

DOE/RL/10930--T2

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TR-5146-1

# MESSAGE DEVELOPMENT FOR SURFACE MARKERS AT THE HANFORD RADWASTE DISPOSAL SITES

31 December 1984

APPROVED FOR  
PUBLIC RELEASE  
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Prepared under:

Contract No. M56-SBB-329956

for

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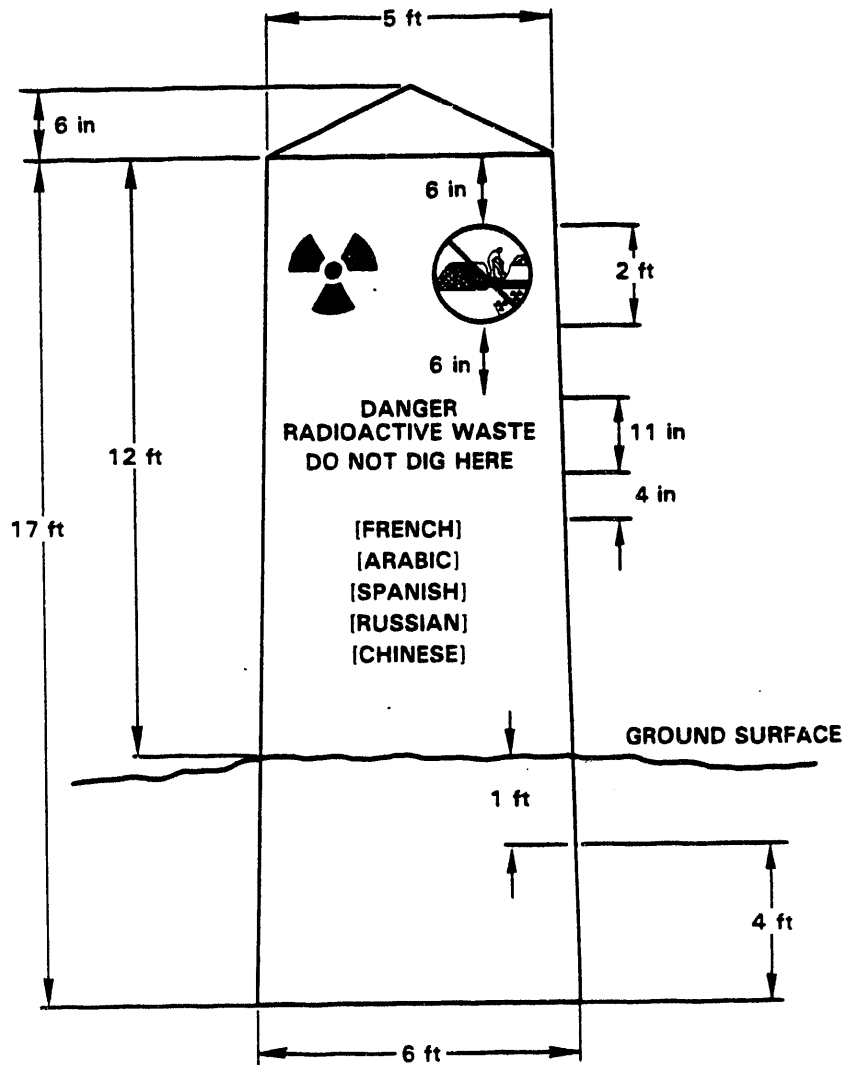
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EXECUTIVE SUMMARY

At the Hanford Reservation in Washington, there are sites which received liquid and solid transuranic wastes from the late 1940's until 1970. Rockwell Hanford Operations (Rockwell) is investigating the feasibility of several options for the permanent disposal of these wastes. One option is to stabilize the wastes in their present locations and to add barriers to minimize water infiltration and root penetration into the wastes.

This report forms part of the project to develop a marking system for transuranic wastes on the Hanford Reservation. The focus of this report is the development of the message system to appear on the surface markers. A logical framework is developed to deduce what is required by the message system. Alternatives for each message component are evaluated and justification is provided for the choice of each component. The components are then laid out on the surface marker to provide a legible, comprehensible message system.

The surface markers are tall, standing monoliths which ring the perimeter of each disposal area (Fig. ES-1). Based on the logical framework, it is recommended that three domains of representation -- symbols, pictures, and language -- be used in the message system. The warning symbol chosen for the message system is the radiation trefoil. Two other options were considered, including the warning symbol developed by the Human Interference Task Force for a high-level waste repository. The trefoil was preferred because of the widespread usage and international acceptance which it already enjoys.



(NOT TO SCALE)

Figure ES-1 Surface Marker - Front View

A 'do not dig' pictograph was developed based on the principles incorporated in international driving signs (upper right, Fig. ES-1). Several options were developed for this pictograph and the rationale for the preferred option is given in the report.

The front panel of the marker is completed by a warning and simple message (message levels 1 and 2) repeated in the six languages of the United Nations. The logical framework identified that the warning should be strong yet credible, provide a description of the wastes, and specifically identify actions to be avoided. This can be accomplished in the seven word message shown on the front of the marker. The six languages of the United Nations are used because we cannot predict which language will be recognizable in the distant future. By incorporating the six languages in most widespread use today, however, we significantly increase the likelihood that one language will be recognizable at the time of investigation.

One side of the marker is devoted to a pictorial description of the site and the consequences of disturbing the barrier mounds (Fig. ES-2). The uppermost panel is a top plan of the site. Additional features could include an arrow identifying the marker at which the investigator is standing and marking each barrier mound with the radiation trefoil. The latter is not feasible on the scale at which the figures are drawn but would be legible on the full scale marker. The six panels show the consequences of disturbing the site. In keeping with the guidelines developed for the marking system, the message is strong but credible.

The other side panel (not shown) contains a more complete written description of the wastes, disposal methods, and consequences of disturbing the site (message level 3). The proposed text is given in Table ES-1. It is readable at an eighth grade level of education and covers the 'who-what-where-why-when' information identified in the logical framework as components of the basic message to be placed at the site.

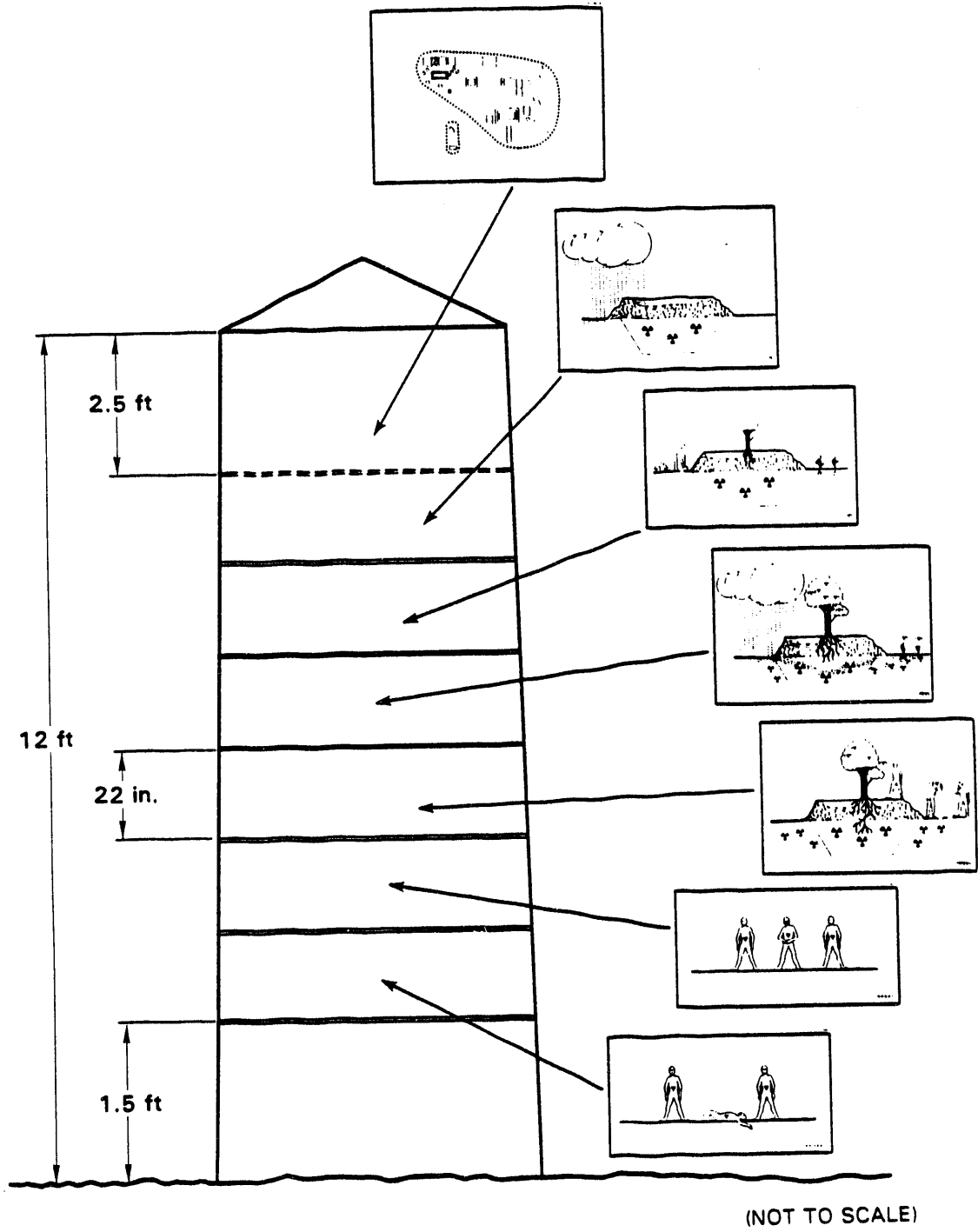


Figure ES-2 Surface Marker - Side View



TABLE ES-1  
LEVEL 3 MESSAGE

"This area contains disposal sites for long-lived radioactive wastes. Each disposal site is marked by a raised mound of earth and rock. These mounds are designed to keep water, animals and humans away from the dangerous material. Do not build houses on the mounds. Do not plant crops on the mounds. Do not dig for water within the area outlined by these markers. The soil below the mounds does not look, feel, or smell unusual, but it is contaminated by radioactive wastes. Disturbing the mounds does not cause immediate sickness or death. Disturbing the mounds may cause exposure of humans to radioactivity which may result in cancer and death. Illness may not occur for several years after exposure. These disposal sites and markers were built by the United States government in \_\_\_\_."

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The specifications for the messages are summarized in Table ES-2. The layout and letter size meet the human engineering design criteria specified in military standards and the guidelines given by the American Institute of Graphic Arts. One result of incorporating these design criteria is that the marker must be 4 ft thick in order to legibly accommodate the message system. By incorporating redundancy in terms of how the information is conveyed and the level of detail at which it is conveyed, we provide the future investigator with multiple opportunities to reconstruct the message in its entirety.

TABLE ES-2  
SPECIFICATIONS FOR SURFACE MARKER MESSAGES

MESSAGE	SPECIFICATIONS
Radiation Symbol	Front Panel - Upper Right 2 ft Diameter
Do Not Dig Pictograph	Front Panel - Upper Left 2 ft Diameter
Message Levels 1 and 2	Front Panel - Center and Bottom 'DANGER. RADIOACTIVE WASTE. DO NOT DIG HERE.' 3 lines of text, 3 in. letters, 1 in. between lines, 4 in. separation between languages
Map	Left Side - Top within 2.5 ft Height
Pictographic Series	Left Side - Center and Bottom Each Panel 22 in. High
Message Level 3	Right Side 1 in. letters, 0.4 in. between lines, 3 in. between languages
Suggested type font is Helvetica Medium with 0.5 in. depth of inscription.	

1.

INTRODUCTION

1.1 BACKGROUND

At the Hanford Reservation in Washington, there are sites which received liquid and solid transuranic wastes from the late 1940's until 1970. Rockwell Hanford Operations (Rockwell) is investigating the feasibility of several options for the permanent disposal of these wastes. One option is to stabilize the wastes in their present locations and to add barriers to minimize water infiltration and root penetration into the wastes (Ref. 1).

The work performed by and for Rockwell has included the development of surface and subsurface markers to identify the disposal sites (Refs. 2 through 5). The Environmental Protection Agency (EPA) requires disposal systems to be identified by the most permanent markers practicable in its proposed Rule on "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Wastes; 40 CFR 191" (Ref. 6).

This report focuses on the message content of the surface markers. This project is identified as Task C-4 in the TASC contribution to the Rockwell marker development plan (Ref. 2). Recommended technical specifications for the form, size, and shape of prototype surface markers are given in Ref. 7. This report sets a logical framework which identifies the desired components of the message to be inscribed on the surface markers. Specific examples for each component are then developed and evaluated. The message content is being developed

at this time to allow refinement of the message through a cycle of review. The objective is to reach a consensus on the message content of the marking system by the time the tests and trade-off studies for the material aspects of the marking system are completed.

