# Concentration-Averaging and Encapsulation Branch Technical Position, Revision 1

## Volume 2

## Response to Stakeholder Comments and Technical Basis


**U.S. Nuclear Regulatory Commission**
**Office of Nuclear Material Safety and Safeguards**



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# 1. INTRODUCTION

Volume 2 of this CA BTP contains background information that supports and explains the staff positions contained in Volume 1. Section 2 is a summary of the major issues raised by stakeholders and how they have been addressed in this revision to the CA BTP. Section 3 contains the staff's response to each of the specific comments raised by stakeholders on the 2012 draft of the CA BTP (NRC, 2012a). Section 4 contains the technical basis for the positions in Volume 1. Reasonably foreseeable yet conservative intruder-exposure scenarios are the basis for most of the staff positions, and the details of the scenarios are presented in this section. Section 5 identifies the key contributors to this revision of the CA BTP.

# 2. SUMMARY OF MAJOR ISSUES RAISED BY STAKEHOLDERS

This section provides a summary of the major issues raised by stakeholders in commenting on all of the drafts and how they have been addressed in this revision. The staff published three drafts of the CA BTP for public comment. Detailed responses to each of the stakeholder comments on the 2012 draft (NRC, 2012a) are contained in Section 3 of this volume. In some cases, additional detail is provided in Section 4, which contains the technical basis for the revised CA BTP positions. Additional issues were raised by stakeholders on the earlier drafts and are addressed in the 2012 draft revised CA BTP.

## 2.1 Sealed Sources

Sealed sources are subject to NRC licensing requirements to provide reasonable assurance of protection of public health and safety and security. Because of their high activity and portability, however, if sources became unsecured or abandoned, there could be negative consequences for public health or environmental damage. Further, some of these sources, if used either individually or in aggregate in radiological dispersal devices commonly referred to as "dirty bombs," could cause significant social disruption and economic impacts in the billions of dollars (U.S. Department of Energy (DOE), 2013). Two major studies of sealed-source security since then have recommended steps to increase disposal options for sealed sources (NRC, 2010a; DHS, 2010).

One cause of the disposal challenges for certain sealed sources is the lack of risk-informed averaging constraints in the 1995 CA BTP (NRC, 1995a).[1] To improve national security, the Department of Homeland Security recommended that the CA BTP be revised to enable the disposal of higher-activity sources (DHS, 2010). This revision of the CA BTP incorporates risk-informed, performance-based regulatory policies that permit the disposal of some higher activity of discrete items, including sealed sources, in cases where intruder protection can continue to be ensured. The staff has ensured continued protection of an inadvertent intruder by basing recommended activity constraints on intrusion scenarios that are more realistic than the intrusion scenarios used in the 1995 CA BTP, and limiting the projected dose to an intruder who finds and carries away a discrete item, such as a sealed source. For example, for $^{137}$Cs, one of the common radionuclides used in sealed sources for research, medical, and industrial purposes, the recommended activity constraint for discrete items has been increased from 1.1 TeraBecquerel (TBq) (30 Ci) to 4.8 TBq (130 Ci), based on a new, more risk-informed analysis

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1 The CA BTP is frequently listed in disposal facility licenses and its positions are therefore binding on licensees wishing to dispose of their sources.

described in Section 4.1. In addition, the revised CA BTP better recognizes that site-specific averaging approaches may be appropriate, rather than just the default generic averaging approaches specified in the CA BTP. The revised CA BTP specifies a different process that entities can use to propose disposal of higher activity discrete items such as sealed sources, based on site- or waste-specific factors. Licensees, for example, could propose to the disposal facility regulator the disposal of sources in excess of the new 4.8 TBq (130 Ci) limit on $^{137}Cs$ because of the design features at a particular site. Most stakeholders who commented on these increases in the discrete item activity limits were in favor of the change. The DOE Offsite Source Recovery Project, which collects and stores unwanted or abandoned sources, was a proponent of these revisions to the sealed-source guidance for disposal of discrete items.

## 2.2 Factors of 2 and 10 for Averaging

For mixtures of discrete items, such as activated metals from a nuclear power plant (NPP), the CA BTP recommends constraints on how concentrated the radioactivity can be in any single item, because these items can vary considerably in their radioactivity concentration. Discrete items, as defined in this CA BTP, are activated metals, sealed sources, cartridge filters, contaminated materials, and components incorporating radioactivity into their design. These waste types were identified as discrete items because they are expected to remain intact for long periods of time after disposal and items in these waste types typically contain significant radioactivity. They therefore could pose a risk to an intruder who could handle the item wihout understanding the radiation hazard and receive a radiation exposure.

The 1995 CA BTP recommends that individual items have radionuclide concentrations no more than a Factor of 1.5 or 10 different from the *average* of the mixture. The “Factor of 1.5” applies to radionuclides that emit gamma radiation, which are more hazardous for discrete items. The 1995 CA BTP also specifies a “Factor of 10” constraint for the other two types of radioactive emissions (alpha and beta radiation) also based around the mixture average. This Factor of 10 was designed to limit extreme averaging measures (for example, averaging an item with greater-than-Class-C (GTCC) concentrations with Class A concentration waste resulting in a Class A final mixture). These factors ensure uniformity of mixtures of items, but such mixtures could be uniformly low risk, and result in projected doses far below 5 mSv/yr (500 mrem/yr).[2] Thus, there is no relationship between the 1995 CA BTP position and acceptable risk (or dose).

The revised CA BTP ties these factors to the class limit for radionuclide concentrations, and not the average of the mixture, and is therefore better tied to risk to human health, because the class limits are based on a maximum radiation dose of 5 mSv/yr (500 mrem/yr) to an inadvertent intruder. The staff also revised the Factor of 1.5 to a “Factor of 2” since the uncertainty associated with intruder protection does not justify the precision implied by the first factor. The Factor of 2 is also consistent with the revised, more risk-informed exposure scenarios.

The graphs in Figure 1 illustrate the difference between the 1995 and revised CA BTP for averaging concentrations in mixtures of discrete items to determine whether waste is Class A, B, or C.

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2 5 mSv (500 mrem) was the projected dose used for intruder protection in the draft EIS for 10 CFR Part 61 (NRC, 1981). Specifically, 5 mSv (500 mrem) was used in the calcualtions that were the first step in developing the waste classification tables in 10 CFR 61.55.

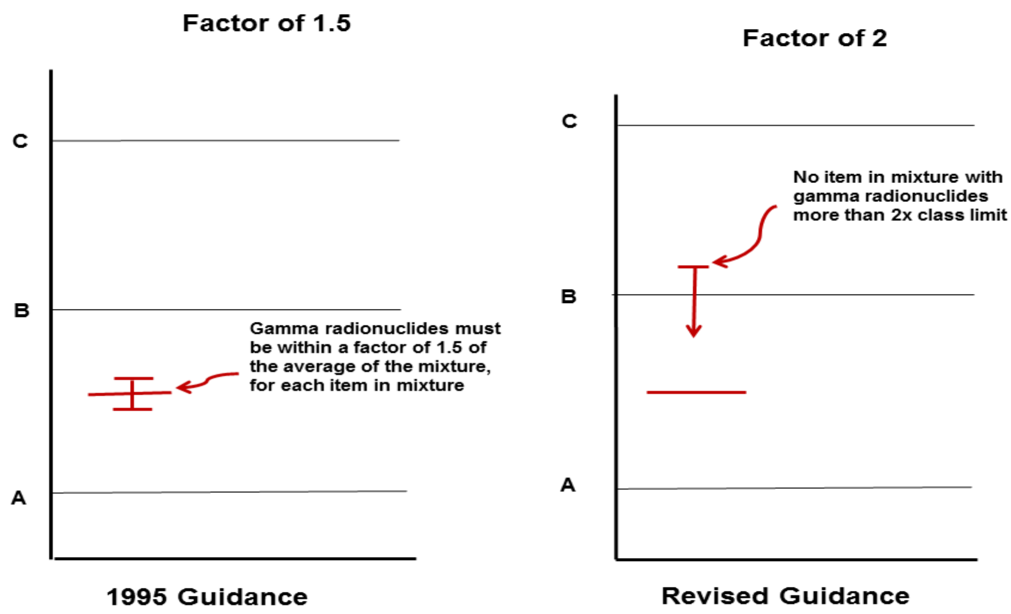


**Figure 1. Primary Gamma Radionuclide Averaging Constraint for 1995 CA BTP vs Revised CA BTP for Mixture of Items with Same Average Concentration**

## 2.3 Cartridge Filters

Cartridge filters are a significant waste stream for NPPs. Typically containing removable filter media in a perforated stainless steel housing, these filters remove solid radioactive particulates in water used in various reactor systems. The 1995 CA BTP classifies filters as discrete items subject to the Factors of 1.5 and 10 averaging constraints. As such, each filter must be characterized and packaged so that the averaging constraints are met. Based on information received from stakeholders concerning the hazard associated with these filters, the revised CA BTP enables licensees to justify treatment of the filters as blendable waste not subject to special averaging constraints. Licensees must document the basis for their conclusion, which could be that the hazard to an intruder is not significant based on the radionuclide concentrations, the physical configuration of the filters, or both.

Several stakeholders argued that the historical data on radionuclide concentrations in cartridge filters supported a blanket classification of all cartridge filters as blendable wastes. Single blendable waste streams are not subject to averaging constraints. In addition to reviewing the commenters' data and arguments that primary gamma emitters in cartridge filters do not justify treatment as discrete items, the staff obtained its own data from records of shipments from generators and waste processors to disposal facilities. The staff reviewed the reported radioactivity for primary gamma emitters ($^{60}$Co,$^{137}$Cs, and $^{94}$Nb).[3] The staff found that in several cases, $^{137}$Cs activities/concentrations were significant (e.g., one package had 3.4 TBq (92 Ci) of

[3] The staff evaluated typical concentrations of gamma emitters because the most hazardous exposure pathways for alpha- and beta-emitting radionuclides (i.e., ingestion and inhalation) require the radionuclides to be dispersed, as they may be in blendable waste. Therefore, concentrations of gamma-emitting radionuclides were the most relevant for distinguishing whether a waste stream warrants being treated as discrete items because the staff does not expect discrete items to be ingested or inhaled, which would increase the alpha- or beta-radiation hazard.

$^{137}Cs$). In addition, activities and concentrations of radionuclides on cartridge filters could change, particularly if the current CA BTP averaging constraints were eliminated for all cartridge filters in the future. As a result, the staff continues to believe that cartridge filters should not be given a blanket designation as blendable waste in the CA BTP. However, the CA BTP now states that a justification can be provided by licensees for groupings of filters to treat them as blendable waste, when it can be shown that no gamma hazard to the intruder is expected to be present. The CA BTP also states that the concentration of non-primary gamma emitters should not be greater than Class C.

## 2.4 Blendable Waste

The 1995 CA BTP (NRC, 1995a) does not use the term "blendable waste". Instead, the 1995 CA BTP addresses two categories of waste: (1) discrete items and (2) wastes assumed to be homogeneous. However, in its decision approving blending of low-level radioactive waste (LLW) (NRC, 2010c), the Commission directed the staff to develop "a clear standard for determining homogeneity" of blended waste. The revised CA BTP introduces the term "blendable waste" to describe waste that is not treated as discrete items, but which has unknown homogeneity.[4]

The concern with the homogeneity of blended waste is that pockets of relatively concentrated waste might persist in a blended product. For example, if a resin with Class C radionuclide concentrations is blended with a Class A resin and disposed of as Class A waste, a hazard could be posed if the waste is not adequately blended and an intruder encounters some of the more concentrated waste in a disposal facility that does not have the intruder barriers required for Class C waste.

The revised CA BTP does not impose averaging constraints on most blendable waste. It does impose restrictions on averaging radionuclide concentrations in two or more distinct blendable waste streams if either of the waste streams is significantly more concentrated than the class limit of the product (i.e., more than a Factor of 10). The revised CA BTP provides guidance on (1) identifying distinct blendable waste streams, (2) determining when averaging constraints apply, and (3) applying averaging constraints. If no averaging constraints apply, the concentration of a radionuclide for waste classification may be based on its total activity in a container divided by the volume of the waste in the package (or mass of waste in the package, as appropriate, depending on the units of the class limits provided in Title 10, "Energy," of the *Code of Federal Regulations* (10 CFR) 61.55, "Waste Classification").

<u>Definition of Blendable Waste</u>

The CA BTP makes a distinction between waste that is "blendable," indicating it has the properties needed for blending, and waste that is "blended," indicating two or more blendable waste streams have been physically mixed together. For the CA BTP, a waste stream is considered to be "blendable" if:

[4] In the 2012 draft CA BTP (NRC, 2012a) , the term "mixable" was used to describe waste that was not discrete and therefore could be blended to create a radiologically homogeneous product. In response to comments on the 2012 draft CA BTP, this term has been replace with the term "blendable" in the revised CA BTP.

- the waste can be physically mixed to create relatively uniform[5] radionuclide concentrations or

- the waste is not expected to contain durable items with significant activity.[6]

Examples of blendable wastes include contaminated soils, ash, ion-exchange resins, evaporator bottom concentrates, and contaminated trash. Except for contaminated trash, these waste streams are considered blendable because of their physical form, which makes them unlikely to be handled by an inadvertent intruder (e.g., NRC staff does not expect an intruder to handle handfuls of resin, ash, or soil for as long as an intruder might be in close contact with a discrete item such as a sealed source). In contrast, contaminated trash might contain items that could persist in the environment and be handled by an inadvertent intruder (e.g., rubber gloves, boots, and plastics). However, contaminated trash is unlikely to contain items that have enough activity to present a hazard to an inadvertent intruder who handles them. Furthermore, it would cause unnecessary worker dose (contrary to "as low as is reasonably achievable" (ALARA) principles) to require items in contaminated trash to be treated individually. Thus, the revised CA BTP indicates that contaminated trash can be treated as blendable waste.

This position is generally consistent with the 1995 CA BTP position that contaminated trash can be assumed to be homogeneous if it is disposed of in containers. The only difference between the revised position on contaminated trash and the position in the 1995 CA BTP is that the revised CA BTP removes the constraint that the trash must be disposed of in containers to be considered blendable. This constraint was removed because the decision to treat contaminated trash as blendable waste in the revised CA BTP was based on its radiological properties rather than its physical characteristics. These radiological properties are not affected by whether the waste is placed in a container or not.

<u>Basis for the Averaging Positions for Blended Waste</u>

When the Commission approved blending of LLW, it directed the staff to consider homogeneity ". . . in the context of the volumes of waste an intruder could encounter in reasonably foreseeable inadvertent intruder exposure scenarios . . .". In accord with this Commission direction, the NRC staff considered how an inadvertent intruder could be exposed to a "hot spot" of blendable waste.

In the draft Environmental Impact Statement (EIS) for 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," the NRC considered potential exposures to waste exhumed during the construction of a house. Specifically, the NRC staff assumed an intruder exhumes more than two hundred cubic meters of waste and spreads it over approximately one thousand square meters of land. Although an intruder exhuming this much waste could exhume a hot spot, the effect of a hot spot would be diluted because the waste is assumed to be spread over a relatively large area. Typically, exhuming a larger amount of waste could cause greater exposures. However, a smaller amount of exhumed waste could cause similar exposures if the waste is significantly more concentrated than the waste class (i.e., as in a hot spot).

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5 Radionuclide concentrations are "relatively uniform" if an intruder who encounters the waste is unlikely to encounter waste more than a factor of 10 more concentrated than the class limit.

6 Durable items with significant contamination are considered "contaminated items" instead of contaminated trash.

Therefore, to evaluate exposures to a hot spot, the NRC staff considered activities that could result in exhuming a small amount of relatively[7] concentrated waste (i.e., a hot spot). The NRC staff considered doses to an individual unknowingly drilling a well into a waste site (acute scenario) and another individual subsequently living and gardening on the site (chronic scenario). The analysis was based on the assumption that the waste had been properly classified, but that the activity in the waste package was concentrated in a hot spot.

The staff considered two different types of well-drilling scenarios, which are discussed in more detail in Section 4 of this volume. In the first, a mixture of drill cuttings and drilling mud is placed in a disposal pit near the well and covered with clean soil (mud rotary drilling scenario). In the second, a similar well is drilled but drill cuttings are spread on the land surface and mixed with soil (exposed drill cuttings scenario). In both scenarios, intrusion was evaluated at 100 years after site closure for Class A waste, 300 years after site closure for Class B waste, and 500 years after closure for Class C waste. In each case, the threshold volumes for demonstrating waste is adequately blended (Table 1 in Volume 1 of this guidance) and the guidance on demonstrating that waste is adequately blended are based on a probabilistic dose assessment. The probabilistic assessment varied parameters such as garden size, plant uptake of radionuclides, and time spent directly on top of or near the contaminated area.

The NRC staff agreed with a comment it received indicating that mud rotary drilling, in which cuttings are disposed of in a covered mud pit, is a common drilling method. The NRC staff evaluated potential exposures from mud rotary drilling. The NRC staff also considered the effects of drilling methods in which drill cuttings are spread on the land surface. These methods, (e.g., cable tool drilling, auger drilling) are sometimes used for drilling wells for water and also have other applications, such as drilling boreholes for site exploration. Furthermore, exposure to drill cuttings spread on the land surface serves as a surrogate for other potential intrusion scenarios in which a small amount of waste is exposed on the land surface. Drilling scenarios in which cuttings are spread on the land surface are commonly used to evaluate protection of an inadvertent intruder (NCRP, 2005).

Other commenters expressed concern that the focus on intruder protection in the CA BTP could cause licensees to make decisions that increase worker dose or dose to the public. These commenters generally found the restrictions of the CA BTP too stringent, and suggested that NRC should allow concentration averaging over much larger volumes, such as entire waste trenches. The NRC staff understands the importance of worker protection. Protection of both radiological workers and members of the public is essential to the NRC's mission. Worker protection is ensured by a number of NRC regulations, including 10 CFR Part 20, "Standards for Protection against Radiation." Worker protection also is explicitly recognized as a performance objective for LLW disposal in 10 CFR 61.43, "Protection of Individuals during Operations." Thus the Part 61 performance objectives require protection of both workers and an inadvertent intruder.

Other commenters criticized the use of generic scenarios to support generic guidance, such as the threshold volumes for demonstrating waste is adequately blended (Table 1 of Volume 1 of this guidance). Commenters noted that the generic scenarios do not account for site-specific disposal site features such as geohydrological features, depth of burial, waste characteristics, engineered disposal features, and their degradation over time. The staff agrees that site-specific analyses might be beneficial and has provided an Alternative Approaches section

[7] Concentrated relative to its waste classification.

to facilitate licensees' use of site-specific analyses. However, the NRC staff also believes that licensees should continue to have an option to use the generic positions in the CA BTP if they choose. The generic positions in the revised CA BTP allow for the classification of LLW without the burden of performing a special analysis.

Identifying Blendable Waste Streams

As discussed in Section 3.2 of Volume 1, the revised CA BTP distinguishes between single blendable waste streams and mixtures of two or more distinct blendable waste streams. As defined in the revised CA BTP, a single waste stream has relatively uniform radiological and physical characteristics. Often, the waste results from a single process. Because single blendable waste streams are expected to have relatively uniform radionuclide concentrations (i.e., a low potential for hot spots), they are not subject to averaging constraints. That is, radionuclide concentrations in single blendable waste streams may be averaged over the volume or mass of the waste. In general, waste streams should be considered distinct if the concentrations of radionuclides of concern typically differ by more than a Factor of 10. Because of the potential for hot spots if waste from two or more distinct waste streams is inadequately blended, mixtures of two or more distinct blendable waste streams can be subject to averaging constraints in some circumstances.

NRC Information Notice 86-20, "Low Level Radioactive Waste Scaling Factors, 10 CFR Part 61," (NRC, 1986) provides a list of waste streams that might warrant establishment of unique scaling factors for waste classification. This list can provide guidance for identifying distinct waste streams at NPPs. For example, for Pressurized Water Reactors (PWRs), these waste streams might include primary purification filters, primary purification resins, chemical and volume control system evaporator bottoms, radwaste polishing resins, and secondary system wastes (filters and resins). For Boiling Water Reactors (BWRs), these waste streams might include cleanup filters and resins, condensate polishing resins, evaporator bottoms, and radwaste ion-exchange resins. For both PWRs and BWRs, these waste streams also typically include contaminated trash.[8] These waste streams are examples of distinct waste streams that might be identified at a particular facility and are not a prescriptive list. In general, each licensee may identify different waste streams for the purpose of concentration averaging.

The revised CA BTP maintains the position of the 1995 CA BTP that a collection of wastes within a licensee's facility for operational efficiency, occupational safety,[9] or occupational dose reduction is not subject to averaging constraints. This reasoning is based in part on NRC experience with these wastes and the staff determination that potential hot spots in these wastes are unlikely to present significant hazards to an inadvertent intruder. This reasoning does not apply to wastes that have already been packaged separately for shipping, because recombining these wastes once they have been packaged separately does not appear to promote operational efficiency, occupational safety, or occupational dose reduction.

8 NRC Information Notice 86-20 uses the term "dry active waste". As discussed in the NRC's response to Comments 2 and 3 from the State of Utah (CA BTP Volume 2, Section 3.3), this CA BTP uses the term "contaminated trash" which corresponds to waste streams 39 and 40 on the NRC Form 541, the Uniform Low-Level Radioactive Waste Manifest.

9 Occupational safety was added as a consideration in the revised CA BTP in response to stakeholder comment.

Averaging Constraints and Thresholds for Demonstrating Adequate Blending

As previously discussed, the concern regarding the homogeneity of blended waste is that unmixed volumes of relatively concentrated waste might persist in a blended product that is disposed of at a lower waste classification than the concentrated waste stream would be alone (i.e., without blending). Therefore, averaging constraints apply in some cases when two or more distinct blendable waste streams are blended and one of the influent waste streams is significantly more concentrated (i.e., by more than a factor of 10) than the blended product.

The 1995 CA BTP included a “Factor of 10” constraint on waste blending which limited blending to waste streams with radionuclide concentrations within a Factor of 10 of the average concentrations in the blended product. To make this position more risk informed, the revised CA BTP considers radionuclide concentrations in blended waste in terms of the waste class of the product, instead of the average radionuclide concentrations in the product. That is, the revised CA BTP places no restriction on blending waste streams if each influent waste stream has a sum of fractions of 10 or less based on the waste class of the blended product (rather than the average concentrations in the product).

The revised CA BTP also provides guidance for blending waste streams that have a sum of fractions greater than 10, which was contrary to the guidance in the 1995 CA BTP. Specifically, the revised CA BTP includes threshold volumes for when to determine whether waste is adequately blended. Within these threshold volumes, radionuclide concentrations in blended waste can be averaged without any additional constraint.

These threshold volumes depend on radionuclide concentrations in the influent waste streams and the waste class of the blended product. Both the class of the final product and the concentrations in the influent waste streams affect the potential radioactivity in a hot spot. In general, larger averaging volumes are appropriate for less concentrated influent waste streams and lower classes of blended products.

Licensees using more concentrated influent waste streams or larger averaging volumes than those shown in Table 1 of Volume 1 of the revised CA BTP should demonstrate that the waste has been adequately blended. In general, waste is adequately blended when there is reasonable assurance that there are no volumes of waste larger than 0.2 $m^3$ (7 $ft^3$) that have a sum of fractions of more than 10, based on the class of the blended product. Alternative approaches to determining that waste is adequately blended may be appropriate based on site-specific conditions, as described in Section 3.8 of the revised CA BTP.

In general, a demonstration that waste is adequately blended can be based on process knowledge, reasoned conclusions, or direct measurements (e.g., by samples or surveys). For example, a licensee can show that a particular process mixes waste adequately by testing the process with physically similar but nonradioactive materials (e.g., resins colored with fluorescent dye tracers). Alternately, measurements may be taken of individual waste packages. Direct measurements typically are not the preferred method for demonstrating that waste has been adequately blended if other methods are available because direct measurements might not maintain doses ALARA.

## 2.5 Increased Assurance that Waste Is Classified Correctly

The CA BTP specifies acceptable averaging constraints that waste generators and processors may use to classify waste shipped to a disposal facility. In commenting on drafts of the CA BTP, several stakeholders stated that regulators in States with disposal facilities need to have greater oversight and documentation of information concerning waste disposed of in the facility they regulate and sent by waste processors and generators regulated by other entities. They argued that such oversight is necessary to provide additional assurance that waste is in compliance with the disposal facility's license and the waste classification requirements. They requested that the CA BTP state that generators should provide additional documentation with waste shipping manifests and that a new section of NRC's review procedures for Agreement State programs[10] be developed to address waste processors. Waste processors are currently evaluated as part of the materials program for an Agreement State, which has broad scope and includes many other types of licensees.

Under the Atomic Energy Act of 1954, as amended (AEA), all licensed LLW processors and generators currently shipping waste to a licensed disposal facility are subject to independent oversight by either NRC or an Agreement State regulator. A basic premise of the Agreement State program is that each Agreement State will have a program that is adequate and compatible with NRC's regulations, ensuring protection of the public health and safety. As an example, one Agreement State might regulate the manufacture of sealed sources, while other Agreement States regulate the licensed users of these devices. The latter rely on the regulatory program of the Agreement State in which the sources are manufactured to ensure that the design and manufacture of the sources are safe. Similarly, a waste processor in one State sending waste to a disposal facility in another State is regulated under the AEA by either an Agreement State regulatory organization or the NRC. Waste characterization and classification practices are included in the regulated activities, because they potentially affect safety. The NRC, with Agreement State assistance, conducts periodic reviews of all Agreement State programs to ensure that they remain adequate and compatible.

With respect to suggested revisions to the CA BTP, the purpose of the CA BTP is not to prescribe inspection and oversight procedures, which are designed to ensure that regulations and guidance are being appropriately implemented, but to provide acceptable approaches for waste classification and concentration averaging practices. Inspectors can then evaluate whether licensees used these approaches or other comparable approaches. Notwithstanding this limited scope, the staff supports the desire of regulators in States with disposal facilities to have greater assurance that waste is classified appropriately and believes that there are measures that can be adopted outside of the CA BTP that will provide this assurance. The staff also believes that discussion among the affected regulators would be useful, and that some action by NRC could be needed, depending on the outcome of meetings with the States. Some State regulators in States with disposal facilities already have established practices for improved oversight of waste generated or processed by a licensee in another State. For example, the governor of Utah signed H.B. 124, "Radiation Control Amendments," on April 1, 2013, approving expanded generator site access permit legislation that would help to address this concern. States use several different approaches now and the staff believes it would be beneficial to understand and discuss these in determining what more NRC might do.

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10 Specifically, commenters requested that a new section of NRC's review procedures for NRC's Integrated Materials Performance Evaluation Program (IMPEP) be developed.

Staff responses to comment 2.d in Section 3.2 and comment 5 in Section 3.3 provide more information on this issue.

## 2.6 Risk-Informed, Performance-Based Regulation

Not long after the 1995 CA BTP was issued, the Commission published a Policy Statement, "Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities" (NRC, 1995b), that formalized the Commission's commitment to risk-informed regulation through the expanded use of probabilistic risk assessment. On March 1, 1999, the Commission approved the issuance of the "White Paper on Risk-Informed and Performance-Based Regulation" (White Paper) (NRC, 1999a) that defines terms and Commission expectations for both risk-informed and performance-based regulation. The Commission directed that the White Paper was to be used by the NRC and interested parties. Since then, the Commission, through its Strategic Plan (NRC, 2014a), has continued to endorse risk-informed, performance-based regulation. The 1995 CA BTP was not developed with the benefit of this guidance and several of its positions were ripe for improvement under the new regulatory policy. This section describes revisions to better conform the CA BTP to agency policy. In general, stakeholders supported the application of the agency's risk-informed, performance-based regulatory policy in the revision to the CA BTP. There was considerable discussion with stakeholders of exactly what "risk-informed" meant for particular issues, such as LLW blending, and this section provides background for the public comments on risk-informing specific averaging positions in Section 3.0. There was significant support for the new performance-based approaches in the revised CA BTP.

Definitions and Concepts for Risk-Informed Regulation

The NRC has defined key terms related to risk-informed and performance-based regulation in the White Paper. "Risk-informed" means an approach to decisionmaking in which risk insights are considered along with other factors such as engineering judgment, safety limits, and redundant and/or diverse safety systems to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to health and safety. "Risk insights" refers to the results and findings that come from risk assessments and might include improved understanding of the likelihood of possible outcomes, sensitivity of the results to key assumptions, relative importance of the various system components and their potential interactions, and the areas and magnitude of the uncertainties.

The NRC's White Paper defines risk as the answer to these three questions:

- What can go wrong?
- How likely is it?
- What are the consequences?

A risk assessment, which is used to provide risk insights for decisionmaking, is a formal process for answering these questions. The first question, "What can go wrong?", is usually answered in the form of a "scenario" (a combination of events and/or conditions that could occur) or a set of scenarios. For NRC's waste classification system and the CA BTP, the scenarios involve an inadvertent intruder into the waste after the disposal site is closed for 100 years and institutional controls can no longer be relied upon. Hypothetical intruder scenarios were used to develop the waste classification tables in 10 CFR 61.55. In ways consistent with that approach, other hypothetical scenarios were postulated for the revised CA BTP to ensure that hot spots in the waste are not a safety hazard to the intruder. That is, the scenarios considered in the development of the positions in the revised CA BTP differed from the scenarios used in the development of 10 CFR Part 61 because they included explicit consideration of the potential effects of hot spots in the waste. However, they are similar to the approach used to develop 10 CFR Part 61, and, specifically, the waste classification tables in 10 CFR 61.55, in considering potential consequences for an inadvertent intruder. The averaging positions in this CA BTP limit the size and intensity of radioactive hot spots based on postulated intruder scenarios. In both the development of 10 CFR Part 61 and the revised CA BTP, the staff postulated reasonably foreseeable but conservative intruder actions. In the development of the revised CA BTP, the staff considered scenarios such as the drilling of a well into the disposal facility, or a "carry-away" scenario for a discrete item, in which the item is picked up by an intruder and carried to a home or transported to a workshop where further exposure to radiation occurs.

