

# Development of Protective Action Recommendation Logic for use during a General Emergency

Proposed Revision to NUREG-0654, FEMA-REP-1, Supp.3 11/13/08

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## Introduction

In late 2004, the Nuclear Regulatory Commission (NRC) staff initiated a project with Sandia National Laboratories to analyze the relative efficacy of alternative protective action recommendation (PAR) strategies in reducing consequences to the public from a spectrum of nuclear plant core melt accidents. The study results are documented in NUREG/CR-6953, Vols. 1 & 2 "Review of NUREG-0654, Supplement 3, Criteria for Protective Action Recommendations for Severe Accidents," (informally, the PAR Study). The PAR Study provides a technical basis for improving NRC PAR guidance.

A draft of NUREG/CR-6953 was provided to the Advisory Committee on Reactor Safeguards (ACRS) for review. ACRS documented their review in a July 27, 2007, letter to the Nuclear Regulatory Commission (ADAMS Accession No. ML071980087) concluding that NUREG-0654 Supplement 3 should be revised. ACRS also recommended that PAR strategies should not become overly complicated such that they slow down decision making during emergencies. The staff agreed with the ACRS recommendations.

The PAR Study analyzed the relative efficacy of alternative PAR strategies for the protection of public health and safety during a spectrum of core melt accidents. The staff selected a series of source terms and evaluated the potential consequences to the public under the various strategies. Three General Emergency accident conditions were analyzed:

- Rapidly progressing severe accident;
- Progressive severe accident; and
- Severe accident without loss of containment.

It should be noted that rapidly progressing severe accidents are very unlikely to occur but are currently required to be addressed as an important element of the emergency preparedness planning basis.

The PAR Study staff examined various PAR strategies for each of the three General Emergency accident conditions:

1. Immediate radial evacuation (current strategy);
2. Lateral evacuation (perpendicular to the plume);
3. Staged evacuation (close-in population leaves first, others shelter-in-place);
4. Shelter-in-place followed by radial evacuation;
5. Shelter-in-place followed by lateral evacuation;
6. Preferential sheltering (in large public structures) followed by radial evacuation; and
7. Preferential sheltering followed by lateral evacuation.

The PAR Study staff modeled a hypothetical site with generic weather and a population of about 80,000 based on 100 residents per km<sup>2</sup> in the 10-mile emergency planning zone (EPZ). The relative benefit of alternative PAR strategies was compared to the current strategy and reported qualitatively.

Many of the PAR Study results suggest that the NRC should consider improvement of its PAR guidance. A synopsis of results follows:

- Radial evacuation (away from the plant) should remain the major element of protective action strategies.
- Sheltering-in-place should receive more emphasis in protective action strategies. For sites with long evacuation times under rapidly progressing severe accident conditions, sheltering-in-place provides more protection than immediate evacuation. According to the PAR Study, sites with evacuation times longer than about 4 hours should implement initial sheltering followed by evacuation for rapidly progressing severe accident scenarios. However, a site-specific analysis should be performed to determine the appropriate strategy.
- Staged evacuation, wherein the public close to the plant is evacuated first while those further out shelter-in-place, should be considered because it is more protective than immediate radial evacuation. Although in some scenarios the improved efficacy of staged evacuation is not large, the strategy decreases demand on offsite response organization resources as well as disruption to the public.
- Precautionary protective actions such as evacuating schools and parks during a Site Area Emergency (SAE) are prudent.
- Strategies that reduce evacuation time reduce consequences. The NRC has drafted rulemaking and guidance to enhance licensee assessment of evacuation issues.
- Evacuation time estimates (ETE) are important in preplanning PAR strategies. The NRC has drafted rulemaking to enhanced regulatory oversight of ETEs.
- Advance planning for the evacuation of special needs populations that do not reside in special facilities may not be consistently addressed within all nuclear plant EPZs. This issue warrants additional review to determine extent.

