loss of a bus of EAC, is covered in a separate worksheet to avoid making the LOOP worksheet too large. LOOP with stuck open SORV is also covered in a separate worksheet, when applicable. In some plants, LOOP with failure of 1 EAC bus and LOOP with stuck-open SORV are large contributors to the plant's core damage frequency (CDF).

Following the SDP worksheets, the SDP event trees corresponding to each of the worksheets are presented. The SDP event trees are simplified event trees developed to define the accident sequences identified in the SDP worksheets. For special initiators whose event tree closely corresponds to another event tree (typically, the Transient(Reactor trip) or Transients w/o PCS event tree) with one or more functions eliminated or degraded, a separate event tree may not be drawn.

We considered the following items in establishing the SDP event trees and the core-damage sequences in the SDP worksheets; Section 2.1 gives additional guidelines and assumptions.

1. Event trees and sequences were developed such that the worksheet contains all the major accident sequences identified by the plant-specific IPEs or PRAs. The special initiators modeled for a plant is based on a review of the special initiators included in the plant IPE/PRA and the information provided by the licensee.

2. The event trees and sequences for each plant took into account the IPE/PRA models and event trees for all similar plants. Any major deviations in one plant from similar plants typically are noted at the end of the worksheet.

3. The event trees and the sequences were designed to capture core-damage scenarios, without including containment-failure probabilities and consequences. Therefore, branches of event trees that are only for the purpose of a Level II PRA analysis are not considered. The resulting sequences are merged using Boolean logic.

4. The simplified event-trees focus on classes of initiators, as defined above. In so doing, many separate event trees in the IPEs often are represented by a single tree. For example, some IPEs define four or more classes of LOCAs rather than the three classes considered here. The sizes of LOCAs for which high-pressure injection is not required are some times divided into two classes; the only difference between them being the need for reactor scram in the

smaller break size. Some consolidation of transient event tree may also be done besides defining the special initiators following the criteria defined above.

5. Major actions by the operator during accident scenarios are credited using four categories of Human Error Probabilities (HEPs). They are termed operator action =1 (representing an error probability of 5E-2 to 0.5), operator action=2 (error probability of 5E-3 to 5E-2), operator action=3 (error probability of 5E-4 to 5E-3), and operator action=4 (error probability of 5E-5 to 5E-4). An human action is assigned to a category bin, based on a generic grouping of similar actions among a class of plants. This approach resulted in designation of some actions to a higher bin, even though the IPE/PRA HEP value may have been indicative of a lower category. In such cases, it is noted at the end of the worksheet. On the other hand, if the IPE/PRA HEP value suggests a higher category than that generically assumed, the HEP is assigned to a bin consistent with the IPE/PRA value in recognition of potential plant-specific design; a note is also given in these situations. Operator's actions belonging to category 4, i.e., operator action=4, may only be noted at the bottom of worksheet because, in those cases, equipment failures may have the dominating influence in determining the significance of the findings.

The four sections that follow include the Categories of Initiating Events Table, Initiators and System Dependency Table, SDP Worksheets, and the SDP Event Trees for the Limerick Generating Station, Units 1 and 2.

1.1 INITIATING EVENT LIKELIHOOD RATINGS

Table 1 presents the applicable initiating events for this plant and their estimated likelihood ratings corresponding to the exposure time for degraded conditions. The initiating events are grouped into rows based on their frequency. As mentioned earlier, loss of offsite power and special initiators are assigned to rows using the plant-specific frequency obtained from individual licensees. For other initiating events, industry-average values are used, as per SECY-99-007A.

May 2, 2001

Table 1 Categories of Initiating Events for Limerick Generating Station

Row	Approximate Frequency	Example Event Type	Estimated Likelihood Rating		
I	> 1 per 1-10 yr	Reactor Trip, Loss of Power Conversion System (Loss of condenser, Closure of MSIVs, Loss of feedwater)	A	B	C
II	1 per 10-10^2 yr	Loss of offsite power, Inadvertent or stuck open SRVs	B	C	D
III	1 per 10^2 - 10^3 yr	Loss of DC Bus, Loss of Service Water	C	D	E
IV	1 per 10^3 - 10^4 yr	Small LOCA (RCS rupture), Medium LOCA (RCS rupture),	D	E	F
V	1 per 10^4 - 10^5 yr	Large LOCA (RCS rupture), ATWS	E	F	G
VI	less than 1 per 10^5 yr	ISLOCA, Vessel rupture	F	G	H
			> 30 days	3-30 days	< 3 days
			Exposure Time for Degraded Condition		

Note:

1. The SDP worksheets for ATWS core damage sequences assume that the ATWS is not recoverable by manual actuation of the reactor trip function or by ARI (for BWRs). Thus, the ATWS frequency to be used by these worksheets must represent the ATWS condition that can only be mitigated by the systems shown in the worksheet (e.g., boration).

2. A Loss of Instrument Air (LOIA) initiator frequency at Limerick is very low, and the LOIA impact is also low. As a result the LOIA contribution to CDF is in the 10^{-8} to 10^{-9} range and is not included in this table.

1.2 INITIATORS AND SYSTEM DEPENDENCY

Table 2 provides the list of the systems included in the SDP worksheets, the major components in the systems, and the support system dependencies. The system involvements in different initiating events are noted in the last column.

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Table 2 Initiators and System Dependency Table for Limerick

Affected System		Major Components	Support Systems	Initiating Event Scenarios
Code	**Name**			
PCS	Power Conversion System	3 MDP, 3 TDP, MOV, MSIVs, turbine bypass valves	Non-safeguards DC, safeguards DC (MSIVs), Offsite power, TECW, SW	Trans (Rx trip), SLOCA, IORV, MLOCA, LLOCA, LOOP, LODC
HPCI	High Pressure Coolant Injection	1 TDP, MOV	Division II & IV DC power, (Late AC), act	All but LLOCA & LODCII
RCIC	Reactor Core Isolation Cooling	1 TDP, MOV	Division I & III DC, (Late SW, ESW and AC), act	All but MLOCA, LLOCA, & LODCI
SRVs/ADS	Safety Relief Valves / Automatic Depressurization System	14 RV, AOV	Division I & III DC power, IG, act	All but LLOCA
LPCI	Low Pressure Coolant Injection	4 MDP, MOV	AC, Division I - IV DC, SW or ESW, act	All
RHR	Residual Heat Removal	4 MDP, MOV, 2 HX	AC, Division I - IV DC, SW or ESW, RHRSW	All
CS	Core Spray	4 MDP, MOV	AC, SW, Division I - IV DC, act, HVAC	All
Cond xfer	condensate transfer	2 MDP, valves	AC	Trans (Rx trip), SLOCA, IORV, MLOCA, LOOP, LODC, LOSW
RWST xfer	Refueling Water Storage Tank transfer	2 MDP, valves	AC	All but LLOCA & ATWS
CRD	Control Rod Hydraulic System	2 MDP, valves	Division III & IV DC, AC	All but LLOCA & ATWS

Table 2 (Continued)

AC	AC power (non-EDG)	Breakers, transformers	DC	All
EDGs	Emergency Diesel Generators	4 Engine Generators	Division I - IV DC, ESW, FO transfer, act	LOOP
FO transfer	EDG fuel oil transfer	MDPs	AC	LOOP
DC	DC Power	battery, charger	AC	LODC
act	Actuation	instrumentation	DC, AC	All
SLC	Standby Liquid Control	3 MDP, MOV, Explosive valves	AC, act, RWCU valves	ATWS
TECW	Turbine Enclosure Cooling Water	MDP, MOV	SW, AC	All
RECW	Reactor Enclosure Cooling Water	MDP, MOV	SW, AC	All but LLOCA
SW	Service Water	3 MDP, MOV	Offsite power	LOSW
ESW	Emergency Service Water	4 MDP, MOV	AC, Division I - IV DC, act	All
RHR SW	RHR Service Water	4 MDP, MOV	AC, DC	All
IA	Instrument Air	Air compressor	AC, TECW	All
IG	Instrument Gas	compressor, accumulator, HP bottles	AC, IA, RECW, Service air	All but LLOCA
CV	Containment Venting	AOV, MOV, ductwork	AC, IA	All but ATWS & LOSW

Table 2 (Continued)

HVAC	ECCS Room Cooling (HPCI, RCIC, CS, & RHR)	Valves, Fan Coolers	ESW, AC, act	All

Notes:

1. Information herein was developed from the Limerick IPE dated July, 1992 and the 1997 Limerick PRA, LGS 97.

2. The baseline IPE core damage frequency (CDF) from internal events was 4.3 x 10^{-6} events/Rx year and 3.2 x 10^{-6} events/Rx year for the PRA.

3. Emergency DC power has four divisions as follows: Division I & II are 125 V-DC and 250 V-DC; Division III & IV are just 125 V-DC. There are two worksheets for loss of DC, Loss of Division I DC and Loss of Division II DC. They both use the same event tree (LODC). In the initiating event scenario column, LODC means that the system is used in both worksheets.

4. HPCI and RCIC have room coolers that are cooled by SW and then ESW as a backup to SW, however room coolers are not required for operability. The Div. III and IV DC dependency for HPCI and RCIC is only for selected system isolations, not normal system operation.

5. Limerick has two internal flooding sequences in their top 25 dominant sequences. These are not included herein.

6. At Limerick, one stuck open SRV is the equivalent of a SLOCA.

7. In the Limerick IPE, battery duration for required loads on a LOOP is 8 hours (time to CD in SBO is 10 hrs). Limerick has a turbine bypass capacity of 25%.

8. The RHR pumps in both RHR and LPCI mode require ESW or SW for room cooling and for pump cooling (IPE p. 3.2-15).

9. The TECW system cools the IA compressors and the condensate pumps. SW directly cools the Reactor Feed pumps. CRD was previously cooled by TECW, but a modification subsequent to the IPE removed this dependency so that they are now self-cooled.

10. RECW cools the recirculation pump seal coolers, the drywell chilled water, the RWCU non-regenerative HX, and the post accident sampling system (PASS).

11. The Primary Containment IG system is the normal nitrogen supply system for the ADS valves. Each ADS valve has an accumulator sized for two activations. There are also instrument gas bottles to back up the accumulators. And there are connections for manually connecting outside sources of air.

Table 2 (Continued)

12. The major components of the Condensate Transfer System and the RWST Transfer System are: the common RWST, the two unit CSTs, the common Refueling Water Pumps(2), the common Condensate Transfer Pumps(2), and the Condensate Transfer Jockey Pump. All five pumps may be used by either unit. Also, the system piping is configured in such a way as to permit the water of any tank to supply a user of either unit. This system provides the normal supply to the ECCS keep full system and as such can be used to send water from the tanks to the reactor vessel.

