As Permanent as Practicable: The reality of Permanent Markers - 16191

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ABSTRACT

The regulatory requirements in the United States do not require any specific time frame for the duration of permanent marker systems to inform future generations of the presence of deep geologic nuclear waste repositories. The requirement is for markers to be "as permanent as practicable." For the Waste Isolation Pilot Plant in New Mexico, the U.S. Department of Energy chose a 10,000 year Passive Institutional Controls program goal. Passive Institutional Controls are to be designed prior to facility closure and implemented prior to the completion of the Active Institutional Controls program. Nuclear waste repositories across the world are actively developing marker and message systems, as required by their own regulations, for time frames either specified in those regulations or to be proposed to the regulator by the implementing organization. Time frames may be based upon the radioactive characteristics of the various isotopes being disposed of in the repository under consideration, or they may be based on some utility function that balances investment, practicability and risk.

Scientifically, there are a number of time frames that make sense. However, an important determinant of effectiveness that has not been taken into consideration is the impact of the human connection, the receiver of the message. The major obstacle that the permanent marker systems need to overcome is the impact that humans will have over time. Historically, no monument has ever survived more than a few thousand years when humans come in contact with it. No matter what size of monument or topic the monument represents, humans have a history of destroying monuments beginning just a few generations after the monument's construction. The only way to ensure that a monument system can endure long time frames is to isolate it from humans. Eliminating contact with humans for whom the messages are meant defeats the very purpose of having an informative marker and message system.

A more reasonable and historically supported time frame of 1,000 years would assure that no unreasonable cost would be incurred by current generations. Future generations could decide to continue maintaining the message, or not; and the likelihood of destruction of the markers by subsequent generations would be reduced since the knowledge of the markers and messages would have been transmitted within a more reasonable time frame over which language continuity, for example, would likely be manageable.

Future preservation of the marker system and future human actions cannot be controlled, but the goal is to build a marker and message delivery system that reduces the likelihood of inadvertent future human disturbance of a deep geologic repository. This is the typical regulatory requirement on future information systems. Regulators who insist on an extremely long time frame for marker effectiveness should consider the historical realities of "permanent" markers and monuments and propose a more reasonable time frame. Perhaps it would be more practicable to require 1,000 years for informing future generations and then allow them to determine what they wish to do to protect the future for another, perhaps similar, period of time.

INTRODUCTION

During the late twentieth century, a group of scholars, scientists and engineers were tasked with the development of a Passive Institutional Controls (PIC) program at the Waste Isolation Pilot Plant (WIPP) in the United States. United States Federal Regulations 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, Final Rule, December 1993 [1], states:

"Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location." (40 CFR 191.14(c)).

In February 1996, the Environmental Protection Agency (EPA) published 40 CFR 194, Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations. 40 CFR § 194.43 [2] states the criteria for PIC markers as:

"(a) Any compliance application shall include detailed descriptions of the measures that will be employed to preserve knowledge about the location, design, and contents of the disposal system. Such measures shall include:

(1) Identification of the controlled area by markers that have been designed, and will be fabricated and emplaced to be as permanent as practicable;….."

And…

"(3)(b) Any compliance application shall include the period of time passive institutional controls are expected to endure and be understood."

40 CFR § 194.43 also states:

"(3)(c) the Administrator may allow the Department to assume passive institutional control credit, in the form of reduced likelihood of human intrusion, if the Department demonstrates in the compliance application that such credit is

justified because the passive institutional controls are expected to endure and be understood by potential intruders for the time period approved by the Administrator. Such credit, or a smaller credit as determined by the Administrator, cannot be used for more than several hundred years and may decrease over time. In no case, however, shall passive institutional controls be assumed to eliminate the likelihood of human intrusion entirely."

