12. Passive Institutional Controls

12.1 INTRODUCTION

In developing the 40 CFR part 191 rule, EPA recognized that the quantification of risk over long periods of time was subject to considerable uncertainty and consequently introduced assurance requirements into the rule to qualitatively address this uncertainty. One of these assurance requirements deals with passive institutional controls. Passive institutional controls are designed to reduce the probability of inadvertent human intrusion into a repository by conveying information about location, design, and hazards of the WIPP. Preliminary PA runs conducted by SNL have shown that human intrusion presents the most serious problem in demonstrating compliance with the disposal standards (SAN92). Human Intrusion can disturb the natural and engineered barriers used in the repository to contain the waste.

In this chapter the necessity of incorporating passive institutional controls in the WIPP compliance criteria is discussed in terms of their ability to reduce the likelihood of human intrusion.

12.1.1 Regulatory Background

This sub-section defines passive institutional controls from a regulatory point of view. The regulations of principal interest are 40 CFR parts 191 and 194. NRC rules involving site markers and records are included to furnish perspective on a similar regulatory approach.

EPA Regulations

Passive institutional controls (PICs) are defined in §191.12(e) as follows (50 FR 38085):

(1) permanent markers placed at the disposal site,

(2) public records and archives,

(3) government ownership and regulations regarding land or resource use, and

(4) other methods of preserving knowledge about the location and contents of a disposal system.

PICs are one of the assurance requirements specified in §191.14. The assurance requirements are designed to provide additional confidence that the containment requirements (§191.13) are realized. Substantial uncertainty is inherent in the long-term, 10,000-year prediction of disposal system performance necessitated by the Containment Requirements. The Assurance Requirements balance the quantitative uncertainties involved in calculating the magnitude of radioactive releases to the accessible environment. As noted in the preamble to the 40 CFR part 191 Standards, "Each of the assurance requirements was chosen to reduce the potential harm from some aspect of our uncertainty about the future" (50 FR 38072).

The specific regulatory requirement stipulating the use of passive institutional controls is included as §191.14(c), which 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."

The role of passive institutional controls is to reduce the probability of inadvertent human intrusion into the repository during the regulatory time frame. Therefore, the possibility that institutional knowledge of the repository will be lost must be considered.

The compliance criteria related to passive institutional controls are included in §194.43 of 40 CFR part 194. This section requires the compliance certification application to include "detailed descriptions of the measures that will be employed to preserve knowledge about the location, design, and contents of the disposal system" and estimates of "the period of time passive institutional controls are expected to endure and be understood."

Conceptually, some credit could be allowed in PA for the use of PICs. In theory, providing such credit might create an incentive for enhanced PICs. EPA proposed allowing credit for PICs and solicited public comment on such in the 40 CFR part 194 (60 FR 5766) proposal. In finalizing 40 CFR part 194, EPA consulted the WIPP Review Committee of the National Advisory Council on Environmental Policy and Technology (NACEPT) on three issues, including PICs. The Committee agreed that PICs would be likely to decrease the possibility of inadvertent intrusion into the WIPP but expressed concern about the ability of a rigorous method by which to determine the appropriate reduction due to PICs in the future. Some members of the Committee stated that, if credit were to be approved, the size of the credit

should not reflect that PICs would be effective for more than a small fraction of the 10,000-year regulatory time frame.

NRC Regulations

Though WIPP is not subject to NRC licensing regulations, NRC regulations covering disposal of high-level wastes in geologic repositories similarly require the use of site markers and records (10 CFR part 60). License applications must contain a SAR which includes:

> (8) A description of the controls that the applicant will apply to restrict access and to regulate land use at the site and adjacent areas including a conceptual design of monuments which would be used to identify the controlled area after permanent closure (§60.21c).

When the repository is ready for permanent closure, a license amendment must be obtained which provides:

> (2) A detailed description of the measures to be employed - such as land use controls, construction of monuments, and preservation of records - to regulate or prevent activities that could impair the long term isolation of emplaced waste within the geologic repository and to assure that relevant information will be preserved for future generations. As a minimum, such measures shall include:
>
> > (1) Identification of the controlled area and geologic repository operations area by monuments that have been designed, fabricated, and emplaced to be as permanent as practicable;..... (§60.51a).

12.1.2 General Background

A 1984 study conducted by the Human Interference Task Force for the Office of Nuclear Waste Isolation (ONWI)(HUM84) concluded that long-term communication is the primary method for reducing the likelihood of human intrusion at nuclear waste repositories (GIL85). Vehicles for such communication can involve both markers and records. The two are closely intertwined. A limited record can be inscribed on a marker, a marker can designate the location of an on-site vault containing records, or a marker can specify off-site archives where records are located.

The ONWI Task Force asserted that, for messages on markers to be communicated, they must be detectable, durable, comprehensive, conveyed at several levels of sophistication and imparted by several techniques. The logic diagram developed by the Task Force to provide a framework for modeling future communication, taken from ONWI 84, is presented in Figure 12-1.

Assuming the markers survive and the messages inscribed on them remain legible, several scenarios can be postulated. If society either continues to advance technically or remains static, the message may be understood.[1] However, it is likely that the inscribed message will be understood at the site only if the message is periodically updated. Sebeok relates a widely accepted generalization in the field of semeiotics (communication through signs); namely, all natural language and human communication systems change over time (SEB84). An example can be drawn from the evolution of the English language. General comprehension of Middle English (ca. 1,100 - 1,500 A.D.) is limited and general comprehension of Old English (ca. 400 - 1,100 A.D.) is virtually non-existent. It has been estimated that only about 12% of basic English words and an even lower percentage of complex vocabulary items will exist in 12,000 A.D. (GIV82). The Nordic Committee for Nuclear Safety Research (NKS) provides an interesting example of this English language change over the past 600 years. The quotation is interesting because it illustrates the changes in the English language and typifies the difficulty that society may have in just a few centuries understanding English of today. The following is a quotation from "Sir Gawain and the Green Knight" written in about 1375 A.D. (JEN93):

> The stele of a stif staff the sturne hit bi gripte
> That was wounden with iron to the wandes ende,
> And al bigraven with grene in gravios werkes.[2]

[1] In the context used here, society refers to present day U.S. society.

[2] The grim man gripped it by its great strong handle, which was wound with iron all the way to the end, And graven in green with graceful designs.

Figure 12-1 Human Interference Logic Flow

The message may not be understood by societies of the future. Such future societies possibly would not have the technology or the motivation to intrude into a deep geologic repository. However, a future society might take actions which could represent indirect interference with a geologic repository. One example would be the development of large scale irrigation or reservoir projects which could disrupt ground water flow patterns (HUM84). Large scale irrigation has been employed for millennia. Durant noted that extensive irrigation was used by the ancient Sumerians beginning about 4,000 B.C. This was the cornerstone upon which the Sumerian culture was built (DUR54, p. 124). If society regresses and then advances to a state of civilization akin to today's society, the new society might not understand any message which survives on the site markers. Language continuity may be lost. Future linguists might be able to decipher the marker inscriptions, but timing and knowledge of such decoding at the repository site might not be contemporaneous with the intent to explore for resources. The roles of markers and messages and the extent to which they may be expected to persist will be discussed more fully in subsequent sections.

The following sections discuss the four categories of passive institutional controls identified in the 40 CFR part 191 standards: (1) permanent markers, (2) public records and archives, (3) government ownership and regulations, and (4) other methods of preserving knowledge about the disposal system. It should be noted that records can be located either on-site or off-site. Since on-site records are closely tied to markers, they will be discussed with markers in Section 12.2, while off-site records will be considered in Section 12.3.

12.2 PERMANENT MARKERS

Permanent markers are the foundation of any passive institutional control strategy. This section includes examinations of archeological monuments to provide an historical perspective on the persistence and understood purpose of various monuments. Examples of monuments and megaliths which have endured and whose purpose is clearly understood are described. Ancient structures which have not persisted and/or been understood are described here to the extent possible. Programs conducted by various government agencies related to the marking of radioactive waste repositories are also discussed. The merits of a no-marker strategy are briefly recounted, although such a strategy would not be acceptable from a regulatory viewpoint. As mentioned previously, the discussion of permanent markers also includes the messages embodied in or contained on the markers.

This section focuses on permanent surface markers. Underground markers are considered in Section 12.5.

12.2.1 Archeological Analogues

12.2.1.1 Introduction

EPA has long recognized that the study of ancient markers or monuments may provide insight into the effectiveness of passive markers. At the very least, WIPP planners can learn about materials and forms of construction which are expected to last for very long periods of time. Beyond this, it is conceivable that the study of ancient monuments can provide information on how best to record messages and build markers in order to convey clearly a message to future civilization.

In 1982, DOE's Human Interference Task Force (HITF) engaged The Analytic Science Corporation (TASC) to develop recommendations of marker design based on a study of selected archeological sites. The resulting technical report by Maureen F. Kaplan (KAP82) considered the pyramids of Egypt, Stonehenge in England, the Nazca Lines in Peru, Serpent Mound in the United States, the Acropolis of Athens, Greece, and the Great Wall of China.

Kaplan classified potential messages regarding the WIPP into four levels:

- Level I: Attention getter, i.e., "something is here."
- Level II: Attention getter and warning, i.e., "something is here and it is dangerous."
- Level III: Basic information, i.e., what, who, when, why, what actions to avoid, and where to find information.
- Level IV: Full record of information, i.e., plans, drawings, environmental impact statements, etc.

Kaplan pointed out that "the medium of the message may determine the level of information the marker can convey." An earthwork, for example, can convey little beyond a Level I or perhaps a Level II message. On the other hand, the media usually employed to convey Level IV messages (paper, plastic, metal, electronic media) are not nearly as likely to survive the

millennia as is an earthwork.

Kaplan emphasized the importance of identifying the audience to whom a message is addressed and the undesirable actions to be warned against. She went on to discuss such actions. She concluded that "the primary emphasis in the marker system design should be on detection by sight," and noted that "the distance at which the message is detectable may be determined, in part, by whether it is desirable to actively call attention to the site or to warn people once they have decided to investigate the area." She discussed various possible marker designs and message contents, stressing that because "Level III and Level IV information may only be carried by the written word," it is important to incorporate written text into on-site monuments and to store records elsewhere as well.

Kaplan's study served as the primary basis for the analysis of monuments that appears below. Among her important observations were:

- Monuments that require no maintenance survive best;
- Monuments made of stone or earth survive best;
- Metals are not suitable marker materials; since they tend to be recycled;
- Markers should be shaped and sized to minimize their potential for reuse;
- The majority of ancient monuments were meant to be detected by sight, at ground level;
- If the component parts of a marker are small, and the public is not excluded from the vicinity of the marker, the chance that the marker's message (to say nothing of the marker itself) will survive are relatively slim.

A logic diagram formed from these observations led to the conclusion that the WIPP marking system should be comprised of durable, megalithic, monolithic stones with engraved symbols. Kaplan proposed that if the markers were to be visible from the air, an earthwork should be incorporated into the design. A basic design was proposed that consisted of outer rings of monoliths conveying Level I and II information. The outer rings surround a tumulus over a vault in which Level IV information would be stored. Immediately surrounding the vault are megaliths conveying Level III information. Kaplan concluded with a discussion of media in

which Level IV information can be encapsulated and of potential designs for the monoliths.

Other HITF reports relevant to this study include *Communication Measures to Bridge Ten Millennia* (SEB84), *Communications Across 300 Generations: Deterring Human Interference with Waste Deposit Sites* (TAN84), *Reducing the Likelihood of Future Human Activities That Could Affect Geological High-Level Waste Repositories* (HUM84), and *Expert Judgement on Markers to Deter Inadvertent Human Intrusion into the Waste Isolation Pilot Project* (TRA93). The last report will be addressed in the conclusion of this section.

When developing the 40 CFR part 194 proposal, EPA examined a range of ancient monuments wider than that previously investigated by DOE. Published discussions of twenty-five ancient monuments and classes of monuments were examined in an attempt to answer the following seven questions:

- What message(s) were the monument's creators attempting to convey?
- Were they trying to convey this message to future civilizations or to their own people?
- What has been involved in interpreting the message by modern scholars?
- How sure are we that we have the message right?
- If the message had been "Don't dig here because it is dangerous," is it likely that we would have gotten the message before digging there?
- What physical and environmental characteristics have permitted the monument to withstand the ravages of time and vandalism?
- What physical and environmental characteristics have permitted the monument to convey its meaning clearly through the millennia?

In many, if not most cases, the published literature does not contain explicit answers to all of these questions. Answers often had to be inferred from the evidence.

In addition to previous monument studies connected with the WIPP (e.g., KAP82), results from other studies were used. No new archeological research was conducted which would

most likely would have been redundant.

Below, four examples from the 25 archeological analogues listed below are discussed with reference to the seven questions. Summary observations are made at the end of this sub-section. The 25 archeological examples studied are: pyramids of Egypt, Egyptian funerary and temple monuments, monuments of Mesopotamia, Great Wall of China, pyramids and related monuments of Mesopotamia, Adena and Hopewell mounds, Mississippian mounds, Wisconsin effigy mounds, John East mound, Stonehenge, West Kennet long barrow, Knowth passage tomb, Avebury stones, Maltese temples, Easter Island statues, Nan Madol, Nazca lines, Intaglios of the California, Arizona, and Nevada deserts, Chacoan roads, Lascaux caves and similar paleolithic painted caves, Australian rock art, African rock art, Adamgarh painted caves, general rock art in the Western United States, and North Fork and Jeffers petroglyphs.

12.2.1.2 Monuments of Mesopotamia

Duration: Up to ca. 6,000 years so far.