1.3 SDP WORKSHEETS

This section presents the SDP worksheets to be used in the Phase 2 evaluation of the inspection findings for the Limerick Generating Station. The SDP worksheets are presented for the following initiating event categories:

1. Transients (Reactor Trip) (TRANS)
2. Transient without PCS (TPCS)
3. Small LOCA (SLOCA)
4. Inadvertent/Stuck Open Relief Valve (IORV/SORV)
5. Medium LOCA (MLOCA)
6. Large LOCA (LLOCA)
7. Loss of Offsite Power (LOOP)
8. Anticipated Transients Without Scram (ATWS)
9. Loss of DC Bus I (LODCI)
10. Loss of DC Bus II (LODCII)
11. Loss of Service Water (LOSW)
12. ISLOCA and LOCA Outside Containment (LOC)

Table 3.1 SDP Worksheet for Limerick — Transients (Reactor Trip) (TRANS)

Estimated Frequency (Table 1 Row) __________ **Exposure Time** _____ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Power Conversion System (PCS)	1/4 Steam lines, turbine bypass valves, condenser, 1/2 steam jet air ejector, 1/4 circ. water pump, 1/3 condensate pumps, 1/3 main feed pumps (operator action = 3)
High Press Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/14 valves (5 ADS and 9 SRVs) manually opened (operator action = 2)
Low Press Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Containment Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or [1/2 condensate transfer pumps and 1/2 RWST transfer pumps] (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 TRANS - PCS - CHR - LI (4, 8)			
2 TRANS - PCS - CHR - CV (5, 9)			
3 TRANS - PCS - HPI - LPI (10)			
4 TRANS - PCS - HPI - DEP (11)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:
If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

(1) LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP).

(2) Limerick credits PCS for the CHR function and the condensate pumps for LI. This worksheet only credits these items as part of the PCS function.

(3) LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

(4) LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI. The RHR SW pump injects through the LPCI line in Unit 1 and through the A LPCI line in Unit 2.

(5) CRD pump flow of 200 gpm can prevent core damage after 4 hours of HPI.

(6) Regarding the use of RHR for the CHR function, the Limerick IPE uses an HEP of 1 E-6 for suppression pool cooling, hence equipment failures dominate this activity. Thus, this worksheet uses a multi-train system for credit.

Table 3.2 SDP Worksheet for Limerick — Transients without PCS (TPCS)

Estimated Frequency (Table 1 Row) __________ Exposure Time __________ Table 1 Result (circle): A B C D E F G H

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
High Press Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/14 valves (5 ADS and 9 SRVs) manually opened (operator action = 2)
Low Press Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Containment Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or 1/2 RWST transfer pumps (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 TPCS - CHR - LI (3, 7)			
2 TPCS - CHR - CV (4, 8)			
3 TPCS - HPI - LPI (9)			
4 TPCS - HPI - DEP (10)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:
If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

<u>Notes</u>:

(1) TPCS includes the following transients that result in the loss of the PCS: MSIV closure, loss of condenser, turbine trip without bypass, loss of vacuum, and loss of feedwater.

(2) LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

(3) LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP).

(4) LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI.

Table 3.3 SDP Worksheet for Limerick — Small LOCA (SLOCA)

Estimated Frequency (Table 1 Row) _________ **Exposure Time** _________ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Power Conversion System (PCS)	1/4 Steam lines, turbine bypass valves, condenser, 1/2 steam jet air ejector, 1/4 circ. water pump, 1/3 condensate pumps, 1/3 main feed pumps (operator action = 3)
High Press Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/14 valves (5 ADS and 9 SRVs) manually opened (operator action = 2)
Low Press Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Containment Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or [1/2 condensate transfer pumps and 1/2 RWST transfer pumps] or 1/3 condensate pumps plus hotwell makeup (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 SLOCA - CHR - LI (3, 7, 11)			
2 SLOCA - CHR - CV (4, 8, 12)			
3 SLOCA - PCS - HPI - LPI (13)			
4 SLOCA - PCS - HPI - DEP (14)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event: If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

<u>Notes</u>:

1. CRD pump flow of 200 gpm can prevent core damage after 4 hours of HPI.

2. LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP).

3. LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

4. Need to depressurize to 600psig for use of condensate pumps in LI.

5. LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI.

Table 3.4 SDP Worksheet for Limerick — Inadvertent/Stuck Open Relief Valve (IORV/SORV)

Estimated Frequency (Table 1 Row) _________ **Exposure Time** _________ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Power Conversion System (PCS)	1/4 Steam lines, turbine bypass valves, condenser, 1/2 steam jet air ejector, 1/4 circ. water pump, 1/3 condensate pumps, 1/3 main feed pumps (No credit)
High Press Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	1/13 valves (5 ADS and 9 SRVs) manually opened plus IORV / SORV, (operator action = 2)
Low Press Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Containment Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or [1/2 condensate transfer pumps and 1/2 RWST transfer pumps] or 1/3 condensate pumps plus hotwell makeup (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 IORV - CHR - LI (3, 7, 11)			
2 IORV - CHR - CV (4, 8, 12)			
3 IORV - PCS - HPI - LPI (13)			
4 IORV - PCS - HPI - DEP (14)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:
If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

(1) LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP).

(2) LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

(3) LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI.

(4) SRVs may fail to reclose when demanded in transients such as MSIV closure or turbine trip without bypass. In such transients, the PCS function could not be credited. Considering such scenarios, this SDP worksheet conservatively does not credit PCS.

Table 3.5 SDP Worksheet for Limerick — Medium LOCA (MLOCA)

Estimated Frequency (Table 1 Row) __________ **Exposure Time __________** **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Early Containment Control (EC)	Passive operation of SP, with 3/4 pairs of vacuum breakers remaining closed (1 multi-train system)
High Press Injection (HPI)	HPCI (1 ASD train)
Depressurization (DEP)	2/14 valves (5 ADS and 9 SRVs) manually opened (operator action = 2)
Low Press Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system) or 1/3 condensate pumps plus hotwell makeup (operator action = 2)
Cont. Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Cont. Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or [1/2 condensate transfer pumps and 1/2 RWST transfer pumps] (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 MLOCA - CHR - LI (3, 8)			
2 MLOCA - CHR - CV (4, 9)			
3 MLOCA - LPI (5, 10)			
4 MLOCA - HPI - DEP (11)			
5 MLOCA - EC (12)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:
If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

(1) Failure of EC/ Suppression Pool (SP) could be due to downcomer vent pipe failures, vacuum breaker failures, or inadequate SP level. At Limerick there are 4 pairs of vacuum breakers; one pair can fail but the remaining three must remain closed. The LGS 97 PRA gives credit for LI on failure of EC. This credit is not given in this worksheet.

(2) LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP).

(3) The MLOCA automatically depressurizes to < 600 psig, thus allowing use of the condensate pumps for LPI with appropriate operator actions.

(4) LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

(5) LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI.

Table 3.6 SDP Worksheet for Limerick — Large LOCA (LLOCA)

Estimated Frequency (Table 1 Row) ________ **Exposure Time __________** **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Early Cont. Control (EC)	Passive operation of SP, 1 vacuum breaker in each pair of 4 must remain closed and 1/4 pairs must open when needed (1 multi-train system)
Low Press Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system)
Cont. Heat Removal (CHR)	1/4 RHR pumps plus 1/2 RHR HXs in 1/2 trains in SPC or CSC mode (1 multi-train system)
Cont. Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/3 condensate pumps (operator action = 2)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LLOCA - CHR - LI (3)			
2 LLOCA - CHR - CV (4)			
3 LLOCA - LPI (5)			
4 LLOCA - EC (6)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event: If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

(1) Failure of EC/ Suppression Pool (SP) could be due to downcomer vent pipe failures, vacuum breaker failures, or inadequate SP level. At Limerick there are 4 pairs of vacuum breakers; one vacuum breaker in each pair can fail but the remaining vacuum breakers in all four pairs must remain closed.

(2) LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

Table 3.7 SDP Worksheet for Limerick — Loss of Offsite Power (LOOP)

Estimated Frequency (Table 1 Row) _________ Exposure Time _________ Table 1 Result (circle): A B C D E F G H

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
DC Batteries (B)	1/4 DC batteries (1 multi-train system)
Emergency Power (EAC)	1/4 EDGs (1 multi-train system)
Recovery of LOOP in 5 hrs (RLOOP 5 h)	Recovery of offsite power within 5 hrs (operator action = 1)
HPSUCAL	Realign the suctions of HP systems from SP to CST (operator action = 2)
Recovery of LOOP in 10 hrs (RLOOP-10h)	Recovery of offsite power within 10 hrs (operator action = 2)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/14 valves (5 ADS and 9 SRVs) manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Containment Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or [1/2 condensate transfer pumps and 1/2 RWST transfer pumps] or 1/3 condensate pumps plus hotwell makeup (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LOOP - CHR - LI (1, 2, 6)			
2 LOOP - CHR - CV (1, 2, 7)			

3 LOOP - HPI - DEP (1, 2)				
4 LOOP - HPI - LPI (1, 2)				
5 LOOP - EAC - HPI (3, 8) [SBO sequence}				
6 LOOP - EAC - (RLOOP -10 h) (9) [SBO sequence]				
7 LOOP - EAC - (RLOOP-5 h) - HPSUCAL [SBO sequence] (10)				
8 LOOP - B (11)				

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

<u>Notes</u>:

1. In Limerick on a station blackout, operator action is needed at 5 or 10 hours for the following reasons:

- at 5 hrs need to align the suction of HPCI and RCIC systems from the suppression pool (SP) to the CST due to SP heat up (HPSUCAL). The LGS 97 PRA HEP for HPSUCAL is 1.5 E-3.
- at 10 hrs will get core damage due to battery depletion at 8 hours, failure of HPCI and RCIC, and subsequent boil-off of reactor water.

2. All RLOOP actions in Limerick include recovery of either offsite power or an EDG. The failure events imply failure to recover either offsite power or an EDG.

3. HPCI and RCIC operability depend on which EDG is recovered and therefore which battery is charged. The event tree does not map failures of multiple EDGs which should be taken to a Phase 3 analysis.

4. LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP).

5. LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

6. LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI.

7. At Limerick the LOOP initiation frequency in the LGS 97 PRA is 3.85 E-2 events per reactor-year.

8. The Limerick IPE also credits recovery of FW after successful recovery of offsite power. This is not credited here.

9. For sequences in the above worksheet, the numbers in parentheses refer to the corresponding sequence in the ETs. For the LOOP ET there are some transfers to the TPCS ET. These are indicated by (1), and (2). All of the sequences in the TPCS event tree apply here, i.e., LOOP-CHR-LI, LOOP-CHR-CV, LOOP-HPI-DEP, and LOOP-HPI-LPI.