## 1.2 ORGANIZATION OF THIS REPORT

The logical framework for identifying the components is presented in Chapter 2. Chapter 3 contains the basis for the specific examples developed for each component. A summary is provided in Chapter 4.

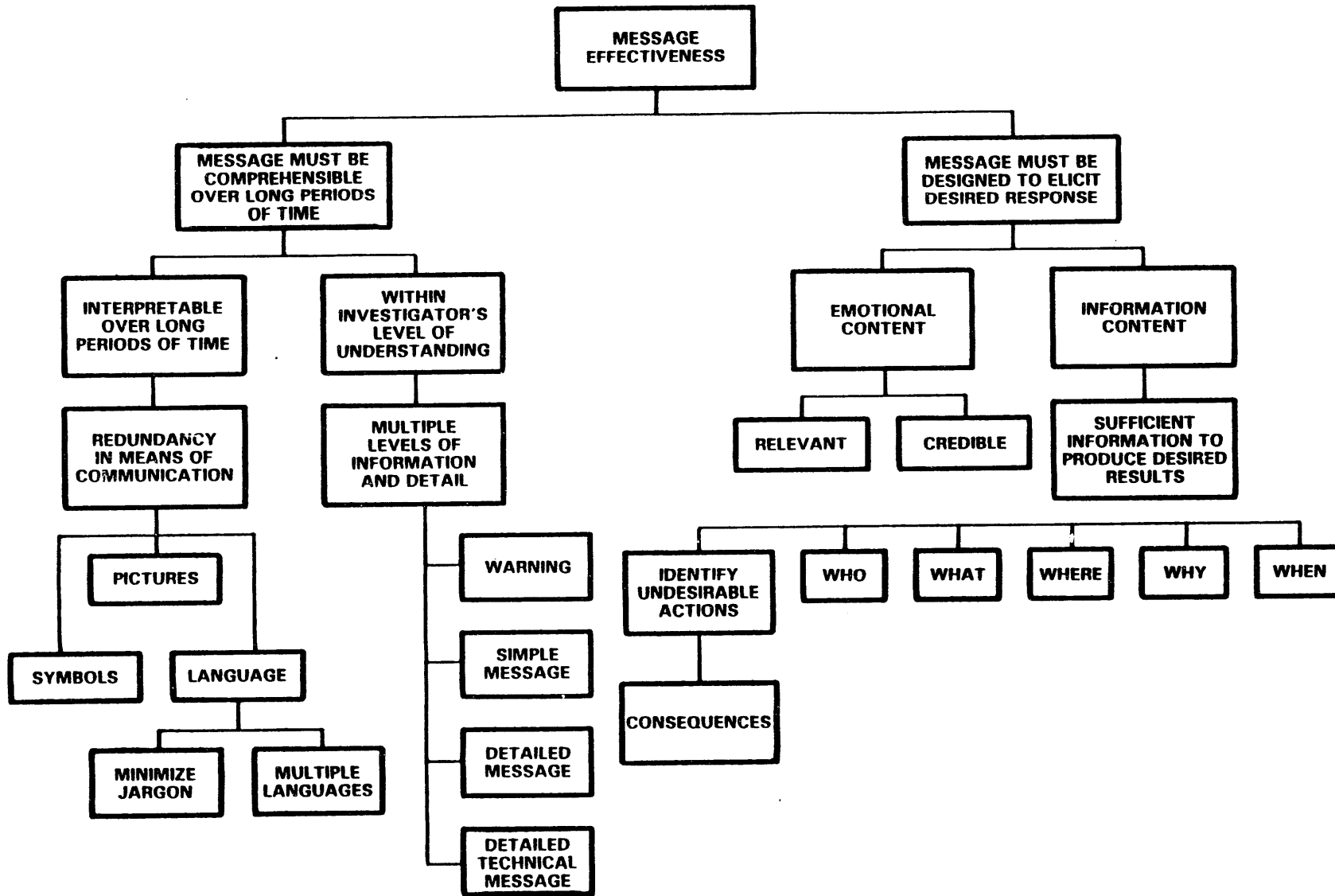
2. LOGICAL FRAMEWORK FOR MESSAGE DEVELOPMENT

For the marking system to inhibit or dissuade human interference at the disposal sites, the message must be both comprehensible and elicit the desired response. Initial efforts for Rockwell to outline the factors involved in creating messages which would be effective over long periods of time were presented in an earlier report (Ref. 2). Since that time, the Human Interference Task Force has presented its recommendations for marking high-level waste repositories (Ref. 9). Other volumes written by specialists in various disciplines in support of the Task Force work also have appeared recently (Refs. 9 and 10). The analytical framework presented here (Fig. 2-1) takes into account these recent developments and has tailored them to Rockwell's needs.

2.1 MESSAGE COMPREHENSIBILITY

For the message to be comprehensible over long periods of time, the investigator must be able to interpret the message and to have its contents be within his or her level of understanding. Although shown as separate branches in the logic, there is a great deal of interplay between interpretability and understanding, because different means of communication can carry different levels of information.

There are three general domains for the presentation of information: pictorial, symbolic, and semantic/language (Refs. 11 and 12). There is a debate whether pictorial/symbolic information is processed differently within the human mind than



2-2

Figure 2-1 Logic Diagram for Effective Messages

is written information (Refs. 13 through 15). In any case, it appears that redundancy in the message enhances its ability to be interpreted: "Even out of context, re-presentation of an item may lead to some degree of recognition, and in this situation recognition can be enhanced by active reconstruction of the initial contexts," (Ref. 16, p. 5). This leads us and others to the conclusion that all three types of messages should be used in the marking system (Refs. 2, 8 and 9).

It is relevant to point out that we are taking an empirical approach to developing the message. This is because the fields of semiotics, psychology, psycholinguistics and so forth are not sufficiently developed to allow the design of the message "from first principles down." Psychology has focused on how an individual processes information, not on the generation-to-generation relay thereof. The processing of information within an individual and between individuals is very complex and not yet thoroughly understood. One consultant to the Human Interference Task Force called for a generation-by-generation relay of information based on this lack of understanding (Ref. 10).

This overlooks the archaeological evidence. The fact that we can translate texts which are several thousand years old tells us that messages can survive and have survived through time, cultural and linguistic changes, even if we do not understand the process by which this occurs. We also learn from archaeology that if contemporary written records are not created, we remove the possibility of recovering detailed information. Since we cannot predict which languages will be recognizable in the future, the message should be given in several languages which are in widespread use today (Refs. 2 and 9).

Technical vocabulary and jargon should be minimized since these appear to hamper the interpretability of the text at later times. For example, texts on how to make glass were written in Assyrian about 669-626 B.C. and were found in excavations which took place in the mid 1800's. The texts were not adequately translated until specialists in general areas cooperated, e.g., language, glass-making, ancient glass, and locally available materials (Ref. 17). Keeping the text simple yet accurate should also increase the number of people who can interpret it.

The message must lie within the investigator's level of understanding once he or she has interpreted it. Simple messages are more easily conveyed and may be easier to transmit. Complex information offers better explanations and may result in more knowledgeable actions (or lack of action). A combination of messages could address a range of future investigators at the site, providing another type of redundancy in the message design. The Human Interference Task Force has identified four levels of messages: caution, warning message, detailed message and detailed technical information (Ref. 8). These are similar to the levels suggested in Refs. 9 and 19. The specific messages proposed by the Task Force are discussed in Chapter 3.

## 2.2 RESPONSE TO THE MESSAGE

At this point we assume the message has survived, been noticed, and been correctly interpreted. The message should elicit the desired response (i.e., do not disturb these mounds) in order to be effective. For this to occur we need the emotional content and the information content of the messages to be consistent. When we speak of the emotional content



of the message we refer to those factors which make the investigator realize that he or she has a personal stake in paying attention to and heeding the message, i.e., the message is relevant. Simply stating that the waste is there may not be sufficient to trigger this response; stating that the waste is hazardous may be more effective.

The hazard of the waste must be accurately described for the message to be credible. Overstating the hazard (e.g., "you will die if one stone is removed") is likely to be counterproductive. In the near-term, the suggestion to create horror stories to deter trespassing at such sites has already lost credibility with today's public (Refs. 10 and 19). In the long term, the entire message may be discarded if immediate death does not occur upon initial investigation of the barrier. Overstating the hazard also leads to an undesirable inconsistency between what is on the marker and what is in the safety analysis of this disposal option.

Understating the hazard is not acceptable; this approach runs counter to the entire process of designing a safe disposal system. The best approach is also the most difficult. Correct portrayal of the hazards of the waste must address the facts that the contaminated earth will not look or feel significantly different and that illness may not appear until years after initial exposure.

The information content of the message should be sufficient to produce the desired result (e.g., take no action at this place). The surface markers and the barrier mounds will identify the existence and location of the disposal sites. Other basic information includes the contents of the sites and the risks from intrusion. In other words, it is desirable to say not only that "something is here," but to include what the

material is, that it is hazardous, and what action should be avoided to maintain safety. Listing general actions to be avoided relieves the investigator of deciding what to do or not to do. Additional information would be who built the disposal mounds, why they were built, and when they were built. If the technological level of the investigator is similar to our own, the "what" and "when" information would allow him or her to estimate the remaining hazard of the waste. Specific examples for messages of differing information content are given in Chapter 3.

Experience indicates that people warned by dangers generally avoid them. There are exceptions. Certain individuals are attracted to danger, particularly danger associated with challenge (Ref. 9). Breaching a barrier mound is unlikely to hold the same type of challenge as scaling the outside of a skyscraper, so this type of individual may not be of great concern for this project. Another exception are those individuals who disregard warnings even though cognizant of the hazard, such as cigarette-smokers. With regard to this category of individuals, the Department of Energy has taken the position that, for the disposal of high-level wastes, this generation bears no responsibility if a later generation decided to do something which would affect the behavior of the disposal system if that generation is fully cognizant of the hazards and consequences of that action (Ref. 20).

3. MESSAGE DEVELOPMENT

This chapter focuses on the development of specific messages for the surface markers. The message content, such as a specific symbol or wording, is discussed in Section 3.1. The physical emplacement of the messages, e.g., letter height, is outlined in Section 3.2.

3.1 MESSAGE CONTENT

This section presents and evaluates alternative designs for the symbols, pictures, and languages for the surface marker. Each domain of representation is presented separately.

3.1.1 Symbols

Three possible symbols for the markers at the Hanford site have been identified, see Fig. 3.1-1. The first candidate is the uranium symbol which appears in an authoritative guide to international graphic symbols (Fig. 3.1-1a, Ref. 21). It has symmetry, regularity, and simplicity -- three properties which gestalt theorists and recent developers of signs believe make a symbol more readily recognized, more stable, and more readily remembered (Refs. 9, 21 through 23). The marking system being developed by Rockwell is for transuranic wastes so the uranium symbol is not totally inaccurate. Two points weigh against the choice of this symbol. First, its meaning is merely descriptive. It would be preferable to identify a symbol which has a warning connotation. Second, the defense wastes are a mixture of isotopes and it is preferable to identify a symbol which accurately reflects this situation.

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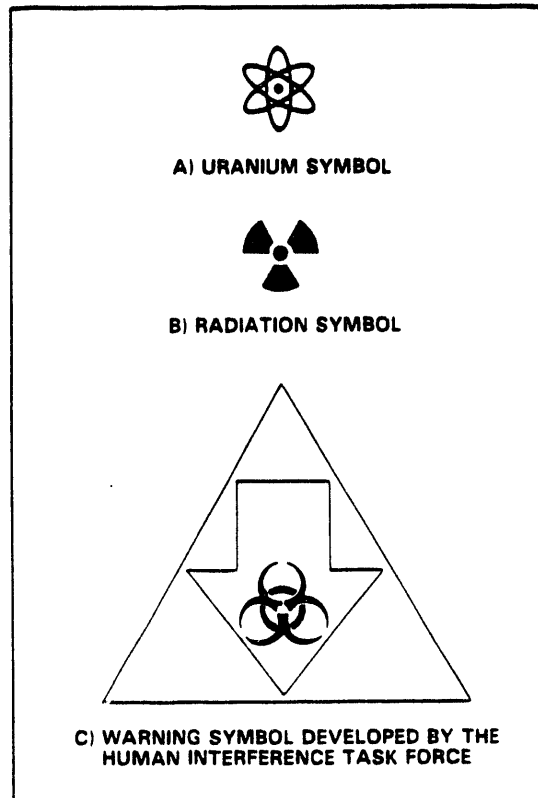


Figure 3.1-1 Options for Warning Symbol

The second candidate is the standard radiation symbol (Fig. 3.1-1b). It has the properties of symmetry, regularity and simplicity -- making it a "good" figure (Refs. 21 and 22). The symbol has a warning connotation and it does not restrict the materials which could be the source of the radiation. The radiation sign has the added benefits of long-term usage and international acceptance. It was recommended as the standard radiation symbol by the International Commission on Radiation Protection in 1956 and was adopted by the U.S. Nuclear Regulatory Commission in 1960. The American National Standards Institute adopted it in 1969 and it has been required for the labeling of all radioactive material by the U.S. Department of Transportation since 1978 (Refs. 9, 24 and 25). The military

standard on marking for storage also requires the use of the radiation trefoil denote radioactive materials in accordance with NRC and DOT regulations (Ref. 26).

