RESULTS OF EVALUATIONS FOR
REALISTIC EXPOSURE SCENARIOS

## 1. BACKGROUND

Issue 2.0 in SECY-02-0177 was a staff-initiated review of overall use of scenarios for both restricted and unrestricted release and the need for policy guidance regarding conservative or more realistic scenario identification and justification by the licensee. Experience with licensees' decommissioning plans and license termination plans under the license termination rule (LTR) has raised questions and concerns, by both the staff and licensees, about the potentially unnecessary conservatism that has been inherent in most dose assessments.

The staff has, and will continue to, advance projects that will strengthen and improve the technical aspects of dose modeling through both guidance development and research. This includes: (1) improving the models, (2) widening the suite of computer codes available, (3) improving our understanding of the uncertainties and variabilities in the important parameters, and (4) providing flexible guidance so that licensees can model their sites appropriately in a cautious but reasonable approach without requiring the analyses to be overly conservative. The present guidance development has increased the acknowledgment of the flexibility inherent for the licensee in model and parameter selection. However, the main policy-related concern is what justification is required to choose land uses for analysis, especially if the assessment period is 1,000 years. As has been noted by the National Research Council's National Academy of Sciences, in their 1995 "Technical Basis for Yucca Mountain Standards," and others, forecasting human behavior (and, by extension, land use) over more than a few decades is impossible and would have no technical basis.

In this review, a distinction will be raised between two specific types of scenarios: (1) land-use scenarios, and (2) exposure scenarios. Land-use scenarios are defined as the more general scenario of the future use of the land, without specifying a specific exposure group. Exposure scenarios are the combination of a specific land-use scenario and a specific exposure group. Thus, knowledge of the expected land use may not be sufficient in itself to determine the specific group to be analyzed as different exposure groups may be developed from a given land-use scenario. For example, the future land use at a site may be justified as industrial and this would be the land-use scenario. There are a variety of exposure scenarios for industrial land use including, but not limited to: (1) workers involved in construction on the site; (2) maintenance crews; (3) long-term workers of the site, using current buildings and structures; and (4) long-term workers in areas constructed post-license termination. Having justified the land-use scenario, the licensee must justify which exposure scenario involves the critical group at the site. The critical group will depend on the radionuclides (and their concentrations) and the available exposure pathways at the site.

Not all exposure scenarios need to be explicitly developed and may be eliminated as not impacting the critical group, in a number of instances, by qualitative arguments. For example, if the radionuclides present in an industrial land-use scenario are primarily an external hazard (e.g., cobalt-60 or thorium), the most important factor is time on the site. Therefore, the critical scenario is more likely to be a long-term-worker exposure scenario. The licensee could likely

justify not quantifying the maintenance or construction workers, because these scenarios generally involve less exposure time and would result in less dose than the long-term worker.

It is a common perception that the LTR results in requiring licensees to base remediation and site release criteria on the generally very conservative residential-farmer exposure scenario, especially for unrestricted release or, for restricted release, where the institutional controls are assumed to fail. In the residential-farmer exposure scenario, the critical group is assumed to be future occupants, of the site, that have a house and produce a substantial fraction of their own food, including vegetables, fruits, grain, meat, milk, and possibly even fish. However, the LTR would allow the licensee to justify alternate scenarios more appropriate to the site. There may be a number of reasons why licensees choose to use the residential-farmer scenario rather than justifying an alternative scenario. These reasons include the need, under current guidance, to justify the scenario for the next 1,000 years, lack of extensive alternative scenario development, and, potentially, licensee desire to avoid being a 'test case' for the NRC staff's review, likely resulting in a longer licensing review.

## 2. ISSUE DESCRIPTION AND DESIRED OUTCOME

Issue: Clear direction and guidance are needed for selecting realistic exposure scenarios, for both unrestricted release and restricted release, that appropriately considers institutional control effectiveness and radiological risk.

Eventual Desired Outcome: Implement dose assessment exposure scenarios and modeling assumptions that are risk-informed, realistic, and reflect a logical extension of existing site-specific conditions for the foreseeable future. Specifically, identify what justifications are adequate to use scenarios other than the generic screening scenario of a resident farmer, in light of the 1,000-year dose-modeling time period.