Table 3.8 SDP Worksheet for Limerick — Anticipated Transients Without Scram (ATWS)

Estimated Frequency (Table 1 Row) __________ Exposure Time __________ Table 1 Result (circle): A B C D E F G H

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Overpressure Protection (OVERP)	8/14 SRVs (1 multi-train system)
Reactivity Control (SLC)	1/3 SLC pumps inject in auto. (1 multi-train system)
Recirculation Pump Trip (RPT)	Manual or automatic trip of recirculation pumps (1 multi-train system)
High Pressure Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Level Control (LC)	Operator controls RV level at TAF (operator action = 1)
Depressurization (DEP)	2/14 SRVs manually opened (operator action = 2)
Inhibit ADS (INH)	Operator inhibits ADS (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system) or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains in SPC plus 1/4 RHR SW pumps (1 multi-train system)
Overfill of Rx Vessel (OVRFL)	Operators prevent overfill of Rx Vessel by injection systems (operator action = 2)

Circle Affected Functions	**Recovery or Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 ATWS - OVERP (15)			
2 ATWS - RPT (14)			
3 ATWS - SLC (13)			

4 ATWS - LC (12)			
5 ATWS - INH (11)			
6 ATWS - DEP (5, 10)			
7 ATWS - LPI (4, 9)			
8 ATWS - CHR (2, 7)			
9 ATWS - OVRFL (3, 8)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

(1) For simplicity this worksheet considers only full ATWS initiators. Additionally, we have combined the ATWS initiator with failure of Alternate Rod Insertion (ARI) and Manual Rod Insertion (MRI).

(2) For Limerick, overfill of the Rx Vessel is identified as leading to core damage due to flushing out of the boron and reactor re-criticality. This can happen either at high pressure or after depressurization.

(3) For Limerick, LC is identified as having an HEP of 0.24.

Table 3.9 SDP Worksheet for Limerick — Loss of DC Bus I (LODCI)

Estimated Frequency (Table 1 Row) _________ **Exposure Time** _________ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	Full Creditable Mitigation Capability for Each Safety Function:
Power Conversion System (PCS)	1/4 Steam lines, turbine bypass valves, condenser, 1/2 steam jet air ejector, 1/4 circ. water pump, 1/3 condensate pumps, 1/3 main feed pumps (operator action = 3)
High Press Injection (HPI)	HPCI (1 ASD train)
Depressurization (DEP)	2/11 valves (2 ADS and 9 SRVs) manually opened (operator action = 2)
Low Press Injection (LPI)	1/3 RHR pumps in 1/3 trains in LPCI Mode (1 multi-train system) or 1/1 LPCS trains (with 2/2 pumps per train) (1 single train system)
Containment Heat Removal (CHR)	1/3 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Containment Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or [1/2 condensate transfer pumps and 1/2 RWST transfer pumps] (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	Recovery of Failed Train	Remaining Mitigation Capability Rating for Each Affected Sequence	Sequence Color
1 LODC I - PCS - CHR - LI (4, 8)			
2 LODC I - PCS - CHR - CV (5, 9)			
3 LODC I - PCS - HPI - LPI (10)			
4 LODC I - PCS - HPI - DEP (11)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

<u>Notes</u>:

(1) There are four safety related divisions of DC (I through IV) at Limerick. This initiating event considers the loss of a single safety related DC bus. This results in a manual reactor shutdown by Tech Specs within 8 hours, however the PCS is not lost. None of the above safety functions are totally lost, but some redundancy is lost as follows:

- Div I DC Bus (125/250 VDC) - RCIC, Div. I of ADS, 1 CS pump, Div I LPCI, Div I RHR
- Div II DC Bus (125/250 VDC) - HPCI, 1 CS pump, Div II LPCI, Div II RHR
- Div III DC Bus (125 VDC) - Div. III of ADS, 1 CS pump, Div III LPCI
- Div IV DC Bus (125 VDC) - 1 CS pump, Div IV LPCI

Note that both CS pumps per train are required, thus loss of one CS pump implies failure of that train. We have included worksheets only for loss of Div I and Div II. Loss of Div III and Div IV are less severe and are bounded by the Div I and II loss. The same event tree (LODC) is used for both loss of Div I and Div II, due to their similarity.

(2) The LGS 97 PRA IE frequency for Loss of a DC Bus is 1.5 E-3 events per reactor-year.

(3) LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP). We assume that 3 ADS valves are lost for either a loss of Div I or Div II DC.

(4) LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI.

(5) LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

(6) Limerick credits condensate in LI, but this is only credited in PCS here.

Table 3.10 SDP Worksheet for Limerick — Loss of DC Bus II (LODCII)

Estimated Frequency (Table 1 Row) __________ **Exposure Time** __________ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Power Conversion System (PCS)	1/4 Steam lines, turbine bypass valves, condenser, 1/2 steam jet air ejector, 1/4 circ. water pump, 1/3 condensate pumps, 1/3 main feed pumps (operator action = 3)
High Press Injection (HPI)	RCIC (1 ASD train)
Depressurization (DEP)	2/11 valves (2 ADS and 9 SRVs) manually opened (operator action = 2)
Low Press Injection (LPI)	1/3 RHR pumps in 1/3 trains in LPCI Mode (1 multi-train system) or 1/1 LPCS trains (with 2/2 pumps per train) (1 single train system)
Containment Heat Removal (CHR)	1/3 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Containment Venting (CV)	CV through 18" or 24" containment purge line (operator action = 2)
Late Inventory, Makeup (LI)	1/2 CRD pumps or [1/2 condensate transfer pumps and 1/2 RWST transfer pumps] (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LODC II - PCS - CHR - LI (4, 8)			
2 LODC II - PCS - CHR - CV (5, 9)			
3 LODC II - PCS - HPI - LPI (10)			
4 LODC II - PCS - HPI - DEP (11)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:
If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

(1) There are four safety related divisions of DC (I through IV) at Limerick. This initiating event considers the loss of a single safety related DC bus. This results in a manual reactor shutdown by Tech Specs within 8 hours, however the PCS is not lost. None of the above safety functions are totally lost, but some redundancy is lost as follows:

- Div I DC Bus (125/250 VDC) - RCIC, Div. I of ADS, 1 CS pump, Div I LPCI, Div I RHR
- Div II DC Bus (125/250 VDC) - HPCI, 1 CS pump, Div II LPCI, Div II RHR
- Div III DC Bus (125 VDC) - Div. III of ADS, 1 CS pump, Div III LPCI
- Div IV DC Bus (125 VDC) - 1 CS pump, Div IV LPCI

Note that both CS pumps per train are required, thus loss of one CS pump implies failure of that train. We have included worksheets only for loss of Div I and Div II. Loss of Div III and Div IV are less severe and are bounded by the Div I and II loss. The same event tree (LODC) is used for both loss of Div I and Div II, due to their similarity.

(2) The LGS 97 PRA IE frequency for Loss of a DC Bus is 1.5 E-3 events per reactor-year.

(3) LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP). We assume that 3 ADS valves are lost for either a loss of Div I or Div II DC.

(4) LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI.

(5) LGS 97 PRA gives failure to vent containment, when procedures call for it, an HEP value of 4E-3.

(6) Limerick credits condensate in LI, but this is only credited in PCS here.

Table 3.11 SDP Worksheet for Limerick — Loss of Service Water (LOSW)

Estimated Frequency (Table 1 Row) __________ **Exposure Time** __________ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Start ESW Pump (OP-ESW)	Operator starts ESW pump on LOSW (operator action = 2)
High Press Injection (HPI)	HPCI (1 ASD train) or RCIC (1 ASD train)
Depressurization (DEP)	2/14 valves (5 ADS and 9 SRVs) manually opened (operator action = 2)
Low Press Injection (LPI)	1/4 RHR pumps in 1/4 trains in LPCI Mode (1 multi-train system) or 1/2 LPCS trains (with 2/2 pumps per train) (1 multi-train system)
Containment Heat Removal (CHR)	1/4 RHR pumps and 1/2 RHR HXs in 1/2 trains plus 1/4 RHR SW pumps (1 multi-train system)
Containment Venting (CV)	No credit for CV on LOSW
Late Inventory, Makeup (LI)	1/2 CRD pumps or [1/2 condensate transfer pumps and 1/2 RWST transfer pumps] (operator action = 2); or 1/4 RHR SW pumps injecting through the LPCI line (operator action = 1)

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LOSW - CHR - LI (3, 7)			
2 LOSW - CHR - CV (4, 8)			
3 LOSW - HPI - LPI (9)			
4 LOSW - HPI - DEP (10)			

5 LOSW - (OP-ESW) (11)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

(1) The Service Water System that is lost in this initiating event is the non-safety related system, which cools the following: HVAC for RHR, CS, HPCI, and RCIC, control enclosure coolers, RFPs, RHR pump motors , TECW, (condensate pumps and air compressors), and RECW (recirculation pumps, drywell chilled water, RWCU, and PASS). On a LOSW, the operators are directed to manually shutdown the plant. If they do not shutdown, there will be an eventual scram due to loss of air to the outboard MSIVs or due to loss of cooling to the condensate pumps and RFPs. CRD pumps are self-cooled and are credited.

(2) If the LOSW is accompanied by an ESF actuation signal or by a LOOP, then ESW will automatically start to supply ECCS room coolers, the RHR motor coolers, RCIC room cooler, and the control enclosure coolers. If just a LOSW occurs , then operators must manually start an ESW pump (OP-ESW). Check valves will open to supply ESW to the noted loads. Neither HPCI nor RCIC need room cooling for success. The HEP in the PRA for starting the ESW on LOSW is 0.01 to 0.03. The common cause failure probability of losing ESW given a LOSW is 0.01.

(3) Operators can also manually re-align additional loads to ESW once it is running: recirculation pump cooling, RECW, and TECW. This is currently not credited in the PRA, but is being considered for the next update.

(4) The LGS 97 PRA IE frequency for LOSW is 1.5 E-3 events per reactor-year.

(5) The Limerick IPE does give some credit for operator recovery of a failed SW system..

(6) LGS 97 PRA IPE gives an HEP of 5 E-4 for depressurization (DEP).

(7) LGS 97 PRA IPE gives an HEP of 0.1 to the actions necessary to cross tie RHR SW to LPCI.

Table 3.12 SDP Worksheet for Limerick — Interfacing System LOCA (ISLOCA) and LOCA Outside Containment (LOC)

Estimated Frequency (Table 1 Row) ________ Exposure Time __________ Table 1 Result (circle): A B C D E F G H

Initiation Pathways:	**Mitigation Capability: Ensure Component Operability for Each Pathway**
ISLOCA PATHWAYS:	
LPCI Injection Lines	Four lines: loops A & B have 2 MOVs and a check valve, loops C & D have 2 MOVs and 2 check valves.
Core Spray Injection Lines	Two injection lines, line A has 1 check valve and 2 MOVs; line B has 2 check valves and 2 MOVs
RHR Drop Line	A single line with 2 MOVs (HV-1F008 & HV-1F009)
LOC PATHWAYS:	
HPCI steam Line	Two MOVs HV-55-1F001 and HV-55-1F002
RCIC steam Line	Two MOVs HV-49-1F007 and HV-49-1F008
RWCU System Lines	
Feedwater Lines	Two lines each with one NO MOV (1FO0011A & B) and 3 check valves (1F010A & B, 1F074A & B, 1F032A & B)
Main Steam Lines	Four steam lines each with 2 MSIVs

Circle Affected Component in Pathways	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Pathway**	**Sequence Color**

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event: If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

<u>Notes</u>:

1. The initiation and applicable components are defined using generic insights based on NRC studies on ISLOCA. Some plant-specific additions were included.