These results guide revision of NUREG-0654 Supplement 3, which was first published in July 1996, as a draft report for interim use and comment. Additional insights from the PAR Study, as well as input from State and local government emergency response professionals, stakeholders, and industry, have been considered in the development of revised guidance.

In addition to the technical analyses documented in NUREG/CR-6953 Vol. 1, the staff has conducted a public telephone survey of plume exposure pathway emergency planning zone (EPZ) populations. The public survey provided information on the tendencies of this population with respect to emergency response. These insights have assisted the staff in improving the PAR guidance. The staff published the survey results as NUREG/CR-6953 Vol. 2.

## **Previous Guidance**

The guidance of this Supplement to NUREG-0654 supersedes all previous guidance on the development of PAR logic for nuclear plant accidents. This includes the guidance contained in Appendix 1 of NUREG-0654, FEMA-REP-1 Rev.1 "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power

Plants,” published in November 1980 and NUREG-0654, FEMA-REP-1 Rev. 1, Supp. 3, “Criteria for Protective Action Recommendations for Severe Accidents,” published in July 1996 as a “Draft Report for Interim Use and Comment”. 10 CFR 50.47(b)(10) states: “Guidelines for the choice of protective actions during an emergency, consistent with Federal guidance, are developed and developed and in place...” This supplement is considered as the “Federal guidance” referred to in the regulation and it will be used to determine compliance with 50.47(b)(10). It should be noted that there is no intent to affect the protective action guidelines developed and promulgated by the Environmental Protection Agency (EPA). The EPA protective action guides remain the appropriate federal guidance on radiological criteria for consideration of protective actions.

## **Implementation of Guidance**

The PAR Logic Diagram contained in Attachment 1 of this supplement should be used to develop a site-specific PAR logic diagram for use by the licensee emergency response organization. **It is not intended to be used without site-specific modification.** The site-specific PAR logic diagram is expected to be contained in emergency plan implementing procedures used by the nuclear plant emergency response organization. The procedure used by shift personnel and that used by the augmenting organization may differ, reflecting the expectation that the augmenting organization should be available to implement portions of the logic diagram that take place well after the initial General Emergency declaration and notification of offsite response organizations.

The notes supporting the PAR Logic Diagram contain direction for the development of site-specific elements and criteria that replace the general guidance of the diagram. The diagram will be simplified when the site-specific elements are developed and the diagram is deployed in an emergency plan implementing procedure.

Each site is expected to determine the evacuation time estimate for the 2 mile radius and to perform a dose based analysis to determine whether evacuation or shelter-in-place is the appropriate PAR for the unlikely large early release scenario. It is expected that only sites with higher population densities would have to consider the use of shelter-in-place rather than immediate evacuation in this scenario. However, those sites that implement protective action strategies that create long evacuation times for the public within the 2 mile radius would have to consider the efficacy of initial shelter-in-place for this scenario. One example of a strategy that may create long evacuation times within the 2 mile radius is the immediate evacuation of the whole plume exposure emergency planning zone (EPZ) without consideration of wind direction, projected doses or severity of accident. Appendix 2 of this supplement provides assumptions suitable for use in these analyses. Other assumptions may be used if appropriately justified.

This guidance suggests that nuclear plant operators and the offsite response organization (ORO) responsible for implementing protective actions discuss and agree to various elements and criteria of the PAR Logic Diagram. However, in no case is it intended that nuclear plant operators delay the recommendation of protective actions pending discussions with OROs at the time of a General Emergency. OROs have the responsibility to decide which protective actions to implement. Operators have the responsibility to make timely PARs in accordance with federal guidance and plant conditions. Operators must provide timely PARs to OROs so as to allow them to make timely and well informed decisions.

It is expected that nuclear plant operators will develop PAR procedures that embody ORO input at the various decision points where it is called for in the guidance. The agreement should be made in terms of criteria that can be put into the logic diagram. This criteria and the approved PAR logic diagram in plant emergency plan implementing procedures is the plant commitment to OROs of what PARs will be provided immediately upon the declaration of a General Emergency. In the rare case where a responsible ORO chooses not to participate in the development of a site specific PAR Logic Diagram in accordance with this guidance, the licensee may use ORO emergency plans and or implementing procedures as a basis to develop the necessary decision points.

