Institutional designs for long-term stewardship of nuclear and hazardous waste sites

Bruce E. Tonn*

Hoskins Library, School of Planning, University of Tennessee-Knoxville, 1401 Cumberland Avenue, Suite 108, Knoxville, TN 37996, USA

Received 17 April 2000; received in revised form 25 July 2000; accepted 17 August 2000

Abstract

Within the borders of the United States reside numerous nuclear and hazardous waste sites that will pose risks to humans and ecosystems for many centuries, and in some cases several millennia. This article evaluates several designs for an institution to act as the steward for these sites. To offer lessons learned about the characteristics of long-lasting human institutions, several that have existed for hundreds and thousands of years are reviewed, including the Dominican monastic order, the Sangha community of Buddhist monks, and universities such as those located in Oxford and Paris. Six alternative institutional designs are evaluated over a set of four evaluation criteria. It is recommended that the United States establish a new type of secular nonprofit institution, entitled The Stewardship Institution, to act as steward for the sites. This option is judged most able to focus on the mission of stewardship, meet its technical challenges, survive inevitable periods of political and economic instabilities, and meet current generation cost and implementation concerns. Other institutions considered include a consolidated national stewardship organization, a religious organization, and a new state of the union called the Legacy State. © 2001 Elsevier Science Inc. All rights reserved.

Keywords: Long-term stewardship; Nuclear waste sites; Innovative institutional designs

1. Introduction

In 1995, the US Department of Energy (DOE) published a document concerning environmental management that asked the following question: “What are we doing today that will prompt another generation to say, ‘how could those people — scientists, policy-
makers, and environmental specialists — not have seen the consequences of their actions?"

[1]. One answer to this question concerns the proper long-term management of DOE’s sites contaminated with radioactive and hazardous wastes. In response, in 1999, DOE asked this second question: “How do we ensure effective long-term stewardship of sites with residual waste and contamination?” [2]. This is an important question because it relates directly to our obligations to future generations to protect them from unacceptable risks associated with these sites [3–5]. This article tackles this question and expands the focus to include not only DOE’s sites but also other hazardous waste sites around the country.

The stewardship issue is extremely important. This is because it has been judged that: many sites cannot be cleaned to where they do not pose risks to humans and ecosystems; there are no magic technological fixes to render dangerous wastes harmless; and some wastes will need to be stored and isolated from the environment for many years. One major notable effort in this area concerns plans for the protection of the Waste Isolation Pilot Project (WIPP) site in New Mexico [6]. The WIPP will accept many thousands of barrels of radioactive waste over the next several decades, then it will be closed down. Over time, the salt formations will close in on the wastes and entomb the wastes until they are no longer harmful to life, which is estimated to be 10,000 years from now. One major concern about the WIPP is keeping its contents isolated from humans and the environment over this time period, given the assumption that the current federal government will not exist long enough to carry out the stewardship responsibilities. One team examined intrusion scenarios [7] while another team tackled the task of designing markers and other methods for communicating the risks posed by the site to distant future generations [8]. Additionally, DOE, along with the US Environmental Protection Agency (EPA), has been working to involve communities in which nuclear and/or hazardous waste sites reside in nascent stewardship discussions and activities [9].

This article is motivated by a concern that institutional issues have not received sufficient attention with respect to stewardship of nuclear and hazardous waste sites. Current thinking appears to assume two extreme institutional scenarios, either that: (1) the United States will continue on as a stable political entity far into the future and will be able to maintain continuously a federally led but community-based stewardship effort for as long as necessary; or (2) the United States government, or at least its control over the sites, will cease to exist, causing a loss of institutional memory about the sites. Discussions associated with this second scenario appear to assume a major depopulation of the continental United States, leaving no one to communicate to future generations the risks posed by the sites much less the existence of the sites. Thus, in this second case, the response has been to develop markers and other communication devices for the most dangerous sites that will be able to communicate to those distant future generations who might continue to live around the sites and/or repopulate regions around the sites the existence of the sites and what dangers the sites may pose [2].

It is argued that this set of scenarios needs to be expanded to facilitate a more thorough analysis of the stewardship problem. Neither of these scenarios are highly probable. Given the historical record of governments worldwide, it is a low probability event that the United States federal government will survive for the duration of the stewardship responsibilities. Even if the US government were to survive into the long term, the probability of its being stable enough and economically able to commit resources to stewardship is also low.
With respect to the second scenario, it can be argued that it is improbable that North America will significantly depopulate at any point within the next 10,000 or more years. In fact, the continent has already been continuously populated for over 10,000 years. Indeed, parts of Africa have been continuously populated for many tens of thousands of years. A more probable scenario is one that assumes that people will be around the sites, people who could provide continuous stewardship of the sites. This article explores this scenario in more depth.