The third candidate is the symbol developed by the Human Interference Task Force (Ref. 8). The triangle denotes warning (Refs. 21 and 23), originally an arbitrary choice but now in widespread usage in signs. The arrow pointing down is placed within the triangle to countermand any downward action. Within the arrow is the international biohazard symbol.

The Task Force chose the biohazard symbol rather than the radiation symbol on the grounds that there might be only two to five high-level waste repositories in the U.S. while there are potentially many thousand of sites for biohazardous wastes. The Task Force overlooks the number of sites which could be marked with the radiation symbol, e.g., those for transuranic wastes, low-level wastes and uranium mill tailings. The disposal of radioactive wastes has been more heavily regulated than the disposal of toxic wastes. It is quite possible to envision a scenario where some type of marking is required for disposal sites for radioactive wastes but not chemically toxic wastes. In addition, the hazard of radioactive materials diminishes with time while toxic wastes can remain hazardous indefinitely. It is not necessarily beneficial to confuse these materials in the public's mind.

The symbol may also be trying to accomplish too much. The American Institute of Graphic Arts comments on symbols in general:

"We are convinced that the effectiveness of symbols is strictly limited... They are much less effective when used to represent a process or activity... The use of symbols alone, without consideration for the

verbal messages and all other signing, will only add to the confusion."

(Ref. 25)

The symbol, by including the directional arrow within the warning triangle, is trying both to portray a process and to interdict it. This message, in itself, may be confusing to the observer. In addition, a triangle on its base is not as effective a warning shape as a triangle on its point (Ref. 27). Rotating the Task Force symbol, however, would make its meaning even less clear. Finally, Tannenbaum's remarks on the Task Force symbol conclude:

"However, because its "flares," though representative of circles, create an asymmetrical clutter at the focal center, it may be less preferable, in gestalt terms at least, than the trefoil (as well as being more difficult to copy and reproduce faithfully)."

(Ref. 9)

Based upon the above information, we suggest that Rockwell use the radiation trefoil as its warning symbol. It appears to be a "good" figure in gestalt terms. A great deal of effort is being expended in the development of comprehensible symbols (Refs. 21-23, 27-29). Yet it appears that interpretability of a symbol is a function of context and experience (Ref. 30). The radiation trefoil has an international consensus behind it as well as nearly three decades of use to establish its context. This consensus and widespread recognition of the trefoil symbol should not be discarded lightly. We cannot expect a symbol to be recognizable in the future if it is not widely recognized today -- not without an immense effort to educate the public on a national and international basis. The effort is already in progress for the radiation trefoil and there appears to be no benefit in duplicating it for another symbol which serves the same purpose.

3.1.2 Pictures

Pictures are another means of providing information across various languages. Tannenbaum discusses the development of a pictograph or a series of pictographs for high-level waste marking systems. He mentions that there are few reliable, comprehensive research data to assist the developers of the pictographic message. He suggests that the meaning of the overall sequential message be made clear and that the interconnections between its constituent parts follow logically and symbolically. His closing observation notes that fairly complex messages require fairly complex codes (Ref. 9).

This implies that very detailed information should be left to the written messages. Pictorial representations range from late Paleolithic cave paintings (c. 28,000 B.C.) to complex Egyptian funerary art to modern efforts. One property for understandable pictures which is stressed repeatedly is simplicity (Refs. 23, 25). The key seems to be visual realism as well as the absence of details unnecessary for comprehension (Refs. 9, 18, and 31).

We propose that three different ideas be conveyed by pictures: "do not dig," "where is the waste buried," and "what happens," conveying information on warning, waste location and consequences of intrusion respectively. Each idea is developed separately.

Four variations on a "Do Not Dig" pictograph have been developed for marking disposal sites. The Human Interference Task Force did not develop such a pictograph (Ref. 8). A single pictograph is limited in the amount of information it can convey. The concept of "do not dig" is important to the preservation of the disposal system. Disturbing the earth could take place for several reasons such as:

- Preparing a house foundation
- Obtaining fill for other activities
- Digging a well
- Preparing the soil for planting.

All these actions can be subsumed under the general concept "do not dig." These activities would not affect the functioning of a high-level waste repository, which may be why the Task Force did not deem it necessary to develop such a sign.

The concept which we wish to convey is "do not disturb the barrier mounds." Four variations are shown in Fig. 3.1-2. All are based on the international convention of a circle with a diagonal line across it as denoting a prohibited action. The format is most commonly used in international driving signs (Refs. 21 and 23). The simplest option shows a shovel with a line across it (Fig. 3.1-2a; first proposed in Ref. 2). Although simplicity is a desired feature of a pictograph (Ref. 23), this variation is too simple. We wish to ban the action, not the implement. The pictograph also does not indicate where the digging is prohibited.

The second variation was first proposed as a symbol for the marking system for high-level waste (Fig. 3.1-2b; Ref. 32). It is an improvement over Fig. 3.1-2a because it shows the action to be avoided. It is not acceptable, however, because it does not show a barrier mound, that is, it has not adequately defined where not to dig.

Figure 3.1-2c errs on the side of too much complexity. This was first proposed in Ref. 2 and has actually been tested on prototype surface markers. Two concepts are shown: do not dig at the barrier's edges and do not plant deep-rooted crops.



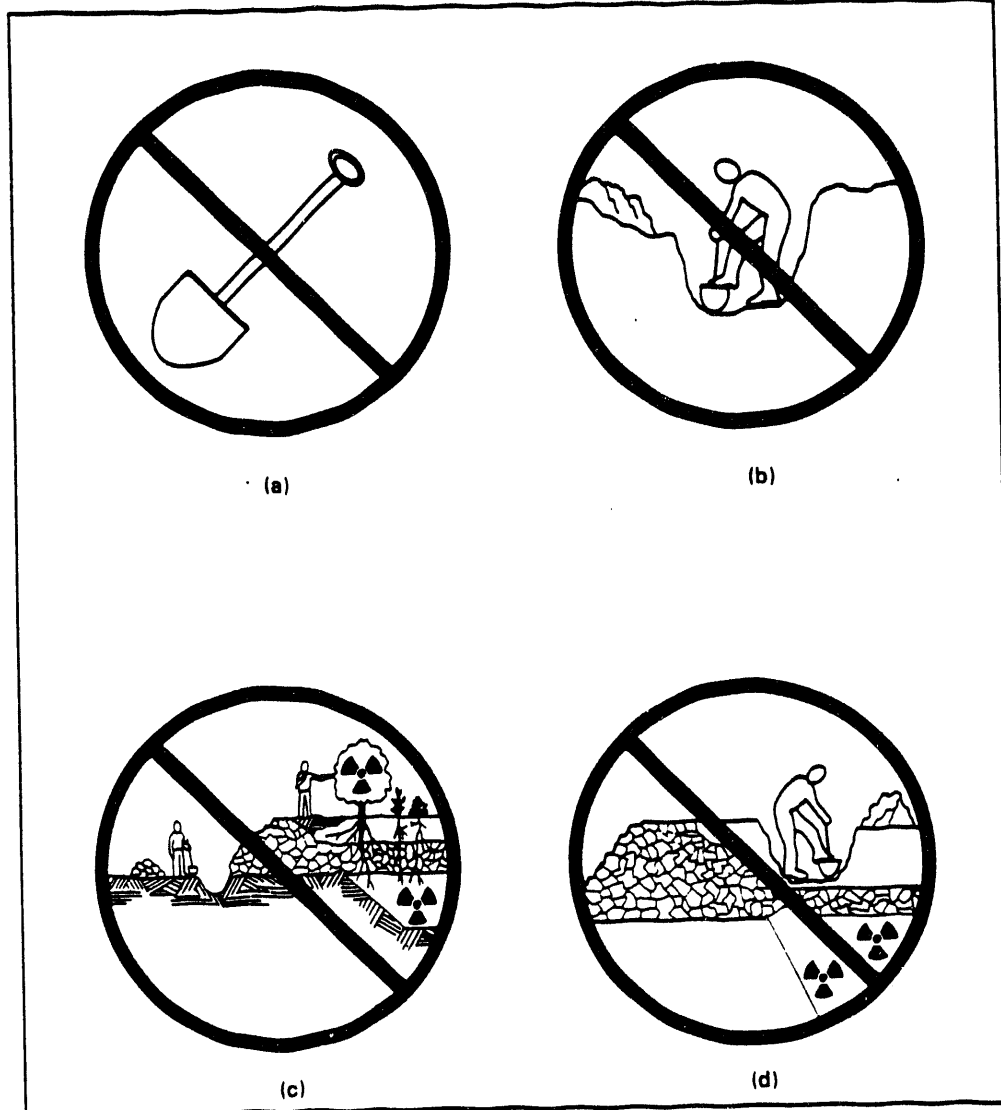


Figure 3.1-2 Variations on Do Not Dig Pictograph

The humans are shown in detailed form and different patterns are used for the soil, barrier material, and the wastes. Three types of crops are shown although we cannot identify what each one is. Finally, one observer requested that the trefoil within the tree be rotated to look less like a face. There is simply too much detail in this figure for it to be effective.

The fourth variation is the one proposed for the prototype surface marker and is a simplified version of Fig. 3.1-2c (Fig. 3.1-2d). The barrier mound is shown with a contrasting pattern to denote the basalt rubble. Simplified picture of a human is shown digging through the barrier mound toward the contaminated material below. This version omits the busy detail of the patterns for the uncontaminated and contaminated soil and the detailed portrayal of the human figures. It also omits showing how deep rooted plants can become contaminated. This omission is corrected in the sequential pictograph discussed below.

The location of the wastes can be clearly shown by the use of a map such as Fig. 3.1-3. The position of each barrier mound should be marked. Additional options to consider include marking each barrier mound with a radiation trefoil and the addition of an arrow indicating the exact marker at which the observer is standing. The scale of Fig. 3.1-3 is too small to allow the inclusion of the radiation trefoils. Given the proposed scale of the actual marker (see Section 3.2), the trefoils can be included. The inclusion of the symbol with each barrier mound will help define the areas to be left undisturbed. The trefoil should be included on every barrier mound not just those for transuranic wastes. It is extremely difficult to convey in pictures the difference in the hazard between low-level and transuranic wastes. Marking some, but not all the barrier mounds on the figure will only lead to confusion. For simplicity, a top plan is preferred to an isometric view.

A pictographic representation of the hazards associated with a high level waste repository has been developed by the Human Interference Task Force (Ref. 8). The pictograph series is reproduced in Fig. 3.1-4; the description is taken directly from the Task Force Report.

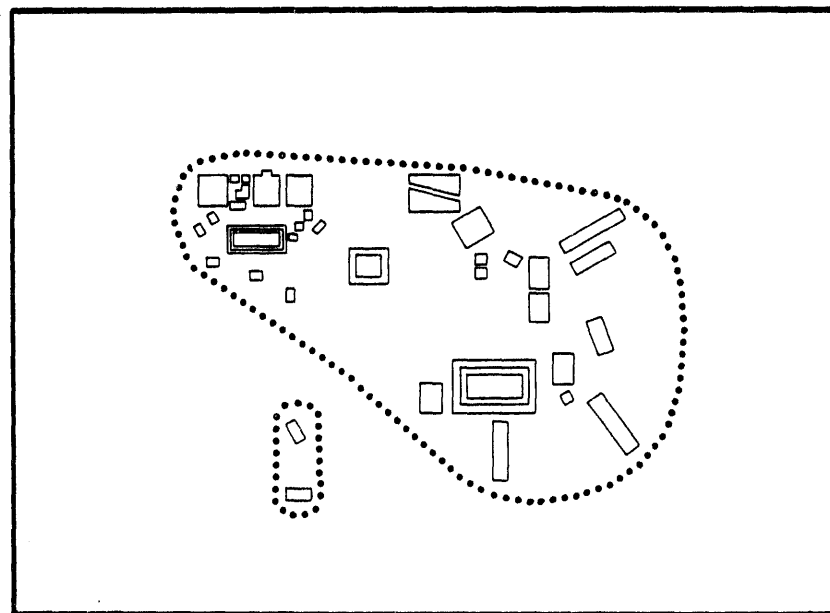


Figure 3.1-3 Map of 200 East Area

"The pictograph that follows was developed using the concepts and guidelines discussed by Givens (Ref. 18). The objective is to convey to the reader the sense that if the area below the markers is disturbed, toxic substances will enter the ground water and lead to severe consequences. The pictograph relies on several visual images acting in concert to relay the message.