The second question, "How likely is it?" is usually answered using evidence to quantify the probability of the scenario and the uncertainties involved. In some programs, data might exist on the frequency of a particular type of occurrence or failure mode (e.g., accidental overexposures). In other situations, there might be little or no data (e.g., core damage in a reactor) and a predictive approach for analyzing probability and uncertainty will be required, according to the White Paper. Typically, considerable data are available for probabilistic risk assessments for NPPs, whereas other NRC programs, such as nuclear security, have limited or no data. A recent NRC report, "A Proposed Risk Management Regulatory Framework" acknowledged that, in the materials area, risk assessments are largely qualitative (NRC, 2012c).[11] The same report also noted that that estimating the risk of security-initiated events, such as the detonation of a "dirty bomb," is difficult, and methods are not well established. Further highlighting the difficulty in quantifying the probability of security events, in 2010, the Advisory Committee on Reactor Safeguards (ACRS) recommended that the NRC establish a research project to explore the possibility of risk-informing security requirements and building on PRAs to create a unified framework for the evaluation of both safety and security (ACRS, 2010). In the waste program, a National Academies report also highlights the difficulties in establishing a probability of intrusion (NAS, 1995). The report states that ". . . there is no technical basis for predicting either the nature or the frequency of occurrence of intrusions [for the then-proposed Yucca Mountain repository]." A further complicating factor for quantifying the probability of intrusion for the CA BTP is that, like the waste classification system in 10 CFR Part 61, its positions are for *generic* disposal facilities (i.e., facilities located anywhere in the United States). It is more likely that a disposal facility in a populous region of the country will be intruded into than a facility located in a sparsely populated area, all else being equal. These differences are not accounted for, however, with a generic system.

The third question, "What are the consequences?", can be answered for each scenario by assessing the probable range of outcomes (e.g., dose to the public) given the uncertainties, according to the White Paper. For the CA BTP, an acceptable consequence is that the dose to

[11] Other programs, such as the Department of Defense, use non-numeric (qualitative) estimates of likelihood, such as "frequent," "occasional," or "improbable" for risk-assessments. Military Standard "System Safety Program Requirements" describes their system safety procedures. Qualitative estimates of risk, such as "high," "medium," and "low," based on the product of a severity category and probability level are also used in other programs. In determining risk, DOD defines probability levels as, for example, frequent ("likely to occur often during the life of an item"), occasional (likely to occur sometime in the life of an item") or improbable ("so unlikely it can be assumed occurrence may not be experienced in the life of an item"). Non-mandatory guidance specifies quantitative risk ranges (e.g., "probability of occurrence less than $10^{-3}$ but greater than or equal to $10^{-6}$ in the life of an item). (DOD, 2012)

the inadvertent intruder must be limited to 5 mSv/yr (500 mrem/yr), the projected dose that was used in the development of the waste classification system in 10 CFR Part 61. Unacceptable consequences need to be controlled by placing constraints on the amount of averaging of waste concentrations for the purpose of classifying waste.

<u>Approach for Intruder Protection in 10 CFR Part 61 and the 1995 CA BTP</u>

The NRC regulation governing disposal of LLW in 10 CFR Part 61 contains four performance objectives, including the performance objective requiring the protection of an individual inadvertently intruding into a waste disposal facility (10 CFR 61.42, "Protection of Individuals from Inadvertent Intrusion"). This performance objective requires that the "Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed." In addition to this broad requirement, 10 CFR Part 61 also contains a number of prescriptive requirements to help to ensure that this overall performance objective in 10 CFR 61.42 is satisfied. These requirements rely on "defense-in-depth" to help ensure protection of an intruder. Defense-in-depth ensures that safety will not be wholly dependent on any single element of the design or post-closure controls to protect an intruder. These prescriptive requirements for intruder protection are the following:

- A State or the Federal government must own the land on which waste is disposed of to minimize the potential for abandonment of the site.
- The government owner must carry out an active institutional control program after closure to control access to the site. In addition, the program must also include environmental monitoring, custodial care, and periodic surveillance. The program can be relied on to prevent intrusion for up to 100 years.
- Markers or monuments must be in place after 100 years to identify the site and to discourage inadvertent intrusion.
- The disposal site is to be selected so that projected population growth and future developments are not likely to affect the ability of the disposal facility to meet the 10 CFR Part 61 performance objectives, including protection of an inadvertent intruder.
- Waste must meet the concentration limits for the appropriate waste class in 10 CFR 61.55. These limits are based on reasonably foreseeable but conservative inadvertent intruder scenarios analyzed in the draft EIS for 10 CFR Part 61 (NRC, 1981).
- For Class C waste, at least a 5-meter depth of disposal or a 500-year barrier must be used to inhibit contact with the waste.
- Class B and C wastes are required to be structurally stable for 300 years, which limits intruder exposures by providing a recognizable waste form.

The above approach relies on defense-in-depth and deterministic assumptions about the performance of the disposal facility. Single values are specified for parameters affecting intruder protection. For example, stability of the waste is expected for 300 years, but the likelihood of the stability lasting for more or less than this time period is not explicitly considered in the intruder analysis. The 300-year time period should be justified by a license applicant in licensing. Institutional controls can be relied upon up to 100 years and no credit can be given under the regulation in 10 CFR 61.59(b), "Institutional control," for a longer period of time.

The technical basis for 10 CFR Part 61 also addresses the questions "What can go wrong?" and "How likely is it?". First, the draft EIS for 10 CFR Part 61 (NRC, 1981) accounted for the small likelihood of intrusion into a disposal site by using a 5-mSv/yr (500-mrem/yr) radiation dose for the purposes of calculating allowable waste concentrations as compared to the 0.25-mSv/yr (25-mrem/yr) limit used for protection of offsite members of the public from releases of radioactivity (10 CFR 61.41, "Protection of the General Population from Releases of Radioactivity"). The technical basis for Part 61 also took credit for depth of disposal and the resultant reduced likelihood of intrusion in specifying Class C concentration limits. With respect to the question "What can go wrong?," the NRC selected a limited number of "…reasonably conservative actions on the part of the intruders [that] are assumed to occur. In addition, some judgment is made as to the likelihood and extent of the scenarios occurring depending upon specific waste forms and disposal practices." (NRC, 1981, Vol. 2, pp. 4–6).

The 1995 CA BTP specifies constraints on the averaging of waste concentrations for the purpose of classifying waste as A, B, C, or greater than Class C. Several of these constraints are based on engineering judgment about the appropriate amount of averaging. They do not rely on a postulated scenario or an evaluation of the consequences to intruder protection. Several positions are also based on highly improbable scenarios that the staff has re-examined in revising the 1995 CA BTP. The following section describes the 1995 CA BTP constraints and improvements in the 2015 revisions to make them more risk informed.

<u>"Risk-informed" and the 2015 CA BTP</u>

The following are risk insights from the staff's re-evaluation of the 1995 CA BTP and a description of the revisions and their bases in the 2015 CA BTP.

- The 1995 CA BTP constrained the averaging of discrete items with its Factors of 1.5 (which applied to primary gamma emitters) and 10 (which applied to other radionuclides). The factors applied to the *average* radionuclide concentrations in a mixture of certain discrete items, such as activated metals, in such a way that radionclide concentrations in individual items had to be within those factors when applied to the average of the mixture. These factors ensure *uniformity* of mixtures of items, but such mixtures could be uniformly low risk, and far below 5 mSv/yr (500 mrem/yr). Thus, there is no relationship between the CA BTP position and acceptable risk (or dose). The revised CA BTP ties these factors to the class limit for radionuclide concentrations (not the average of the mixture), which has a relationship to risk because the class limits are based on a limit of 5 mSv/yr (500 mrem/yr) projected dose to an inadvertent intruder. The staff also revised the Factor of 1.5 to 2, because the uncertainty associated with intruder protection does not justify the precision implied by the first factor.

- The 1995 CA BTP included a "Factor of 10" concentration limit on waste blending which limited blending to waste streams with radionuclide concentrations within a Factor of 10 of the average concentrations in the blended product. The revised CA BTP makes this position more risk informed in two ways. First, as in the previous example, the revised CA BTP considers radionuclide concentrations in blended waste in terms of the waste class of the product instead of the average radionuclide concentrations in the product. That is, the revised CA BTP places no restriction on blending waste streams if each influent waste stream has a sum of fractions of 10 or less based on the waste class of the blended product. In addition, the revised CA BTP provides guidance for blending waste streams that have a sum of fractions greater than 10. This guidance includes volume thresholds for determining waste is adequately blended. Below these threshold volumes, radionuclide concentrations in blended waste can be averaged without any additional constraint. In addition, the revised CA BTP provides guidance on demonstrating that waste is adequately blended if larger averaging volumes are used. The volume thresholds and the guidance for demonstrating waste is adequately blended are based on a probabilistic dose assessment, as described in Section 4 of this volume.

- In the 1995 CA BTP, all cartridge filters were defined as discrete objects subject to averaging constraints. Each filter had to be radiologically characterized to ensure that it met the constraints for mixtures of items. The revised CA BTP allows the treatment of such filters as blendable waste not subject to averaging constraints, with a documented justification. This more risk-informed position is justified because in practice many filters do not present a gamma hazard to an intruder based on their actual radionuclide concentrations.

- The staff re-evaluated the intruder scenarios that were the basis for the encapsulation position in the 1995 CA BTP. Using more realistic but still conservative scenarios, the staff increased the activity constraints for several radionuclides in discrete items of waste, including sealed sources. One example of a less realistic scenario in the 1995 CA BTP is for sealed sources. For an encapsulated source, the 1995 CA BTP assumed that at 500 years, an intruder would be in contact with the surface of the encapsulated mass for 2,360 hours per year. In addition, the projected dose applied to this scenario was 0.5 mSv/yr (50 mrem/yr), not 5 mSv/yr (500 mrem/yr), as was used for other scenarios and in the development of the waste classification tables in 10 CFR 61.55. The 1995 CA BTP stated that 0.5 mSv/yr (50 mrem/yr) was used for this position because of potential exposures to other types of waste, but used 5 mSv/yr (500 mrem/yr) as a basis for other scenarios that could also involve exposures to other types of waste. The staff has therefore used 5 mSv/yr (500 mrem/yr) in establishing new constraints in this revised CA BTP. In addition, the staff believes that the 1995 CA BTP scenario for this position of an intruder being in direct contact with an encapsulated source for 2,360 hours/year is extremely unlikely and should not be the basis for the averaging position. In the revised CA BTP, the staff evaluated scenarios for both small items (such as a sealed source) and large items that are, in the staff's view, reasonably foreseeable but conservative for a generic site.

Performance-Based Revisions to the CA BTP

Performance-based regulation is an approach to regulatory practice that establishes performance and results as the primary bases for decisionmaking (NRC, 2014a). In the context of the revisions to the CA BTP, performance-based regulation is characterized by (1) measurable, calculable, or objectively observable parameters that either exist or can be developed to monitor performance and (2) licensees having flexibility to determine how to meet the established performance criteria in ways that will encourage and reward improved outcomes.[12]

In revising the CA BTP, the staff's objective has been to make the CA BTP more performance-based than the 1995 CA BTP. The ultimate performance measure for the CA BTP is protection of an inadvertent intruder, the performance objective in 10 CFR 61.42. 10 CFR Part 61 itself contains a waste classification system and associated measures to control intruder exposures, which are designed to help ensure compliance with the intruder-protection

[12] See the NRC's "Strategic Plan Fiscal Years 2014-2018," (NRC, 2014a) for a more complete description of "performance-based" regulation.

performance objective. The 1995 CA BTP and the revised CA BTP recommend concentration-averaging constraints that ensure that hot spots do not pose an unacceptable hazard to an inadvertent intruder. These constraints are measurable and meeting them helps to ensure that the overall performance objective is met. An example is the Factor of 2 constraint applied to radionuclide concentrations in mixtures of discrete items.

A significant revision is the improved flexibility for licensees to use site-specific averaging approaches rather than the generic approaches specified in the CA BTP. The 1995 CA BTP established a high bar for deviating from the averaging recommendations in the position, stating that alternative approaches for averaging should be approved under the NRC's regulation in 10 CFR 61.58, "Alternative requirements for waste classification and characteristics." This provision states that "The Commission, upon request, may authorize provisions for the classification and characteristics of waste on a specific basis if, after evaluation of the specific characteristics of the waste, disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives in Subpart C of 10 CFR Part 61." By citing a provision in the regulations that applies to alternatives to the *requirements* in 10 CFR Part 61 (and not NRC staff guidance like the CA BTP), the staff in effect discouraged performance-based approaches to intruder protection. In addition, not all regulatory authorities for States that license disposal site have this provision in their regulations, so the regulatory mechanism for obtaining approval of alternatives to the 1995 CA BTP is not even available to all licensees. Thus, some regulators could not authorize deviations from the 1995 CA BTP under that provision, even though site-specific features might have justified other averaging approaches. The revised CA BTP acknowledges that site-specific and other approaches may be used, and deviations from staff guidance in the CA BTP do not need a 10 CFR 61.58 formal approval as was previously specified.

# 3. ANALYSIS OF PUBLIC COMMENTS ON 2012 DRAFT

## 3.1 Background

On June 11, 2012, NRC staff published a *Federal Register* Notice seeking public comments on a May 2012 draft Revision 1 of the Concentration-Averaging and Encapsulation Branch Technical Position (NRC, 2012a). The draft addressed comments that the staff received at an October 20, 2012, public workshop in Albuquerque, New Mexico, as well as written comments received after the workshop. See Appendices D and E of the 2012 draft (NRC, 2012a) for the staff's analysis of each of those comments and how they were considered in the 2012 draft. NRC received 8 letters in response to the June 11, 2012, Notice. Six letters were from organizations other than States and are identified in Section 3.2, Table 1. Two comment letters were from the States' organizations and are identified in Section 3.3. In Section 3.2, the staff analyzes comments in the six letters from non-State entities and discusses how they have been addressed in the revised CA BTP. Because the numbering in the draft and revised versions has changed, when commenters refer to a section in the 2012 draft, the new section in the revised BTP is provided in brackets. In some cases, if the staff refers to a section or table in the revised CA BTP, the corresponding section or table in the 2012 draft BTP is noted in brackets and designated as a section in the draft version as an aid to clarity.

## 3.2 Stakeholder Input (Other than from States)

The following are the documents related to stakeholder comments (excluding State organizations' comments, which are addressed in Section 3.3) on the 2012 draft CA BTP (NRC, 2012). Each of the individual comments in these letters is analyzed after the table. The main categories for the comments were as follows: (1) general comments; (2) blending and blendable waste streams; (3) classification of discrete items, including the Factors of 1.5 and 10; (4) cartridge filters; (5) definitions; (6) averaging of sealed sources, activated metals, and other discrete items; (7) alternative approaches and use of site-specific intruder analysis in lieu of generic averaging constraints; (8) scenario selection for inadvertent intruder, including probability of intrusion; (9) encapsulation and volume for averaging; (10) stakeholder views on ACRS's December 13, 2011, comments on the CA BTP; (11) increasing the confidence in generators' and processors' classification fo waste; and (12) other comments.

**Table 1. Documents Related to May 2012 Draft CA BTP Public Comments (Excluding State Organizations)**

| Document Type | Author | Date | Organization | ADAMS[13] Accession No. |
|---|---|---|---|---|
| Draft Rev. 1 of CA BTP | NRC staff | May 2012 | NRC | ML121170418 |
| *Federal Register* Notice (77 FR 34411) | NRC staff | June 11, 2012 | NRC | ML121170393 |
| Letter | Lisa Edwards | October 5, 2012 | Electric Power Research Institute | ML12284A264 |
| Letter | Thomas E. Magette | October 5, 2012 | Energy*Solutions* | ML12296A055 |
| Letter | J. Scott Kirk | October 8, 2012 | Waste Control Specialists | ML12284A262 |
| Letter | Frank Marcinowski | October 12, 2012 | U.S. Dept. of Energy | ML13072A073 |
| Letter | Andrew Armbrust | October 4, 2012 | ASME (formerly the American Society of Mechanical Engineers) | ML12284A263 |
| Letter | Christopher Thomas | October 8, 2012 | HEAL Utah | ML12286A383 |

1. General

   a. One commenter expressed the view that the 2012 draft CA BTP is well written, much more easily understandable, and marks a substantial improvement of the guidance issued in 1995. The commenter noted, however, that many of the subject areas are complex and that uniform implementation of the CA BTP is crucial for both the licensed community and the Agreement States that have regulatory oversight responsibilities over these facilities. The commenter encouraged the NRC to schedule workshops after issuance of the revised CA BTP to provide the necessary training to ensure that this guidance is understood and well-positioned for uniform implementation across the

13 The NRC's Agencywide Documents Access and Management System (ADAMS) is accessible from the NRC web site at http://www.nrc.gov/reading-rm/adams.html.

country.

NRC Staff Response:

The staff agrees that after the revised CA BTP is published, generators, processors, Agreement State regulators, NRC staff (e.g., inspection staff in the Regions), disposal facility operators, and others will benefit from training on the revised staff positions. The staff will prepare an implementation plan that will include training for users of the CA BTP. This might include workshops at NRC HQ and at other locations, subject to the availability of travel funds, as well as webinars and videos, depending on available resources.

b. One commenter objected to all changes that allow wastes with higher radionuclide concentrations than currently allowed to come to Utah as Class A waste. The commenter believes that much of the motivation behind revising the CA BTP lies in the desire for generators in the rest of the country to send additional waste streams to Utah, thus forestalling the need to open new regional nuclear waste disposal sites to take locally generated waste. The commenter suggested that the recent opening of the Texas Waste Control Specialists site to Class B and C out-of-compact wastes has obviated much of the perceived need to rewrite the CA BTP to send higher radionuclide concentration waste to Utah.

NRC Staff Response:

NRC staff has revised the CA BTP to be consistent with the agency's risk-informed, performance-based regulatory policy that was developed after the 1995 version of the CA BTP was published, and to implement the Commission's October 13, 2010, decision on LLW blending (NRC, 2010). Both of these agency positions put protection of public health and safety foremost. The staff has specifically revised the following positions in the 1995 CA BTP to implement the risk-informed, performance-based policy that continues to provide for protection of an inadvertent intruder while ensuring worker safety. None of these changes alter the legal status of the Utah facility to accept waste other than Class A waste, or allow wastes other than Class A to be disposed of in the Utah facility.

- To implement the Commission's decision on blending, the restriction on inputs to a blending process has been replaced with criteria that the product (i.e., blended waste) must meet to protect an inadvertent intruder from potential hot spots in the waste. Specifically, the revised CA BTP provides guidance on volume thresholds and a criterion for demonstrating that waste is adequately blended.

- The staff has revised or eliminated certain averaging constraints that were not tied to public health and safety and which caused unnecessary worker exposures associated with additional surveys to demonstrate compliance with the constraints. For example, the 1995 CA BTP stated that concentrations of radionuclides in activated hardware and other discrete items from reactors had to be within a Factor of 1.5 of the average concentration (above and below) of each of the primary gamma-emitting radionuclides, even if the average concentration was well below the waste class limit. The revised CA BTP constrains radionuclide concentrations in a discrete item in a container of activated hardware waste to be within a Factor of 2 of the waste class limit. The previous position cannot be justified on a health and safety basis.

- The staff has increased some of the the gamma activity limits for disposal of Class B and C discrete items, including sealed sources, based on protection of an inadvertent intruder. For Class A items, the Class A gamma activity limit for one of the radionuclides ($^{60}$Co) has decreased, another has stayed the same, and a third has increased by a factor of 2, based on more risk-informed intruder assumptions used in the NRC staff's safety analyses.

- The staff has added a new section, "Alternative Approaches," which discusses site- or waste-specific averaging approaches. The default CA BTP positions are based on a generic LLW disposal site. But alternative approaches may be consistent with risk-informed, performance-based regulation if there is reasonable assurance of compliance with the performance objectives in 10 CFR Part 61.

It is possible that the revisions to the CA BTP could result in more radioactivity being disposed of at facilities. Such disposals would not affect protection of public health and safety. The detailed technical bases for this conclusion are contained in Section 4 of this volume of the revised CA BTP.

c. One commenter expressed the view that although the CA BTP makes many references to homogeneous waste and the desire for homogeneity, no reference is made to risk as a decisionmaking factor. The commenter suggested that this focus on homogeneity appears inconsistent with statements in the 2012 draft CA BTP that, after several hundred years the waste would be indistinguishable from the surrounding soils, because if the waste is indistinguishable from soil it should not pose a hazard. The commenter also stated that it would be unfortunate to unnecessarily expose workers to much greater risk for little benefit in the long term.

NRC Staff Response:

The NRC staff understands the commenter's focus on worker protection. Protection of both radiological workers and members of the public is essential to the NRC's mission. Worker protection is ensured by a number of NRC regulations, including 10 CFR Part 20. Worker protection is explicitly recognized as a performance objective for LLW disposal in 10 CFR 61.43.

Protection of individuals who might inadvertently intrude upon LLW is required by the NRC in 10 CFR 61.42. The guidance in the CA BTP for blendable waste streams is based on the projected dose to an inadvertent intruder who exhumes a small and unrecognized amount of radioactive material from a hot spot in the waste. In response to the comment about statements in the 2012 draft CA BTP that certain wastes would be indistinguishable from soil after 100 years, the NRC staff would like to clarify that the statements should have emphasized that the waste would be *physically* indistinguishable from soil, but not necessarily radiologically indistinguishable from soil. Even if waste is physically similar to soil and (i.e., not recognized as a hazard at the time of intrusion), hot spots in the waste can contain elevated concentrations of radioactivity and pose a hazard to an intruder.

With respect to the commenter's suggestion that the guidance should be based on the risk of intrusion, the NRC staff notes that it based the guidance on the projected consequence of intrusion (i.e., dose), rather than the risk of intrusion (i.e., dose explicitly multiplied by an estimated probability of intrusion). As explained in the response to Comment 1.f, this use of projected dose instead of risk is consistent with how intruder protection was treated in the analyses supporting the development of NRC's regulations governing LLW disposal (10 CFR Part 61). Details of the dose projections used to support the guidance are provided in Section 4 of this volume.

d. One commenter noted that throughout the document there are references to specific fill-volume percentage criteria for mixing wastes in containers and stated that there is no technical basis provided for these percentages. As an example, the commenter noted that in Section 4.2.1 [3.2.1], there are references to fill volumes of 90 percent needed to average radionuclide concentrations over the container. The commenter stated that it is not clear why that fill volume would be required and expressed concern that there is no indication that the waste handler may choose to fill to a lower volume and compress the container after filling to minimize void spaces.

   NRC Staff Response:

   The CA BTP does not recommend particular fill volumes. Fill volumes are referred to only in the context of how much volume a licensee should take credit for when averaging radionulide concentrations. The CA BTP states that if containers are 90 percent or more full, the entire container volume may be used for the purposes of concentration averaging. This position has not changed from the 1995 CA BTP. If the fill volume is less than 90 percent, generators and processors may average the concentration of waste over the volume of the waste. The CA BTP recommends this limit because, without a minimum, licensees could significantly dilute waste concentrations by averaging over empty space in the container. As with encapsulation (addressed in Section 3.3.4 of the CA BTP), the staff has recommended constraints on the amount of nonradioactive volume over which waste may be averaged, so that extreme measures are not used to lower the waste class. Note that as a practical matter, 10 CFR 61.56(b)(3) requires licensees to minimize void spaces within waste (and between waste and its package) to the extent practical.

   With respect to the CA BTP not stating that containers may be compressed after they are filled, the staff agrees that this practice needs to be acknowledged in the CA BTP. The fill volumes apply to the waste disposal containers at the time of shipment to the disposal facility after processing, including compaction, has occurred. Licensees may fill to lower volumes and subsequently compact containers to achieve a 90 percent fill volume. Alternatively, licensees could average over the volume of the waste, rather than the container, for less than 90 percent fill volumes. The staff has added clarifying language to Section 3.5 of the CA BTP

e. A commenter expressed the view that insufficient justification was provided for the position in Section 4.2.2 [now Sections 3.2.2 and 3.4] that blending dissimilar mixable waste types is not desirable. The commenter suggested it might be appropriate to blend dissimilar waste types if the waste is indistinguishable from soils in several hundred years, if there is no increase in worker risk, and if avoiding mixing does not achieve a decrease in risk to a future member of the public.

NRC Staff Response:

As the commenter notes, the 2012 draft CA BTP, like the 1995 CA BTP, indicates that blending of dissimilar waste types should be addressed on a case-by-case basis and approved by the regulatory authority. The 2012 draft CA BTP also indicates that licensees wishing to blend dissimilar waste types should ensure that the wastes are physically and chemically compatible. This concern is unrelated to whether the waste types will physically resemble soil many years after site closure, and is based on a comment from the ACRS (ACRS, 2011), which expressed concern about the potential hazard of unforeseen chemical reactions between different waste types (e.g., hydrogen generation). In the revised BTP, the concern about chemical and physical compatibility is addressed but the need for specific regulatory approval has been changed. Instead, the revised CA BTP indicates that licensees combining a blendable waste type with a different blendable or discrete waste type (e.g., combining ion-exchange resins with soils or cartridge filters) should document that the waste types being combined are physically and chemically compatible and make the documentation available for inspection.

f. One commenter questioned the references to the size of potential hot spots in waste throughout the document. The commenter stated that the important issues are the probability of the intruder hitting a hot spot in a large disposal facility, the isotopes in the hot spot, their radioactive decay rates, and the year that the intrusion occurs. The commenter also stated that the size of a hot spot should not be a determining factor.

NRC Staff Response:

The NRC staff agrees that the identity of radionuclides in a hot spot, their decay rates, and the year of intrusion are all directly related to the projected dose to an inadvertent intruder. These factors were included in the dose calculations that formed the basis of the draft guidance and have been retained in the calculations supporting the revised CA BTP.

In addition to these factors, the size of a hot spot is also considered because it affects the projected dose to an inadvertent intruder. For discrete items, size is a key consideration in scenario selection. To ensure that gamma-emitting items do not compromise the protection of the inadvertent intruder, the CA BTP considers different scenarios for small items, such as sealed sources, as compared to larger items. The small item carry-away exposure scenario is based on the assumption that items smaller than 280 cubic centemeters (cc) (0.01 $ft^3$) could be easily carried away (e.g., in a coat pocket or backpack). Larger gamma-emitting items, on the other hand, are modeled with a different scenario in which the items are treated as scrap metal and moved with construction equipment. Therefore size is a key consideration in establishing guidance for managing discrete gamma emitters. For blendable waste, hot-spot size was considered in the calculations supporting the draft and revised CA BTP because hot-spot size affects the total activity of a radionuclide that an inadvertent intruder could exhume (see Figure 2), which is directly related to dose.

The commenter is correct in noting that the NRC staff did not explicitly include the probability of hitting a hot spot in the calculations supporting the generic look-up values in the draft or revised CA BTP. However, consideration of the probability of intrusion is addressed as an alternative approach, in Section 3.8 of Volume 1 of the revised CA BTP. With respect to the generic look-up values provided in the revised CA BTP, the staff notes that the 5-mSv/yr (500-mrem/yr) projected dose the NRC staff uses as a basis for intruder protection was established in the draft EIS for 10 CFR 61 (NRC, 1981). In the draft EIS, this value is applied as a limit on the consequence of intrusion (i.e., dose), rather than the risk of intrusion (i.e., dose explicitly multiplied by an estimated probability of intrusion). The NRC staff has used the 5 mSv (500 mrem) value in the same way in developing the guidance in the CA BTP.

Although the draft EIS did not project doses explicitly multiplied by probability, the use of a projected dose of 5-mSv/yr (500-mrem/yr) implicitly acknowledges that inadvertent intrusion might not occur. Specifically, NRC has previously indicated that it is appropriate to use 5 mSv/yr (500 mrem/yr) for intruder protection instead of 1 mSv/yr (100 mrem/yr), the public dose limit in 10 CFR Part 20, because intrusion is a "hypothetical" event that might not occur (NRC, 1994). Furthermore, 5-mSv/yr (500-mrem/yr) is a factor of 20 greater than the 0.25-mSv/yr (25-mrem/yr) limit established in 10 CFR 61.41 for protection of the general population from releases of radioactivity. This difference is largely attributable to the difference between the hypothetical nature of intrusion and the more likely possibility of exposure to small offsite releases, implying a 5 percent probability of intrusion. In addition, the inaccessibility of Class C waste to intruders was explicitly considered in establishing the Class C limits in 10 CFR 61.55, further reducing the implied probability of intrusion into Class C waste by as much as an additional factor of 10 (i.e., 0.5%).

Thus, because (1) 5 mSv/yr (500 mrem/yr) was originally applied to dose rather than risk and (2) the value implicitly acknowledges that intrusion might not occur, the NRC staff has applied the limit to the consequence of reasonable, yet conservative, inadvertent intrusion scenarios. Development of a different value that would be appropriate to apply to the risk of intrusion is beyond the scope of the CA BTP.

g. One commenter expressed concern that the CA BTP is "extremely difficult to implement" because of the complexity of the calculations and generic assumptions used in those calculations.

   NRC Staff Response:

   The CA BTP specifies constraints on averaging for a relatively small proportion of commercial LLW: waste streams containing items that are considered individually (e.g., sealed sources, activated metals) and certain mixtures of two or more distinct blendable waste streams. For all other individual waste streams, the CA BTP allows concentration averaging without constraint.

   This revision to the CA BTP is expected to be more easily implemented than the 1995 version now used by licensees. The Factor of 10 concentration limit on blending of wastes has been eliminated, provisions have been added which would enable the treatment of cartridge filters as blendable waste (and thus not be subject to averaging constraints), and the new Factor of 2 and Factor of 10 concentration limits will simplify the packaging of discrete items in a container by specifying a fixed upper limit on radionuclide concentrations, rather than constraining all items to be within a specified range of the average radionuclide concentrations.