Description: The ancient Sumerians, Babylonians, Assyrians, and other civilizations of Mesopotamia (roughly, modern Iraq) constructed major urban centers with extensive fortifications and religious and secular buildings. Emblematic of the Sumerians, and to some extent, their successors was the ziggurat, virtually a constructed mountain made of brick, topped with a religious structure. Some ziggurats rivaled the Egyptian pyramids in scale. Most Mesopotamian buildings were made of mud brick, so their upper parts have tended to collapse, forming mounds or "tells." Foundations and lower rooms are often preserved within these tells, as are the remains of older buildings that were covered by later construction. Fired clay tablets containing written material in cuneiform script are commonly found in Mesopotamian tells, as are elaborately carved statuary and bas-relief panels portraying rulers, wars, rituals, and aspects of daily life (WOO63; MAL65).

- What message(s) were the monument's creators attempting to convey?

Cuneiform writing, both on tablets and on monuments, transmitted historical data, religious observations, proclamations of law, and political propaganda. Tablets also contain more humble writings such as inventories, financial accounts, textbooks, and student's essays.

Huge structures such as palaces and ziggurats were presumably intended to impress the viewer and, in the case of the ziggurat, to convey a sense of religious awe.

- Were they trying to convey this message to future civilizations, or to their own people?

Some Mesopotamian monuments were rather explicitly addressed to the future. For example, around 500 B.C. the Persian emperor Darius had the following inscribed in cuneiform script in three languages (Old Persian, Elamite, and Akkadian) on the Rock of Bihistun along the caravan road between Babylon and Ecbatana:

Saith Darius the King:
Thou who shalt hereafter
Behold this inscription
Or these sculptures,
Do thou not destroy them
(But) thence onward
Protect them as long
As thou shalt be in good strength.

Having at the time some three thousand years of rising and falling civilizations to look back upon, and having extensive contact with cultures other than his own (e.g. the Greeks), Darius may certainly have contemplated the idea of communicating with other civilizations in the future. However, Mesopotamian monuments appear to have been designed to

communicate information, ideas, directions, and impressions to both the people of the communities in which they existed and to surrounding contemporary groups.

- What has been involved in interpreting the message by modern scholars?

Archeological research, including major excavations, has been conducted extensively in Mesopotamia for over a century. One major breakthrough occurred in the late 1830s, when Henry C. Rawlinson was successful in translating the cuneiform script on the Rock of Bihistun. An excavation uncovering the library of Nineveh in the 1850s produced some 25,000 tablets that provided a rich source of messages from the ancient Assyrians. Increasing scholarly fluency in reading cuneiform script has been the key to interpreting such messages.

- How sure are we that we have the message right?

Scholars can be quite certain that they understand straightforward written messages correctly. Religious parables and the propaganda of warriors and rulers, however, are less firmly understood.

- If the message had been "Don't dig here because it is dangerous," is it likely that we would have gotten the message before digging there?

Because of increased fluency in reading cuneiform script, this message would certainly be understood. However, many excavations took place in Mesopotamia before scholars became familiar with cuneiform. Moreover, since most cuneiform records are buried, it is impossible to read their messages without digging.

- What physical and environmental characteristics have permitted the monument to withstand the ravages of time and vandalism?

Since the mud-brick structures of the Mesopotamian cities have collapsed, they have not entirely withstood environmental degradation. They have also been the victims of extensive vandalism. However, as upper walls have settled down over lower rooms and stabilized, the lower rooms have been protected. Monuments carved on hard stone have survived well, as have tens of thousands of fired clay tablets of cuneiform script.

- What physical and environmental characteristics have permitted the monument to convey its meaning clearly through the millennia?

The fact that cuneiform texts were both inscribed on stone monuments and imprinted on fired-clay tablets has been the key to understanding the messages of the ancient Mesopotamian.

12.2.1.3 Intaglios of the California, Arizona, and Nevada Deserts

Duration: Up to 10,000 years (DAV80).

Description: The intaglios consist of gigantic geometric, anthropomorphic, and zoomorphic figures scratched into a "desert pavement." This hard surface is created by soil deflation in arid areas or by aligning rocks which become cemented in as part of the pavement. While they are most commonly found in the California desert west of the Colorado River, others have been discovered east of the river in Arizona, in Nevada, and elsewhere.

- What message(s) were the monument's creators attempting to convey?

There is no widespread agreement about what messages the intaglios were intended to convey. They have been interpreted as reflecting shamanistic symbols, messages about water, astronomical observation points, maps, gaming facilities, and "random, perverse behavior" (DAV80, HUD79, RAV85).

- Were they trying to convey this message to future civilizations, or to their own people?

There is no evidence that the builders of the intaglios were trying to communicate with future civilizations.

- What has been involved in interpreting the message by modern scholars?

Contemporary scholars have used vertical and oblique aerial imaging, intensive surface survey and mapping, and test excavation to interpret the intaglios.

- How sure are we that we have the message right?

There is no general agreement among scholars about the message of the intaglios.

- If the message had been "Don't dig here because it is dangerous," is it likely that we would have gotten the message before digging there?

Because of the hardness of the desert pavement, the intaglios are not particularly conducive to digging. On the other hand, there is nothing in their character that discourages digging.

- What physical and environmental characteristics have permitted the monument to

withstand the ravages of time and vandalism?

The extreme aridity of the desert and the stability of the desert pavement have tended to preserve the intaglios. Their remoteness has also been crucial in their preservation.

- What physical and environmental characteristics have permitted the monument to convey its meaning clearly through the millennia?

The intaglios convey a message with only Level I complexity.

12.2.1.4 Australian Rock Art

Duration: ca. 25,000 years so far (possibly 35,000 years).

Description: Australian rock art includes paintings, engravings, and peckings. Subjects and styles vary with time and location and contain both simple and complex representations. Most are polychromatic. Many pictures overlap or are superimposed on one another. Some of the art includes symbols that appear to convey information on direction, movement, the act of speaking, and events in the time known today as "the dreamtime." Australian rock art is found in rock shelters and overhangs. Aboriginal Australians continue to create rock art.

- What message(s) were the monument's creators attempting to convey?

The messages encoded in Australian rock art have been the subject of intense debate. Chalapka asserts that the art portrays a wide variety of human experiences which reflect the artist's physical, social, and cultural environment. For example, many motifs relate to hunting, plant gathering, and swamp life. Dominant plant and animal figures may represent the local subsistence base. Paintings reflect economic and socio-cultural activities, as well as "mythic" events and spirits (CHA84, GRA93). Some intent to record contemporary events, and possibly to influence them, is suggested by such sites as the Emu Dreaming and Pig galleries on the Cape York Peninsula. At this site, "a half dozen white men with rifles are

depicted. In the Pig Gallery, birds are shown standing atop the bodies of two of the men, beaks thrust into their armpits" (GRA93).

- Were they trying to convey this message to future civilizations, or to their own people?

The intended recipients of the messages are also the subject of considerable debate. There is, however, nothing to suggest an intention to communicate with future civilizations.

- What has been involved in interpreting the message by modern scholars?

Since aboriginal Australian culture remains alive today, ethnography, oral history, studies of folklore, and consultation with Aboriginal experts have been primary bases for what is known about Australian rock art. Archeological research and comparative analysis of artistic elements have also made important contributions.

- How sure are we that we have the message right?

The messages of Australian rock art are not thoroughly understood.

- If the message had been "Don't dig here because it is dangerous," is it likely that we would have gotten the message before digging there?

Although much Australian rock art is very abstract, much of it is also highly representational. Often both the external and internal characteristics of animals are portrayed. It is conceivable that a representational pictograph warning against digging would be understood. It is also conceivable that a pictograph representing a human's internal structure becoming afflicted would be understood as well.

- What physical and environmental characteristics have permitted the monument to withstand the ravages of time and vandalism?

Although the painted pictures are especially fragile, they have been protected from the weather and preserved by their location in rock overhangs. Some paintings may have also been maintained over the years, because they have continued to figure in the ceremonial life of Aboriginal communities.

Chalapka identifies five variables that affect the survival of the Australian rock art:

1. Degree of protection. The less moisture present, the greater the isolation from humans and animals, and the greater the distance from the exterior of the shelter, the more likely the paintings will survive.

2. Type and matrix of host rock. The harder and more stable the rock, and the greater its ability to absorb pigment, the more likely the art will survive.

3. The properties of the pigment. The pigment's ability to be absorbed is a variable of survival. Hematite-based pigments survive best.

4. The method of application. If the pigment is applied directly to the rock, rather than onto a clay base, the painting will survive longer.

5. Climate at the time of execution. If the climate is dry, the pigment is more likely to be absorbed and has a better chance of having a protective mineral coating form over it.

- What physical and environmental characteristics have permitted the monument to convey its meaning clearly through the millennia?

To the extent that Australian rock art has conveyed its meanings, it has done so because of the physical survival factors listed above. Also, Aboriginal Australians are still living today and are able to interpret the paintings.

12.2.1.5 Rock Art in the Western United States (General)

Duration: ca. 10,000 years so far.

Description: Many Native American groups of the western United States produced both pictographs (painted rock art) and petroglyphs (pecked, ground, scratched, or incised rock art). Such art, particularly pictographs, has been produced in recent times and is probably being produced today. However, the rock art tradition dates back at least several millennia, and rock art sites up to 10,000 years old have been reported (HED83). Styles and motifs vary widely from tribe to tribe, region to region, and through time, but geometric, anthropomorphic, zoomorphic, and abstract styles are common.

- What message(s) were the monument's creators attempting to convey?

Much of the rock art in California, particularly pictographs in the Chumash area along the south coast, is thought to represent astronomical phenomena (e.g. HED83, HUD78). Some

sites are ethnographically associated with specific rituals, such as the initiation of girls into womanhood (e.g. TRU88). Some petroglyphs are identified as trail markers and other mnemonic devices, vision quest location markers, and hunting ritual depictions (e.g. MUR87). Several scholars see representations of sexual parts and acts in rock art as part of fertility rituals. Others identify elements of rock art as vehicles to telling and remembering of origin stories and other traditions. Rock art may also serve as markings for social group boundaries (HED83). Petroglyphs in the form of Hopi clan symbols in the Southwest are thought to have marked the route to sacred sites, and as reflecting the journeys of the Hopi ancestors recorded in tribal tradition (JUD50). In short, western North American rock art probably was intended to convey a wide array of messages, most of which are not completely understood today.

- Were they trying to convey this message to future civilizations, or to their own people?

Rock art was probably intended to communicate messages with the artist's fellow religious practitioners, or hunters, other members of the artist's family, clan, or tribe, and (in the case of boundary markers and some trail markers) with other groups. Some rock art may have been intended for communication with the supernatural. There is no evidence to suggest an attempt to communicate with future civilizations.

- What has been involved in interpreting the message by modern scholars?

Interpretation of rock art in the American west has involved ethnographic consultation, excavation of rock art sites, photography, rubbings and tracings, and a wide range of comparative analyses.

- How sure are we that we have the message right?

There is little agreement about what messages are embedded in western American rock art. In a few cases, the testimony of ethnographic consultants has generated a fair amount of certainty about the meaning of particular rock art sites (e.g. TRU88).

- If the message had been "Don't dig here because it is dangerous," is it likely that we would have gotten the message before digging there?

In cases where rock art is representational, it is possible that such a message could be transmitted. However, the highly abstract, presumably symbolic, forms that dominate much western American rock art would not be likely to convey such a message readily.

- What physical and environmental characteristics have permitted the monument to withstand the ravages of time and vandalism?

Pictographs survive best when well protected from exposure to the elements. Petroglyphs often survive on exposed surfaces, but do erode and weather. Petroglyphs deeply pecked or polished into very hard rock, like granite, survive best. Pecked and polished petroglyphs survive more readily than scratched or engraved forms. Burial under sand or silt can preserve petroglyphs in almost pristine condition (TUR94). Since human vandalism is a major cause of petroglyph destruction, remoteness from human settlements promotes survival.

- What physical and environmental characteristics have permitted the monument to convey its meaning clearly through the millennia?

On the whole, the meaning of western North American rock art has not been clearly conveyed.

12.2.1.6 Summary Observations on Archeological Analogues

The review of archeological analogues to the WIPP marker system suggests that there are few specific analogues which address all the questions posed in this section. There is little evidence to suggest that the monuments, structures, and other markers discussed above were explicitly intended to convey much -- if any -- information into the distant future. Even highly permanent and seemingly message-rich structures like the various pyramids and the megalithic structures of England and Europe have contemporary functions such as housing the dead, supporting temples, making astronomical observations, and impressing the population with the power of the government or the awesomeness of religious rites. To the extent messages were encoded in the structures, they seem for the most part to have been, or at least are today understood as, fairly simple Level I or II messages, on the order of "the pharaoh who built this structure was very powerful."

Some of the monuments were certainly intended to mark historical events for future reference.

The stelae of the Maya and other Mesoamerican civilizations are an example, as are the painted tombs of the Egyptian pharaohs, Australian rock art, and such Mesopotamian monuments as the Rock of Bihistun. With the exception, perhaps, of markers like the Rock of Bihistun, there is little reason to think that these monuments were meant to convey information to future civilizations that their creators thought would be substantially different from their own. There is little reason to believe that anyone who created a monument in the past designed it with an eye to communication across thousands of years of cultural and linguistic change.

Some monuments do communicate warnings against disturbance, but these have been notably ineffective. Tombs explicitly marked as protected by supernatural sanctions have routinely been looted by treasure seekers and excavated by archaeologists. In almost all cases of archeological analogues, the value of what was contained or hidden was vastly understated, and the threat or hazard was overstated or imaginary. Of course, no one in the past warned against deep drilling, so the possible effectiveness of such a warning cannot be directly assessed.

The review of archeological analogues has produced some information relevant to the WIPP, however, which may be summarized as follows:

1. The "monuments" that have managed to convey fairly detailed information over millennia (e.g., paleolithic rock art, Australian rock art, Egyptian tomb paintings and carvings, Mesopotamian cuneiform inscriptions, and Mesoamerican stelae) have done so because they have been inside something very protective, like a cave, rock shelter, or excavated tomb, or because they have been buried.