2. This worksheet contains pathways for both ISLOCA and LOC. Licensees typically analyze these events separately, however the Limerick IPE did not.

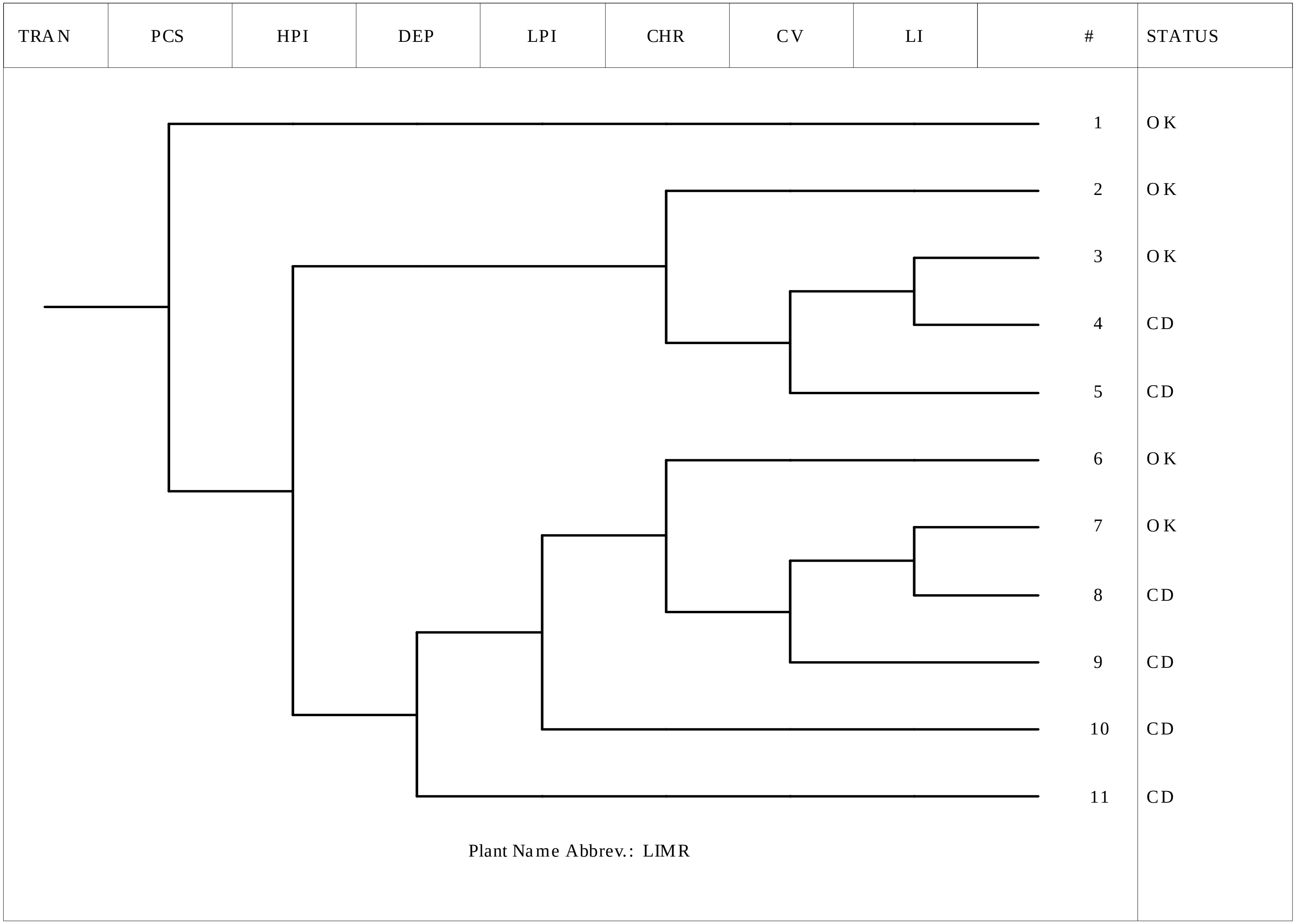
3. This worksheet is different from the other worksheets, in that ISLOCA is typically an unmitigated initiating event in most PRAs. Therefore the right side of the worksheet contains valves, whose failure may lead to an ISLOCA or LOC rather than mitigating systems to address an event in progress. As such, it is not intended to be referenced by the last column of Table 1.2, Initiators and System Dependency Table.

1.4 SDP Event Trees

This section provides the simplified event trees, called SDP event trees, used to define the accident sequences identified in the SDP worksheets in the previous section. The event tree headings are defined in the corresponding SDP worksheets.

The following event trees are included:

1. Transient (Reactor Trip) (TRANS)
2. Transients without PCS (TPCS)
3. Small LOCA (SLOCA)
4. Inadvertent Stuck Open Relief Valve (IORV/SORV)
5. Medium LOCA (MLOCA)
6. Large LOCA (LLOCA)
7. Loss of Offsite Power (LOOP)
8. Anticipated Transients Without Scram (ATWS)
9. Loss of a DC Bus (LODCI)
10. Loss of Service Water (LOSW)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PCS
HPI
DEP
LPI
CHR
CV
LI
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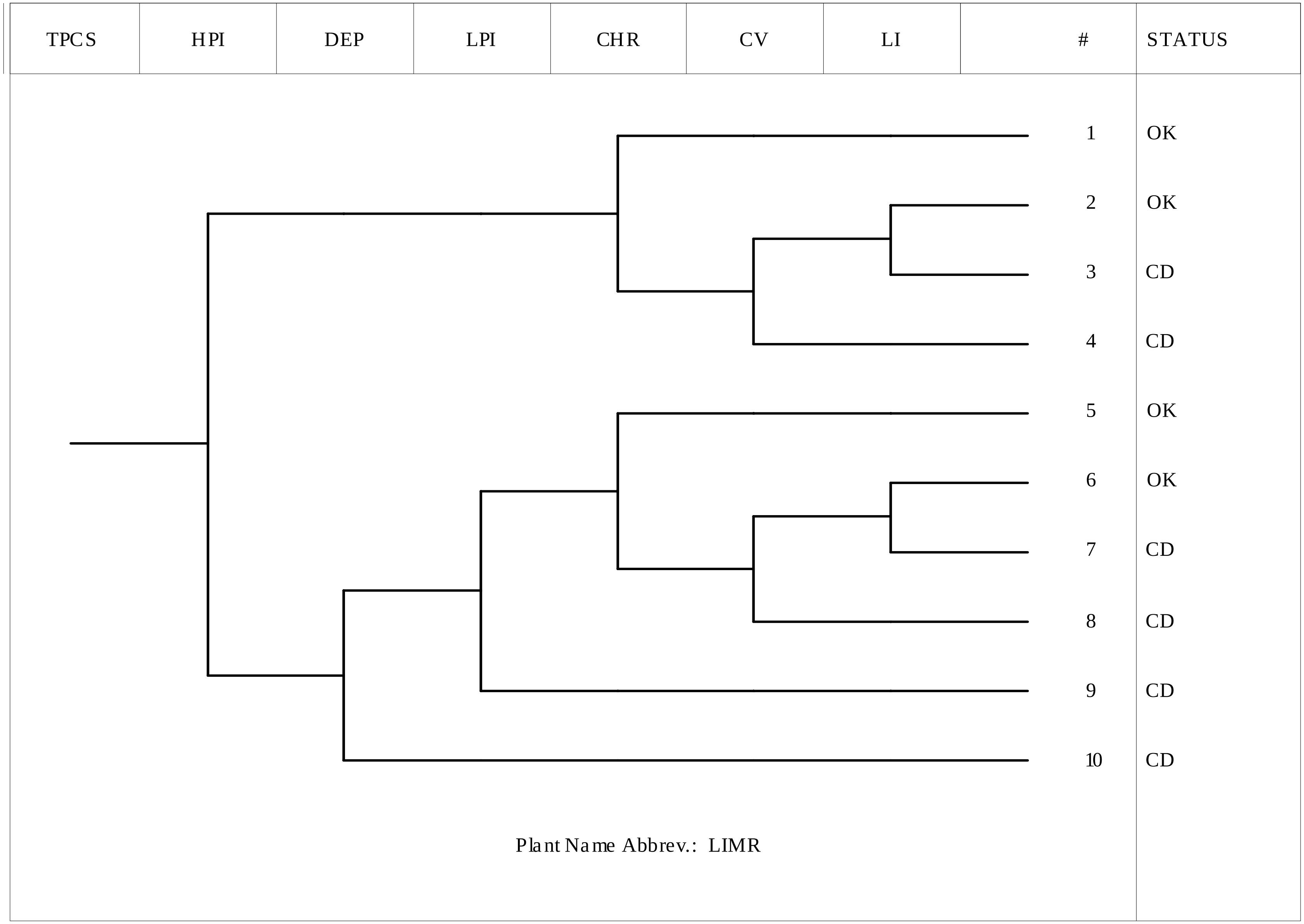
8 CD
9 CD
10 CD
11 CD
Plant Name Abbrev.: LIMR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DEP
LPI
CHR
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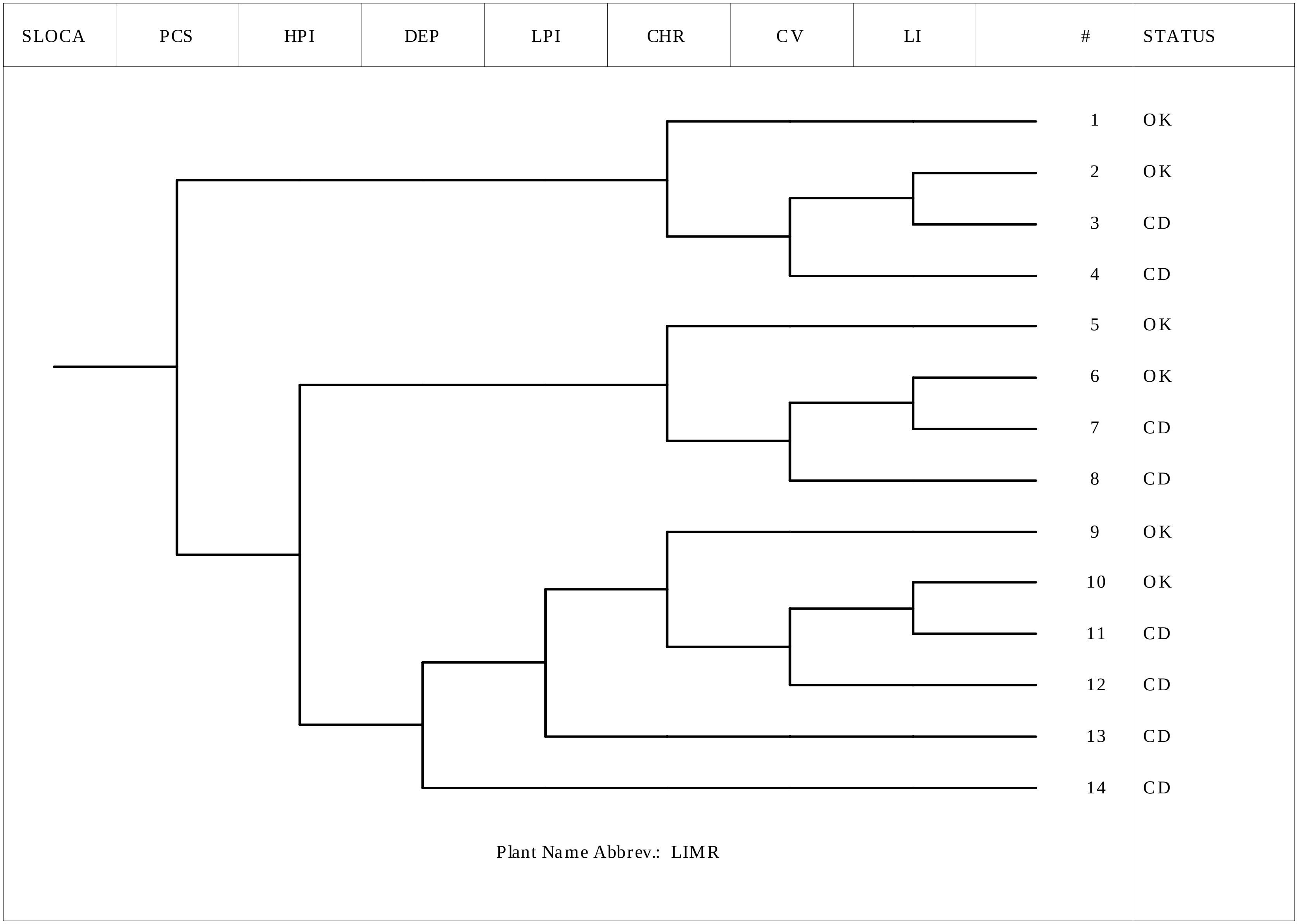
Plant Name Abbrev.: LIMR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DEP
LPI
CHR
CV
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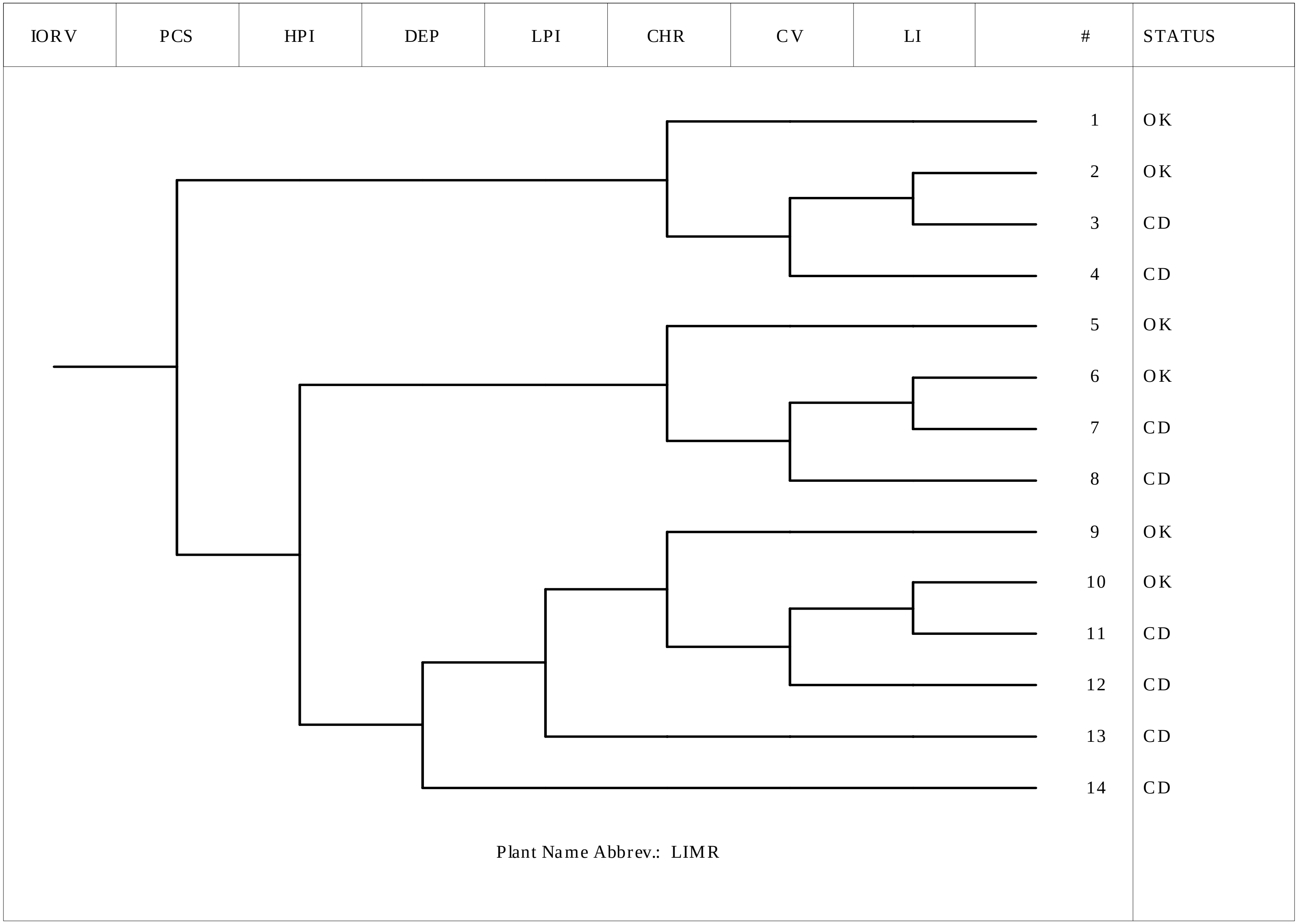
14 CD
Plant Name Abbrev.: LIMR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CV
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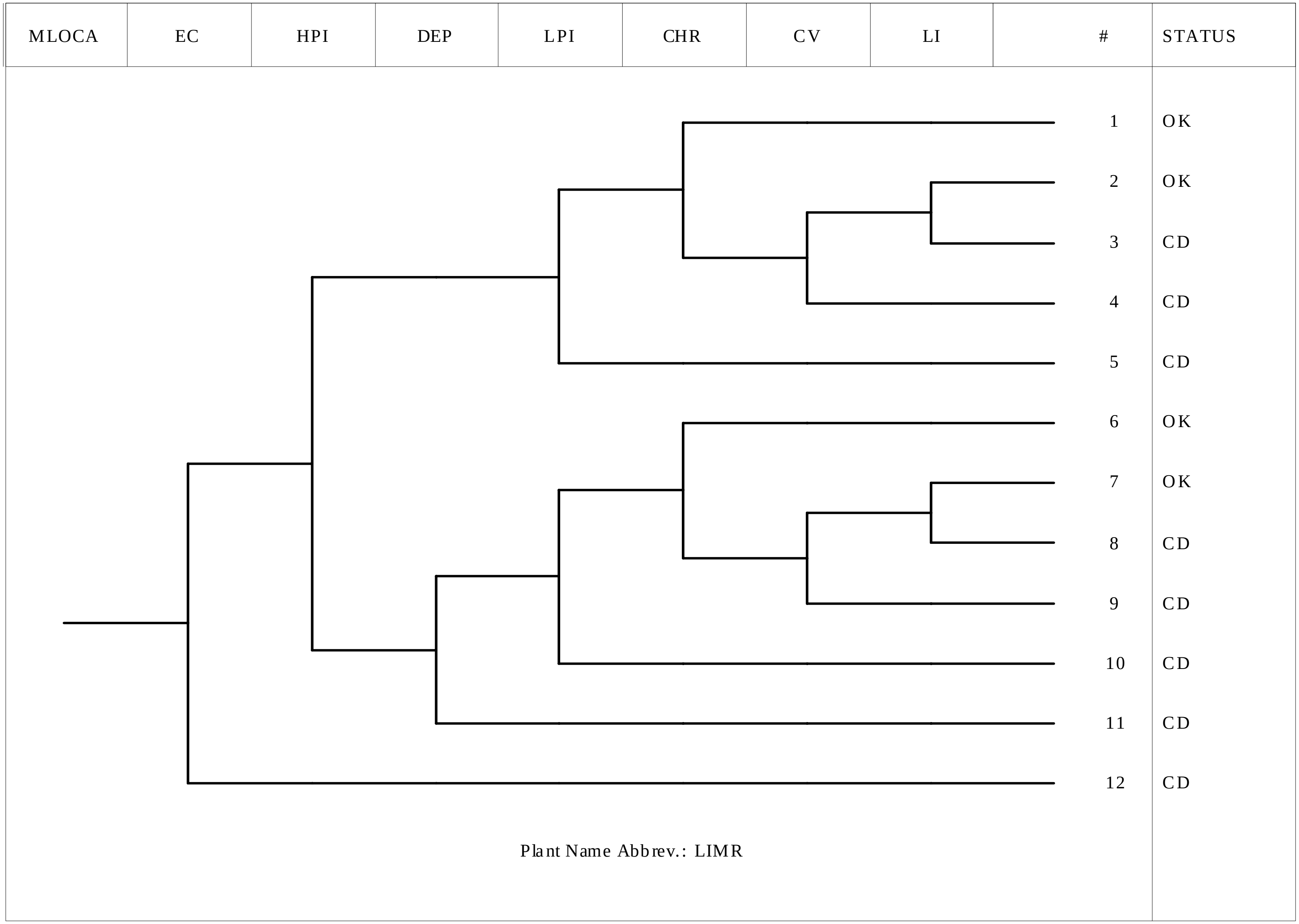
Plant Name Abbrev.: LIMR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CV
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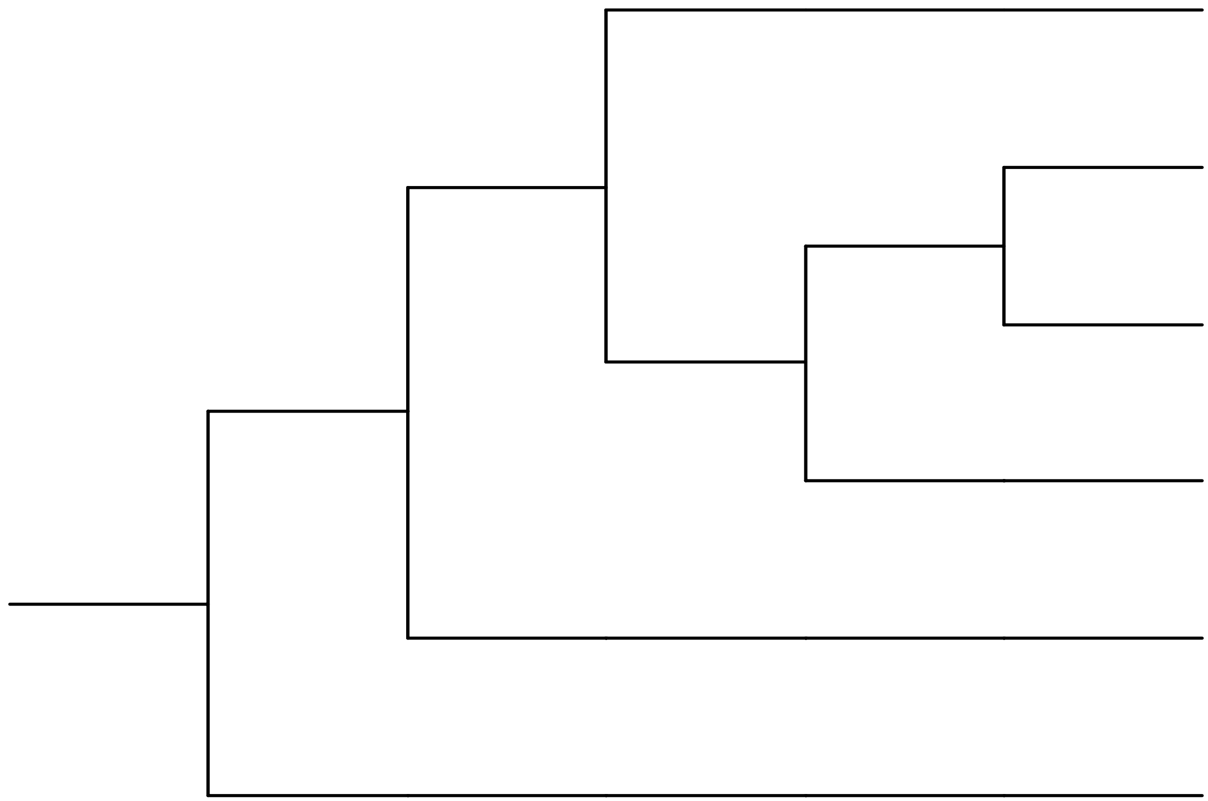
12 CD
Plant Name Abbrev.: LIMR