   With respect to the complexity of calculations supporting the constraints recommended by the CA BTP, the NRC staff performed calculations to generate generic guidance so that licensees would not need to perform complex calculations to implement the guidance. These generic “lookup” positions on intruder assessments do not place a computational burden on the licensees or States with disposal facilities. As noted by the commenter, these calculations rely on certain generic assumptions. The scenarios used as the basis for the CA BTP were developed as reasonable yet conservative exposure scenarios, which the NRC staff believes to be appropriate for setting limits in generic guidance written for a very broad range of conditions. Licensees who wish to take further consideration of site-specific factors may, in agreement with the applicable State regulator, perform site-specific calculations, as described in the Alternative Approaches section of the CA BTP (Section 3.8). The CA BTP gives licensees a choice, because either the generic positions or site-specific alternative approaches can be used.

h. One commenter expressed the view that the current draft CA BTP introduces unnecessarily conservative assumptions in the bases for the averaging constraints. Specifically, the commenter expressed concern with an exposure scenario the commenter characterized as a conservative domestic well-drilling scenario that amplifies the importance of homogeneity. The commenter suggested that this scenario leads to several technical problems in the CA BTP, including the exclusion of cartridge filters from “homogeneous wastes,” an absence of specificity in an acceptable minimum waste-to-binder ratio for encapsulation and solidification, an unsubstantiated concern about the long-term gamma hazards from discrete items of activated metal, and unbalanced risk factors in the assumed equivalence of $^{94}$Nb in activated metals with $^{60}$Co and $^{137}$Cs in other less stable waste forms in setting averaging constraints.

   The commenter stated that each of these technical issues arise from the NRC’s concerns over inadvertent intrusion by drilling into discrete hot spots in waste after closure of a disposal site. The commenter also stated that the well-drilling concerns focus either on unlikely hot spots in waste already predefined as homogeneous or from the unearthing of discrete gamma sources. The commenter noted that the gamma-source concern is in response to historical sealed-source accidents that were caused by loss of licensee control of sealed sources and not from intrusion into an LLW disposal site.

   NRC Staff Response:

   In developing the 1995 CA BTP, NRC determined that the hazard of certain discrete wastes needed to be managed and established averaging constraints at that time. In this revision to the CA BTP, the staff continues to believe that the hazard from hot spots needs to be addressed. The revised CA BTP positions are more risk-informed than those in the 1995 CA BTP.

   The commenter elaborated on each of the above concerns in more detailed comments. The staff addresses these in detail in the sections noted below:

   - a conservative domestic well-drilling scenario that amplifies the importance of homogeneity (see response to Comment 2.e),
   - the exclusion of cartridge filters from “homogeneous wastes” (see response to comments in Section 4),
   - an absence of specificity in an acceptable minimum waste-to-binder ratio for encapsulation and solidification (see response to Comment 9.a),

- an unsubstantiated concern about the long-term gamma hazards from discrete items of activated metal (see response to Comment 6.b), and
- unbalanced risk factors in the assumed equivalence of $^{94}Nb$ in activated metals with $^{60}Co$ and $^{137}Cs$ in other less stable waste forms in setting averaging constraints (see response to Comments 6.c and 6.d).

The NRC staff would like to clarify that the well-drilling scenario applies only to certain mixtures of two or more blendable waste streams. In the draft 2012 CA BTP (NRC, 2012), the well-drilling scenario was not used in conjunction with waste streams that were "already predefined as homogeneous," because no averaging constraints were applied to waste streams that were deemed to be homogeneous in the 2012 draft. In addition, the well-drilling scenario has not been used in developing averaging constraints that apply to discrete items (i.e., activated metals, sealed sources, cartridge filters, contaminated materials, and components incorporating radioactivity into their design). The staff continues to believe that these waste types might pose a unique hazard and that averaging constraints are appropriate. In developing averaging constraints for discrete items, the staff has used stylized carry-away scenarios.

i. One commenter noted that the NRC has held several meetings with the licensed community, the general public and other stakeholders, including the ACRS, regarding revisions to the CA BTP. The commenter indicated that NRC was directed by the Commissioners to incorporate its risk-informed, performance-based philosophy as part of any revision to the CA BTP, as specified in the Staff Requirements Memorandum for SECY-10-0043 (NRC, 2010c) and that NRC has developed policy, guidance, and regulations that have been risk-informed and performance-based for more than a decade. The commenter noted that, despite this history, concerns were raised during some of these stakeholder meetings regarding the nature of revising the CA BTP in a risk-informed manner as directed by the Commissioners.

   The commenter stated that the NRC's Strategic Plan (for Fiscal Years 2008-2013) defines "risk-informed" as an approach to decisionmaking in which risk insights are considered along with other factors such as engineering judgment, safety limits, and redundant and/or diverse safety systems. The commenter expressed the view that the CA BTP should be revised to include a discussion of how the CA BTP was risk informed—especially given the deliberations raised during the stakeholder meetings regarding quantitative versus qualitative approaches to assessment of future intruder scenarios and the directive articulated by the Commissioners to make potential revisions to the CA BTP risk informed.

   NRC Staff Response:

   The staff agrees with the comment. The application of a risk-informed, performance-based approach to revising the CA BTP has been added in Section 2.6 of this volume.

j. A commenter believes that it is good practice to encourage waste handlers to minimize contact with radioactive waste and to encourage the "one-touch" practice of waste handling during generation. This refers to the practice of packaging waste, at the time of generation, with the intent of preparing the waste for disposal. By minimizing waste handling, unnecessary worker doses can be minimized, a goal under any well-designed ALARA program. The commenter expressed the view that it is not clear in the CA BTP that the NRC encourages this practice and in fact, there are many instances throughout the CA BTP where NRC encourages segregating waste streams resulting in increasing the worker exposure while not indicating how segregation of waste provides additional protection for future generations. The commenter referred to Section 4.1, page 9-10 and Figure 1, page 11, Nodes C and D, of the 2012 draft (NRC, 2012) as examples of where waste segregation is encouraged. The commenter believes that it is only necessary to segregate waste streams when the potential to negatively impact future generations is greater than the impact to workers, particularly for short-lived radionuclides. The commenter believes this concept should be reworked to require an impacts analysis from waste segregation and worker potential dose should be included in the analysis.

NRC Staff Response:

In developing guidance for concentration averaging, the staff agrees that the impacts to workers need to be considered along with intruder protection. Protection of both radiological workers and members of the public is essential to the NRC's mission. Worker protection is ensured by a number of NRC regulations, including 10 CFR Part 20, "Standards for Protection against Radiation." Worker protection also is explicitly recognized as a performance objective for LLW disposal in 10 CFR 61.43, "Protection of Individuals during Operations." Thus the Part 61 performance objectives require protection of both workers and an inadvertent intruder.

The CA BTP specifies constraints on averaging for a relatively small proportion of the volume of commercial LLW: (1) waste streams containing discrete items (defined in the BTP as activated metals, sealed sources, cartridge filters, contaminated materials, and components incorporating radioactivity into their design) and (2) certain mixtures of blendable waste streams (see Section 3.2.3). The waste streams containing discrete items that are considered individually are typically the most radioactive and hazardous and contain most of the radioactivity in LLW. For the majority of the volume of LLW, the CA BTP does not result in any additional handling, because no averaging constraints are specified. Thus, "one-touch" handling can be performed by generators for these wastes.

The CA BTP recommends separate handling of certain discrete items that might be intact at the time intrusion is postulated to occur in 10 CFR Part 61 (100 or 500 years), such as sealed sources. These hot spots pose a potential hazard to an inadvertent intruder. For example, a 36.9 TBq (1,000 Ci) $^{137}$Cs sealed source could cause a dose of more than 30 mSv (3 rem) at 500 years after closure at a generic site. The staff believes that this hazard needs to be managed and has recommended a generic activity constraint[14] for $^{137}$Cs in discrete items, including sealed sources, of 4.8 TBq (130 Ci). Such items are not a significant fraction, by volume, of the LLW produced.

The staff agrees with the commenter that waste handling and worker doses should be minimized. The staff also notes that while much of the guidance in the CA BTP is based on "waste types," segregation of wastes into waste-type categories often occurs

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14 As discussed in Section 4.3.3 of this volume, licensees may apply the Table 2 activity limits or the Factor of 2, (or the Factor of 10, depending on the classification-controlling radionuclides) to gamma-emitting radionuclides. In general, the Table 2 activity limits are less restrictive for small items such as sealed sources.

naturally at the point of generation. For example, contaminated soils, spent ion-exchange resins, and activated metals are already segregated at the point of generation.

Minimizing waste handling may be particularly important for "legacy wastes." Legacy wastes are wastes that were generated by past activities (typically decades ago), and that often are not well characterized. Opening waste containers, removing individual items of waste, and fully characterizing them for the purposes of meeting the averaging constraints in this guidance would cause additional hazards to workers and might not be justified. In some cases, information might be available to demonstrate that the waste classification and averaging provisions in this CA BTP have been met. In other cases, either a licensee may need to characterize some waste to show that it meets the applicable waste acceptance criteria (WAC) or a licensee could propose an alternative approach. The staff has added a new provision in "Alternative Approaches" in Section 3.8.7 that allows for different averaging provisions from those in Sections 3.2 – 3.5 of the CA BTP to be used for some legacy wastes, based on consideration of worker exposures and hazards and potential long-term doses to an inadvertent intruder.

k. One commenter suggested that phrases such as "NRC staff recommends" or "staff proposes" should be replaced with "should," in a way similar to how the word "should" is used in other NRC guidance documents.

NRC Staff Response:

The NRC staff agrees with the comment and has changed the CA BTP text as suggested.

2. Blending and Blendable Waste Streams

a. One commenter noted that process wastes from NPPs typically consist of ion-exchange resins and various types of filter media. The commenter stated that best efforts are employed at most NPPs to promote thorough mixing of these types of wastes and obtain representative samples. The commenter expressed the view that, while no method is perfect, process wastes approach homogeneity in the context of the disposal environment. The commenter noted that research conducted by the Electric Power Research Institute (EPRI) evaluated the technical aspects of homogeneity in NPP process waste. The commenter agreeed with EPRI's analysis, and supported the treatment of process wastes from NPPs as homogenous wastes for characterization and disposal with no further demonstrations of homogeneity required. The commenter suggested that concentrations for the determination of waste classification should be based on the weight and volume of the overall waste mixture.

NRC Staff Response:

Section 3.2 of the revised CA BTP indicates that radionuclide concentrations in single blendable waste can be averaged over the weight or volume of the waste. The CA BTP also allows unconstrained concentration averaging for collections of blendable wastes within a licensed facility for operational efficiency, operational safety, or operational dose reduction. Thus, most spent ion-exchange resins and filter media may be classified based on the average radionuclide concentrations, as the commenter suggests. As discussed in more detail in the response to Comment 2.h, the CA BTP constrains averaging for some mixtures of two or more distinct blendable waste streams.

b. A commenter stated that allowing waste blending in the CA BTP is an unwarranted reversal of prior policy that advised against waste blending for the purpose of intentionally reducing the waste classification; furthermore, the commenter stated, waste blending is an enterprise wholly undertaken as a means to get around Utah's ban on Class B and C radioactive waste.

   NRC Staff Response:

   NRC staff analyzed waste blending in its Commission paper, SECY-10-0043, "Blending of Low-Level Radioactive Waste," (NRC, 2010b). After it received the paper, the Commission held a public meeting to receive input from a wide variety of stakeholders. On October 13, 2010, the Commission issued its decision on the paper, approving blending of LLW, subject to certain constraints such as development of "a clear standard for determining homogeneity" (NRC, 2010c). The issues raised by the commenter here were addressed in the Commission paper and considered by the Commission in its decision. Blending of LLW involves mixing of waste with waste, so that there is no dilution (i.e., the mixing of radioactive waste with nonradioactive materials to reduce the concentration).

   The staff also notes that waste is not classified until it is ready for shipment for disposal. The waste class defines the hazard that waste presents during disposal, not at intermediate points before final disposal. With respect to the State of Utah and the industry blending proposal, only Class A waste is acceptable for disposal in accordance with the facility license, and nothing in the revised BTP changes that legal status.

c. One commenter suggested that the practice of waste blending should be specifically prohibited because of what the commenter views as practical flaws in the position related to the reattribution of waste and a disposal facility regulator's access to waste classification documents. In addition, the commenter pointed out that waste blending should be prohibited because of the increased availability of Class B and C waste disposal. The commenter recommended that the process of waste reattribution be further scrutinized and perhaps drastically limited in order to ensure greater control of processed waste.

   NRC Staff Response:

   The staff analyzed the issue of waste blending in SECY-10-0043, "Blending of Low-Level Radioactive Waste," (NRC, 2010b),and addressed the issues the commenter raised, along with many others. After consideration of all of the issues, the Commission decided to make the agency's position on blending risk-informed and performance-based. There is no safety basis for prohibiting blending of LLW.

   With respect to attribution, NRC addressed this issue in its promulgation of the final rulemaking for the uniform waste manifest (NRC, 1995c). Attribution is the identification of the generator of waste. When waste is processed, the processor may, in some circumstances, be identified as the generator of the waste, instead of the entity that ships the waste to the processor. Blended or processed waste sent to a disposal site must be characterized, packaged, classified, and otherwise meet all of the WAC for the disposal facility. Whether the waste is attributed to the entity that initially generated the waste does not necessarily affect the disposal facility's safety performance and, therefore, attributing the waste to a particular licensee, while it might be important for other reasons, is not required for safety. Aside from NRC's requirements, States and Compacts have requested that the original generator be identified for waste shipped to a disposal site, in order to ensure compliance with Compact laws. The staff has offered to meet with the States and Compacts on this issue.

d. A commenter raised concerns with the staff's guidance related to waste homogeneity, and the practice of "reattribution" of waste by waste processors.[15] The commenter quoted at length from a recently issued report by the Utah Office of the Legislative Auditor (see the commenter's original letter in ADAMS under Accession No. ML12286A383). To summarize, the commenter expressed the view that the process of waste reattribution effectively blinds Utah State regulators as to the origin, radionuclide constituents, and classification of the various "influents" into blended waste packages that ultimately arrive in Utah for disposal. Therefore, in the commenter's view, it would be impossible for Utah regulators to independently verify or evaluate the NRC's proposed threshold below which waste is exempt from a homogeneity demonstration [called the threshold for demonstrating adequate blending in the revised CA BTP], to determine whether an influent to the blended waste package had a sum of fractions within a certain multiple of the Class A limit.

   The commenter noted that the homogeneity test proposed by NRC in the 2012 draft CA BTP (NRC, 2012) has to do with limiting the size of "hot spots" by demonstrating that "the waste does not contain pockets larger than 0.15 $m^3$ (5 $ft^3$) with a sum of fractions greater than 10"; the CA BTP further states that, "In general, homogeneity demonstrations may be based on process knowledge, reasoned conclusions, or direct measurements (e.g., by samples or surveys)." The commenter stated that Utah regulators currently have no access to process documents or manifests held by waste processors (typically located in Tennessee), let alone the ability to perform direct measurements by samples or surveys, on blended waste packages. The commenter stated that Tennessee regulators do have access to the various manifests and documents and could perform samples and surveys; however, they have no mandate to do so. Furthermore, Utah is where the waste will ultimately be disposed and where inadvertent intruder incidents might occur, and therefore Utah regulators should have access to perform the various tests described, in the commenter's opinion.

   NRC Staff Response:

   The commenter raises two basic concerns that relate to NRC's health and safety responsibilities. The first is that the disposal facility operator needs to know the composition of the waste shipped for disposal from generators and processors in other States, both to ensure safety and for compliance with the regulations and facility license conditions. The second is that there needs to be independent oversight of licensed activities such as processing, waste classification, and waste characterization to provide assurance that required safety measures are being implemented by licensees that ship waste to the disposal facilities. The commenter specifically stated that regulators in States with disposal facilities need to have greater oversight and documentation of information about waste disposed in the facility it regulates. A third concern is that the

[15] The CA BTP specifies a test for blended waste to ensure that it is adequately blended. "Attribution" or "reattribution" is the process for deciding which entity is the waste generator. In practice, waste sent to a disposal facility is sometimes attributed to a waste processor (meaning the processor is then formally identified as the generator of the waste), and the original identity of the entity shipping waste to the processor is not required by the NRC's regulations to be reported to the disposal facility operator.

State of Utah should know the origin of the waste. The staff addresses each of these below:

Composition of the waste shipped for disposal: The staff agrees with the commenter that the original character of waste might change during processing. Waste that is shipped from the processor to a disposal facility needs to be classified and characterized appropriately and in accordance with the regulations. Processing might change the concentration of radionuclides in waste or remove certain radionuclides. The waste processor needs to account for changes in waste characteristics as a result of waste processing and is required to sign and certify the composition and classification of the waste shipped on the shipping manifest.

Independent oversight of generators and processors: Under the AEA, all licensed activities are regulated by the NRC and the Agreement States. Although licensees are responsible for meeting the regulations and for ensuring protection of public health and safety, the NRC and the States implement licensing, inspection, and enforcement programs to independently oversee licensee programs. In addition, the NRC periodically conducts independent reviews of Agreement State programs to ensure that they are adequate and compatible with the NRC's regulations. Thus, a waste processor sending waste to a disposal facility in another State is regulated under the AEA by either an Agreement State's regulatory organization or the NRC. Waste characterization and classification practices are included in the regulated activities because they potentially affect safety.

At the same time, the States with disposal facilities, in commenting on the CA BTP, indicated that they are seeking greater assurance that generators and processors are classifying and characterizing their waste appropriately. See, for example, Comment No. 5, "Agreement State Oversight and Enforcement of CA BTP Implementation by Generators," in Section 3.3 of Volume 2 of this document. In the response to that comment, the staff has agreed to work with the States on exploring and developing methods by which they can gain greater assurance that waste is characterized and classified appropriately. The staff is also aware that the governor of Utah signed H.B. 0124, "Radiation Control Amendments," on April 1, 2013, approving expanded generator site access permit legislation that would help to address the commenter's concerns.

Origin of the waste: When waste is shipped to a waste processor, some or all of it may be attributed to the processor, meaning that the original generator would not be reported to the disposal facility's operator under NRC regulations. The NRC's requirements for shipping manifests in Appendix G, "Requirements for Transfers of Low-Level Radioactive Waste Intended for Disposal at Licensed Land Disposal Facilities and Manifests," to 10 CFR Part 20 address waste attribution. A principal reason for the waste manifests is to ensure that the waste characteristics, including radionuclide concentrations, are reported, along with classification of the waste. Operators of disposal facilities need to know the inventory of waste shipped to their site in order to perform site assessments to demonstrate protection of public health and safety. The NRC's shipping manifest requirements specifically allow the attribution of waste to the processor in certain cases, which means that identifying the origin of the waste might not be required. States and LLW Compacts may have additional requirements related to the origin of the waste that might apply, however.

e. One commenter stated that selecting an alternative drilling scenario would eliminate the need for CA BTP guidance for tests of homogeneity in wastes that are already considered (pre-defined) homogeneous. The commenter stated that previously submitted EPRI research shows that the drilling method, disposition of drill cuttings, and information management (i.e., knowledge of local geology, records of historical land use, and records of previous borings) are subject to strict regulatory requirements and technical analysis. Based on this research, the commenter concluded that many of the assumptions included in the CA BTP scenario would be precluded or would have an extremely low probability of occurrence. The commenter indicated that mud-rotary drilling is the most probable drilling method, based on an extensive review of the industry and on interviews with well drillers. The commenter also noted that mud-rotary drilling was selected by NRC as the most probable drilling method at Yucca Mountain (NRC, 2001). The commenter suggested that a previously submitted report about drilling wells could be used to develop probability distributions that would permit a more risk-based, probabilistic assessment.

   NRC Staff Response:

   The NRC staff would like to clarify that the intent of the 2012 draft CA BTP (NRC, 2012) was that designated homogenous waste types would be considered homogeneous without any further demonstration of homogeneity. Thus the commenter's concern that the 2012 draft CA BTP called for "further tests of homogeneity in wastes that are already considered (pre-defined) homogeneous" highlights the need for the staff to clarify this section of the guidance. In response to this and other comments, this section of the guidance has been revised extensively.

   The revised guidance emphasizes that averaging constraints apply to (1) discrete items (i.e., activated metals, sealed sources, cartridge filters, contaminated materials, and components incorporating radioactivity into their design) and (2) certain mixtures of two or more distinct blendable waste streams. Averaging constraints do not apply to single blendable waste streams. In addition, as discussed in more detail in Section 3.2 of Volume 1, averaging constraints do not apply to collections of blendable wastes from within a licensed facility that are combined for occupational efficiency, occupational safety, or occupational dose reduction.

   The NRC staff agrees that drilling methods that collect drill cuttings in a disposal pit (e.g., mud-rotary drilling) appear to be more common for drilling residential water wells than methods in which cuttings are spread on the land surface (referred to here as an "exposed-cuttings" scenario). The NRC staff agrees that it is useful to evaluate the potential effects of mud-rotary drilling at a LLW site. As discussed in greater detail in Section 4.0 of this volume, a mud-rotary drilling scenario illustrates the potential effects of long-lived radionuclides.

   While the NRC staff finds the mud-rotary drilling scenario to be informative, it has determined that other drilling methods should also be considered. Methods in which drill cuttings are spread on the land surface (e.g., cable tool drilling and auger drilling) are sometimes used for drilling wells for water. These drilling methods also have other applications, such as drilling boreholes for site exploration. Furthermore, a scenario in which an intruder drills a well and spreads drill cuttings on the site serves as a surrogate for other potential intrusion scenarios in which a small amount of waste is exposed on the land surface. Drilling scenarios in which cuttings are spread on the land surface are commonly used in both NRC and DOE LLW analyses (NCRP, 2005; Koffman, 2004). The NRC staff finds the drilling scenario to be a reasonable yet conservative scenario to use to evaluate a dose to compare to the 5-mSv (500-mrem) value the NRC uses for intruder protection.

With respect to the commenter's suggestion that NRC staff use the EPRI drilling data to develop probability distributions for drilling scenarios, the NRC staff notes that it has not explicitly weighted scenarios with probabilities as the basis for any of its positions in the CA BTP (see the response to Comment 1.c). Instead, as discussed further in the response to Comment 1.f, the NRC staff has chosen reasonable yet conservative scenarios as the basis for the generic "lookup" positions in the CA BTP. Licensees who choose to take advantage of site-specific or waste-specific characteristics can use an Alternative Approach as described in Section 3.8 of the CA BTP.

f. Two commenters questioned the persistence of hot spots in blendable waste after disposal. One commenter disagreed with this assumption as a basis for an intruder scenario and stated that it had conducted research that indicates that homogeneity in the package should be the normal expectation for mixable [now called "blendable"] waste and cartridge filters in the context of the disposal environment and any intruder scenario. The commenter further indicated that physical and chemical diffusion of energy, atoms, and chemical concentrations are well documented and that the principle is basic to science and consistent with the second law of thermodynamics (Callister, 2004; Perry and Green, 1984). A second commenter stated that the assumed persistence of hot spots over extended intervals is inconsistent with the behavior of physical systems and noted that "*Any system when left to itself will tend to change to a condition of maximum probability"* (Sienko and Plane, 1966). The commenter suggested that, relative to waste disposal, this behavior should be viewed as the system (a container of mixed materials) moving toward maximum randomness or disorder.

   NRC Staff Response:

   The NRC staff appreciates the comments related to the second law of thermodynamics and understands that systems tend toward disorder. However, the staff also understands that many processes can remain far from thermodynamic equilibrium for extended periods of time because of kinetic limitations. Specifically with respect to LLW, the NRC staff is not aware of studies that demonstrate that hot spots are reliably removed during transportation or during waste disposal. Such studies potentially could form the basis for an alternate approach to demonstrating that waste is adequately blended. The NRC staff expects that the necessary demonstration would rely on studies of radionuclide distribution in physically, chemically, and radiologically similar wastes. For example, a study that demonstrates that hot spots in blended ion-exchange resins are reliably eliminated during transportation to a disposal site could serve as a basis for a reasoned conclusion that similar mixtures (e.g., waste composed of the same types of ion-exchange resins with a similar range of radionuclide concentrations) are adequately blended.

g. Two commenters addressed the basis for the threshold for when a licensee should demonstrate waste homogeneity (Table 1 in the 2012 draft CA BTP (NRC, 2012)). One noted that a stated objective for this revision is to be "more risk-informed and performance-based than the 1995 CA BTP," and expressed the view that this goal was not achieved with the volume-based limits in Table 1 of the 2012 draft CA BTP, which the commenter stated were “based upon highly deterministic calculations.” The commenter also expressed the view that such calculations based on generic facility assumptions are inappropriate, particularly because the commenter believes the scenarios to be “restrictive” and “not reasonable for most current disposal facilities.” The commenter proposed that the table be removed in its entirety and replaced by a description of an acceptable method for preparing appropriate limits on a site-specific basis. A second commenter asked for justification for the use of 0.1% of the national annual disposal volumes for Class A or Class B and C disposal volumes as part of the basis for some of the values in the table.

NRC Staff Response:

The NRC staff agrees that site-specific approaches can be more risk-informed than approaches based on generic information. For this reason, the staff has provided guidance regarding alternative approaches (Section 3.8) that take advantage of site-specific and waste-specific conditions. However, the NRC staff also finds it is appropriate to supply generic guidance for licensees who do not choose to perform site-specific calculations.

The purpose of Table 1 of Volume 1, “Thresholds for Demonstrating Adequate Blending,” is to provide a simple reference for licensees using small averaging values or blending waste with lower-concentration input streams to determine whether they should demonstrate that the waste streams have been adequately blended. This purpose of supplying a simple reference is not served by providing guidance for site-specific analyses alone. Licensees who use larger volumes or more concentrated influent waste streams than shown in Table 1 should demonstrate that the waste streams are adequately blended. Alternately, licensees may use site-specific calculations as an alternative approach to demonstrate that potential hot spots in the waste mixture do not pose a hazard to an inadvertent intruder. Examples of relevant alternative approaches are provided in Sections 3.8.1 and 3.8.5 of Volume 1 the revised CA BTP. In addition, as described in Section 3.8 of Volume 1, other approaches beyond the examples provided in Section 3.8 could be proposed by licensees for review by the disposal facility’s regulator.

Although the NRC staff disagrees with the suggestion that Table 1 should be removed from the guidance, the staff did make substantive changes to the table in response to comments. The most significant change is that the table has been revised in terms of averaging volumes instead of annual production volumes. Regarding the request for a more rigorous explanation for using 0.1% of national annual LLW production volumes as a basis for some of the values in the 2012 draft of Table 1, as indicated in the 2012 draft (NRC, 2012), the value of 0.1% per licensee was chosen subjectively to limit the cumulative contributions from multiple licensees. Additional justification is not provided here because the table has been revised so that it no longer relies on the threshold value of 0.1% of national annual disposal volumes.

Averaging volume is related to potential dose because a larger container that meets class limits can contain more radioactivity than a smaller container meeting the same class limits. Therefore, if the radioactivity in a container is concentrated in a hot spot, a hot spot in a larger container can contain more radioactivity than a hot spot in a smaller container of the same class. Thus, Table 1 in Volume 1 of the revised CA BTP limits the amount of activity in potential hot spots by limiting the container volume over which concentrations can be averaged. As previously noted, licensees choosing to average concentrations over larger packages can demonstrate that the waste is adequately blended or can use an alternative approach to demonstrate that hot spots in the waste do not pose a hazard to an inadvertent intruder.

h. Two commenters suggested alternatives to the phrase "ion-exchange resins mixed as part of the design of a nuclear power plant" in the list of homogeneous waste types. One commenter suggested that the staff should clarify the designation because only a subset of NPPs are designed with systems which promote the mixing of various waste streams. The commenter stated that plant-specific equipment and design will dictate whether ion-exchange resins, filter media, and charcoal are loaded into the same vessel or separate vessels or are collected separately or together into tanks. The commenter stated that waste might sometimes be placed directly into disposal liners because of plant design, operational efficiency, ALARA considerations, or some other necessity. The commenter suggested that the wording should be changed to state that "waste shipped from nuclear power plants that is predefined as homogeneous need not be further evaluated for homogeneity." The commenter also suggested that Section 4.2.2 [Section 3.2.2] of the CA BTP should be annotated as only applicable to blending of wastes by waste processors.

   Another commenter provided a contrasting view and suggested that the waste type designation be edited to include spent ion-exchange resins "mixed as part of the design of a nuclear power plant or radioactive waste processing facility." The commenter stated that processor facilities and equipment, which are explicitly designed to effectively mix such materials, will meet or exceed the performance of power reactor waste systems, which are designed only to be common collection points. Therefore the commenter suggested that processor systems explicitly configured to achieve homogeneity in the final waste stream also should not be subject to homogeneity demonstrations.

   NRC Staff Response:

   The NRC staff understands the concern that the phrase "as part of the *design* of a nuclear power plant" (emphasis added) might be interpreted to exclude current practices of waste collection in NPPs that have been developed to promote operational efficiency or occupational dose reduction. This was not the intent. The NRC staff previously stated that the practices described in the 1995 CA BTP were considered acceptable under the envelope of safety defined in the draft and final EIS for Part 61. The NRC staff has no new information to indicate that the practices previously allowed by this provision create waste outside the envelope of safety defined in the draft and final EIS.

   With respect to the specific suggestion that the designation be changed to read, "waste shipped from nuclear power plants that is predefined as homogeneous need not be further evaluated for homogeneity," the NRC staff has two concerns. First, the staff is concerned because the intent of the 2012 draft CA BTP (NRC, 2012) was that designated homogenous waste types would be considered homogeneous without any further demonstration of homogeneity. Thus, the commenter's concern that the 2012 draft CA BTP called for "further tests of homogeneity in wastes that are already considered (pre-defined) homogeneous" indicates the need for the staff to clarify this section of the guidance. As discussed in the response to Comment 2.e, this section of the guidance has been largely rewritten. Second, the NRC staff is concerned that designating only the location from which the resins are shipped (i.e., "from a nuclear power plant") could lead to unintended consequences, because the location from which the waste is shipped is not directly related to waste characteristics. Thus, the NRC staff recognizes the need for a change in the language of the CA BTP but has not adopted the wording suggested by the first commenter.

