

MARKER DEVELOPMENT FOR HANFORD WASTE SITE DISPOSAL

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ABSTRACT

Certain radioactive wastes, including stored wastes in single-shell tanks and pre-1970 solid waste burial grounds and contaminated soil sites, are currently located at the Hanford Site. The Hanford Defense Waste-Environmental Impact Statement is being prepared to assess options for the disposal of these wastes. In-place stabilization and disposal is being considered. Barrier and marker systems are being designed and developed for placement over the wastes following site preparation. Archaeological analogues have been examined to provide guidance for the design of markers intended to communicate for up to 10,000 yr. Materials, dimensions, and messages have been specified for both surface and subsurface prototype markers. A prototype surface marker has been designed, and its procurement is pending. The integration of the barrier design and markers into a system has also been planned. Plans for placement of both surface and subsurface markers have been completed.

INTRODUCTION

Among radioactive wastes located at the Hanford Site are wastes stored in single-shell tanks, pre-1970 solid-waste burial grounds, and contaminated soil sites. The Hanford Defense Waste Environmental Impact Statement (HDW-EIS) is being prepared to assess options for disposal of these and other waste types. One option being considered is in-place stabilization and disposal. Technology needed for implementation of the in-place stabilization and disposal option is being developed pending possible selection of this disposal option after completion of the National Environmental Policy Act (NEPA) process.

Protective barrier and marker systems are being developed for possible placement over the wastes following site preparation. Site preparation, in the case of the single-shell tanks, would involve pumping of free liquids, isolation, and placement of gravel fills in the void space of the tank. The gravel fill is to eliminate the potential for future subsidence or collapse of the barrier upon deterioration and loss of the structural strength of the tank concrete. In the case of the burial grounds and contaminated soil sites, preparation would involve filling voids in the waste zone by grout injection or reduction of the voids using pile-driving techniques.

The following are intended functions of the barrier and marker systems once emplaced.

- Deter plant and animal intrusion into the waste zone.
- Inhibit water infiltration to the waste zone.
- Deter inadvertent human intrusion into the waste zone.

- Resist erosion due to wind and water.

The barrier and marker systems must be designed and constructed in such a way that wind and water erosion will not significantly degrade the performance of the systems over a period of thousands of years. In addition, the systems must function without maintenance. The systems must also continue to function adequately following the impact of expected natural events such as earthquakes, range fires, dust devils, cloudbursts, etc.

The focus of this paper is the design of marker systems to deter inadvertent human intrusion. Regulatory requirements and marker materials, dimensions, messages, arrangement, and testing are discussed.

WHY DISPOSAL SITES MUST BE MARKED

A regulatory responsibility to mark radioactive waste disposal sites exists. Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-level and Transuranic Radioactive Wastes (40 CFR 191) requires that, "disposal systems shall be . . . identified by the most permanent markers and records practicable to indicate the dangers of the wastes and their location."

A social responsibility also exists to mark disposal sites based upon the following considerations.

- Regulations stress that no undue burdens be placed on future generations. Unmarked disposal sites would pose a major burden to future generations. The present generation has experienced the consequences of unmarked sites, particularly hazardous waste sites.
- Intrusion by humans is often the most credible worst-case scenario when the long-term

environmental effects of disposal are assessed. Marking systems can reduce the likelihood of human intrusion.

- Barriers that will absolutely preclude determined human intrusion cannot be constructed. The emphasis must be placed on providing warning to the potential intruder.
- Accurate predictions of human actions far into the future are not possible. However, well-designed markers will tend to increase the possibility of controlling human action at a waste site by providing information on which future generations can base judgments and actions.

FACTORS CONSIDERED IN MARKER DESIGN

Three major factors must be considered in marker design.

- The marker and the message it contains must be capable of existing for the required time. (For Hanford waste sites containing transuranic elements in concentrations of regulatory concern, the required time is 10,000 yr.)
- The marker and its message must be easily detected.
- The message must be comprehensible to present and future generations.

In the case of marker existence, a number of factors must be taken into account. For instance, should the marker be located far from the waste site, near the waste site, or on the waste site? The marker must also be capable of existing for thousands of years without human maintenance given the impact of expected natural processes such as weathering, wind, and water erosion.