2. In some cases of European paleolithic and Australian rock art, images have survived for possibly up to 35,000 years. These images are often portrayed in the very fragile medium of paint.

3. Certain graphic images communicate clearly through the millennia. Anthropomorphic and zoomorphic figures painted on cave walls during the paleolithic period in Europe and Africa and by Australian aborigines and prehistoric Native Americans are easily recognizable as such today. Geometric figures that presumably had symbolic meaning when they were produced, such as intaglios, the Nazca lines, and prehistoric rock art, convey their meaning much less reliably, if at all.

4. Detailed (ca. Level IV) information on ancient monuments has for the most part

survived to the present because it was inscribed or otherwise written on the monuments themselves (e.g., Mayan stelae, Egyptian tombs, Mesopotamian monuments), embodied in a literature that has survived or been recovered (Great Wall of China, pyramids of Egypt, Mesopotamian monuments), or embodied in the oral history and cultural practices of a population that remained resident in the vicinity (Mesoamerican pyramids and other structures).

5. The other major source of information on ancient monuments has been archeological research. This has almost always involved excavation. Excavations conducted in and around such monuments have never reached depths that would compromise waste containment if conducted at the WIPP site. Future excavations could be taken to such depths if archaeologists believe that there is something important to be learned and do not realize the danger of deep excavation.

6. Most ancient monuments have attracted people to dig into or around them in search of treasure or recyclable material, or for purposes of scientific research. An exception is the Chacoan road system, which has not enticed or suggested that it would be profitable to dig. This is because the roads do not convey the impression that anything would be gained by digging in their vicinity.

12.2.1.7 The WIPP Markers Panel Report

In late 1993, DOE published the opinions of two expert panels assembled by SNL to offer advice about the WIPP marker system (SAN93). The recommendations of the panels can be summarized as follows:

Team A

1. Warnings should be conveyed through a gestalt sense of place, through written languages and scientific symbols, and through the use of the human face with expressions.

2. The WIPP and a buffer area should be surrounded by earthen berms, jagged and threatening in shape, to create a threatening sense of place.

3. Within the "keep" created by the berms there should be multiple "message kiosks" containing Level II messages in some seven languages -- the languages of the United

   Nations plus a local indigenous Native American language. The messages should be inscribed on a granite wall protected by a partially encircling "mother wall."

4. Also, a world map should be constructed within the "keep" showing other disposal sites, together with the original WIPP buildings, which should be left to decay. The map should be visible from the tops of the berms.

5. Level IV information should be contained in concrete rooms buried at the four corners of the berm system, designed to permit access but preclude the removal of the information. The information should be inscribed on redundant layers of stone tablets in multiple languages, each tablet being too large to be removed intact through the entryway, which would be blocked by a sliding stone plug.

6. Construction should employ materials that are too large, too difficult, and too worthless to tempt recycling or relocation to museums.

7. Message design should include the use of inscribed pictographs[3] of human faces expressing shock and disgust.

Team B

1. The marking system should employ both surface and buried markers.

2. The messages must be truthful.

3. The outer extent of the marker system should be visible from the center.

4. The area marked should be surrounded by berms, which should not include a buffer area. The berms should be spiked with materials having anomalous properties (e.g. magnetic, radar reflective, dielectric).

5. The warning messages should be conveyed in number of ways so that if one message is not completely understood, the message in another form can be used to fill in the gaps. Messages should be conveyed in multiple languages, scientific symbols, and pictographs. They should be inscribed on stone monoliths and buried in "time capsules."

6. The original WIPP buildings should be left in place for future archeological study, which will preserve knowledge of what was done there.

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[3] The word "pictograph" is often used to mean painted rock art, as opposed to incised, pecked, or inscribed "petroglyphs." Following common WIPP practice, the term is used in a more general sense here, to mean pictures on stone -- in this case, inscribed.

7. Detailed information should be stored off-site.

8. The marker system should include a map showing other disposal sites around the world, and perhaps an international radiation warning symbol.

9. In the center of the marked area there should be a granite structure containing detailed information about the WIPP and its dangers, in both textual and pictograph form, inscribed on large stone slabs.

10. Testing marker designs for durability and cross-cultural understanding should be undertaken between now and the time of implementation.

EPA reviewed the report of the Markers Panel and its recommendations as an aid in what types and to what extent PICs should be required at the WIPP.

12.2.2 NRC Studies

No NRC work on markers has been uncovered in the development of this background information document.

12.2.3 NASA Studies

Four NASA deep space probes which have left the solar system contained symbolic messages for other possible civilizations in the universe. These included the Pioneer 10 and 11 and the Voyager 1 and 2 spacecraft. A gold-anodized plaque on Pioneer uses various symbols to depict the position of our sun relative to various pulsars, the relative size and physiognomy of male and female compared to the spacecraft, and the track of the spacecraft from Earth past Jupiter (NGS75).

Each Voyager spacecraft included a copper disc (protected by an aluminum cover) with greetings from Earth people in 60 languages. The record also contained samples of music from different cultures and ages ranging from the 1958 recording of "Johnny B. Goode" by Chuck Berry to Beethoven's Fifth Symphony and various Earth sounds (NGS90, NASA 77). The record also contained digitized pictures describing the blue planet. Instructions and equipment were included in the spacecraft for retrieving the contained information.

12.2.4 NEA/OECD Studies

In 1990, a Working Group on Future Human Actions at Radioactive Waste Disposal Sites was established by the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD). This group's purpose was to review and summarize work of OECD member countries regarding treatment of future human actions on post closure safety assessments of geologic repositories (NEA93). In discussing site marker systems, the Working Group noted that some markers have already survived for 5,000 years and, consequently, the task of devising markers which will persist and be understood "appears daunting but feasible." The Working Group described surface marker studies conducted by DOE in the United States and Agence National pour la Gestion des Dechets Radioatifs (ANDRA) in France. (DOE work will be documented in Section 2.5 below.) The French approach is based on concern that on-site messages may be misunderstood. Site markers may arouse curiosity and thereby encourage intrusion. The elements of this approach as presented by the Working Group are:

- Markers should not be located directly above the repository, but rather 10 to 20 km away. This distance should limit direct intrusion due to curiosity and allow the markers to be located in the same political and geographical region as the repository itself.

- Markers should be sufficiently large enough to be recognized by any people living in the vicinity of the site.

- Markers should contain redundant messages indicating the exact position of the disposal site. This information should be in a form recoverable by a civilization knowing the basic elements about radioactivity; otherwise, the situation would be equivalent to that for a marker built directly above the repository. Thus, the messages and particularly the location of the disposal site should be encoded, for example, using the symbols and quantities used in nuclear physics.

The Working Group concluded as follows:

> "In summary, the Working Group considers that marker systems can form a useful part of a system of warnings to future generations about the location and contents of the repository. While well-designed markers may be durable and interpretable for long periods of time, the Working Group notes that it will be difficult to take credit for marker longevity for periods much beyond one thousand to several thousand years from repository closure and decommissioning."

The NEA Working Group also met with the WIPP Markers Panel to hear presentations on the expert judgments rendered by the Panel and to audit the probability elicitation session of one of the Markers Panel teams (TRA93).

12.2.5 DOE Studies

DOE has done a significant amount of work on markers for geologic waste repositories. This work falls broadly into two categories:

- Studies in the early 1980s under the aegis of the Office of Nuclear Waste Isolation (ONWI) directed toward repositories for high-level waste (KAP82, HUM84)
- Studies beginning in the late 1980s and continuing today on markers for the WIPP site (HOR91)

Some of the concepts developed in the ONWI work were subsequently considered by DOE for application at a low-level waste disposal site being studied at Hanford, Washington (ADA86). Further information from these two DOE programs is presented in the following sections.

12.2.5.1 ONWI Program

A Human Interference Task Force operating under the direction of ONWI conducted extensive studies on reducing the likelihood of human-initiated processes and events affecting geologic waste repositories. The multi-disciplinary Task Force included members with expertise in law, sociology, political science, nonverbal communication, nuclear physics, environmental science, archeology, climatology, linguistics (and semeiotics), behavioral psychology, materials science, nuclear waste management and engineering (HUM84, SEB84, TAN84).

Assuming a remote, flat, non-glacial site, the Task Force proposed that granite markers about seven meters high and spaced at intervals no greater than 1000 meters should be used to define the perimeter of the site. The monolithic triangular pyramids would be inscribed with appropriate messages and warnings in several languages, supplemented with symbols and pictograms. The site would also be centrally marked with three large triangular monuments defining the location of three granite storage vaults where site records would be stored.

The Task Force suggested that these markers could be supplemented with earthworks and anomalies capable of being detected by remote sensors. Recommended earthworks included an arrow-shaped central plaza about 100 meters across and several meters high, on which are located the central markers and storage vaults described above and a segmented berm located several hundred meters from the central plaza, as shown in Figure 12-2. To enhance the durability of these earthworks, the Task Force suggested that they be covered with 0.15 to 0.30 meters of an aggregate asphalt mixture. This proposal was based on the fact that natural asphalts have been used since antiquity. This protective layer would also hinder growth of vegetation on the earthworks. Because various materials would be used in constructing the central plaza, it should create an anomaly which would remain recognizable by several remote sensing techniques.

The Task Force reached no conclusions as to the effectiveness of markers and other measures to reduce the likelihood of human intrusion. The Task Force noted that any such conclusions must be based on site-specific analysis. These analyses should use probabilistic assessment techniques to estimate the effectiveness of a highly redundant system even though some elements may fail. The Task Force observed that the expected longevity of earthworks, monuments and vaults was a subject requiring further investigation.

Figure 12-2. ONWI Conceptual Design of Site Markers for Geologic Repository

12.2.5.2 WIPP Program

In a 1979 study conducted by the WIPP Technical Support Contractor (WTAC) for DOE, crude probabilistic estimates were made of the time over which monuments and records would persist beyond the period of effectiveness for active institutional controls (BRA79). The probabilistic estimates were based on considerations such as the observations that records of land ownership and transferral in the U.S. can be traced back to the 1700s, and grave stones in U.S. cemeteries are still legible after about 300 years. From this type of anecdotal evidence, it was estimated that there was a 50% probability that markers would persist for 200 years beyond active institutional controls. There was also a 50% probability that accessible records would be available for 110 years after markers were lost. The study assigned a 95% probability to the postulate that active institutional controls would last for 100 years. It was also assumed to be likely that economically recoverable hydrocarbon resources would be depleted by the time that active and passive institutional controls were lost. However, it was presumed that a 50% probability of drilling at the WIPP still existed for a 50 year period beyond loss of institutional controls. Based on these assumptions, the time of isolation was calculated to be at least 450 years with 50% probability. Probabilities of various isolation periods are summarized in Table 12-1.

Table 12-1. Isolation Times Prior to Drilling in the WIPP Site Area

Probability[a]	Time of Isolation (years)
0.50	450
0.90	300
0.95	250
0.98	200
0.99	150

[a] Probability that Time of Isolation beyond active institutional controls is at least this duration.

The credit for active and passive institutional controls estimated in the WTAC study is relatively short compared to the 10,000 year containment period required by 40 CFR part 191. More recently, in support of its WIPP-related PA activities, DOE and SNL organized four teams of experts (the Futures Panel) to provide judgments on the probability of future human-

initiated processes and events. The Southwest Team of experts cited an instance in their summary report where marking of a radioactive location near WIPP has been vitiated (HOR91, p. D-15). Under the aegis of the Plowshare Program (see 12.2.5.3 for more detail), an underground nuclear detonation was conducted in 1961 at the Gnome Test Site, about six miles from the WIPP. The test was performed in a bedded salt formation at a depth of about 1,250 feet, as compared to the WIPP repository depth of 2,150 feet. The Gnome Site was marked with a single monument which, according to the Southwest Team, already shows signs of weathering and has shifted from its original location.

WIPP Markers Panel.[4] Using a formal process similar to that involved in setting up the Futures Panel, SNL organized an expert judgment panel called the Markers Panel 1991. The panel served the following two purposes:

- Qualitative - to develop design guidelines for markers and messages needed to communicate with future societies concerning the location and dangers associated with buried TRU wastes at WIPP.

- Quantitative - to estimate the probability that markers would survive for the required time period and convey the intended message.

The Markers Panel was divided into two multi-disciplinary teams with expertise in such areas as anthropology, materials science, architecture, linguistics, environmental engineering, astronomy, semeiotics, archeology, and communications. Each team developed a total marker system design which addressed architectural design, material properties, linguistics, message levels, message media, and other marking components (e.g., international symbols and standards). Based on the conceptual marker systems, each team was asked to estimate probabilistically:

- the durability of the marker system for various periods up to 10,000 years

- the ability of future societies to understand the message embodied in the marker system

The teams were asked to assume three different levels of technology in future society; higher

[4] See also Section 6.2.1.7.

than current levels, at current levels, and lower than current levels. In assessing these probabilities, Team A divided the regulatory future into time periods of 200; 500; 1,000; 5,000; and 10,000 years after closure of the WIPP repository while Team B considered periods of 500, 2,000 and 10,000 years after closure. Each member of Team A developed individual probability estimates while Team B developed a consensus estimate. Results of these expert elicitations, reproduced from Reference SAND 93, are included as Tables 12-2 and 12-3.

Team A's estimates that the marker system would persist for 500 years ranged from 0.85 to 0.99. The lowest probability estimates are for a society where a high level of technology is dominant. Some Team A members felt that such a society might be able to remove the entire WIPP repository markers. Presumably, they would understand the consequences of such action. Team B estimated the probability of marker persistence after 500 years to be 0.9, independent of the state of technology.