Specifically, this article argues that this nation needs to undertake an extended discussion about institutions other than the federal government that could possibly endure for the duration of the stewardship responsibilities. It is important to consider the possibility that the federal government will be unable to maintain its stewardship commitments over time due to political and/or economic instabilities. However, political instability does not necessarily mean a whole-scale depopulation of regions around waste sites, much less the continent of North America. Nor does it mean that memory of the sites need be lost. In many more probable scenarios, North America will continue to be highly populated, if not highly technologically advanced. It is most likely that people will still live around the sites. Most important for the solution of this problem is that in these kinds of scenarios, people who could act as stewards for the sites will continuously be around. In other words, there are scenarios where government as we know it disappears, but there is no need to abandon the plan for active human stewardship of the sites. It is argued that a well-designed stewardship institution could weather political and economic instabilities over time to carry out its responsibilities for protecting the many future generations that may live in areas around the sites. Indeed, in some scenarios, our technological civilization may also remain strong many tens of thousands of years into the future, resulting in the generation of many times the current quantity of nuclear and hazardous wastes than currently exist. In these scenarios, the stewardship institution becomes a virtually permanent component of society, maybe outlasting many generations of local, regional, and continental governments.

This article further details the stewardship problem facing the United States (Section 2). Section 3 reviews a set of human institutions that have lasted hundreds and thousands of years. This assessment serves to provide evidence that a stewardship institution can in fact be designed and be successful and also provides insights into key stewardship institution design criteria. Section 4 more clearly lays out a set of criteria used to evaluate potential stewardship institution options. Section 5 presents six alternative institutional designs for consideration.

2. The stewardship problem

An exact description of the stewardship problem facing the US cannot be given at this point in time. This is because all the sites that may require stewardship have not yet been identified and assessments of the need for stewardship for identified sites have not yet been completed. Nevertheless, enough information is currently available to allow a strong characterization of the problem.

The US DOE has responsibility for the most hazardous and complex sites that will require stewardship for the longest period of time. DOE estimates that 109 sites in 28 states nationwide will require some degree of long-term stewardship [2]. The sites “range from
small sites (approximately the size of a football field) with limited contamination, such as the General Atomics Site in California, to large and complex ones such as the Nevada Test Site (larger than the State of Rhode Island).” At least two dozens of these sites can be considered to fall into the latter category, including the Hanford site in the state of Washington, the Oak Ridge Reservation in Tennessee, the Savannah River site in South Carolina, the Rocky Flats Environmental Technology site in Colorado, the Portsmouth Gaseous Diffusion Plant in Ohio, and Los Alamos and Sandia National Laboratories and the WIPP in New Mexico.

The US EPA is involved with a large number of sites (the exact number has yet to be determined) that are associated with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Over 1200 of the most hazardous sites, known as Superfund sites, are on the National Priorities List (NPL) [10]. Many of these may require long-term stewardship. Additionally, EPA is responsible for administering the Resource Conservation and Recovery Act (RCRA). There are over 1500 potential solid waste management units that may need remediation [11], and many of these may require long-term stewardship. Lastly, EPA is a nexus within our society for the remediation of tens of thousands of brownfields sites, which are typically abandoned lands in urban areas that may have environmental liabilities. How many of these sites may need long-term stewardship is not yet known.

The US Department of Defense (DOD) conducts cleanup activities at more than 10,000 sites, including nearly 2000 contaminated military installations. The US Department of Interior (DOI) is responsible for overseeing approximately 13,000 former mining sites, whose remaining hazards include tailings and leachates, blasting caps, wires, and open holes. The General Services Administration also owns land around the country that may be contaminated in one way or another.

In summary, one can estimate that there are at least two dozens of very large and complex sites in the country that will require long-term stewardship, maybe 500–2000 medium-size sites, and maybe 2000–5000 smaller sites. The land area involved, as noted above, is least as large as the State of Rhode Island, which is 1212 square miles. All the sites combined may double or more this land area estimate.

These sites contain all manners of hazardous substances, from radioactive materials to toxic organic and inorganic contaminants. Radionuclide half-lives range from 163 days for curium-242 to 30 years for cesium-137 to 24,100 years for plutonium to 4,468,000,000 years for uranium-238. “Organic contaminants include polychlorinated biphenyls (PCBs), chlorinated solvents, and polynuclear aromatics. Inorganic contaminants include mercury, arsenic, lead, cadmium, and asbestos. Unlike radiological constituents, chemical contaminants do not have well-defined rates of decay. Depending on site conditions, they may persist for a short time (as with some chlorinated organic solvents exposed to sunlight) or in perpetuity (as with inorganics such as lead and asbestos” [2].

Unfortunately, it does not seem possible at the present time to eliminate all the risks posed by such materials at the sites. This is because of cost, technology, and risk considerations. Examples of residual hazards at the sites include:

- engineered units — landfills and other land-based waste disposal units with engineered controls;
soil and buried waste — contaminants left in place in soils and old burial grounds;
facilities — entombed reactors, canyons, and other buildings with residual contamination; and
water — residual contaminants in groundwater or surface water sediments [2].

Stewards of such sites would need to conduct the following operations:

- “monitoring: the regular sampling of all contaminated and potentially contaminated media to identify the failure of physical controls and to provide continuous understanding of the nature and extent of the contamination;
- maintenance: upkeep of remediation systems to ensure long-term effectiveness;
- surveillance: the regular oversight of remediation and institutional systems to ensure that all necessary activities occur;
- enforcement: the legal implementation of the constraints required to maintain the protection of human health and the environment (e.g., barriers to entry and barriers to exposure);
- inspection and reevaluation: the periodic review of existing systems and activities to ensure their continued need and/or effectiveness; and
- public participation: the continuous involvement of the public to ensure citizens’ concerns are addressed and relevant public information is provided” [2].