Assuming that the conceptual PICs plan submitted in the Certification Application would result in a 700 year credit towards the performance assessment, the Department of Energy (DOE) stated in the scope of the PICs conceptual plan [3]:

"The DOE has a reasonable expectation that a sufficient number of components of the PIC described in this report will endure and be understood to provide future generations with a warning regarding the location, design, and contents of the disposal system during the entire regulatory time frame of 10,000 years. For details discussing the basis of this expectation and the quantitative credit used in the performance assessment see WIPP/CAO-96-3168, Effectiveness of Passive Institutional Controls in Reducing Inadvertent Human Intrusion into the Waste Isolation Pilot Plant for Use in Performance Assessments, May 1996." [4]

This connection to the Performance Assessment and the regulatory period of 10,000 years is the basis for DOE's assertion that the PICs program will last for the full regulatory time frame. After review of the Compliance Certification Application, the EPA stated in their Certification Decision of May 18, 1998 [5],

"The EPA proposed to deny DOE's request under § 194.43(c) that the likelihood of human intrusion into the WIPP during the first 700 years after closure be reduced by 99 percent based on the anticipated effectiveness of PICs. The EPA denied the credit because DOE did not use an expert judgment elicitation to derive the credit, as explicitly envisioned by the Agency."

Once the credit for the PICs program in the Performance Assessment was denied, the DOE moved on to begin preparatory activities to open the Waste Isolation Pilot Plant and never removed the 10,000 year expectation in the PICs conceptual plan.

DESCRIPTION

Time for a New Conceptual Plan

Now that almost 20 years have passed since the development of the WIPP PICs conceptual plan for certification, many parts of the original conceptual plan have been identified as no longer feasible. Some items no longer feasible include:

- Salt has been determined to not be appropriate for development of berms.
- Quarry's and equipment able to produce the size of granite needed for the monoliths no longer exist.
- The durability over thousands of years of the monolith design has been identified as questionable.

(EPA presentation, November 17, 2009)[6]

To be able to design a marker system capable of lasting into deep time (i.e., more than 1,000 years) previous marker type systems must be studied. To provide a template to guide us on how to begin to review historical markers there are a couple of items that we must keep in mind. The first is the regulatory requirement of being "practicable". Webster's dictionary defines practicable as: "capable of being put into practice or of being done or accomplished." [7]

The successful design of a marker system is one that can complete the task that it has been designed for, such as preventing inadvertent intrusion into the geologic repository. Material scientists can and have developed materials that can last tens of thousands of years, or are resistant to erosion and are extremely resistant for the environment that they will be placed in. However, there is one criterion that was not taken into consideration. This brings us to the second item to keep in mind, humans and their ability to be destructive and indifferent to the past.

For the WIPP Marker system a number of various materials were evaluated and reviewed. (Permanent Markers Materials Analysis, Hart, August 31, 2000) [8]. These materials included:

- Rock Material
- Concrete
- Local Earth Materials
- Metals and Metallic Alloys
- Ceramics
- Polymers.

The design criteria that these materials were evaluated to included:

- Durability
  - The ability of a material to resist destruction by a number of different forces or mechanisms.
- Strength
  - Resistance to nonrecoverable strain, measured by the stress needed to cause a specified amount of yield or rupture.
- Inscribability
  - Includes any means of imposing symbols and letters into the marker material.
- Detectability
  - Easily recognizable. This applies to both above and below ground markers
- Intrinsic Value
  - The material must have a low intrinsic value so as to not become an object that would motivate future generations to remove the marker in part or in whole.

Overall this was a very scientific and in-depth evaluation of a number of various materials that a marker system could be constructed out of. Unfortunately, the impact of humans and human activities was not well considered.

To be able to understand and trend the impact of humans and human activities on monuments the basic understanding of the *Le Longue Durée* should be taken into consideration. *Le Longue Durée* is a concept of the study of history first noted by Francois Simiand and later by Fernand Braudel, which gives priority to long-term historical structures over short term events. This long-term historical study is over thousands of years and in social scientific methods can show trending of the effect of humans on the environment or the effect of the environment on humans. In evaluating this long-term trending of the effect of humans, the evaluations were divided into three categories.

Category 1 is the short-term human impact. Short-term analysis is identified as 100 years or less. In theory, short-term human impact should produce the least amount of information loss on a monument system since language continuity and message understanding is least affected by time. However, that is not always true.