A number of factors must also be considered concerning marker detectability. For instance, should the marker be detectable at ground level, above ground level, or below ground level? Should the means for detection require the use of mechanical, chemical, or electrical devices, or should the human senses be relied upon?

Finally, in the case of message comprehensibility, should languages be relied upon with the knowledge that specific languages have been known to change over time? What languages should be used? Should symbols and pictures be used in place of, or in addition to, languages?

Given the uniqueness of the design problem, a decision was made to rely largely upon judgments derived from a study of the past to guide design. Human artifacts thousands of years old are in existence and, in many cases, are capable of providing valuable information about what can survive over long periods of time. The design approach involved looking at these "ancient markers" to learn how to design markers that can communicate far into the future.

THE USE OF ARCHAEOLOGICAL INFORMATION IN MARKER DESIGN

Information concerning the following structures was examined to provide clues as to how to proceed with marker design: (The years listed are how long each structure has been in existence.)

- Pyramids, Egypt (5,000 yr)
- Stonehenge, England (5,000 yr)
- Acropolis, Athens (2,400 yr)
- Serpent Mound, Ohio (3,000 yr)
- Great Wall, China (2,200 yr).

These structures were chosen for examination because they are thousands of years old, are of large enough scale to be relevant to the Hanford Site marking system and, from a weathering and erosion point-of-view, some are located in more humid and more adverse climates than the Hanford Site. A number of other similar archaeological sites could have also been examined. For instance, large numbers of mounds exist in the eastern United States that are similar to the one chosen for examination (Serpent Mound, Ohio).¹ These mounds are analogous in some ways to the barriers proposed for use in the disposal of a variety of Hanford waste sites. However, it was decided that Serpent Mound was representative of the other numerous mounds so that proper conclusions could be drawn for that type of site. Another example involves the hundreds of stone circles that exist in England.² In this case, Stonehenge was thought to adequately represent that type of structure.

LESSONS LEARNED FROM ANCIENT MARKERS

An examination of the Egyptian pyramids, Stonehenge, and other structures enabled a number of conclusions to be drawn on the design of objects that can last and communicate for thousands of years. Table I lists, in abbreviated form, the conclusions drawn from the structures studied.

Ancient structures provided a number of lessons about marker existence and durability. For instance, although metals are intrinsically durable and can last thousands of years, metal objects tend to be removed and recycled. An example of this are bronze statues that were known from literature to be present at the Athenian acropolis from 178 to 27 B.C. The statues are now absent. Bronze shields attached to the Parthenon have also disappeared even though the dowel holes are still present.

Another example of lessons learned involves the size and placement of potential markers. At Stonehenge, one-third of the stones are missing yet the plan of the site can be reconstructed from the remaining stones. Stonehenge also provides clues about marker size. In general, stones larger than about twice human size in the above-ground portion tend to stay in place and not be reused for other purposes or placed in museums.

TABLE I
Examples of Lessons Learned from
Ancient Structures.

Lesson	Structure
Materials should have little intrinsic value.	Egyptian pyramids
Markers should delimit the area.	Stonehenge
Markers should be redundant.	Stonehenge
Metals should not be used in markers.	Acropolis of Athens
Markers should be detectable at eye-level.	Positive example: Stonehenge Negative example: Serpent Mound
Marker size should be at least two times human size above grade.	Stonehenge
Durable (non-organic) materials should be used.	All structures
Markers should use language because language conveys most detail.	Egyptian pyramids

All of the structures examined are constructed of durable, nonorganic materials such as stone. Generally organic materials will degrade much more readily than nonorganic materials. Even stones, if they have intrinsic value, are subject to removal from the site. At the Chephren Pyramid, Giza, Egypt, limestone blocks were scavenged from the facing of the pyramid up to a level where it was not possible to take more. Large monolithic (megalithic) stones are therefore preferred as opposed to markers constructed of joined smaller stones.

Ancient structures also provide information about marker detectability. Stonehenge provides a positive example in that the circular plan can be detected from eye-level. The Serpent Mound in Ohio provides a negative example wherein the shape of the serpent can only be easily recognized from a vantage point above the earthwork. In general, reliance on mechanical, electrical or chemical means of detection is not advisable given the unpredictable state of future technology.

