The US National System for Disposal of High-level and Transuranic Radioactive Wastes: Legislative History and its Effect on Regulatory Approaches

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1. Introduction

The United States (US) has two radioactive waste disposal facilities of particular interest to the international community. Both are deep geologic disposal sites aimed at containment of very long-lived radionuclides. The first is the Waste Isolation Pilot Plant (WIPP). Located in bedded salt deposits in the southwestern US, it is currently operating for the disposal of transuranic waste (containing high concentrations of nuclides heavier than uranium), the legacy of past production of atomic weapons. The second is the Yucca Mountain facility proposed for the disposal of high-level radioactive waste and spent nuclear fuel, chiefly from commercial power plants.

The management and long-term performance of these facilities are subject to two separate sets of safety standards. These two Regulations establish different criteria for judging the adequacy of each facility. The differences between the Regulations cannot be attributed solely to technical differences in the form or characteristics of the wastes. Rather, some significant differences derive from the legislative history in the US, legislation aimed both at national nuclear policies overall and at waste disposal in particular. In fact, the existence of separate standards for the WIPP and Yucca Mountain is itself a direct outcome of the underlying legislative foundation.

This paper will examine the legislative history that led to the safety standards for WIPP and Yucca Mountain. Examples from the safety standards will be used to illustrate how differences stem from relevant legislative action. First in the paper, early legislation addressing national US nuclear programs will be discussed. Next will be presented the establishment and responsibilities of the major agencies involved in nuclear waste disposal, the US Environmental Protection Agency, US Nuclear Regulatory Agency, and US Department of Energy. Then follows a discussion of how legislation focused on nuclear waste disposal has modified the traditional roles of these Agencies and directed the form and content of safety standards. This information provides context for understanding the approaches for regulating the WIPP and Yucca Mountain. The standards will be described, and examples of similarities and differences between the standards will be discussed, with attention to how such differences can be traced to the underlying legislation.

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2. Establishing Regulatory Agencies and Roles

2.1. Early National Nuclear Policies: The Atomic Energy Acts of 1946 and 1954

The earliest nuclear-related legislation in the US came quickly on the heels of the "atomic age" ushered in by the use of atomic bombs at Hiroshima and Nagasaki. The Atomic Energy Act of 1946 was aimed at maintaining strict control over nuclear technology and directing it toward military purposes. It emphasised the need for secrecy, availability of raw materials, and production of nuclear weapons. The 1946 Law allowed no use of atomic energy by private parties or commercial purposes; its use was restricted solely to the Federal government. A five-member Atomic Energy Commission (AEC) was established to manage the US's atomic energy programs.

Succeeding years produced a growing interest in the potential peaceful uses of atomic energy. The progress of other nations, notably Great Britain and the Soviet Union, in the field led to concerns that the US might sacrifice its leadership role if further investments were not made in nuclear energy. This interest was further spurred by long-term energy requirements. In response to these concerns, the US Congress passed the Atomic Energy Act of 1954.

In contrast to its predecessor, the 1954 Act sought specifically to "encourage widespread participation in the development and utilisation of atomic energy for peaceful purposes." To accomplish this goal, the legislation greatly expanded the role of the existing AEC. Three primary responsibilities were assigned to the AEC:

- to continue its weapons programme,
- to promote private use of atomic energy for peaceful application, and
- to protect public health and safety from the hazards of nuclear power.

The AEC was given broad discretion in carrying out these responsibilities.

Experience garnered after 1954 showed, however, that the placement of promotion and regulatory functions in the same body was problematic. Political events soon after passage of the 1954 Act exerted intense pressure on the AEC to demonstrate progress in expanding the commercial uses of atomic energy. This climate made the promotion responsibilities of the AEC more immediate than the regulatory functions. There were also concerns that restrictive or inflexible Regulations could discourage private investments in nuclear technology. In this atmosphere, the AEC adopted a regulatory strategy that emphasised partnerships with industry and a desire to produce Regulations that were not "overly burdensome".

A series of events over the 20 years after the 1954 Act engendered intense criticism of the AEC's regulatory programs. The AEC's handling of issues such as secret reactor tests, licensing delays, thermal pollution, and other environmental issues reinforced concerns over Regulation. Internal AEC reforms and legislation aimed at increasing public scrutiny of AEC licensing decisions did little to alleviate the controversy.