LLOCA	EC	LPI	CHR	CV	LI	#	STATUS



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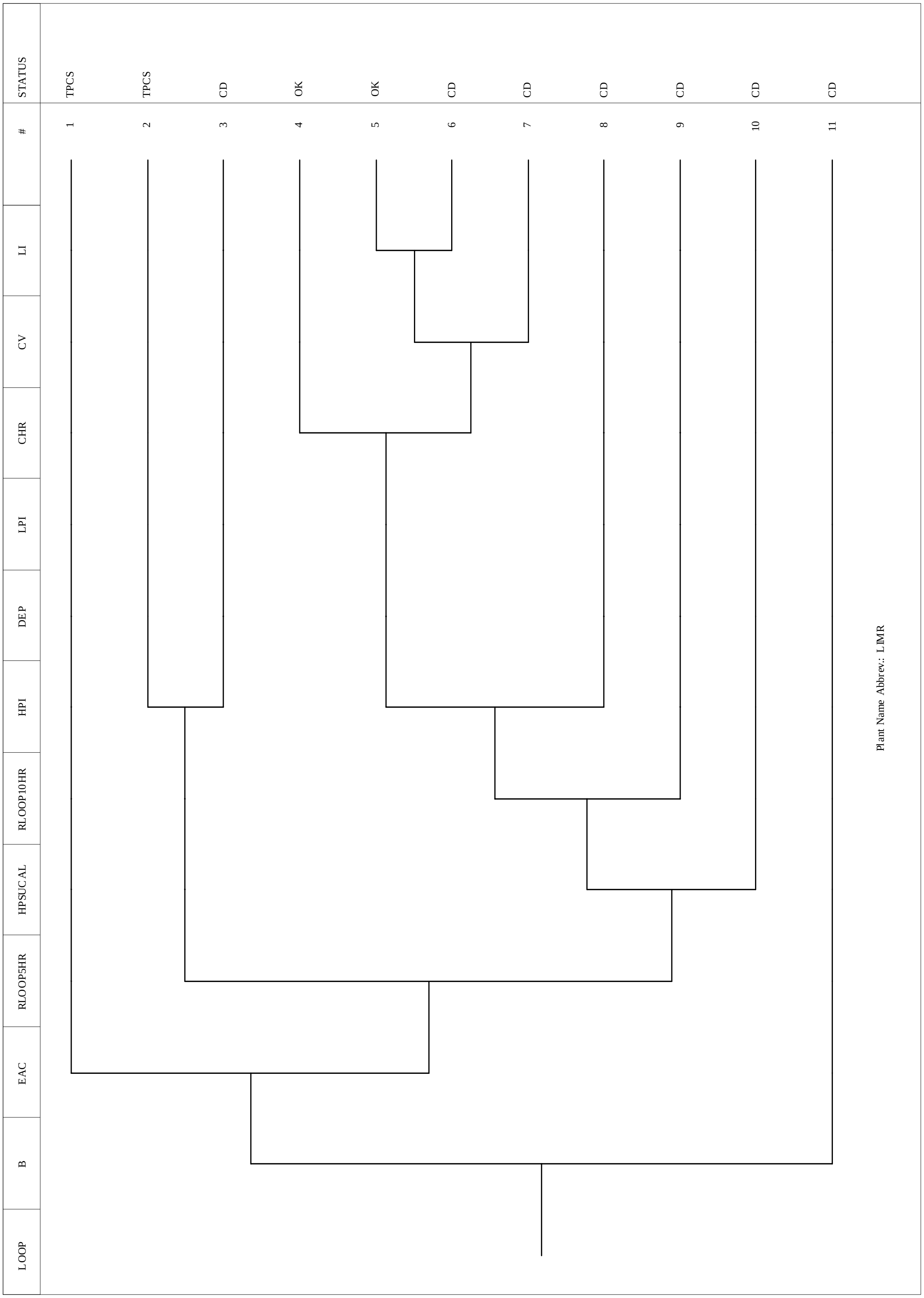
Plant Name Abbrev.: LIMR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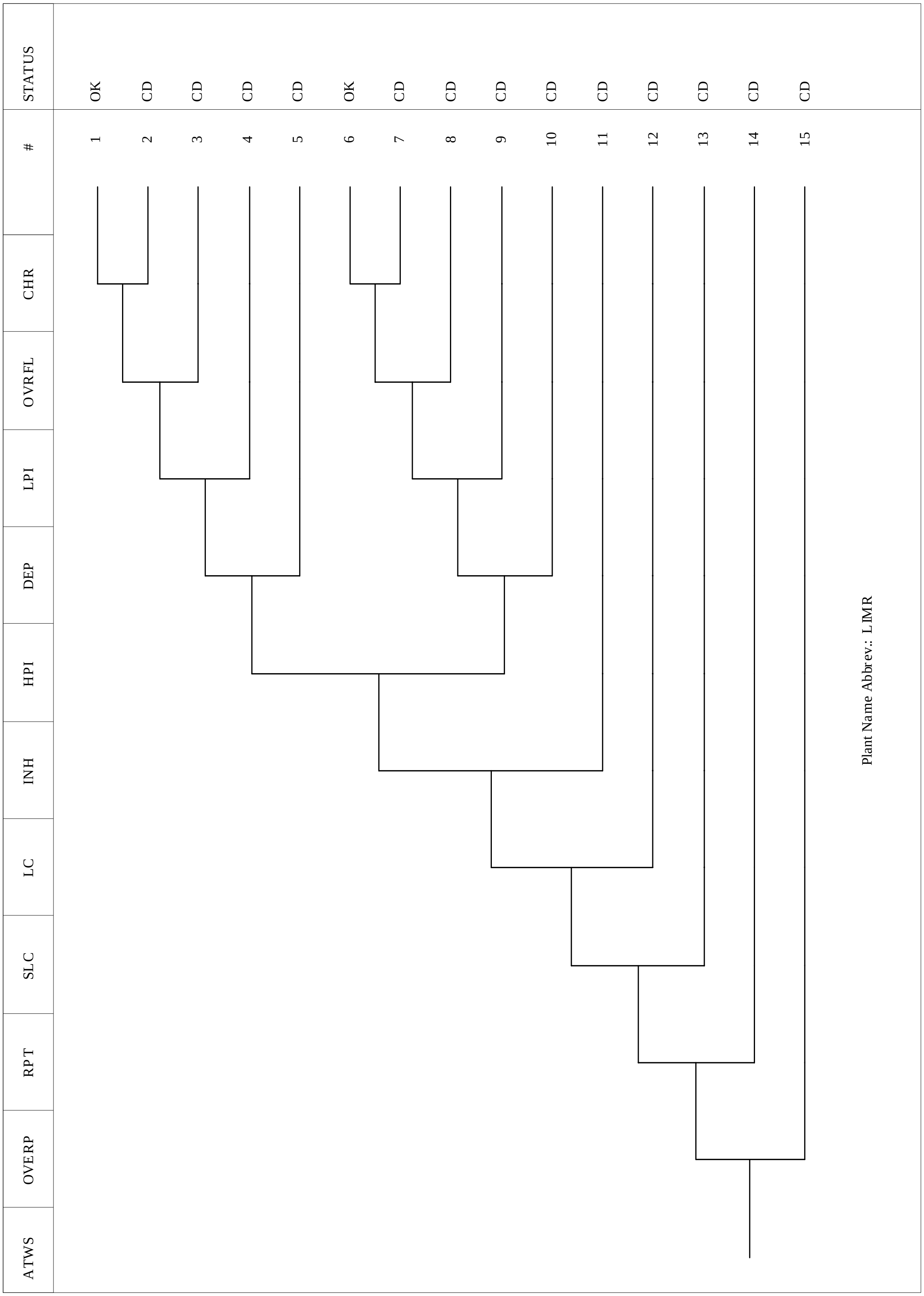
CD 6
CD 7
CD 8
CD 9
CD 10
CD 11
Plant Name Abbrev.: LMR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DEP
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SLC
RPT
OVERP
ATWS
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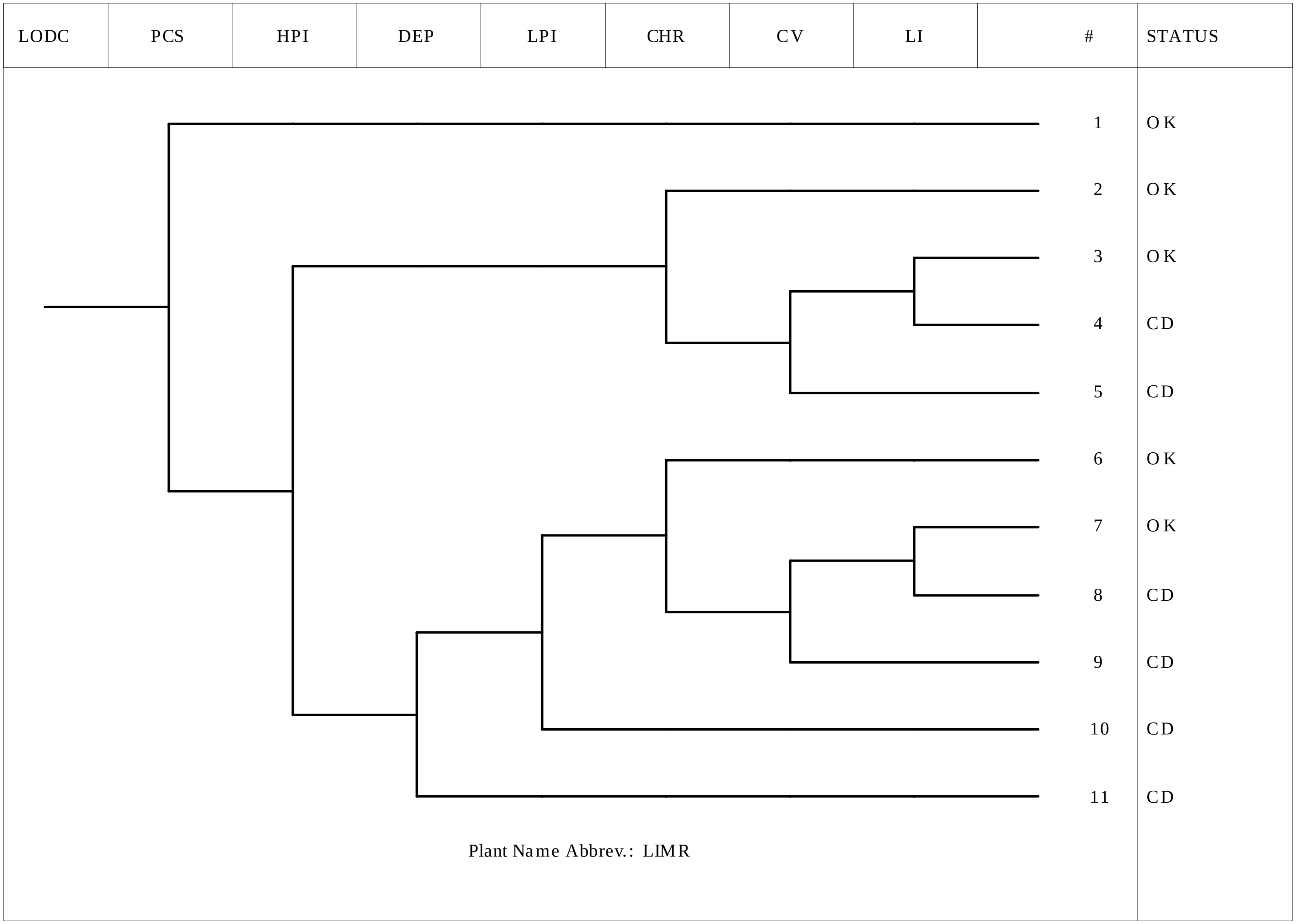
14 CD
15 CD
Plant Name Abbrev.: LIMR