These types of operations can be mapped to the four types of residual hazards listed above. For example, with respect to water, stewards would have to maintain ongoing pumping and treating of contaminated ground water, and conduct groundwater and surface water monitoring over time. With respect to soil, the stewards would have to maintain and replace soil caps placed over sites, and work to maintain land-use restrictions until risks have decreased to acceptable levels. With respect to engineered units, stewards would need to maintain and repair fences and physical barriers and warning signs. With respect to facilities, the stewards would need to enforce limitations on reuse and conduct structural maintenance and repairs. In all these areas, the stewards would be responsible for maintaining records of contaminants, stewardship activities, and use restrictions.

3. Examples of long-lasting institutions

The crux of the stewardship problem is that people find it hard to believe that any human institution can last the duration of the stewardship assignment, 10,000 years or more. Indeed, history is replete with failed governments. From ancient times to today’s world, the typical story is one of rise and fall, of kingdoms, sheikdoms, monarchies, dictatorships, and even democracies. Leaders come and go, bringing with them new ideas, religions, policies, and programs and leaving legacies easily changed by succeeding leaders and generations. In addition to governments, history has seen similar cycles for human settlements and cities, rise and fall, establishment and abandonment, and rediscovery. Modern-day institutions, such as the private corporation, are no more stable. Only a handful
of American companies, out of millions, have managed to stay in business over 100 years and few of the survivors remain in the same business. For example, fully one-third of the 1970 Fortune 500 companies had been acquired or broken into pieces or had merged with other companies by 1983 [12]. The life expectancy of the average European or Japanese company is less than 13 years [13]. Thus, at first glance, it appears that, institutionally speaking, active human stewardship of nuclear and hazardous waste sites even for hundreds of years into the future is an insurmountable challenge.

However, a closer look at history reveals numerous human institutions that have indeed survived for hundreds of years and even thousands of years. Many of these institutions are religious, such as the Catholic Church. Examples of current monastic orders founded many years ago include: the Dominican monastic order or Order of Friars Preachers that was founded in 1216 through the leadership of Santo Domingo De Guzman or Saint Dominic; the Franciscan monastic order that was founded in 1210 by Francis of Assisi, which called for a contemplative life combined with the active duties associated with secular clergy; the Jesuit order, or Society of Jesus, that was founded in 1540 under the leadership of Ignatius of Loyola; and the Sangha community of Buddhist monks that was founded by Siddhartha Guatama around 500 BCE [14]. A less well-known group are the Falashas Jews, who were descendants of Jews in Canaan who left that area before the Temple period for Ethiopia and maintained their religion despite isolation from the larger worldwide Jewish community for over 2000 years and in spite of persecution from others in Ethiopia [15].

These and other long-lasting religious institutions share many characteristics. First, their mission is clear: they exist to maintain a religious community. In a sense, they are stewards of the faith in their communities. Second, members of these institutions believe that the missions are worthy of devotion and sometimes large personal sacrifices. Third, they have evolved some manner to support themselves. The Christian monastic institutions mentioned above are largely self-sufficient. On the other hand, the Sangha depend wholly upon the generosity of the laity, a generosity that is well ingrained into the social fabric of the larger community. Many religious institutions are stewards of places and relics — e.g., the Western Wall, the Dome of the Rock, and the Shroud of Turin. However, none hold stewardship responsibilities analogous to those discussed herein.

There are several other examples of long-lasting institutions. Many universities have admirable histories, including the University of Paris, founded about 1170, the colleges established at Oxford, including University College (1249), Balliol College (1263), and Merton College (1264), and also the Jagiellonian University in Cracow, Poland, founded in 1364. Institutions embodied in the establishment of law also have long histories. For example, maritime law, while possibly first being developed by the Egyptians or Phoenicians, can be more definitely attributed to Rhodes about 2000 years ago, as testified to by surviving written comments from Roman emperors. Human institutions associated with indigenous cultures can sometimes be traced by very long periods of time. For example, the *N'ium chai* is a curing ceremony trace dance practiced by the Bushman of the Kalahari that can be traced back approximately 40,000 years [16].

The Smithsonian Institution is an example of a secular stewardship institution that has existed for an impressive length of time. The Smithsonian was established by an act of Congress in 1845 after a US$500,000 bequest by James Smithson to the United States for the
purpose of establishing an institution for the “increase and diffusion of knowledge.” The Smithsonian Institution is now often called “America’s Attic” because of its mission as steward of some 140 million valued artifacts from our past [17]. The federal government currently provides funding to support about half of the Institution’s budget; the remainder is raised through many other means, such as donations and subscriptions to its highly regarded magazine, *The Smithsonian*. Thus, the Smithsonian Institution enjoys some financial independence from the federal government.

While the Smithsonian has not proven its mettle over the very long term, it is an example of a modern secular institution that has a clear mission, a dedicated staff, many of whom indeed pass up more lucrative jobs in the private sector to enjoy the intrinsic benefits of working there, and an evolving ability to support itself within the larger American community without relying totally on federal funding. Although nonprofits such as the Smithsonian do not have exceptionally long histories, it can be argued that a well-conceived nonprofit could possibly carry out the stewardship responsibilities for this nation’s nuclear and hazardous waste sites.

4. Characteristics for long-lasting institutions to maintain stewardship over nuclear and hazardous wastes

This section sets out four categories of characteristics or criteria over which to judge alternative stewardship institutions.