## 3. EVALUATIONS

### 3.1 Present Approach and Guidance

In the LTR, the consideration of the scenario comes as part of the definition of critical group. The 10 CFR 20.1003 definition of critical group is "... the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances." The "applicable set of circumstances" is generally called the scenario. In the Statement of Considerations (SOC) for the final rule, it is noted that "...such analyses should consider exposure ... using cautious but reasonable assumptions." (62 ***FR*** 39068) The rule, also, specifies, in 10 CFR 20.1401(d), that calculations should determine the peak annual dose expected, within the first 1,000 years, after license termination.

The staff's current approach and guidance are discussed in the Nuclear Material Safety and Safeguards (NMSS) Consolidated Guidance for Decommissioning (draft NUREG-1757, Volume 2). This guidance was developed with substantial public involvement through the use of public meetings on draft portions of the original guidance document, the NMSS Decommissioning Standard Review Plan (NUREG-1727, September 2000). This specific guidance development was part of a larger effort to help licensees use the LTR. To assist the vast majority of licensees, guidance development focused on the use of screening analyses

and simple site-specific methods. NRC developed a computer code, the DandD computer code, to perform screening analyses and simple site-specific calculations, and published, in the Federal Register, tables of screening values for licensee use. All these screening analyses and simple methods used the conservative residential-farmer exposure scenario as, or the basis for, its compliance scenario. By using this approach, the licensee was largely freed from having to justify what potential scenarios could occur over the next 1,000 years. Guidance was developed to assist licensees in removing pathways of exposure because of physical limitations at the site (Appendix M, draft NUREG-1757, Volume 2). NUREG-1727's Appendix C (Appendix I of draft NUREG-1757, Volume 2) did have a section on developing site-specific scenarios. However, it appears that the overall tone that readers received was that alternate scenarios would require analyzing anything that could potentially occur at the site over the next 1,000 years.

In summary, guidance has tended to result in licensees reverting to the use of a residential farmer exposure scenario. In part, the guidance is based on the concept that if the dose analysis is needed for a 1,000 year period, the scenario modeled should have an expectation of lasting a 1,000 years. However, as has been noted by the National Research Council's National Academy of Sciences and others, forecasting human behavior (and, by extension, land use) over more than a few decades is impossible and would have no technical basis. Therefore, the current guidance suggests that alternate scenarios are generally limited to either sites with relatively short-lived residual radioactivity (less than or equal to 30 years); sites with physical constraints on use (e.g., non-potable groundwater); or consideration of institutional controls. Although the guidance does not preclude the use of alternate scenarios in other situations, the licensee is responsible, and must take the initiative and the related additional costs, for providing the justifications and specific scenarios.

For restricted release scenarios, the licensee is guided to calculate scenarios both where all the restrictions completely fail and where partial failure of restrictions may be important. However, the guidance does not discuss weighting the risk of the scenario, when determining the needs for the durability and length of institutional controls. The reader is left with the impression that all failure and partial-failure scenarios are treated equally. In addition, the use of scenarios, consistent with current guidance, in evaluating the need for institutional controls, or the effects of failure, may result in unnecessary regulatory burden. The conservative dose estimates may result in sites pursuing restricted release in cases where unrestricted release may have been possible, or requiring the licensee to adopt restrictions that are more durable or comprehensive than necessary.

Only a few licensees have attempted to develop alternate scenarios for unrestricted release. The staff has taken the position that unrestricted land-use scenarios are normally based solely on physical characteristics such as natural impediments of the land that may constrain the future use of the site. In one case, where the site is also involved in complying with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the staff relied on consensus determinations from a variety of stakeholders to develop the land-use scenario. The staff has not yet supported justifications based primarily on restrictions flowing from State and Federal regulations for unrestricted release, as these regulations have been considered institutional controls, which, by the LTR, requires an analysis assuming that these restrictions fail. There are a number of factors that may account for the low number of licensees taking advantage of that flexibility. These include: (1) scenarios are licensee-initiated

and -justified; (2) not all NRC staff understand the guidance's flexibility; and (3) lack of comprehensive staff guidance including the lack of well-developed examples of alternate scenarios. Each is discussed below.