The second commenter suggested the designation be changed to include spent ion-exchange resins "mixed as part of the design of a nuclear power plant or radioactive waste processing facility." The NRC staff understands the commenter's position that processing facilities specifically designed to physically blend waste might mix waste more thoroughly than collection systems that are not specifically designed to blend waste. Moreover, the NRC staff expects that a processing facility designed to mix wastes with very different radionuclide concentrations will include features to facilitate verification that the process is functioning as designed. As described in Section 3.2.2, a licensee can show that a particular process blends waste adequately by testing the process with physically similar[16] but nonradioactive materials.

As described in Section 3.2.1, the revised CA BTP does not constrain averaging for packages containing single blendable waste streams. In addition, the NRC staff does not constrain concentration averaging in collections of blendable wastes within a licensed facility for operational efficiency, operational safety, or operational dose reduction. These decisions are based in part on NRC experience with these wastes and the staff determination that potential hot spots in these wastes are unlikely to present significant hazards to an inadvertent intruder.

The NRC staff lacks similar experience with waste created by intentional blending of wastes with radionuclide concentrations above and below a class limit to create waste with a certain waste class. The NRC staff addressed the potential scale of intentional blending to create Class A waste, as well as other issues related to waste blending, in a paper for the Commission, SECY-10-0043 (NRC, 2010b). In response to this NRC staff paper, the Commission instructed the NRC staff to develop a clear standard for determining the homogeneity of blended waste SRM-SECY-10-0043 (NRC, 2010c). For these reasons, the NRC staff has not adopted the wording suggested by the second commenter.

Specifically, with respect to spent ion-exchange resins, the staff has made the following changes to the revised CA BTP. Throughout the document, the phrase "mixed as part of the design of a nuclear power plant" has been removed from the description of spent ion-exchange resins. In place of this qualification, the CA BTP has been changed to clarify when wastes are considered single waste streams (which are not subject to averaging constraints) as opposed to when they are considered a mixture of separate waste streams. The CA BTP guidance on blending separate waste streams includes threshold averaging volumes, below which no demonstration of the adequacy of blending is expected. The revised CA BTP also provides guidance on demonstrating that waste is adequately blended if a licensee chooses to use averaging volumes larger than the volumes in Table 1. The revised CA BTP also reinstates an provision similar to the provision in the 1995 CA BTP for a collection of wastes from multiple sources within a licensed facility for operational efficiency, worker safety, or worker dose reduction.

16 In this context, "physically similar" refers to characteristics that could affect physical mixing (e.g., particle size, liquid content).

i. A commenter expressed concern that the term “mixable,” used in the 2012 draft CA BTP (NRC, 2012a), could easily be confused with an existing term, “Mixed Waste,” which refers to waste containing both radioactive and nonradioactive hazardous constituents. The commenter recommended using the term “blendable waste” rather than “mixable waste.”

NRC Staff Response:

The NRC staff agrees with this comment about the term “mixable” and has replaced it with the term “blendable” as the commenter suggested.

j. One commenter referenced previously submitted comments (Waste Control Specialists LLC (WCS), 2011) regarding the NRC's Interim Guidance to the Agreement States on waste blending (NRC, 2011). The commenter noted previous requests that the NRC provide (1) a robust definition of homogeneity that includes measurable parameters and (2) specific requirements on the types of measurements and number of samples that should be taken from blending equipment to demonstrate that the average concentration and measurement uncertainty is known to within acceptable limits. The commenter noted that a draft approach to address these requests was provided in the August 2011 draft of the CA BTP and was revised in the 2012 CA BTP (NRC, 2012a). The commenter stated that the NRC revised the approach described in the August 2011 CA BTP because it would be difficult to achieve for wastes near class limits.

NRC Staff Response:

The NRC staff appreciates the summary of NRC responses to the commenter’s previous concerns and makes one clarification. As explained in Appendix D of the 2011 draft of the CA BTP, the NRC staff revised the draft guidance on uncertainty in waste classification calculations because the staff determined that the draft approach was not consistent with keeping worker doses ALARA. As indicated in the 2012 draft of the CA BTP (NRC, 2012a) and the revised CA BTP, the NRC staff assumes that licensees will use existing quality-assurance programs for waste classification.

k. One commenter expressed the view that inconsistent approaches had been used to assess the likelihood of intrusion versus those used for blended waste. The commenter discussed the 20-mSv/yr (2-rem/yr) value used in the draft 2012 CA BTP to determine the threshold for when waste homogeneity [now referred to as adequate blending] should be demonstrated. The commenter strongly disagreed with the use of 20 mSv/yr (2 rem/yr) and noted that it was equivalent to the annual occupational radiation protection standard currently being used by many in the international community and is also the limit under consideration by the NRC for future revisions to 10 CFR Part 20. The commenter concluded that the NRC’s use of 20-mSv/yr (2-rem/yr) indicates that waste blending only works if the radiation dose limits for protecting members of the public are raised to levels more closely used for protecting occupational workers. The commenter suggested that Agreement States hosting a disposal facility might prefer that waste processors simply collect additional measurements to demonstrate that the waste has been blended adequately enough to comply with the guidance on homogeneity.

NRC Staff Response:

The commenter is correct in noting that two different values were used in the development of the homogeneity guidance in the 2012 draft CA BTP (NRC, 2012a). In brief, the NRC staff used 5 mSv/yr (500 mrem/yr) in most instances and used 20 mSv/yr (2 rem/yr) only when specific additional measures were used to limit the probability of intrusion into a hot spot. As explained in the 2012 draft CA BTP, NRC staff found this approach to be consistent with the requirement in 10 CFR 61.40, “General requirement,” for “reasonable assurance” of intruder protection and with International Atomic Energy Agency (IAEA) guidance in *Specific Safety Requirements No. SSR-5* (IAEA, 2011). However, in response to this and other comments (e.g., Comment 2.g), the NRC staff has revised the guidance so that it no longer uses 20 mSv/yr (2 rem/yr). Five mSv/yr (500 mrem/yr) is the only value used in the development of the revised CA BTP.

l. One commenter stated that it was not clear how the discussion of container size in Section 4.2.2.1 of the 2012 draft CA BTP (NRC, 2012a) correlates with risk and asked for an explanation of how the discussion was used to establish guidance.

NRC Staff Response:

The analyses supporting the CA BTP assume that waste is properly classified based on the classification tables in 10 CFR 61.55. That is, the analyses assume that all packages meet the limits of their designated waste class. Because waste class is based on radionuclide concentrations, within a waste class, a larger package can contain more activity than a smaller package (i.e., concentration multiplied by volume equals activity). Therefore, a hot spot in a larger package could potentially contain more activity than a hot spot in a smaller package could. The amount of activity in a hot spot is related to risk because the amount of activity an intruder encounters is directly related to dose (see Figure 1 in Volume 2).

In response to this comment, this explanation has been provided in Section 4.0 of this volume. To further clarify the guidance in the CA BTP, all explanatory text related to package size has been moved from Volume 1 of the CA BTP to the technical discussion in Section 4.6 of this volume.

m. One commenter noted that Section 4.2.2.1 of the 2012 draft CA BTP (NRC, 2012a) states that, “While an intruder exhuming many waste packages ... will naturally homogenize waste over a relatively large volume, an intruder exhuming a relatively small volume of waste (e.g., a well driller) is more susceptible to encountering hot spots in the waste and averaging the exhumed waste of a much smaller volume.” The commenter expressed concern that it is not clear why someone excavating a smaller volume is more likely to hit a hot spot, or why the exhumed waste would necessarily be homogenized over a smaller area or volume (e.g., the commenter noted that bore hole cuttings can be greatly diluted with drilling mud).

NRC Staff Response:

The NRC staff agrees this text should be clarified. As the commenter notes, an intruder who exhumes more waste is proportionally more likely to encounter hot spots than someone exhuming a smaller volume of waste, if all other factors are equivalent. This text has been clarified in the revised document. With respect to the commenter’s question about averaging volumes, the quoted text was meant to convey that more waste is disturbed when excavating for a basement (i.e., approximately 200 $m^3$ (7,000 $ft^3$)) than when drilling a well (i.e., approximately 2 $m^3$ (70$ft^3$)). The NRC staff understands that other sources of dilution (e.g., drilling mud) must be considered. Mixing with uncontaminated drill cuttings, drilling mud, and dilution with clean soil on the land surface were considered in the calculations supporting the 2012 draft and revised CA BTP. These assumptions are described in greater detail below. To clarify the guidance, explanatory statements such as the one quoted by the commenter have been moved from the body of the guidance to Section 4 of this volume, where modeling assumptions are more fully addressed.

The NRC staff understands that an intruder who exhumes a large volume of waste is likely to receive a greater dose than an intruder who exhumes a small amount of waste. As discussed in the 2012 draft CA BTP, an intruder who exhumes a small amount of waste is likely to receive a significant dose only if he or she encounters waste with radionuclide concentrations significantly greater than the class limits (i.e., more than a Factor of 10 above the class limits).

If packages are appropriately classified, the average radionuclide concentrations in a package are expected to be at or below the class limits. Thus, an intruder exhuming multiple packages is expected to be exposed to waste at or below the class limits. An intruder exhuming a much smaller volume of waste might encounter waste from only a portion of a package. That waste might have radionuclide concentrations significantly above the class limits, even if the package is appropriately classified, if other portions of the package contain waste with concentrations well below the limits.

The commenter also asked about the volumes over which waste is assumed to be averaged once it is exhumed. In the draft EIS calculations supporting the development of the waste classification tables, an intruder is assumed to exhume 232 $m^3$ (8190 $ft^3$) of waste mixed with 680 $m^3$ (24,000 $ft^3$) of clean cover. This mixture is then assumed to be further mixed with clean soil when it is spread on the land surface, for a total waste-to-clean-soil ratio of 1 to 8. The analyses supporting the revised CA BTP used a range of waste volumes representing the volume of a hot spot an intruder might encounter with a well bore (see Figure 2 in this volume). The exposed-cuttings scenario considered in this analysis assumes that radionuclides are exhumed in a well bore ranging from 10 to 30 cm (4 to 12 inches (in)) in diameter with a total waste depth ranging from 1 to 20 m (3 to 80 feet (ft)). The waste is assumed to be mixed with clean soil on the land surface to a depth of 0.15 m (6 in) in a garden that ranges from 96 $m^2$ (1,030 $ft^2$) to 860 $m^2$ (9,260 $ft^2$) (5$^{th}$ percentile to 95$^{th}$ percentile values). These assumptions result in a total waste-to-clean-soil ratio ranging from approximately $4 \times 10^{-1}$ to $2 \times 10^{-4}$.

n. One commenter expressed the view that NRC should provide justification for the 0.6-$m^3$/yr (21-$ft^3$/yr) limit on blending waste with a sum of fractions greater than 100 before demonstrating waste homogeneity (Table 1 in the 2012 draft CA BTP ). The commenter suggested that the decision of whether a waste generator is exempt from demonstrating homogeneity should be based on the potential risk of the waste generated, not merely on volume generated.

NRC Staff Response:

All of the values in Table 1 of the 2012 draft CA BTP (NRC, 2012) were based on potential doses to an inadvertent intruder. Although the volume of waste generated was one factor affecting dose, other factors were considered, including radionuclide concentrations, half-lives, and degree of mixing with clean cover material, as explained in Section 4.6 of this volume.

The NRC staff agrees that additional explanation should have been provided for the value of 0.6 $m^3$/yr (21 $ft^3$/yr) in Table 1 the 2012 draft CA BTP. In brief, the value was based on the projected dose to an inadvertent intruder who was assumed to encounter a hot spot with radionuclide concentrations more than 100 times greater than the class limit. The upper limit to how concentrated the waste in the hot spot could be was set by assuming that the average concentration in the package met the class limits. The 0.6-$m^3$/yr (21 $ft^3$/yr) annual volume limit was chosen to limit the total amount of activity an intruder could exhume. Additional justification is not provided here because the value no longer appears in Table 1. In response to this and other comments (e.g., see Comment 2.g), the table has been revised in terms of averaging volumes rather than annual volumes produced.

3. Classification of Discrete Items, Including Factors of 1.5 and 10

   a. A commenter agreed with NRC's use of the waste class limit rather than a factor of the package average for determining limits for concentration averaging among items within a waste container. The commenter stated that the practice of using a Factor of 10 above and below the package average does not truly account for risk in the context of potential intruder scenarios and introduces inconsistent and arbitrary restrictions on averaging. The class limits defined in 10 CFR 61.55, the commenter pointed out, while not entirely based on a probabilistic assessment of risk, were developed with some evaluation of consequence and are more appropriate in the commenter’s view to use as limits for averaging.

      NRC Staff Response:

      The staff appreciates the comment.

   b. A commenter stated that the discussion of whether to conservatively classify a mixture by the highest classification piece in the mixture in Section 4.3 [now 3.3.2] is counter to the risk of blending waste streams. In the commenter’s view, there does not appear to be a need to identify specific hot spots based on current activity levels, particularly for those radionuclides which decay quickly. Also, it is not clear to the commenter what the basis is for “two times the classification limit” for a nuclide, particularly where it is a short-lived radionuclide and might be indistinguishable from the other wastes in the container in 100 years. The commenter could see no link to actual or potential risk to a future member of the public or inadvertent intruder. The commenter asked that these assumptions be reconsidered in a risk-informed framework.

      NRC Staff Response:

      The option of conservatively classifying a mixture of discrete items by the piece in the mixture with the highest classification is a screening criterion that licensees may use to simplify waste classification. It is meant to provide flexibility and give licensees an easy-to-use alternative. It is a conservative approach to averaging, but might be an efficient one and could reduce worker exposures. This position was also contained in the 1995 CA BTP. The NRC staff concluded that this option should be available in the revised CA BTP because it provides a safe alternative that may offer efficiencies for licensees. The revised CA BTP provides for the use of other options—averaging in accordance with the specified constraints (such as the Factor of 2 for discrete items) or site-specific approaches, for example—and the staff expects that licensees will generally use these rather than this conservative classification option.

The technical basis for the Factor of 2 concentration limit is explained in Section 4.4 of this volume, which includes the exposure scenario and projected dosess. Radioactive decay and consideration of the timing of intrusion (i.e.,at 100, 300, or 500 years after site closure) were included in the technical basis. The Factor of 2 concentration limit in this revised CA BTP is more risk-informed than the Factor of 1.5 constraint in the existing 1995 CA BTP (NRC,1995a). The Factor of 2 is linked to the appropriate classification limit rather than being linked to the average of the mixture. In addition, the Factor of 2 is only applicable to the primary gamma emitters (i.e., $^{60}Co$, $^{137}Cs$, and $^{94}Nb$). Of these, $^{60}Co$ has the shortest half-life, but in high concentrations can still be a hazard to an intruder at 100 years after closure.

c. A commenter stated that the limits set in 10 CFR 61.55 Table 1 apply to long-term exposures rather than acute exposures that might be attributed to sources and other discrete items. It would be more appropriate in this case, in the commenter's view, to allow averaging of $^{94}Nb$ on the basis of the Factor of 10 to be consistent with other long-term exposures. The commenter stated that, based on the discrete-item scenario, an item excavated at any time after closure would cause a dose of less than 1 mrem/yr at Class A limits. The commenter further stated that, in the short-term scenarios in which $^{60}Co$ and $^{137}Cs$ are considered present, $^{94}Nb$ might be present at its Class C limit and not generally regarded as contributing significantly to the scenario. The commenter stated that a bounding calculation assuming a discrete item with $^{94}Nb$ at a Factor of 10 above the Class C limit confirms that exposures estimated at approximately 0.7 mSv/yr (70 mrem/yr) are consistent with the general objective to protect the intruder without restrictive averaging.

NRC Staff Response:

One of the purposes of the CA BTP is to specify averaging constraints for discrete items containing gamma-emitting radionuclides, such as $^{94}Nb$, that could pose a hazard to an inadvertent intruder who is exposed to the item at some time after the 100-year period that institutional controls can be relied upon. In Section 4.3 of this volume the staff has provided a technical basis for the Factor of 2 concentration limit. The staff postulated a large item carry-away scenario in which an inadvertent intruder into a disposal facility is exposed to activated metal with $^{94}Nb$. The staff used a projected dose of 5 mSv/yr (500 mrem/yr), which is consistent with the projected dose used in developing the 10 CFR 61.55 waste classification tables. Thus, the staff has a technical basis for the Factor of 2 concentration limit and does not believe that a Factor of 10 is appropriate in this case.

In addition, the 0.7 mSv/yr (70-mrem/yr) dose cited above appears to be from Chart 1 on page 3 of EPRI's October 5, 2012, letter (EPRI, 2012b) providing comments on the 2012 draft CA BTP (NRC, 2012a). As stated in the letter, the 0.7-mSv/yr (70-mrem/yr) dose at 500 years is based on the "fractional mix in historical activated metal waste." Among other things, the EPRI analysis appears to include non-gamma-emitting radionuclides and uses the average of activated metal items. It does not address the distribution of activity of $^{94}$Nb in discrete items. Notwithstanding these differences between the staff's and the commenter's views, licensees could propose an alternative approach employing a Factor of 10 concentration limit for $^{94}$Nb in activated metal at a specific site, in accordance with the alternative approaches in Section 3.8.

4. Cartridge Filters[17]

   a. A commenter suggested that NRC staff should reconsider the blanket treatment of all cartridge filters as discrete items. The commenter noted that NRC provided an exception whereby some filters may be treated as homogenous (Section 4.3.4 in the 2012 draft CA BTP) (NRC, 2012a), but noted that this section is not referred to in all prior references to cartridge filters and homogeneous waste within the CA BTP. The commenter noted that Section 4.3.4 of the 2012 draft CA BTP also places the burden on each licensee to develop a technical basis that is subject to inspection defining why their cartridge filers are homogenous.

   The commenter stated that historical data on radionuclide concentrations in cartridge filters support treating all filters the same. The commenter also suggested that projected dose-rate comparisons provided in graphs in the comment support consideration of cartridge filters as a homogeneous waste type rather than as discrete items in the CA BTP. The commenter stated that previous research demonstrated that cartridge filters do not contain any significant quantities of long-lived gamma emitters (EPRI, 2012a). The commenter suggested that inclusion of cartridge filters in the definition of a homogeneous waste type could be worded as follows: "…cartridge filters that can be demonstrated through process knowledge not to contain primary gamma emitters in excess of the values in Table A [Table 2 in the revised CA BTP] and…". Similarly, the commenter suggested that Section 4.3 in the 2012 draft of the CA BTP [Section 3.3 in the revised CA BTP] could then be revised to include only cartridge filters containing primary gamma emitters in excess of the values in Table A [Table 2 in the revised CA BTP] and that alternately, Table C in Section 4.6 [Table 4 in Section 3.5 of the revised CA BTP] should include a paragraph under the column titled "Allowable Classification Mass or Volume" to be consistent with Section 4.3.4, "Cartridge Filters as Homogeneous Waste" [Section 3.3.3 in the revised CA BTP ].

   NRC Staff Response:

   The staff agrees with several of the commenter's recommendations for revisions to the CA BTP. The staff has revised the CA BTP to note, in Section 3.2 on blendable wastes, that cartridge filters that can be demonstrated through process knowledge to contain lower amounts of primary gamma emitters than indicated in Table 2 [Table A in the 2012 draft CA BTP] can be considered as blendable wastes, as suggested by the commenter. The staff has not precluded licensees from using generic information or other industry data to justify treatment of its filters as blendable waste, as long as the justification can

17 See also the response to comments in item 6 concerning activated metals and other discrete items being treated the same as sealed sources; those comments and the staff responses also address cartridge filters.

provide reasonable assurance that an intruder would not receive an unacceptable dose. The staff has also revised Table C [Table 4] to address the volume for averaging of filters that are justified as blendable waste.

The staff continues to believe that the CA BTP should not provide a blanket designation of all cartridge filters as blendable waste, and that a justification should be provided by licensees for filters or groupings of filters to treat them as blendable waste. In addition to reviewing the commenter's data and arguments that primary gamma emitters in cartridge filters do not justify treatment as discrete items, the staff obtained its own data from the DOE Manifest Information Management System (MIMS) database. MIMS contains records of shipments from generators and waste processors to disposal facilities. The staff obtained data for fifteen years (1997-2011) of shipments of cartridge filters (descriptor code 27, "mechanical filter" in NRC's uniform shipping manifest form) in shipping containers. The staff reviewed the reported radioactivity for primary gamma emitters ($^{60}$Co, $^{137}$Cs, and $^{94}$Nb) on a per-package basis, because radioactivity data for individual filters were not available. Because concentrations are averages over packages, some individual filters will have higher $^{137}$Cs concentrations than the package average and present a greater hazard to the intruder. The staff found that in several cases, $^{137}$Cs activities/concentrations were significant (one package had 3.4 TBq (92 Ci) of $^{137}$Cs, for example). In addition, activities and concentrations of radionuclides on cartridge filters could change in the future, particularly if the current CA BTP averaging constraints were eliminated for all cartridge filters.

The staff also considered non-primary gamma emitters in the treatment of cartridge filters as blendable waste. The May 2012 CA BTP stated that for a filter to be considered to be blendable waste, the concentration of non-primary gamma emitting radionuclides on the filter should not be greater than Class C. No comments were received on this provision and it remains in the revised CA BTP. For transuranic radionuclides, for which the Class C concentration limit is 10X the Class A limit, this provision helps to ensure that cartridge filters treated as Class A blendable waste will have TRU concentrations no more than 10X the Class A limit. Because the Factor of 10 is applied to transuranic radionuclides in cartridge filters treated as discrete items, transuranic radionuclides are effectively subject to the same constraint when filters are treated as blendable waste as when they are treated as discrete items.

b. A commenter agreed with EPRI's assessment of cartridge filters as more properly treated as bulk material, similar to dry active waste (DAW) rather than discrete items. The commenter stated that cartridge filters are not mechanically or radiologically similar to either high-activity sealed sources or activated metal objects and are unlikely to contain radioactive material as intrinsically part of their structure over long periods of time. Mechanical cartridge filters as used in NPP systems have the lowest decontamination factor of any of the filtration systems typically installed in plants and are also unlikely to contain significant quantities of long-lived gamma-emitting radioisotopes, according to the commenter. The commenter recognized that NRC has identified an alternate approach to the handling of cartridge filters. The commenter also recommended that NRC explicitly recognize processing techniques that can alter the form of items such as cartridge filters to be consistent with the characteristics of a mixable waste and to specify that the form of the waste in its final presentation for disposal should be the basis for any application of restrictions on concentration averaging.

NRC Staff Response:

The staff's analysis of the treatment of cartridge filters as bulk material or blendable waste is contained in the response to comment 4.a above. With respect to acknowledging processing techniques that can alter the form of cartridge filters (e.g., shredding), see Section 3.2.3 of Volume 1 regarding solidification of waste. Finally, Section 3.1.2 of Volume 1, "Radiological characterization," notes that waste classification is only required for the final waste form presented for disposal. "Classification" includes consideration of hot spots and application of the averaging constraints to the final waste form.

c. A commenter disagreed with the position that site- and manufacturer-specific analyses be conducted to justify treatment of cartridge filters as homogenous wastes. The commenter referred to the analysis presented by EPRI in their letter dated February 16, 2012, in response to the previous CA BTP draft (EPRI, 2012a). The commenter repeated EPRI's statement that the continued treatment of filters as discrete items results in unnecessary occupational exposure to individuals engaged in sampling, characterization, and subsequent packaging of these items. The risks associated with this work are not accompanied by reductions in the potential external dose rate threat to an inadvertent intruder, according to the commenter and EPRI.

   NRC Staff Response:

   The staff's analysis of the treatment of cartridge filters as blendable wastes is contained in the response to comment 4.a. This analysis addresses EPRI's arguments concerning the gamma hazard associated with cartridge filters. The CA BTP 's treatment of cartridge filters has been extensively revised from the 1995 version. The revised CA BTP enables, with documented justification, the treatment of cartridge filters as blendable wastes not subject to individual sampling and characterization. See Section 3.3.3 of the revised CA BTP.

d. A commenter noted that, in the discussion regarding treating cartridge filters as homogeneous waste, there are several references to the use and styles of cartridge filters. The commenter requested that the CA BTP provide greater detail to the reader regarding the source of these cartridge filters and the types of radionuclides they typically contain. The commenter stated that many filters are used in radioactive waste management and it is confusing to the reader exactly which filters are being discussed. In addition, the commenter expressed the view that the statement that filters do not need to be treated as discrete waste if radioactive material might spill out of a filter if it is handled by an inadvertent intruder appears counter-intuitive. The commenter suggested that material spilling onto an intruder would be more dangerous than material remaining in the filter housing.

   NRC Staff Response:

   Section 2.3 of this volume, "Cartridge filters" provides additional information on the origin, design, and hazard of these filters. Cartridge filters are mechanical filters typically used to remove solid particles containing radioactivity from liquids in NPPs. They contain one or more disposable filter elements. These elements are usually constructed of woven fabric, wound fabric, or pleated paper supported internally by a stainless steel basket (EPRI, 2008). In addition, an IAEA publication (IAEA, 2001) describes the uses of filters in nuclear applications. Readers can also find information on the radioactivity found in cartridge filters in an industry letter commenting on the 2012 CA BTP (EPRI, 2012a).

The NRC staff agrees that the scenario the commenter describes (i.e., contaminated filter media spilling directly on an intruder) could cause a hazard. When the NRC staff discussed the filter media separating from the housing in the 2012 draft CA BTP, the staff intended to address the media separating from the filter housing and being dispersed as blendable waste would be before an intruder directly contacted the filter housing. If the filter media is likely to remain with the housing until an intruder handles it, and it has significant gamma activity (i.e., greater than Table 2 values) the filter should be treated as a discrete object. However, if the generator can justify that the medium is likely to disperse as blendable waste, or it does not have significant gamma activity, the licensee can document this justification and treat the filters as blendable waste, as discussed in Volume 1, Section 3.3.3.

5. Definitions

   a. One commenter suggested the document should provide additional definitions in the glossary, including but not limited to the terms "relatively uniform" in Section 4.2 [now Section 3.2] and “Concentration Averaging” and “Stability.” The commenter also requested more information about specific waste types. The commenter expressed concern that the document identifies some waste types generically and stated that it is difficult to determine the origin of this waste. As examples, the commenter noted "spent ion-exchange resins mixed as part of the design of a nuclear power plant" and "filter cartridges." The commenter asked if there are some ion-exchange resins that are not included as a designated homogeneous waste type and whether there was a reason for excluding them. Regarding "filter cartridges", the commenter asked if the designation referenced a specific waste stream. The commenter suggested the origin of the named waste streams should be clearly defined in the CA BTP text, the glossary, or both.

   NRC Staff Response:

   In response to the comment, the NRC staff has added several terms to the glossary including “concentration averaging” and “stability”. In addition, the staff has added a footnote in Section 3.2 of Volume 1 of the revised CA BTP to indicate that radioactivity in waste is relatively uniform if there is reasonable assurance that an intruder who encounters the waste will not encounter waste that is 10 or more times more concentrated than the class limit. The guidance in Section 3.2 of Volume 1 provides a more detailed discussion of assessing the uniformity of blendable waste.

   In response to the comment about waste types, the NRC staff has expanded the descriptions of waste types in the revised CA BTP. In particular, additional background has been provided regarding filter cartridges, which are principally used to remove radionuclides from water at NPPs. See in particular Section 2.3 “Cartridge Filters” in this volume and the staff’s response to comment 4.d in this section.

   The NRC staff has avoided specifying the origin of various waste types when possible to allow flexibility. For example, contaminated soils are listed as an example of blendable waste, irrespective of the origin of the soil (e.g., from a decommissioning site, a reactor site, or a materials site). As discussed further in response to Comment 2.h, the example of "spent ion-exchange resins mixed as part of the design of a nuclear power plant" has been changed to "spent ion-exchange resins". The 2012 draft guidance had intentionally excluded ion-exchange resins from other sources, such as ion-exchange resins intentionally blended during processing, because the NRC staff does not have sufficient experience with the excluded resins to designate them as a homogeneous waste type. The revised guidance does not focus on the origin of the spent ion-exchange resins, but clarifies when the resins are considered a single blendable waste stream and when they are considered a mixture of two or more distinct blendable waste streams (see the response to Comment 2.h).

6. Averaging of Sealed Sources, Activated Metals, and Other Discrete Items

   a. A commenter raised a concern that restrictions on the disposal of sealed sources would seem to promote the very issue that drove the events; that is, proper disposal was more difficult than simple abandonment of the source. The commenter expressed the view that the supporting calculations used by NRC appear to be based on suppositions designed to justify the ends, rather than realistic assumptions of potential events. Given the issues with high-activity sealed sources involving handling, disposal, and security, the commenter suggested that the NRC should implement rules that make disposal as simple and straightforward as possible. The commenter recognized that the revision to the CA BTP makes disposal of sealed sources easier than in the 1995 CA BTP; however, the commenter recommended that the NRC re-evaluate the position and premise that sealed-source abandonment issues need to be addressed through restrictions on proper disposal.

   NRC Staff Response:

   The staff acknowledges the tradeoffs that the commenter raised. Ultimately, permanent disposal is the goal for all LLW, including sealed sources which can be highly radioactive and might pose a threat to public health and safety or national security if control is lost. At the same time, the concentration limits in the waste classification tables in 10 CFR 61.55 and the averaging positions in this CA BTP constrain disposal of sources to a degree, so that the inadvertent intruder performance objective can be satisfied. These constraints are not designed to address abandonment issues, but to protect an inadvertent intruder.

