

**Low-Level Radioactive Waste Management in the United States  
Where Have We Been: Where Are We Going - 10417**

**The Richard S. Hodes, M.D. Honor Lecture Award**

Larry W. Camper  
Director, Division of Waste Management and Environmental Protection  
U.S. Nuclear Regulatory Commission  
Washington, D.C. 20555-0001

**ABSTRACT**

Over the past forty years within the United States (U.S.), a regulatory infrastructure for low-level radioactive waste (LLW) has emerged that is based principally on the origin of the LLW, rather than the risk associated with the waste *per se*. The term LLW has been a changing and somewhat unprecise term over the years. Today, LLW is defined in 10 CFR Part 61 as radioactive waste that is not classified as high-level radioactive waste (HLW), transuranic waste (greater than 100 nanocuries per gram) (TRU), spent nuclear fuel (SNF), or byproduct material as defined in Section 11e(2) of the Atomic Energy Act of 1954, as amended (AEA) [1]. This definition in Part 61 is the same as the definition of LLW in the Low-Level Waste Policy Act (LLWPA) of 1980 and 1985 as well as in the Nuclear Waste Policy Act of 1982. This paper will briefly examine certain of the key historical policy foundations of this regulatory infrastructure, as well as significant aspects of the operational management process that has emerged for handling and disposing of LLW, based upon the waste classification scheme set forth in Part 61. The paper will focus primarily upon some of the significant challenges currently facing the industry, certain potential challenges facing the industry in the future, and offer discussion as to what the future holds for addressing these issues.

**INTRODUCTION**

In the U.S., a regulatory infrastructure for the management of LLW has emerged over the past forty years that is based principally on the origin of the LLW, rather than on the risk associated with the waste *per se*. The definition of LLW has been exclusionary and included all radioactive wastes that were not HLW, including SNF, TRU, and Greater-Than-Class C (GTCC), as defined in 10 CFR Part 61 [1]. GTCC is technically LLW, but is not suitable for near-surface disposal as defined in 10 CFR Part 61. The regulatory infrastructure, while complicated, including major actions by the Federal and State governments as well as by Compact Commissions, has been successful in ensuring that LLW is safely managed and disposed of in a manner that is adequate to protect public health and safety. Today, there are several thousand generators of LLW in the U.S., ranging from research labs (generating small amounts of waste) to sites undergoing decommissioning (generating millions of cubic feet of generally low activity waste) to operating nuclear power plants (generating highly radioactive waste in resins and hardware). There are several dozen brokers and processors for these wastes and three operating disposal facilities. Thus, in addition to the overarching regulatory infrastructure, an operational supporting industry has emerged utilizing different business models to facilitate this authorized activity. The

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authorized supporting industry operates to ensure that LLW is disposed of safely in accordance with the LLW waste classification scheme and performance objectives set forth in 10 CFR Part 61. This paper will cite and briefly discuss certain of the key milestones that have played a critical role in producing the existing regulatory infrastructure for the management and disposal of LLW. The history of regulating the LLW industry in the U.S. is indeed rich and complicated, so this paper will attempt to address only those key regulatory actions that have most significantly affected the operational status of the industry with an emphasis on U.S. Nuclear Regulatory Commission (NRC) actions in that regard.

Today, this regulatory and operational infrastructure is facing significant challenges unlike those presented in the past, such as the implications for generators in the thirty-six states that no longer have disposal access for Class B and C waste given the closure of the Barnwell, South Carolina site in 2008. While the existing LLW disposal infrastructure does not face a current disposal capacity problem, it does face a disposal access issue. This problem may grow as the existing host states for LLW disposal face political pressure regarding continued disposal or disposal of new waste streams within their boundaries. As a result of the closure of Barnwell and other issues, such as cost containment, as well as emerging industry trends, the authorized supporting industry is seeking new and innovative ways to dispose of Class B and C waste, and low specific activity waste, including low activity waste containing Special Nuclear Material.

In addition to the changes cited above, given the steady reduction of the overall LLW volume by the authorized industry, completion of site cleanup by the U.S. Department of Energy (DOE), and the current hiatus in nuclear power reactor decommissioning, there is a need for the current operating commercial sites to maintain their financial viability. Looking to the future, a number of very challenging issues are emerging that will further test the existing regulatory infrastructure for LLW in the U.S. including: disposal of large quantities of depleted uranium by DOE and the commercial enrichment industry; disposal of unique waste streams that may emerge from fuel reprocessing initiatives; NRC's efforts to risk-inform the existing LLW classification scheme in 10 CFR Part 61; emerging changes in the LLW classification scheme used by the International Atomic Energy Agency (IAEA); and, of course, the never ending question of clearance or exemption for the materials at the very lowest end of Class A waste. Another interesting challenge for the existing process will be available disposal capacity and access to accommodate the next bow wave of nuclear power reactor decommissioning, which should take place between 2035 and 2050. This time frame may seem distant at the moment, but given the record to date in terms of developing new commercial disposal capacity under the auspices of the LLWPA, it may be time to consider what actions should be taken to ensure that there will be viable commercial disposal available in the future. This is especially the case in view of the current political climate surrounding the disposal of radioactive waste. This paper will briefly discuss these challenges and attempt to offer what the future may hold in addressing them. This discussion will not be exhaustive, but should provide reasonable and hopefully stimulating insights as to just how these issues may play out in terms of regulatory infrastructure adjustments. It should be noted that all views or opinions as to future outcomes of these various issues are the sole responsibility of the author and do not necessarily reflect the views or opinions of the NRC or its staff.

## **EARLY HISTORY**

In the early years of the U.S. domestic atomic energy industry, the Atomic Energy Commission (AEC) used three methods to dispose of radioactive waste (i.e., dilution and dispersion, shallow land burial, disposal at sea) [2]. In the 1960's, commercial interest in ocean disposal began to decline and it ended completely by 1970. One of the principal reasons for ending ocean disposal was the adverse public reaction to polluting the ocean and the other motivation was economic because land disposal was considerably less expensive [2]. In addition, the AEC decided to endorse a new disposal policy permitting land burial using commercial disposal sites. Under this policy, it was envisioned that the private sector would identify sites with favorable geologic and meteorologic conditions and provide the same disposal service to commercial generators at a lower cost. The intent was to locate disposal sites in those regions generating the wastes [2]. Between 1962 and 1971, six shallow burial LLW disposal facilities were licensed and operated to dispose of U.S. commercial LLW. Most of these facilities were located with the boundaries of or adjacent to a much larger Federal Reservation operated by the AEC. Three of these disposal sites: Barnwell, South Carolina; Maxey Flats, Kentucky; and West Valley, New York, were licensed by their respective host states through the Agreement State Program with the AEC (predecessor to the current NRC) as authorized by Section 274 of the AEA [2]. The remaining three sites: Beatty, Nevada, Richland, Washington; and Sheffield, Illinois, were licensed by the AEC because their host states were not Agreement States at that time.