Finally, ancient structures provide valuable information about message comprehensibility. It is desirable that languages be used on or associated with markers because language can convey more detailed information than symbols or pictures. Because of associated written evidence, the purpose, date, and builders of the Pyramids are well known. In the case of Stonehenge, and particularly in the case of Serpent Mound, little is known about the purpose, date, and builders because of the lack of associated text. Even though languages change with time, funerary texts from Egypt have communicated across cultures for thousands of years.

Symbols, on the other hand, tend to have meaning only for the societies that create them. Because of these findings, the decision was made to

maximize the use of languages on the marker, while including pictograms and a minimum of symbols.

SURFACE MARKER DESIGN GUIDELINES

Considering lessons learned from the past, a number of design guidelines can be derived for application to surface markers. A number of design details can also be derived from a consideration of geomorphic evidence as well as data from stone preservation research.

- Markers should be placed on a well-drained foundation to avoid subflorescence. Ancient reliefs of Seti I in Karnak, Egypt, from 1300 B.C. have been damaged by salt. (Subflorescence is the crystallization of soluble salts beneath the surface of stones where outward moving moisture is the transport mechanism. Stone peeling at the surface can result.)
- Megaliths of basalt or granite stone should be used. (Granite and basalt are the most durable stones in terms of weathering, erosion, and damage in polluted environments.)
- Messages should be engraved (not raised) on polished surfaces that are recessed into the stone. Polished, recessed surfaces are less susceptible to water and wind erosion and provide a less suitable surface for lichen growth. Engraved letters are less subject to damage than raised letters.
- Twenty inches (50.8 cm) of the monolith between grade (ground level) and the recessed message surfaces should not bear

inscriptions because the bulk of wind-transported sand movement in deserts takes place below that level.^{4,5}

The application of these design guidelines led to the design for surface markers depicted in Fig. 1. The initial markers will be made of granite, the quality of which will be insured by meeting the following American Society for Testing and Materials (ASTM) specifications for granite building stone (C 61580):⁶

- Maximum water absorption by weight, 0.4%
- Minimum density, 160 lb/ft³ (2,560 kg/m³)
- Minimum compressive strength, 19,000 lb/in² (1.3 x 10⁸ Pa)
- Minimum modulus of rupture, 1,500 lb/in² (10.3 x 10⁶ Pa)
- Minimum abrasive resistance, 12 per ASTM method C-241.

Basalt is also an attractive marker material but much less experience exists in the quarrying and inscription of basalt for use as monuments.

SURFACE MARKER MESSAGES

Because of the importance of language in communicating detail, the decision was made to maximize the use of language. (See Fig. 2.) The front face of the marker contains a short warning message, "DANGER-- RADIOACTIVE WASTE--DO NOT DIG HERE," in the six languages of the United Nations and in the

front face of the marker contains a short warning message, "DANGER--RADIOACTIVE WASTE--DO NOT DIG HERE," in the six languages of the United Nations and in the language of the Indians indigenous to the region. (See Fig. 3.) The right marker face contains a long, detailed message in all six languages concerning the actions that should not be taken at the site and the consequences of taking them. (See Fig. 4.) The only symbols used on the marker are the radiation symbol, which is an internationally recognized symbol, and a slash across a pictogram showing a human digging on the barrier mound. The slash symbol is also internationally recognized as meaning DO NOT. (See Fig. 5.) The left face of the marker contains a location map showing the marker in relationship to other markers and to the disposal sites and burial mounds (barriers). A six panel pictogram is also included which attempts to show pictorially the consequences of digging or farming on the barriers over the waste sites. (See Fig. 6.) The pictograms are included to address the remote possibility that all six languages change beyond recognition in the future, and to also warn illiterate future intruders.