   In the revised CA BTP, the staff has taken steps to allow for more realism in the evaluation of source disposal. Most of the activity limits applicable to discrete items have been increased as compared to the 1995 CA BTP, based on more realistic scenarios. Commercial LLW disposal facilities have only been used for approximately 50 years and there is very little experience that the NRC staff can draw on when projecting future inadvertent human intrusion. Therefore, the staff has used analogues such as sealed-source accidents in developing stylized scenarios to assess the impacts of human intrusion. Based on these accidents, the staff concluded that sealed radioactive sources are not always recognized as being hazardous (the human senses fail to recognize the gamma hazard), and the unrecognized sources may be carried to homes or scrap-metal recyclers. Other handling scenarios are also possible.

   It is true that the accidents referenced in the draft 2012 CA BTP occurred after a loss of licensed control, and were in locations more accessible than waste disposed of below ground. On the other hand, disposal facility licenses are terminated at the end of the institutional control period, and some of the waste remains hazardous for longer than the 100-year period during which institutional controls can be relied upon. The staff believes that using sealed source accidents as an analogue is a reasonable approach for assessing potential dose impacts to an intruder because the longer time frame associated with disposal offsets the waste being less readily accessible to humans. As noted above, the revised CA BTP uses more reasonable scenarios than the 1995 version, and many of the radioactivity limits for discrete items of waste have been raised as a result.

In addition, the new Alternative Approaches procedure in Section 3.8 of the revised CA BTP provides guidance for an applicant or licensee to propose disposal of sources with higher activity based on site- or waste-specific considerations. Applicants or licensees are strongly encouraged to discuss any such proposal with the disposal site regulator. This provision might be particularly useful for sites that have deeper disposal or more robust engineered barriers than was assumed in the technical basis for 10 CFR Part 61. It could also be used justify use of different intruder exposure scenarios from those in Section 4.3 of this volume to permit disposal of higher activity sources. In this revision of the CA BTP, the staff has attempted to achieve a balanced approach for sources that ensures that the waste classification and intruder protection requirements are met while being mindful of the hazards of lost or stolen sources and the need to reduce or eliminate those hazards by permanently disposing of sealed sources. The revised CA BTP is an improvement over the previous version and has the potential to enable safe disposal of many sources that are now constrained by the 1995 CA BTP. The staff does not believe that eliminating all constraints on source disposal in the interest of improving source security would be appropriate or protective of the inadvertent intruder.

b. One commenter suggested that averaging constraints for sealed sources should not apply to other types of waste. The commenter stated that there is a significant difference between the long-term gamma dose hazards presented by sealed sources and non-sealed source waste. As examples, the commenter discussed items of activated metal and cartridge filters. The commenter noted that that sealed sources typically contain only one radionuclide (commonly $^{137}Cs$), whereas activated metal and cartridge filter wastes consist of predictable mixes of fission and activation products. The commenter noted that activated metals are dominated by stainless steel in which $^{93}Nb$ is activated to $^{94}Nb$. The commenter stated that cartridge filters contain comparatively little $^{137}Cs$ because cesium is soluble, and even less $^{94}Nb$, which is present almost exclusively in activated metal.

   The commenter stated that the gamma hazards from these non-sealed source wastes are dominated by short-lived isotopes of cobalt that do not present a long-term gamma risk. To illustrate this point, the commenter evaluated the potential exposure from a piece of activated metal and from a cartridge filter at 100, 300, and 500 years after disposal. The commenter considered typical (historical) mixtures of radionuclides for activated metal, a BWR cartridge filter, and a PWR cartridge filter. To estimate potential exposures conservatively, the commenter increased the radionuclide concentrations in each type of waste until the limiting 10 CFR 61.55 Table 1 or Table 2 sum of fractions was a factor of 10 greater than the Class C limit (i.e., the maximum concentration for non-primary gamma-emitting radionuclides in discrete objects allowed by the averaging constraints in the CA BTP).

The commenter provided two graphs to show the projected doses at exposure distances of 3 cm (1.2 in) and 2 m (6.5 ft) and compared the dose projections to the projected dose from a 4.8-TBq (130-Ci) $^{137}Cs$ source 1 cm (0.4 in) in diameter by 2 cm (0.8 in) long. The commenter stated that the graphs demonstrate that neither discrete items of activated metal nor cartridge filters pose a carry-away intrusion hazard in the way that mono-isotopic sealed sources do. Based on this observation, the commenter concluded that a distinction between sealed sources and other types of waste should be made in the CA BTP.

NRC Staff Response:

The NRC staff appreciates the commenter's modeling of potential exposures from an activated metal item, BWR cartridge filter, and PWR cartridge filter. The NRC staff agrees with some of the commenter's conclusions and disagrees with others.

With respect to items of activated metal, the NRC staff notes that the commenter's graphs show that, under the averaging constraints of this CA BTP (i.e., at ten times the Class C limit), a piece of activated metal could result in an exposure of approximately 1 Gray per hour (1 Gy/h)[18] (100 milliRoentgen per hour (mR/h)) at 3 cm (1.2 in) from the item at 500 years after disposal. The NRC staff finds that this result demonstrates that activated metal could present a long-term gamma hazard.

With respect to cartridge filters, the NRC staff notes that the commenter's graph also shows an exposure of approximately 100 mC/kg-h (100 mR/h) at 3 cm (1.2 in) from a PWR cartridge filter at 500 years after disposal. On further investigation of the source term that the commenter used, the NRC staff determined that the projected exposure was caused by very low-energy photons (i.e., approximately 7 keV) emitted by Ni-59. Although these photons contribute to exposure, they do not contribute appreciably to dose. The NRC staff independently reviewed data from the MIMS database and determined that while cartridge filters often do not contain significant concentrations of radionuclides that are expected to pose a gamma radiation hazard, they might under some circumstances (see the response to Comment 4.a).

In general, the sealed source hazard results from the combination of three factors: (1) pocketable size, (2) high gamma activity levels, and (3) durability. In this context, NRC has quantified "pocketable size" as being less than 280 cc (0.01 $ft^3$), "high gamma activity levels" as activity levels above the values in Table 2 of Volume 1 of the revised CA BTP, and "durability" as being able to remain intact for hundreds of years after disposal. NRC analyses show that if these criteria are met, the long-term doses could be unacceptably high (i.e., greater than 5 mSv (500 mrem)). The NRC staff concludes that, independent of their origin, items that meet these three criteria present the same hazards as sealed sources and should be subject to the same averaging constraints.

Items of activated metal could be pocketable, might have significant long-term gamma activity, and are physically durable. For these reasons, the revised CA BTP does not

18 The commenter provided the graph in units of air kerma, R. The equivalent standard units for air kerma are Coulombs per kilogram (mC/kg). However, the more common standard unit of absorbed dose, Gy/h, has been used here. The exact conversion of air kerma to absorbed dose is energy and tissue dependent. The conversion given here is an approximation.

distinguish between sealed sources and activated metal items in terms of averaging constraints.

Cartridge filters, on the other hand, are not pocketable and often do not have significant long-term gamma activity. In addition, although the filter housing might be durable (e.g., stainless steel), the filter medium that contains the radioactivity typically is not durable (e.g., paper or synthetic filter media). For these reasons, the NRC staff does distinguish between the averaging constraints that are applicable to sealed sources and those that are applicable to cartridge filters. Whereas sealed sources and activated metal are subject to averaging constraints for discrete items (See Comment 6.c), licensees can justify treating cartridge filters as blendable waste (See Comment 4.a).

c. Based on consideration of typical radionuclide distributions in various types of waste, a commenter observed that even at the maximum averaging constraint of ten times the Class C limit, a 280-cc (0.01-$ft^3$) piece of activated metal with a typical radionuclide distribution would only contain approximately 19 MBq (0.5 mCi) of $^{94}$Nb. The commenter noted that this $^{94}$Nb activity is only 50 percent of the Table A value [Table 2] and expressed the view that this consideration made the piecemeal consideration of items of activated metal moot. The commenter also suggested that the Factors of 2 and 10 alone were sufficient to limit the gamma hazard from activated metal and cartridge filters and that further consideration of the gamma hazards from these waste streams (e.g., applying Table A [Table 2]) is not necessary.

NRC Staff Response:

In response to this comment, the NRC staff re-evaluated the application of Tables 2 and 3 [Tables A and B in the 201 draft CA BTP], as well as the Factors of 2 and 10 concentration limits. Table 2 [Table A] applies to the three primary gamma-emitting radionuclides (i.e., $^{60}$Co, $^{94}$Nb, and $^{137}$Cs). Table 3 [Table B] applies to radionuclides other than the primary gamma-emitting radionuclides. The Factor of 2 applies to primary gamma-emitting radionuclides when they control the waste classification. The Factor of 10 applies to all radionuclides of concern, including the primary gamma-emitting radionudlies when they do not control the waste classification.

In the 1995 CA BTP, Tables A and B were applied to the individual pieces from a component sectioned into smaller pieces. The values in Table B of the 1995 CA BTP were applied to all sectioned pieces to determine which could be considered part of the original component and which should be considered individually. The values in Table A of the 1995 CA BTP were applied in a similar way, but only to sectioned pieces smaller than 280 cc (0.01 $ft^3$). In addition, in the 1995 CA BTP, the Table A and B activity limits serve as the activity limits for encapsulating items. The Factor of 10 was applied to all nuclides of concern in certain mixtures of discrete items,[19] and the Factor of 2 was applied to the primary gamma emitters in each piece in a mixture when the primary gamma-emitting radionuclides controlled the waste classification. Thus, in the 1995 CA BTP, Tables A and B were fairly independent of the Factors of 2 and 10. The tables

19 These mixtures could include (1) individual items that did not result from sectioning, (2) original components that might have been sectioned but are considered as a single item because all pieces meet the Table A and B [Tables 2 and 3 respectively] limits, and (3) sectioned pieces that did not meet the Table A or B limits.

were applied to encapsulation and to sectioned pieces and the factors applied to mixtures of items considered as discrete objects.

In the 2012 draft (NRC, 2012), the application of Table B was expanded to all discrete items, and the application of Table A was expanded to all discrete items smaller than 280 cc (0.01 $ft^3$). With this change, discrete items being considered individually were subject to both Table B and the Factor of 10. If the primary gamma-emitting radionuclides controlled the waste classification, the Factor of 2 was applied to the primary gamma emitters in each item, and items smaller than 280 cc (0.01 $ft^3$) were also subject to both Table A and the Factor of 2.

The commenter is correct in noting that for small items the Factor of 2 always limits concentrations of the primary gamma-emitting radionuclides to values smaller than those in Table A. The commenter suggests that the more restrictive limit imposed by the Factor of 2 makes Table A unnecessary. The NRC staff understands this position and finds that a stronger statement could be made. Because the NRC staff has determined that Table 2 [Table A] is protective, the observation that the Factor of 2 is more restrictive than Table 2 [Table A] for small objects implies that the Factor of 2 is too restrictive for these small objects.

To evaluate this implication, the NRC staff evaluated the exposure scenarios used to develop Table 2 [Table A] and the Factor of 2. Unlike Table 2 [Table A], which limits radionuclide activities, the Factor of 2 limits radionuclide concentrations. The Factor of 2 is based on consideration of exposure to 1.7 $m^3$ (60 $ft^3$) of stainless steel objects in a 2.55 $m^3$ (90 $ft^3$) container, half of which have elevated $^{94}$Nb concentrations (see Section 4.4 of this volume for details). When applied to small objects, this concentration limit is not risk informed because it restricts the activities of the primary gamma-emitting radionuclides to values much smaller than the activities actually considered in establishing the Factor of 2. The NRC staff did not find a reason why the more restrictive limits imposed on small objects by the Factor of 2 are necessary.

Based on these considerations, the NRC staff has changed the CA BTP to allow the licensee to apply *either* Table 2 [Table A] or the Factor of 2; the licensee may pick the less restrictive limits or may base the selection on other operational considerations. Showing that either the Table 2 limit or the Factor of 2 has been met is sufficient. In choosing between these limits, the licensee is not restricted by the size of the item[20]. In general, the Factor of 2 concentration limit is more restrictive for smaller items and Table 2 is more restrictive for larger items.

In response to this comment, the NRC staff also considered the application of Table 3 [Table B] and the Factor of 10 to radionuclides other than the primary gamma-emitting radionuclides. Because both the Table 3 values and the Factor of 10 are based directly on the 10 CFR 61.55 class limits, the relationship between Table 3 and the Factor of 10 is slightly simpler than the relationship between Table 2 and the Factor of 2, which are based on independent exposure scenarios. As described in Section 4 of this volume,

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20 In the 2012 draft CA BTP (NRC, 2012), Table A was applied only to items smaller than 280 cc (0.01 $ft^3$). The size at which the Factor of 2 becomes less limiting is different for each radionuclide. However, in general, the Table 2 [Table A] limits are less restrictive than the Factor of 2 limits for items smaller than 280 cc (0.01 $ft^3$) as well as for items slightly larger than 280 cc (0.01 $ft^3$). Thus a licensee may choose to apply the Table 2 [Table A] limits to items larger than 280 cc (0.01 $ft^3$).

Table 3 and the Factor of 10 are based largely on maintaining consistency with the CA BTP encapsulation policy. In general, the Factor of 10 is more restrictive for smaller items and the Table 3 limits are more restrictive for larger items. The NRC staff did not find a risk-based reason to require application of the Factor of 10 to small objects. Therefore, the NRC staff changed the CA BTP to allow the licensee to apply *either* Table 3 or the Factor of 10; the licensee may pick the less restrictive value or may base the selection on other operational considerations. Showing that either the Table 3 limit or the Factor of 10 has been met is sufficient.

7. Alternative Approaches and Use of Site-Specific Intruder Analysis in Lieu of Generic Averaging Constraints

    a. The commenter expressed appreciation for NRC's new direction on the use of alternate approaches for averaging. The commenter expressed the view that while this provision has always been available in one form or another, the revised CA BTP 's identification of the disposal facility's regulatory authority as the one to review and approve [when necessary] the alternate method removes an unnecessary test of authority. However, given the tight resources in Agreement State agencies and the highly technical nature that some of these types of approaches might involve, the commenter hoped that the NRC will be in a position to support the Agreement States in a review and that the Agreement States will be in a position to request such help.

       NRC Staff Response:

       The NRC expects to support Agreement States on implementation of the CA BTP, when requested. NRC and Agreement State staffs routinely coordinate and cooperate on LLW issues.

    b. One commenter believed that it is important to differentiate the approaches in Section 3.8 [Section 4.9], which are ways to demonstrate compliance with 10 CFR 61.55(a)(8), from the approaches in 10 CFR 61.58, which address alternative waste classification requirements. The commenter stated it also is important to specify that invoking 10 CFR 61.58 is not necessary for the purposes of implementing Section 3.8 [Section 4.9] of the CA BTP. The commenter suggested that, to clarify this distinction, two new sentences should be added to the end of Section 4.9 to read:

       > Alternative approaches to averaging as described in this section or other approaches as may be approved by the disposal facility regulator are acceptable methods to demonstrate compliance with the provisions to determine the concentration of waste under 10 CFR § 61.55(a)(8). Use of 10 CFR § 61.58 or an exemption is not necessary to invoke the provisions of this section.

       NRC Staff Response:

       The staff agrees that "Alternative Requirements for Waste Classification" (10 CFR 61.58) in Section 3.7 of the CA BTP [Section 4.8] and "Alternative Approaches for Averaging" in Section 3.8 [Section 4.9] of the CA BTP are subject to different review procedures by the regulator. The former is for deviations from the waste classification or characteristics *requirements*, the latter for licensees' use of approaches different from the *guidance* in the CA BTP. The clarifying sentences that the commenter has suggested have been added to the CA BTP.

c. A commenter agreed with the NRC that engineering controls for protecting a future intruder from unknowingly exhuming Class A, B, and C LLW should be considered when determining the time that intrusion occurs. The commenter noted that, at the Texas Compact Waste Disposal Facility located in Andrews County, Texas, the Texas Commission on Environmental Quality (TCEQ) has stipulated requirements that Class A, B, and C LLW must be placed within reinforced concrete canisters, disposed of at a depth of at least 7.6 m (25 ft) below grade and protected by an additional reinforced concrete barrier to protect an inadvertent intruder. In the commenter's opinion, these robust design and engineering controls are more than adequate to ensure that an intruder will not encounter the waste for a period of at least 500 years for Class A, B, and C LLW. As such, the commenter supports the language in CA BTP Section 3.8.5 [Section 4.9.6], because it provides clarity that 500 years can be the initial time frame for considering intrusion into the waste as the basis of a realistic exposure scenario to support an alternative approach to concentration averaging.

   NRC Staff Response:

   The staff has revised the CA BTP to be more performance-based (i.e., it provides guidance for site- and waste-specific averaging approaches that can be proposed by licensees). NRC staff strongly encourages disposal facility licensees to submit proposals to Agreement State regulators for different concentration-averaging approaches that are based on the enhanced barriers in place at the disposal facility. Such proposals could be the basis for discussions between the licensee and the disposal facility regulatory authority to help ensure that waste shipped to a disposal facility and and whose radionuclide concentrations are averaged under an alternative approach would be suitable for the disposal facility. The staff notes that in order for 500 years to be the initial time for intrusion in a site-specific intruder scenario used to support an alternative approach to averaging,[21] the intruder barrier requirements specified in 10 CFR 61.52(a)(2) must be satisfied.

d. One commenter stated that Section 3.8.3 of the 2012 draft CA BTP [Section 4.9.4] does not accurately capture the DOE system of conducting probability-of-intrusion calculations. The commenter clarified that, while it is true that the government intends to maintain long-term control of DOE disposal sites, DOE requires that inadvertent intruder assessments be conducted at all DOE-owned disposal facilities in the unlikely case that the government loses those institutional controls. The commenter indicated that this requirement is found in the Manual (M) to the DOE Order (O) DOE O 435.1, *Radioactive Waste Management* (i.e., DOE M 435.1-1, *Radioactive Waste Management Manual,* at IV.P.(2)(h)). The commenter indicated that sites can request to assess to a longer time period for inadvertent intruder analyses for those sites that are unlikely to support an inadvertent homesteader and noted that only one DOE disposal site has provided this justification.

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[21] Approaches for *classifying* waste different from the provisions in 10 CFR 61.55, as opposed to alternative approaches for *averaging* radionuclide concentrations, would need to be approved under 10 CFR 61.58 or the compatible regulation in an Agreement State.

NRC Staff Response:

Section 3.8.3 of the CA BTP [Section 4.9.4] has been revised to indicate that DOE requires that inadvertent intruder assessments be conducted at all DOE-owned disposal facilities and that the likelihood of intrusion can be considered. The revised text also states that licensees can request permission to assume a longer time period before intrusion occurs. The staff acknowledges that DOE's approaches for protecting an inadvertent intruder are different in some ways from 10 CFR Part 61. For example, DOE does not use the generic Class A, B, or C classification system prescribed in 10 CFR Part 61, but develops site-specific WAC. This revised CA BTP facilitates the use of site-specific intruder assessments, as used in the DOE program, when safety can be demonstrated.

8. Scenario Selection for Inadvertent Intruder, including Probability of Intrusion

   a. A commenter noted that the relevant performance objective for protecting the inadvertent intruder reads:

> § 61.42 Protection of individuals from inadvertent intrusion. Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or <u>contacting the waste</u> at any time after active institutional controls over the disposal site are removed [emphasis added].

The commenter noted that Federal regulation talks about protecting individuals from "contacting the waste" after active institutional controls are removed. For this reason, the commenter suggested that the inadvertent intruder exposure scenario must envision someone coming into direct contact with waste; for instance, when a person drills a well or some similar scenario. The commenter believes that "using probability of intrusion" to relax physical safeguards and precautions violates the inadvertent intruder performance objective. The commenter believes that any attempt to either (1) assume that there is no scenario under which an individual could come into direct contact with the waste or (2) assign large probabilities to intruder events not happening violates the inadvertent intruder performance objective. This protection cannot be "assumed away" by simply stating that all "direct contact" scenarios are unlikely.

NRC Staff Response:

The CA BTP provides generic guidance applicable to a range of waste generators and disposal sites. The intruder scenarios used as the bases for this generic guidance all are based on the assumption that an intruder unknowingly comes into direct contact with waste, as the commenter recommends. Furthermore, as described in greater detail in the response to Comment 1.f, the NRC staff generally does not modify the projected dose to an inadvertent intruder by multiplying it by a probability of intrusion.

In addition to providing generic guidance, the CA BTP also allows licensees to use Alternative Approaches to consider site-specific factors. For example, Section 3.8.5 [Section 4.9.6] indicates that a licensee may assume that waste is not contacted until 500 years after disposal if the site waste is protected by features compliant with 10 CFR 61.52(a)(2) and the projected performance of these features is supported by an adequate technical analysis. In general, a licensee may propose to use concentration-averaging approaches that are based on site-specific factors.

The staff notes that the language in 10 CFR 61.42, "Protection of individuals from inadvertent intrusion," does not require that the waste be contacted by a postulated intruder. For example, an inadvertent intruder could move onto the disposal site and be exposed to gaseous releases without contacting or disturbing the waste. However, as noted above, the intruder scenarios that are the bases for the revised CA BTP guidance assume direct contact with the waste.

b. A commenter noted that the last sentence of Section 3.8.3 [Section 4.9.4] addresses the consideration of the probability of intrusion under DOE control. Some commercial sites might give DOE ownership and control of all or portions of the site following the termination of licensed commercial operations, according to the commenter. A current example is the federal portion of the WCS site. The commenter recommended that the last sentence be revised as follows:

> Its use of this provision has been limited, according to DOE, and has been based, in part, on the government's extended, long-term control of DOE sites. <u>Regulators for commercial sites should also give appropriate consideration to predicting human intrusion for commercial disposal facilities under long-term DOE control and stewardship.</u>

NRC Staff Response:

10 CFR Part 61.59(b) states that institutional controls cannot be relied on to control access to a site for more than 100 years following transfer of control of the disposal site to the owner (i.e., the State or Federal government). To the extent that a disposal facility licensee relies on such controls beyond 100 years in a justification of an intrusion scenario based on its likelihood, the regulator would consider that information in either granting an exemption to 10 CFR Part 61.6, "Exemptions," or reviewing an alternative averaging approach, as appropriate. The use of different scenarios or probabilities of scenarios in the first case (an exemption) could enable a licensee to dispose of waste with concentrations greater than those specified for particular waste classes in 10 CFR 61.55. In the second case, in which an alternative averaging approach is proposed, because the averaging approaches and the intruder scenarios on which they are based are contained in guidance, no exemption would be needed. The staff has added clarifying language to Section 3.8.3 [Section 4.9.4 of the 2012 draft CA BTP].

c. A commenter noted that on page 39 of Section B.3 of Appendix B to the 2012 draft [Section 4.3 of Volume 2], the following statement is made: "Five hundred years after closure of a LLW landfill, the LLW containers have decayed and the mixable wastes and encapsulating materials have become soil like." The commenter suggested that more realistic scenarios should be able to be considered, particularly for very dry sites. It is understood that cement or metal will eventually degrade; however, after 500 years it is unlikely that the containers or encapsulations will degrade to or become "soil like" materials in very dry environments, the commenter stated. Degradation will take place, the commenter observed, and it would be expected that the container or encapsulation will eventually crack and large pieces of cement or metals (from 0.2 $m^3$ (55-gallon) drums) holding the source will eventually open but not to the point of disintegration of the physical structure to a soil-like condition, especially for durable metals such as stainless steel.

NRC Staff Response:

The NRC agrees that encapsulating media may not become soil-like within 500 years, especially in a dry climate. However, as the commenter acknowledges, it is reasonably conservative to assume the waste container and encapsulating medium could crack and open, which would be sufficient to expose the encapsulated waste. The small item carry-away scenario does not depend on the encapsulating medium becoming soil-like, only that an inadvertent intruder could pick up the discrete item without realizing the gamma hazard. In response to this comment, the CA BTP text has been revised to remove references to the encapsulating medium becoming soil-like.

Licensees who wish to take further consideration of site-specific factors (such as a very dry climate) may, in coordination with the applicable disposal facility State regulator,[22] rely on site-specific calculations, as described in the Alternative Approaches section of the CA BTP, to dispose of waste. The CA BTP gives licensees a choice, because either the generic positions or the site-specific Alternative Approaches can appropriately protect an inadvertent intruder.

d. A commenter stated that the intruder scenarios described in the sealed source sections and Appendix B [now Section 4 in this volume] could be improved by making reasonably representative stylized inadvertent scenarios in terms of behavior. In the commenter's view, while an isolated rare member of the population might pick up interesting rocks and bring them home, in the commenters' LLW disposal program, they do not typically plan to protect the "rare" future individuals in a population but plan to protect the future average member of the public.

NRC Staff Response:

The staff appreciates the comment. The staff has used intruder scenarios to develop concentration-averaging approaches that are consistent with the approach used by the NRC in the draft EIS for Part 61. The staff has also used more reasonable scenarios in this revision of the CA BTP than were used in the 1995 CA BTP and, consequently, several of the Table 2 (formerly Table A) activity limits have increased. In addition, the new Alternative Approaches section of the revised CA BTP could enable further increases in activities of discrete items, including sealed sources, for disposal based on site-specific features and scenarios, within the concentration limits in the waste classification tables

In this revision, the staff has postulated reasonable yet conservative stylized scenarios for assessing the impact of hot spots in waste on an inadvertent intruder. In contrast to the commenter's opinion, the staff does not believe the BTP is designed to protect "rare" individuals. However, it also is not designed to limit protection to the "average member of the public." Instead, the BTP is designed to protect the "average member of the critical group," where the "critical group" is defined in 10 CFR Part 20 as "the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity

[22] Or the NRC, if there is no Agreement State.

for any applicable set of circumstances." Based on experience with unsecured sources, the staff believes that some people might pick up a small item after 500 years and potentially receive a significant dose in a few hours, depending on the radioactivity of the item. The stylized scenarios used by the staff are intended to be representative of potential, but unlikely, exposures and are a defense-in-depth measure. Different scenarios from the one previously described in the 2012 draft (NRC, 2012) could result in a few hours of exposure at close proximity to the intruder.

e. One commenter stated that, in an earlier set of comments, the commenter provided a probabilistic methodology for assessing a future inadvertent intruder. The commenter stated that the method considers the size of the "hot spots" expected in a large disposal facility against the total size of the facility and conducts an analysis of the likelihood that any inadvertent intruder would happen on just those hot spots. The commenter noted that the probability would be far less than one. The commenter suggested that NRC give further consideration to such an approach.

   NRC Staff Response:

   Staff appreciates the suggestion to calculate the probability of intrusion based on the cumulative area of the hot spot(s), divided by the area of the landfill. As noted in the NRC's response to comment 1.f, the projected dose of 5 mSv/yr (500 mrem/yr) was originally applied to the consequence (dose) to the inadvertent intruder, rather than being applied to the risk (i.e., the dose multiplied by the probability). The use of a projected dose of 5 mSv/yr (500 mrem/yr) implicitly acknowledges that intrusion is unlikely to occur, because it exceeds the 1 mSv/yr (100-mrem/yr) public dose limit contained in 10 CFR Part 20. For the CA BTP, the NRC staff has applied the projected dose of 5 mSv/yr (500 mrem/yr) to the dose consequence of reasonable yet conservative inadvertent-intrusion scenarios. The commenter is suggesting that higher projected doses could be used for low-likelihood intrusion scenarios. Development of a different limit that would be appropriate for a risk-based intrusion is beyond the scope of the CA BTP.

f. A commenter stated that the inadvertent intruder scenarios described in the background section in Appendix B [Section 4 of this volume] are based on several inadvertent intruder scenarios described in NRC's draft EIS (NRC, 1981). The commenter believes that it would be helpful if the scenarios were updated in the CA BTP to include more realistic inadvertent intruder scenarios.

   NRC Staff Response:

   The staff notes that the intruder scenarios the commenter refers to, which are discussed in Section B.2, "Background," in Appendix B to the 2012 draft [Section 4.2 of this volume], were used to develop the waste classification tables in 10 CFR 61.55. These scenarios are described in detail in NRC's draft EIS for 10 CFR Part 61 (NRC, 1981).

   Section 4 of this volume contains other scenarios that are intended to complement the exposure scenarios presented in the NRC's draft EIS for Part 61. In the draft EIS intruder exposure scenarios, the waste is assumed to be either unrecognizable (in the construction and agricultural scenarios), or intact and recognizable as being hazardous (in the discovery scenario). The 1995 CA BTP and this updated CA BTP provide complementary scenarios in which certain discrete items (e.g., stainless steel items) remain intact, but are not recognized as being hazardous. This revised CA BTP also analyzes a well-drilling scenario that is consistent with common practice in radiation protection (NRCP, 2005).

Licensees who wish to take credit for site-specific factors and “more realistic” intruder exposure scenarios may, in coordination with the applicable disposal facility State regulator,[23] perform site-specific calculations as described in the Alternative Approaches section [now Section 3.8 of Volume 1]. The revised CA BTP gives licensees a choice, because either the generic positions or the site-specific alternative approaches can appropriately protect an inadvertent intruder. These alternative scenarios only apply to the averaging constraints, and could not be used, under the current 10 CFR Part 61, to classify waste differently from how it is done in the 10 CFR 61.55 tables.

g. The statement that hot spots of gamma activity might be more significant to intruder doses than hot spots associated with other nuclides has not been justified, according to one commenter. The commenter stated that, while the pathways of concern for alpha or beta emitters are inhalation and ingestion, instead of external exposure, inhalation and ingestion would be likely pathways following the intruder’s disturbances.