The commercially operated LLW disposal sites adopted the practice of near-surface, shallow-land burial disposal technology adhered to at the then existing AEC facilities. This disposal method relies on relatively simple engineering design to isolate wastes from infiltrating with the natural geologic characteristics of the site as the principal attenuations of any radioactive material that might be released to the accessible environment [2]. The fundamental technical assumption behind this near-surface disposal method was that the nature and rates of natural process acting on the earthen trench system would be sufficient to slow the movement of radionuclides from the disposal trenches to the accessible environment until they had decayed to acceptable background levels.

After several years of operation, the West Valley, Maxey Flats, and Sheffield sites began to encounter surface and/or ground water management problems. The remaining LLW sites had problems of a different nature. The Beatty and Richland sites were temporarily closed in 1979 by the Governors of those States as a result of waste packaging violations and transportation safety issues. Subsequently, the Governor of South Carolina ordered that waste accepted at the Barnwell site be reduced by fifty percent over a two year period [2].

In 1975, the U.S. Geological Survey received direct LLW appropriations to develop geohydrologic guidelines that could be used to establish technical criteria for selecting, evaluating, licensing, and operating new LLW disposal sites [2]. To reduce the potential for the environmental transport of radionuclides at disposal sites, the National Academy of Sciences independently recommended that arid sites in the West be considered because the geohydrologic

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settings there would be less complex and, presumably, performance could be more reliably predicted. Other recommendations were made that some form of engineered barrier, working in concert with the natural system, be integrated into future LLW facility designs [2].

In 1974, Congress abolished the AEC by passing the Energy Reorganization Act whereby the AEC's regulatory functions were placed within the newly created NRC and the AEC's atomic energy promotional functions were placed within the newly created Energy Research and Development Administration, which was later absorbed into DOE when DOE was created in 1977. The NRC commenced operations in January 1975 and began focusing its attention on several broad issues that were essential to protecting public health and safety. Initially, the NRC regulated LLW using a collection of generic regulations specified in 10 CFR Parts 30, 40, and 70 [2]. However, in response to the needs and requests expressed by the public, the States, Congress, industry and others, one of the earliest rulemaking efforts the NRC was to undertake was the development of a set of comprehensive requirements for licensing the near-surface land disposal of LLW.

In 1978, NRC began development of its LLW regulation by relying on an extensive National Environmental Policy Act scoping process. The NRC determined that an "umbrella regulation" would be needed that would include comprehensive standards, technical criteria, and licensing procedures in order to protect public health and safety [2]. Following several years of study and development, the NRC issued a Final 10 CFR Part 61 Regulation in December 1982 covering all phases of shallow, near-surface LLW disposal from site selection through facility design, licensing, operations, closure, post-closure, stabilization, and termination of the institutional controls. During the development of 10 CFR Part 61, the NRC staff placed a great deal of emphasis on evaluating and protecting against inadvertent re-entry into disposed LLW and explored ways of classifying LLW for use in standardized exposure scenarios in order to predict potential doses to receptors [2]. In large part because of the evaluation of an inadvertent intruder,

10 CFR 61.55 introduced a three-tier waste classification system for LLW that was based on the concentrations of the longer-lived radionuclides. These classes are designated Class A, B, and C in ascending order of potential radiological hazard [2]. The regulation specifies design standards applicable to each class of LLW. Since the regulation was created in 1982, 10 CFR Part 61 and its counterparts in the Agreement States have served as the basis for licensing and regulating LLW disposal sites. The regulation has not undergone a major updating or revision since its inception.

## **LLW POLICY ACT OF 1980 AND AMENDMENTS ACT OF 1985**

Congress established a national policy for disposal of commercial low-level radioactive waste in the Low-Level Waste Policy Act of 1980, as amended in 1985. Under this law, each State was given the responsibility for providing disposal capacity for waste generated within its borders, and States are authorized to form regional compacts that could provide a regional facility for its

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member States [2]. Compacts have the ability to ban out-of-region waste from their facilities. The goal of this new policy was to create more disposal capacity and to provide for regional equity in disposal of LLW generated in the U.S.

Congress passed this legislation after three of six privately developed disposal facilities were closed by States due to performance issues. In addition, the States with those remaining three sites objected to carrying the burden for LLW disposal for the entire U.S. The States, including the National Governors' Association, argued for giving the States responsibility for developing new disposal capacity because LLW facility development primarily involves state and local issues. Congress' passage of the 1980 Act addressed this State concern and also provided a mechanism for sharing the burden of LLW disposal among different regions of the country through the compact system [2].

## **WASTE CLASSIFICATION AND WASTE FORM TECHNICAL POSITIONS**

NRC published its final regulation for licensing of land disposal facilities for LLW in 10 CFR Part 61 on December 27, 1982. The rule became effective on January 26, 1983. To assist licensees in meeting the new requirements, NRC published two technical positions shortly after it completed the rule, which addressed waste classification and waste form. Both were published on May 11, 1983 [3]. The waste classification technical position describes procedure acceptable to NRC to determine the presence and concentrations of radionuclides listed in the waste classification tables in 10 CFR 61.55, and thereby, classifying waste for near-surface disposal [4]. The technical position on waste form provides guidance on test methods for implementing the 10 CFR 61 waste form requirements, primarily the structural stability requirements. The position included guidance on processing waste into a stable form, designing acceptable high-integrity containers, packaging cartridge filters, and minimizing radiation effects on ion-exchange resins [5].

The waste form technical position was revised and published on January 24, 1991, to address issues associated with implementing the position. A new appendix addressing cementitious waste forms was included in the position. Field experience and laboratory testing of cement-solidified LLW indicated that there were some unique chemical and physical interactions between the cement constituents and the chemicals and compounds in the waste materials. The new guidance for cement forms addressed specimen preparation, statistical sampling and analysis and waste characterization [6].