4.1. Ability to carry out stewardship responsibilities over the long term

One main insight to be drawn from the assessment of long-lasting institutions above is that they have a strong reason for being and rarely stray from their main responsibilities. The missions of the institutions are strong enough for people to dedicate their lives to. The missions are clear enough for people to thoroughly understand, both intellectually and intuitively. The institutions do not have a plethora of conflicting and/or changing goals. Thus, the lesson learned is that any proposed stewardship institution needs to have as its sole focus the stewardship of the nuclear and hazardous waste sites. The institution also needs to have a stature or uniqueness or some other quality that sets it apart from other institutions, which makes it intrinsically special and, therefore, attractive enough for people’s lifetime dedication/devotion.

4.2. Ability to meet the technical challenges of stewardship

Unlike most other long-lasting institutions, the stewardship institution will need to maintain a high degree of technical capability and knowledge. Its members will need to thoroughly understand nuclear physics, chemistry, ground water flows, and the impacts on human and ecological health of the materials in the sites they are stewarding. They will need to be able to deploy, use, and maintain the technologies needed to monitor the sites. They will need to pass this knowledge down to future generations of institution members without any
slippage and continue to communicate this knowledge to surrounding populations. In the best case, the stewardship institution may even generate new knowledge about the sites and new technologies to reduce the risks of the sites. At a minimum, the institution should stay current with the latest best understanding of the above disciplines as they relate to the institution’s responsibilities. In other words, it needs to be a learning institution [18]. It should also continue to develop methods to communicate information about the sites many thousands of years into the future just in case it ceases to exist.

The stewardship institution must be flexible enough to handle changes in its stewardship responsibilities. Most discussions today seem to assume that the general amount of nuclear and hazardous wastes needing stewardship will not increase appreciably in the near term and will then decline over time. This situation is represented by the steady state stewardship responsibilities curve depicted in Fig. 1. For discussion purposes, and in an ad hoc fashion, the magnitude of today’s stewardship responsibilities was assigned a level of 100. This level will remain constant for hundreds of years until the risks posed by the most serious hazardous wastes sites decrease. Another virtual steady state will exist for several thousands of years until the risks posed by the most serious nuclear waste sites decrease. Stewardship responsibilities would end around 10,000 years from now under this scenario.

However, it is also possible that over the next several thousand years, the magnitude of nuclear and hazardous wastes needing stewardship may appreciably increase. The increased stewardship responsibilities curve in Fig. 1 depicts a fourfold increase in responsibilities. This scenario could be generated in many different ways. Most likely, the need to contain global warming and the eventual depletion of fossil fuels will require a huge commitment to nuclear power; both fission and fusion technologies will produce long-lasting radioactive

---

Fig. 1. Potential stewardship responsibilities over time.
wastes. Additionally, advanced economies will continue to generate hazardous wastes, possibly in new and more toxic forms. Efforts to extend our exploration of space may also carry with them the generation of deadly and long-lasting by-products. It may take several thousands of years to learn completely how to eliminate the generation of and/or to make harmless such wastes. In this scenario, the stewardship responsibilities could extend twenty thousand years or more into the future. Thus, from a technical viewpoint, the stewardship institution should be able to expand and contract over time to meet stewardship needs of those societies it is serving.

4.3. Ability to survive changing political and economic landscapes

The institution charged with stewardship of the sites over many hundreds and thousands of years must be able to weather political and economic change. Fig. 2 helps to explain this challenge. Each point in the figure represents a different political and economic landscape. The \( x \) axis represents the economic stability of the social environment. The \( y \) axis represents the political stability of the social environment. Each axis ranges from a high degree of instability to a very high degree of stability. The most stable political and economic landscapes lie in the upper right-hand quadrant of the figure, in the area bounded by points ABCDE. The least stable landscapes lie in the lower left-hand quadrant, in the area bounded by points FEIJ. The lower right-hand quadrant of Fig. 2 indicates landscapes

![Fig. 2. Scope of social environments facing stewardship institutions and strategic responses.](image-url)
which are unlikely to exist in reality. It is argued, in essence, that a modicum of political stability is needed for a high degree of economic stability. On the other hand, the figure indicates that social environments characterized by high political stability, but low economic stability are possible.

It can be argued that the social situation in the United States at the beginning of the 21st century can be described as falling into the upper right-hand quadrant of Fig. 2. That is, the United States is enjoying a period of high political and economic stability (see state number 1). In this situation, the stewardship institution should follow a strategy of political and economic interdependence with existing political and economic institutions. It can conduct its activities within a stable governmental framework. The stewardship institution can rely on the police powers of the relevant political jurisdictions to help protect the sites and punish those who break the laws. In addition to its technical responsibilities, its main external activities should focus on continually educating the local community about the sites. The stewardship institution should also be able to count on economic assistance from society to fund its activities and provide for its members. It may be that the stewardship institution will generate revenue when it accepts additional wastes into the sites it is responsible for maintaining and/or accepts new sites for stewardship, as indicated by the increased stewardship responsibilities scenario in Fig. 1.