3. Establishment of the Nuclear Regulatory Commission: The Energy Reorganization Act of 1974

In response to concerns over the AEC's regulatory objectiveness, as well as concerns over the gradual lengthening of the licensing process, Congress in 1974 passed the Energy Reorganization Act. The twin goals of this legislation were to increase the efficiency and reliability of energy sources and assure public health and safety. Congress recognised that it was in the public interest to separate licensing and regulatory functions from other functions. The Act abolished the AEC and divided its functions between two newly created Federal Agencies: the Energy Research and Development Administration, charged with the responsibility of promoting nuclear power, and the Nuclear Regulatory Commission (NRC), devoted to Regulation.

4. Establishment of the Environmental Protection Agency: Reorganization Plan No. 3 of 1970

Meanwhile, concern was growing about pollution and environmental issues. There was recognition that all environmental media were interrelated, and that these links were not effectively addressed by existing Federal agencies which were generally devoted to specific media, air, water, or land. To provide better control of pollutants, President Nixon decided that a single Agency should be formed to address research, monitoring, regulation, and enforcement on environmental issues. This was accomplished through Reorganisation Plan No. 3 of 1970.

The Plan established a new US Environmental Protection Agency (EPA). Importantly for our purposes, radiation was recognised as one of the pollutants that could appear in all media. Accordingly, some functions of the AEC under the Atomic Energy Act of 1954 were transferred to the EPA. Specifically, EPA was provided authority to establish "generally applicable environmental standards for the protection of the general environment from radioactive material. As used herein, standards mean limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material" [Section 2(a)6]. The authority to issue licenses under such generally application environmental standards, as well as to regulate activities within the boundaries of nuclear facilities, continued to reside with the AEC (later to be transferred to the NRC, as described above).

5. Establishment of the Department of Energy: The Department of Energy Organization Act of 1977

In response to the US energy crisis in the mid-1970s, Congress passed the Department of Energy Organization Act of 1977, thereby establishing the US Department of Energy (DOE, or the Department). The new Department was intended to unify Federal organisation and planning of energy resources from production through delivery. Among the responsibilities assigned to the new Department were those formerly managed by the Energy Research and Development Administration (created by the split of the Atomic Energy Commission in 1974). These responsibilities include management of programmes for nuclear weapons, naval reactors, and energy development. Most relevant to our purpose, the DOE is authorised to "provide for safe storage, processing, transportation, and disposal of hazardous waste (including radioactive waste) resulting from nuclear materials production, weapons production and surveillance programs, and naval nuclear propulsion programs" [Section 91(a)3 of the Atomic Energy Act of 1954].

6. Summary of Agency Roles and Responsibilities Based on National Nuclear Legislation

As described above, legislation aimed generally at national nuclear and energy policies established the key agencies and their roles related to the regulation, licensing, and disposal of radioactive waste. In summary, the regulatory scheme for radioactive materials was established:

- The EPA was to establish generally applicable safety standards related to radioactive material.

- The NRC was to establish and implement licensing requirements for radioactive material used in commercial and industrial applications, under its AEA authority and consistent with any Regulations established by EPA under its AEA authority.

- The DOE was to oversee and control all aspects of safety related to military application of nuclear energy, including waste disposal. While EPA regulations could apply, NRC licensing requirements related to such regulations would be enforced by DOE at its own sites.

Ensuing actions modified this general scheme as it applies specifically to disposal of spent nuclear fuel and of high-level and transuranic radioactive waste.

7. History of Safety Standards for Nuclear Waste Disposal

Over the course of the development of nuclear energy for both military and civilian purposes, radioactive waste disposal emerged as a critical issue. The sweeping Atomic Energy Act, and the establishment of the various regulatory agencies described previously, provided the instruments to begin addressing the challenges of radioactive waste disposal. As we will see, however, the evolution of the regulatory scheme and safety standards would be affected by ongoing legislative actions aimed directly at waste disposal issues.