On January 17, 1995, the staff published revised guidance on concentration averaging and encapsulation, to expand on the guidance previously published in the 1983 waste classification technical position. The 1995 guidance defines a subset of concentration averaging and encapsulation practices that the staff would find acceptable in determining the concentrations of 10 CFR 61.55 tabulated radionuclides [7]. The 1983 guidance devoted only a few paragraphs to concentration averaging, whereas the 1995 revision included 20 pages of guidance. The updated guidance primarily addressed discrete waste forms (i.e., waste forms that would not be

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significantly mixed with soil in postulated intruder scenarios). Soil mixing was assumed in the draft environmental impact statement for 10 CFR Part 61, which lowers the postulated radiation exposures to inadvertent intruders. The 1995 position also addresses blending and mixing of homogeneous wastes, such as ion exchange resins, and limits the concentrations of batches that may be mixed according to a “factor of 10” rule. However, the technical position also allows for mixing without constraints for homogeneous wastes if occupational dose reductions or operational efficiencies can be demonstrated [7].

## **BELOW REGULATORY CONCERN**

Section 10 of the LLRWPA requires that the NRC establish standards for determining when radionuclides are present in waste streams in sufficiently low concentrations or quantities as to be “below regulatory concern” (BRC), thereby potentially exempting them from NRC LLW regulation. The Commission issued its BRC Policy Statement in July 1990, proposing that if radioactive materials did not expose individuals to a dose of more than 1 millirem per year (mrem/yr), or a population group to more than 1000 person-rem per year (collective dose), then the waste stream in question could be eligible for an exemption from regulatory control [8]. The BRC policy was an effort by the NRC to develop a general statement of Commission policy (July 3, 1990, 55FR 27522) that would provide a broad framework for making decisions on exempting, from regulatory control, certain practices involving small quantities of radioactive material, including recycle of solid materials [8]. There was extensive public comment, from licensees, the States, and citizens groups when the BRC policy was issued. The Commission decided that a more extensive public involvement process in establishing such a decision framework would be beneficial and hence instituted a moratorium on the BRC Policy in July 1991. Subsequently, in October 1992, the U.S. Congress enacted the Energy Policy Act of 1992 that revoked the BRC Policy Statement. Subsequently, the NRC envisioned conducting rulemakings to implement through the Administrative Procedures Act process some of the approaches of the BRC policy; the license termination rulemaking completed in 1997 (62 FR 39058, July 21, 1997) was an example of such a rulemaking.

In 2005, NRC staff completed a draft proposed rule on disposition of solid materials that addressed release of these materials from regulatory control [9]. The Commission has deferred the rulemaking because of higher priority work. NRC’s current approach is to make decisions on disposition of solid materials by using a set of existing guidelines, primarily based on survey instrument capabilities. In a report reviewing NRC’s current approach, the National Academies indicated that the current approach is “sufficiently protective of public health and safety that it does not need immediate revamping.” [10]

## **STRATEGIC ASSESSMENT AND REBASELINING**

In 1996, the NRC undertook a strategic assessment of 20 of the agency’s “direction setting issues” to determine how best to address them in the future. The NRC’s LLW regulatory program was one of these issues. For the LLW program, the staff presented six alternative

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implementation strategies, ranging from becoming a national leader that would be active in promoting the development of new disposal sites, to asking Congress to transfer the program to the U.S. Environmental Protection Agency. After consideration of public comments, the Commission decided in 1997 to “maintain the current program,” which at that time comprised approximately 5 to 10 FTE. The specific kinds of activities included in this option were limited to specific actions, such as providing technical assistance to States and limited guidance development. The Commission based its 1997 decision in part on the perceived needs and scope of the national program, which by that time had diminished because the LLRWPA had been in place for nearly 10 years and most of the new siting efforts by States had come to a halt. The Commission also decided that the NRC’s role should be limited primarily to those activities that had a direct bearing on the agency’s regulatory mission to protect public health and safety and the environment. The basic Commission decision in 1997 concerning the size and scope of the LLW program remains in effect and has guided planning and budgeting since that time.

## **LOW-LEVEL WASTE PROGRAM STRATEGIC ASSESSMENT**

Since that decision, several issues grew in importance, in part because no new disposal sites have been developed. Examples of these issues include the following: (1) desire of industry for greater flexibility and reliability in LLW disposal options; (2) increased need for storage of Class B and Class C LLW because of the closing of the Barnwell, South Carolina disposal facility in 2008 to out-of-compact waste generators; (3) coming need to dispose of large quantities of power plant decommissioning waste as well as depleted uranium from enrichment facilities; (4) increased security concerns; and (5) new waste streams that may be generated (e.g., by the next generation of nuclear reactors and the potential re-emergence of nuclear fuel reprocessing in the U.S.).

Because these new demands on the LLW program resources were greater than the resources available, the program needed a strategy to identify and prioritize the tasks to be performed. Consequently, NRC staff undertook an effort to assess the current LLW regulatory program to ensure that it remains positioned to achieve agency objectives. The strategic assessment process involved four major steps: (1) development of strategic objectives and goals; (2) information gathering; (3) evaluation of the information obtained; and (4) decision making. The complete report is contained in SECY-07-0180, issued on October 17, 2007 [11].

With regard to the first step, the staff formulated a strategic objective to be consistent with and to complement the overall agency goals provided in the NRC’s FY 2004 – 2009 Strategic Plan [12] and, at the time, draft FY 2007-FY 2012 Strategic Plan [13]. As indicated in both plans, the agency’s overarching strategic objective is to, “enable the use and management of radioactive materials and nuclear fuels for beneficial civilian purposes in a manner that protects public health and safety and the environment, promotes the security of the nation, and provides for regulatory actions that are open, effective, efficient, realistic and timely.” Both plans call for the assessment of key issues affecting the safe management of civilian LLW and further note that NRC programs should, “... anticipate challenges and respond quickly to changes in the

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regulatory and technical environment.” As a result, it was determined that the strategic objective of NRC’s LLW regulatory program was to provide for a stable, reliable, and adaptable regulatory framework for effective LLW management, while maintaining safety, security, and protection of the environment.

After considering stakeholder input and factoring in its own experience, the staff developed a list of proposed activities that supported the strategic objective and were responsive to identified programmatic needs. The staff evaluated 20 activities and assigned them priorities of high, medium, or low. After consideration of the potential activities that the staff could undertake to improve the LLW regulatory framework, the staff believed, like the NRC Advisory Committee on Nuclear Waste and Materials, that the current regulations are fully protective of the public health and safety and worker health and safety. At the same time, there were a number of opportunities for better risk-informing the LLW regulatory framework and improving the effectiveness of LLW management and regulation. The current definition of the NRC term “Risk-Informed” is cited in the “NRC Strategic Plan: FY 2008 – FY 2013,” (NUREG-1614, Volume 4) as the following: “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. Such an approach is used to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety.”