The stewardship institution needs to prepare, and be able, to transform itself for any social landscape represented in Fig. 2. For example, the social landscape may transit to state number 2, in the area bounded by points GAEF, which is characterized by a fair amount of political stability but a high level of economic instability. In this situation, the stewardship institution cannot count on external society to fund its activities. It will need to be economically independent. In the extreme, the stewardship institution will need to produce its own food, clothing, shelter, and other necessities of life, as well as husband and maintain its technological base. The stewardship institution in this situation needs to maintain its interdependence with local governments. It may need to be more active in protecting the surrounding population from the sites and, just as important, protecting the sites from the surrounding population.

There may be a few possible situations, labeled state number 3 in the figure and found in the area bounded by the points EDHI, where the stewardship institution can coexist economically with local economic organizations in a social landscape characterized by high political instability. However, it is more likely that high economic instability will be joined by high political instability, as indicated by state number 4, which is bounded by points FEIJ. In these situations, the stewardship institution will need to transit to a very insular state-of-being, analogous to a wholly independent monastery or convent. Total economic self-sufficiency will need to be joined by a strong ability to survive without the political protection and support of the larger population. It may be that the stewardship institution will need to abandon numerous smaller hazardous waste sites that pose lower risks over shorter periods of time in order to consolidate its efforts on the larger nuclear waste sites. This strategy would also improve the ability of the stewardship institution to protect its own members during this period of time. In the next-to-worst situation, the stewardship institution may fragment as communications are cut between the sites with the hope of reconsolidating in better times.
In the worst situation, which is off-the-figure to the lower left-hand side and labeled by a number 5, a catastrophe strikes, resulting in extreme if not total depopulation of the land area now occupied by the United States. In this case, it is assumed that the members of the stewardship institution would also perish. In any case, the problems facing any survivors would dwarf any long-term risks posed by the sites, rendering stewardship of the sites a meaningless activity. It is assumed that even in this case, the stewardship institution would have implemented a marker policy to improve the probability of communicating to future generations the dangers of the sites.

4.4. Ability to meet current generation cost and implementation concerns

The current political environment must also be taken into account when considering different institutional options. Of course, tomorrow’s political environment may be quite different from today’s, which makes this discussion potentially ephemeral. Additionally, this assessment of today’s political environment may differ from other people’s assessments. Nevertheless, this analysis would be incomplete without this discussion.

This said, it can be argued that economic cost is one very important criterion over which all stewardship options will be judged. Costs in the near term will be weighed very heavily, much more heavily than long-term costs. The character of the institution will also be an issue of importance. Innovative institutional designs will invariably be skeptically received. Options that are designed to outlive the political system known as the United States will be very difficult to discuss by a political system not used to contemplating its own mortality. Thus, in the best of worlds, alternative stewardship institutions should cost relatively less rather than more to establish in the short term and take forms that are familiar to today’s decision makers and public.

5. Institutional options and assessment

This section presents and assesses six alternative designs for an institution to maintain stewardship responsibilities over nuclear and hazardous waste sites. The section concludes with a summary and a recommendation.

5.1. Alternative 1. Federal government organization — National Stewardship Administration

This first alternative is to have one central federal government organization assume responsibility for all of the nuclear and hazardous waste sites in the United States. As discussed in Section 2, numerous federal agencies currently have responsibility for sites that may require stewardship, including DOE, NRC, EPA, DOD, DOI, and GSA. Each agency is essentially coping on its own with its stewardship problem — working out separate approaches and standards, independently competing for funds from Congress, etc. This is the situation that will continue to exist in the near term barring a decision by Congress to support another approach.

This alternative requires the consolidation of all stewardship responsibilities into one, independent federal agency. Consolidation will provide the program with the needed focus.
Association with the federal government may also provide the institution with a sense of identity and a modicum of public spirit needed for this task. In the near term, it is likely that a consolidated federal stewardship organization could be quite effective technically. This solution is very cost competitive with the other alternatives. This is because there will be no significant costs associated with building this new stewardship institution. There would be efficiencies gained through the consolidation of management, suppliers, etc. Additionally, there will be no costs associated with endowing this organization with the capability for being economically independent (i.e., allowing the organization to transit from today’s social landscape to states 2 or 4 in Fig. 2) because by default, this alternative implicitly assumes that the social landscape in general and the United States government in particular will exist as is into the distant future. Lastly, a federal organization to carry out stewardship responsibilities should not be seen as too radical for today’s decision makers as it is virtually the current default solution.

Unfortunately, this alternative does not meet the third evaluation criterion very well. The main problem is that a federal stewardship institution could not weather substantial political and/or economic change. If the government of the United States were to collapse, this institution would disappear. Its responsibilities could be taken up by successive governments, certainly, but even in these situations, there may not be the institutional continuity essential for stewardship success. If the government were in jeopardy, it is most likely that it would also be facing economic hardship; cutting funds to a stewardship organization would probably be an easy decision to make. Referring to Fig. 2, this alternative is unlikely to be effective in states 2, 3, and 4. Thus, this alternative is not a good solution for a long-lasting institution to steward nuclear and hazardous wastes.


During the past several decades, all levels of government in the United States have acted to privatize services that had been provided directly by government and its employees. These services run the gamut from garbage collection at the local level to prison management at the state level to uranium processing at the federal level. These decisions have been taken, it has been argued, to improve the quality of these services while reducing their costs to the taxpayers. It is natural to assume that if the United States moves to the point of considering the creation of a stewardship institution that many will argue that this service should be contracted out to the private sector. Under this scenario, the federal government would continue to own the sites but would issue a request for proposals to steward the nuclear and hazardous waste sites. Bidders would respond with approaches to stewardship and estimated costs. The federal government would choose the proposal with the best combination of quality and cost. The federal government would reimburse the company for services provided over the life of the contract.