### **Implementation of the PAR Logic Diagram at a General Emergency**

Licensees are expected to provide immediate notification to OROs upon the declaration of an emergency. In the case of a General Emergency declaration the notification must be accompanied by a PAR. The PAR must be developed in accordance with approved site emergency plan implementing procedures. The previous guidance of Supp. 3 noted that it was to be used for severe accidents. In practice this was translated into the expectation that it would be used for General Emergencies. However, it should be noted that the emergency action level schemes approved by NRC are conservative. A General Emergency is a serious event and warrants a protective action offsite, but it is not necessarily synonymous with a severe accident as the term is used in nuclear plant accident consequence analyses. This guidance recognizes that disparity and requires evacuation (or shelter-in-place as appropriate) of the closest population but provides a decision point for increase of protective actions after that initial protective action. General Emergencies are very unlikely events. That one would be followed by severe core melting is even more unlikely and that containment would rapidly fail is still more unlikely. The PAR Logic Diagram in this guidance reflects this probabilistic perspective in a qualitative manner, while requiring escalated protective actions when appropriate.

### **Termination of Protective Actions**

It is not the responsibility of the licensee to make any recommendation for terminating protective action direction already given to the public. That protective action should not be terminated until fully discussed among responsible state and local officials with the licensee supplying input regarding plant status.

### **Definition of Terms**

- **“Shelter-in-place”** is intended to mean that instructions are given to remain indoors, turn off ventilation (as appropriate for the region and season), seal windows, monitor communications channels and prepare to evacuate. The instructions should also specify that shelter-in-place is safer than evacuation at this time or, alternately, that others more immediately threatened are evacuating and the roads should remain open for them. The intent is that the public remain where they are or seek shelter close by but not return home to shelter. Communications with the sheltered population must be clear and often to be effective.
- **“Heightened Preparedness”** is intended to mean that the population within the plume exposure emergency planning zone is informed of the serious emergency at the nuclear plant, told that they should monitor the situation and to prepare for the possibility of evacuation, shelter-in-place and/or other protective actions. Further, if an evacuation is taking place, the public not involved should be asked to stay off the roads to allow those

immediately threatened to evacuate. Communications with this population must be clear and often to be effective.

### **Precautionary Protective Actions at Site Area Emergency**

The NRC does not require that precautionary protective actions be recommended by licensees to OROs at a Site Area Emergency declaration. It was apparent for the accidents analyzed in the PAR Study that precautionary protective actions taken earlier than a General Emergency would reduce consequences. However, a review of 4 actual Site Area Emergencies that have taken place since 1980 shows that none of them required offsite protective actions. Some of these emergencies were declared due to an overly conservative emergency action level scheme that has largely been replaced at nuclear plants. Site Area Emergencies are rare and likely to be even rarer in the future due to this enhancement.

The OROs at many sites already take precautionary protective actions upon declaration of a Site Area Emergency. These actions include sounding sirens, informing the population that an event has taken place at the site, evacuating schools, closing parks and preparing special needs facilities for potential evacuation. Based on the PAR Study and the historical record, it can be noted that precautionary protective actions are prudent only for a Site Area Emergency that is a precursor to a more serious event and that such an event has not occurred in the past 300 years of power reactor operations since the Three Mile Island accident (~30 years and 100 reactors). However, such an accident is part of the emergency preparedness planning basis and licensees are required to be prepared for such an event. It is expected that operators will likely be able to discern whether a Site Area Emergency is potentially a precursor to a more serious accident or as in the 4 historical cases that core damage is not likely.