Among the high priority tasks were to update the LLW storage guidance, to complete an analysis of depleted uranium disposal, to prepare a procedure for reviewing low-activity waste disposal requests, and to update the Concentration Averaging Branch Technical Position. The first three of these tasks have been completed, and the staff is addressing LLW blending, one topic in the CA BTP, at this time. The resolution of the blending issue will help guide the revisions to the remainder to the BTP.

## **UPDATING LLW STORAGE GUIDANCE**

As noted above, the updating the LLW storage guidance was a high priority task identified in the Low-Level Waste Strategic Assessment. On July 1, 2008, the Barnwell LLRW disposal facility closed to LLRW generators in thirty-six States, leaving them no option for disposal of their Class B and C LLRW. Thus, most generators of LLW would be forced to store these wastes for an indefinite period of time after Barnwell closed. For materials and fuel cycle licensees, the applicable storage guidance was first published in 1990, in Information Notice 90-09, “Extended Interim Storage of Low-Level Radioactive Waste by Fuel Cycle and Materials Licensees,” and for nuclear power reactor licensees, in 1981, in Generic Letter 81-38, “Storage of Low-Level Radioactive Wastes at Power Reactor Sites.” [14, 15] These guidance documents were particularly useful when access was denied to generators in Michigan from 1990 through 1995, and for many U.S. generators from 1994 to 1995, when Barnwell closed to all but generators in the Southeast LLRW Compact. There have been a number of changes since the guidance was first published that warranted an update. The September 11, 2001, terrorist attacks heightened



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concern about the security of stored LLW in general and sealed radioactive sources in particular; and NRC has developed specific guidance to better ensure the security of high risk materials. This security guidance has now been referenced and/or included in the updated LLW storage guidance. As a result of having to store waste, rather than dispose of it, licensees may need to increase their license possession limits. This could result in possession of radionuclides of concern in quantities exceeding these threshold limits. In such cases, additional requirements – like those cited above – may be imposed on licensees, and this fact is highlighted in the revised storage guidance.

The nuclear power industry also took steps to address the loss of access to Barnwell, including the development of its own guidance for use by power reactor licensees. The Electric Power Research Institute developed at-reactor storage guidance for use by power plants, and the Nuclear Energy Institute submitted it to NRC for review and endorsement. The industry developed these guidelines for generic use by Part 50 and 52 licensees to provide a consistent approach to implementing an operational program for safe interim storage of LLW at a commercial nuclear power plant site. Designed for a storage period of as long as the full operational lifetime of a nuclear power plant, the guidelines describe an operational program that is structured to assure safe interim storage of LLRW for as licensed under 10 CFR Part 50 or 52. A group of industry experts in LLW management developed the guidance. On December 30, 2008, NRC issued Regulatory Issue Summary (RIS) 2008-32, “Interim Low-Level Radioactive Waste Storage at Reactor Sites,” finding that the EPRI guidance “... to be consistent with NRC information contained in this RIS and other NRC guidance...” and “... provides an acceptable method for record keeping, determining waste forms, and waste containers and monitoring and inspecting the interim long-term storage of LLRW.” [16, 17] Although NEI and EPRI had also indicated that Class B/C waste could be concentrated to GTCC waste, NRC did not take a position on that proposal.

Updating the guidance for materials licensees and endorsing guidance for power reactors’ LLRW storage helped to ensure that licensees will address the important issues in assuring safety and security of LLRW. This updated guidance is also the basis for revisions to NRC inspection procedures for LLRW storage. These procedures are used by NRC regional inspectors to evaluate licensee programs and will help to ensure that licensee programs are being appropriately implemented in this time of increased storage of LLRW.

## **CURRENT AND POTENTIAL CHALLENGES/OUTCOMES**

Today, the existing LLW regulatory infrastructure and operational industry face a number of immediate and foreseeable challenges and the outcomes of these challenges may greatly influence the industry for many years to follow. So, what are these challenges and where are we going as we work to address them? The solutions to these existing challenges will need to be addressed in a manner that continues to adequately protect public health and safety, while accommodating the existing regulatory and operational infrastructure. In contrast, some of the solutions to these existing challenges may markedly change the existing structure and will

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necessarily take a considerable amount of time and involve substantial input from the various stakeholders through highly visible and meaningful public processes.

## **IMPORTATION OF FOREIGN WASTE**

In 1995, the NRC amended its regulations in 10 CFR Part 110 to conform the regulatory requirements for the import and export of radioactive waste to the guidelines of the Code of Practice on the International Transboundary Movement of Radioactive Waste (Code) [18]. Since a basic principle of the Code was to require countries to track movements of radioactive waste across their borders so as to prevent radioactive waste from ending up in a country not prepared for safe management and disposal, the NRC amended its regulations to require specific licensing of both imports and exports of radioactive waste with limited exceptions. The NRC reviews import/export license applications against the criteria defined in 10 CFR Part 110 and determines whether or not to issue an import license for radioactive waste based on its own health and safety and common defense and security evaluation. While the NRC has exclusive jurisdiction within the U.S. for granting or denying licenses to import radioactive waste, the NRC evaluation is formed only after consulting with the Executive Branch, the applicable host State, and the applicable LLW Compact and also considering public comments. The NRC bases its licensing decisions on the following criteria found in 10 CFR Part 110.43: (1) the proposed import will not be inimical to the common defense and security; (2) the proposed import will not constitute an unreasonable risk to the public health and safety; and (3) an appropriate facility has agreed to accept the waste for management or disposal [18].

Since the 1995 rule was promulgated, the NRC has issued fourteen licenses for the import of radioactive waste. Of those licenses, eight have authorized import for disposal in the U.S.; of those eight, four have authorized import of U.S. origin waste; and the remaining six licenses authorized import for processing and return of the process waste to the country of origin [19]. On September 14, 2007, the NRC received a request from EnergySolutions, Inc. (ES) for a license to import up to 20,000 tons of radioactively contaminated material from nuclear power facility operations in Italy [20]. After characterization in Italy, the contaminated materials would be inspected, sorted and processed at ES facilities licensed by the State of Tennessee, for recycling and beneficial reuse. The applicant estimates that after the processing in Tennessee, approximately 1,600 tons of material would be sent for disposal at ES's Clive, Utah disposal facility, which is licensed by that Agreement State. According to its application, no hazardous or mixed waste would be imported, and ES would review and approve the content of each prospective shipment from Italy to the U.S. to ensure compliance with its domestic materials possession limits.