- The ground surface exhibits peripheral markers and a central monument to denote relevance to the site where those markers and monument exist
- The ground-water system is indicated by water-drop shapes and by the chemical symbol for water (the only departure from icons, used as a redundant measure)

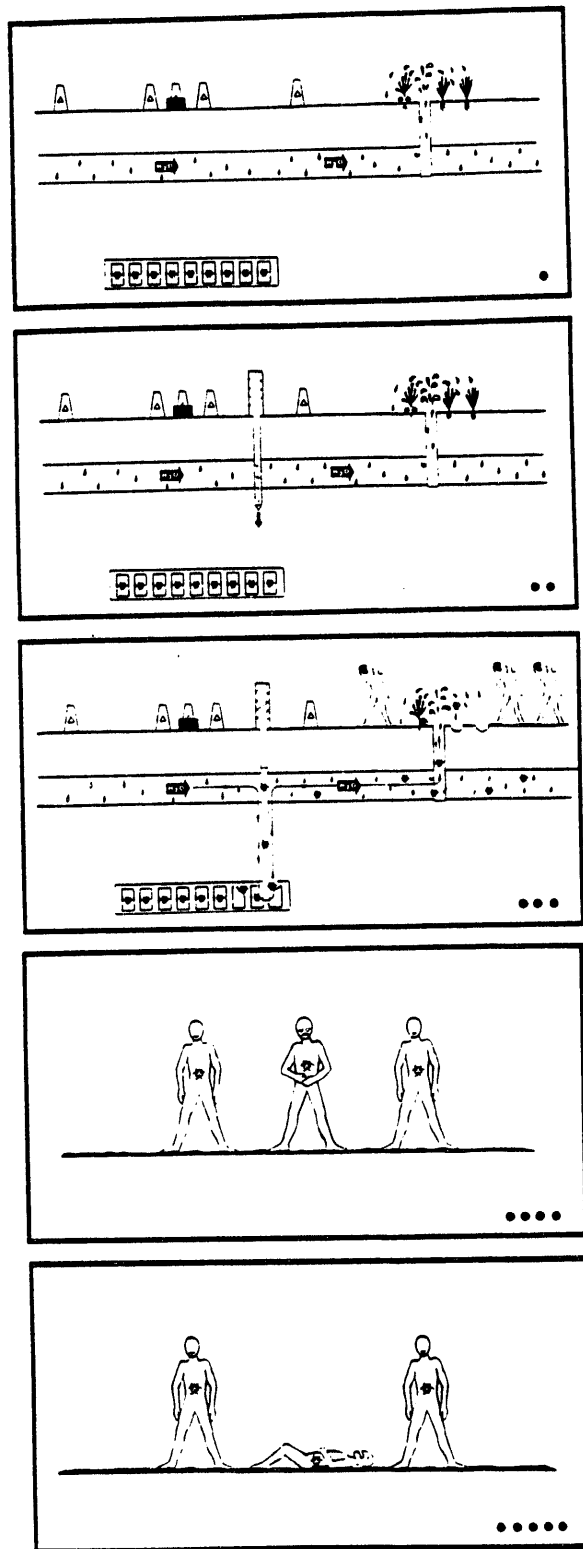


Figure 3.1-4 Human Interference Task Force Pictographic Series

- A repository far below the surface is depicted with the biohazardous symbol. The fact that the object portrayed below the surface is a repository may not be at all evident to a future reader from the first frame; however, the movement of the dark material from the repository through the aquifer and into the vegetables in the third frame, coupled with the movement of the biohazardous symbol, should imply the burial of biohazardous materials below the surface
- The pictographic sequence exaggerates reality with regard to the rapidity of contaminant transport and uptake, and with regard to the severity of the consequences. However, exaggeration is necessary because both the clarity and the relevance of the message may suffer if the pictograph attempts to indicate contaminant transport time of thousands of years. Similarly, the consequence portrayed, a painful death, over-exaggerates the cause-effect relationship and the rate of the individual's demise (one out of three suffer death in the pictograph, whereas a  $10^{-4}$  to  $10^{-6}$  chance would be more representative).

The pictographic sequence is read top-to-bottom which is appropriate on a pancultural basis, i.e., various cultures read right-to-left and left-to-right, but all read top-to-bottom (Ref. 18).

The pictograph is intended to be indicative of the type of message that can be delivered using this technique. Additional work would be required to reach agreement on the message(s) to be delivered and the most appropriate icons to be used." (Ref. 8).

The pictographic series includes some useful features, such as the dots in the lower right-hand corner of each picture

which give the sequence of the panels. The possibility, though not the certainty of death from contamination is well conveyed (parts 4 and 5). Cancer is a painful way of dying so I do not agree with the Task Forces' opinion that the figures overestimate the consequences. They do overestimate the likelihood of contracting a fatal cancer (one-in-three) but this exaggeration may be necessary in a long term message.

The proposed pictographic series for the Hanford site is shown in Fig. 3.1-5. Since this series of figures will be on each surface marker it will be possible to see a barrier mound from where the observer is standing. The patterns of visual images is similar to that proposed for the Task Force pictograph. An important point in the series is given in Fig. 3.1-5b; no immediate adverse effects are seen at the time the barrier is disturbed. The consequences occur only later. This is an accurate portrayal of the situation. The pictographic series, therefore, follows the guidelines of relevance and credibility established in Chapter 2.

This series of figures provides the explanation for the "Do Not Dig" symbol on the front of each marker. The last two panels do not show the barrier mound because sickness and death may occur at times and places removed from eating the crops grown on the disposal area. No further description of the sequence is given here; if the general meaning is not clear, the pictograph needs to be modified. As with the "Do Not Dig" symbol, it is expected that the pictograph may be modified in the review cycle.

### 3.1.3 Language

The Human Interference Task Force identified four message levels: caution, warning/simple message, detailed

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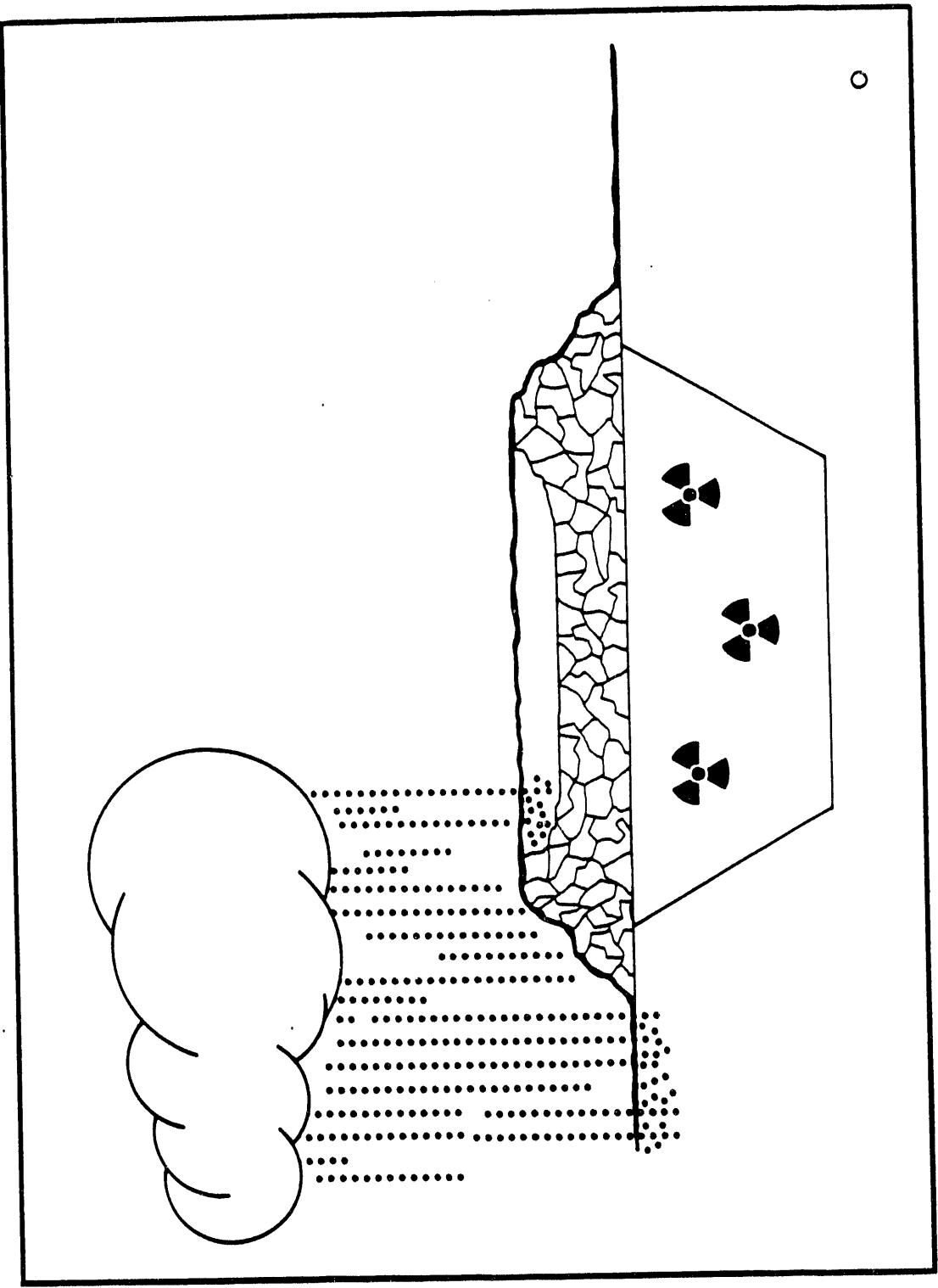