8. EPA's Initial Action

EPA first took action in the 1970s to address waste disposal under its authorities provided by the Atomic Energy Act and Reorganization Plan Number 3. A series of public workshops was conducted to gather information on public concerns and issues associated with radioactive waste disposal. In 1978, EPA issued draft Criteria for Radioactive Wastes. This generic guidance was intended to apply to all radioactive wastes. It became evident that such guidance was impractical to implement because it did not account adequately for the characteristics of different types of waste. The guidance was withdrawn in 1981 [40 CFR Part 191: Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-level and Transuranic Radioactive Wastes; Final Rule. US Federal Register, Volume 58, p. 66399 (58 FR 66399), published 20 December 1993].

9. The Nuclear Waste Policy Act of 1982

Impetus was soon provided for EPA to develop more specialised standards. The Nuclear Waste Policy Act (NWPA) of 1982 affirmed the Federal government's responsibility to provide for safe and environmentally sound disposal of commercial high-level radioactive waste and spent fuel (while also acknowledging that the costs of such disposal are primarily the responsibility of the generators and

owners of such waste). The NWPA excluded waste generated from any defence-related activities, focusing only on waste from civilian nuclear power plants [Section 111(a)(4), section 8(a)]. For these civilian wastes, the NWPA clearly focused the national policy on mined geologic repositories.

For the DOE, the NWPA placed the burden of evaluating and selecting candidate sites for repositories, and for developing the disposal system. It established formal procedures for evaluating and selecting sites and specified certain geologic and population factors to be considered in evaluations. Also included were necessary steps to be taken to inform and involve State and local governments in the decision making process [Section 112]. These requirements established a scheme for narrowing the number of candidate sites from five or more, to three, then to a final selection to be approved by Congress and the US President [Section 112; see also 50 FR 38067].

For the EPA, the NWPA reiterated the Agency's responsibility to establish safety standards for the performance of repositories for high-level waste and spent nuclear fuel. The Act did not provide additional authority, instead emphasising that EPA's existing authorities were sufficient to accomplish its charge.

Finally, the NWPA affirmed NRC's authority to evaluate and license any such repositories for commercial wastes. The Act required NRC to establish licensing criteria consistent with the safety standards to be issued by EPA.

10. Standards for Disposal of Spent Nuclear Fuel, High-level and Transuranic Radioactive Wastes

Following the mandate of the NWPA, EPA in 1985 issued safety standards for waste. As directed by the NWPA, these standards apply to disposal of spent nuclear fuel and high-level waste [Chapter 40, Part 191 of the US Code of Federal Regulations (40 CFR 191)]. EPA chose also to include transuranic waste under the same standards; in doing so, the Agency stated that "because transuranic wastes have very long half-lives and represent a potential hazard for very long times… [they require] the same controls… as would be required for high-level wastes" [47 FR 58197, 29 December 1982]. Although developed primarily through consideration of mined geologic repositories, the standards apply to any type of disposal allowed under Law (i.e., excluding ocean disposal) [58 FR 66399].

The NRC and DOE were to be responsible for implementing the standards, NRC for disposal of commercial wastes, and DOE for disposal of defence-related wastes at its own facilities.

Shortly after EPA issued the safety standards at 40 CFR 191, hereafter referred to as the "disposal standards", a number of States and environmental groups challenged the standards in Federal court. The Court found that several portions of the standards relating to individual dose limits and protection of ground water had not been adequately justified. Although the validity of most provisions was upheld, the Court in 1987 suspended the application of the disposal standards in their entirety [58 FR 66399].

11. The Nuclear Waste Policy Act Amendments of 1987

Meanwhile, the DOE had progressed in identifying and evaluating candidate sites for geologic disposal of high-level waste and spent nuclear fuel from power plants, and a separate site for disposal of transuranic waste from defence nuclear activities. The extensive nomination, recommendation, and

evaluation process mandated in the 1982 NWPA was dramatically simplified by amendments made to the Act in 1987. The amendments restricted site characterisation studies for disposal of high-level waste and spent fuel to only the Yucca Mountain site which had previously been recommended as a candidate site by the DOE to the President as part of the original evaluation process [Section 2(30), Section 113].