NRC Staff Response:

The staff agrees that the technical basis in Appendix B of the 2012 draft CA BTP [now Section 4 of this volume] could be clearer on this point and has made appropriate revisions to it. The CA BTP addresses hot spots associated with alpha, beta, and gamma radiation. As the commenter notes, the pathways of concern for alpha or beta emitters are inhalation and ingestion and these pathways are addressed for blendable wastes in the CA BTP. In order to address the hazards associated with discrete items that are intact at the time of intrusion, the 1995 CA BTP postulated certain handling scenarios involving external exposure to gamma radiation. It was assumed that an intruder would not immediately recognize the hazard associated with these discrete items. Accidents involving gamma-emitting sealed radioactive sources were one reason that the NRC recommended limits on averaging of discrete items that might survive intact in an LLW disposal facility. The text in Section 4 of this volume has been clarified to note this point.

9. Encapsulation and Volume for Averaging

a. Two commenters recommended that the CA BTP contain separate guidance for encapsulation of waste and encapsulation of sealed sources in Section 4.5 [Section 3.3.4]. Separate guidance for waste and sources is warranted, the commenters suggested, because the waste streams of concern (principally discrete activated-metal items and cartridge filters) do not pose the long-term gamma risk that sealed sources do. The commenters also stated that encapsulation of sources and waste have different design functions. The commenters provided specific suggestions for a new encapsulation subsection that would specify encapsulation criteria for certain LLW other than sealed sources. Included in the new section were the Factor of 2 and 10 concentration limits for mixtures of discrete items and a minimum waste loading constraint of 14 percent. The 0.2 $m^3$ (55-gallon) drum volume constraint for sealed

[23] Or the NRC, if there is no Agreement State.

sources could be exceeded for these other wastes as long as the minimum waste loading was 14 percent.

The commenters noted the NRC's concerns about extending waste-to-binder loadings to unusual circumstances, such as the grouting of reactor internals into a reactor pressure vessel and averaging over the entire volume. To address the staff's concern, one commenter recommended a container size limitation of 5.7 $m^3$ (200 $ft^3$), another 9.37 $m^3$ (331 $ft^3$). The 5.7-$m^3$ (200-$ft^3$) limitation is based on the volume specified in a previously approved NRC topical report. The 9.37-$m^3$ (331-$ft^3$) limit is based on the current maximum size of a commercially available disposal liner that could be used for this purpose and for which a shielded shipping cask (Department of Transportation (DOT) 7A Type A, IP-1 and IP-2) exists.

NRC Staff Response:

The staff agrees in part and disagrees in part with the commenters' suggestions. Most of the constraints on encapsulated waste apply irrespective of whether a sealed source or other type of LLW is involved. Those constraints are principally that (1) the encapsulated mass must meet the concentration limits in the waste classification tables in 10 CFR Part 61.55, (2) the amount of nonradioactive material used in averaging should be constrained, and (3) the concentration or activity of discrete encapsulated items should be constrained to ensure intruder protection. For simplicity and clarity, the staff has treated all encapsulated waste items in one section of the revised CA BTP.

With respect to the other suggestions, the staff agrees that a minimum waste loading is an appropriate method for ensuring that licensees do not use extreme measures in calculating waste concentrations. The staff has previously approved a minimum waste loading of 14 percent in a topical report (NRC, 1999), and this value has been incorporated in the CA BTP. To ensure that discrete encapsulated items do not pose a hazard to an intruder, either the Factors of 2 and 10 or the Table 2 and Table 3 activity limits for primary gamma radionuclides and other-than-primary gammas apply to these individual items, respectively.

b. One commenter suggested that the staff should update Table C [now Table 4], "Volume and Mass for Determination of Concentration," to include "mixable" waste with solidified ion-exchange resins. The commenter suggested that this approach would be consistent with the discussion in Section 4.2.1 ["Mixable Wastes and Homogeneous Waste Types," now included in Section 3.2 of the revised CA BTP] and avoid confusion or misinterpretation during the course of inspection activities or other evaluations of waste processing.

NRC Staff Response:

The NRC staff agrees that Table 4 [formerly Table C], "Volume and Mass for Determination of Concentration," should be updated. As discussed in the response to Comment 12.d, the entry for "solidified ion-exchange resins" has been changed to address solidified wastes more generally. However, as discussed in the response to Comment 2.i, the revised CA BTP has replaced the term "mixable" waste with the term "blendable waste". Blendable wastes are not subject to averaging constraints in most cases. Mixtures of these waste streams might be subject to additional averaging constraints in some circumstances, as discussed in Section 3.2.2. In response to this comment, Table 4 has been updated to indicate that single blendable waste streams may be averaged over the volume or weight of the waste.[24] Table 4 directs readers to Table 1 for thresholds for demonstrating adequate blending for mixtures of two or more blendable waste streams (i.e., waste streams that do not contain discrete items).

c. A commenter recommended that the use of containers currently in use should not be deemed an extreme measure and, conversely, using a container larger than those typically used could be considered an extreme measure. Specifically, the commenter recommended that the second sentence of Section 4.5 [now Section 3.3.4] should read:

> "However, the amount of credit allowed for encapsulation should be limited to disposal containers typically used at disposal sites so that extreme measures cannot be taken solely for the purposes of lowering the waste classification."

NRC Staff Response:

The staff has increased the limit on the size of containers, but in order to ensure that extreme measures for concentration averaging are not employed, is also specifying a waste-loading minimum of 14 percent for containers larger than 0.2 $m^3$ (a 55-gallon drum). The staff understands that typical disposal containers, currently in use, are smaller than 9.4 $m^3$ (331 $ft^3$). Larger sizes can be proposed by the licensee or applicant in accordance with the alternative approaches guidance in Section 3.8 of Volume 1 of the revised CA BTP.

d. A commenter recommended that the following bullet be added just before Section 4.6 [Section 3.5] as a cross-reference to Section 4.9.5 [Section 3.8.4], "Large Components," to allow case-by-case reviews similar to those permitted by the previously approved NRC topical reports noted in the fourth bullet of Section 4.5 [Section 3.3.4] for larger volumes:

> "Notwithstanding the above, other averaging volumes may be approved as provided in Section 4.9 [now Section 3.8, 'Alternative Approaches'] if there is reasonable assurance that the performance objectives of Part 61 are met. See for example, Section 4.9.5 [Section 3.8.4, 'Large Components']."

NRC Staff Response:

The staff has added similar text to Section 3.5 of the revised CA BTP.

e. A commenter stated that the CA BTP focuses on waste in containers, but also needs to address bulk waste disposal.

NRC Staff Response:

The staff has clarified text in Section 3.5 [Section 4.6 of the 2012 draft CA BTP], "Determining the Volume of the Waste," to indicate that the CA BTP covers bulk wastes

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24 Or the fill-volume of the container, if there is less than 10 percent void space.

as well. The CA BTP states that the volume for the purposes of concentration averaging is the fill volume of the container or the mass of the waste. For bulk waste, the container could be, for example, a rail car.

In addition, text related to contaminated soil has been revised. The draft 2012 CA BTP inadvertently changed the position in the 1995 CA BTP that radionuclide concentrations in contaminated soil could be averaged over the volume or mass of waste in a disposal container to indicate that concentrations could be averaged only if the soil was packaged to achieve 90 percent or greater fill volume. As described in the response to Comment 1.d, the intent was only to limit averaging over void space, not to require that soils be packaged (e.g., as previously indicated, the relevant container could be a rail car). This text has been clarified in the revised CA BTP.

10. Stakeholder Views on ACRS's December 13, 2011, Comments on the CA BTP (ACRS, 2011)

    a. One commenter agreed in principle with the comments by the ACRS dated December 13, 2011, regarding the revision (ACRS, 2011). However, the commenter understood that not all of the ACRS's comments can be implemented within the context of the limited scope of the CA BTP revision. The commenter expressed the hope that the NRC can accommodate more of the ACRS comments in the planned rulemaking for 10 CFR Part 61 now in progress.

       NRC Staff Response:

       The staff is considering some of the ACRS comments in the development of the proposed rule to revise 10 CFR Part 61. The December 13, 2011, ACRS comments and the staff's response to them can be found in Appendix G to the 2012 draft CA BTP (NRC, 2012).

    b. With respect to allowing reliance on perpetual care funds for institutional controls to prevent or mitigate the impacts of inadvertent intrusion in developing averaging positions, a commenter expressed several concerns. (In its December 13, 2011, letter, the ACRS had noted that current disposal facilities had collected large perpetual care funds, that there was little chance of a complete loss of information about the location of disposal sites, and that inadvertent intrusion was "very unlikely.") The commenter stated that the institutional control period of 100 years should not be lengthened under any circumstance. The commenter also believes that the availability of money today – for instance, in the form of a perpetual care fund – does not on its own constitute reasonable assurance of adequate and active institutional controls 100 or more years from today. The commenter pointed out that funds can be raided for other purposes. The commenter believes there are many real-world examples that show loss of institutional controls in fewer than 100 years.

       NRC Staff Response:

       10 CFR Part 61.59(b) states that institutional controls may not be relied on to control access to the disposal site for more than 100 years following transfer of control of the site to the owner (the State or Federal government). A licensee could request an exemption from this requirement under 10 CFR 61.6 to rely on institutional controls for longer periods. In order to grant such an exemption, the Commission or Agreement

State regulator for the disposal facility would have to determine that the exemption was authorized by law, would not endanger life or property or the common defense and security, and is otherwise in the public interest. The staff appreciates the commenter's views on this issue, which could be raised and considered if an exemption were ever requested by a disposal facility operator.

11. Increasing the Confidence in Generators' and Processors' Classification of Waste

    a. One commenter noted that the regulations established by the TCEQ prohibit dilution of radioactive waste for the purpose of changing its waste classification. The commenter expressed the opinion that the prohibition serves, among other things, to prevent shifting the burden of regulatory responsibility from waste processors to an Agreement State hosting a disposal facility. The commenter stated that Agreement States hosting a disposal facility have expressed reservations regarding the CA BTP because it might shift the burden of responsibilities onto their shoulders if a waste processor inadequately characterizes waste stream homogeneity, especially for waste blended to the upper limits for Class A LLW.

       NRC Staff Response:

       The staff acknowledges the comment. With respect to a State that hosts a disposal facility having increased responsibility as a result of waste blended to the upper limits of Class A, the Agreement States regulating the processors and disposal facilities have to implement a licensing and inspection program that provides reasonable assurance that licensed activities are being implemented appropriately. At the same time, the Agreement States hosting a disposal facility have requested that the NRC consider means by which they could gain greater assurance that waste shipped by generators and processors is characterized properly, and the NRC has agreed to explore with them how that can best be accomplished(see response to Comment 4 in Section 3.3).

12. Other

    a. A commenter stated that the final sentence in the first paragraph on page 7 of the 2012 draft CA BTP could be read as providing that the 1983 CA BTP remained in effect following the 1995 CA BTP as a matter of chronology. To clarify the intent that portions of the 1983 CA BTP remain in effect today, the commenter proposed a new last sentence that reads, "As noted above, the 1983 CA BTP remains in effect with the exception of Section C.3, initially replaced by the 1995 CA BTP, and now replaced by this version."

       Staff Response:

       The staff agrees in general with the comment and has revised the CA BTP as suggested by the commenter to address those portions of the 1983 that remain in effect. One other section of the 1983 CA BTP concerning the use of shipping manifests has also been superseded and that is noted in Section 1.5 in Volume 1 of the revised CA BTP.

    b. A commenter noted that Figure 2, "Classification of Individual Items," and Figure 3, "Concentration Averaging for Mixable Waste," are introduced before Figure 1, "Classification of Mixtures of Activated Metals, Contaminated Materials, and Cartridge

Filters," is introduced and discussed in the 2012 draft CA BTP. The commenter recommended introducing Figure 1 first.

NRC Staff Response:

The staff has reorganized the CA BTP and revised and added figures to explain the text to improve readability and flow. The staff believes that the revisions will address the commenter's concern.

c. A commenter noted that Nodes P, Q and R in Figure 3 are not cited in the narrative of the 2012 draft CA BTP.

   NRC Staff Response:

   As noted in the previous comment response, the staff has reorganized the CA BTP and revised and added figures to explain the text to improve readability and flow. The new figures are cited in the text.

d. One commenter recommended that all solidified materials should be assumed to be uniform, as solidified liquids are. The commenter expressed the view that this change would be consistent with the averaging volumes and masses provided in Table C of the 2012 draft CA BTP (now Table 4). Specifically, the commenter stated that the table in the 2012 draft (NRC, 2012) indicates that "solidified resins and other solidified material" may be averaged over the volume or mass of the solidified waste if homogeneity is maintained. The commenter also suggested that, by the definition of "solidification" in the CA BTP glossary, solidified materials must be homogeneous because the definition specifies that "solidification" results in a "solid, radiologically homogenous material."

   NRC Staff Response:

   As the commenter notes, Table C of the draft 2012 CA BTP [Table 4] indicates that concentrations in either "solidified liquids" or "solidified ion-exchange resins" may be averaged over the volume or mass of the solidified waste.[25] The two categories are listed separately because the entry for solidified ion-exchange resins contains the additional constraint that the radionuclide concentrations can be averaged only if the solidified mass is homogeneous. In contrast, solidified liquids are assumed to be homogeneous.

   Both NRC guidance (NRC, 1991) and industry standards (American National Standards Institute (ANSI)/American Nuclear Society (ANS)-55.1) state that solidified waste should be adequately mixed to produce a physically uniform product. The NRC staff expects that the degree of mixing required to create a physically uniform product will also eliminate radiological hot spots. Therefore, in response to this comment, staff has updated the CA BTP text and Table 4. The revised guidance indicates that radionuclide concentrations in solidified waste may be averaged over the total volume or mass of the

[25] Although the commenter cited an entry for "solidified resins and other solidified material"," none of the previous drafts of the table (i.e., the 1995, 2011, or 2012 versions) have included a general entry for "solidified material."

solidified waste form if the solidified waste is physically uniform, in accordance with NRC guidance and industry standards.

e. A commenter recommended deleting the extra “Table” from the text “Table Table A.”

NRC Staff Response:

The staff agrees and the CA BTP has been corrected.

f. A commenter noted that the term “Dispersal” should be “Disposal” in the reference to Appendix G to 10 CFR Part 20 on Page 27 in Section 4.7 of the 2012 draft CA BTP.

NRC Staff Response:

The staff agrees and the CA BTP has been corrected.

g. A commenter noted that Appendix C of the 2012 draft BTP contains staff responses to comments on earlier drafts, many of which are annotated as “superseded” by the current draft. These might be a source of significant confusion in the commenter’s view if they are retained in the revised CA BTP, and therefore the commenter recommend all superseded responses be deleted.

NRC Staff Response:

The staff agrees with the comment. In response, the staff has included in the revised CA BTP only the responses to comments on the 2012 draft (NRC, 2012). Earlier drafts of the CA BTP containing responses to comments on previous drafts are cited in the revised CA BTP and available in NRC’s ADAMS for readers interested in the evolution of the revised positions. Some of the earlier responses might also provide insights on the basis for positions in the revised CA BTP and help to resolve uncertainties in interpreting the revised CA BTP positions.

h. A commenter noted that the 2012 draft CA BTP identifies an activity level (specifically, the threshold limit of 37 MBq (1 mCi)) as the primary decision factor for classifying a container with multiple items, yet there is no description of how this equates to dose to an inadvertent intruder in 100 or 500 years. The commenter stated that because each isotope decays at different rates and is associated with different potential doses at different times, knowing the radioactivity at the time of disposal provides only a small portion of the required information. It appeared to the commenter as though this chosen activity level is associated with $^{94}$Nb. $^{94}$Nb has a half-life of 20,000 years, which is far longer than $^{60}$Co or $^{137}$Cs, and its activity is not at all relatable to other isotopes, the commenter stated. Based on research conducted by the Electric Power Research Institute and presented at the 2012 RadWaste Summit, the commenter believes that many of the assumptions made by NRC on radioactivity in the activated metals might need to be updated.

NRC Staff Response:

In the 1995 CA BTP and this revised CA BTP, the 37-MBq (1-mCi) constraint for primary gamma-emitting radionuclides is a simple and conservative screening criterion that licensees are not required to use, but may choose to use for reasons of efficiency in classifying waste. It allows licensees to opt out of performing any additional calculations. If each item in a mixture has an activity level of 37 MBq (1 mCi) or less, the mixture can be concentration-averaged, without considerations of other criteria such as the Factor of 2 or 10 concentration limits. This screening criterion is based on $^{94}$Nb, the longest-lived of the primary gamma-emitting radionuclides in the waste classification tables in 10 CFR 61.55. This activity constraint applies at the time of disposal and is based on a 5 mSv (500-mrem) projected dose to an inadvertent intruder 500 years later. The 37-MBq (1-mCi) constraint is derived in Section 4 of Volume 2 for $^{94}$Nb, and this limit is the most restrictive limit of all the Table 2 activity limits on primary gamma-emitting nuclides. The NRC does not expect that this easy-to-use option for classification will be used very often, but the NRC determined that this option should be available.

The 37-MBq (1-mCi) constraint is one of two easy-to-use and conservative screening criteria that allow licensees to opt out of performing any additional calculations, such as the measurements and calculations required to demonstrate that a container meets the Factor of 2 and the Factor of 10 concentration limits. The other screening criterion is to classify a mixture based on the highest classification of any item in the mixture. The staff has revised the text in Section 3.3.2.1 to emphasize that these are optional screening criteria.

With respect to EPRI's comments at the 2012 RadWaste Summit, EPRI's formal comments on the CA BTP (EPRI, 2012b) address in detail their concerns with activated metals. See responses to EPRI's comments in 6.b and 6.c.

i. A commenter noted that, as described in the NRC analysis in Appendix B of the 2012 draft CA BTP, Section B.3 [Section 4.3 in this volume], exposure to a 4.8-TBq (130-Ci) $^{137}$Cs source in the small item carry-away scenario NRC analyzed would cause an intruder dose of about 5 mSv (500 mrem) at 500 years. This is a projected acute dose from an immediate event. Therefore, the commenter recommended, in the second paragraph of the NRC analysis, the sentence "The dose from a 5.2 TBq (140 Ci) $^{60}$Co source will be 5 mSv/yr (500 mrem/yr) at 111 years" should be corrected to read "5 mSv (500 mrem)" and the calculation should be reported at 100 years.

   NRC Staff Response:

   The staff agrees that the exposure is an acute event and the text has been corrected to report the dose in units of mrem rather than reporting the dose rate in units of mrem/yr. The dose calculation has also been revised slightly since the 2012 draft (NRC, 2012). In the revised calculation (see Section 4.3 of this volume), a 4.5-TBq (120-Ci) $^{60}$Co source after 100 years of decay results in a projected dose of 5 mSv (500 mrem) to an inadvertent intruder. The NRC staff chose to use 5.2 TBq (140 Ci) for $^{60}$Co in Table 2 of the revised CA BTP because 5.2 TBq (140 Ci) is the Class A limit for $^{60}$Co in a 0.2-$m^3$ (55-gallon) drum. The dose from this source is projected to be 5 mSv (500 mrem) at 101 years after disposal. The NRC staff found that this decision provided reasonable assurance of intruder protection because it is unlikely an individual would both (1) intrude into the disposal site during the first year after institutional controls and (2) encounter a source that was disposed of in the last year of site operation. Both of these conditions would need to be met for the intruder to encounter the source after only 100 years of decay. Furthermore, the staff determined that because of the stylized nature of the intrusion scenarios, it was not meaningful to distinguish between the dose at 100 years and the dose at 101 years after site closure.

j. A commenter stated that, in order to appropriately calculate the potential future dose in Appendix B, Section B.3 of the 2012 draft CA BTP, it would be necessary to know the presumed distance from source to receptor. The commenter recommended that the NRC consider including all additional parameters that were used in MicroShield® [26] to determine the projected dose to an inadvertent intruder. As examples, the commenter suggested NRC list the equivalent density shielding for the human body by muscles and bones, distance to the organs of interest, and which tissue-weighting factors were used (i.e., International Commission on Radiological Protection (ICRP) 26/30 (ICRP 1977, 1982) or ICRP 60 (ICRP,1991)).

   NRC Staff Response:

   Sections 3.3 and 3.4 of this volume [previously Sections B.3 and B.4 of Appendix B in the 2012 draft (NRC, 2012)] have been modified and now provide all MicroShield® modeling details necessary to reproduce the results presented in these appendices, except for the density of air, because the results are fairly insensitive to any reasonable value of air density.

k. A commenter recommended that in the last paragraph of Appendix B, Section B.4, under "NRC Analysis," [now Section 4.3.2 of this volume] that the text "5 mSv (505 mrem)" should be changed to "5 mSv (500 mrem)".

   NRC Staff Response:

   The staff's calculated dose was 505 mrem, which the staff rounded to 500 mrem for decision making. To prevent confusion, the text will be changed to show the rounded number (500) rather than the actual number (505).

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26 MicroShield® is a photon shielding and dose assessment program developed by Grove Software, Lynchburg, VA.

## 3.3 Input from Agreement States and LLW Forum

Agreement States that regulate LLW disposal facilities and the LLW Forum's Disused Source Working Group (DSWG) provided comments on NRC's 2012 draft of the CA BTP (NRC, 2012). The LLW Forum facilitates State and LLW compact implementation of the Low-Level Radioactive Waste Policy Act of 1980 and the 1985 Amendments and promotes the objectives of the LLW regional compacts. Some members of the DSWG are from Agreement States that regulate LLW generators and disposal facilities. The State of Utah also provided its own comments. Agreement States regulate all of the operating disposal facilities in the United States and the licenses and waste-acceptance criteria for the disposal facilities cite the CA BTP in whole or in part.

The following documents were submitted by the State of Utah and LLW Forum's DSWG.

**Table 2. Comments from State Organizations**

| Document Type | Author | Date | Organization | ADAMS ML # |
|---|---|---|---|---|
| Letter | Todd Lovinger | October 6, 2012 | DSWG, LLW Forum | ML12284A265 |
| Letter | Rusty Lundberg | October 8, 2012 | State of Utah, Department of Environmental Quality | ML12307A110 |

The staff analyzed these comments in the sections below. In its October 6, 2012, letter, the DSWG listed its original comments on the August 2011 draft, the staff's response to their comment in the 2012 draft (NRC, 2012), and the DSWG's reaction to the staff's response. To eliminate duplication, the staff has consolidated issues and comments from the DSWG's October 6, 2012, letter. Each unique concern is presented below, along with a staff response.

Disused Source Working Group

1. The Revised CA BTP and States' Acceptance of Larger Sources

    The DSWG asked that the staff clarify that the CA BTP, as NRC guidance, does not force a State with a disposal facility to accept larger (higher activity) sources.

    NRC Staff Response:

    The staff agrees that the CA BTP is NRC guidance and therefore the States are not forced to accept larger (higher activity) sources that could be permitted under the revised CA BTP. The staff also recognizes that States that regulate disposal facilities have a variety of factors to consider in determining whether to adopt guidance. At the same time, the staff believes that the revised CA BTP has the potential to improve management and disposal of LLW in the United States. The staff is willing to participate in public meetings and conduct training of State staff, subject to availability of travel funds, if these activities would help to address any concerns that the States might have.

2. Compatibility

   The commenter suggested that the States with disposal facilities should have the ability to promulgate rules that are more stringent than NRC to protect their public health and environment. The commenter also expressed the view that NRC should work directly and specifically with States with disposal facilities on compatibility issues that relate to disposal of LLW.

   NRC Staff Response:

   The NRC values the views of the Agreement States (and especially those of the States with disposal facilities) on LLW disposal rulemakings. The proposed rulemaking for the ongoing revision to 10 CFR Part 61 was sent to the Commission on July 18, 2013 in SECY-13-0075 (NRC, 2013) and the Commission responded with their approval, provided the staff makes the changes noted by the Commission, in Staff Requirements Memorandum-SECY-13-0075 (NRC, 2014b). Two Agreement State staff members from States with LLW disposal facilities are on the NRC working group for the rulemaking that has developed rule language that implements the changes to the proposed rule required by the Commission.

   The Commission noted that the proposed rule should be published with a compatibility category "B" applied to the most significant provisions of the revised rule, including the Compliance Period, the Protective Assurance Period and its analytical threshold, and the WAC. Category B is for regulatory requirements that have significant transboundary implications. For category B regulations, Agreement State program elements should be essentially identical to those of the Commission; therefore, the States would not be able to promulgate more stringent requirements.

   The proposed rule is currently in the final review process at the NRC and is expected to be issued for public comment by March 2015. The Commission directed the staff to allow for a 120-day public comment period and to specifically solicit comments on the appropriateness of the category B designation. The Agreement States will have an opportunity to submit comments once the proposed rule is published in the *Federal Register*. These comments will be carefully considered before the rule is finalized.

3. Changes in the Sealed Source Activity Limits

   a. The commenter stated that disposal fees and taxes at the Barnwell Disposal Facility are based on volume, not activity. An increase in the maximum activity for sealed sources per container would mean more source term for the Disposal Facility with no corresponding increase in funds for long-term care at the facility, according to the commenter. The commenter recommended that the NRC acknowledge that it might be difficult for States to raise fees in current economic conditions, and that the NRC would support the potential need for fee increases.

      NRC Staff Response:

      The staff appreciates that fee increases might be controversial and are not automatic. The NRC would consider supporting State actions that would facilitate disposal of sealed sources rather than their indefinite storage, based on a specific request.

b. In the commenter's view, it appears that the focus of the CA BTP revision is on changes for larger commercial sealed source disposal in States with disposal facilities. The scope of this issue should not solely focus on the back-end disposal remedy for sealed sources, the commenter believes. If front-end issues [during the original licensing of sources] are not also addressed in recognition of their impact to future available options, the problem will not be solved. In the commenter's opinion, the NRC's continued commitment to addressing front-end issues will address this concern.

   NRC Staff Response:

   The Federal government has other initiatives to address front-end issues associated with sealed sources, such as financial assurance for disposal of disused sources. The *Energy Policy Act of 2005* directed the Radiation Source Protection and Security Task Force to evaluate and provide recommendations relating to the security of radiation sources in the United States from potential terrorist threats, including acts of sabotage, theft, or use of a radiation source in a radiological dispersal device. The Task Force includes independent experts from fourteen Federal agencies and one State organization (the Organization of Agreement States) and is chaired by the NRC. The independent Task Force members represent agencies with broad authority over all aspects of radioactive source control, including regulatory, security, intelligence, and international activities. The Task Force report addresses improvements in source tracking, licensing, transportation and import/export, along with disposal.

   The Task Force published a 257-page report in August 2006 (NRC, 2006) with numerous findings and recommendations. It updated the report in August 2010 (NRC, 2010a) and in August 2014 (NRC, 2014c). At an October 19, 2011, meeting in Santa Fe, New Mexico, the NRC staff briefed the LLW Forum's DSWG, including members from the States with disposal facilities, on how front-end sealed-source issues are being addressed.

   The staff agrees that these other issues are also important and is committed to addressing them. Resolution of some of them could mitigate disposal concerns.

c. A commenter originally stated that the CA BTP should make a clear statement against the destruction of sealed sources in order to meet the blending definition and requirements. After reading the staff's response, which stated that the staff felt it was premature to recommend against destruction of all sources at this time, the commenter requested that the CA BTP should include a detailed scenario that discusses the physical destruction techniques, source criteria, and any limitations being considered by the Federal Government. The commenter also suggested that the NRC get feedback from stakeholders.

   NRC Staff Response:

   The U.S. Department of Homeland Security Nuclear Government Coordinating Council and Nuclear Sector Coordinating Council on the Removal and Disposal of Disused Sources published a report on June 30, 2010, entitled "Sealed Source Disposal and National Security: Recommendations and Messaging Strategy," (DHS 2010). The report recommended that the NRC and the Agreement States consider expanded physical destruction of sources. In revising the CA BTP, the staff received minimal feedback and input from members of the public, aside from the above comment.

The 1995 CA BTP (NRC, 1995), 2012 draft CA BTP (NRC, 2012), and revised CA BTP each state that small sources (3.7 MBq or 100 μCi) can be mixed with trash. Because trash is frequently compacted or incinerated, either of which could or would destroy the sources, the CA BTP in effect acknowledges that such destruction is acceptable, on a small scale. The staff agrees with the comment that destruction of large sources might raise other safety and environmental issues that should be evaluated. The staff has not endorsed destruction of sources in excess of 3.7 MBq (100 μCi) in the revised CA BTP. Because the CA BTP has been made available as drafts for public comment three times, the staff is issuing the revised CA BTP as a final document and is not requesting additional feedback on destruction of larger sources as part of the CA BTP revisions. However, the staff expects that regulatory approval of the destruction of large sources, such as 36.9-TBq (1000-Ci) $^{137}$Cs sources, would need to consider worker safety issues, ALARA considerations, and potential impacts on a disposal facility's ability to isolate waste. In addition, the staff believes that a separate effort to receive input from the public would be useful. The staff is not aware of any plans for the destruction of large sources at this time. In addition, the increases in sealed source disposal constraints in the revised CA BTP and allowance for alternative approaches should facilitate disposal of intact sources and reduce if not eliminate interest in destruction of sources.

4. Public Outreach

The commenter recommended that the NRC consider, upon finalization of the CA BTP, conducting public meetings in States with disposal facilities to assist States in addressing concerns of the stakeholders adjacent to the disposal sites. For the future, the commenter also recommended that the NRC should agree to attend and support public-involvement meetings in States with disposal facilities during the proposal phase of projects. The NRC should consider using the States' interested-party notification lists to ensure that interested parties and stakeholder groups in each of the States with a disposal facility are notified of proposed changes to NRC rules or guidance.

NRC Staff Response:

The NRC staff agrees that engaging with stakeholders would be beneficial and would be willing to conduct or participate in meetings on the CA BTP revisions with stakeholders in the vicinity of the disposal sites, assuming availability of funds and on request by the affected States. The NRC also agrees that early engagement on future projects in States with disposal facilities would be beneficial and would be willing to consider participation in meetings on request and subject to the availability of travel funds. The staff is also willing to use States' notification lists, with the permission of the States.