Figure 3.1-5 Proposed Pictograph Series for the Hanford Site - 1st Panel

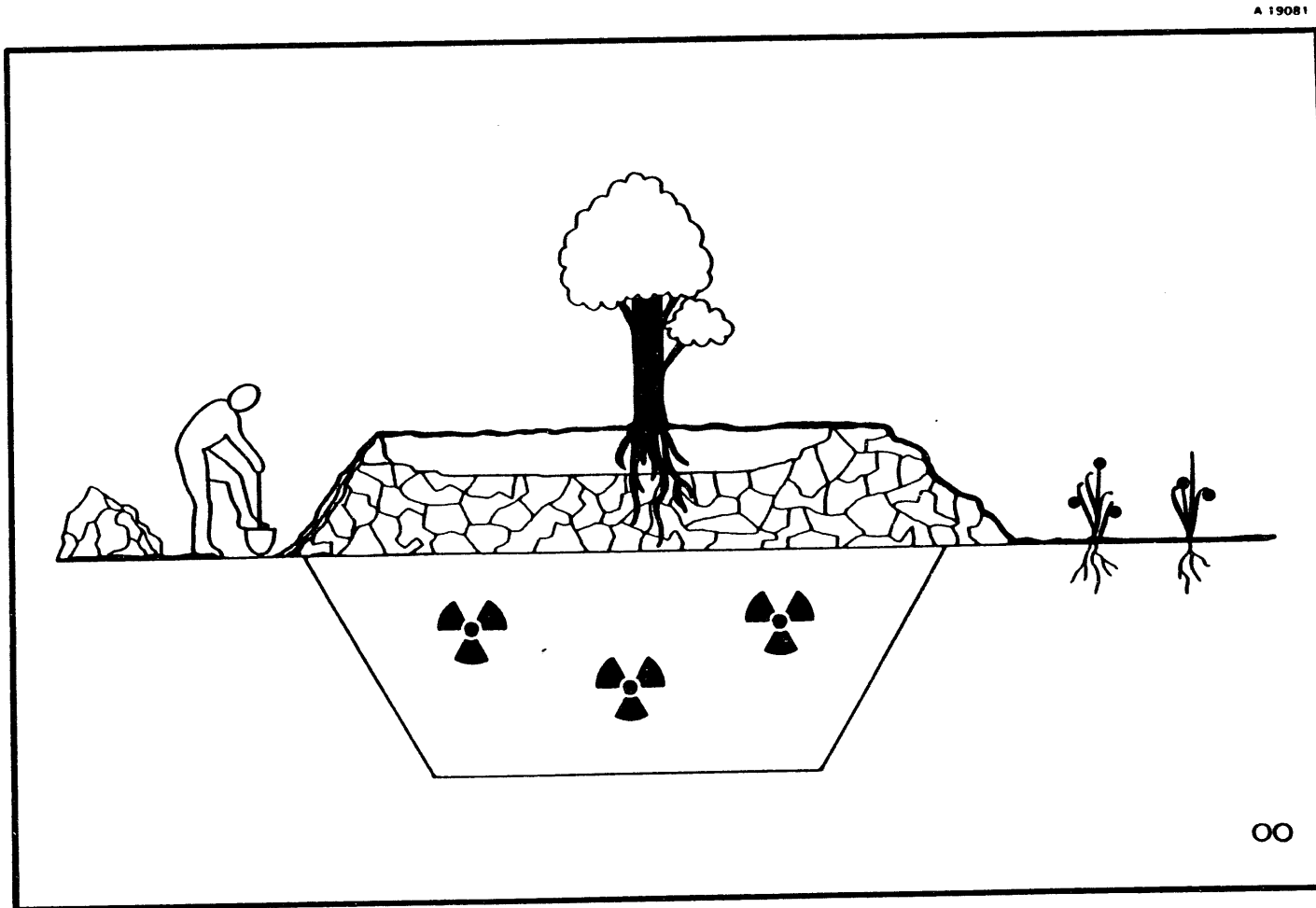


Figure 3.1-5b Proposed Pictograph Series for the Hanford Site - 2nd Panel



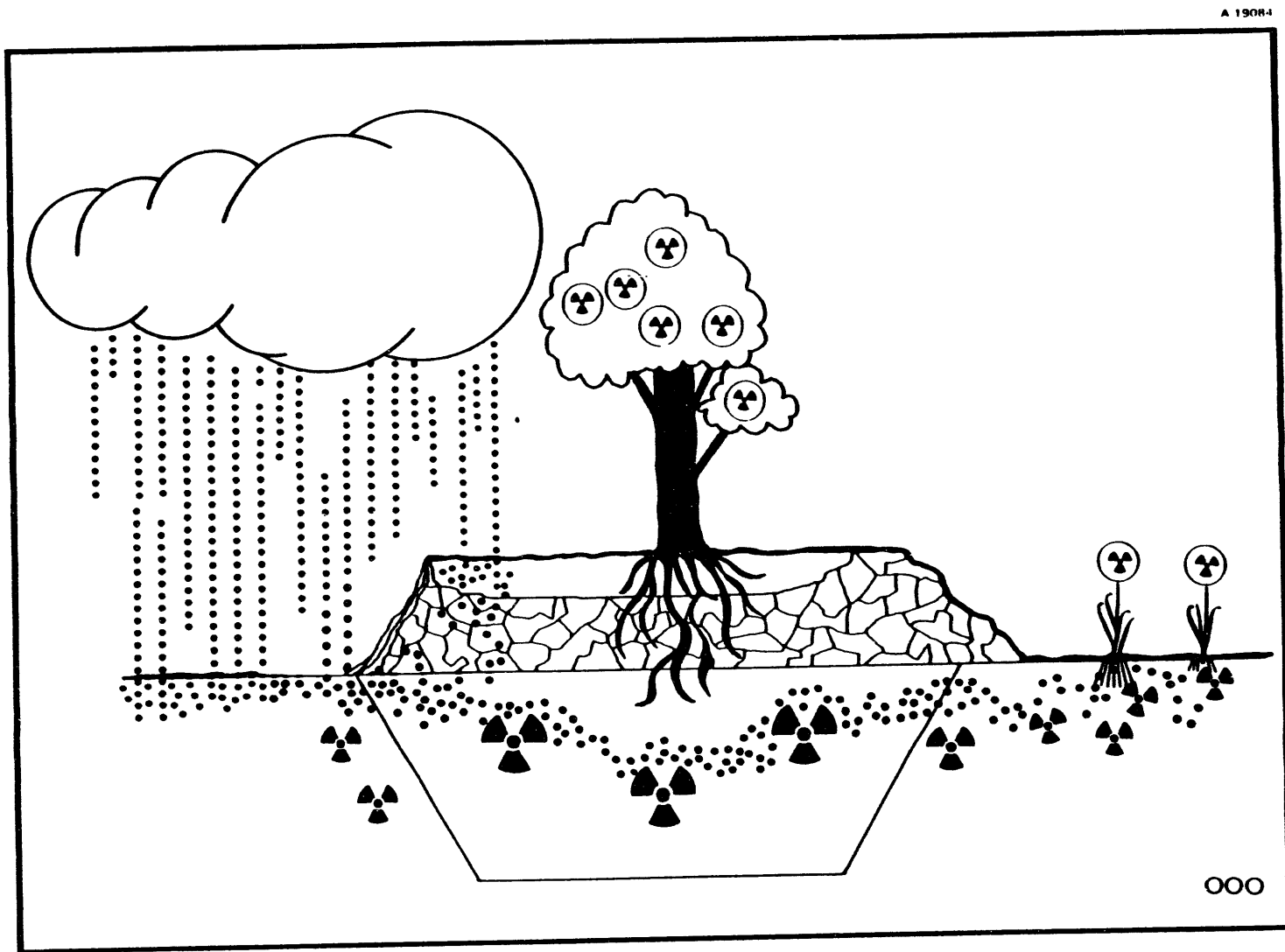


Figure 3.1-5c Proposed Pictograph Series for the Hanford Site - 3rd Panel

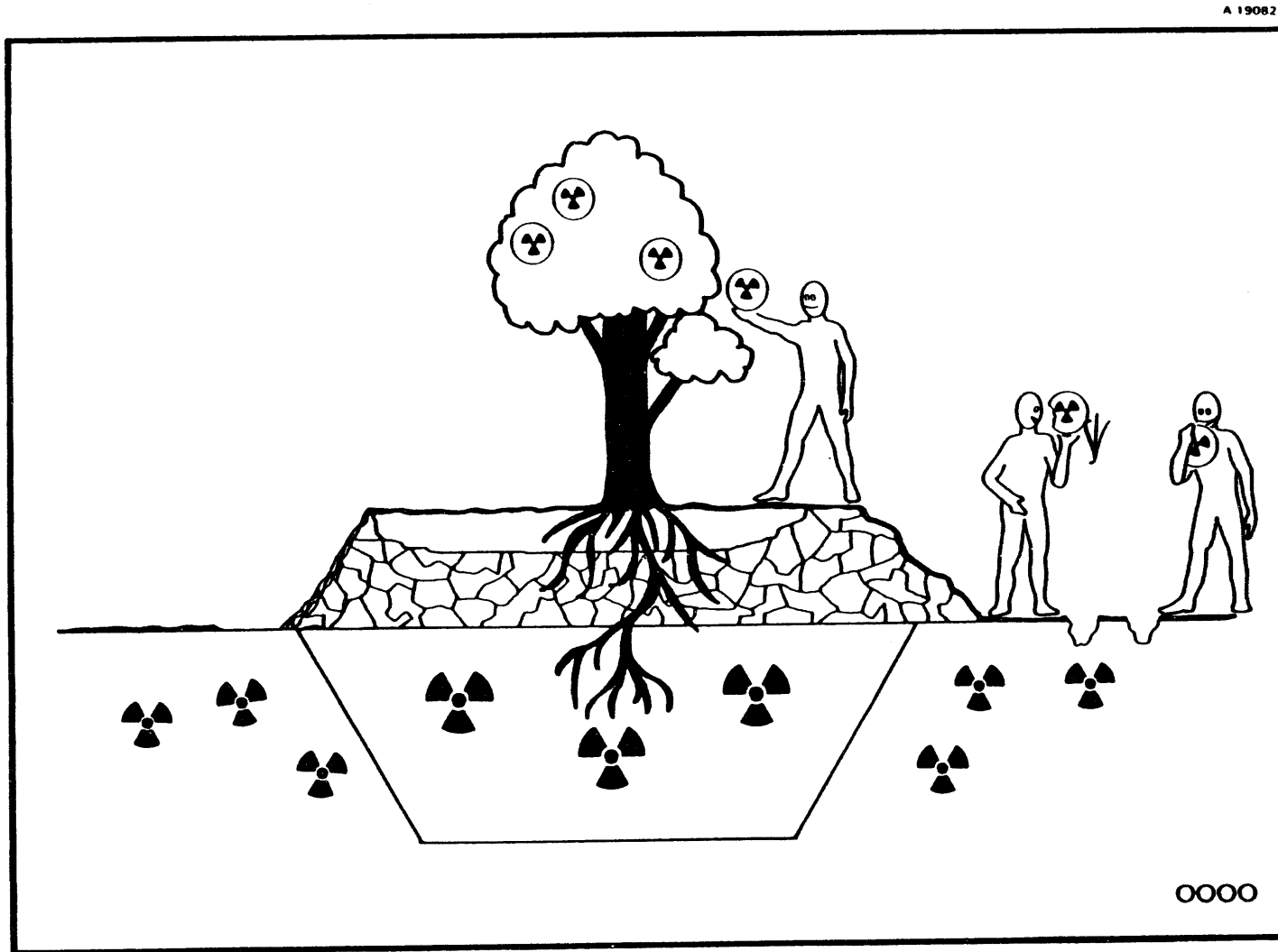
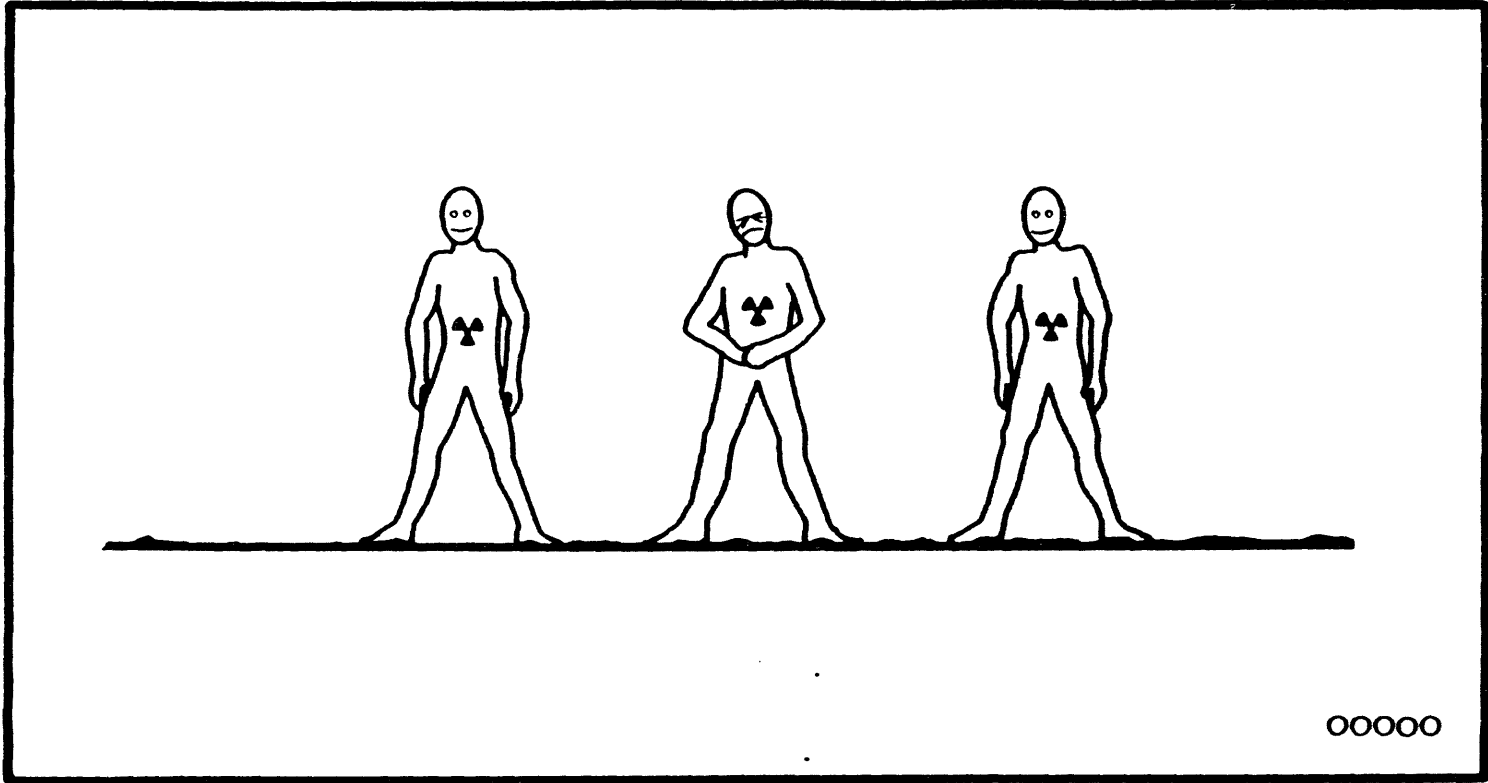