While both teams estimated that there was a high level of probability that the marker system would persist for a considerable period, it should be noted that the Panel was directed to exclude cost as a factor in the conceptual marker system designs (TRA93, p. F-21). The extent to which the elicited probabilities would be reduced if a cost perspective was included is unknown, but interviews with some of the members of the Markers Panel suggest that this should not have a significant effect. The materials proposed for the marker systems are of intrinsically low cost. What is not clear is whether the design and construction are also of relatively low cost. They may not be.[5] One member of Team A observed that a successful marker system at WIPP "will have to be one of the greatest public works ventures in history." This statement was predicated upon more elaborate earthworks than the Team A consensus recommendation. If DOE is to take credit for a marker system capable of persisting for several millennia, DOE must be prepared to make a concomitant obligation for the construction of such a system. A scenario developed by one of the Futures Panel teams posed the possibility that a future bureaucracy functioning in the year 2020 might become embroiled in a major debate on closure costs and choose to authorize only a modest marker system (BEN91). The scenario, as outlined from the perspective of someone recounting the debate 25 years hence, is as follows:

[5] The NKS Working Group KAN-1.3 indicated that the structures proposed by the WIPP Markers Panel might cost tens of millions of dollars (NKS93).

> "The markers recommended by a panel of experts convened by the now defunct Department of Energy in 1990 are widely viewed as extravagant in view of the fact that the WIPP repository has not been used to capacity and is such a controversial topic. It now seems unlikely that the site could ever be forgotten, its potential hazard is thought to be less than originally foreseen, and it seems politically dangerous to advocate large sums of money for it in view of the pressing current social problems which followed the costly conventional weapons buildup of the 1990s. After protracted debate lasting several years, Congress finally appropriates money for the markers, although design compromises must be made because it is not enough to pay for the extensive marker system envisioned in 1990."

In reviewing such a scenario, EPA recognized a more probable future argument in which an elaborate system of PICs had been described in a long ago compliance application because they were, “the right thing to do.” The Department of the future was tasked with justifying the expenditures of limited funds so that they could provide the most protection for the public and the environment. Without a documented and quantifiable benefit to justify implementing such a system, more pressing needs with quantifiable benefits could take priority.

In eliciting expert judgment as to the probability that the message contained on/in the markers would be correctly interpreted by future intruders, various levels of technology and various time periods were considered in a manner similar to that used to assess the probability of marker persistence. In addition, five conceivable motivations for intrusion were appraised including drilling for water, mineral exploration, drilling to create injection wells for waste disposal, archeological investigation, and other scientific investigation. Generally, the panelists grouped the first three intrusion modes together and treated the last two as a second group. Probabilities estimated by the two panels for intrusion driven by mineral exploration are summarized in Table 12-4 (TRA93).

Table 12-2. Probabilities of Marker System Persisting - Team A

Expert	Dominant Technology	Years After Closure				
		200	500	1,000	5,000	10,000
Ast	High	.99	.98	.95	.75	.50
	Medium	.99	.98	.95	.75	.60
	Low	.99	.98	.95	.75	.60
Brill	High	.99	.98	.95	.70	.50
	Medium	.99	.98	.95	.70	.50
	Low	.99	.98	.95	.85	.80
Goodenough	High	.99	.98	.90	.85	.70
	Medium	.99	.98	.95	.90	.75
	Low	.99	.98	.98	.95	.80
Kaplan	High	.95-.99	.95-.99	.90-.95	.80	.70
	Medium	.95-.99	.95-.99	.90-.95	.80	.70
	Low	.95-.99	.95-.99	.90-.95	.90	.85
Newmeyer	High	.90	.85	.70	.65	.60
	Medium	.95	.90	.85	.80	.60
	Low	.95	.90	.85	.85	.65
Sullivan	High	.90	.85	.80	.70	.50
	Medium	.95	.90	.85	.80	.70
	Low	.95	.90	.85	.80	.70

Source: Table 5-1 TRA93

Table 12-3. Consensus Probabilities of Marker System Persisting - Team B

Dominant Technology	Years After Closure		
	500	2,000	10,000
High	.90	.85	.85
Medium	.90	.80	.60
Low	.90	.70	.40

Source: Table 5-2 TRA93

Table 12-4. Probability of Correct Interpretation of Marker Message Intrusion by Mineral Exploration

Expert	200 Years Technology =			500 Years Technology =			1,000 Years Technology =			5,000 Years Technology =			10,000 Years Technology =		
	H[a]	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Ast	.99	.99	.98	.98	.95	.70	.95	.90	.50	.90	.20	.10	.90	.20	.05
Brill	.99	.99	.95	.95	.95	.90	.95	.95	.70	.95	.95	.60	.95	.95	.50
Goodenough	.99	.99	.99	.95	.95	.70	.90	.90	.50	.65	.60	.15	.50	.40	.02
Kaplan	.99	.98	.95	.98	.90	.70	.97	.85	.65	.95	.80	.50	.90	.75	.02
Newmeyer	.99	.99	.90	.90	.85	.80	.80	.70	.50	.70	.60	.40	.50	.30	.20
Sullivan	.95	.95	.80	.90	.90	.60	.85	.85	.40	.70	.70	.10	.40	.40	.01
Team B	500 Years			2,000 Years			10,000 Years								
	.90	.90	.80	.90	.85	.70	.99	.80	.30						

[a] The levels of technology being more advanced than today (H), similar to today's level (M), and less advanced than today (L).

Source: Table 5-4, TRA93

Turning again to Team A's 500 year estimates, it can be seen that the probability of correct interpretation of the marker message ranged from 60 to 90% for a technologically less advanced society to 90 to 98% for a technologically more advanced society. On the same basis, the Team B probability estimates ranged from 70% to 90%. Higher probabilities were assigned to understanding the marker message by potential intruders seeking archeological or other scientific knowledge.

If one averages the individual Team A estimates and then averages Team A and Team B estimates, the probability of correct interpretation of the marker message by a future society conducting mineral exploration with the same level of technology as today is 0.91 at 500 years after closure. Performing the same type of averaging for marker system persistence, the probability that the system will persist at the current level of technology after 500 years is 0.93. The probability that the markers will persist and that their message will be correctly interpreted is therefore 0.84.

The Markers Panel recommended to DOE that additional study is warranted in three areas:

- Durability of marker materials under the WIPP site conditions including the mechanism for attaching or inscribing messages and the interaction of wind, sand, and water with marker materials and configurations
- Interpretation of graphic or pictorial messages that are independent of culture
- Interpretation of written messages that are independent of culture

EPA did not review the Markers Panel Team's results in order to apply numerical values to credit for PICs or even develop a credit methodology. Instead, EPA noted the great variability and uncertainty in the efforts of the two teams.

12.2.5.3 Project PLOWSHARE and Related Tests

The Atomic Energy Commission (AEC) established the PLOWSHARE program in June 1957, under the technical direction of the Lawrence Radiation Laboratory (LRL), now Lawrence Livermore National Laboratory (LLNL). The program consisted of 27 nuclear detonations conducted at the Nevada Test Site (NTS) and other sites in Colorado (2) and New Mexico (2) from 1961 to 1973. The nuclear tests were all underground, either shaft or

cratering shots, and had yields of no more than 200 kilotons. The PLOWSHARE nuclear detonations were designed to explore nonmilitary applications of nuclear explosives. The primary potential use envisioned was in large-scale engineering projects such as canal, harbor, and dam construction, the stimulation of oil and gas wells, and mining.

The 1963 atmospheric nuclear test ban treaty caused cancellations of many of the plans, such as those for dredging canals and excavating harbors. Other factors contributing to the failure of PLOWSHARE to fulfill its goal were changes in national priorities, Government and industry's disinterest in the program, public concern over the health and safety aspects of using nuclear power for civil applications, and shortages in funding. Several other underground nuclear tests (Vela Uniform Events and weapons tests) were also conducted away from the NTS. A total of 11 underground nuclear tests were conducted at locations other than the NTS since the beginning of testing through December 1973.

Comments on a few of these tests relevant to human intrusion and PICs are discussed below.

Project Gnome:

Project Gnome, a shaft detonation, was fired on December 10, 1961, at a site 40 kilometers southeast of Carlsbad, New Mexico. The site was in the Salado formation of the Delaware Basin. This geologic formation consisted primarily of halite (rock salt), with minor traces of anhydrite, polyhalite, silt, and claystone. The top of the salt formation was approximately 710 feet below the site surface. The device was buried 1,184 feet underground in bedded rock salt at the end of a 1,116-foot hooked tunnel meant to be self-sealing. A shaft 1,216 feet in depth and ten feet in diameter ended in a station room connected to the tunnel. The detonation, which had a yield of 3.1 kilotons, resulted in an underground dome-shaped chamber 60 to 80 feet high and 160 to 170 feet in diameter.

All Gnome site decontamination and decommissioning activities were completed and terminated on September 23, 1979. A concrete and bronze monument was erected at the Gnome surface ground zero location as an historical marker. The following wording was inscribed on two bronze plates:

Historical plate:

United States
Atomic Energy Commission
Dr. Glenn T. Seaborg, Chairman

Project Gnome

December 10, 1961

The first nuclear detonation in the Plowshare Program to develop peaceful uses for nuclear explosives was conducted below this spot at a depth of 1,216 feet in a stratum of rock salt. The explosive, equivalent to 3,100 tons of TNT, was detonated at the end of a horizontal passage leading from a vertical shaft located 1,116 feet southwest of this point. Among the many objectives was the production and recovery of useful radioactive isotopes, the study of heat recovery, the conduct of neutron physics experiments, and the provision of seismic source for geophysical studies.

Restrictive plate:

No excavation and/or drilling is permitted to penetrate Section 34, Township 23 South, Range 30 East, New Mexico Principal Meridian, at any depth between the surface and 1,500 feet. (DOE81)

If Section 34 is leased, a "special stipulation" is to be put into the lease by the U.S. Geological Survey (USGS). This stipulation would require the drilling operator to abide by the lease stipulation to protect the area between the surface and 1,500 feet below the surface; no exceptions are to be allowed. The BLM is to ensure that no drilling or excavation will occur.

Project Rulison:

Project Rulison was an experiment co-sponsored by AEC and Austral Oil Co. to determine the technical and economic feasibility of using nuclear explosives to stimulate the flow and recovery of natural gas from the Mesa Verde formation in the Rulison Field, Garfield County, Colorado. The test, conducted near Rifle, CO on September 10, 1969, consisted of a 43 kiloton nuclear explosive emplaced at an 8,426 foot depth. Production testing began in 1970 and was completed in April 1971. Cleanup was initiated in 1972 and wells were plugged in 1976. Some surface

contamination resulted from decontamination of drilling equipment and fallout from gas flaring (burning). Soil was removed during the cleanup operations.

Project DRIBBLE:

Project DRIBBLE was comprised of four explosive tests, two nuclear and two gas. It was conducted in the Tatum Salt Dome area of Lamar County, Mississippi, near the communities of Baxterville and Purvis, under the Vela Uniform Program. The purpose of Project DRIBBLE was to study the effects of decoupling on seismic signals produced by explosives tests. The first test, SALMON, was a nuclear device with a yield of about 5.3 kilotons, detonated on October 22, 1964, at a depth of 2,710 feet. This test created the cavity used for the subsequent tests, including STERLING, a nuclear test conducted on December 3, 1966, with a yield of about 380 tons, and the two gas explosions, DIODE TUBE, conducted on February 2, 1969, and HUMID WATER, conducted on April 19, 1970.

The nuclear tests resulted in the release of radioactive elements into the salt rock. Although most of these radioactive elements remain in the salt dome, some contamination in the form of radioactive drill cuttings, drilling muds, and water was brought to the surface during the drilling of boreholes into the shot cavity. Today, the Tatum Dome Test Site has largely returned to its original state. Except for the monument the U.S. Department of Energy erected over the location of the actual subsurface detonations (called Surface Ground Zero), there is little indication of any of the past activities at the site. The areas where soils were excavated have been backfilled and seeded and now have a well established cover of vegetation. Wildlife is abundant at the test site and the area is used for timber production and hunting.

Although the residual levels of radioactivity remaining at most of the test sites are not extensive enough or high enough to pose an imminent or substantial risk to the environment or public health, DOE, in conjunction with EPA and the involved states, has continued to investigate and monitor the sites. These continued investigations are driven, in part, by the environmental laws of the states and federal governments and, in part, by the concerns that have been raised by the public with respect to the safety of the sites. For example, U.S. Senator Lott identified four major issues related to the Tatum Dome Test Site in an October

1989 letter to the U.S. Department of Energy. One of those issues was: "The control of access to Surface Ground Zero"(DOE93b).

In addressing Senator Lott's issues, DOE has committed to conducting additional investigations and studies at the Tatum Dome Test Site. As such, DOE will conduct a Remedial Investigation at the site to determine if the use of the nonradioactive hazardous substances at the site has resulted in contamination of the soil, groundwater, or surface water. A feasibility study will also be performed to determine what measures can be taken to reduce risks associated with the site. One of the measures that will be evaluated is the need for fencing of the site to maintain institutional control over access to the facility.

The routine annual site visits by the Environmental Monitoring Systems Laboratory include groundwater, air, and biological sampling. Results are reported annually in EPA's Off-site Environmental Monitoring Report.

As to how much radioactivity was released and how much is left, the Nevada Environmental Restoration Project (ERP) is presently sponsoring a determination of this for all underground tests at the NTS. This work is being performed by the LLNL and the LANL. To date, similar work for NTS off-site tests has not been funded. For the NTS on-site tests, ERP personnel are calculating inventories of fuel, fission products, and activation products initially and at the end of 1992. The work and calculations for the NTS on-site PLOWSHARE are probably complete by now, however, the results are classified, but DOE/NV expects to declassify summaries (DOE94a).