SURFACE MARKER ARRANGEMENT

Based upon archaeological observations of ruins like Stonehenge, markers placed in a geometrically regular pattern allow a perimeter to be perceived more easily if some of the markers are destroyed or removed. Perception of the plan of a site is also aided if a person standing at a stone (marker) can see the next respective stone marker on each side. A rectangular perimeter of markers around 200 East and 200 West Area is therefore being considered. (See Fig. 7.) (Separate marker perimeters around the 200 East and 200 West Areas were also considered.) The actual spacing of markers will be

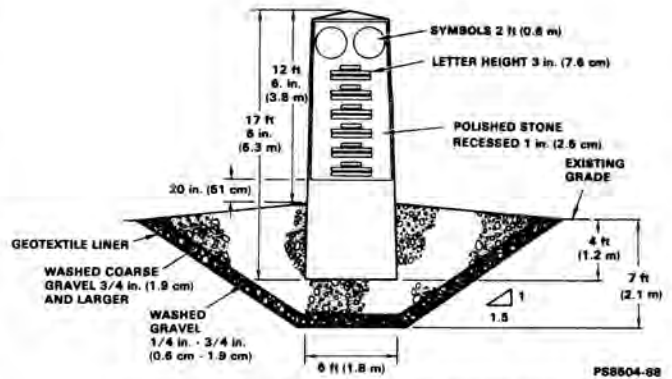


Fig. 1. Surface Marker Key Dimensions.

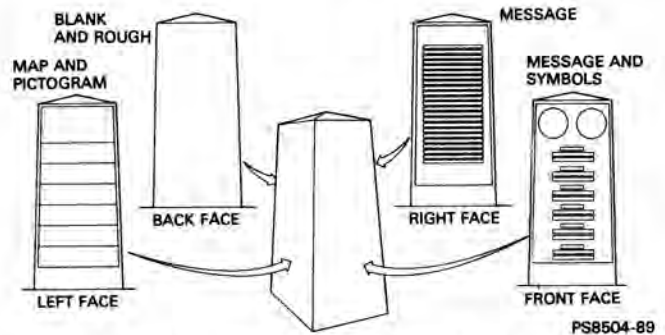


Fig. 2. Four Faces of Surface Marker.

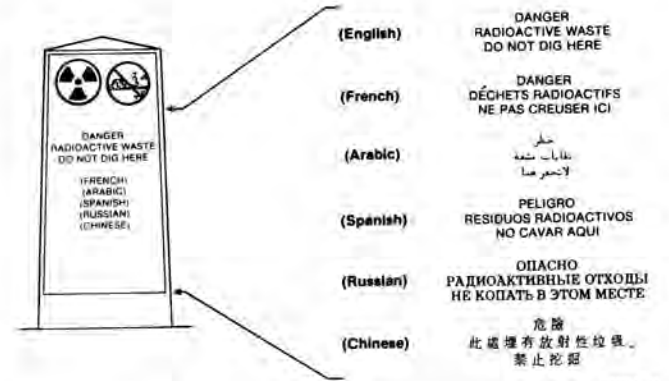


Fig. 3. Front Face of Surface Marker.

determined by field surveys, but an initial estimate is that markers will be no less than 1/8 mi (200 m) apart. Another essential consideration in marker placement is that the barrier mounds must be visible from the surface markers. The pictograms and messages on the markers refer to the barrier mounds; specifically, as to actions that should not be taken. The visual tie-in between markers and mounds is essential. Again field surveys will be made when specific disposal plans reach a more advanced stage.

SUBSURFACE MARKER DESIGN

In the interest of providing redundancy to the marker system and in warning the persistent intruder, subsurface markers are proposed for use in addition to surface markers. The rationale is that

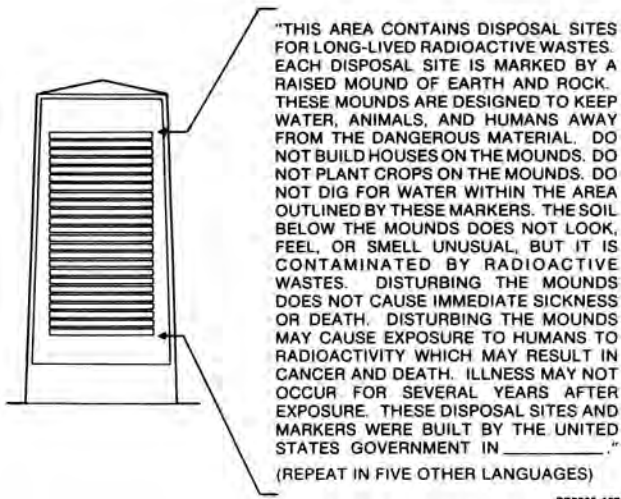


Fig. 4. Right Face of Surface Marker.