-58-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PCS
HPI
DEP
LPI
CHR
CV
LI
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STATUS
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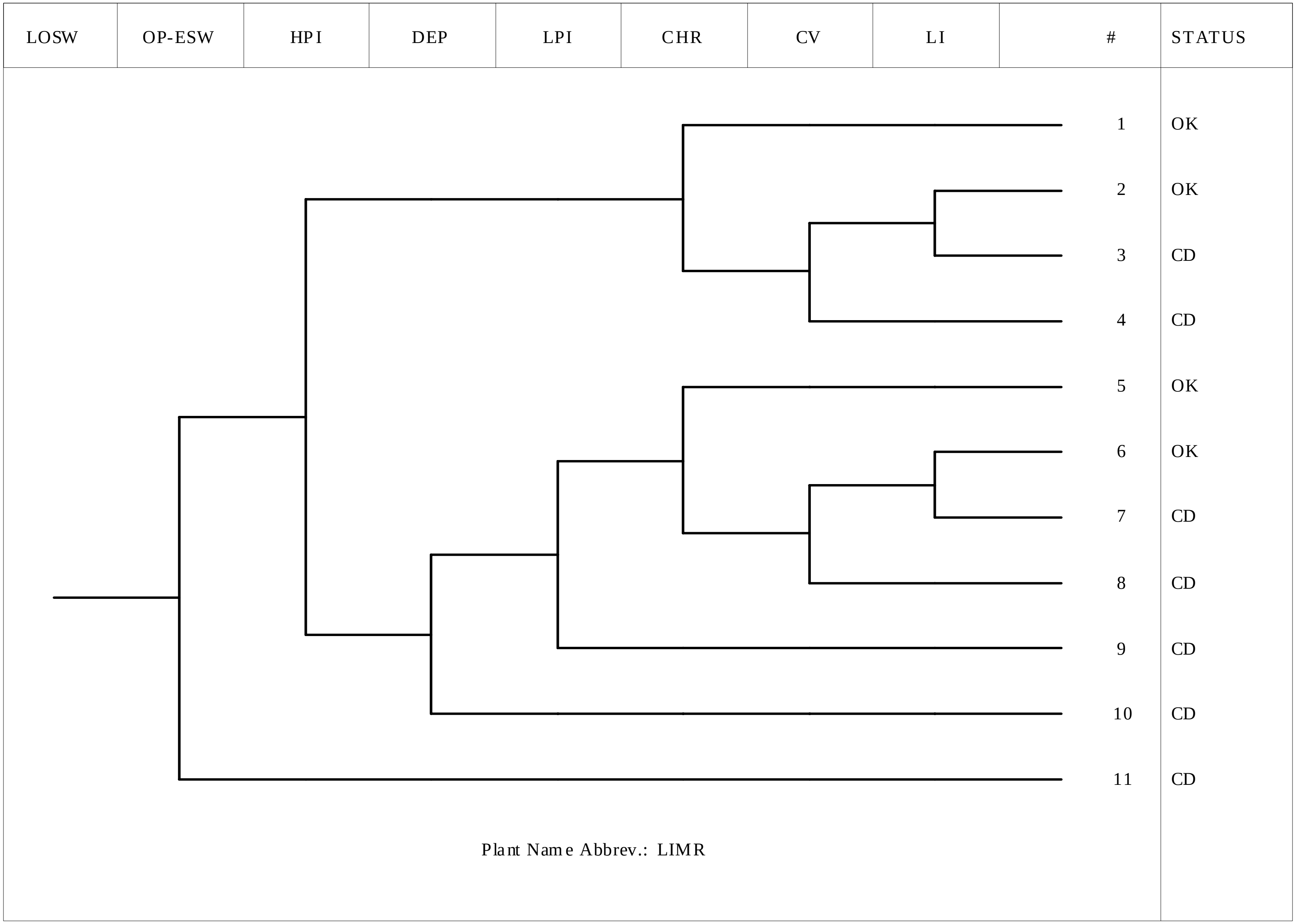
7 OK
8 CD
9 CD
10 CD
11 CD
Plant Name Abbrev.: LIMR


LOSW
OP-ESW
HPI
DEP
LPI
CHR
CV
LI
#
STATUS
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3 CD
4 CD
5 OK
6 OK
7 CD
8 CD
9 CD
10 CD
11 CD
Plant Name Abbrev.: LIMR

2. RESOLUTION AND DISPOSITION OF COMMENTS

This section is composed of two subsections. Subsection 2.1 summarizes the generic assumptions that were used for developing the SDP worksheets for the BWR plants. These guidelines were based on the plant-specific comments provided by the licensee on the draft SDP worksheets and further examination of the applicability of those comments to similar plants. These assumptions which are used as guidelines for developing the SDP worksheets help the reader better understand the worksheets' scope and limitations. The generic guidelines and assumptions for BWRs are given here. Subsection 2.2 documents the plant-specific comments received on the draft version of the material included in this notebook and their resolution.

2.1 GENERIC GUIDELINES AND ASSUMPTIONS (BWRs)

Initiating Event Likelihood Rating Table

1. Assignment of plant-specific IEs into frequency rows:

Transient (Reactor trip) (TRANS), transients without PCS (TPCS), small, medium, and large LOCA (SLOCA, MLOCA, LLOCA), inadvertent or stuck-open SRVs (IORV), anticipated transients without scram (ATWS), interfacing system LOCA (ISLOCA), and LOCA outside containment (LOC) are assigned into rows based on consideration of industry-average frequency. Plant-specific frequencies can be different, but are not considered. Plant-specific frequencies for LOOP and special initiators are used to assign these initiating events.

2. Inclusion of special initiators:

The special initiators included in the worksheets are those applicable for the plant. A separate worksheet is included for each of the applicable special initiators. The applicable special initiators are primarily based on the plant-specific IPEs. In other words, the special initiator included are those modeled in the IPEs unless it is shown to be a negligible contributor. In some cases, in considering plants of similar design, a particular special initiator may be added for a plant even if it is not included in the IPE if such an initiator is included in other plants of similar design and is considered applicable for the plant. Except for the interfacing system LOCA (ISLOCA) and LOCA outside containment (LOC), if the occurrence of the special initiator results in a core damage, i.e., no mitigation capability exists for the initiating event, then a separate worksheet is not developed. For such cases, the inspection focus is on the initiating event and the risk implication of the inspection finding can be directly assessed. For ISLOCA and LOC, a separate worksheet is included noting the pathways that can lead to these events.

3. Inadvertent or stuck open relief valve as an IE in BWRs:

Many IPEs/PRAs model this event as a separate initiating event. Also, the failure of the SRVs to re-close after opening can be modeled within the transient tree. In the SDP worksheet, these events are modeled in a separate worksheet (and, are not included in the transient worksheets) considering both inadvertent opening and failure to re-close. We typically consider a single valve is stuck or inadvertently open. The frequency of this initiator is generically estimated for all BWR plants. This IE may behave similar to a small or medium LOCA depending on the valve size, and the mitigation capability is addressed accordingly.

4. LOCA outside containment (LOC):

A LOCA outside of containment (LOC) can be caused by a break in a few types of lines such as Main Steam or Feedwater. LOC is treated differently among the IPEs. Separate ETs are usually not developed in the IPEs for LOCs. Thus, credit is usually not taken for mitigating actions. LOC sequences typically have a core damage frequency in the E-8 range. As such, LOCs are included together with ISLOCAs in a separate summary type SDP worksheet. Plant specific notes are included to explain how the particular IPE has addressed LOCs.