All NTS off-site PLOWSHARE sites have been decommissioned. This has included plugging wells into the cavities and cleanup of surface structures and waste sites. Remedial investigations/feasibility studies are being conducted. Monuments were erected at Gnome and the Tatum Dome sites warning against excavating at the sites. Similar warnings were attached to the property deeds. Status of site markings at the other NTS off-site locations is not well documented and is currently being investigated (DOE94b).

12.2.6 No Marker Strategy

§191.14 requires sites to be "designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location." In spite of this regulatory admonition to mark the WIPP site, some have argued

that a no-markers strategy is preferable and some have argued that markers should be located away from the site of the repository.

The presence of markers on which the meaning of the inscriptions has been lost might create a desire by future archaeologists to understand the function of the site. This desire could result in intrusion. The markers could constitute an, “attractive nuisance”, encouraging intrusion. Kaplan suggests that a marker with a so-called Level I message which serves solely as an attention-getter might have this result (KAP82). She also suggests that such a situation could be avoided if a Level II message is conveyed which is both an attention-getter and a warning ("something is here and it is dangerous"). Kaplan points out that an earthwork marking a site may convey only a Level I message. But, if the earthwork were in the form of a recognizable hazardous/radioactive waste symbol, the marker could reduce the likelihood of human intrusion rather than serve as an invitation to future intrusion. However, Givens remarks that prohibitions, curses, and other dire warnings have been "sorry failures" in deterring tomb robbers (GIV82).

The no-marker strategy was rejected by the WIPP Marker's Panel and the NKS Working Group KAN-1.3, but the working group report did not elaborate on the basis for their decision (JEN93). It should also be noted that the recent NAS report on the Yucca Mountain high-level waste repository briefly states a conclusion about the desirability of marking a repository site (NAT95, p. 108), namely:

> ... passive markers could attract the curious and actually increase the risk of intrusion. Nonetheless, we conclude that the benefits of passive markers outweigh their disadvantages, at least in the near term.

As discussed below, two of the four teams on the WIPP Futures Panel recommended that consideration be given to not marking the site, or at least not employing surface markers, out of concern that markers would draw attention to the site and possibly encourage curiosity seekers (below-grade markers could still be detected by and warn off technically advanced societies). However, both teams on the Markers Panel rejected that advice and concluded that the site must be marked in some manner, including surface and sub-surface markers, to reduce the risk of inadvertent intrusion.

The French national waste management authority, ANDRA, has expressed similar concerns to those of the two Futures Panel teams. ANDRA has suggested that markers might be

misunderstood by persons in a future society that lacked a knowledge of radioactivity, engender curiosity in such persons, and, if the society was sufficiently advanced to have deep drilling capabilities, lead to human intrusion into the repository. ANDRA proposes an alternative marking strategy in which markers would be placed off-site and information about the location of the repository encoded so that it could only be recovered by a civilization understanding basic elements of radioactivity. This strategy will be discussed in greater detail subsequently.

The WIPP Markers Panel did not consider the use of off-site markers nor (apparently) review the ANDRA proposal.

12.2.6.1 Futures Panel

The 1991 Futures Panel for the WIPP site (HOR91) consisted of four separate review teams (Boston, Southwest, Washington A and Washington B). On the issue of markers, two teams—Boston and Southwest—recommended that consideration be given to <u>not</u> marking the WIPP site. The Boston Team recommended as follows (HOR91, pp. C-68 to 69):

> The marker panel should consider the possibility of not marking the site. There is at least some reason to believe that markings of any kind will be attractive to a future society and draw special attention to the region of WIPP. Most of the potential intrusions we studied would, if truly inadvertent, be extremely unlucky to penetrate the repository by chance. For example, without knowledge of the specific location of the transuranics at WIPP, a future wild cat driller would have an extremely small chance of hitting the wastes stored at WIPP. We ask that the marker panel at least consider whether the small risk of a coincidental penetration is more or less favorable than attracting attention to the site with permanent markers. (Another panel on hearing this recommendation suggested subsurface markers - no markers on the surface - but clear markers underground near the site.)

This recommendation was based in part on various intrusion scenarios the team postulated. For example, the team postulated one scenario in which institutional memory of WIPP is lost but local folklore holds that something valuable was dumped in the area years ago. "Treasure hunters" locate the markers and interpret them as warning people to stay away from the treasure, confirming their conviction that they choose the correct site to dig for the treasure.

> The markers had an effect opposite to that intended by the WIPP designers: the treasure hunters understood the warnings as confirming their selection of the site as

containing something valuable and they started to excavate. As they encountered

additional warning markers on different levels, they became increasingly convinced that they had picked the correct location. (p. C-45)

The Southwest Team Report within HOR91 made similar recommendations (p. D-44):

- **No-marker strategy?** Consider a "no surface marker" strategy, or a "soft" marker which erodes in a few centuries, to meet short-term marking needs. Hidden markers could still be placed underground. This avoids attracting curiosity seekers, yet the hidden markers below can warn off high technological societies. The risk lies in the Seesaw Scenario, since wildcatters in a reviving era receive no warning at all.

- **To Mark or Not to Mark:** The crucial decision confronting the Marker Panel is whether to use surface markers at all. A "soft" surface marker which erodes in a few centuries will cover the short-term possibilities, and then avoid curiosity seekers in the far future. High technologies will still be able to sense the buried markers.

  Much of the Egyptian legacy came from King Tut's tomb, the only major unviolated burial site. It was covered by the tailings of a later tomb. Unmarked, it escaped the grave robbers.

  But not marking the WIPP imposes ignorance on our descendants, who may wish to avoid the site but could no longer locate it well. Also, low-tech wildcatters in re-emergent technological societies would have no warning.

12.2.6.2 Markers Panel

The 1993 "Markers Panel" report for the WIPP site (TRA93) was based on two expert panel reports: Team A (AST92) and Team B (BAK92).

Section 1.3 of AST92 addressed the question -- "Should the site be marked?" -- and concluded:

> We... feel that it is essential that the WIPP site be marked in some manner, and cannot agree with the conclusions of two of the Futures panel teams and other authors [ROC77][6] which suggested not marking it. We take it as uncontroversial that all people have an inherent right to understand as far as possible the forces that might profoundly affect their well-being...

Similarly, the preface to BAK92 states that the panel reached a unanimous opinion that:

> The site should be marked, on the assumption that leaving it unmarked would pose greater risks to the future. Current mining activities in the area, alone, would make the choice of not marking extremely risky for present-day (i.e., living) humans, and cumulatively more dangerous for those living between now and 12,000 A.D. At present the WIPP is in an area of active oil production, gas production and potash mining...Surface and buried markers should be used in tandem to enhance message redundancy...Only the land directly above the waste panels themselves -- about a ½ square-kilometer area -- should be marked. (A) this would put the marker system on a cognitive scale better geared to human perception than one spread thinly over 16 square miles. (B) Additionally, it would reduce confusion that could arise from boring beneath a marker system beyond the panels and uncovering nothing unusual....

AST92 stated as one of its criteria for the marking system that:

> The site must be marked. Aside from a legal requirement, the site will be indelibly imprinted by the human activity associated with waste disposal. We must complete the process by explaining what has been done and why. (p. F-11)

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[6] ROC77 states: "Intelligent life is notoriously incautious in indulging its curiosity. Construction of a large concrete mausoleum, for example, would almost guarantee that concerted efforts would be made to breach it by intelligent, but uninformed, life. On social grounds, such a method is held to be quite reversible. Additional irreversibility cannot be provided by warning messages, symbols, or labels. We cannot assume that even a society that has the technology to undo rather irreversible storage will know enough about radioactivity to proceed cautiously, or that it will be able to decipher a message it cannot read... Indeed, the presence of such an indecipherable message would only arouse additional interest. 'Interesting' geological formations such as salt domes are equally likely to draw attention. The society that drills into them may know nothing of radiological hazards, but still be sufficiently advanced technologically and scientifically to be curious about the formation itself and its possible contents... A condition for site location that aids irreversibility is that it be as uninteresting as possible, and so draw no attention for other reasons." (p. 27)

In other words, the site's presence will be detectable whether or not it is marked. The report states that:

> so much buried metal and radioactive material will leave a 'signature' that scientists of the future will have no difficulty in detecting. What we need to do, of course, is to 'complete' the marking by letting them know why it is there. Also, it is projected that after settling of the excavated and filled salt deposits, ground levels will be depressed by at least a half foot. Even today's geologists and archaeologists can detect such a depression; those of the future will presumably be able to do so even more readily. (p. F-24)

12.2.6.3 ANDRA Off-Site Marker Concept

Discussions in an OECD Nuclear Energy Agency working group on human intrusion inspired work in France on a different design for marker systems (NEA95). The design was motivated by concern that on-site messages may not be correctly understood, and that the markers may arouse curiosity and actually increase the risk of human intrusion.

A paper by the French national waste management authority, ANDRA, describes a concept for off-site markers based on the reasoning outlined below (RAI93). (The paper notes that a report published in 1987 by a special working group in France recommended a study of the potential benefits as well as disadvantages of marking nuclear waste repositories (GOG87). The ANDRA paper notes that some of the participants in this working group defended the concept of marking the surface of a repository site, but others remained unconvinced, which was the basis for the study.)

In RAI93, ANDRA considered three options:

1. Markers built directly above the disposal site
2. Leaving the site unmarked and allowing its existence to be forgotten
3. Markers built off-site

The ANDRA researchers explained the justification for off-site markers as follows:

> ...if messages are misunderstood or not understood at all, the marker may stir up

curiosity as a probe of an ancient civilization or valuables. It could therefore increase the probability of human intrusion in the sense that it is only useful to prevent inadvertent intrusion and not intrusion due to curiosity. Other possibilities have thus to be thought out.

We propose a different marking system that presents the advantages of a marker but do (sic) not increase the risk of intrusion: the marker is not located directly above the disposal but several kilometers away. It is monumental enough to resist to erosion and to be known by any people living around, but it is far enough from the site to prevent any intrusion due to misunderstanding of the messages and therefore to curiosity.

We think that 10-20 kilometers away from the site would be a good distance since the marker and the site have to be in the same geographical and political region. (p. 217)

The ANDRA authors propose to describe both the contents and the location of the repository in messages written on the marker. However, they would encode the message about the location so that the information would only be recoverable by a civilization knowing basic elements about radioactivity (such as by encoding with symbols and values commonly used in nuclear physics). In this manner, a civilization unable to understand the message regarding the dangers of the repository would not be lured to dig there.

The core of ANDRA's analysis is an evaluation of the probability of human intrusion resulting from inadvertence or misunderstanding of markers, as a function of technological level, for each of the three marker concepts. The analysis is summarized as follows:

- At a low technological level, there is a low potential for human intrusion regardless of the marker concept because humans would not have the capability to drill deep into the repository.

- At an intermediate technological level, humans would have the capability to drill deeply but would not have an understanding of radioactivity.[7] Because of the capability to drill, the risk of inadvertent human intrusion is higher than at the low

[7] The authors suggest that this technological level corresponds to the period from the Roman era, when 400 m-deep mines were dug, to the end of the 19th century, when radioactivity was discovered.

technological level even if the site is not marked. If the site is marked, there is an additional risk that the message will be misunderstood and will actually encourage human intrusion. (This analysis assumes that the net effect of on-site markers for this technological level is negative: the probability that the markers will be misunderstood and will encourage intrusion is much greater than the probability that the markers will be understood and will prevent inadvertent intrusion.)

- At a high technological level (equal to or greater than our own), the encoded messages would be understood. Either an on-site or off-site marker will prevent inadvertent intrusion. The risk that an on-site marker will be misunderstood and encourage intrusion is also eliminated, making the effectiveness of on-site and off-site markers equal. Both marker concepts are preferable to no marker because they prevent inadvertent intrusion.

In effect, ANDRA separates the analysis of the potential for human intrusion into different cases depending on technological level, and finds very different results for intermediate and high technological levels. The ANDRA researchers agree that markers prevent inadvertent intrusion if civilization is sufficiently advanced to understand them, but feel that such prevention can be equally achieved through off-site markers that would not invite a less advanced civilization to explore the site out of curiosity.

EPA did not reconsider the "no markers" option because markers are an established and codified requirement. The same arguments that were used to support the "no markers" argument could be applied to the "no credit" argument. However, the Agency found that the primary responsibility was to require that the site be marked with markers that had the highest probability of surviving, being understood, and therefore protecting the public and the environment.

12.3 PUBLIC RECORDS AND ARCHIVES

This section discusses the use of public records and archives as passive institutional controls. Such controls are designed to increase the probability that institutional knowledge of the WIPP repository will not be lost by future societies. This section deals specifically with records and archives located away from the repository site. With regard to the types of records to be considered for archival purposes, the NKS Working Group has suggested the

following (JEN93):

- Geographical location of the repository
- Chemical and physical properties of the waste
- Design of the repository including physical shape and barriers
- Background information and data used in the final safety (risk) assessment
- Various background materials including the final safety assessment, laws and regulations, general information from and about society, and operational records of the repository

12.3.1 Regulations

12.3.1.1 WIPP Land Withdrawal Act (LWA)

Under the terms of the WIPP LWA, 16 square miles of land around the WIPP site are withdrawn from all forms of entry, appropriation, or disposal under the public land laws. According to Sec. 3(c), of the LWA, Land Description, the boundaries of the land withdrawn for the WIPP site are described on a map, issued by BLM which is entitled "WIPP Withdrawal Site Map," dated October 9, 1990, and on file with the New Mexico State Office of the BLM. Under the LWA, the Secretary of the Interior is required to publish a description of the withdrawal area in the *Federal Register* and to file copies of the legal description of the withdrawal area and the site map with the U.S. Congress, the Governor of the State of New Mexico, the Secretary of Energy, and the Archivist of the United States.