It is recommended that OROs consider the implementation of precautionary protective actions appropriate for their locale at a Site Area Emergency declaration after conferring with licensee personnel regarding the nature of the event and likelihood of core degradation. Should operators be unable to provide this assessment it is prudent to implement precautionary protective actions. It is not recommended that these precautions be automatic at Site Area Emergency.

### **Analysis of the Efficacy of Sheltering versus Evacuation for Large Early Release Scenarios**

Attachment 2 provides the assumptions that are to be used to evaluate whether sheltering or evacuation results in reduction of population dose in the large early release scenario. Other methods may be used if sufficiently justified. Sites with evacuation time estimates that are more timely than the criteria below need not perform the calculation and may just assume that evacuation is the appropriate PAR in this scenario (assuming no impediment to evacuation):

- Plume exposure EPZ (10 mile 360 degree) evacuation in less than 6 hours or
- 2 mile radius evacuation in less than 90 minutes

Assumptions:

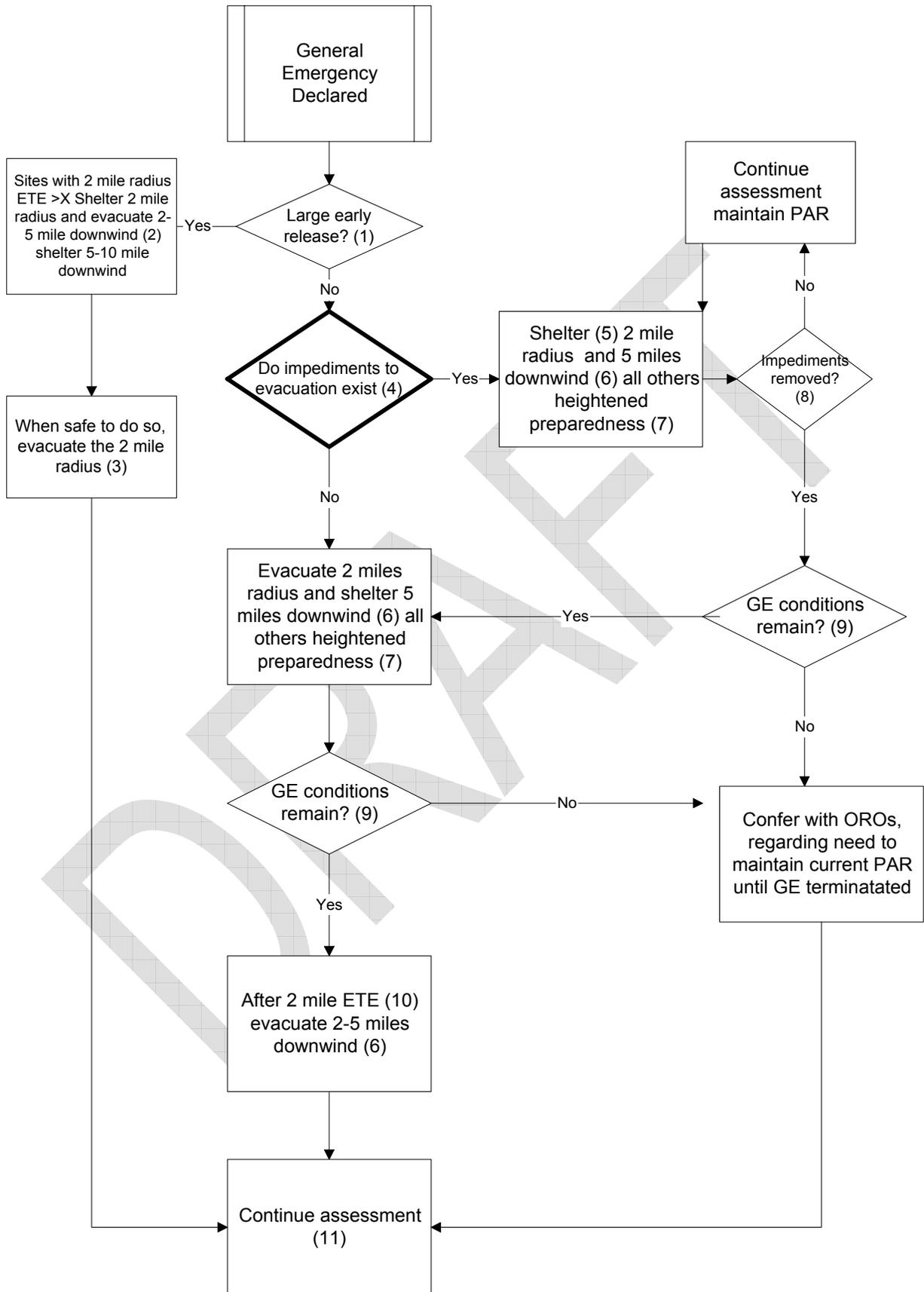
- Use evacuation times for 90% of the general public, not including special needs populations (i.e., without the “tail” of the evacuation),
- Evening hours,