Like Alternative 1, this alternative has some benefits in the short term but few long-term benefits. With respect to the short term, this is probably the most cost effective of all the alternatives. Additionally, the winning bidder, it is assumed, would be technically qualified to carry out stewardship responsibilities. As described above, this privatization alternative fits with today’s conventional wisdom about the appropriate roles of government and the private sector.
A private sector stewardship organization, it is strongly argued, would have little chance to survive in the long term. The mind and soul of any private sector company are directed toward profit. Any line of business that cannot make a profit must be dropped, lest the entire company go bankrupt. Any level of political or economic instability would jeopardize the government’s ability to keep paying the company for its stewardship services. In fact, the government would probably move to protect the jobs of its employees by first canceling service contracts with private companies. Without a government contract, it is most likely that the private sector company would cease its stewardship business, thereby ending the stewardship of the sites. The government could pick up the stewardship responsibilities, but again at a risk of discontinuity. In any case, even more so than Alternative 1, the risk is high with this alternative that it will not provide a long-lasting solution to the stewardship problem.

5.3. Alternative 3. Local community organization(s)

Communities around the country are becoming involved in decision making concerning nuclear and hazardous waste sites. For example, the community of Oak Ridge, TN has organized two major groups to provide oversight of and technical assistance to the DOE with respect to decision making about the Oak Ridge Reservation (for example, see Ref. [19]). Conventional stewardship scenarios that assume political and economic status quo typically include a high degree of community involvement. For example, community groups would provide a sustained effort to educate people about the sites, maintain information repositories in local libraries, and even assume some of the day-to-day stewardship responsibilities. The natural extension of this alternative is to delegate stewardship responsibilities to the communities themselves, given their interests and local knowledge, with government continuing to own the sites and providing financial support to the community groups.

This alternative suffers from numerous problems both in the short term and in the long term. In the short term, this solution would result in a fragmentation of the stewardship responsibilities across the country. In an attempt to maintain some form of standardization and quality control across the sites, a federal organization would still need to exist to manage the program. This institutional design would make this a very difficult if not impossible management task. In addition, the social capital needed to support strong community stewardship organizations may be very difficult to maintain in the US. There is a high level of internal migration. Any major economic downturn in the Oak Ridge region, for example, could result in a high level of out-migration, thereby diminishing the ability of community stewardship groups to remain intact. Most of these community groups will be manned by volunteers. When their lives require them to devote time and energy to other endeavors, people will do so, to the cost of the volunteer organizations. The nature of the work would make it problematic that volunteers would devote the time to learn about the technical aspects of the task. Many writers have commented on how the decline in social capital in the US can be traced to reductions in volunteer activities [20]. In summary, it is very unlikely that volunteer community groups could carry out their responsibilities even a relatively short time into the future. The long-term prospects are extremely doubtful, as political and economic instabilities typically do the most damage at the community level. One cannot expect
community groups devoted to stewardship to exist in stages 2, 3, and 4 of Fig. 2. Overall, this alternative has very little to recommend for it.

5.4. Alternative 4. Secular nonprofit organization — The Stewardship Institution

This alternative calls for the establishment of a new nonprofit organization to accept the stewardship responsibilities for the nation’s nuclear and hazardous waste sites. For discussion purposes, let us call this organization The Stewardship Institution (TSI). TSI would be established as a 501C (3) nonprofit organization, given current federal law. It would qualify for this designation because the public interest nature of its stewardship mission, its educational activities, and its ongoing research program. This designation would then exempt it from various taxes, including local property taxes. It is assumed that the federal government would fund most of TSI’s activities during this period of high political and economic stability. However, all land and other property associated with the sites would be transferred to TSI.

Nongovernment institutions are playing an ever larger role in US society. Nonprofits teach our young, provide health care and other social services, and increasingly conduct sophisticated research. TSI would be modeled after two prominent existing US nonprofits, the Smithsonian Institution, discussed above, and The Nature Conservancy, whose mission is land conservation.1

These two institutions demonstrate several points. First, nonprofits are currently carrying out important stewardship responsibilities, of important artifacts that document our past and of important resources to help ensure our future. Second, both enjoy a measure of economic independence from the federal government, The Nature Conservancy particularly so. Third, both organizations are technically sophisticated. In addition to curators whose responsibilities are to preserve fragile artifacts and to educate future generations about their collections, the Smithsonian Institution also employs numerous scientists with expertise in many areas, including natural science, astronomy, and ecology. The Nature Conservancy employs people who understand ecology, environmental science, biology, and other topics associated with land and natural habitats. Fourth, both institutions have existed for many years, at least relative to many other American institutions, though far less than the thousands of years that TSI would need to exist. In summary, there are reasons to believe that a nonprofit institution such as TSI could maintain focus on its central mission, possess the technical capabilities to achieve its mission, weather economic instabilities to a degree to help ensure its existence for many years, and be familiar to today’s decision makers.