Fig. 5. Do-Not-Dig Pictogram for Surface and Subsurface Markers.

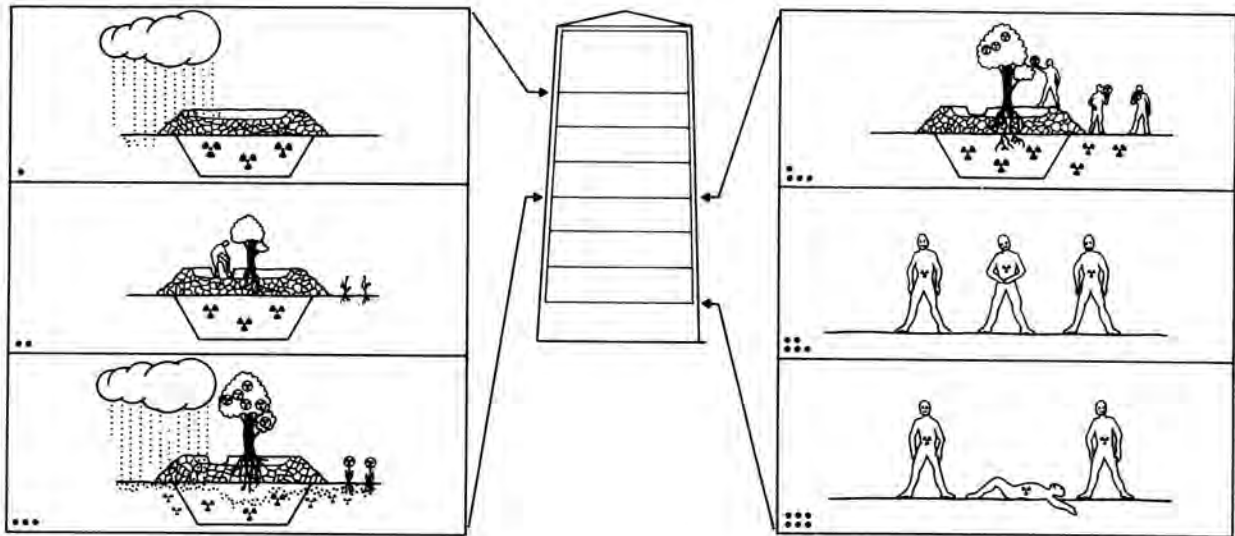


Fig. 6. Left Face of Surface Marker.

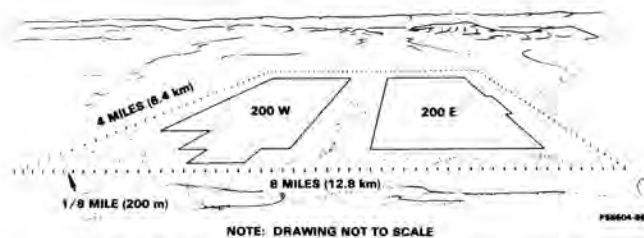


Fig. 7. Perimeter Surface Marker Arrangement.

in the unlikely event that all surface markers are removed or destroyed, subsurface markers placed within the barrier could be uncovered by any intruder digging or farming on the barriers, and could provide a warning to stop such activities. Because potsherds larger than 5 in. (12.7 cm) are seldom found in archaeological digs, the decision was made to limit the size of subsurface markers to 5 in. (12.7 cm) in diameter. Pottery was chosen as the material for the markers because such materials have survived for thousands of years, are routinely uncovered in archaeological digs, and are less costly than modern ceramics, which were considered for use.

Five subsurface marker prototypes were tested. (The prototypes were made by Bennington Potters of Bennington, Vermont.) The five prototypes were made of varying proportions of pioneer kaolin, clay kaolin, silica, and nepheline syenite with yellow clay stain added. Four types were ram pressed, while one type was formed in a mold. All types had a yellow body with incised letters in magenta. All were fired to 2,200 F (1,205 °C). One type was completely covered with a glaze while the other four had the incised lettering glazed only. Details concerning the properties of the five prototypes are given in Table II.