No characterisation activities were to be conducted at any other candidate sites. The NWPA Amendments emphasised that DOE should consult extensively with the State of Nevada, in which the Yucca Mountain site is located. The amendments also retained the requirements for final Presidential and Congressional approval of the site.

DOE also had identified a candidate site for disposal of transuranic wastes, long-lived radioactive wastes generated during the production of nuclear weapons and through subsequent (and ongoing) decontamination and decommissioning of production sites. The authorisation to proceed with such a facility had been approved in 1979 with the passage of the DOE National Security and Military Applications of Nuclear Energy Act [Public Law 96-164]. By 1987, construction of a test facility (known as the Waste Isolation Pilot Plant) had been completed, shipping containers had been designed, and the disposal system was poised to begin accepting waste.

After 1987, therefore, the US waste disposal programme found itself in the position of having two potentially viable disposal sites but no safety standards applicable to them, since application of EPA's standards had been suspended by the court decision that year. In 1992, Congress resolved this situation with two key pieces of legislation.

12. The Waste Isolation Pilot Plant Land Withdrawal Act of 1992

The Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act (WIPP LWA) of 1992 solidified the decision to use the WIPP site for disposal of defence-related transuranic waste. Management authority for the land containing the site was transferred to the Department of Energy for continuing characterisation, construction, and operation of the WIPP. Other land uses such as mining, drilling, and grazing were strictly prohibited unless found not to interfere with WIPP-related purposes and expressly approved by the Department of Energy [Section 3].

The legislation also settled the question of what safety standards would apply to disposal at the WIPP. The LWA reinstated all portions of the EPA's disposal standards (40 CFR 191, issued in 1985) except the specific provisions found unjustified by the Court. EPA was directed to reissue those portions of the standards, which the Agency did just over a year later. Thus, in 1993, there existed complete safety standards at 40 CFR 191 with applicability to radioactive waste disposal sites in general, and to the WIPP as a member of this category.

The WIPP LWA did not, however, allow unilateral application of EPA's safety standards. The legislation specifically exempted from EPA's safety standards any site required to be characterised under the NWPA as a candidate site for disposal of high-level waste and spent nuclear fuel. The list of such sites had been narrowed to Yucca Mountain by amendments to the NWPA. Therefore, the language in the WIPP LWA effectively exempted only Yucca Mountain from the existing disposal standards [Section 8(a) and (b)].

The LWA also significantly modified the licensing and oversight regime for the WIPP. Prior to passage of the LWA, the Department of Energy (under its Atomic Energy Act and DOE Organisation Act authority) was to serve as owner and operator of the WIPP. In addition, DOE would have retained

responsibility for implementing EPA's regulations at the WIPP. In effect, this meant that DOE would be assessing for itself, without independent oversight, whether its disposal facility complied with the disposal standards. Significant concerns had been raised, particularly by officials and citizens in the State of New Mexico (where the WIPP is located), regarding this lack of independent oversight.

Congress addressed these concerns in the WIPP LWA by designating EPA as the regulatory agency responsible for implementing and enforcing the disposal standards at the WIPP. The LWA required EPA to certify whether or not the WIPP will comply with the disposal standards, and to establish criteria for making such a decision. A positive certification of compliance was required before the WIPP could begin operation. The LWA also established an ongoing oversight role for EPA during the operating life of the facility, with periodic evaluations to ensure that the WIPP would continue to comply with the disposal standards [Section 8].[1]

13. The Energy Policy Act of 1992

While the WIPP LWA had resolved the regulatory scheme regarding disposal of defense-related transuranic waste, it had, by exempting Yucca Mountain from EPA's existing disposal standards, left a gap in regulation of high-level waste and spent fuel disposal. This gap was filled with the passage of the Energy Policy Act (EnPA) in 1992. The EnPA directed EPA to establish "public health and safety standards for protection of the public from releases of radioactive materials stored or disposed of in the repository at the Yucca Mountain site." These standards "shall be the only such standards applicable to the Yucca Mountain site" [Section 801(a)(1)].