5. Agreement State Oversight and Enforcement of CA BTP Implementation by Generators

The DSWG and individual States submitted a number of comments concerning States' ability to verify and enforce the characterization and classification of waste shipped from generators and processors to disposal sites in accordance with the guidance in the CA BTP. Some States with disposal facilities expressed a desire for increased visibility of other States' regulation of their generators and of generators' classification methods, in order to improve the enforceability of the disposal facilities' license requirements. The States' comments on this issue are consolidated into the single comment below.

Readers interested in the earlier thread of comments and responses can read the DSWG's October 6, 2012, letter (ADAMS No. ML12284A265).

Summary of State and Compact comments:

One commenter stated that, to a large degree, the CA BTP has, in the commenter's opinion, the same flaw as the 1995 CA BTP guidance, in that separate regulatory jurisdictions govern generators and disposal sites. The commenter noted that the regulatory bodies have different interests and motivations and are separate and independent of one another. As such, the commenter believes that States where waste is generated are more apt to worry about elimination and transfer of the waste from their jurisdiction and pay less attention to disposal-site considerations (e.g., design, site characteristics, and performance assessment results). In the commenter's view, because States with disposal facilities will live with the long-term fate and consequences of LLW disposal, they are more likely to be concerned about adverse effects that waste treatment, classification, and packaging might have on their local environment and public health from the perspective of both the near term and "deep time." The commenter expressed concern that the States with disposal facilities are without legal jurisdiction to oversee or enforce waste characterization and classification by a generator located in another State.

The same commenter stated that the CA BTP classification guidance for each waste container is just that: guidance. The commenter argues that there is no guarantee that it will be uniformly applied in all States where waste is generated. The States with disposal facilities will depend on each State where waste is generated to voluntarily implement the new guidance for each generator and the NRC will not be able to compel the Agreement States to invoke the guidance. In the commenter's view, it is likely that there will be a high degree of variability in if, how, and when the new guidance is implemented. While the CA BTP calls for States where waste is generated to cooperate with State regulators in States with disposal facilities, there is no guarantee that it will happen.

Another State noted that it could not absolutely verify the waste classification or homogeneity even under the current BTP. The State currently relies on generators' process knowledge and analytical results (typically dose-to-activity conversions using scaling factors). The State commented that it requires the disposal facility to review the paperwork to confirm that the methodology and calculations are satisfactory. Additionally, the State commentor noted that, in that State, the disposal facility's operator is required to forward for the State's review all Class C waste disposal requests, whether they apply the guidance in the CA BTP or not (although that State only requires a cover letter describing the request and the classification documentation (e.g., the Radman™ analysis) and not the entire paperwork package). If the State has questions after its review, it may ask to see the entire package or other supporting data.

A different State commenter noted that it understood that the NRC staff cannot *require* additional paperwork with a shipment without changing the rule, noting that the CA BTP is guidance and not a requirement. As such, the State commenter recommended that the CA BTP provide not only technical guidance but other guidance to encourage the concurrent use of administrative tools (such as additional documentation to accompany the manifest) that might increase stakeholder confidence. The commenter also noted that not all States have the resources to conduct site visits to generator and processing facilities. The commenter suggested that, because the public might perceive the revisions to the CA BTP as being less restrictive for generators and processors, language that guides these facilities to substantiate waste classification determinations made under the new guidance would provide a reasonable balance to the proposed revisions.

Another State noted that, although the 2012 draft CA BTP adds a sentence in the introduction in response to comment that it is expected that Agreement States that regulate processing and those that regulate disposal “would consult one another,” this is the only reference to how this will be applied across the States. Without the NRC leading the way to foster this cooperative approach, the State argued, the statement falls short of having any impact. A passive approach to coordination, the State believes, will leave a disconnect related to classification of waste and regulation of that waste from the handling/processing licensee to the disposal licensee.

A different State noted that it requires in a license condition that generators and processors meet the packaging and classification guidance in the CA BTP. The commenter expressed the view that, however well-meaning this requirement is, it is currently uninspectable in the generator States, because the State regulating the disposal facility has no jurisdiction in the generating State, nor can the disposal facility’s State easily independently verify if generators actually classify their waste as required. Instead, the State regulating the disposal facility depends on the generators to perform (and the NRC or other Agreement States to confirm) accurate waste characterization and classification. The State regulating the disposal facility is without legal power or reach to independently verify whether generators actually comply with the NRC classification guidelines.

A commenter noted that waste for disposal comes from generators and processors that States with disposal facilities do not regulate. The commenter also remarked that other State regulators and the NRC, who do have authority over generators and processors, have a different regulatory emphasis from States with disposal facilities and are independent. The commenter expressed the view that, even if it is assumed that the NRC-prescribed consultation occurs among regulators on each decision, there are inherent drivers that will always impact how disposal concerns from States with disposal facilities are considered and potentially acted on.

The States’ concerns with oversight of generators in other jurisdictions also applies to the use of the CA BTP ’s Alternative Approaches section (which the States argue makes the disposal facility’s WAC more complex) and to “attribution,” or the identification of the original generator by a waste processor, which States with disposal facilities might not have visibility of.

To address the above concerns, the DSWG and States requested these specific actions:

i) The NRC should add Waste Processors as a non-common-performance indicator to the IMPEP and include staff from States with disposal facilities as Integrated Materials Performance Evauation Program (IMPEP) team members.[27]

[27] IMPEP is an NRC program for reviewing the performance of Agreement States and NRC’s Regional offices. IMPEP currently has criteria (or performance indicators) for the materials and LLW disposal programs. Currently waste processors are reviewed as part of the materials program.

ii) The NRC should add guidance to the CA BTP to strongly encourage generators to provide additional documentation as necessary to aid States with disposal facilities in confirming the proper waste classification for each shipment. The following language was suggested:

> "Generators and processors should work closely with disposal facilities and State regulators to develop supporting documentation that would accompany the waste shipment manifest for shipments where the CA BTP is utilized in classifying the waste shipment. This documentation may include information such as the following: identification of the parts of the guidance that were used in the waste classification; a summary of pertinent data, calculations and/or processes used in classifying the waste; a certification statement that all data and calculations have been verified as correct and that the classification was performed in accordance with the guidance; a written signature by a company official."

iii) It would be helpful if a disposal facility's WAC (as approved by the State regulator) required the generator to identify what sections of the guidance in the CA BTP, if any, are being applied in the waste classification process for each waste package. It could be in the form of a checklist. This is an approach that States with disposal facilities could use to help identify these waste packages and associated generators, thereby providing opportunity for paperwork auditing at the least. Including such guidance in the CA BTP would be helpful to States with disposal facilities as well.

NRC Staff Response:

The staff supports the desire of States with disposal facilities to have greater assurance that waste is classified appropriately and believes that there are measures that can be adopted that will provide additional assurance. However, the staff continues to believe that there needs to be further discussion among the affected regulators before a specific approach is adopted. The staff is willing to facilitate these discussions. The purpose of the CA BTP is not to prescribe inspection and oversight procedures, which are designed to ensure that regulations and guidance are being appropriately implemented. The CA BTP defines criteria that regulators and regulated entities can use in waste classification. At the same time, regulatory oversight of the implementation of the CA BTP criteria through inspection and enforcement programs is important and needs to be addressed.

A basic premise of the Atomic Energy Act's Agreement State program is that each State will have a program that is adequate and compatible with NRC's regulations, ensuring protection of the public health and safety. As an example, one State might regulate the manufacture of sealed sources, while other States regulate the licensed users of these devices. The latter rely on the regulatory program of the State in which the sources are manufactured to ensure that the design and manufacture of the sources are safe. The NRC, with State assistance, conducts periodic reviews of all Agreement State programs to determine whether they remain adequate and compatible (i.e., through the IMPEP program). Thus, whatever different interests States might have regarding LLW management, those interests cannot affect their responsibility to protect public health and safety. This responsibility includes ensuring that requirements relevant to waste classification are appropriately implemented by generators and processors.

Notwithstanding the above framework, the staff is aware of several tools that States with disposal facilities and others currently use to gain additional assurance that waste is classified correctly. These include the following:

- The Washington Department of Health (DOH) began the Point-of-Origin Inspection Program in 1992. The goal of the program is to identify any deficiencies at generator facilities before waste is shipped for disposal. Identifying deficiencies before the waste is shipped will reduce subsequent packaging or waste-form violations on receipt at the commercial LLW disposal site. DOH achieves this goal through random inspections of generator facilities. Washington is currently the only State in the nation that conducts point-of-origin inspections.

- The Utah Department of Environmental Quality implements a Generator Site Access Permit program that provides additional assurance that generators have classified their waste appropriately (see Utah Radiation Control Rules R313-26). In addition, during the 2013 General Session, the Utah Legislature passed H.B. 124, "Radiation Control Amendments," which was signed by the Governor on April 1, 2013. These actions occurred after the DSWG provided comments on the 2012 draft of the CA BTP (NRC, 2012). The bill addresses issues concerning the State's oversight of shipments of LLW to the Energy*Solutions* Clive facility. The Utah Department of Environmental Quality is moving forward in making appropriate revisions to the radiation control rules.

- The U.S. Department of Energy published a report, "Methods for Verifying Compliance with Low-Level Radioactive Waste Acceptance Criteria" (DOE, 1993), that might also have useful information. This report was based on the Washington DOH's generator inspection program.

- Waste Control Specialists has developed a Waste Acceptance Plan for its disposal facility in Andrews County, Texas, that addresses oversight of waste generators' classification of radioactive waste. The State of Texas has authority to oversee the implementation of this plan.

The staff appreciates the desire of States with disposal facilities to have greater assurance that waste is classified appropriately and believes that measures like the above could be adopted in other States that will provide this assurance. However, as noted earlier, the staff continues to believe that there needs to be further discussion among all of the affected regulators, and is willing to facilitate these discussions if that would be useful. As the list of tools above illustrates, States have used different approaches to gain additional assurance that waste is characterized and classified appropriately. The NRC staff is reluctant to specify a single approach for all programs. Furthermore, the staff is unable to specify such an approach in the CA BTP, which is not an inspection or oversight document.

6. Depleted Uranium

The commenter pointed out that the existing NRC rule at 10 CFR 61.42 mandates that the disposal facility ensure that an inadvertent intruder, a site occupant, or those persons that might contact the waste be protected " *… at any time after active institutional controls over* *the disposal site are removed*." For Class A and B waste,[28] the active institutional control period is defined as a maximum of 100 years (see 10 CFR 61.7(b)(4)). In contrast, it appears that the existing 10 CFR 61.42 requirement could be applied to a much longer period of time for LLW with long-lived isotopes and especially for wastes such as depleted uranium that exhibit significant in-growth of daughter products, in the commenter's view.

NRC Staff Response:

In the 1995 CA BTP and in the revised version, NRC staff has used 100-, 300-, and 500-year timeframes, identical to those timeframes used in the 1981 draft EIS (NRC, 1981) and the 1982 final EIS for Part 61 (NRC, 1982), to ensure that intruder doses are within acceptable limits in a way consistent with the technical bases for the waste classification tables in 10 CFR 61.55. Even though LLW contains some long-lived wastes, the long-term risk to the intruder from typical commercial LLW is no greater after 100, 300, or 500 years than it is at those times when it is disposed of as Class A, B, and C waste, respectively. At the same time, the staff, in SECY-08-0147, "Response to Commission Order CLI-05-20 Regarding Depleted Uranium," (NRC, 2008) identified a need to revise the regulation to address large quantities of depleted uranium, a new waste stream that was not analyzed in the development of 10 CFR Part 61. The proposed rule addressing depleted uranium and other unique waste streams is currently in the final review process at the NRC and is expected to be issued for public comment by March 2015. Depleted uranium, unlike other LLW, becomes more hazardous over time due to ingrowth of progeny and will need to be assessed for longer than the 100-, 300-, and 500-year periods that are the current basis for the waste classification system.

b. A commenter recommended that NRC acknowledge the significant in-growth of DU progeny over extended periods of time (10,000 years or greater), and the increased public health risk that comes with it.

NRC Staff Response:

As noted above, DU becomes more radioactive over time with the in-growth of progeny. The staff's analysis of depleted uranium disposal contained in SECY-08-0147, "Response to Commission Order CLI-05-20 Regarding Depleted Uranium," provides an analysis of the unique hazards associated with DU disposal (NRC, 2008). That paper concludes that:

> ". . .near-surface disposal (i.e., at a depth of less than 30 meters [m], as defined in Part 61) may be appropriate for large quantities of DU under certain conditions. However, unfavorable site conditions, such as shallow disposal (i.e., at a depth of less than 3 m) or disposal at humid sites with a potable groundwater pathway, could exceed the performance objectives of Part 61, Subpart C."

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[28] Class C waste is defined as that material that will remain hazardous to an intruder beyond 100 years (see 10 CFR 61.7(b)(5)).

The NRC acknowledges these issues related to DU disposal. However, the staff did not revise the CA BTP to address the hazards of DU disposal because they are not closely related to concentration averaging or encapsulation. The hazards of DU disposal are primarily associated with disposal of large volumes of DU, whereas the revised CA BTP provides guidance related to protecting an inadvertent intruder from hot spots in LLW.

State of Utah, Department of Environmental Quality, October 8, 2012 comments

1. The commenter agreed with the position in the draft 2012 CA BTP (NRC, 2012) that not all blendable waste[29] is homogeneous and suggested that NRC establish a criterion or ratio for average (or maximum) waste particle size to container volume as part of the definition of blendable waste. The commenter suggested that, when individual waste pieces or particles are large relative to the size of the container, there is less ability to homogenize the container's contents. The commenter provided the example that a criterion could be specified that the maximum waste particle size in the package must be 10 times less than the container volume.

   NRC Staff Response:

   The CA BTP is focused on appropriate concentration averaging for discrete items (Section 3.3). The NRC staff has not adopted the proposed definition for blendable waste because, depending on the container size, it could unintentionally include small discrete objects (e.g., sealed sources). In response to this comment, the NRC staff has clarified the definition of blendable waste to indicate that (1) it can be physically mixed to create relatively uniform[30] radionuclide concentrations or (2) the waste is not expected to contain discrete, durable objects with significant activity.

2. The commenter requested that the CA BTP provide a more consistent description of dry active waste (DAW) and provide detailed examples of the types of physical materials that constitute this waste form. The commenter supplied a table that compares the types of items the IAEA, Government Accountability Office (GAO), and various NRC programs use in descriptions of DAW. These items include solid laboratory wastes, glassware, labware, charcoal, incinerator ash, soil, air filters, cleaning rags, protective tape, paper coverings, discarded clothing, plastic coverings, tools, equipment parts, and demolition rubble. In addition, the commenter indicated that the description of DAW used by the GAO included "compactible trash," including cellulosic materials, rubber gloves, boots, and plastics, as well as "non-compactible trash," including steel and concrete. The commenter suggested that a standardized definition of DAW is critical to the CA BTP because the CA BTP concepts of homogeneity are dependent on some waste forms degrading to "soil-like" material in 100 years or less. The commenter then presented information about the degradation of various components of DAW (see Comment 9).

[29] Referred to as "mixable waste" in the 2012 draft CA BTP (NRC, 2012) and in the comment.

[30] Radionuclide concentrations are "relatively uniform" if an intruder who encounters the waste is unlikely to encounter waste more than a Factor of 10 more concentrated than the class limit.

NRC Staff Response:

As the commenter notes, the term “DAW“ is used widely in industry, in a variety of contexts beyond concentration averaging for waste classification. Because of the widespread use of the term, a more specific definition of the term “DAW” is beyond the scope of the CA BTP. However, the NRC staff acknowledges the ambiguity caused by using this term in the CA BTP when NRC has not precisely defined it. Furthermore, the term “DAW” is not used on NRC Form 541, “Uniform Low-Level Radioactive Waste Manifest Container and Waste Description” (the uniform manifest). In response to this comment, the term “DAW” has been removed from the revised CA BTP. The term “contaminated trash,” which was used in the 1995 CA BTP, has been retained in the revised CA BTP. This term applies to waste descriptor codes 39 and 40 of the uniform manifest (Compactible Trash and Noncompactible Trash). As described in the response to Comment 3, the NRC staff has revised the basis for allowing unconstrained concentration averaging in contaminated trash and no longer relies on the assumption that the waste will become soil-like within 100 years of disposal.

3. The commenter questioned the NRC’s basis for considering containerized DAW to be a homogeneous waste type. The commenter noted that Section 4.2 of the 2012 Draft CA BTP (NRC, 2012) states that DAW should be considered a homogenous waste because it is “*… expected to degrade within approximately 100 years to a more well mixed and soil like state.*” The commenter then presented detailed information that indicates that this assumption might not be valid. Specifically, the commenter discussed various components of DAW, including paper, rags, clothing, wood, rubber gloves and boots, plastics, steel, and building debris. The commenter noted that these materials represent some of the less degradable components of municipal solid waste, and then cited recent studies of municipal solid waste that indicate that these items will not degrade to a “soil-like” state within 100 years (see e.g., Barlaz, 2004; Rathje, et al.,1992; Suflita, et al.,1992; and Rathje and Murphy, 1992). The commenter discussed the importance of the availability of oxygen, waste particle size, waste moisture content, waste pH, and waste temperature to waste degradation. The commenter then noted that LLW disposal sites might be less conducive to waste degradation because they are designed to isolate waste from infiltrating water and might isolate waste from the atmosphere (and therefore limit oxygen supply) with clay barriers designed to limit radon emanation.

   NRC Staff Response:

   The NRC staff appreciates the detailed comments regarding DAW. The term is used widely in industry and, as the commenter describes, can include a variety of different types of materials. As the commenter indicates, the term is not precisely defined by the NRC. As explained in the response to Comment 2, because of the ambiguity caused by the use of the term, it has been removed from the BTP. The term “contaminated trash,” which was used in the 1995 CA BTP, has been retained in the revised CA BTP. The term “contaminated trash” applies to waste descriptor codes 39 and 40 (i.e., Compactible Trash and Noncompactible Trash) of NRC Form 541, “Uniform Low-Level Radioactive Waste Manifest—Container and Waste Description.”

   The commenter specifically expressed concern about the rate of degradation of several items that are included as “contaminated trash” (e.g., paper and discarded clothing). The NRC staff understands the concern that these materials might not become soil-like within 100 years of disposal, especially when isolated from the environment. In response to this comment, the NRC staff revisited the basis for allowing unconstrained concentration averaging for DAW (i.e., treating contaminated trash as blendable waste). In the 2012 draft CA BTP, the NRC staff indicated that DAW "may be considered a homogeneous waste type for purposes of waste classification when placed in containers because it is expected to degrade within approximately 100 years to a more well-mixed and soil-like state." Further consideration shows this assumption to be unnecessary.

If trash is treated as blendable waste, the assumption that the waste becomes soil-like within 100 years is likely to be conservative (i.e., maximizes projected dose) because it enables the agricultural scenario to occur. If the waste remains recognizable as contaminated trash, the material is unlikely to be spread on the land surface and mixed into the top layer of soil to be used in a garden, even if the radioactive hazard is not recognized. Other scenarios in which the material is segregated and treated as municipal trash are expected to result in a smaller dose than the postulated agricultural scenario because if the material remains identifiable as trash, an intruder is less likely to interact with it extensively.

To warrant consideration as discrete objects, individual items in the trash would need to (1) have significant radioactive contamination and (2) be likely to be handled by an intruder (as described in Section 4.4 of this volume).

Consideration of the typical radiological properties of contaminated trash shows that individual items are unlikely to have significant radioactive contamination. An NRC survey of LLW (NUREG-1418) indicates that contaminated trash typically has radionuclide concentrations well below Class A limits. Furthermore, a survey of Class A waste (NUREG/CR-6147) further shows that even the $99^{th}$-percentile concentration of $^{137}Cs$, which causes the primary hot-spot concern in Class A waste, is only approximately 30 percent of the Class A limit. More recent experience with disposal of contaminated trash has not indicated that hot spots are a concern in this waste type. Thus, the NRC staff concludes that it does not reasonably expect hot spots in contaminated trash to pose a hazard to an inadvertent intruder and it would not be consistent with ALARA principles to require items in contaminated trash to be treated as discrete items.

4. The commenter noted that in Section 4.2.2.1, "Threshold for Demonstrating Waste Homogeneity," [now Section 3.2.3], the first paragraph describes criteria for deciding whether the homogeneity test needs to be performed, as it relates to its sum of fractions. The commenter suggested that adding an equation to illustrate the requirement would be helpful.

   NRC Staff Response:

   The blendable waste section has been reorganized so that the relevant section in the revised CA BTP is Section 3.2.3, "Averaging for Multiple Blendable Waste Streams (Blended Waste)". In response to this comment, a footnote has been added to the guidance to cite the appropriate equation in 10 CFR 61.

5. The commenter requested that NRC staff consider adding text to Section 4.3.2 [now Section 3.3.2.2], Table A [Table 2] to clearly state that Agreement States are not required to adopt the changes made in Table A [Table 2]. The State commenter expressed concern that the revised CA BTP, in the State's view, increased the Class A activity limit above which a discrete item [or "individual item" in the 2012 draft (NRC, 2012)], including a sealed source, should be considered a discrete item for disposal.

NRC Staff Response:

The staff agrees that States are not required to adopt the changes made to the table, because the CA BTP is guidance. The staff believes that the more general statement about the CA BTP, which is stated in Section 1.2, "Purpose of this Guidance Document" (and in several places in the responses to comments), should assure the commenter that it has authority to determine whether or not to adopt the new Table 2 [formerly Table A] limits. NRC staff would like to clarify that Table 2 does not provide the criteria for determining when a piece of waste should be treated as a discrete object, as implied in the comment. All sealed sources greater than 100 µCi, including those less than the Table 2 [Table A] activity limits, should be treated as discrete items, and not blendable waste, according to the revised CA BTP.

6. The commenter stated that the use of individual site-specific WAC by generators to package and classify waste is of particular interest or concern for States with disposal facilities for at least three reasons:

   - Generic Assumptions Behind LLW Classification System: The original NRC rules (from the early 1980s) for LLW classification already took into account general assumptions for inadvertent intruder protection. Individual site-specific WAC might require LLW generators to be more aware of and fully understand a given disposal site's individual WAC requirements for purposes of waste packaging and classification. The commenter expressed concern that this potentially creates more opportunity for generators, waste processors, and brokers to make mistakes in waste packaging or classification in order to comply with a disposal site's unique WAC.

   - Added Burden on States with Disposal Facilities: The commenter expressed concern that the proposed change places more burden on States with disposal facilities to verify waste classification after arrival at the disposal sites.

     To assist the States with disposal facilities, the commenter recommend that the NRC add new criteria to both the common and non-common performance indicators in its IMPEP program. For example, common performance indicators are important in this effort, in the commenter's view, in that radiation control programs and Agreement States have the responsibility to oversee and approve decommissioning projects, which inherently generate waste, some of which is LLW. The purpose of adding these performance indicators to the IMPEP review process is to enhance regulatory oversight of LLW generators, waste processors, treatment facilities, and brokers in meeting applicable WAC requirements, as determined by States with disposal facilities.

   - Need to Preserve the Existing Classification System: The commenter expressed the view that any new dependence of generators on individual disposal-site WAC to package and classify waste must not supersede or replace the existing LLW classification system in 10 CFR Part 61.

NRC Staff Response:

The staff appreciates the commenter's concerns. Although disposal sites currently have WAC which are more detailed than the waste classification system in 10 CFR Part 61 or the

CA BTP, the use of site-specific WAC for waste classification would be a change and would likely result in new, and potentially more, criteria. It should be noted that the CA BTP is only addressing site-specific *averaging* approaches within the existing waste classification requirements in 10 CFR 61.55. As a separate effort, NRC is developing a proposed rule that might enable disposal facility licensees to develop WAC that would replace the 10 CFR 61.55 waste classification tables with a site-specific WAC. The proposed rule is currently in the final review process at the NRC and is expected to be issued for public comment by March 2015. The Agreement States are represented on the NRC working group that is developing the rule. The consideration of a WAC option in the rulemaking was directed by the Commission in its Staff Requirements Memorandum SRM-COMWDM-11-0002/COMGEA-11-0002, "Revision to 10 CFR Part 61," (NRC, 2012d).

With respect to the State's desire to have increased assurance that waste is characterized and classified appropriately, this comment is similar to several others and this issue is addressed in detail in response to Comment No. 5. The reader is referred to that response.

# 4. TECHNICAL BASIS FOR CONCENTRATION AVERAGING AND ENCAPSULATION GUIDANCE

## 4.1 Introduction

This section provides the technical basis for the CA BTP. The BTP guidance is based on protection of an inadvertent intruder, which is one of the four performance objectives in 10 CFR Part 61 (specifically, 10 CFR 61.42). The CA BTP provides separate guidance for discrete items and blendable waste. The intruder scenarios considered for both of these waste categories are presented in this section.

## 4.2 Background

The concentration limits for Class A, B, and C LLW (10 CFR 61.55 Tables 1 and 2) are based on protection of an inadvertent intruder. Specifically, class limits were established to limit projected intruder doses to 5 mSv/yr (500 mrem/yr) in certain specified exposure scenarios. These scenarios, as well as development of the class limits, are described in the EIS supporting 10 CFR Part 61. As described in the EIS, in each scenario the NRC staff assumed that an intruder resides on a closed LLW disposal site and inadvertently exhumes LLW.

In one EIS scenario, the intruder recognizes the hazard and receives only a "discovery" dose. The results of this "intruder-discovery" scenario were one factor in the basis for the Class B limits in 10 CFR 61.55 Table 2. In the other two EIS scenarios ("intruder-construction" and "intruder-agriculture"), the NRC assumed that the exhumed waste is physically indistinguishable from soil and that the intruder is unaware of the radiological hazard of the waste. These scenarios are one factor in the basis for the Class A and C limits. For each waste class, the NRC staff then applied adjustment factors to the radionuclide concentrations calculated based on these scenarios.

In the draft EIS, the NRC increased the Class A limit for $^{137}Cs$ by a factor of 20 and the $^{137}Cs$ Class B and C limits by a factor of 10 because average concentrations of $^{137}Cs$ in LLW were expected to be far below the peak allowable concentrations. In the final EIS, the NRC increased the Class C limits for all radionuclides except $^{137}Cs$ [31] by a factor of 10 because of (1) the reduced likelihood of significant exposures with incorporation of passive warning devices, (2) the difficulty of contacting wastes disposed of at greater depths or with an intruder barrier, and (3) the expectation that average concentrations would be lower than peak allowable concentrations.

After 10 CFR Part 61 became final, a number of well-publicized accidents occurred that involved small, highly radioactive sealed sources. The worst of these accidents occurred in Brazil and resulted in large social disruptions, a very expensive cleanup, and radiation doses leading to deaths (IAEA, 1988). This accident, as well as accidents in the Republic of Georgia, Morocco, and other locations demonstrated that the radiation hazard associated with small items is not always recognizable. The sealed sources involved in these incidents typically were less than 280 cc (0.01 $ft^3$) and some were composed of corrosion-resistant stainless steel. Although these sources were not secured and were in locations such as abandoned buildings that were readily accessible to members of the public, the NRC decided to consider the consequences of exposure to small items of LLW. This type of scenario was first considered in the 1995 CA BTP. Exposure to discrete items of LLW was not considered in the EIS for 10 CFR Part 61.

A major purpose of this revised CA BTP is to provide guidance for the disposal of discrete items so that their disposal falls within the "envelope of safety" defined in the EIS for 10 CFR Part 61. The guidance for discrete gamma-emitting items is based on two handling scenarios: one for small items (< 280 cc (0.01 $ft^3$)) and one for large items (> 280 cc (0.01 $ft^3$ )) (Section 4.3 of this volume). The guidance for discrete items that are primarily alpha- or beta-emitting is based on regulatory considerations, as described in Section 4.4 of this volume. The guidance on concentration averaging for blendable waste is based on a separate exposure scenario in which waste is dispersed, as described in Section 4.6 of this volume.

## 4.3 Gamma-Emitting Discrete Items (Table 2 and the Factor of 2)

To evaluate potential hazards from gamma-emitting discrete items, staff assumed that knowledge of a former disposal facility is temporarily lost, and a trench is inadvertently cut through it (e.g., as part of a civil works project). Small items (< 280 cc (0.01 $ft^3$)) were considered separately from large items (> 280 cc (0.01 $ft^3$)) because the size of an item affects how an individual could be exposed. Small items (< 280 cc (0.01 $ft^3$)) are assumed to be "pocketable." That is, the staff considered that an individual could find a small item, put it in a pocket, and take it from the site. The staff assumed that larger items are discovered by a construction crew, picked up with construction equipment, and temporarily stored in a workshop. Details of these scenarios are provided in Sections 4.3.1 and 4.3.2.

For both small and large items, the NRC staff used Microshield® (version 7) to evaluate the projected dose to an intruder. The staff then selected constraints that would limit the projected dose to an intruder to 5 mSv (500 mrem) in each scenario. The staff used the small-item carry-away scenario as the basis for the Table 2 activity limits and the large-item carry-away scenario as the basis for the Factor of 2 concentration limit.

The staff selected Microshield® because it is widely available and easy to use. While Microshield® is appropriate for evaluating stylized intruder exposure scenarios, it would not be

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31 The Class C limit for $^{137}Cs$ was not increased by a factor of 10 between the draft and final EIS, because it had already been increased by a factor of 10, as compared to the scenario-based value, in the draft EIS.

appropriate for evaluating actual human exposures, especially for short distances. Actual human exposures (e.g., for dose reconstruction) should be modeled with more advanced methods that use fewer approximations. For example, instead of explicitly calculating absorption in a human, Microshield® uses an effective dose equivalent rate. The calculations described in this section used an effective dose equivalent rate from ICRP 51 (ICRP, 1987) for an isotropic orientation. An isotropic orientation was chosen to provide a surrogate for dose averaging because of the large number of variable potential orientations between the source and the intruder. Buildup was assumed to occur in the source.