Figure 3.1-5d Proposed Pictograph Series for the Hanford Site - 4th Panel

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3-17

Figure 3.1-5e Proposed Pictograph Series for the Hanford Site - 5th Panel

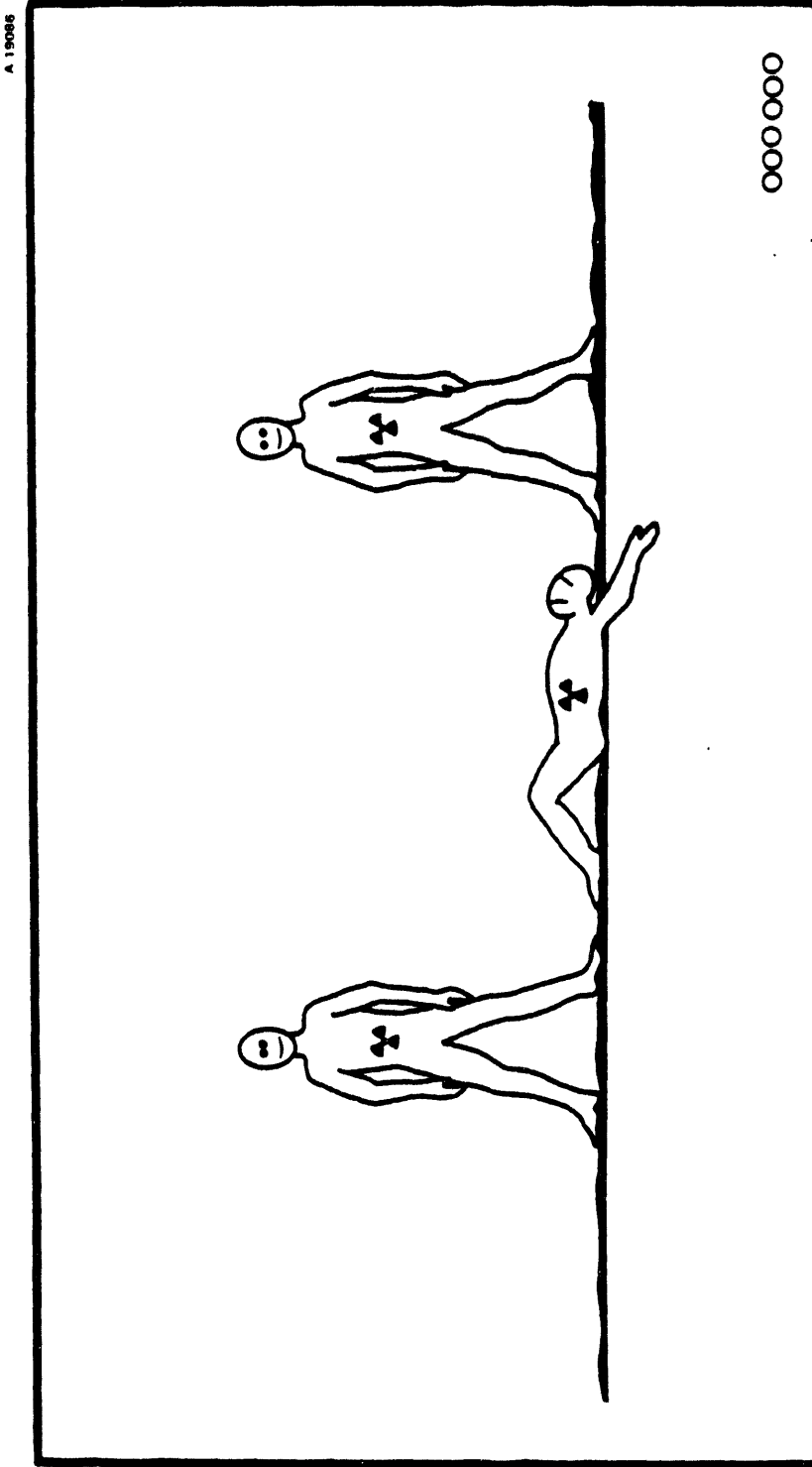


Figure 3.1-5f Proposed Pictograph Series for the Hanford Site - 6th Panel

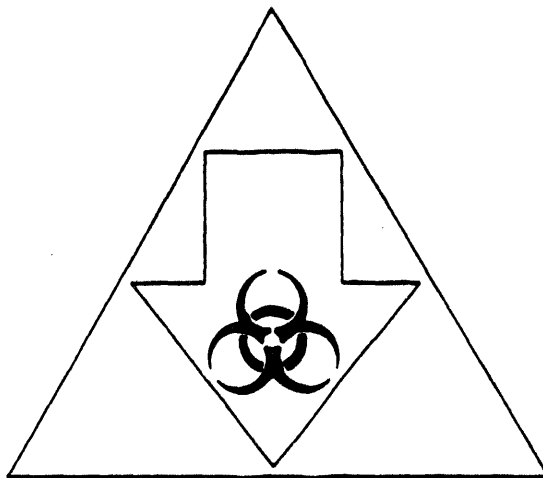
THE ANALYTIC SCIENCES CORPORATION

message, and detailed technical information. These are summarized in Table 3.1-1 and Fig. 3.1-6 (both taken from Ref. 8). The rudimentary message (i.e., something is here) will be quite evident from the barrier mounds and marking system itself.

The Task Force work provides us with examples to how to develop written messages for a marking system. Given the differences between the types of disposal, i.e., deep-mined repository versus near-surface, we may want different types of information in the messages. The surface of the ground can be worked significantly without disturbing the efficiency of a high-level waste repository. This is not the case for the in-situ disposal methods under evaluation for the Hanford wastes. The level of technology required to disturb the Hanford wastes is therefore lower than for disposal in a deep-mined repository.

TABLE 3.1-1  
SUMMARY OF MESSAGE LEVELS DEVELOPED BY  
THE HUMAN INTERFERENCE TASK FORCE

MESSAGE LEVEL	DESCRIPTION
Rudimentary	Simple connotation that something made by humans is at the site
1	Caution message: "CAUTION - BIOHAZARDOUS WASTES BURIED HERE."
2	Simple written message: "CAUTION - BIOHAZARDOUS WASTES BURIED HERE. Radioactive wastes are buried ___ meters below the surface within a ___ hectare area bounded by ___ markers. Further information located ___".
3	Detailed message: nature, location, and emplacement time of wastes along with information regarding why actions are to be avoided (Fig. 3.1-6).
4	Detailed technical information: approximately 500 to 1,500-page technical description of the repository and the risk of potential human interference.



The United States of America, in the year \_\_\_\_, buried \_\_\_\_ metric tons of radioactive waste below this area. The surface of the land is safe, but the buried material could be dangerous if it were improperly moved or if the repository is damaged.

The buried radioactive waste was produced by the fission of uranium to generate electricity. The waste includes radioactive elements, such as plutonium, uranium, and cesium. The radioactive waste was stabilized in a glass material that has been packaged in metal canisters.

There are \_\_\_\_ waste canisters, buried \_\_\_\_ meters below the surface. These canisters have been emplaced in a (type of rock) formation in rows \_\_\_\_ meters apart, \_\_\_\_ canisters per row, and \_\_\_\_ meters from adjoining canisters. The canisters are located over an area \_\_\_\_ meters long and \_\_\_\_ meters wide.

The radioactive waste has been buried at this location and in this manner to ensure that the waste does not become dissolved in circulating ground water. If ground water contaminated by the waste were to reach the outside environment and enter a food chain, it could possibly harm living creatures. The waste should continue to be left undisturbed if possible. Proper instructions for moving the waste or using the land above it without affecting these wastes can be found. More detailed information has been placed at other major libraries and archives.

These messages should be translated into languages common to your time. Future readers will be better able to understand and follow these messages if they are changed to the current language.

Figure 3.1-6 Example of Third Level Message Developed by the Human Interference Task Force

To counterattack this, it is desirable to make the warning message stronger (but still credible) and to identify actions which should be avoided for the potential intruder.

There are several possible deficiencies in the messages developed by the Task Force. The emphasis appears to be on a description of the disposal method rather than warning why the wastes should not be disturbed. No prohibited actions are specifically identified for the investigator of the site. The consequences of interference are very mildly stated, e.g., "...possibly harm living creatures." A warning this benign is not likely to make the message relevant to the reader nor to inspire him or her to translate it into languages common at that time. Finally, although the wording is relatively simple, some of the concepts are not, such as a food chain. In sum, the message developed for the wastes at the Hanford site should contain stronger warnings, a more definite description of the consequences of intrusion, and list some prohibited actions. This may be done by reducing the amount of emphasis placed on describing the wastes and the method of disposal.

Message Levels 1 and 2: Message level 1 is included within message level 2 as developed by the Task Force. They are treated as a single block of text here. The proposed wording for the Hanford markers is "DANGER. RADIOACTIVE WASTE. DO NOT DIG HERE." The first three words follow the guidelines given in 10CFR20 for the labeling of radioactive materials (Ref. 24). The word "danger" is preferred to "caution" because it denotes a stronger warning yet is still credible. The phrase "do not dig here" overstates the situation since digging is undesirable only on the barrier mounds and not in the intervening areas. This oversimplification is offset by the directness of the message. In 34 letters and 7 words, the message conveys a warning, a description of the material and specifically identifies a prohibited action.

Message Level 3: Several publications on technical writing stress simplicity, brevity and clarity (Refs. 33 through 35). This message should include the following components:

- Warning
- Description of wastes and barrier mounds
- Prohibited actions
- Consequences if interference occurs with the mounds
- Date of disposal (this will allow the future investigator to calculate the remaining hazard if it is within her or his level of technology)
- Who built the disposal mounds and when.

This message should also be as easy to read as possible. The proposed text is:

"This area contains disposal sites for long-lived radioactive wastes. Each disposal site is marked by a raised mound of earth and rock. These mounds are designed to keep water, animals and humans away from the dangerous material. Do not build houses on the mounds. Do not plant crops on the mounds. Do not dig for water within the area outlined by these markers. The soil below the mounds does not look, feel, or smell unusual, but it is contaminated by radioactive wastes. Disturbing the mounds does not cause immediate sickness or death. Disturbing mounds may cause exposure to humans to radioactivity which may result in cancer and death. Illness may not occur for several years after exposure. These disposal sites and markers were built by the United States government in \_\_\_\_."

The message contains all the information components identified in Fig. 2-1. The consequences of interfering with the mounds



are plainly and clearly stated. The message therefore meets the guidelines presented in Chapter 2.

Another way of evaluating the message is to use an index to measure its readability. Several indices have been developed. All appear to measure about the same thing and the Gunning Fog Index is the best known (Refs. 35 and 36). The proposed text for the Hanford wastes has a Fog Index of 8, indicating that it is readable at an eighth-grade reading level. In contrast, the Fog Index for the third level message developed by the Task Force is 12, i.e., the reader is assumed to be a high school graduate.

The level 4 message -- the detailed technical information -- is best suited for off-site means of relaying the information. An environmental impact statement would be a level 4 message. This can be widely disseminated in paper format. Condensed versions of this information is likely to occur in the form of media reports and public information brochures. Since this detailed information will not occur on the marker itself, it is not discussed further in this report.

## 3.2 PHYSICAL EMPLACEMENT OF THE MESSAGE

### 3.2.1 Description of the Marker

The specifications for the test surface markers are given in the Rockwell Hanford Operations supporting document WD-TI-131 (Ref. 7). The marker will be a tapered four-sided or hexagonal form wider at the bottom than at the top. For this study we assume the form is four-sided. The truncated top will be pyramidal with a slight rise to shed water. The dimensions given for the test marker are 17 ft to the base of

the pyramidal top, 6 ft wide at the base and 5 ft wide at the top. No information is given on the thickness of the marker.