The NRC solicited views from the states of Tennessee and Utah, the Southeast Compact Commission and Northwest Interstate Compact, and the Executive Branch via the Department of State. The regulatory authorities in both Tennessee and Utah have informed the NRC that the material can safely go to the ES facilities in their respective states. The Southeast Compact Commission expressed no objection to the application. The Executive Branch (U.S. Department

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of State) provided the NRC with the Italian Government's view that the application is consistent with the Joint Convention obligations. The NRC also offered members of the public the opportunity to submit comments or request a hearing on this application. The NRC received requests for a hearing from the State of Utah, a consortium of public interest groups, and an environmental group, as well as over 2,900 comments on the application [19].

The members of the Northwest Interstate Compact unanimously adopted a resolution stating that the existing compact procedures do not address the import of foreign waste and that such waste would need Compact approval before disposal at the ES facility in Utah [19]. The Compact notified the NRC by letter on May 15, 2008, that "... should it choose to issue the import license, it is doing so with the understanding there is no facility within the Compact region that is authorized to legally accept this waste for disposal." Prior to the Compact's resolution, ES filed a lawsuit in Federal District Court against the Northwest Compact challenging the Compact's authority over the proposed import. By Order dated October 6, 2008, the NRC held in abeyance the proceedings pertaining to the ES application for a license to import LLW from Italy for ultimate disposal at the ES disposal facility in Clive, Utah, as well as the accompanying application for a license to export LLW back to Italy. In its abeyance Order, the NRC stated that, "... until the dispute over the authority of the Northwest Compact is resolved or ES outlines an alternative plan for disposal of the imported low level radioactive waste," it will not be clear whether "an appropriate facility has agreed to accept the waste for management or disposal," which is a key criterion under the NRC regulations for issuance of a radioactive waste import license. The NRC concluded that devoting further adjudicatory resources to this proceeding now would be inefficient and, accordingly, held further proceedings on the ES license applications in abeyance until further notice, directing ES to provide NRC with status reports every six-months until there is a judicial resolution of the pending lawsuit or the jurisdictional dispute is otherwise resolved [19].

On May 15, 2009, the Federal District Court in Utah issued an Order finding that the Northwest Compact had no authority to restrict the flow of LLW generated outside the Compact's region to the ES facility in Clive, Utah [19]. The NRC thereafter sought the views of the potential parties to the proceeding on the ES applications regarding how it should proceed in light of the Court's decision. In their responses to the NRC's Order, Utah and the Northwest Compact gave notice that they, along with another party to the Federal lawsuit, the Rocky Mountain Low-Level Radioactive Waste Management Board, planned to appeal the Federal District Court's decision to the Court of Appeals for the 10<sup>th</sup> Circuit Court of Appeals. Eight LLW compacts and the Council of State Governments supported the appeal, either as parties or as *amici curia* [19]. The parties completed their briefings on September 28, 2009, and await the Federal Courts's scheduling of oral argument. As of the present time, the proceedings on the ES waste import/export applications remain in abeyance, as the NRC continues to receive six-month status reports and monitor pertinent developments.

The request for importation of the Italian waste has generated a considerable amount of interest in this issue by certain members of the Congress. Specifically, in January 2009, Congressman

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Bart Gordon (D-TN) proposed H.R. 515, the “Radioactive Import Deterrence Act” that proposed, among other things, to strip the NRC of its jurisdiction to authorize the importation of LLW [21]. On December 2, 2009, the full U.S. House of Representatives approved H.R. 515 by a vote of 309 to 112 on a motion to suspend the rules and pass the bill as amended by Subcommittee on energy and the Environment. The bill passed the House under an expedited procedure that requires approval by at least two-thirds of the House members present. Senator Lamar Alexander (R-TN) has introduced a companion bill, S.232 in the U.S. Senate. On January 14, 2009, S. 232 was referred to the Senate Committee on Environmental and Public Work, but no further action has been taken at this time. In December 2009, Senator Alexander indicated that he did not see the need to push this legislation within the Senate given that the matter was still under review by the Federal Court. Thus, the fate of this legislation within the overall Congress is not at all certain at this time.

As cited earlier, the NRC currently has the exclusive authority to authorize the import and disposal of LLW within the U.S. and arguably utilizes a collegial process in interacting with the Executive Branch, States, and Compacts when considering such requests. One of the fundamental tenants of this process is that there is an adequate disposal facility that has agreed to accept the waste for disposal. There is no evidence that this process has not worked in a manner that adequately protects public health and safety. Rather, the motivations around the Congressional actions to date appear to be more focused on concerns about disposal capacity for U.S. generated LLW, general concerns or fear about LLW disposal, or concerns with becoming a disposal site for international waste. Achieving an appropriate balance between adequate protection of public health and safety, political concerns, and ensuring that viable disposal pathways exist for the disposal of LLW within the U.S. should prove to be more challenging as the nuclear industry, both within the U.S. and abroad, seeks solutions to the disposal of LLW.

## **WASTE CONTROL SPECIALISTS DISPOSAL FACILITY**

Waste Control Specialists (WCS) is developing a new LLW disposal facility in Andrews County, Texas (TX) that would accept Class A, B, and C waste from generators in the Texas Compact (comprised of the States of TX and Vermont), as well as Federal waste. WCS reached a major milestone on September 10, 2009, when the Texas Commission on Environmental Quality signed the final license for the disposal of LLW at the facility after more than five years of review. When the facility goes into operation, currently scheduled for early 2011, it will be the first disposal facility to have been developed exclusively under the requirements of the Low-Level Radioactive Waste Policy Amendments Act of 1985.

The new LLW disposal facility is located in west Texas, approximately 30 miles from the City of Andrews, TX and not far from the LES uranium enrichment facility in Eunice, New Mexico. WCS also operates several other facilities on the same site, including a Resource Conservation and Recovery Act hazardous waste cell, an 11e.(2) byproduct material impoundment, storage facilities for radioactive wastes, including GTCC, transuranic, and sealed sources. The Texas

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Compact facility at the site is authorized to accept 2,310,000 cubic feet and 3,890,000 curies of LLW. The Federal Facility is authorized to accept 26,000,000 cubic feet and 5,600,000 curies.