On November 24, 1993, BLM published a description of the WIPP in the *Federal Register* as required by the LWA (57 FR 55277). The notice is included as Appendix 12A. BLM also submitted the required documentation to various governmental organizations on November 16, 1992. A sample transmittal letter is included as Appendix 12B. (While this information was supplied to the Archivist of the United States and presumably has been filed, the existence and location within the Archives have not been uncovered in spite of numerous inquiries.)

12.3.1.2 40 CFR part 194

§194.43 specifies that the compliance certification application include a detailed description of plans for the "placement of records in the archives and land record systems of local, State, and Federal governments, and international archives, that would likely be consulted by individuals in search of unexploited resources." The records must identify:

- The location of the controlled area and the disposal system
- The design of the disposal system
- The nature and hazard of the waste
- Geologic, geochemical, hydrologic, and other site data pertinent to the containment of waste in the disposal system
- The results of tests, experiments, and other analyses pertinent to the containment of waste in the disposal system

12.3.2 Historical Perspective on Use and Survivability of Records

Although records describing the WIPP site have been filed with various government agencies, the key question to be asked is "Will these records persist and for how long?" An essential element in the efficacy of records as a component in a passive institutional controls strategy is survivability of the records. Written or pictographic records have endured for almost 6,000 years. Sumerian inscriptions have been documented on stone dating from about 3600 B.C. and on clay tablets from about 3200 B.C. Egyptian hieroglyphics on various monuments date from about the same time. The famous Code of Hammurabi was inscribed on diorite in about 2100 B.C. (DUR54). Written Chinese, which dates to the Shang dynasty (1766-1123 B.C.), has remained substantially unchanged over the millennia.

Various investigators have suggested that records be located in numerous locations and include several vehicles such as maps, land-use records, geological surveys, and archival facilities (TAN84, GIL85, GIV82). This redundancy in record keeping will increase the probability that records will survive at some location. Even so, Tannenbaum has observed that storage materials may not last for the required 10,000 years; therefore, records must be periodically reproduced and perhaps translated into contemporary language (TAN84). Such

reproduction will require the existence of a "responsible institutionalized authority" to periodically undertake this reproduction and revision. Since the availability of long-term record-keeping materials and the existence of a responsible authority to maintain records for

the entire regulatory period are questionable, the future availability of repository records in useful form for the entire regulatory period is also questionable.

Gillis mentions a downside to record-keeping redundancy (GIL85). Dispersal of the information to ensure its survivability may reduce detectability by persons at the site for whom it is most relevant.

A second key question regarding records is whether they will be understood if they do survive. These are the same key questions which must be answered with regard to markers. The example of the Rosetta Stone, a three language monument used in unlocking Egyptian hieroglyphics, is often cited as an example of how maintenance of records in several languages will promote future understanding (KAP86). However, as Givens has pointed out, translation may be accomplished "at the expense of years of sometimes painful decipherments" (GIV82). He also notes that some ancient scripts remain undeciphered even today, citing Mayan, Indus Valley, Minoan Linear A, Germanic and Turkish runes, and certain African scripts. With regard to the use of icons to covey messages, Givens observes that even the most simple and obvious iconic signals left by antiquity may not be completely understood by a future society.

Seboek also takes issue with use of the Rosetta stone as a "success story" vis-a-vis language redundancy as an aid to communication with future societies (SEB84). He observes that, although the stone's importance was instantly identified as a possible key to deciphering hieroglyphics upon its discovery in 1799, its "mere existence .... did not make solution automatic." The puzzle was not solved until 1822. Kaplan takes a more optimistic view of the deciphering of the Rosetta stone, noting that one month after the stone was made available to scholars, the Greek text had been translated and presented at a scientific meeting (KAP82). This certainly argues for a multiple language approach.

The NEA Working Group cited historical examples, drawn from French experience, of lost records (NEA93). In the civil war of 1870, a fire in the Tuileries Palace destroyed archives relating to Paris. In World War II, many records were destroyed during bombing raids.

These examples reinforce the need for worldwide, redundant record storage. Despite past problems, the Working Group felt that it was reasonable to assume maintenance of records for 500 years.

The Nordic Working Group KAN-1.3 commissioned studies on German archives in the 20th century and the Vatican archives since their inception (JEN93). Both studies provided examples of major losses of archival information as well as successful attempts to protect and shelter the information. In the German study, the interesting observation was made that many losses occurred after World War II. The German people, driven by extreme poverty, found paper in the poorly guarded archives to be useful for such basic needs such as fuel or wrapping groceries. The NKS Working Group deduced from these studies that loss of archival information is often engendered by forces different from or external to the institutions which created the archive. Accordingly, they concluded that "an international and internationally respected archive would represent a robust strategy." The Working Group suggested that IAEA might be a candidate archive manager.

12.3.3 Survivability of Land Ownership Records

12.3.3.1 Introduction

EPA disposal regulations include a requirement that "[d]isposal sites shall be designated by the most permanent . . . passive institutional controls practicable to indicate the dangers of the wastes and their location."[8] The definition of PICs includes "public records," which incorporate state and federal land records. The issue presented in this section is whether existing state and federal land records will effectively delineate the WIPP so as to provide the most "permanent . . . passive institutional controls practicable."

If the benchmark of "practicable permanence" is the time period over which cumulative releases are to be limited, there are innumerable complexities and uncertainties. Use of historical analogues is largely inadequate to determine whether land records of the WIPP withdrawal would survive for even a significant portion of the 10,000 year period following disposal. Writing is believed to have been developed in Mesopotamia as cuneiform only 5,000 to 6,000 years ago. Slightly later, hieroglyphics were developed in Egypt. Chinese

[8] 40 CFR § 191.14(c).

script is the oldest writing still in use. The fact is, however, that writing itself has only been in existence for about 5,000 years. Based upon historical precedent, it would be sheer speculation to conclude that any written record would last for 10,000 years.

12.3.3.2 Historical Land Records

Land ownership records were maintained by different civilizations for a variety of reasons. In most instances, preserving an accurate list of current land owners was not a high priority. In many civilizations, alienation of land (i.e., disposal) was not widespread. In some societies, (e.g., 6th century B.C. Athens) alienation of land from the owning family was largely prohibited. The legendary Doomsday Book, compiled in 1086 A.D. at the behest of William the Conqueror, is the greatest land record of medieval Europe. (It is currently displayed at the Public Record Office in London.) This book was not intended to be an ongoing record of land transfers. It was used as a means of settling feudal controversies that had arisen from the Norman conquest so that the King could obtain needed assurances from all his feudal tenants of substance.

From at least the 2nd century B.C., the Romans had a Cartesian system of land records that was very precise. To the extent that the records have survived, they demonstrate a concern with obtaining an accurate "snapshot" of land ownership from time to time, rather than a record of land transfers. This is consistent with the purpose for which the records were maintained, namely obtaining the correct amount of tribute from each landholder in the provinces.

Some historical land records showing a "snapshot" of land ownership have survived, largely by historical accident. There is no indication that the keeper of the records considered them to be of lasting significance. Thus, there is no way of judging, for example, how durable Roman provincial land records would have been had there been any premium placed upon their lasting existence.

Ironically, the ancient people with the greatest sense of history, the Jews, had no enduring need for land records because of political domination by others and a nomadic existence. This irony was heightened two millennia later in England. In medieval England, an effective system of recordation and registration of security interests in lands was developed by the Exchequer of the Jews. The registration of sealed contracts before officials at the Jewish

Exchequer in certain towns in England was an effective recording system and provided necessary notice to all concerned. It thus fulfilled the chief objectives of livery of seizing[9] and was an extremely successful incursion into the feudal system. The system was too successful to suit those who had a considerable interest in the maintenance of the feudal system and ended with the expulsion of the Jews from England in 1290.

12.3.3.3 State Land Records in the United States

In this country, real estate recording is usually done at the county level under state law. The systems generally resemble the type first used in the Massachusetts Bay Colony in the 1600s. Documents which may affect title to real estate are presented for recording. Recording gives legal priority over possible conflicting interests. Otherwise, title may be lost to a subsequent transferee who has recorded his deed or other document affecting title.

As a rule, recording is not a prerequisite to legal validity between the parties to a land transaction. Deeds and other instruments may create interests in property even if they are not recorded. Furthermore, recording a void instrument will not normally make it effective. Unless there is a land registration system in effect, which is unusual in this country, acceptance of an instrument for recordation is not an official determination that the instrument is legally effective.

Recording systems tend to use either a grantor-grantee or tract index, the former being older and more prevalent. In a grantor-grantee index, instruments are indexed alphabetically according to the grantor's and grantee's surnames. The grantee index is used to search from the present back to the beginning of the recording system to establish the chain of owners. The grantor index is used to find adverse recorded conveyances made by or through each owner during the time that the owner was the apparent or actual owner of the property in question. This type of index is inexpensive to maintain but difficult to use.

A tract index organizes instruments according to the property they affect. Instruments affecting each segment of land are indexed for that parcel. A tract index is easy to use, but more expensive to maintain than a grantor-grantee index.

[9] Ancient ritual involving the giving of notice of land ownership.

Recording system in this country do not necessarily show who is the actual owner of a particular piece of property. Unrecorded interests may be valid and recorded interests may be void. It would be unusual for these records to show a withdrawal of public land.

A system of title registration, as opposed to recordation, is used in a few parts of the United States and throughout the United Kingdom and Scandinavia. Perhaps the most popular system of land registration is the so-called Torrens system, which is modeled after a title registration method used for ships. Under this system of land registration, the government actually determines that a valid conveyance has been made. In other words, each time a document is registered, there is an administrative determination analogous to the judicial determination made in a quiet title action[10]. Registration of a conveyancing document is a prerequisite to its validity in most of those jurisdictions having a registration system. Therefore, a registration system is much more likely than a recordation system to show who is the actual owner of a particular piece of property. However, governmental action, such as a reservation or withdrawal of public lands, would not necessarily be reflected in a registration system.

12.3.3.4 Public Land Records

Public land records are maintained by the BLM. These records generally consist of a master title plat, a use plat, mineral lease plats, an historical index, a serial register, and case files. The master title plat is a copy of the official survey or a composite of several surveys. It contains references to all patents, reservations, withdrawals, rights-of-way, and similar actions. The references on the master title plat have generally consisted of weighted lines and abbreviations. The use plats show what uses are being made of public lands. Exceptions are grazing leases. Oil and gas leases appear on a separate use plat. Other mineral leases appear on separate plats.

The historical index is a chronological narrative of reservations, withdrawals, and other actions that have affected the use or title to public lands. Much of the same information will

[10] Quiet title actions are lawsuits that are brought to settle land ownership disputes. The court decides who owns the land and , after all appeals have been exhausted, that decision is controlling. The point being made here is that under a system of land registration, every time a document is registered, the administrative body that registers the document has to decide whether the document is valid and whether there has been a conveyance, i.e. who owns the land. This is similar to what a court does in a quiet title action, and very dissimilar to what most county "recording" offices do when they simply accept for filing, a document that is given them, and make no determination concerning its validity or who actually owns the property.

appear on the master title plat and the use plat.

The serial register is an index to all filings made with respect to a particular application, such as an offer to lease. In the serial register, an offer to lease, for example, would be the date of issuance of the lease, approval of any assignments, and any applications for extension. There is a serial register sheet for each filing.

The case file contains the original instruments that have been filed for an oil or gas lease, the land office copy of the lease or application, and related correspondence. Case files are listed under the serial number for the particular offer, application, or lease.

In addition to the records listed above, there are other public land records that are available, but these are of solely historic significance because they do not necessarily contain current information. These are the tract books and the plat books. The plat book contains plats arranged by township and range numbers. The tract book contains entries affecting lands by land description.

Because the WIPP is located on public lands, the durability and reliability of the public land record system is relevant to determine the extent to which there would be permanent, passive, institutional controls. The United States Supreme Court attempted[11] to define away much of the problem of ownership of public lands by excluding from the definition of "public lands," lands that were subject to the claim of a third party, whether or not that claim was valid.[12] If lands to which any questions exist regarding title are excluded from the definition of "public lands," administration of the public lands becomes easier.

12.3.3.5 Past Problems With Public Land Records

It is possible to describe particular circumstances in which the public land records system has

[11] The Court has not been consistent in its definition of "public lands." To the extent, however, that they attempted to define away the problem, as stated in the text, they probably succeeded in alleviating some of the burdens associated with administering the public lands, i.e., the federal land management agency's problems, but did little to solve the problems of the claimants who may otherwise have had a valid claim to public lands.

[12] *Newhall v. Sanger* , 92 U.S. 761, 763 (1875); *Bardon v. Northern Pacific R.R.* , 145 U.S. 535, 545 (1892).

not proven to be a reliable indication of land use, title,[13] or description. These have been recurrent problems that can be examined to see whether or not the public land records are a passive institutional control that is permanent and practicable for purposes of describing the WIPP withdrawal.

The previously mentioned approach taken by the Supreme Court over a century ago to alleviate the problem of third party claims is indicative of one problem that has beset the public land record system and the administration of the public lands for many years. In the Treaty of Guadalupe Hidalgo in 1848, the United States obtained lands that had previously been owned by Spain. The United States was confronted with claims of title based upon Spanish grants. Some of these were recognized by the United States; others were not. However, this is not a problem that should have any bearing on the public land records accurately and enduringly depicting the WIPP withdrawal.

Another issue with the public land records system that was ultimately recognized by Congress when it enacted the Federal Land Policy and Management Act ("FLPMA")[14] in 1976, was inaccurate surveys.[15] Some of the original surveys of the public lands erroneously omitted entire tracts of land. Omission of these lands from the surveys was due to simple error, laziness, or, in some cases, outright fraud on the part of the surveyors. Generally, it has been held that title to these omitted lands is in the United States and that they are subject to administration under applicable public land laws. Although this could be a problem in administering the WIPP withdrawal and identifying the lands withdrawn based upon existing public land records, this is extremely unlikely.