1) Licensee-Initiated or -Justified Scenarios

Our current approach relies on licensees' submittals and their justification of the chosen scenario(s). The decision on which scenario to use depends on a number of factors, with guidance being just one. Although current guidance does allow a large amount of flexibility, the licensee needs to have the expertise and information to justify its approach. Therefore, most licensees use the most expedient method and just choose to use default approaches. Another reason licensees tend to use the generic scenarios is that, generally, they are reluctant to become a test or special case, as these tend to make NRC reviews take longer. This results in greater expense, either, directly from NRC fees, and licensee staff and contractor time in supporting the decommissioning plan or LTP, or indirectly, through time delays in decommissioning or having such proposals rejected. Since not many licensees are pursuing the alternate scenarios, the staff is not approving many such requests, which the licensees may perceive as staff reluctance to approve more realistic scenarios.

2) Staff's Lack of "Corporate" Knowledge of Successes

Staff understanding of the details of dose modeling is growing with every case that is reviewed. Although some staff have worked on cases where more realistic scenarios have been involved, no "library," database, or wide corporate knowledge of these cases exist. Usually the only staff aware of the flexibilities inherent in the staff guidance are the dose modeling specialists and the few project managers with sites that have already performed site-specific modeling. Licensee interactions with staff that have not been previously involved in one of the cases using alternate modeling may reinforce the licensee's perception of staff reluctance. Although draft NUREG-1757 Volume 2 has tried to improve this with added emphasis on the flexibility in the staff guidance, information on actual site approvals (and rejections) of proposed alternate scenarios could lead to improved use of realistic scenarios. This information will also help remind the staff that management will support it in approving site-specific alternate scenarios.

3) Lack of Well-Developed Examples of Alternate Scenarios

One daunting task facing licensees that choose to develop alternate scenarios is deciding which scenarios to analyze. After tackling the issue of possible land use at the site, the licensee may need to analyze a number of exposure groups to find which is the critical group. In addition, as the number of pathways decreases, the importance of re-use exposure scenarios will rise. In these cases, the greatest exposure will be for the media containing residual radioactivity to be removed from the site and used in an alternate way. For example, if a gravel pit contained residual radioactivity that did not pose an external hazard, the on-site realistic doses would be very small per unit of radioactivity. However, the use of the gravel containing residual radioactivity offsite as an underlying drainage layer for a garden could result in higher doses because of the food ingestion pathway. Guidance or good sets of examples are limited in this area as

most have focused only on the conservative use of the residential farmer exposure scenario. The development of NUREG-1640, which analyses generic dose assessments for various re-use scenarios, will help the staff understand the importance of re-use analyses but, for on-site analyses, there is limited information (such as Appendix M of draft NUREG-1757, Volume 2), especially if the land-use scenario is not residential.

3.2 Case Studies

The following two cases describe sites that have chosen to pursue more realistic scenarios that the staff has approved. There are a number of other sites that could use the approach for more realistic scenarios or risk-informing the use of institutional controls.

1) Nuclear Fuel Services, Inc.

Nuclear Fuels Services, Inc., a fuel fabrication licensee in Erwin, Tennessee, provided a decommissioning plan for part of its operating site. As part of the proposed decommissioning plan, the licensee asked to use a set of alternate exposure scenarios whereby the groundwater was not a dose pathway and the critical group did not perform animal husbandry. The reasoning for eliminating the ground-water pathway was, in part, its connection with the surface water and, therefore, the likelihood of potential bacterial and other contamination keeping a reasonable individual from using it for drinking or gardening. The licensee argued that the site is being encroached on by suburban residential use and use by a farmer would not be reasonable. The licensee considered four exposure scenarios: 1) suburban resident, 2) industrial worker, 3) recreational user, and 4) construction worker. The site's decommissioning concentration guideline levels (DCGLs) were based on the most limiting scenario on a radionuclide-specific basis. Part of this approval involved efforts of consensus-building between the State of Tennessee, the U.S. Environmental Protection Agency (EPA), and the U.S. Nuclear Regulatory Commission (NRC), on appropriate scenarios, including the assumption that ground-water use was not a reasonable assumption. The licensee did include dose assessments for the resident farmer and ground-water use for comparison purposes.