In late 2008, the Governor of Texas announced the appointments to the Texas Low-Level Radioactive Waste Compact Commission. Since that time, the Commission has addressed issues associated with the operation of the new facility, including import and export issues. WCS is currently not authorized to accept out-of-compact waste, but could do so in the future if authorized by the Commission. WCS has indicated that it supports the importation of Class A, B, and C waste into the Texas Compact.

One of the most significant questions facing the LLW industry within the U.S. today is whether or not the Texas Compact Commission will expand the authorization for the WCS site to receive LLW from outside of the existing Texas Compact. For example, the Texas Compact could authorize the WCS site to receive Class B and C waste from the thirty-six states which currently do not have authorized access to dispose of such waste due to the restrictions imposed on the Barnwell, SC site. In a letter dated September 22, 2009, WCS indicated to the NRC, "We are optimistic that the WCS facility will eventually be open for disposal of Class A, B, and C LLW by non-regional generators." [22] Should such a change take place, it could have a profound impact on the growing interest in blending of homogenous Class B and C waste with Class A waste to produce a lower waste class with authorized disposal at the ES facility in Clive, Utah. However, it should be noted that disposal access for the Class B and C waste will also have to consider the cost for disposal access for the Class B and C waste at the WCS site and thus, economics will also be a huge driver in this consideration. The economic component of this site is further compounded by the fact that WCS has stated publicly that authorization to dispose of commercial waste from outside the Texas Compact is critical to the financial success of the site. The granting of a license to operate the WCS site in Texas is a significant development in the commercial management of LLW within the U.S. and simply cannot be overstated. However, expansion of authority for this site beyond the existing Texas Compact is not a certainty, but may happen in time and provide disposal access for licensees including nuclear power plants who do not have such access. This would be quite a development indeed.

## **DEPLETED URANIUM DISPOSAL**

The licensing and operation of new uranium enrichment facilities in the U.S. has created a waste stream not previously considered in the development of NRC's land disposal regulations in 10 CFR Part 61 in the late 1970's and early 1980's. Although uranium and its various isotopes were considered in small quantities being generated at that time, the depleted uranium (DU) waste stream from enrichment plants was not. That waste stream has relatively high concentrations and large quantities of DU. When 10 CFR Part 61 was promulgated in 1982, there were no commercial facilities generating large amounts of DU waste and therefore, the technical basis for the rulemaking considered only the types of uranium-bearing waste streams being typically disposed of by NRC licensees at the time. The NRC concluded that those waste

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streams posed an insufficient hazard to warrant establishing a concentration limit for uranium in the waste classification tables in 10 CFR Part 61.

With the existing DOE stockpile of DU at the Paducah and Portsmouth Gaseous Diffusion Plants and the recent licensing of LES National Enrichment Facility and the United States Enrichment Corporation American Centrifuge Plant, more than 1 million metric tons of depleted uranium hexafluoride ( $\text{DUF}_6$ ) will need a disposition path. Existing disposal facilities, such as the ES facility in Clive, Utah and the WCS facility in Andrews County, Texas have expressed interest to their Agreement State regulators in disposal of large quantities of DU at their sites.

In the license proceeding for the LES National Enrichment Facility, the question of disposal of DU tailings was addressed. In a Memorandum and Order for the LES proceeding, CLI-05-20, dated October 19, 2005 [17], the Commission directed the staff to, "... outside of the LES adjudication, to consider whether the quantities of depleted uranium (DU) at issue in the waste stream from uranium enrichment facilities warrant amending section 61.55(a)(6) or the section 61.55(a) waste classification tables." [23] The current waste classification for DU is based upon §61.55(a)(6), which specifies that if radioactive waste does not contain any of the radionuclides listed in either of two listed waste classification tables, it is Class A waste [3]. DU does not contain the radionuclides listed in the specified tables, and therefore, under a plain reading of the regulation, DU is Class A waste.

In responding to the Commission's request, NRC staff completed a technical analysis to understand the impacts of near-surface disposal of large quantities of DU, such as those expected to be generated at uranium enrichment facilities [24]. The technical analysis addressed whether amendments to § 61.55(a) are necessary to assure large quantities of DU are disposed of in a manner that meets the performance objectives in Subpart C of 10 CFR Part 61. The analysis concluded that near-surface disposal of large quantities of DU may be appropriate, but not under all site conditions. Shallow disposal of large quantities of DU or disposal at humid sites with a potable groundwater pathway would likely result in the performance objectives not being met. Because of the unique characteristics of the waste and the additional considerations required for its disposal, staff concluded that existing regulations need to be amended to ensure that large quantities of DU are disposed of safely.

In the Commission decision on this issue, contained in the Staff Requirements Memorandum for SECY-08-0147 [25], the Commission approved the staff's recommendation to proceed with rulemaking in 10 CFR Part 61 to specify a requirement for a site-specific analysis for the disposal of large quantities of DU and the technical requirements for such an analysis; and to develop a guidance document for public comment that outlines the parameters and assumptions to be used in conducting such site-specific analyses. The Commission noted that, in revising 10 CFR 61.55(a)(6) in this limited scope rulemaking, the Commission is not proposing to alter the waste classification of DU, but noted that for waste streams consisting of significant amounts of DU, there may be a need to place additional restrictions on the disposal of the DU at a specific

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site or deny such disposal based on unique site characteristics and those restrictions should be determined by a site specific analysis which satisfies the requirements of the proposed new 10 CFR 61.55(a)(9) [25].

The Commission also directed the staff to conduct a public workshop inviting all potentially affected stakeholders, including licensees, state regulators and federal agencies. At this workshop, the staff should discuss the issues associated with the disposal of DU, the potential issues to be considered in rulemaking, and technical parameters of concern in the analysis so that informed decisions can be made in the interim period until the rulemaking is final.

The NRC staff has initiated the efforts leading to development of the technical basis for the rulemaking, as directed by the Commission, by conducting two public meetings convened by a facilitator, which included invited panelists representing different stakeholder views. The invited panels provided the NRC with some very interesting and useful feedback on a myriad of technical and policy questions posed to the panels. A number of key technical and policy issues were presented to or discussed by the panels including the following: (1) need to identify or define unique waste streams; (2) what are significant quantities of DU?; (3) defining an appropriate period of performance given the long half-life of DU and in-growth of radon progeny over time; (3) requirement to perform and update performance assessments; (4) need to define the intruder dose in 10 CFR Part 61; (5) what should be in the regulation versus what should be in guidance (e.g., exposure scenarios)?; (6) what will be the level of compatibility assigned to the rule?; (7) changes to the requirements for preparing a technical analysis to accommodate the performance assessment requirement; and (8) conforming changes to the concepts section in 10 CFR Part 61.7.