Initiating Event and System Dependency Table

1. Inclusion of systems under the support system column:

This table shows the support systems for the support and frontline systems. Partial dependency, which usually is a backup system, is not expected to be included. If included, they should be so noted. The intent is to include only the support system and not the systems supporting the support system, i.e., those systems whose failure will result in failure of the system being supported. Sometimes, some subsystems on which inspection findings may be noted have been included as a support system, e.g., EDG fuel oil transfer pump as a support system for EDGs.

2. Coverage of system/components and functions included in the SDP worksheets:

The Initiators and System Dependency Table includes systems and components which are included in the SDP worksheets and those which can affect the performance of these systems and components. One to one matching of the ET headings/functions to that included in the Table was not considered necessary.

SDP Worksheets and Event Trees

1. Crediting of non-safety related equipment:

SDP worksheets credit or include safety-related equipment and also, non-safety related equipment as used in defining the accident sequences leading to core damage. In defining the success criteria for the functions needed, the components included are typically those covered under the Technical Specifications (TS) and the Maintenance Rule (MR). No evaluation was performed to assure that the components included in the worksheets are covered under TS or MR. However, if a component was included in the worksheet, and the licensee requested its removal, it may not have been removed if it is considered that the components is included in either TS or MR.

2. No credit for certain plant-specific mitigation capability:

The significance determination process (SDP) screens inspection findings for Phase 3 evaluations. Some conservative assumptions are made which result in not crediting some plant-specific features. Such assumptions are usually based on comparisons with plants of similar design and to maintain consistency across the SDP worksheets of similar plant designs.

3. Crediting system trains with high unavailability

Some system component/trains may have unavailability higher than 1E-2, but they are treated in a manner similar to other trains with lower unavailability in the range of 1E-2. In this screening approach, this is considered adequate to keep the process simple. An exception is made for steam-driven components which are designated as automatic steam driven (ASD) train with a credit of 1, i.e., an unavailability in the range of !E-1.

4. Treating passive components (of high reliability) same as active components:

Passive components, namely isolation condensers in some BWRs, are credited similar to active components. The reliability of these components are not expected to differ (from that of active components) by more than an order of magnitude. Pipe failures have been excluded in this process except as part of initiating events where appropriate frequency is used. Accordingly, a separate designation for passive components was not considered necessary.

5. Defining credits for operator actions:

The operator's actions modeled in the worksheets are categorized as follows: operator action=1 representing an error probability of 5E-2 to 0.5; operator action=2 representing an error probability of 5E-3 to 5E-2; operator action=3 representing an error probability of 5E-4 to 5E-3; and operator action=4 representing an error probability of 5E-5 to 5E-4. Actions with error probability > 0.5 are not credited. Thus, operator actions are associated with credits of 1, 2, 3, or 4. Since there is large variability in similar actions among different plants, a survey of the error probability across plants of similar design was used to categorize different operator actions. From this survey, similar actions across plants of similar design are assigned the same credit. If a plant uses a lower credit or recommends a lower credit for a particular action compared to our assessment of similar action based on plant survey, then the lower credit is assigned. An operator's action with a credit of 4, i.e., operator action=4, is noted at the bottom of the worksheet; the corresponding hardware failure, e.g., 1 multi-train system, is defined in the mitigating function.

6. Difference between plant-specific values and SDP designated credits for operator actions:

As noted, operator actions are assigned to a particular category based on review of similar actions for similar design plants. This results in some differences between plant-specific HEP values and credit for the action in the worksheet. The plant-specific values are usually noted at the bottom of the worksheet, when available.

7. Dependency among multiple operator actions:

IPEs or PRAs, in general, account for dependencies among multiple operator actions that may be applicable. In this SDP screening approach, if multiple actions are involved in one function, then the credit for the function is designated as one operator action considering the dependency involved.

8. Crediting late injection (LI) following failure of containment heat removal (CHR), i.e., suppression pool cooling:

Following successful high or low pressure injection, suppression pool cooling is modeled. Upon failure of suppression pool cooling, containment venting (CV) is considered followed by late injection. Late injection is credited if containment venting is successful. Further, LI is required following CV success. The suction sources for the LI systems credited are different from the suppression pool. HPCI, LPCI, and CS are not credited in late injection. No credit is given for LI following failure of CV. The survival probability is low and such details are not considered in the screening approach here.

9. Combining late injection (LI) with low pressure injection (LPI) or containment venting (CV):

In some modeling approaches, LI is combined with LPI or CV. In the SDP worksheet approach here, these functions are separate. As discussed above, LPI and LI use different suction sources, and CV and LI may be two different categories of operator actions. In these respects, for some plants, SDP event trees may be different than the plant-specific trees.

10. Crediting condensate trains as part of multiple functions: power conversion system (PCS), low pressure injection (LPI), and late injection (LI):

Typically, condensate trains can be used as an LPI and LI source in addition to its use as part of the power conversion system. However, crediting the same train in multiple functions can result in underestimation of the risk impact of an inspection finding in the SDP screening approach since it does not account for these types of dependencies in defining the accident sequences. To simplify the process and to avoid underestimation, condensate train is not credited in LPI, but may be credited in LI.

11. Modeling vapor suppression success in different LOCA worksheets:

Vacuum breakers typically must remain closed following a LOCA to avoid containment failure and core damage. Some plants justify that vapor suppression is not needed for SLOCA. These sequences typically have low frequency and are not among the important contributors. However, an inspection finding on these vacuum breakers may make these sequences a dominant contributor. Accordingly, success of vapor suppression is included in the SDP worksheets. It is included for all three LOCA worksheets (LLOCA, MLOCA, and SLOCA); for plants presenting justification that they are not needed in a SLOCA appropriate modifications are made.

12. ATWS with successful PCS as a stable plant state:

Some plants model a stable plant state when PCS is successful following an ATWS. Following our comparison of similarly designed plants, such credits are not given.

13. Modeling different EDG configurations, SBO diesel, and cross-ties:

Different capabilities for on-site emergency AC power exist at different plant sites. To treat them consistently across plants, they are typically combined into a single emergency AC (EAC) function. The dedicated EDGs are credited following the standard convention used in the worksheets for equipment (1 dedicated EDG is 1 train; 2 or more dedicated EDGs is 1 multi-train system). The use of the swing EDG or the SBO EDG requires operator action. The full mitigating capability for emergency AC could include dedicated Emergency Diesel Generators (EDG), Swing EDG, SBO EDG, and finally, nearby fossil-power plants. The following guidelines are used in the SDP modeling of the Emergency AC power capability:

a) Describe the success criteria and the mitigation capability of dedicated EDGs.

b) Assign a mitigating capability of “operator action=1" for a swing EDG. The SDP worksheet assumes that the swing EDG is aligned to the other unit at the time of the LOOP (in a sense a dual unit LOOP is assumed). The operator, therefore, should trip, transfer, re-start, and load the swing EDG.

c) Assign a mitigating capability of “operator action=1" for an SBO EDG similar to the swing EDG. Note, some of the plants do not take credit for an SBO EDG for non-fire initiators. In these cases, credit is not given.

d) Do not credit the nearby power station as a backup to EDGs. The offsite power source from such a station could also be affected by the underlying cause for the LOOP. As an example, overhead cables connecting the station to the nuclear power plant also could have been damaged due to the bad weather which caused the LOOP. This level of detail should be left for a Phase 3 analysis.

14. Recovery of losses of offsite power:

Recovery of losses of offsite power is assigned an operator-action category even though it is usually dominated by a recovery of offsite AC, independent of plant activities. Furthermore, the probability of recovery of offsite power in “X” hours (for example 4 hours) given it is not recovered earlier (for example, in the 1st hour) would be different from recovery in 4 hours with no condition. The SDP worksheet uses a simplified approach for treating recovery of AC by denoting it as an operator action=1 or 2 depending upon the HEP used in the IPE/PRA. A footnote highlighting the actual value used in the IPE/PRA is provided, when available.

15. Mitigation capability for containment heat removal:

The mitigation capability for containment heat removal (CHR) function is considered dominated by the hardware failure of the RHR pumps. The applicable operator action is categorized as an operator action with a credit 4, i.e., operator action=4. For this situation, the function is defined as 1 multi-train system since the operator action involved is considered routine and reliable, and is assigned a credit of 4. No other operator action in the worksheets is generically assigned this high credit.

16. Crediting CRD pumps as an alternate high pressure injection source:

In many plants, CRD pumps can be used as a high pressure injection source following successful operation of HPCI or RCIC for a period of time, approximately 1 to 2 hours. In some plants, CRD system is enhanced where it can be directly used and does not need the successful operation of other HPI sources. In the worksheets, if the CRD pumps require prior successful operation of HPCI or RCIC as a success criteria, then CRD is not credited as a separate high pressure injection source. If the CRD can be used and does not require successful operation of HPCI or RCIC, then it is credited as a separate success path within the HPI function.

2.2 RESOLUTION OF PLANT-SPECIFIC COMMENTS

This section documents the comments received on the material included in this report and their resolution.

Comments on Initiator and System Dependency Table

Split the line entry for Instrument Air and Instrument Gas

Revised the support systems as per licensee comments

Added a few items to the major components for selected systems

Added information on the new 1997 Limerick PRA (LGS 97)

Indicated that HVAC room coolers are not required for HPCI or RCIC operations.

Comments on Worksheets

Added LGS 97 initiating event frequencies for LOOP, LODC, and LOSW.

Dropped credit for LI after CV failure throughout the worksheets.

Added information for mitigating systems details on PCS, LPCS, CRD, & LI systems.

Added some information on Unit 1 and Unit 2 differences.

Updated HEPs for LGS 97 PRA.

Limerick gives credit for LI success to prevent core damage on EC failure during MLOCA. NRC considers this action unlikely and generically does give credit, thus credit is not provided here.

On the LOOP event tree Limerick requested a reordering of the top events to place HPI prior to RLOOP. We have maintained the standard order with RLOOP then HPI. This creates no notable differences in the sequences.

Limerick requested that 1/4 RHR pumps in the LPCI mode and 1/4 EDGs be credited as two multi-train systems. Generically at all BWRs these are credited as only one multi-train system.

Limerick takes credit for condensate as LPI on ATWS, however generically NRC is not allowing any credit in the notebooks for PCS components.

Limerick has dropped the ATWS-RPT sequence with no explanatory justification. This sequence has been maintained pending adequate justification.

Added an ISLOCA and LOCA outside containment (LOC) worksheet.

REFERENCES

1. NRC SECY-99-007A, Recommendations for Reactor Oversight Process Improvements (Follow-up to SECY-99-007), March 22, 1999.

2. Philadelphia Electric Company, Limerick IPE submittal, July, 1992.

3. Limerick PRA model revision LGS 97.