An appropriate example of the short-term impact of humans and human activities on monuments can be found within thirty miles of the WIPP site. This location is called the Gnome Site. The Gnome Site was the first nuclear test of the Plowshare program and was the first continental nuclear weapon test since the Trinity test to be conducted outside of the Nevada Test Site. The Gnome site is located approximately 25 miles southeast of Carlsbad, New Mexico and was designed to focus on scientific experiments and not military or defense experiments. Gnome was detonated on December 10, 1961, fifty four years ago. In less than two generations, the monument placed at the location of the Gnome site is weathered, has been vandalized, and actually has been moved from its original location by cattle using the monument as a scratching post. (Figure 1)

Another example of the short-term impact of humans and human activities on monument systems is the burial site of the first nuclear reactor in the United States. The wartime reactor developed and researched by Enrico Fermi in the 1940's was located on 19 acres in the Forest Preserve District of Cook County outside of Chicago. After decommissioning in 1954, the two research reactors were buried at the site and two granite markers were placed at the burial locations. The Site A marker (Figure 2) and the Plot M marker (Figure 3). Both markers have been vandalized even though they are located in a government protected forest preserve.

Figure 1. The monument at the Project Gnome site, November 2015. Over a dozen bullet holes can be identified along with a missing plaque on the top of the monument.

Figure 2. Site A marker in the Forest Preserve District of Cook County. In addition to weathering, obvious acts of vandalism have occurred in an attempt to alter the message carved in the stone.

Figure 3. Plot M marker at the Forest Preserve District of Cook County. Obvious weathering has occurred on the monument enhancing a natural fracture in the stone that is beginning to intersect with the inscription.

We can conclude from these examples that even during extremely short timeframes of just a couple of generations, the effects of humans and human activities on marker systems can be dramatic and the importance of the message they are passing on to future generations can quickly be forgotten or ignored. The result of this review shows that even in the first one hundred years after the placement of a monument, the needs and desires of the current generations greatly outweigh the monument and its message.

The Category 2 timeframe, to be reviewed, is from 100 to 3,000 years. It is expected that this time frame would show more effect of humans and human activities on a marker system than in Category 1. Examples of the Category 2 timeframe are numerous.

One example is the tsunami stones found in Japan. The time frame for the tsunami stones ranges from 500 to 700 years old and many were natural stone that was eroded from centuries of weathering with their inscriptions worn off or illegible and the language not recognized by many of today's modern Japanese citizens. Even with being in extremely poor condition, many citizens of Japan residing outside of the major cities had not only heeded the message on the stones, but passed the messages down from generation to generation. Such as the small rural township of Aneyoshi. (Figure 4) Aneyoshi and its citizens survived the tsunami of 2011 by not only heeding the messages on the tsunami stones but also by passing the messages from generation to generation through teachings in school. Unfortunately, many of those who did not heed the tsunami stone warnings and relied on modern technology to protect them were victims of the earthquake and resulting tsunami.

Figure 4. Tsunami stone located on the outskirts of the city of Aneyoshi, Japan.

This is an example of not only having a marker system, but also a system to teach the meanings of the markers to future generations. Lives were saved because of this type of approach. In addition, the current generation has erected a new tsunami stone to ensure the message is passed on to future generations. (Figure 5)

Figure 5. A modern tsunami stone erected on the outskirts of Aneyoshi, Japan.

Numerous monuments and archeological sites that fall under the Category 2 time frame have not interacted as well with humans as the tsunami stones. One of the

largest Mayan pyramids from the third century BC was destroyed by a construction company while digging for crushed rock (May 2013). (Figure 6)

Figure 6. Construction equipment destroying a 3,000 year old Mayan pyramid.

The wars in the Mideast and Syria have resulted in the destruction of many archeological and monument structures. The Buddha's of Bamiyan carved into a cliff in central Afghanistan (507-554 AD) were destroyed by the Taliban in 2001. (Figure 7)