Beyond establishing the narrow applicability of these new standards, to Yucca Mountain only, the EnPA (in contrast to previous legislation) also provided considerable guidance on the form and content of the safety standards. Primarily, the EnPA required a study by the US National Academy of Sciences (an independent scientific organisation) on the technical basis for such standards, with particular attention to how the issue of potential human intrusion into the repository should be treated in safety standards [Section 801(a)(2)]. The Act further required that EPA's safety standards for Yucca Mountain shall be "based upon and consistent with the findings and recommendations of the National Academy of Sciences".

Under the EnPA, DOE retained its role as developer, operator, and owner of the proposed Yucca Mountain facility. NRC's role was solidified as the licensing and oversight authority, with emphasis on its responsibility to conduct its role in concert with EPA's safety standards.

In response to the EnPA, the National Academy of Sciences (NAS) completed its study in 1995 and EPA issued final Yucca Mountain safety standards in 2001. These standards are found at Chapter 40, Part 193 of the US Code of Federal Regulations (40 CFR Part 193).

1 . EPA accomplished the primary tasks mandated by the WIPP LWA and is continuing its oversight of the WIPP facility. "Compliance Criteria" for implementing the disposal standards and judging compliance with the disposal standards were issued in 1996 at 40 CFR 194 and a certification of compliance in 1998. The WIPP began operation and received its first shipment of waste in 1999. The first "recertification" is expected to occur in 2003.

14. Comparison of Safety Standards For Nuclear Waste Disposal

As described above, there are two major sets of safety standards that have been developed for disposal of spent nuclear fuel (SNF) and high-level (HLW) and transuranic radioactive waste. These are:

- The "disposal standards" at 40 CFR Part 191. These apply generally to facilities for disposal of SNF, HLW and transuranic waste, except that they do not apply to Yucca Mountain. The major facility to which these standards apply is the WIPP. For convenience and clarity, these standards will be referred to as the "WIPP standards" for the remainder of the discussion.

- The "Yucca Mountain standards" at 40 CFR Part 193. By legislative mandate, these standards apply only to the proposed Yucca Mountain facility for disposal of SNF and HLW.

The following discussion describes the WIPP and Yucca Mountain facilities and outlines the safety standards that apply to each facility. Similarities between the two standards will be highlighted. Finally, several differences between the two standards will be discussed, with an emphasis on how these differences derive from the legislative history underlying the safety standards.

15. The Waste Isolation Pilot Plant (WIPP)

The WIPP, located in the southwestern US, is already in operation for the disposal of transuranic waste. Waste is located nearly 655 meters (2150 feet) underground in bedded salt deposits. EPA's disposal Regulations at 40 CFR Part 191, which apply to the WIPP, address performance over a 10 000 year time frame. The Regulations limit the amount of waste released into the environment (activity of each radionuclide, in terms of Becquerels or curies); performance assessments to show compliance with these "release limits" must include both natural events and potential human intrusion. The Regulations also include separate limits on individual doses and concentrations of radionuclides in ground water; compliance is demonstrated using performance assessment. These also carry a 10 000 year regulatory time frame, but apply solely to "undisturbed performance" of the disposal system, which does not include consideration of human intrusion.

In addition to the quantitative performance measures discussed above, the disposal regulations also include several "assurance requirements," sometimes also known as "defense-in-depth measures." These qualitative requirements are intended to compensate for some of the inherent uncertainties in predicting performance over such long time frames. The assurance requirements call for active and passive institutional control for given periods of time, monitoring of the site, use of engineered barriers, consideration of the presence of resources, and some capacity for removal of waste after disposal.

16. The Yucca Mountain Disposal Facility

The Yucca Mountain site is proposed for disposal of spent fuel and high-level radioactive waste, but has not been fully built nor licensed for operation. The site is located in a desert climate in the western US. Waste would be placed 300 meters below the surface; two aquifers lie another 300 meters below the proposed waste rooms. Like the WIPP Regulations, EPA's Regulations for Yucca Mountain apply over a 10 000 year time frame. A performance assessment is used to demonstrate compliance

with an individual protection standard, but must take into account only releases from the "undisturbed" Yucca Mountain disposal system i.e. including natural events but not potential human intrusion. DOE also must comply with a separate ground water standard that limits the concentrations of radionuclides in nearby aquifers, based on undisturbed performance. Performance assessment may be used to demonstrate compliance with the ground water limits but is not required for that purpose.