1 Founded in 1951, The Nature Conservancy’s mission is land conservation. It carries out its mission by identifying lands that ought to be conserved and face development or other threats and then acquiring the land or otherwise making provisions to conserve the land. Thus, The Nature Conservancy routinely purchases valuable lands and/or their development rights. Often times, the lands are then placed in trusts or transferred to governments as parks or wilderness areas. Currently, The Nature Conservancy has worked to protect over 11 million acres of habitat in the US and 60 million acres elsewhere in the world and manages 1340 preserves. The majority of this organization’s budget is raised through donations from its more than one million members. See http://www.tnc.org.
One uncertain point is whether TSI or some such nonprofit would develop an internal cohesion and external identity needed to weather political instabilities. In other words, could it exist on its own in a political environment that was no longer capable of granting any legal legitimacy for its existence? Would people feel strongly enough to keep the organization going through thick and thin, to recruit new people into the fold as needed, and to become economically self-sufficient? Could the organization take on a mentality of a monastery or an educational institution such as Harvard University, which have existed for hundreds of years? Having TSI members live on or next to the sites might work to help build this kind of identity, and would also provide property tax benefits in the short term.

In addition to this long-term concern, there are two short-term concerns. The first is whether current laws regulating nonprofits in the US would need to be amended to support the needs of a stewardship institution. For example, what liabilities might TSI have with respect to human and ecological health? The second issue is cost. It is argued that TSI should receive a substantial endowment of technology to support its monitoring and research efforts and to provide the basis for potential economic self-sufficiency. This endowment could be a substantial financial commitment for the current generation.

5.5. Alternative 5. Religious organization

From the discussion in Section 3, it is clear that many of the most longest-lasting human institutions are religiously based. Many of these institutions are self-sufficient. Some of these institutions are technological in that they apply technologies to grow food, make clothing, etc. Additionally, many religious institutions run major universities, thus providing a link to science and technology. From the discussion of Alternative 4, it is also clear that a major potential deficiency of a secular nonprofit organization is that it may not develop the identity to persevere into the indefinite future. Thus, it is logical to consider a religiously based institution to be the steward of the nuclear and hazardous wastes sites. Under this scenario, the land and other property associated with the sites would be transferred to an existing religious organization. There are many potential options in the US, including the Catholic church, any number of Protestant denominations, and various Jewish, Islamic, Buddhist, and other organizations.

Several questions surround this alternative, the least of which is whether any existing major and legitimate religious institution would actually offer to undertake this essentially never-ending and daunting commitment. First, would the religious organization’s mission suffer a dilution of its mission if it accepted this stewardship responsibilities? If so, then both goals would suffer. It could also be that the two missions could conflict philosophically, now or in the future, presumably putting at risk the secondary stewardship mission. For example, it can be argued that it would be necessary for this organization to consider the sites as sacred in order to institutionalize their importance. Labeling a ‘defiled’ site as sacred may be seen as contradictory and difficult to implement.

Second, most religious organizations are not known for their technological expertise, notwithstanding the fact that some are self-sufficient and many run universities. In fact, many people see them as a counterbalance against the rise of technology in society. While any organization has the theoretical potential to gain this expertise, building and
maintaining this expertise in a religious organization may be unreasonable to expect. Third, many religious organizations have suffered periods of intolerance, which could threaten the perceived neutrality and legitimacy of its stewardship operations. Fourth, while many religious institutions have survived for many years, it is not a given that their mission will remain constant over the next several thousands years. If religious ideas and/or practices change substantially, then old religious institutions may perish and new ones may arise. These changes could put into risk the continuity of the stewardship activities. Overall, one can have serious reservations about giving stewardship responsibilities to religious organizations.


This alternative calls for the establishment of a new state in the United States. For discussion purposes, let us call it Legacy State. This state would be unique among the states in several ways. First, this state would have a mission, to be the steward of the country’s nuclear and hazardous waste sites. Second, its land area would be mostly composed of those sites, plus some adjacent lands for homes of Legacy State citizens. Thus, to establish Legacy State, these lands would need to be deeded over from the current owners (e.g., the US government, state governments, private property owners). Over time, Legacy State’s land area would change, as additional sites become deeded over for stewardship and as sites lose their need for stewardship. In the latter case, these sites could then be deeded back to appropriate third parties. Third, obviously, Legacy State would have no borders per se. Unlike other states and political jurisdictions, its land area would not be approximately contiguous and spatially proximate. Instead, Legacy State would spread throughout the United States in a noncontiguous fashion. This arrangement is sometimes referred to as a nonspatial government [21].

The citizens of Legacy State would carry out the stewardship responsibilities. Unlike other states, Legacy State citizenship would be highly controlled. No one would be allowed to ‘migrate’ into the Legacy State. People would be invited to become citizens as the need arises for new members to carry out stewardship responsibilities. Presumably, people deciding to leave Legacy State or who are asked to leave could settle in any other state in the United States, as is the current case. Numerous questions need to be addressed with respect to establishing the Legacy State. These questions include: What would be the citizenship of immediate family members? What would be the citizenship of ‘retired’ citizens? and Would the new state have two senators and a congress person?

Another interesting question concerns how Legacy State would be governed. Legacy State would need to have a very stable governing structure; its mission will be constant over hundreds if not thousands of years. Pluralistic democracy, with contested elections and political parties, appears too unstable for this purpose. Models that put too much power into the hands of one individual and/or which are characterized by questionable power transfer processes must also be avoided. Consensus models, such as those employed by Native American tribes over generations, should be considered for this purpose.