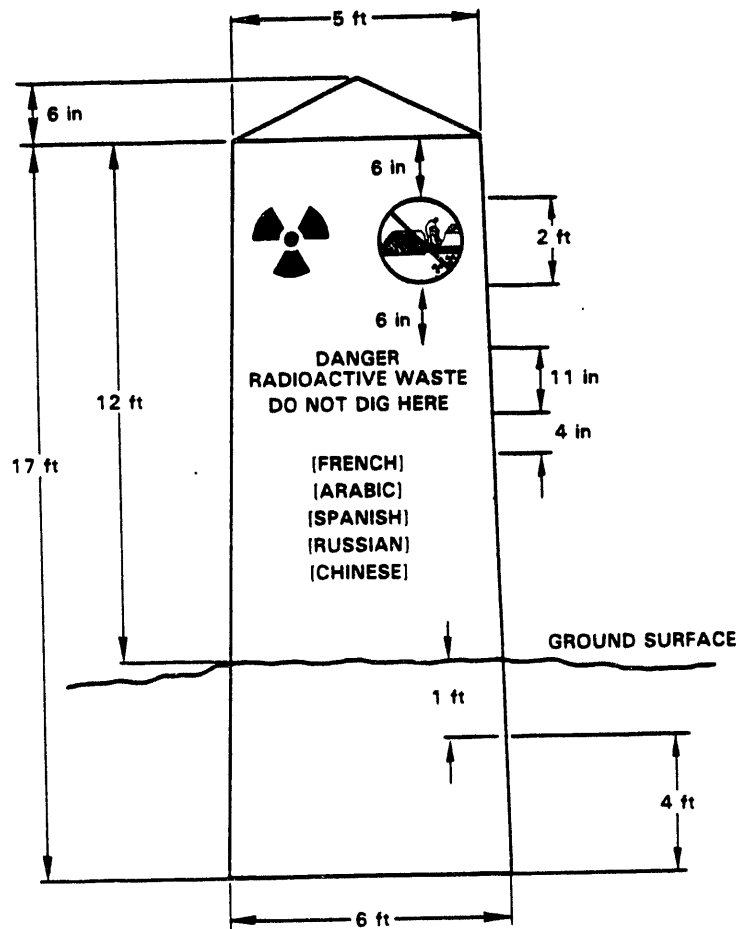
The marker will be emplaced 4 ft deep in the soil with an additional foot of material mounded up around the base (Fig. 3.2-1). This leaves 12 ft as the initially visible part of the marker. We suggest that approximately the lowest 2 ft be left uninscribed. This is an area which is most likely to be subjected to wind erosion and efflorescence, or to be obscured by wind deposited debris (Ref. 2). Leaving the lower area blank creates a "sacrificial area" which can be damaged without diminishing the effectiveness of the marker.

A raised 1 in. band will be left on all sides of the inscribed messages to minimize the effects of wind erosion. (This detail is too small to be shown on Fig. 3.2-1). The three inscribed surfaces of the marker will be polished to shed water and therefore minimize corrosion.

### 3.2.2 Guidelines for Legibility

Legibility is an overriding concern in the design of effective displays. This section presents the guidelines and thinking used to develop the layout of information on the surface markers.

The first question to be addressed is to determine an effective viewing distance for the marker. As shown in Fig. 3.2-1, the sides of the marker stand 12 ft above the level of the plane. How far back does an individual have to stand in order to see the entire marker without effort? The most recent military standard on human engineering design criteria describes an optimal visual zone as lying within  $15^\circ$  of the normal line of sight (Ref. 37, Section 5.2.1.4.8, Fig. 2).



(NOT TO SCALE)

Figure 3.2-1 Surface Marker - Front View

This situation is illustrated in Fig. 3.2-2. Using a range in viewing height of 5-6 ft, the viewing distance ranges from 22.4 to 26 ft. The same military standard gives a specified visual angle of 0.0047 radians as a recommendation for the size of displayed letters (Ref. 37, Section 5.5.5.15). For a viewing distance of 26 ft this translates into 1.5 in. letter size.

The guidelines given by the American Institute of Graphic Arts (Ref. 23) vary somewhat from those given in the

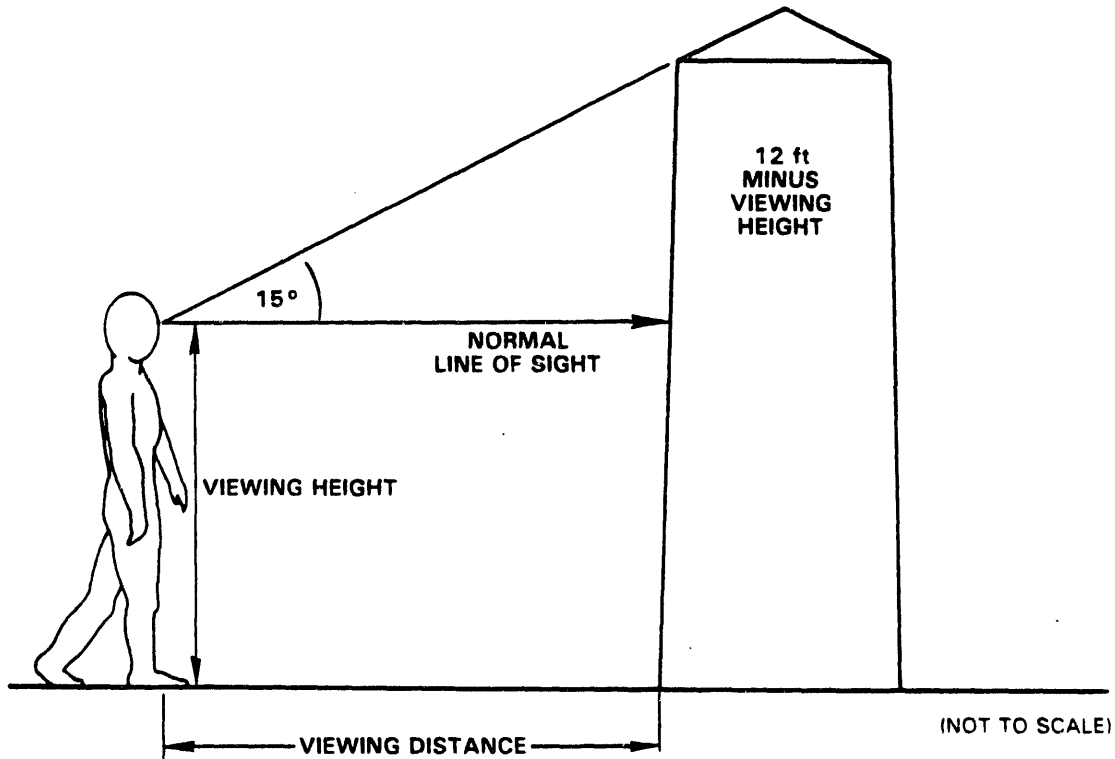


Figure 3.2-2 Viewing Distance of Marker

military standard. In the latter case a viewing angle of  $10^\circ$  is coupled with a letter size based on a visual angle of 0.0017 radians. For the 12 ft marker, this implies a viewing distance of 34 to 40 ft with a letter size of 0.8 in. A review and evaluation of several recommendations for letter size notes that the military standard specifies the largest visual angle for letter size and that such a letter size is 98% legible to a tested population (Ref. 38). For reference, the same article notes that a visual angle of 0.0028 rad is 90% legible.

Helvetica Medium was chosen as a type font by the American Institute of Graphic Arts because of its legibility,

compatibility with symbols and aesthetic quality (Ref. 23). It also meets the military guidelines for a simple font (Ref. 37). It is the only type font we have seen recommended for displays and we propose it for the marking system.

The final point to determine is the depth of the inscription. A depth of 1 in. is suggested in recommended technical specifications for the test marker (Ref. 7). A study on basalt estimated that an alteration depth of 9 to 10 mm may develop by 10,000 years. This study did not estimate the depth of surface loss, only alteration (Ref. 39). This implies an inscription depth of 0.5 in. is likely to be adequate. For perspective, it should be noted that ancient inscriptions were usually cut no more than an eighth to a quarter inch deep and even monumental inscriptions are usually under 0.5 in. in depth. Many of these inscriptions, however, have survived for a few thousand years (Ref. 2). The depth of inscription is an area where useful feedback can be obtained from the stone carver.

### 3.2.3 Marker Layout

The front panel of the marker is shown in Fig. 3.2-1. The frontal view of the marker is intended to catch the investigator's attention. Toward this purpose, the front view contains the radiation trefoil, the do not dig photograph, and message levels 1 and 2. The symbols are 2 ft in diameter, implying that the general form will be visible at some distance (>150 ft, Ref. 23) and that the smaller features such as the trefoils within the pictograph will be legible. Three lines of text are used for the level 1 and level 2 messages. The letter size is 3 in., well above the recommended guidelines. Lines of text within a given language have 1 in. spacing between them. The text in English, then, is 11 in. high. Each 11 in. block of text is separated by a blank area 4 in. in

height. The total text for the front panel (i.e., message levels 1 and 2 in the six languages of the United Nations) is 86 in. long. This will allow the lower 1 ft 10 in. of the marker to remain blank.

One side panel is devoted to giving information about the site in pictures (Fig. 3.2-3). The top 2.5 ft is allocated for the map of the site. The bottom 1.5 ft of the marker is left blank. The central area contains the pictographic description of the site and the consequences of disturbing it. There are no blank spaces between the panels and each panel is 22 in. high. At the present spacing of the pictograph, it would fit into an area roughly 30 in. wide. Allowing for the 1 in raised band around the edge of each panel, the width of the marker need only be 32 in. wide. The map for the 200 east area also seems to fit within this area. Using a viewing distance of 26 ft and a visual angle of 0.0028, any part of the pictograph which is 0.9 in. large will be 90% legible. It is also likely that the investigator will step closer to the marker once his or her attention is caught. At a distance of 10 ft, anything roughly a third of an inch high is 90% legible.

The second side panel is dedicated to the level 3 message. We may assume that the investigator will move in from the 26 ft viewing distance (determined for the front panel) to read this information. A viewing distance of 15 ft results in a visual viewing angle of 28° for a normal line of sight located 5 ft above the ground. This is outside of the optimal range of viewing without any head rotation but it is within the span allowable for eye rotation alone and certainly within any head/eye rotation combination allowed within DoD human factors criteria (Ref. 37). At this distance, a letter size of 1 in. exceeds the military standard and is over 98% legible (Refs. 37 and 38).

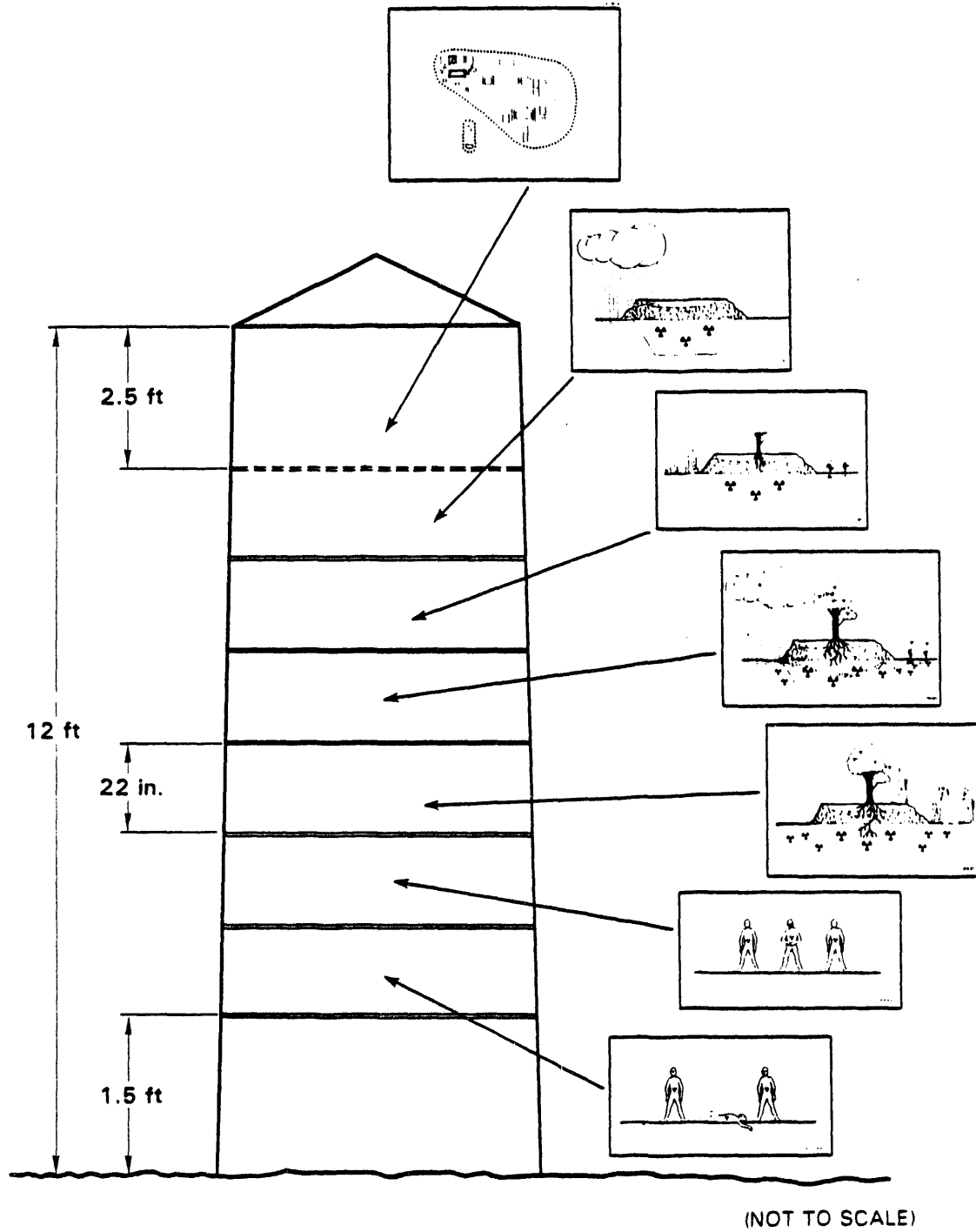


Figure 3.2-3 Surface Marker - Side View

Assume we allow a 3 in. spacing between each of the six blocks of text and a 2 ft blank margin at the base of the marker. This allows us 8.5 ft for the six blocks of text or 17 in. apiece. Allowing 0.4 in. between each line of text, a 17 in. space accommodates 12 lines of text.