The potential effects of human intrusion are analysed entirely separately from those due to unlikely natural events (and included in undisturbed performance scenarios). EPA's Yucca Mountain standards specify certain assumptions that must be made in analysing the human intrusion scenario. The key assumptions are that only a single borehole is considered and that this borehole must be assumed to penetrate a degraded waste package and then reach an underlying aquifer. As with the ground water standard, conduct of a performance assessment is optional for demonstrating compliance with the dose limit for human intrusion; a deterministic analysis may be used instead.

Finally, the regulations require that DOE calculate the peak individual dose that would occur after 10 000 years following disposal but within the period of geologic stability. No numeric standard is applied to the results of this analysis, but it is considered an indicator of long-term disposal system performance.

17. Similarities Between the WIPP and Yucca Mountain Safety Standards

There are many similarities in the regulatory approaches for WIPP and Yucca Mountain. Some of these are based on the fact that both are deep geologic disposal facilities and that there are some analogous waste properties. Others can be attributed to the precedent set by the WIPP Regulations. That is, unless there was a need, technically, legally, or politically, to depart from provisions established for WIPP, generally they were maintained. The advantage of retaining provisions, unless conditions dictated otherwise, is to promote consistency which is readily understandable to the public. Furthermore, such consistency reduced the regulatory workload because the WIPP provisions had been developed, justified, and successfully implemented before the Yucca Mountain safety standards were completed.

Among the key similarities between the two sets of standards are:

- Use of a 10 000 year regulatory time frame.
- Inclusion of standards for individual protection, with identical dose limit.
- Inclusion of standards for protection of ground water, with identical concentration limits, based on pre-existing regulations for drinking water.
- No consideration of human intrusion in judging compliance with the individual and ground water limits.
- Recognition that complete certainty in performance assessments is neither necessary nor attainable; use of the concept of establishing a "reasonable expectation" of compliance.

If the WIPP Compliance Criteria, i.e. the regulations that implement the disposal standards specifically at the WIPP, with EPA as the implementing and licensing agency, are also considered, several other similarities emerge. These provisions are generally directed at defining the scope of performance assessments:

- Extremely unlikely events are excluded from performance assessments. These are defined as events estimated to have less than one chance in 10 000 of occurring within 10 000 years of disposal.

- To limit unreasonable speculation about essentially unknowable characteristics of the future, e.g. evolution of society or human biology, knowledge, and technology, such factors are assumed to remain constant throughout the regulatory time frame. The constant values are based on conditions and knowledge at the time a license application is prepared.

- Performance assessments must consider changes in factors which are reasonably predictable over the 10 000 years after disposal: climate, geology, and hydrology.

The similarities between the two sets of safety standards reflect EPA's priorities of protection of public health and of ground water as a valuable resource. They further reflect a common approach to the scope of performance assessments and the need to accommodate the substantial uncertainties that accompany projections of performance over very long time periods.

18. Differences Between the WIPP and Yucca Mountain Safety Standards

The differences between the WIPP and Yucca Mountain standards can be grouped into two main categories: those due to differences in the site or waste characteristics, and those due to the underlying legislation. The very existence of separate safety standards for Yucca Mountain is a direct result of legislative action regarding the US disposal program. However, the Energy Policy Act of 1992, in particular, contained specific directions affecting the form and content of the Yucca Mountain standards. This Congressional direction necessitated some departures from the approaches established by the already existing WIPP safety standards.

The differences due to site characteristics are relatively few in number. Site characteristics are more likely to become relevant in the performance assessment and/or licence application when more specific information is gathered and presented. Therefore, site-specific characteristics typically would be addressed in licensing criteria rather than in generalised performance or safety standards. Generally, the standards that apply to WIPP provide broad guidelines, a reasonable approach since they have the potential to be applied at other types of disposal sites, while the Yucca Mountain standards provide specific direction, since they are intended to apply only to a single site. The most significant differences due to site characteristics are related to assumptions about the location and characteristics of individuals who must be considered in projecting individual doses. For example, the WIPP standards contain only general guidelines for considering patterns of individual consumption and activities. In contrast, the Yucca Mountain standards specify that, when evaluating potential pathways and exposures, the affected individuals must be assumed to have a diet and living style similar to those people currently residing in the town nearest the proposed Yucca Mountain facility. Similarly, the location for judging compliance with the ground water standards is significantly further away from the disposal facility for Yucca Mountain than for the WIPP; this is due to differences in ground water flow and the location of populations near the respective sites.