- Normal weather

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Attachment 1  
Protective Action Logic Diagram

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## Protective Action Recommendation Logic Diagram Notes

### Note 1

- Large early release: This is a General Emergency (GE) with rapid loss of containment integrity and loss of ability to cool the core. This element is only used for those unlikely scenarios where containment integrity can be determined as bypassed or immediately lost during a GE. If this scenario can not be identified, assume it is not taking place and answer “no” to this decision block.

### Note 2

- Initial sheltering is only appropriate for sites with longer evacuation times (see implementation guidance to establish actual site specific criteria) otherwise immediate evacuation of the 2 mile radius and 5 mile downwind sectors is appropriate. However, sites with longer evacuation times must perform an analysis to determine whether initial sheltering is more protective than immediate evacuation for large early releases. It is expected that only sites with high population density within 2 miles would shelter.

### Note 3

- Evacuation after the initial sheltering period is critical to reducing public exposure. However, the large early release scenario can not be precisely characterized in advance. While the worst case scenario is known, it is extremely unlikely and should not be used as the sole model. In general, accident analyses show that the source term is expected to be initially large and that it will be reduced within a few hours due to exhaustion of the available radionuclide. Mitigative actions may also be implemented to reduce the source term. While the timing of this reduction can not be specified, the licensee must identify when it would be safer for the 2 mile radius to evacuate. This is expected to be within 4 hours but a set time can not be specified and the determination would be based on information available to the licensee.

It is also expected that evacuation of the sheltered population would be discussed with OROs and plans made for rapid evacuation of the public through potentially contaminated areas. It should be noted that lateral evacuation could reduce exposure if plume meander has been minimal.

### Note 4

Impediments include:

- Evacuation support not yet in place: e.g., the GE is the initial notification to offsite response organizations or if there is a previous emergency classification notification, the GE notification occurs prior to preparations to support evacuation. However, many sites have a low population density within 2 miles and evacuation support readiness will not ever be considered an impediment. This element must be discussed and agreed to with OROs. The expected time for evacuation support to be put in place should be agreed to with OROs in advance and embodied in the site-specific PAR logic diagram for those sites where delay of a 2 mile radius evacuation is necessary pending support set up. The licensee would base the recommendation on the agreement and would not confer with OROs on this matter before making the initial PAR.

- Hostile action event: Many OROs consider that initial sheltering is preferred in this type of event. This element would be discussed and agreed to with OROs. The licensee would base the recommendation on the agreement and would not confer with OROs before making the initial PAR.
- Licensees are not responsible to solicit information or make a determination if weather or other impediments (e.g., earthquake, wildfire) to safe public evacuation exist at the time of the emergency. However, the licensee will consider an impediment to exist if OROs notified the licensee that an impediment exists, e.g., roads are closed due to deep snow.

Note 5

- **“Shelter-in-Place”** is intended to mean that instructions are given to remain indoors, turn off ventilation (as appropriate for the region and season), seal windows, monitor communications channels and prepare to evacuate. The instructions should also specify that sheltering is safer than evacuation at this time or, alternately, that others more immediately threatened are evacuating and the roads should remain open for them. Communications with the sheltered population must be clear and often to be effective.