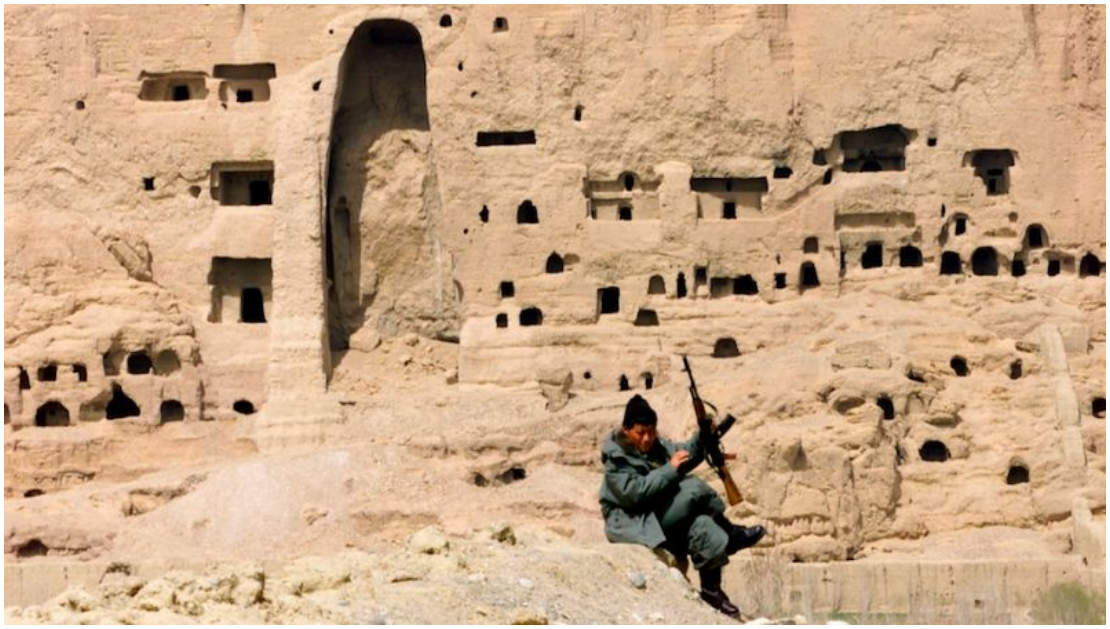

Figure 7. The Buddha's of Bamiyan in central Afghanistan after destruction by the Taliban.

Religious extremists aren't the only ones destroying monuments and archeological sites. Ten ancient tombs from the Sixth Dynasties (220-589) have been destroyed in Nanjing, China (2007) to make way for the construction of a department store. (Figure 8)

Figure 8. Ancient tombs from the Sixth Dynasty were destroyed to make way for an IKEA department store. Though there are laws against this type of destruction, the laws are not enforced.

The final time frame, Category 3, is from 3,000 years to 40,000 years. This time frame is expected to have the most impact from not only humans and human activities, but also environmental conditions.
Category 3 examples of monuments are primarily restricted to archeological sites. For this category the existence of any kind of recognizable structure is the primary way of identifying the existence of any man made object. For this review, the impact of humans and human activities on these structures has been limited to modern humans and human activities occurring within the las few hundred years. Examples of the impact of humans and human activities are many.

One example is the destruction of archaeological sites on the Dakar Rally in 2009, when the rally was run in Chile and Argentina instead of the usual Paris and Dakar. A pre-Columbian hunter-gatherer camp had been destroyed by the race. (Figure 9)

Figure 9. Petroglyphs partially destroyed by four wheel drive automobiles during the Dakar Rally 2009.

In the 1870's, archaeologist Heinrich Schliemann believed that he had found the city of Troy. Troy was a city from 3,000 BC that was the setting of the Trojan War. Schliemann realized that the location was actually nine cities stacked on top of each other. Schliemann used a new invention to help excavate the various levels of the city to finally reach the original city of Troy. The new invention was dynamite.