One side of the subsurface marker has the same pictogram as found on the surface marker so that a tie-in between the two types of markers exists. (See Fig. 5.) The other side has a radiation symbol in the center with the English words, "DO NOT DIG HERE--HAZARDOUS WASTE BELOW," arranged around the radiation symbol.

SUBSURFACE MARKER ARRANGEMENT

Subsurface markers are prepared for placement in three layers within the barrier covering waste disposal sites. (See Fig. 8.) The deepest layer of

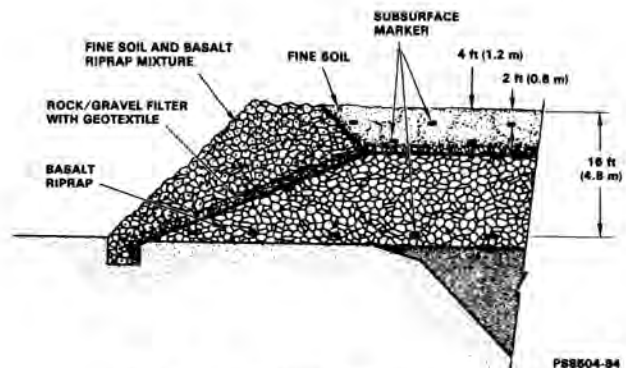


Fig. 8. Proposed Arrangement of Subsurface Markers.

subsurface markers will be placed roughly at the bottom of the rock portion of the barrier near ground level. This layer will be about 16 ft (4.9 m) below the top of the barrier. The other two marker layers are in the upper soil portion of the barrier at depths of 2 ft (0.6 m) and 4 ft (1.2 m) below the top of the barrier. All subsurface markers are to be placed on 9.8-ft (3-m) centers with the two top layers offset relative to each other to increase the likelihood of subsurface markers being uncovered by a digging intruder. Because of the concentration of subsurface markers this placement pattern provides, there is a likelihood that a basement digger, farmer, or other digging intruder will encounter several of the subsurface markers.

SUBSURFACE MARKER TESTING

The five subsurface marker prototypes were subjected to testing and compared for their ability to withstand chemical, mechanical, and thermal shock. The tests demonstrate that all of the subsurface

Table II

Properties of Subsurface Marker Prototypes

Type	Shape and dimensions	Forming method	Body compositions	Surface treatment
A	Disk 5 in. (12.7 cm) dia. 0.5 in. (1.27 cm) thick	Ram pressed	Porcelain with yellow slip sprayed over all surfaces	Magenta glaze in incised lettering only
B	Same as Type A	Liquid clay slip in plaster molds	Yellow clay body formula (15% yellow clay stain by weight)	Magenta glaze in incised lettering only
C	Same as Type A	Ram pressed	Yellow clay body formula (20% yellow clay stain by weight)	Magenta glaze in incised lettering only
D	Lenticular 5 in. (12.7 cm) dia.--0.5 in. (1.27 cm) thick at center, tapering to edge	Ram pressed	Yellow clay body formula (20% yellow clay stain by weight)	Magenta glaze in incised lettering only
E	Lenticular (dimensions same as Type D)	Ram pressed	Yellow clay body formula (20% yellow clay stain by weight)	Magenta glaze in incised lettering only--covered overall with clear glaze

marker types can withstand much more severe chemical and thermal environments than will be encountered in the field. The following specific tests were conducted:

- Compressive strength (ASTM C-648)
- Thermal shock (ASTM C-484)
- Thermal crazing (ASTM C-544)
- Alkali resistance (ASTM C-614)
- Color retention (ASTM C-538)
- Chemical resistance (ASTM C-650).

All of the tests were conducted by United States Testing Company, Inc. of Los Angeles.

CONCLUSION

Markers are an essential component of the barrier system for in-place disposal of certain Hanford Site radioactive wastes. Using archaeological information and lessons learned from ancient monuments, designs for both surface and subsurface markers have been completed. The designs address messages, as well as configuration, materials, and arrangement. Subsurface marker

prototypes have been procured and tested for mechanical, chemical, and thermal stress. The work completed to date increases confidence that marker systems can be developed to warn potential human intruders of the dangers from the waste that is disposed of near the surface.

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