Note 6

- Downwind sector(s) and adjacent sectors
- Site specific wind persistence analysis may indicate the need to include additional sectors with initial recommendation. This element must be discussed and agreed to by OROs.

Note 7

- **“Heightened Preparedness”** is intended to mean that the population within the plume exposure emergency planning zone is informed of the serious emergency at the nuclear plant, told that they should monitor the situation and to prepare for the possibility of evacuation, sheltering and/or other protective actions. Further, if an evacuation is taking place, the public not involved should be asked to stay off the roads to allow those immediately threatened to evacuate. Communications with this population must be clear and often to be effective.

Note 8

- In the case where the impediment was time to set up evacuation support (high population site): When the agreed to time has elapsed (e.g., 1 hour) for evacuation support to be in place the PAR should be changed. It is not intended that licensees would confer with OROs prior to changing the PAR.
- In the case where the impediment was a hostile action event: Within 1 hour of the initial PAR, the licensee must discuss with OROs whether the sheltering PAR should be changed. This will be dependant on plant status as well as local law enforcement support obtained by OROs. This activity may be accomplished by the licensee augmented emergency response organization if they are functional.
- In the case where the impediment was due to weather or other causes: If the licensee and OROs have agreed that OROs are responsible to determine evacuation route impediments, the licensee has no responsibility for further PARs unless plant or

meteorological conditions change. OROs will determine when it is safe for the public to evacuate. If this agreement has not been reached, then the licensee is responsible to confer with OROs to determine whether evacuation route impediments have been removed and evacuation of the 2 mile radius is safe.

#### Note 9

- Once a General Emergency is declared termination will not likely occur for some time. However, if the conditions that caused the declaration are ameliorated, (i.e., core cooling is restored) it may not be necessary to expand the PAR to evacuate additional areas. The criteria to be embodied in the site-specific PAR logic diagram are:
  - Core cooling not established or
  - Release is probable or occurring and dose projections show protective action guidelines likely to be exceeded in areas not evacuated or
  - Dose projections from a previous release show that protective action guidelines will be exceeded.

#### Note 10

- Expand the evacuation to the downwind sectors when the time estimate for the 2 mile radius evacuation has lapsed. This may be less than 90 minutes for many sites. The licensee is expected to make this PAR without conferring with OROs and it is not based on verification of evacuation progress.

#### Note 11

- Continue radiological and meteorological assessment and evacuate any areas where dose projections or field measurements indicate that protective action guidelines are likely to be exceeded. Shelter additional areas as appropriate. Maintain heightened preparedness. OROs should communicate often with the public while protective actions are in effect.
- Continue plant assessment to determine if accident conditions warrant changes to PAR.

## Attachment 2

### **Assumptions for Analysis of the Efficacy of Sheltering versus Evacuation for Large Early Release Scenarios**

The calculation methods described in US NRC Regulatory Guide 1.183 "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," July 2000 may be used for this analysis with the following qualifications:

- The analysis need only be performed for the 2 mile radius,
- Containment is considered immediately bypassed or failed
- Physical processes such as plate out may be considered
- Only the large LOCA scenario need be analyzed

Once the source term is developed the licensee must use a dose analysis tool that simulates population movement or sheltering. MACCS2 (reference) is one such tool, but other accepted software may be used. The site evacuation time estimate should be used for data on evacuation timing and speed. The case analyzed should assume that the population shelters during the main portion of the source term (i.e., 120 minutes in the assumed case) and then begins evacuation at some time there after. Where the analysis shows dose savings in excess of 25% for sheltering, it should be used in the PAR Logic diagram. A shadow evacuation of 20% should be included in the evacuation time estimate as well as the population in the 2-5 mile downwind sectors when determining the speed of the 2 mile radius evacuation. If the site uses lateral evacuation for this scenario it may be used in the analysis.