Differences that derive from legislation are more numerous than those attributable to site characteristics. Some may be explained by the fact that NRC has been designated the licensing agency for Yucca Mountain; this role was established by general legislation related to atomic energy programmes, and affirmed by the Energy Policy Act of 1992. For example, EPA justified its decision not to include assurance requirements (qualitative requirements for monitoring, etc.) in the Yucca Mountain standards by stating that NRC was expected to impose such requirements as part of its licensing process. At the WIPP, for which DOE was self-regulating during the development of the safety standards, there was no assurance that such requirements would be considered, so EPA found it necessary to include them.

Most differences between the WIPP and Yucca standards, however, may be traced directly to provisions of the Energy Policy Act of 1992. As noted previously, this Act required the development of separate standards for Yucca Mountain and provided some specific direction on the form and content of those standards. In particular, the statute stated that

> "the [EPA] Administrator shall, based upon and consistent with the findings and recommendations for the National Academy of Sciences, promulgate by rule, public health and safety standards for the protection of the public from releases from radioactive materials stored or disposed of in the repository at the Yucca Mountain site. Such standards shall prescribe the maximum effective dose equivalent to individual members of the public from releases to the accessible environment from radioactive materials stored or disposed in the repository…" [Section 801(b)]

The study by the National Academy of Sciences, which was to serve as the basis for EPA's standards, was required to address whether a dose-based standard provided adequate protection; whether active institutional controls can control intrusion into the repository; and whether it is possible to make supportable predictions of the probability of human intrusion into the repository over a period of 10 000 years. In response to this charge, the National Academy concluded:

- that an individual risk-based standard would protect public health;
- that it is not possible to predict the societal factors related to exposure scenarios in the far future;
- that it is not reasonable to assume that active institutional controls can prevent an unreasonable risk of intrusion into the repository;
- that it is not possible to make scientifically supportable predictions of the probability that human intrusion will occur over 10 000 years; and
- that there is no scientific basis for incorporating the ALARA (as low as reasonably achievable) principle into the safety standards.

The Academy issued a detailed report that included these conclusions and a number of other recommendations on specific aspects of the standards. The conclusions and technical advice of the Academy departed from technical advice that had been provided to EPA by a different peer review panel during development of the WIPP Regulations.

EPA determined that it was not bound absolutely to follow the recommendations of the National Academy of Sciences. Such a binding requirement would have eliminated the Agency's rulemaking discretion, dictating all aspects of the safety standards and eliminating the consultative public

rulemaking process required by other statutes. Nevertheless, the recommendations were highly influential in shaping the Yucca Mountain standards.

Two examples serve to highlight the effect of the National Academy recommendations on the Yucca Mountain standards. The first is the decision not to include "containment requirements" such as those in the WIPP standards. These containment requirements restrict the amount (in Becquerels or curies) of radionuclides which can escape the boundary of the WIPP disposal facility over 10 000 years. They serve to limit population doses and encourage disposal methods that rely on containment rather than dilution. However, because Yucca Mountain is a deep geologic repository clearly intended to contain (rather than dilute) waste, there is no need to discourage dilution. Furthermore, for Yucca Mountain, the National Academy stated that an individual dose limit is adequate to provide protection of human health and that other limits are not necessary for that purpose (in contrast, the peer review panel for the WIPP Regulations endorsed the "use of a societal objective as an upper bound of acceptable health effects" and "the focus on performance standards in terms of release limits rather than individual exposures"). EPA accepted the National Academy's conclusion for the case of Yucca Mountain.[2] Therefore, EPA's Yucca Mountain standards do not include containment requirements, but instead rely solely on an individual dose limit to provide protection of human health (the separate ground water limits in the Yucca Mountain standards, which go beyond the recommendations of the National Academy of Sciences, are aimed primarily at protecting ground water as a natural resource and for future use).