2) Watertown - U.S. General Services Administration (GSA)

The U.S. Army Corps of Engineers (USACE) performed a consensus-building process to identify the appropriate scenarios to analyze under CERCLA for the Watertown-GSA site, and requested that they be used to show compliance with the LTR. This is a site next to the river in the city of Watertown, Massachusetts, that was used as a burn pit for waste from another previously-licensed site, which was remediated to meet the Site Decommissioning Management Plan criteria. The Watertown-GSA site is Federally owned and will revert to State ownership at the end of remediation. The burn pit and surrounding area contain a mixture of uranium and chemicals. Members of the board looking at the scenarios and analysis included the State of Massachusetts environmental agency, State of Massachusetts radiological agency, representatives from local and State planning boards, representation of the State's public parks commission, and local representatives of the community. The long-term plan for the

use of the land is a riverside State park. USACE requested, and received, NRC approval for DCGLs for uranium based on scenarios, approved by consensus on the reasonably anticipated land use, associated with public parks. USACE explored four exposure scenarios related to the public park land-use scenario: (1) construction worker, (2) maintenance worker, (3) child recreational user, and (4) adult recreational user. The compliance analysis for NRC and the State of Massachusetts radiological limits used the construction worker, because of the annual dose limit requirement. The State of Massachusetts used the maintenance worker for the chemical and combined risk analysis because of its focus on lifetime risks.

3.3 EPA Approaches

The staff focused on the guidance EPA had developed for the CERCLA regulations, since the U.S. Department of Energy and American Society for Testing Materials approaches are based on the CERCLA guidance. As noted in the EPA guidance for determining land use (OSWER Directive No. 9355.7-04, May 25, 1995), EPA has also been criticized, like NRC, for too often assuming residential land use. EPA, therefore, modified its approach to use the reasonably anticipated land use. Under this approach, a committee of EPA and other stakeholders, such as local land-use planning authorities, local officials, and the public, develop likely scenarios, taking into consideration land planning, past history and trends. The general time frame of interest is the next few decades. The guidance suggests that the risk from other land uses be evaluated, especially where there is some uncertainty regarding the anticipated future land use. Most sites will have deed restrictions or other devices applied, to increase the likelihood of the reasonably anticipated land use.

An important distinction between NRC's LTR and EPA's CERCLA is one of finality. EPA does not release sites for unrestricted use as NRC does since EPA's CERCLA does not provide for finality. Recently, EPA issued "Final Guidance on Completion of Corrective Action Activities at RCRA Facilities", 68 FR 8757 (February 25, 2003). This document introduced "unrestricted use" to mean generally a cleanup of soil to residential standards and groundwater to drinking water standards. EPA noted that notwithstanding releasing sites, EPA could take action under its imminent and substantial endangerment provisions of RCRA. The staff intends to discuss this recent guidance with EPA. Under CERCLA, EPA requires its sites to undergo a 5-year review of the remedy and, if conditions (such as land use) change, more remediation may be required. This provides assurance that future exposures will largely be limited to the land uses that are considered as part of the remedy analysis. It should also be noted that exposure calculations for EPA's remedies are only done for approximately the next 30 years post-remedy. NRC's approach has been to calculate exposures over the next 1,000-year-analysis time period, to consider such processes as leaching and radioactive ingrowth and decay.

EPA's consensus process to develop scenarios with its 5-year-review periods is more risk-informed in evaluating the potential risks from a number of uses and focusing on the more realistic use of the land than NRC's current approach. On the other hand, NRC's current approach to scenarios is sufficiently conservative, such that, it does not need to rely on periodic site monitoring. Because EPA's approach inherently assumes the 5-year-review periods, the EPA approach is not applicable to most NRC licensed sites released for unrestricted use, because they will not need periodic site monitoring. It may be useful to sites, such as, the Watertown - GSA site, which are undergoing a CERCLA process, and the CERCLA process

could be factored into our implementation guidance, by allowing licensees to use the results of the process as justification for the appropriate scenarios.