The NRC projects that the rulemaking will require three years to complete, but will establish a clear requirement to conduct a site-specific performance assessment for the disposal of significant quantities of DU, such as those resulting from the disposal of the DOE DU stockpiles at Paducah and Portsmouth and that DU generated through commercial enrichment facilities. While completion of the rulemaking will not be complete for three years, the decision by the Commission to proceed with this requirement has already markedly impacted the regulatory oversight for the disposal of significant quantities of DU. For example, within the state of Utah, the regulator, along with the Utah Radiation Control Board, are imposing requirements for a site specific performance assessment that will minimally address the technical parameters to be addressed by the NRC staff within the technical analysis completed as part of SECY-08-0147 for the disposal of DU. ES, the licensee that operates the commercial facility at Clive, Utah is currently working to update the existing performance assessment for the site and provide it to the State regulator by December 2010. The State regulator intends to review the updated performance assessment as promptly as possible, but certainly before completion of the NRC rulemaking, which should be completed by 2012. The decision by the Commission to require that a site-specific performance assessment be completed for the disposal of significant quantities of DU, including specifying the technical parameters to be evaluated and providing guidance to support this new requirement, will ensure that all performance assessments for such disposal are

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completed and done so in a reasonably uniform and consistent manner. Thus, while DU does pose challenges in comparison to most other Class A waste because of its long half-life and in growth of radon progeny over time, the evaluation of site-specific conditions via a dynamic performance assessment will ensure that there is adequate protection of public health safety regarding disposal of this type of LLW.

## **RISK-INFORMING 10 CFR PART 61**

In the decision on DU disposal, the Commission also directed the staff to undertake a longer-term, more comprehensive rulemaking to risk-inform the waste classification system in 10 CFR Part 61. The Commission stated that, "... in a future budget request, the staff should propose the necessary resources for a comprehensive revision to risk-inform the 10 CFR Part 61 waste classification framework, with conforming changes to the regulations as needed, using updated assumptions and referencing the latest International Committee on Radiation Protection methodology. As part of this effort, staff should also identify any corollary or conforming legislative changes necessary to support this rulemaking, if any, as well as recommendations on how to proceed absent such legislation being enacted and other agencies that may be impacted by any changes."

As the staff noted in the analysis of DU disposal in SECY-08-0147 [24], such a revision would likely involve different methodologies and assumptions than the original Part 61 methodology for key variables, such as: disposal configurations, performance periods, institutional control periods, waste forms, site conditions, exposure pathways, and receptor scenarios. The existing Part 61 waste classification framework is well accepted by the LLW disposal industry and has been used successfully for more than two decades. However, as mentioned above, some of the assumptions built into the framework could be considered conservative and inconsistent with today's movement towards risk-informed regulation. In addition, the approaches to incorporate and evaluate the impacts of uncertainty and variability were more limited than those used currently. Staff could also consider, for example, the IAEA's waste classification system to determine if it would be appropriate for use in the U.S.

This rulemaking will likely draw significant stakeholder input, as it could potentially make significant changes to the entire existing waste classification environment. However, a revised, risk-informed framework could reflect current knowledge of the performance of LLW disposal facilities and could present risk-informed concentration limits for all radionuclides. An update of the methodology used to develop the concentration limits could result in higher or lower concentration limits than currently used, which could actually increase or decrease disposal options for some types of wastes (e.g., current Class B/C waste could become Class A waste).

The regulatory effort to risk-inform and performance orient the existing waste classification scheme in 10 CFR Part 61 will pose a number of substantial challenges, will necessarily require a great deal of time and effort, must involve significant opportunity for public involvement, and must align with other ongoing regulatory efforts such as the reexamination of the radiation



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protection requirements in 10 CFR Part 20. Further, given that Part 61 has been in place since 1982 and has not undergone any major revisions since that time, it may prove very difficult for the NRC staff to limit this effort to only addressing the waste classification scheme as directed by the Commission. The revision of the waste classification scheme in Part 61 presents an interesting spectrum of possibilities for the NRC staff to consider and discuss with the public over a rulemaking effort that could take as many as five years to complete once initiated. Of course, the underlying assumption is that the Commission will move beyond only budgeting for this effort and will, in fact, proceed to revise Part 61 and, as indicated, pursue conforming changes and possibly other legislative initiatives including potential suggested modifications to the Low-Level Waste Policy Act of 1980 and the Low-Level Radioactive Waste Policy Amendments Act of 1985 if needed.

The current waste classification scheme in 10 CFR Part 61 is well established and has served well in providing a system to safely manage the disposal of LLW within the U.S. for over 25 years. However, it is not the only system which can achieve the objective of adequately protecting public health and safety relative to the disposal of LLW. A person can envision a spectrum of possibilities for achieving the safe disposal of LLW minimally including the following: (1) reliance on the use of a site-specific performance assessment to determine which and how much LLW may be safely disposed in a given site that would necessarily be driven to a large degree by site-specific conditions (e.g., arid environment versus humid environmental); (2) slight modifications to the existing waste classification scheme resulting from a reexamination of the radionuclides set forth in the existing waste classification tables, using the same technical approach followed in the historical development of Part 61, but with the reexamination informed by current health physics information and current ICRP methodologies; (3) use of the recently revised waste classification scheme developed by the IAEA, as set forth in Classification of Radioactive Waste, GSG-11 that contains five categories of LLW including an exempted or exclusion category for very low activity LLW; or (4) some other risk-informed scheme to be developed that may involve completely different categories of LLW. An interesting component of this initiative will be the relationship between managing the waste while in process versus classification of the waste for disposal. Such is the system that exists today, even though the waste classification tables in Part 61 relate to disposal and were designed primarily to protect an inadvertent intruder. In other words, a waste classification scheme designed for disposal probably cannot be designed in a vacuum that does not consider management of the LLW throughout the process.