Benefits of the Legacy State alternative are many. Legacy State would have a very distinct identity and a focused mission on stewardship. Its citizens could internalize this identity,
thereby helping this institution to meet its goals in the short term and to adapt to changing social landscapes. Its status as a state, it could be argued, would give it extra standing to exist independent of the United States framework if this framework changes into some other framework into the future. Conversely, extreme political instability may result in the demise of these kinds of governmental, as opposed to nonprofit institutions. Because many legal hurdles will need to be cleared to establish Legacy State and because its mission in the near term will be set out in law, Legacy State will be able to do a few things well but will not have a great deal of flexibility to undertake other responsibilities as time passes. The cost of implementing Legacy State would be high, relative to other alternatives, because land would be transferred and Legacy State citizens would need to be endowed with the capabilities to meet their stewardship responsibilities and survive independently in the future. Implementing this solution politically is also problematic.

5.7. Assessment

In summary, the six alternatives discussed above cover a wide range of possibilities, from something akin to the current status quo to several alternatives that could be considered radical in nature. Each meets or does not meet the four evaluation criteria set out in Section 4 in different ways (see Table 1).

It is argued that the weakest alternative is the local community organization, number 3. Communities in the United States suffer from social and economic instabilities and a diffusion of attention that would make stewardship problematic even in the short term. Typically, they do not possess the technical capabilities to meet this responsibility. While it is important to continue to involve communities in stewardship discussions and educational activities, it is not recommended that our society depend on communities to assume stewardship roles.

The federal government and private sector organization options, alternative numbers 1 and 2 can be devised to be on mission, technologically sufficient, and politically acceptable. However, they are also unlikely to survive substantial political or economic

<table>
<thead>
<tr>
<th>Institution/evaluation criteria</th>
<th>Ability to focus on stewardship mission</th>
<th>Ability to meet the technical challenges</th>
<th>Ability to survive political and economic instabilities</th>
<th>Ability to overcome present generation issues (e.g., cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Stewardship Institution</td>
<td>Very high</td>
<td>Very high</td>
<td>Very low</td>
<td>High</td>
</tr>
<tr>
<td>Stewardship, Inc.</td>
<td>Medium</td>
<td>Very high</td>
<td>Miniscule</td>
<td>High</td>
</tr>
<tr>
<td>Local community organizations</td>
<td>Very low</td>
<td>Low</td>
<td>Miniscule</td>
<td>Medium</td>
</tr>
<tr>
<td>TSI</td>
<td>Very high</td>
<td>Very high</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Religious organization</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Legacy State</td>
<td>Very high</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>
instabilities. The private sector alternative is especially unlikely to carry out its mission without federal financial support. Given that great weight is placed on the ability of the stewardship institution to survive political and economic instabilities, these alternatives cannot be strongly supported.

This leaves three alternatives: TSI, the Religious Organization, and Legacy State, numbers 4, 5, and 6, respectively. Each would enjoy a centrality of mission and could be technologically satisfactory. Arguments about whether the Legacy State could survive political and economic instabilities cut both ways; on one hand, its legitimized existence could allow it to transit smoothly into other governmental frameworks, on the other hand, its being identified as government-related could render it vulnerable in times of attacks upon government. In any case, this alternative could be considered too radical by today’s decision makers.

The Religious Organization represents option with the most history of being able to survive for long periods of time. Unfortunately, there are questions about its being able to accept this mission and to meet its technical requirements. In addition, this option could prove to be controversial from the viewpoint of religion’s episodes of intolerance.

This brings us to the remaining, and much preferred option, TSI. A well-designed TSI would have stewardship as its central mission, be technically capable, and internally strong enough to weather periods of political and economic instability. While this option may also generate strong criticism from today’s decision makers, nonprofit institutions are becoming more prominent in US society. Two such institutions, the Smithsonian Institution and The Nature Conservancy, are good models for TSI. Additionally, history reveals many examples of longer lasting nonprofit institutions, such as institutions of higher learning and maritime laws.

6. Concluding remark

Stewardship of nuclear and hazardous waste sites is an immense challenge. The time frames involved push people out of their near-term comfort zones and make them consider not only what technology has wrought but also the possible change and death of their governments and communities over the course of time. TSI is a good option to consider for this assignment. There may be better options not considered here that may arise because of this work. Additionally, TSI may not be the ultimate solution for all time. A well-designed TSI could have the capability of deciding at an appropriate time, say after several hundred years, to shift its stewardship responsibilities to an even more effective institution. However, it is important to implement this option soon, while our society is stable enough politically and economically to make this decision and endow TSI with the requisite resources.

There are many additional points to consider. One important research question is how many people are needed to staff TSI. Hundreds, thousands, tens of thousands? Another question is whether the solution needs to be global rather than current-country specific. Maybe a more global approach could allow for some long-term experimentation with institutional designs — e.g., test out a Religious Organization or Legacy State in places such as Europe and Asia.
Acknowledgments

I wish to thank William Coleman for his support in the research part of this article. I also wish to thank Carl Petrich, Tim Ezzell, Woody Dowling, Mary English, Sam Carnes, Jim Dator, Andrew Schiller, Elizabeth Peelle, and Workineh Kelbessa for their help and comments on the drafts of this manuscript. Two anonymous reviewers also provided helpful comments.

References