4. EVALUATION OF OPTIONS

In considering options for the approach for selecting scenarios to model, it is important to note, as stated in section B.3.2 of the SOC for the LTR, that unrestricted release "requires no additional precautions or limitations on use of the site after licensing control ceases, in particular for those sites with long-lived nuclides." 62 ***FR*** 39069 (July 21, 1997). As noted above, since the rule requires an analysis of the dose over a 1,000-year period, it is reasonable to read the regulations as requiring that the scenario that is modeled be preserved over the time period for the analysis period, i.e., 1,000 years, for long-lived radionuclides. Thus, in determining the scenario, there should be sufficient robustness in the scenario assumptions such that controls are not needed to meet the dose constraints over that time. This raises the fundamental question as to the degree of certainty or expectation that the model analyzed will last for the 1,000 year period.

As noted earlier, the National Academy in its review of Yucca Mountain noted it is not possible to predict future societal uses of land on the basis of scientific analysis . This has lead some to default to a residential-farmer (or more conservatively, a subsistence-farmer) scenario, as that scenario generally creates the highest exposures and, therefore, it is a conservative approach to addressing the uncertainty for the future. However, neither the rule nor SOC directly addresses this issue and, to the contrary, the SOC can be read as not compelling a licensee to default to the residential-farmer scenario. It is also contrary to the position the Commission took in developing 10 CFR Part 63, where the Commission requires the scenario to be based on current land conditions and use.[1]

In the discussion of restricted use in section B.3.3 of the SOC for the LTR, the Commission recognized that absolute assurance was not needed for the scenario. Specifically the Commission stated:

> Requiring absolute proof that such controls would endure over long periods of time would be difficult, and the Commission does not intend to require this of licensees. Rather, institutional controls should be established by the licensee with the objective of lasting 1000 years to be consistent with the time-frame used for calculations (and discussed in Section IV.F.7). Having done this, the licensee would be expected to demonstrate that the institutional controls could reasonably be expected to be effective into the foreseeable future.

[1] It is noted that at Yucca Mountain, 10 CFR Part 63 does not call for the most conservative scenario that could occur in the future, i.e., subsistence farmer. Rather, Part 63 uses a scenario based on current conditions and uses of the land. The Commission noted in section 3.6 of the SOC, for that rule, that present evidence indicated that there are no subsistence farmers in the vicinity of Yucca Mountain. Most importantly, the Commission stated that it "disagrees with the suggestion that the excessive conservatism of the subsistence approach is needed to offset any presumed lack of conservatism from the assumption of current conditions." 66 ***FR*** 55732 (November 11, 2001).

> To provide added assurance that the public will be protected, the final rule incorporates provisions (§20.1405(c)) for financial assurance to ensure that the controls remain in place and are effective over the period needed. With these provisions, the Commission believes that the use of reliable institutional controls is appropriate and that these controls will provide a high level of assurance that doses will not exceed the dose criterion for unrestricted use. (Emphasis added) 62 ***FR*** 39070 (June 21, 1997).

It is clear by this language that the Commission expected that the restricted release scenario be developed with the objective for lasting a 1,000 years. At the same time, the Commission introduced the concepts of expectation and reasonable foreseeability. These concepts are consistent with the approach taken at Yucca Mountain. Consequently, this section considers two options: the current approach, and an approach that is based on what is reasonably foreseeable. The latter approach attempts to predict the future site uses based on 1) the nature of the land and reasonable predictions based on its physical and geologic characteristics; and 2) societal uses of the land based on past historical information, current uses, and what is reasonable foreseeable in the future. Given the difficulty of predicting future uses of land, the scenarios would be based on foreseeable uses within the next few decades and possibly 100 years. Similar to Part 63, this approach assumes a logical extension of today's existing society. The staff believes it is unreasonable to assume extreme changes in the culture of our society, revolutions, wars or other disruptions that could affect scenarios over a 1,000 year period.

4.1 No Change in Current Approach

One option is to continue with the current guidance and approach of analyzing any viable scenario over the next 1,000 years. Under this approach, additional guidance development would be minimal. More emphasis could be placed on explaining, and illustrating, examples of the current flexibility in the guidance and LTR. This option has the following pros and cons.

Pros:

1) This approach requires minimal resource requirements, as it mostly would rely on current guidance with minor improvements;
2) Finality of decisions would be more assured, as sites would be likely to use conservative scenario development;
3) Because of this conservatism, there would be more certainty that exposures would be less than the limit, and the need to exercise actions under 10 CFR20.1401(c) would not be likely;
4) This approach would be consistent with past licensing actions; and
5) The public confidence would likely be higher as the conservatisms would require more remediation at sites.