The different approaches to human intrusion in the two sets of standards also illustrate the effect of the National Academy's recommendations. In the WIPP standards, "all significant events", including human intrusion, are included in the performance assessment used to determine compliance with the containment requirements. The performance assessment is explicitly defined in the standards to be a probabilistic analysis. Thus, by including human intrusion in the performance assessment for WIPP, EPA essentially required that such events be treated probabilistically, that is, that DOE must try to predict the rate and consequences of such an event. This point was reinforced by guidance accompanying the WIPP standards, which discussed factors to be considered by the implementing agency to establish the "frequency and severity" of human intrusion. Such an analysis is possible for the WIPP site, where there are economically viable natural resources and significant drilling and mining activity occurring nearby. Past and current resource exploration and extraction rates provided a basis for establishing future intrusion rates used in the performance assessments. The peer review for the WIPP Regulations did not raise concerns regarding EPA's decision to treat human intrusion events probabilistically in the performance assessment.

In contrast, the National Academy of Sciences' Yucca Mountain report stated that there was no scientifically supportable basis to predict the probability of human intrusion over 10 000 years. The Academy also said that there was no supportable way to predict the exact location (and thus consequences) of an intrusion event. For Yucca Mountain, no mining or drilling occurs in the immediate vicinity of the proposed disposal system. In fact, the US Federal Government owns much of the surrounding land and access is strictly controlled. Nevertheless, there is no scientifically defensible way to preclude intrusion for such long time periods (as the National Academy recognized in its conclusion regarding active institutional controls). For this reason, the Academy recommended that a single "stylised" intrusion event, with set parameters, should be assumed to occur. The results of such an analysis can provide important information about the containment capabilities of a disposal

2. The National Academy of Sciences recommended the use of a *risk-based* individual standard, thus creating a conflict with the language of the Energy Policy Act. EPA resolved this conflict by deferring to the language of the Statute, which clearly stated that the Yucca Mountain standards should "prescribe the maximum effective dose equivalent to individual members of the public".

system. Taking into account site specific information from Yucca Mountain, EPA agreed with the recommendations of the National Academy of Sciences. Therefore, the Yucca Mountain standards include a separate analysis of human intrusion. For this analysis, only a single borehole is considered and this borehole must be assumed to penetrate a degraded waste package and then reach an underlying aquifer. The intrusion is assumed to occur at the time when waste packages have degraded to the point that a driller would not be expected to recognise that he had encountered an unexpected obstacle. Only long-term releases through ground water are considered (in contrast to the WIPP standards, which also consider immediate releases through the borehole to the surface). Long-term releases from the event are subject to the same dose limits that apply to individual doses from undisturbed performance.

Further differences in the safety standards may become evident in the future, since the statutes established different licensing agencies for the WIPP and Yucca Mountain. NRC may choose to adopt different approaches to Yucca Mountain than those used by EPA at the WIPP. Thus, the influence of past legislation will continue to permeate the implementation of the safety standards at these disposal facilities.

19. Conclusion

The US has a relatively long history of national legislation directed at atomic energy and other nuclear issues. The US national programme for disposal of spent nuclear fuel and high-level and transuranic waste has been shaped by both general and specific legislation. General legislation has established the authority for various federal agencies to own, develop, regulate, and license radioactive waste disposal facilities. Legislation on disposal specifically directed the development of WIPP and Yucca Mountain as promising sites for deep geologic disposal. Legislation also modified the licensing authority for the WIPP and required separate safety standards to be developed for Yucca Mountain. The influence of legislative action can be seen even in the safety standards for WIPP and Yucca Mountain; different approaches and requirements for the two facilities can be traced directly to legislative requirements.

It is likely that past legislation will continue to affect the implementation of the safety standards at these disposal facilities, as the WIPP continues operation, and the DOE seeks licensing of the Yucca Mountain facility. It is also possible that future legislative action will influence the disposal of radioactive waste. In fact, the current US Congress is considering statutes which would require additional analyses of terrorist risks, particularly related to transportation of waste, before any recommendation could be made regarding the suitability of Yucca Mountain as a disposal site. The interplay between legislative and regulatory responsibilities will continue to affect policy-making in the US and to be of interest abroad.