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[13] Traditionally the public lands were equated with the public domain obtained by the United States from the 1780s until 1867. This definition has been expanded over the years and now includes interests in land and "acquired lands." 43 U.S.C. § 1702(e). But see, *Columbia Basin Land Protection Association v. Scheslinger* , 643 F.2d. 585, 601 (9th Cir. 1981). Acquired lands were lands that had been in non-federal ownership and, subsequently, were granted or sold to the United States by an individual or a state.

[14] 43 U.S.C. §§ 1701-1782.

[15] Section 211 of FLPMA authorizes the Secretary to convey omitted lands and unsurveyed islands to states or their political subdivisions without regard to the acreage limitations contained in the Recreation and Public Purposes Act. In some circumstances such lands could also be conveyed to an individual occupying and developing such lands for a period of five years prior to January 1, 1975. 43 U.S.C. § 1721.

Until 1976, when FLPMA was enacted, there were no reliable records of unpatented mining claims. The holder of the mining claim did not have to file any notice of the location[16] with the federal government. A valid, unpatented mining claim is a property right and BLM was faced with a serious problem in administering the public lands without any reliable indication of where these claims were. Since enactment of FLPMA, notice of all mining claims, past and future, must be filed with BLM. If the required notice is not filed, the claim is deemed abandoned. Consequently, this is no longer a problem.

A situation that BLM has occasionally encountered arises from administering interests, e.g., oil and gas rights, in land that has not been surveyed under the System of Rectangular Surveys. In Texas, for example, surveys are by metes and bounds and do not always close, which may cause the description to be inadequate. This, however, is not a problem in New Mexico and should not affect the WIPP withdrawal.

Managing 200 years of paperwork relating to the public lands[17] is complicated. This is especially true in light of the roughly 3,000 public land laws that have been enacted, repealed, or amended at various times in our history. Furthermore, BLM public land records are maintained at various offices in the western states and in an eastern state office. This amount of paperwork could affect the viability of BLM public land records as suitable passive institutional control, i.e., the most permanent passive institutional control practicable. Fortunately, as discussed below, the BLM public land records are being converted to disks

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[16] There is no reason to delve into the refinements of the Mining Law of 1872. At the risk of oversimplification, a mining claim is "located" when the miner stakes out his claim and complies with the Mining Law of 1872. No action is required by BLM or the Department of the Interior in order for this claim to be valid. The miner is entitled a patent of the lands containing his claim for which he must make a nominal payment, but he is not required to obtain a patent. If a miner does "proceed to patent" and the Department of the Interior finds that there has not been a valid discovery, not only will the miner not receive the patent, but also the claim will be invalidated.

[17] One of the first problems confronted by the Continental Congress was how to dispose of the western lands that the original states had ceded to the new federal government. The Continental Congress responded by enacting the Land Ordinance of 1785, which established the rectangular system of survey and subsequently, in 1787, the Northwest Ordinance, which provided for new states to be admitted into the union on an equal footing with the existing states when certain conditions were met.

and a software has been developed that will make such records readily accessible.

With regard to land withdrawal, it should be noted that since 1976 the Secretary of the Interior has had authority under FLPMA to withdraw federal lands[18] from "settlement, sale, location, or entry" under the general land laws. Prior to 1976, the Secretary had withdrawal authority delegated to him by the President.

Although there are two cases[19] that suggest otherwise, the well-understood rule is that a withdrawal has no effect upon discretionary disposals, such as oil and gas leases, but simply upon non-discretionary disposals, e.g., settlements, sales, locations, and entries. This is consistent with how withdrawals were defined for the 200 years preceding FLPMA.

The rationale behind this definition is that lands do not need to be "withdrawn" from the operation of the mineral leasing laws, for example. The Secretary of the Interior can simply refuse to issue a lease. On the other hand, when someone can acquire rights in the land without the Secretary or any other official doing anything, such as "locating a mining claim" under the Mining Law of 1872, a withdrawal may be necessary to prevent the lands from passing out of federal ownership or control. Mineral leasing would not be an immediate concern to a knowledgeable BLM employee simply examining New Mexico land records with a view towards a possible withdrawal of those lands from settlement, sale, location, and entry.

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[18] The term "federal lands" is broader than "public lands" and includes land administered by agencies other than BLM.

[19] *Mountain States Legal Foundation v. Andrus* , 499 F. Supp. 383 (D. Wyo. 1980). The court in *Nat'l Wildlife Federation v. Watt*, 571 F. Supp. 1145 (D.D.C. 1983) assumed that the withdrawal provisions in FLPMA could be used to prohibit mineral leasing. Neither opinion is particularly cogent in this regard. The terms used in FLPMA -- "settlement, sale, location, and entry" -- contemplate the transfer of title, not the issuance of a mineral lease. *Udall v. Tallman*, 380 U.S. 1 (1965). For a Court of Appeals decision, albeit pre-FLPMA, that recognizes the distinction between a refusal to issue a lease and a withdrawal, see *Duesing v. Udall*, 350 F.2d 748 (D.C.Cir. 1965), *cert. denied*, 383 U.S. 912 (1966).

Furthermore, Congress itself withdrew the lands comprising the WIPP.[20] There are procedures established in FLPMA that may have uncovered any oil and gas leases and any other "natural resource uses and values of the site and adjacent public and non-public lands"[21] had those procedures been followed. This does not suggest that Congress may not, or should not, exercise its virtually limitless power over public lands and withdraw such lands when the need arises. However, when Congress does so, procedures that Congress itself has established in FLPMA may be ignored, and existing uses of the lands to be withdrawn are not fully assessed or understood.

12.3.3.6 Automation of Public Land Records

BLM is in the midst of an effort to have its public land records placed in a computerized, "user friendly" data base. The focus of these efforts is the Automated Land and Minerals Records System (ALMRS), which combines records of ownership, authorizations, and use affecting the public lands. This information will come from BLM's 400,000 land and mineral case files. Also included will be data on legal land parcels defined in the Public Land Survey System (PLSS). These data will form the Geographic Coordinate Data Base (GCDB), which will incorporate the PLSS and will tie map information to points on the ground by latitude and longitude.

GCDB will allow ALMRS data to be overlaid on discrete parcels and will provide immediate access to data on land ownership, use, and authorizations. This data base will probably be operational by the mid-1990s. In addition, by the year 2000, resource data will be integrated with the ALMRS data to depict the resource values and management concerns relevant to each parcel of public land.

12.3.4 Contemporary Examples of Lost Government Records

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[20] Section 2(22) of the WIPP Land Withdrawal Act defines "withdrawal" to mean an area of land, rather than in its usual sense, which is removing that land from settlement, sale, location, and entry.

[21] 43 U.S.C. § 1741(c)(2). Although the Congressional veto provision in 204(c)(1) of FLPMA, 43 U.S.C. § 1741(c)(1), is probably unconstitutional, *Immigration & Naturalization Serv. v. Chada,* 462 U.S. 919 (1983), there is no reason why Congress cannot direct the Secretary to provide it with certain information concerning a proposed withdrawal as it did in section 204(c)(2).

The following sections describe several contemporary examples where records have been "lost" or at least were unknown or unavailable to those in need of them on a timely basis (e.g., from archives that would likely be consulted by individuals in search of unexploited resources).

12.3.4.1 Oil and Gas Leases Near WIPP

The New Mexico Environmental Evaluation Group (EEG) conducted a detailed analysis of oil and gas leases in the vicinity of the WIPP. EEG described a situation in which the U.S. Department of Energy failed to document the presence of a producing oil and gas well under the southwest corner of the WIPP Land Withdrawal Area (EEG92). A brief history of this loss in institutional knowledge, derived from the EEG report, is described below.

May 1952 - Conoco obtains an oil and gas lease NMPM Lease # NM 02953 covering all of Section 31, T22S, R31E. (This lease lies wholly within what is now the WIPP land withdrawal boundary described in 12.3.1.1 above.)

February 1959 - Conoco lease is divided. The southern half assigned to Richardson and Bass as Lease NM 02953-C.

November 7, 1976 - Bass files for a permit to drill a well on Lease 02953-C.

December 10, 1976 - Energy Research and Development Administration (ERDA), now DOE, files notice in the *Federal Register* of intent to withdraw 17,000 acres of public land including Section 31 T22S, R31E for waste disposal site.

January 20, 1977 - U.S. Geological Survey (USGS) approves Bass application to drill on Section 31.

February 9, 1977 and **December 7, 1977** - ERDA files suit condemning both oil and gas leases on Section 31 from surface to a depth of 6,000 feet.

February 12, 1979 - The court condemns leases on Section 31 to 6,000 feet and awards damages to Conoco, Bass and others.

1980 - DOE issues the Final Environmental Impact Statement which does not show existence of leases on Section 31.

December 11, 1981 - Bass files an application to drill hole on Section 6, T23S, R31E

deviating into Section 31.

December 16, 1981 - The USGS district office transmits the drilling request and notes "drillsite not considered politically sensitive area."

September 13, 1982 - Well deviating under Section 31 is completed and tested.

August 4, 1987 - DOE signs a second modification to the Consultation and Cooperation Agreement with State of New Mexico committing to a prohibition of "slant drilling from under the site from within the site or from outside the site," even though DOE did not have the right to make such a commitment.

May 1990 - DOE reaffirms commitment to prohibit slant drilling under the WIPP in Final Safety Analysis Report.

October 26, 1990 - DOE signs Memorandum of Understanding with Bureau of Land Management (BLM) under which "BLM will prohibit directional drilling underneath the WIPP site boundary, except as may be required for the development of two leases located under Section 31; drilling may be allowed below 6,000 feet of the surface."

As matters currently stand, the rule does not preclude lease holders from drilling additional holes under Section 31 within the WIPP site, as long as the holes penetrate the site at more than 6,000 feet below the surface.

Some observations which may be distilled from the above chronology include the following:

- In spite of the fact that detailed records as to the existence of the oil and gas leases within the WIPP site existed, DOE did not acknowledge such existence over a ten-year period.

- Divided, poorly defined, and/or conflicting responsibilities among various governmental agencies and various levels of organization within the agencies contributed to selective instances of loss of institutional knowledge.

The existence of records, per se, does not guarantee that institutional knowledge will be retained at the locations and be available to those who "need to know." The significant events surrounding this oil and gas lease chronology cover a period of less than 20 years. If this example were typical, it would be inappropriate to assume that records alone can provide adequate information so that adverse actions do not occur over a period of many years.

The example suggests that considerable attention must be directed to the issue of <u>how</u> records are to be retained. The mere existence of records may not be adequate.

It could be asserted that the example described here is a record-keeping anomaly and thus is not a relevant criticism of systematized long-term record-keeping, the goal of which is to

ensure that basic knowledge of the WIPP repository is retained. The argument that "If a good record-keeping system was in place, this would not happen," has some merit. It is certainly necessary to establish a system which defines the kinds of records that should be retained, the retention locations, the materials used for record keeping, and their potential availability to those who need them on a timely basis.

Similar concerns about record keeping were echoed by one of the Futures Panels assembled by SNL. The Washington A Team enumerated the following potential issues with records (HOR91, pp E-7 to E-10):

- Records are inadequate
- Records exist but are not accessible to intruders
- Records are accessible but not understood
- Records are accessible and understood but ignored
- Records are accessible and understood but information is lacking regarding effects of nearby activities such as large scale mining or water withdrawal

In a total record-keeping system, steps can be taken to deal with all of these issues, except the case where records are accessible and understood, but ignored. The burden of that type of conscious action lies on future society, not current society. Nevertheless, the duration of the effectiveness of the best record-keeping system is unknown.

12.3.4.2 Lost AEC Records

Another recent example of the failure of records to maintain knowledge of waste burial operations pertains to low level nuclear waste buried on U.S. Air Force controlled land under the authority and purview of the AEC.[22] This example in no way establishes or suggests that the sites in question pose an immediate or long term risk to human health or the environment. Neither is there any implication of negligence on the part of individuals or the federal government. It is merely intended to illustrate the institutional and social processes that can

[22] The information presented here is taken from a document entitled *Burial of Radioactive Waste in the USAF* (USA72 and revisions).

contribute to the success or failure of passive controls.

Most of the sites in question were created in the 1950s, under the auspices of the AEC and in accordance with accepted industry waste disposal standards. The waste materials consisted of radioactive electron tubes, solid and liquid waste from weapons maintenance, radium oxide paint, and medical research wastes. Some burials were made in accordance with specific AEC (now Nuclear Regulatory Commission) licenses.

"Guidance on constructing and maintaining typical sites was given technical order procedures which included identifying site location on appropriate maps and posting and fencing to prevent unauthorized entry. The Air Force switched to disposal at licensed commercial sites in the 1958-1959 time frame and the technical order requirements for burial, and site maintenance requirements was rescinded. Unfortunately, no alternate instructions were provided on maintaining existing sites and a gradual loss of site records ensued. In 1971, the Air Force initiated an effort to find and consolidate existing site records and reestablish site maintenance."

A review of the facts regarding these sites is as follows:

1. Materials were buried under authorized procedures (Air Force and AEC).

2. The materials were buried on active duty military reservations that themselves could be considered to be under active control. However, the disposal sites were under passive control.

3. The loss of knowledge occurred because of a lapse in institutional reporting and maintenance procedures.

4. The lapse was not longer than 12 years (1958-1971).

5. The 12-year lapse resulted in the loss of many radioactive waste burial sites. Many are still unaccounted for in 1994.

The following three scenarios could account for the reported losses:

1. The facilities at the time of burial did not comply with the technical directive, therefore no location records exist.

2. Interviews with base personnel resulted in an assertion of a burial site but there is no location information. These sites are then reported as lost. The sites may or may not exist.