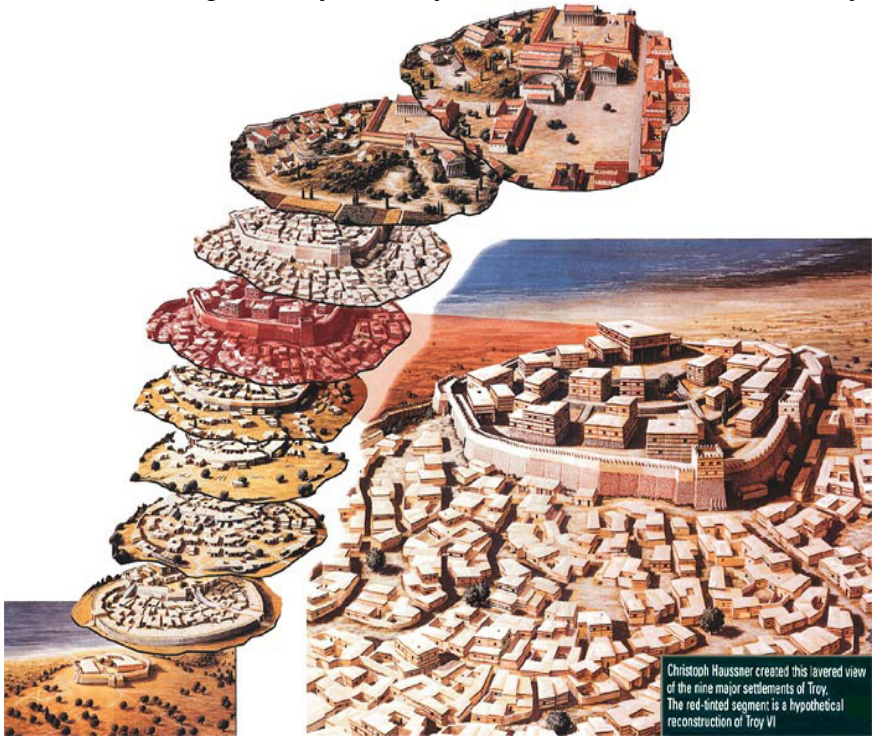

Figure 10. Depiction of the nine layers of the city of Troy.

CONCLUSION

Many countries who are developing geologic repositories for the disposal of nuclear waste have not only accepted the international decree of the International Atomic Energy Agency to inform future generations of the nuclear hazards associated with the geologic repository, but also are developing plans for marker systems that will exist far into deep time as warnings to future generations. Many of these countries have designated time frames of tens of thousands of years for these markers to exist and pass on their messages. In the United States, the Department of Energy has designated a time frame of 10,000 years for the marker system at the Waste Isolation Pilot Plant to exist and pass on its message of warning to future generations.

Using the concept set forth in the historical study of deep history, *Le Longue Durée,* three categories of time were reviewed for impact of human and human activities on monuments and archeological sites. The first category of 0-100 years, showed that no matter how much financial investment is given to the development of a marker system, without human involvement on a daily basis to protect the monuments, vandalism and indifference of the current generations results in the damage of the marker system and possibly there inevitable destruction. The marker system would not be “practicable” as required by regulation.

The second category of 100-3,000 years showed continued monument damage and destruction by generations with the exception of the tsunami stones in Japan. The tsunami stones and the ability of the local communities to not only heed their warning but also pass the message on to future generations shows us that it is possible to have a marker system function for a 1,000 year time frame, if the local community is involved and the societal culture is one that accepts the knowledge of its ancestors as being as important, if not more important, than modern knowledge. Financially burdening the current generation with the development of an “indestructible” marker system will not result in a marker system that is “practicable”. However, there is historical evidence that developing a marker system in conjunction with a local societal culture that assists the marker system in passing along its message to future generations will result in a marker system that is “practicable”.

The third category of 3,000 to 40,000 years showed that no matter how much financial burden a generation accepts in the development of monuments or marker systems, over long time frames, the messages that these markers are passing along will not exist or be understood, and the needs of each future generation will greatly outweigh the monuments and its messages.

The result of this study shows that no matter what the regulatory time frame may be for the existence and effectiveness of markers for geologic repositories of nuclear waste, the reality of a maker system being “as permanent as practicable” can only be based upon the actions of future generations and not by the level of development of the marker system or the amount of financial cost put forth by the current generation in the development of that marker system.

Looking back into deep history to determine trends in human behavior as it pertains to markers and archeological sites has shown that overall; humans are a destructive species that puts its current interests and actions above past human actions. Human history has only one example where a marker system was able to pass on its message to future generations, the tsunami stones. And this marker system was only able to complete its task by the involvement of the local community over hundreds of years. For a marker system to be "practicable" effort needs to be placed in the development of the local societal culture that will involve the local community to support a marker system. To put the weight of a large financial cost for design and construction of a monument/marker system to last tens of thousands of years on the current generation would be a waste of time and money. History has shown us that it would be better using that financial incentive in developing a local societal culture that along with a marker system will pass the message along and be "practicable" for at least a thousand years.

REFERENCES

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