### 4.3.1 Small Item Carry-Away Scenario (Basis for Table 2)

The NRC used the small item carry-away scenario as the basis for Table 2, “Recommended Activity Limits of Primary Gamma Emitters Potentially Requiring Piecemeal Consideration in Classification Determinations,” in Section 3.3.2.2 of Volume 1. Table 2 is also cited in Section 3.3.4 of Volume 1, “Encapsulation of Discrete Items.”

In this scenario, NRC staff assumed that a discrete item is exposed because the waste container has been breached and any encapsulating material, if present, has cracked. For Class A waste, exposure is assumed to occur at the end of the institutional control period, 100 years after closure. Because Class B waste is required to be stabilized (10 CFR 61.7(b)(2)), exposure is assumed to be delayed until 300 years after site closure. Because Class C waste is required to be disposed of at sufficient depth or with robust intruder barriers required to last at least 500 years (10 CFR 61.52(a)(2)), intrusion is assumed to be delayed until 500 years after closure.

In this scenario, an individual finds a discrete item of waste in the excavated soil, is unaware of the hazard, and takes it home. For the first 4 hours, the item is in the individual’s coat pocket (at a 3-cm (1.2 in) exposure distance). After that, the individual is assumed to be an average of 2 meters (6.5 ft) from the item for 15 hours per week for 48 weeks out of the year.

Using these assumptions, the NRC staff calculated the activity of $^{137}Cs$, $^{60}Co$, or $^{94}Nb$ that would result in a projected dose of 5 mSv (500 mrem) to the inadvertent intruder. Staff modeled each item as a sealed source. Modeling the items as sealed sources is expected to bound the dose from other discrete items with the same activities (e.g., pieces of activated metal) because sealed sources are concentrated and are expected to have less self-shielding than other discrete items. All the radioactivity was assigned to one radionuclide for each model run to determine constraints for each radionuclide separately. Licensees should use a sum-of-fractions approach[32] to apply Table 2 values to items that have more than one primary gamma-emitting radionuclide.

For $^{137}Cs$, the activities that resulted in a 5-mSv (500-mrem) projected dose were used directly in the revised CA BTP Table 2 without adjustment. These values were 266 MBq (7.2 mCi) for Class A disposal, 27 GBq (0.72 Ci) for Class B disposal, and 4.8 TBq (130 Ci) for Class C disposal.

For $^{60}Co$, engineering judgment was used to adjust the calculated value for Class A disposal. Using the scenario described in this section, the activity that resulted in a projected 5-mSv (500-mrem) dose to an inadvertent intruder was 4.4 TBq (120 Ci). For Table 2, the staff used

[32] The sum-of-fractions approach is explained in 10 CFR 61.55(a)(7).

engineering judgement to increase this value from 4.4 TBq to 5.2 TBq (120 Ci to 140 Ci). The staff selected 5.2 TBq (140 Ci) because it is the amount of $^{60}$Co that could be disposed in a 0.2-m$^3$ (~55-gallon) drum at the Class A limit, and the difference between 4.4 TBq (120 Ci) and 5.2 TBq (140 Ci) is within the precision of the scenario-based calculation (i.e., different subjective choices about the scenario could yield results in this range). In addition, the dose from a 5.2-TBq (140-Ci) $^{60}$Co source will be 5 mSv/yr (500 mrem/yr) at 101 years. The NRC staff determined that this projected dose provides reasonable assurance of intruder protection because it is unlikely an individual would both (1) intrude into the disposal site during the first year after institutional controls and (2) encounter a source that was disposed of in the last year of site operation. Both of these conditions would need to be met for the intruder to encounter the source after only 100 years of decay. Therefore, the new value of 5.2 TBq (140 Ci) continues to protect the intruder because of $^{60}$Co's short half-life. Furthermore, the staff determined that because of the stylized nature of the intrusion scenarios, it was not meaningful to distinguish between the dose at 100 years and the dose at 101 years after site closure.

For Class B and C disposal of $^{60}$Co, the staff found that the class limit alone was sufficient to protect an inadvertent intruder, and there was no need for an additional constraint in Table 2. This result is attributable to the short half-life of $^{60}$Co (i.e., 5.3 years), which causes considerable decay by the time an intruder could contact Class B or C waste (300 and 500 years after closure, respectively).

For $^{94}$Nb, the activity constraint at the time of disposal would be less than 37 MBq (1 mCi) for Class A (100 years), Class B (300 years), and Class C (500 years) disposal. However, the higher limit of 37 MBq (1 mCi) was selected for practical considerations.

<u>Modeling details for the small item carry-away scenario</u>

- For $^{137}$Cs, staff assumed different sizes for a Class C source than for a Class A or B source. Staff modeled a Class C source as an elongated cylinder of cesium chloride (CsCl) (density = 2.7 g/cc (169 lb/ft$^3$)) that is 2.7 cm (1.06 in.) tall and 1.5 cm (0.59 in.) in diameter. The item is assumed to be lined with 0.47 cm (0.19 in.) of stainless steel (density = 7.8 g/cc (488 lb/ft$^3$)). This size is based on the assumption that the source was used for one half-life before disposal (i.e., the 4.8-TBq (130-Ci) source at the time of disposal was sized for 260 Ci at the time of creation). This assumption allows for appropriate self-shielding for high-activity sources.
- Staff modeled Class A and B $^{137}$Cs sources as cylinders of CsCl that are 1 cm (0.39 in.) tall, 0.56 cm (0.22 in.) in diameter, and lined with 0.1 cm (0.04 in.) of stainless steel. The dimensions were the same for Class A and B sources because self-shielding is insignificant for CsCl sources in this activity range.
- For $^{60}$Co, the NRC assumed that the source is a cylinder of $^{60}$Co (density = 8.9 g/cc) which is 1 cm (0.39 in.) tall and 1 cm (0.39 in.) in diameter. The source is assumed to have a nickel plating of negligible thickness and a stainless steel cladding (7.8 g/cc) 0.37 cm thick.
- For disposal of $^{94}$Nb at any time, the source was assumed to be a point because 1 mCi of $^{94}$Nb could be contained in a very small item. Using a point source is more conservative than modeling a large object because a larger object would have self-shielding and a point source has none.

### 4.3.2 Large Item Carry-Away Scenario (Basis for the Factor of 2)

As in the small-item carry-away scenario, the staff assumed that at some time after the end of institutional controls, knowledge of a LLW site is lost and the site is disrupted. In the large-item scenario, staff assumed that a 2.55-$m^3$ (90-$ft^3$) LLW container has been breached, exposing pieces of activated stainless steel. Staff assumed that there is 1.7 $m^3$ (60 $ft^3$) of activated stainless steel in the container. A construction crew is assumed to use its equipment to move the pieces of steel to a workshop and to store them there for 6 months.

Staff evaluated doses from each of the three primary gamma-emitting radionuclides and found that the doses from $^{94}$Nb were the most limiting. Staff evaluated the potential dose to an intruder if all of the activity in the container were concentrated in different fractions of the activated metal. For example, staff evaluated the dose if 50 percent of the pieces (0.85 $m^3$ (30 $ft^3$) of the total volume) contain $^{94}$Nb at two times the Class C limit and 50 percent of the pieces contain $^{94}$Nb at well below the Class C limit. Staff also evaluated the dose if 10 percent of the pieces contain $^{94}$Nb at ten times the Class C limit and the remaining 90 percent contain $^{94}$Nb at well below the Class C limit.

For computational ease it is assumed that only the higher-activity pieces are removed and that each piece of stainless steel is a 0.03 $m^3$ (1 $ft^3$) square. Each piece of metal is moved three times and the cumulative exposure time for each piece is 21 minutes (7 minutes per move) at 15 cm (6 in.). In the crew's shop, the individual is exposed for 5 hours per week for 6 months at a distance of 2 m (6.6 ft) from the stack of blocks. For blocks at twice the limit, the stack is 1 m high by 1.5 m wide by 0.7 m deep (3 ft high by 5 ft wide by 2 ft deep). For blocks at ten times the limit, the stack is 0.7 m high by 1 m wide by 0.3 m deep (2 ft high by 3 ft wide by 1 ft deep).

Assuming that 50 percent of the items had an $^{94}$Nb concentration twice the Class C limit resulted in a projected dose of 5 mSv (500 mrem), while assuming the radioactivity was concentrated in a smaller fraction of the items resulted in higher projected doses. Thus, individual pieces of activated metal should not exceed two times the Class C limit to provide reasonable assurance that intruder doses do not exceed 5 mSv (500 mrem). This rule is based on consideration of a Class C mixture, but would be protective if applied to a Class A or B mixture. This Factor of 2 concentration limit removes gamma-emitting hot spots from mixtures of items and also places an absolute limit on the boundary between Class C and GTCC waste for discrete items in a mixture in which the primary gamma emitters control the classification.

### 4.3.3 Option to Use Either Table 2 or the Factor of 2

The CA BTP gives licensees the option of applying Table 2 activity limits or the Factor of 2 (or Factor of 10, as applicable[33]) to primary gamma-emitting radionuclides. Staff used the small item carry-away scenario to demonstrate that the Table 2 activity limits provide reasonable assurance of intruder protection for small items. It is also protective to apply the Table 2 limits to larger items for two reasons: (1) larger items with the same activities would experience more self-shielding and (2) larger items would not be placed in a pocket, and an intruder is less likely to be in as close contact with the larger item.

[33] The Table 2 activity limits or the Factor of 2 concentration limits apply when the primary gamma-emitting radionuclides control the waste classification. When primary gamma-emitting radionuclides do not control the waste classification, the licensee may apply either the Table 2 activity limits or the Factor of 10 concentration limits.

Staff used the large item carry-away scenario to demonstrate that the Factor of 2 concentration limit provides reasonable assurance of intruder protection for large items. The Factor of 2 concentration limit also is protective for small items, because the Factor of 2 allows less activity than the Table 2 values for small items.

## 4.4 Radionuclides Other than Primary Gamma Emitters in Discrete Items (Basis for Table 3 and the Factor of 10 Rule)

The most significant exposure pathways for alpha- and beta- emitting radionuclides in LLW[34] are expected to be ingestion or inhalation (breathing re-suspended material or ingesting material from contaminated foodstuffs). These pathways are expected to be most significant if radionuclides are dispersed in the environment rather than remaining contained in (or on the surface of) a discrete object. Because radionuclides dispersed in the environment are physically mixed with one another and with nonradioactive material, alpha- and beta-emitting radionuclides pose less of a hot-spot concern than gamma-emitting radionuclides. Because they pose less of a hot-spot concern, they are subject to less restrictive averaging constraints.

These constraints are the Table 3 activity limits and the Factor of 10 concentration limit. Instead of considering specific exposure scenarios, staff based the averaging constraints for alpha or beta radioactivity in discrete items on other regulatory considerations. The Factor of 10 provides an absolute limit on the boundary between Class C and GTCC waste for discrete items. Table 3 provides consistency between the positions for disposal of discrete items in mixtures and encapsulation. Specifically, if an item has too much radioactivity to be encapsulated, it also has too much radioactivity to be averaged in a mixture of items.

For non-primary gamma-emitting radionuclides in individual discrete items or mixtures of discrete items, licensees may apply either the Table 3 activity limits or the Factor of 10 concentration limit[35]. NRC staff has determined that either the Table 3 activity limits or the Factor of 10 concentration limit adequately constrains extreme measures for concentration averaging.

## 4.5 Encapsulation

The encapsulation position limits extreme measures for averaging radioactivity in a discrete item over nonradioactive encapsulating material. Because the basis for the encapsulation position is limiting extreme averaging, different constraints are applied for low and high waste loadings.

For low waste loadings (i.e., < 14 percent) the CA BTP constrains averaging by placing an upper limit on the volume or mass of encapsulating material over which radionuclide concentrations should be averaged and the activities that can be encapsulated. The volume and mass limits are 0.2 $m^3$ or 500 kg (approximately equivalent to a 55 gallon drum or 1,100 pounds) and the activity limits are provided by Tables 2 and 3.[36] This position is

34 Beta-emitting discrete items could also cause a dose to the skin from direct exposure (i.e., without ingestion or inhalation). However, staff used VARSKIN 5.0 to calculate doses from beta-emitting radionucldies and found the Table 3 limits to be protective for small items (i.e., less than 280 cc [0.01 $ft^3$]). The staff does not expect larger items to be carried close enough to the skin to cause a hazard to an inadvertent intruder.

35 For encapsulated items, the application of Table 3 and the Factor of 10 is slightly different (see Section 4.5).

36 For encapsulation, the Table 2 limits apply, on a sum-of-fractions basis, to the sum of the activities of all of the items smaller than 280 cc (0.01 $ft^3$), and individually to items larger than 280 cc (0.01 $ft^3$). The Table 3 limits apply to each item individually and a sum of fractions is not required.

consistent with the 1995 CA BTP position on encapsulation and with the development of Table 3. It has been kept in the revised CA BTP for regulatory stability.

The Table 3 activity limits reflect the maximum activity that would be allowed by the class limit if the radioactivity is averaged over a 0.2-$m^3$ (~55-gallon) drum. The Table 3 activity limits for radionuclides that have mass-based activity limits are based on the assumption that the encapsulated waste has an average density of 1.5 $g/cm^3$ (94 $lbs/ft^3$). For example, the Table 3 Class C limit for transuranic alpha-emitting radionuclides with a half-life greater than 5 years, other than Pu-241 and curium-242 (Cm-242), is 1.1 GBq (30 mCi). When calculating mass-based concentrations, it is generally acceptable to take credit for the actual density of the material up to 2.5 $g/cm^3$ (156.1 $lb/ft^3$).

For high waste loadings (i.e., > 14 percent), licensees may average the radioactivity of an encapsulated item (or items) over volumes of up to 9.4 $m^3$ (331 cubic feet). This position limits extreme measures for averaging by specifying a minimum waste loading.

## 4.6 Intrusion into Blendable Waste (Basis for Table 1 and the Demonstration of Adequate Blending)

In comparison to the scenarios used to construct the waste classification tables[37], an intruder drilling a well would exhume a much smaller volume of waste. However, an intruder exhuming a small amount of waste could receive a dose comparable to an intruder exhuming multiple waste packages if the small volume of waste is significantly more concentrated than the Class limit (i.e., by more than a factor of 10). To protect an intruder from encountering waste that is significantly more concentrated than the Class limit, the CA BTP provides guidance to limit hot spots in blendable waste.

The staff assessed projected doses from hot spots of various sizes and radionuclide concentrations. The staff represented a hot spot as a sphere (Figure 2 of this volume). Although more conservative assumptions could be made (e.g., a vertically-oriented cylindrical hot spot aligned with the drill bore), the NRC staff judged these geometries to be too improbable to form the basis for the guidance (i.e., not reasonably foreseeable). The staff assumed an intruder would use a well bore in a size range from 0.1 m to 0.3 m (4 in to 12 in). Other assumptions could be used and would yield slightly different results.

The activity in a hot spot was limited by assuming that each container was properly classified. That is, staff assumed that the average activity in the container, including the activity in the hot spot, met the appropriate Class limit. For example, for a given Class limit, if the radionuclide concentrations in the hot spot gave a sum of fractions of 10, the assumed hot spot volume was limited to 10 percent of the container volume. For a given hot spot concentration, meeting the class limit links the possible volume of the hot spot to the container size. This relationship between the hot spot concentration, hot spot volume, and container size forms the basis of the values in the revised CA BTP Table 1, “Thresholds for Determining Adequate Blending.”

To arrive at an appropriate criterion for determining adequate blending if the licensee does not choose to use the Table 1 threshold values, the staff evaluated intruder doses from small

[37] As discussed above, the NRC based the waste classification limits in 10 CFR 61.55 on projected doses to an individual who inadvertently exhumes LLW while constructing a dwelling on a waste site and another who subsequently lives in that dwelling.

concentrated hotspots. An intruder is assumed to exhume more activity from a small, concentrated hot spot than from a larger, less concentrated hot spot because a larger fraction of the hot spot can be intersected by the well bore (Figure 2 of this volume). Therefore, to establish the criterion for determining adequate blending, the staff considered relatively small, concentrated hot spots, as discussed further in the "exposed cuttings scenario" subsection. The staff calculated the amount of each radionuclide exhumed in each case and then calculated projected doses based on those activities using the assumptions described in this section.

In each analysis, staff calculated volumes and concentrations of waste that an intruder could exhume without receiving a dose exceeding 5 mSv/yr (500 mrem/yr).

Scenarios

The NRC staff considered doses to an individual unknowingly drilling a well into a waste site (acute scenario) and another individual subsequently living and gardening on the site (chronic scenario). The staff considered two different types of well-drilling scenarios. In the "mud rotary drilling" scenario, a mixture of drill cuttings and drilling mud is placed in a disposal pit near the well and covered with clean soil. In the "exposed cuttings" scenario,[38] drill cuttings are spread on the land surface and mixed into the top 15 cm (6 in.) of soil in a garden. In both scenarios, intrusion occurs at 100 years after site closure for Class A waste, 300 years after site closure for Class B waste, or 500 years after closure for Class C waste.

Drilling methods in which cuttings are spread on the land surface (e.g., cable tool drilling or auger drilling), though not as common as mud rotary drilling, sometimes are used for drilling wells for water. These drilling methods also have other applications, such as drilling boreholes for site exploration. In addition, assuming drill cuttings are spread on the site serves as a surrogate for other potential intrusion scenarios in which a small amount of waste is exposed on the land surface. Drilling scenarios in which cuttings are spread in a garden are commonly used in LLW analyses to assess potential doses to an inadvertent intruder (NCRP, 2005; Koffman, 2004).

In the "acute exposure" scenario, a well driller is assumed to be exposed by direct exposure, dust inhalation, and incidental soil ingestion. In the "chronic exposure" scenario, a site resident is exposed through the same pathways as the well driller and also consumes ground water and plants grown in the contaminated area. The NRC found that projected chronic doses to an intruder living on the site (in the chronic-exposure scenarios) were greater than projected acute doses to a well driller (in the acute-exposure scenarios).

NRC staff used a probabilistic model developed in the simulation software package GoldSim® (Version 10.5) to evaluate the chronic exposure scenarios. The NRC staff also developed a deterministic RESRAD (RESRAD 6.5) model to represent the chronic intruder scenarios and obtained similar results. The GoldSim analyses treated the well diameter, occupancy factors, and several environmental parameters (e.g., soil sorption coefficients, plant uptake factors) probabilistically in a Monte Carlo analysis. For the exposed cuttings scenario, the GoldSim model also treated the garden area probabilistically.

The staff assumed that outside of the container with the hot spot, the column of waste had radionuclide concentrations at the average values for the appropriate class of waste. Averages

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38 Similar to the "post-drilling" scenario described in NCRP Report 152 (NCRP, 2005).

were based on an analysis of data from DOE's LLW MIMS database for 2007 through 2011. Waste column thicknesses were varied in ranges representative of current LLW sites. Because the average concentrations of most LLW are significantly below the class limits, the remaining column of waste did not contribute significantly to the dose results.

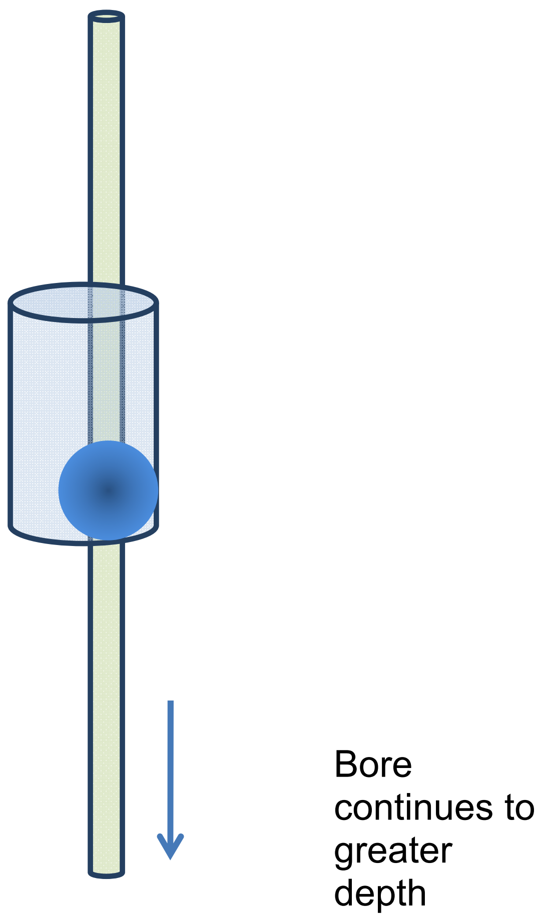


**Figure 2. Well bore intersecting hot spot in container of blendable waste.**

*Mud Rotary Drilling Scenario*

In the mud rotary drilling scenario, the waste is assumed to be diluted with drilling mud and clean well borings in a disposal pit 1.2 m (4 ft) deep with an area of 6.7 $m^2$ (72 $ft^2$) (see NUREG/CR-4370) and covered with 1 m (3.3 ft) of clean soil. In the mud rotary drilling scenario, because the cuttings are initially covered, the hazard from short-lived gamma emitters (e.g., $^{137}Cs$) is essentially eliminated. Instead, the primary exposure pathways are from radionuclides leaching into ground water and long-lived radionuclides that remain in place while the mud pit cover erodes. While no safety concerns were identified for intrusion into Class A waste in the mud rotary drilling scenario, the staff found that a 0.2 $m^3$ (7 $ft^3$) hot spot with a sum of fractions of 10 or greater in Class C waste could present more of a concern. However, these doses were bounded by projected doses in the exposed cuttings scenario.

*Exposed Cuttings Scenario*

In the exposed-cutting scenario, the waste is assumed to be diluted by mixing with the top 15 cm (6 in) of clean soil in a garden that ranges in area from 96 $m^2$ (1030 $ft^2$) to 860 $m^2$ (9260 $ft^2$) ($5^{th}$-percentile to $95^{th}$-percentile values). The garden size was based on probabilistic distributions of home-grown vegetable, grain, and fruit consumption, as well as distributions of garden productivity (see NUREG/CR-5512, Vol. 3). The garden is assumed to support four individuals. The results were sensitive to assumptions about garden size. In general, smaller garden sizes led to higher doses because waste was diluted with less clean soil.

For the calculation of direct exposure, the intruder is assumed to be located on the contaminated soil while gardening. Gardening times are assumed to range from 8 to 200 hours per year ($5^{th}$-percentile to $95^{th}$-percentile range from NUREG/CR-5512 Vol. 3) (NRC, 1999c). The intruder is also assumed to be exposed while located on the property in locations other than the garden (i.e., not directly on the contaminated area). The time outdoors was represented with a range from 600 to 1,500 hours per year ($5^{th}$ to $95^{th}$ percentile values from NUREG/CR-5512, Vol. 3) (NRC, 1999c). For the time spent outdoors but not gardening, the intruder was assumed to spend time primarily in five randomly selected locations on a half-acre property each year. Distance factors for external radiation exposures while located off of the contaminated area were calculated for each of the primary gamma emitters with MicroShield®.

For the exposed cuttings scenario, the most limiting radionuclides for Class A and B waste were neptunium-237 ($^{237}Np$), with a dose primarily resulting from plant ingestion; $^{137}Cs$, with a dose resulting from plant ingestion and external exposure; and $^{99}Tc$, with a dose resulting from plant ingestion and water ingestion. However, $^{237}Np$ does not occur in significant quantities in commercial LLW. Therefore, for Class A and B waste, the revised CA BTP Table 1 threshold values were based on $^{137}Cs$, which was the most limitng radionuclide other than $^{237}Np$.

For waste at the Class C limit, the largest projected doses were caused by $^{237}Np$ and $^{99}Tc$. While typical concentrations of $^{99}Tc$ in LLW are more uncertain because $^{99}Tc$ is difficult to measure, based on a review of MIMS data from 2007 to 2011, the NRC staff does not expect intrusion into a hot spot of $^{99}Tc$ that is significantly more concentrated than the class limit (i.e., by more than a factor of 10) to be reasonably foreseeable in blendable commercial LLW. Excluding $^{237}Np$ and $^{99}Tc$, several raionuclides formed the next tier of projected doses, including $^{59}Ni$, $^{241}Pu$, $^{241}Am$, $^{94}Nb$, and $^{14}C$. Of these, $^{59}Ni$ and $^{94}Nb$ are typically associated with activated metals rather than blendable waste. Therefore, the Table 1 threshold values for Class C waste were based on consideration of potential hotspots of $^{14}C$, $^{241}Pu$, or $^{241}Am$, which all resulted in similar projected doses. The projected dose from a hot spot of $^{137}Cs$ in Class C waste was approximately a factor of two lower than the projected doses from hot spots of these other radionuclides.

Thus, the revised CA BTP Table 1 values for Class A and B waste were based on $^{137}Cs$ while the Class C values were based on $^{14}C$, $^{241}Pu$, or $^{241}Am$. The reader will note that the revised CA BTP Table 1 volume thresholds for Class B waste are larger than the Class A volumes. This apparent inversion occurs because the volumes are given in terms of the class limits, and the 10 CFR 61.55 class limits were not purely based on projected dose. As noted in Section 4.2 of this volume, the 10 CFR Part 61 Class Limits for LLW initially developed in the draft EIS for Part 61 based limiting a projected intruder dose to less than 5 mSV/yr (500 mrem/yr) (see draft EIS Table 7.1). Subsequently, adjustments were made to these values to arrive at the limits ultimately included in 10 CFR 61. Two sets of adjustments were made. First, in the DEIS, the Class A limit for $^{137}Cs$ was raised by a factor of 20 and the Class B and C limits for $^{137}Cs$ were raised by a factor of 10 (i.e., compare DEIS Table 7.1 values[39] with DEIS Table 7.2 values). These values were changed because the staff reasoned that the average concentration of $^{137}$Cs in LLW was likely to be significantly lower than the limit. Second, in response to comments on the draft EIS, in the final EIS the remaining Class C limits (i.e., all but $^{137}$Cs, which had already been raised from the initial dose-based value in the draft EIS) were raised by a factor of 10 to account for the inaccessibility of the waste.

In the context of the revised CA BTP Table 1, the result of these adjustments is that the Class A limit for $^{137}$Cs adjusted for 100 years of decay is greater than the Class B limit for $^{137}$Cs adjusted for 300 years of decay (i.e., the Class A limit adjusted for 100 years of decay is 0.10 Ci/m$^3$ and the Class B limit adjusted for 300 years of decay is 0.044 Ci/m$^3$). The Class C limit for $^{137}$Cs adjusted for 500 years of decay (0.045 Ci/m$^3$) is similar to the Class B limit adjusted to 300 years of decay. However, because the other Class C radionuclide limits also were raised by a factor of 10 (as compared to the risk-based values in draft EIS Table 7.1), $^{137}$Cs is not the limiting radionuclide for the Class C values in the revised CA BTP Table 1.

Unlike the revised CA BTP Table 1 threshold values, which vary depending on waste class, the criterion for demonstrating adequate blending (i.e., waste should not have a hot spot that is larger than 0.2 m$^3$ (7 ft$^3$) with a sum of fractions greater than 10) is the same for all three waste classes. Because of the shorter decay time assumed for Class A waste (i.e., 100 years for Class A as compared to 500 years for Class C), the projected dose from intrusion into a hot spot of $^{137}$Cs in Class A waste was only slightly less than the projected dose from a hot spot of an equivalent size and concentration (relative to the class limit) of $^{14}$C, $^{241}$Pu, or $^{241}$Am in Class C waste. Therefore, consideration of $^{14}$C, $^{241}$Pu, and $^{241}$Am in Class C waste (after 500 years of decay) were used as the basis for the criterion for adequate blending, but consideration of $^{137}$Cs in Class A waste (after 100 years of decay) produced similar results.

As previously discussed, if a package meets the class limits, the package volume multiplied by the class limit determines the upper limit of the activity of a radionuclide in the package. In general, concentrating this activity into a smaller hot spot yields a greater potential intruder dose because the intruder can exhume more of the activity in the hot spot (Figure 2 of this volume). Therefore, to determine the criterion for adequate blending, the staff considered relatively small, concentrated hot spots. Specifically, the staff based the guidance on potential hot spots with a sum of fractions of 100. Although more concentrated hot spots are possible, the staff judged more concentrated hot spots to be very unlikely (i.e., not reasonably foreseeable) in blendable commercial LLW. Furthermore, the staff also modeled potential doses from hot spots sufficiently concentrated and small that an intruder could exhume all of the radioactivity in the hot spot. If the modeled hot spot is small enough that an intruder could exhume all of the radioactivity with a well bore, further concentrating the modeled hot spot into a smaller volume does not change the results because the same amount of activity is exhumed. In general, for each radionuclide, the dose projected by assuming the intruder exhumes all of the radioactivity in a hot spot was within a factor of two of the dose calculated with a hot spots with a sum of fractions of 100.

Therefore, the staff evaluated hot spots with a sum of fractions of 100 composed of various radionuclides and determined hot spot volumes that would limit the projected dose to an

[39] Note the draft EIS text explains that Column 1 in Table 7.1, labeled "Classes A & B" is the boundary between Class A and Class B (i.e., it is the Class A limit). Similarly, Column 2, labeled "Class C" is the boundary between Class B and Class C (i.e., it is the Class B limit). Column 3, labeled "Generally Unacceptable" is the minimum value of what would be considered generally unacceptable for near-surface disposal (i.e., it is the Class C limit).

inadvertent intruder to 5 mSv/yr (500 mrem/yr). The staff determined that for Class C waste with hotspots of $^{14}C$, $^{241}Pu$, or $^{241}Am$, a hot spot with a sum of fractions of 100 should be limited to 0.02 $m^3$ (0.7 $ft^3$) to limit intruder doses to 5 mSv/yr (500 mrem/yr). In practice, it appears to be more practical to detect larger hot spots. Therefore, the BTP guidance limits hot spots with a sum of fractions of 10 to 0.2 $m^3$ (7 $ft^3$), which also limits a hot spot of 0.02 $m^3$ (0.7 $ft^3$) to a sum of fractions less than 100.

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## 6. ACKNOWLEDGEMENTS

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