The revision of 10 CFR Part 61 will elicit many strongly held views by various stakeholders. It will clearly pose a substantial challenge to the NRC staff and the Commission to revise and update the existing waste classification scheme by providing a modernized and-risk informed system, that will be as understood, effective, and utilized as the existing scheme. This challenge cannot be overstated and the overall process must involve the highest levels of scientific integrity and public scrutiny. Anything else will not result in an improved system that is as effective or preferably more effective than the existing waste classification system. As the Chinese proverb

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says, “may you live in interesting times”, such is the case with the issue of risk-informing and modernizing the existing waste classification scheme.

## **BLENDING OF LLW**

Since the closure of the LLW disposal facility at Barnwell, South Carolina on June 30, 2008, to out-of-compact generators, the issue of blending of LLW has received increased attention from stakeholders, industry, and Agreement States, especially blending that results in a change in the classification of the waste, as defined by the radionuclide concentrations in 10 CFR 61.55. Blending, as the staff uses the term, refers to mixing of LLW of different concentrations. It does not involve mixing radioactive waste with non-radioactive waste, (i.e., dilution) and concerns only disposal in a licensed facility, not release of radioactivity to the general environment. Blending is not prohibited or explicitly addressed in NRC regulations. In addition, while NRC staff guidance discourages blending in some circumstances, it also recognizes that some blending--including blending that lowers the classification of a waste--may be appropriate in others. However, the closure of the Barnwell facility to LLW generators in thirty-six States means that there is no disposal option for Class B or C LLW generated in these States; LLW generators have been storing Class B and C LLW onsite since the closure of Barnwell. The lack of a disposal pathway for Class B and C LLW from these generators has increased interest in blending to reduce the radioactivity concentrations of wastes that might otherwise be classified as B or C waste. A disposal pathway exists for Class A waste, which means that Class A waste does not have to be stored at licensees' sites. While some blending of LLW resulting in reduced waste classification has occurred in the past, the scale of blending being considered since the closure of Barnwell is potentially much larger than current practice.

In an October 8, 2009, memorandum [26], NRC Chairman Gregory B. Jaczko directed the staff to prepare a vote paper for the Commission to consider issues related to blending of LLW, including the following: (1) issues related to intentional changes in waste classification due to blending, including safety, security, and policy considerations; (2) protection of the public, the intruder, and the environment; (3) mathematical concentration averaging and homogeneous physical mixing; (4) practical considerations in operating a waste treatment facility, disposal facility, or other facilities, including the appropriate point at which waste should be classified; and (5) recommendations for revisions, if necessary, to existing regulations, requirements, guidance, or oversight related to blending of LLW.

In December 2009, the NRC staff conducted noticed public meetings with three commercial companies that had written to the Commission expressing their views on blending and provided detailed comments as to their views on applicable NRC regulations (i.e., 10 CFR Parts 61 and 20, Appendix G) as well as the 1996 Branch Technical Position on concentration averaging. In addition, the NRC staff will conduct a public meeting in January 2010 to gain insights from the public at large on this topic. The NRC staff is currently obligated to provide the Commission

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with a policy paper as cited above by April 8, 2010, and the Commission has expressed interest in holding a public briefing with stakeholders on this topic.

The issue of blending raises a number of interesting questions and challenges. For example, given that blending is not currently prohibited by NRC regulations nor is it explicitly addressed in the regulations, all of which is complicated by arguably confusing guidance provided over time, what are the options the staff should consider as it communicates with the Commission on this complex issue. At its simplest, there would appear to be three options available in addressing this topic as it moves forward. The options appear to be the following: (1) maintain the status quo, but provide more current and clarifying guidance to assist industry with concentration averaging as addressed in the 1996 BTP; (2) assume a more risk-informed and performance-based outlook to clarify that this waste processing technique is acceptable and in fact, is a viable tool for managing LLW; and (3) assume a regulatory posture that, in essence, eliminates blending as an option for managing LLW, especially when designed to lower the waste classification. Clearly these options or perhaps other options will be articulated by the NRC staff in its paper to the Commission following the cited public meetings. Regardless of what path the Commission ultimately chooses on this issue, the implementation of that decision may involve a rulemaking, a policy statement, or guidance development. The interesting challenge will be to what degree and in what manner do the various business models in place for managing LLW, including blending of this waste, influence the regulatory outcome. At its purest, the concept of risk-informing and being performance-based, as envisioned by the Commission in 1997 should be scientifically driven and open to public understanding and scrutiny. Clearly, the NRC must strive to ensure that such is the case when addressing this complicated issue which has the potential to impact certain business aspects of the LLW industry.

## **CONCLUSION**

This is indeed an interesting and challenging period for the LLW program within the U.S. and promises to be so for the next several years. This paper has provided certain of the significant history leading to the current regulatory infrastructure and has focused upon some of the more notable pressing issues currently facing the existing system for the management and disposal of LLW. Key observations and possible outcomes have been discussed to the extent that a solution is reasonably discernable at the present time. However, there are other issues on the horizon that are noteworthy and may, in time, come to also have a substantial bearing on the LLW program. For example, the next bow-wave of reactor decommissioning is forecast to take place in the U.S. between 2035 and 2050, assuming the existing 104 operating reactors are all decommissioned. Will there be adequate disposal capacity at that time to accommodate them? What will be the political climate in Utah in the future toward the continued operation of the ES site that receives Class A LLW from all over the U.S.? Will new waste streams be identified as the result of increased interest or growth in fuel reprocessing? Will uranium return to a price in excess of \$130 per pound, which, in turn, may lead to more interest in fuel enrichment, which could then result in more DU to be disposed of, and if so, could it be in a new commercial LLW site? Will

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there be other initiatives in the U.S. towards receipt and disposal of foreign waste as the nuclear renaissance grows throughout the world and the world increasingly seeks to find universal solutions to radioactive waste disposal? Will the nuclear renaissance gain additional traction as the world increasingly wrestles with solutions to global warming, which in turn might lead to international efforts to dispose of LLW in sites which are most ideally suited for such disposal based upon site specific conditions, regardless of what country that site might exist within? Will the Commission decide to revisit the issue of exempt materials through a clearance process? To what extent might this initiative be prompted by the international waste classification system that includes an exemption category for very low end LLW?

There are no easy answers to these questions, but it is reasonable to assume that the LLW industry will continue to be a stimulating and rewarding part of the larger nuclear industry in which to work and make professional contributions. Hopefully, these issues will continue to attract young scientists, physicists, and engineers into the LLW arena, so they may work toward finding solutions to all of these challenges. As such, the next thirty years promises to be as exciting or even more exciting than the past thirty years within the LLW industry. So this is where we have been and this appears to be where we are going!

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