Cons:

1) Most sites would continue to use the residential farmer default scenario, thereby, analyses would remain very conservative;

2) This would maintain the large burden on licensees to provide justifications for scenarios other than residential farmer, or to perform more extensive and costly remediation;
3) This approach is largely inconsistent with the actions of other Federal agencies, which are using the reasonably anticipated land use;
4) Compliance is generally driven by an arguably low probability scenario and is not very risk-informed; and
5) It is not consistent with the approach taken in 10 CFR Part 63.

4.2 Allow Justification of Scenarios Based on Reasonably Foreseeable Future

Under this option, for unrestricted release, the guidance for the definition of "applicable set of circumstances" of the LTR would be issued. Instead of the current approach, where, for most analyses, scenarios are based on any viable land uses over the next 1,000 years, this approach would focus land-use scenarios on (1) the nature of the land and reasonable predictions based on its physical and geologic characteristicness and (2) societal uses of the land based on past historical information, current uses , and what is reasonable foreseeable in the future. Analyses would still be performed for 1,000 years. Primary justification for scenarios would still be related to physical features of the site, radionuclide half-life, and the time of peak exposure. However, the reasonably foreseeable future could be based on advice from land planners and other stakeholders on what possible land uses are likely within a time period of the next few decades to around a hundred years. Alternate scenarios to the reasonably foreseeable would be analyzed to understand the robustness of the analysis, similar to suggestions by the International Commission on Radiological Protection (ICRP) in ICRP Publication 82, Protection of the Public in Situations of Prolonged Radiation Exposure. Compliance would still be based on the reasonably foreseeable scenarios but these less likely alternate scenarios would provide the staff with the information to reach a risk-informed decision.

For restricted release analyses, a similar approach would be taken. The range of analyses could assist in deciding which institutional controls would be necessary. The alternate failure scenarios could be used to provide information on how durable these institutional controls need to be. The pros and cons for this approach are:

Pros:

1) Scenario selection is more practicable and, potentially, more understandable to stakeholders;
2) This approach would offer a greater opportunity for an economically feasible, yet safe, remediation at more sites; facilitating the return of the sites to productive use and reducing unnecessary remediation;
3) Some of the sites that would need to be restricted under the current approach could possibly achieve unrestricted release using more realistic scenarios;
4) This approach would be more consistent with the scenario approaches for both low-level and high-level radioactive waste;
5) More realistic scenarios would allow the staff and licensee to focus on the important institutional controls and the level of durability needed for each of them;
6) Speculation on future land use is bounded; and

7) This approach, based on more realistic scenarios, is more risk-informed than the current approach.

Cons:

1) There are important differences between CERCLA and NRC's LTR, specifically, the lack of the 5-year review for NRC's unrestricted-release option. This could result in a decision not being as certain, since one of the unlikely land-use scenarios could occur at a site and result in a dose that exceeds the dose limit;
2) Seeking consensus between stakeholders in some cases may be difficult to obtain, in which case this approach may be resource intensive because of the effort needed to defend the scenario;
3) Both the licensee and NRC will need to invest additional resources to develop and review scenarios for sites looking for unrestricted release;
4) The public may interpret the policy change as a reduction in protection. This could result in a reduction of public confidence; and
5) Based on 10 CFR 20.1401(c) there could be a need to require additional remediation if the actual land use is different than the predicted land use.

## 5. RECOMMENDATION

The staff recommends that the guidance be clarified to note that more realistic exposure scenarios can be justified by licensees assuming reasonable foreseeable (e.g., a few decades and possibly up to 100 years) land use for the 1,000 year analysis time period for both unrestricted and restricted release analyses. This option would be implemented in revised guidance and a RIS.

Note that the staff will provide to the Commission cases that may implement this approach in the near future, e.g., the AAR, Cabot-Reading, Michigan Department of Natural Resources, and Fansteel sites. In addition, if the Commission approves the recommended option, the staff will seek to implement the option in advance of the RIS and guidance, if it will further the decommissioning process.

The staff continues to be committed to improving the other technical areas of dose modeling for decommissioning. These include improving the guidance, pursuing computer model improvements and development, and improving the state of knowledge on individual parameters and processes involved.