3. The facilities did comply, but when active maintenance was lost the site fence and placards were destroyed and the historical records, if any, were not sufficient to establish a location.

12.3.4.3 Spring Valley Munitions Dump

The Spring Valley site in Washington DC is a highly visible example of the burial of potentially hazardous substances (i.e., World War I era chemical munitions) and the subsequent loss of knowledge of these activities until accidental discovery during construction related excavation many years later (BAK94).

The site history begins in 1916-1917 when the U.S. Bureau of Mines established Camp Leach to study chemical warfare agents. American University donated land for this effort during the war emergency. In 1917-1918, the U.S. Bureau of Mines activity was consolidated under military command with the establishment of the American University Experimental Station, under the Chemical Warfare Service. By 1918, there were 1800 staffers at the station.

The burial of chemical munitions at the site was not documented by the Experimental Station. Burial activities were considered routine and not exceptional in terms of present or future hazards. The standing order for burial was that the material must be buried three feet under the surface and not in contact with groundwater.

In 1921, the Secretary of American University, Albert Osborne wrote an article describing the burial of chemical munitions at the site. He did not provide a location for the burial site. After this article, knowledge of the site and any dumping conducted there was apparently lost. Records did exist at American University and at the National Archives in Suitland, Maryland but there was no general awareness of the records.

In 1986, a backhoe operator dug up a cache of chemical munitions. He notified the authorities and the knowledge of the site was reestablished in the subsequent investigation.

The investigation revealed the prior discovery of a "bomb" in the 1950's on the site of the Experimental Station.

Personal memories of the site also existed, but were not part of the institutional memory. One citizen, Eric Olsen, was in possession of and had knowledge of photographs showing burial activities at the Station, taken by his grandfather (BAK94).

The following key points can be derived from the Spring Valley incident:

- There was no real effort or intent of the authorities at the time of burial to retain some sort of institutional memory of the activities.
- One case of early warning of the activities made by A. Osborne, was apparently dismissed as a matter of little interest.
- While records of the activities existed in certain archives, there was no person or institution who retained a knowledge of them.
- The activities were institutionally rediscovered through excavation activities.
- It is not known if other chemical munitions were discovered at the site during the years of residential development, but not reported.

12.3.5 Format for Records

In order to ensure that messages on site markers are understood, it has been suggested that the message be recorded in several languages. For example, the WIPP Markers Panel recommended that the marker message be recorded in the six official languages of the United Nations (English, Chinese, Arabic, French, Spanish, and Russian) as well as Navaho and/or Apache (KAP86, GIV82, ADA86, TRA93). For perspective, it is helpful to recognize that Chinese is the most widely used language spoken on Earth today (Durant). Numbers of people speaking various languages are as follows (TRA94):

- Chinese (Mandarin) - 907 million
- English - 456 million
- Hindi - 383 million
- Spanish - 362 million
- French - 123 million

While comments on the use of multiple languages have primarily involved markers, the same logic can be applied to records. Records should be written in multiple languages as well. As previously suggested in this chapter, consideration of recording information in the major languages used by religious scholars (i.e., Hebrew, Latin and Arabic) also warrants consideration. The ONWI Human Interference Task Force envisioned that detailed information (e.g., 500 to 1,500 pages) in English and a more condensed version (e.g., 200 pages) in multiple languages would be archived (HUM84). There may be a question of institutional will about the extent to which detailed records will be translated into various languages for archival purposes.

Again, drawing a parallel with marker considerations, records must be stored on durable materials. The ONWI Task Force reported that some types of acid-free paper may survive a millennium under reasonable conditions (HUM84). Paper made from cotton or linen fibers has lasted for 1,000 years. Papyrus had survived for considerably longer in Egypt. The Task Force recommended that conventional paper would be a suitable storage medium for records which are periodically updated or maintained, but it proposed that more permanent records be prepared using special papers and stored in a protected environment. The importance of incorporating disposal site information on large numbers of maps widely distributed in the United States and throughout the world was stressed.

The NEA Working Group noted that the principal media currently used for conserving information include paper, microfilm, and magnetic and optical disks (NEA93). They quoted a lifetime of 1,000 years for paper, 200-400 years for microfilm (with one regeneration cycle), and less than 10 years for magnetic and optical media. On this basis, NEA felt that paper and microfilm were the preferred media for long term storage. The same position was adopted by the Nordic Committee for Nuclear Safety Research - NKS (JEN93).

12.4 GOVERNMENT OWNERSHIP AND REGULATIONS

12.4.1 General Comments

While government ownership and regulations regarding land and resource use are embraced in the definition of passive institutional controls, substantive questions have been raised as to the persistence of such governmental controls over the millennia. Historical continuity of governments has ranged from days to centuries.

In studying inadvertent human intrusion, SNL convened four expert panels to estimate modes and likelihoods of future intrusion (HOR91). The teams felt that the likelihood of continued U.S. political control over the WIPP was small or non-existent. Changes in government control can lead to loss of information about a repository. Although physical destruction of information can be predicted for some scenarios (e.g. war, insurrection, and changes in record-keeping practices), one possible result of change in governmental control would be a change in policies regarding the importance of protecting the WIPP site and its records. Even with continuity of government, there is no guarantee that such continuity can be equated to continuity of government policies or continuity of government control over the WIPP site. Governmental policies vary significantly from one administration to the next. A future government might decide it was no longer necessary to maintain ownership of the site or update records for changes in language or technology. However, if some future government makes a conscious decision to take action detrimental to the repository, it is appropriate that the burden of that decision lie with that future society.

History provides numerous examples of instances where government has changed dramatically over the centuries, but institutional knowledge has not been lost. This is particularly true where symbolic or written language is associated with an artifact. The Egyptian pyramids are a classic example. Built nearly 5,000 years ago by an ancient society that is not reflected in the Egyptian society of today, located in an area subjugated by many conquerors since, documented in a symbolic language vastly different than today's languages, and desecrated by thousands of years of vandalism, the funerary monuments still convey a message understood by modern society about their design, construction, and function. The NEA Working Group cited French experience with institutional controls. Louis XVI created the Office of Quarries in Paris to prevent disturbances to buildings constructed over quarry sites (NEA93). The Office is still in existence and maintains control over portions of the Paris infrastructure, in spite of historical trauma including passing from an absolute monarchy to a series of republican governments with interspersed revolution, civil war, invasion, and riot. Institutions frequently outlive the governments which inaugurate them.

12.4.2 WIPP Land Withdrawal Act

Under Sec. 3(a) of the LWA, a sixteen square mile area was "withdrawn from all forms of entry, appropriation and disposal under the public land laws, including without limitation the mineral leasing laws, the geothermal leasing laws, the material sales laws (except as provided

in section 4(b)(4) of this Act[23]), and the mining laws." Jurisdiction over the withdrawn lands is assigned to the Secretary of Energy. The LWA does not give to the U.S. Government a right to any water which it did not already possess at the time the LWA was passed. If the U.S. Government wishes to obtain water rights for purposes associated with the LWA, it must do so in accordance with the laws of the State of New Mexico.

Sec. 4(b)(5) of the LWA prohibits, in perpetuity, surface and subsurface mining or oil and gas production, including slant drilling from outside the withdrawal area on the withdrawn lands. There is one exception to the drilling prohibition. Rights under two existing oil and gas leases are not affected, although, if dictated by regulatory requirements, the Secretary of Energy can acquire these leases. As discussed in Section 3.4.1, slant drilling from outside the withdrawal area into these two leases, which lie in the southwest corner of the WIPP site, is currently permitted at depths below 6,000 feet (EEG92).

Sec. 13(b) of the LWA requires that DOE prepare, within five years of the date of enactment (i.e. October 1997), a plan for the management and use of the withdrawn area after decommissioning. This has yet to be done. However, DOE has prepared a plan for the management and use of the withdrawn area prior to decommissioning as required by Sec. 4(b)(1) of the LWA (DOE93a).

EPA examined actions planned by DOE in the current Land Management Plan as possible precursors to future actions associated with the post-decommissioning plan. DOE has specified that drilling and mining activity within one mile of the WIPP land withdrawal boundary be monitored by DOE in coordination and cooperation with the BLM and/or the State of New Mexico. These agencies have agreed to forward to DOE for review and comment all Applications for Permit to Drill in this boundary zone, together with mining and reclamation plans. According to the Land Management Plan, "this review will afford DOE the opportunity to verify that the proposed oil and gas or mining activities surrounding the withdrawal area will not encroach upon the withdrawn lands." It is possible that if DOE judges a hole is to be drilled too close to the WIPP site boundary, they could request that the permit granted to the operator include a condition that DOE be provided with downhole vertical deviation surveys contemporaneous with the drilling activity. If the surveys detect subsurface deviation which could encroach upon the WIPP site, the driller could be required

[23] Section 4(b)(4) permits the disposal of salt tailings which were produced during mining of the repository but are not needed for backfill.

to take corrective measures or cease drilling. Enforcement of such a provision will probably require continuous monitoring of the drill bit location.

12.5 OTHER METHODS OF PRESERVING DISPOSAL SYSTEM KNOWLEDGE

12.5.1 Subsurface Markers

To provide redundancy in the event that surface markers are destroyed by vandalism, erosion, other aging processes, or natural disaster, it has been suggested that subsurface markers be employed to augment surface markers (ADA86, BEN91). If the surface markers are destroyed or removed, buried markers may still provide a warning to intrusion.

12.5.1.1 Passive Markers

Fired clay subsurface markers were proposed to DOE by DOE contractors specifically for shallow burial grounds at Hanford based on archeological evidence of the longevity of such materials (ADA86). In the Hanford study, it was recommended that three layers of subsurface markers be emplaced at depths of 2, 4 and 16 feet to deter activities such as farming or building construction on the site. While such subsurface markers might deter surface excavation, they might not be discovered in the process of exploratory drilling into an underlying geologic repository. It is highly unlikely that a drilling crew would detect the presence of the markers. The buried markers would create no impediment to the drilling process and would probably be destroyed when contacted by the drill bit or missed entirely. Emplacement of such markers would involve extensive surface excavation.

12.5.1.2 Buried Sensors

Another approach to subsurface markers is to employ buried sensors of various types (BEN91). These could include buried objects or materials which would create an acoustic, magnetic, or radioactive anomaly. To create an acoustic anomaly, large granite shapes whose acoustic signal would define the center of the repository could be buried. Magnetic markers might include buried iron ore or special high field permanent magnets. Radioactive markers could be located outside the boundaries to signal the presence of the repository to intruders entering from various directions. All of these were suggestions made by the Southwest Team of the Futures Panel.

Team B of the WIPP Markers Panel suggested that earthworks at the WIPP site could be spiked with relatively inexpensive, high dielectric constant materials such as metal sulfides or magnetite which provide a strong radar signal to anyone exploring the site by remote sensing (TRA93). The ONWI Task Force felt that the site markers themselves would be readily visible to remote sensors carried by satellite (HUM84).

12.5.2 Protective Barriers

It has been suggested in a report by Ptyalin that the final defensive measure in a defense-in-depth strategy for reducing the likelihood of human intrusion could be a protective barrier system (TOL93). In theory, the protective barrier could reduce the likelihood of drilling in the event that markers and records were lost. The Ptyalin study uncovered no published research on concepts or actual designs of a protective barrier system. Ptyalin outlined the key features which a protective barrier system would need to provide. They are as follows:

- "be capable of disabling a drill bit, be impervious to a drill bit or, at a minimum, be capable of deflecting the drill bit safely away from the disposal system;
- be potentially capable of withstanding multiple encounters with a drill bit without the loss of function;
- be composed on materials of little economic value and will not degrade over the 10,000 year, post closure period; and
- not attract unwanted attention to the site or encourage exploration activities."

Possible locations for the conceptual protective barriers included at the surface of the repository site, just beneath the surface, just above the emplaced waste, and within the waste panels. Combinations of these options are also possible. Location of barriers at or just below the surface would require significant amounts of materials to cover the 0.5 square kilometer footprint of the repository. Ptyalin noted that operators have encountered problems in drilling into old landfills containing layers of rubber tires (at least 10 meters thick), layers of steel fencing, and baling wire. Encounters with these materials resulted in loss of circulation of the drilling mud, inability to cut through the materials, and difficulty in removing the drill string from the borehole. These problems occurred when using small truck-mounted rigs. There is no information to suggest that similar problems would be encountered when using a large

stationary rig capable of drilling to depths of 3,000 to 5,000 meters. The long term stability of such artificial layers is also open to question.

No suitable materials for protective barriers located just above the wastes have been identified. To reduce effectively, the likelihood of drilling intrusion, the material would need to be resistant to attack by the drill bit, have corrosion resistance in the repository environment, and be emplaced with a sufficient areal density to effectively blanket the waste. Advanced materials such as tungsten carbide composites might meet these specifications. However, such an approach would be extremely costly. The buried material could be of sufficient economic value to represent a recoverable resource to some future generation. The impact of further disruption of the natural geologic barriers to accommodate emplacement of a protective barrier would need to be addressed.

The same conceptual material problems exist in considering encasing the waste drums with some sort of armor. While there are materials which might hinder the encroachment of a drill bit, such materials are costly and they may be an attractive resource to future generations. Also, their longevity in the repository environment has not been demonstrated.

EPA's review of the many options for PICs considered by DOE and DOE expert panels supports the approach taken in the rule by clearly demonstrating that while there may be no definite proof of the effectiveness or survivability of a particular PIC system, there are many approaches with positive characteristics and many proposals that seem to hold promise for improving the WIPP disposal system and thus protecting the public health and the environment.

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Appendix 12A:
Federal Register Notice Identifying WIPP Land Withdrawal Area

Appendix 12B:
Letter to U.S. Archivist Transmitting WIPP Land Withdrawal Information