The next question is, how wide must the panel be to accommodate the level 3 message? The level 3 message in English has approximately 750 letters/spaces/punctuation marks. Letter width is roughly 0.6 times letter height in most fonts (Ref. 37). The level 3 message then requires 450 in. of text or a minimum of 37.5 in. per line. A marker width of 48 in. (allowing a working area of 46 in.) would address the additional space requirements that are likely to occur in order to avoid hyphenating words and when changing the language of the texts.



4.

RECOMMENDATIONS

The safe disposal of radioactive wastes is a subject of much interest to the general public and the scientific community. At the Hanford Reservation in Washington, there are sites which received liquid and solid transuranic wastes from the late 1940's until 1970. Rockwell Hanford Operations (Rockwell) is investigating the feasibility of several options for the permanent disposal of these wastes. One option is to stabilize the wastes in their present locations and to add barriers to minimize water infiltration and root penetration into the wastes.

This report forms part of the project to develop a marking system for transuranic wastes on the Hanford Reservation. The focus of this report is the development of the message system to appear on the surface markers. A logical framework is developed to deduce what is required by the message system. Alternatives for each message component are evaluated and justification is provided for the choice of each component. The components are then laid out on the surface marker to provide a legible, comprehensible message system.

The components of the message system are summarized in Tables 4-1 and 4-2 and illustrated in Figs. 4-1 and 4-2. The front panel (Fig. 4-1) includes the warning symbol, a 'do not dig' pictograph and message levels 1 and 2 (warning and simple message) in the six languages of the United Nations. One side panel is devoted to a pictorial description of the site and the consequences of disturbing the barrier mounds. A complete description of the site, disposal methods and associated

TABLE 4-1  
LEVEL 3 MESSAGE

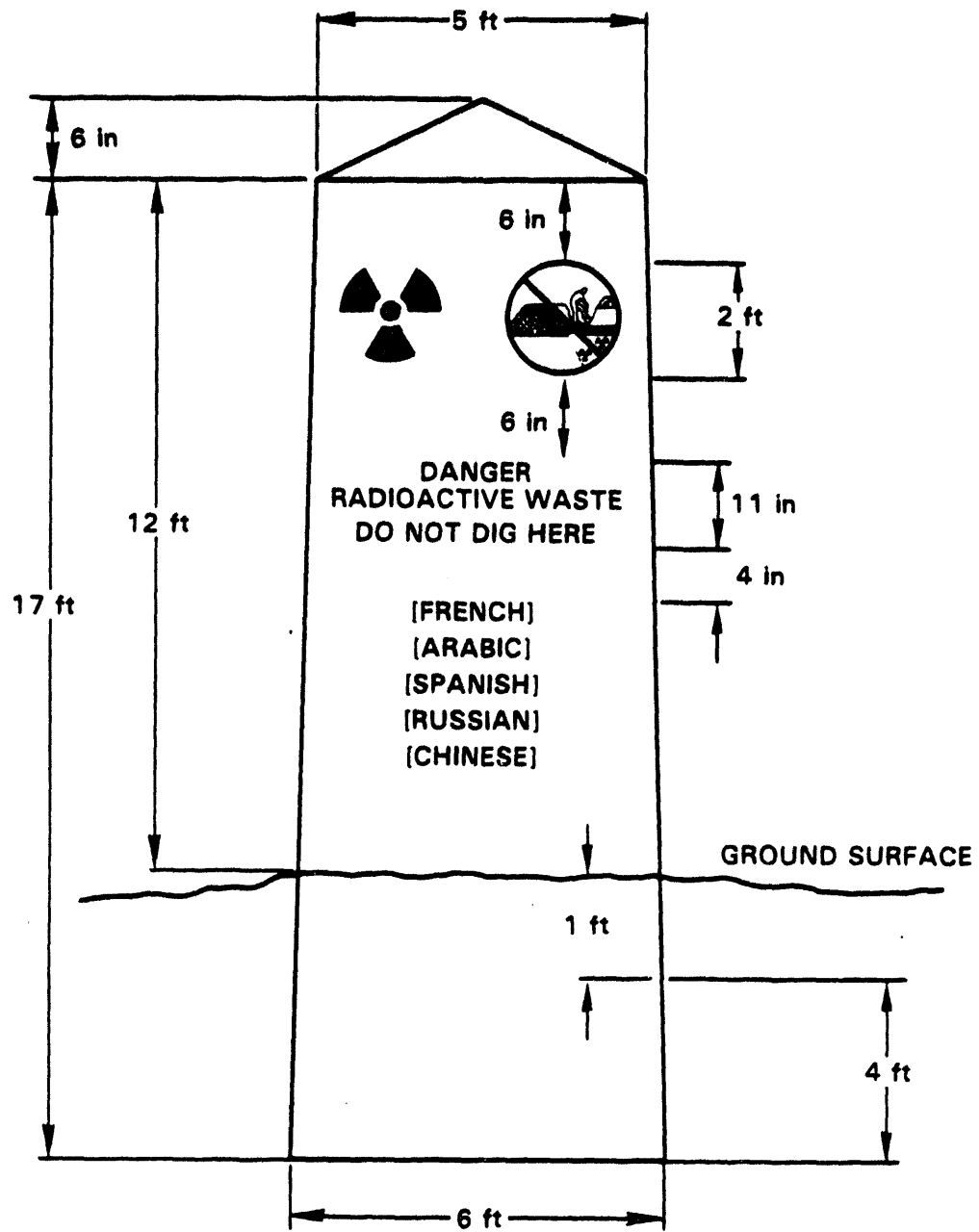
"This area contains disposal sites for long-lived radioactive wastes. Each disposal site is marked by a raised mound of earth and rock. These mounds are designed to keep water, animals and humans away from the dangerous material. Do not build houses on the mounds. Do not plant crops on the mounds. Do not dig for water within the area outlined by these markers. The soil below the mounds does not look, feel, or smell unusual, but it is contaminated by radioactive wastes. Disturbing the mounds does not cause immediate sickness or death. Disturbing mounds may cause exposure of humans to radioactivity which may result in cancer and death. Illness may not occur for several years after exposure. These disposal sites and markers were built by the United States government in \_\_\_\_."

hazards (level 3 message, Table 4-1). This message is also repeated in the six languages of the United Nations.

TABLE 4-2  
SPECIFICATIONS FOR SURFACE MARKER MESSAGES

MESSAGE	SPECIFICATIONS
Radiation Symbol	Front Panel - Upper Right 2 ft Diameter
Do Not Dig Pictograph	Front Panel - Upper Left 2 ft Diameter
Message Levels 1 and 2	Front Panel - Center and Bottom 'DANGER. RADIOACTIVE WASTE. DO NOT DIG HERE.' 3 lines of text, 3 in. letters, 1 in. between lines, 4 in. separation between languages
Map	Left Side - Top within 2.5 ft Height
Pictographic Series	Left Side - Center and Bottom Each Panel 22 in. High
Message Level 3	Right Side 1 in. letters, 0.4 in. between lines 3 in. between languages
Suggested type font is Helvetical Medium with 0.5 depth of inscription	

The layout and letter size of the various components is developed in accordance with the human engineering design criteria given in military standards and by the American Institute of Graphic Arts. One result of the layout is that the marker must be 4 ft thick in order to legibly accommodate the message system. (Marker thickness was not specified in Ref. 7). By incorporating various levels of redundancy in terms of how the information is conveyed and the level of detail at which it is conveyed, we provide future investigators with multiple opportunities to reconstruct the message in its entirety.



(NOT TO SCALE)

Figure 4-1 Surface Marker - Front View

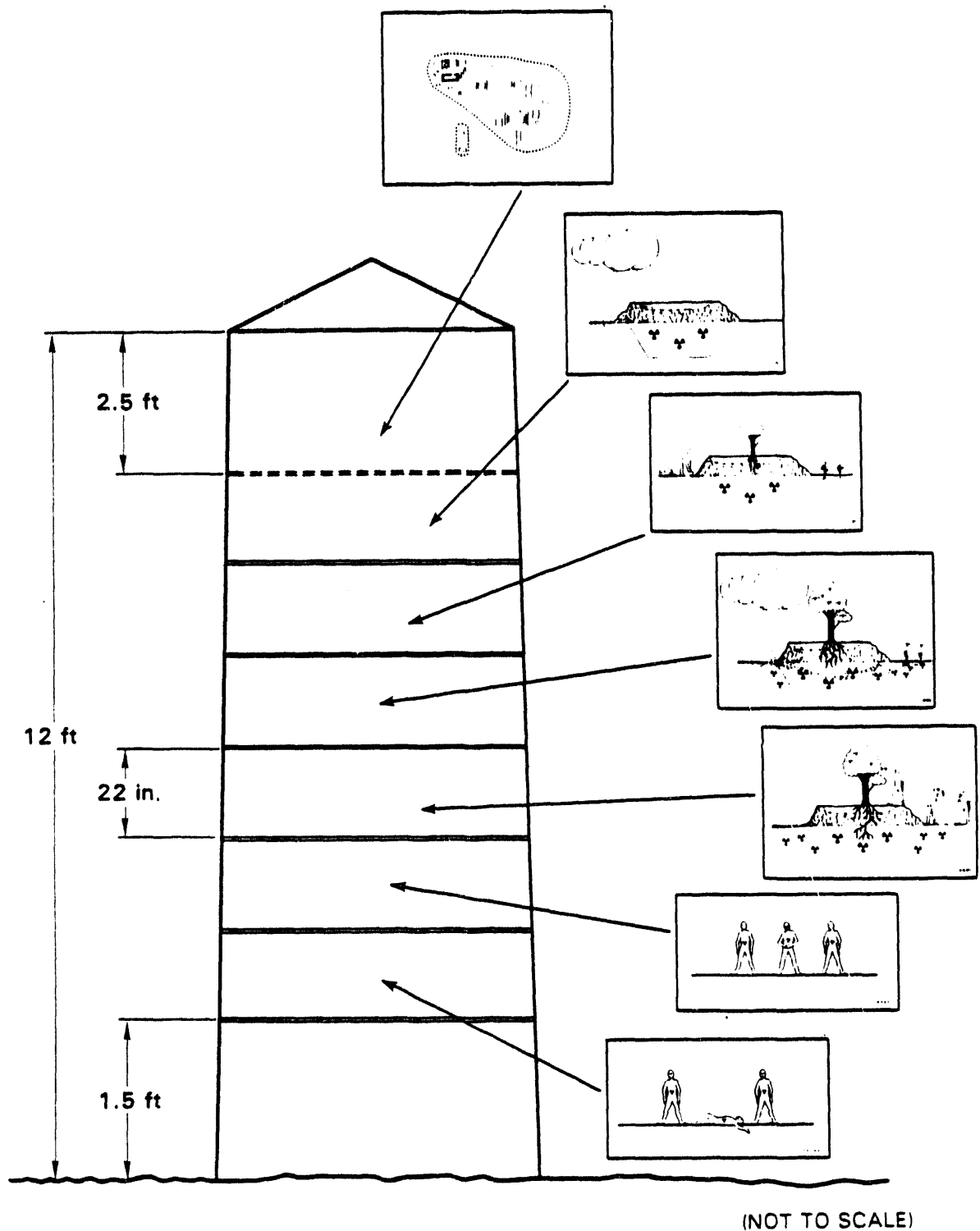


Figure 4-2 Surface Marker - Side View

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