DOE/NV/10872--T213

This report covers the period from January 1 to June 30, 1995. Researchers at the Harry Reid Center for Environmental Studies examined information on natural phenomena and human activities to ultimately recommend specific sites for surface markers to warn future generations of the potential hazards of disposed waste.

The first task was to review the literature to obtain information about the characteristics of surface markers recommended by previous workers in this field. Literature pertaining to previous marker designs was reviewed and summarized. The literature primarily addressed the recommendations presented by a team of consultants which were formed to develop a marker system to warn future generations about radioactive waste. They dealt with the existing conditions at the Waste Isolation Pilot Plant just outside of Carlsbad, New Mexico. Literature concerning archeological markers, such as the Nazca lines in Peru, were also investigated and summarized. The durability of specific marker materials was dealt with in a literature selection.

As previously mentioned, most of the literature dealt with the recommendations made by the team which developed a marker design. Some recommendations made by the committee were the following: 1) the marker should have a variety of ways to convey the warning; 2) an enormous earthwork should surround the entire site; 3) "ugly granite obelisks" should stand 50 feet so that the shifting sand does not bury these structures; 4) a chamber should be on-site which will contain detailed information concerning the site; and 5) redundancy should be conveyed overall.

The main piece of literature reviewed and summarized on the archaeological data was compiled by Maureen Kaplan. The author reviewed a variety of archaeological markers such as the pyramids, Stonehenge, Serpent Mound, Nazca Lines, the Acropolis, and the Great Wall. She made recommendations for the marker design based on the following: the compiled archaeological data on the above mentioned, the type of material to be used, the location of the message on the marker, and the information to be provided on the marker.

DISCLAIMER

Only one journal was found on the durability of marker material. The author considered metals, natural stone, man-made materials, and plastics. The author took into account environmental conditions that exist in both the soil and atmosphere. The data on each material was obtained either from the field or the laboratory.

Overall, the literature was reviewed for past recommendations on the marker design and how the reasoning for the proposed marker pertains to Yucca Mountain. Currently, the information obtained from the literature is being compared with the specifications for a Yucca Mountain surface marker. Attached is a summary of information derived from the literature and a bibliography of documents examined.

The second task was to consider various sites at the Yucca Mountain location to identify areas of exposed, non-faulted bedrock for possible placement of the surface markers. The results of this analysis are presented in the attachment entitled Yucca Mountain and Immediate Vicinity, Potential Areas for Location of Surface Markers Within the CCA.

The next part of the study will involve a site-specific evaluation of designs described in the literature. Additional GIS data has been requested and is needed to complete this phase. Environmental and archaeological concerns will be incorporated into the study as well as topographic and geological features. The study will also focus on the types of materials to be used for the markers as well as design recommendations.

Yucca Mountain Surface Markers
Summary from Literature

I. Marker material

A. Factors to consider when selecting the material
1. Atmosphere
a. humidity
b. contaminants
c. temperature
d. wind
2. Soil
a. moisture content
b. pH
c. conductivity
d. degree of aeration
e. biological activity
3. Human actions
a. recyclability
b. removal, defacement, and vandalism
c. indirect affects, i.e. acid rain

B. What types of materials to consider
1. Titanium
a. advantage: expected to last 10,000 years
b. disadvantage: recyclable
2. Hastelloy C-276
a. highly alloyed nickel-base alloy
b. advantage: expected to last 10,000 years
c. disadvantage: recyclable
3. Granite
a. advantages: hard, compact (fine-grained and lacks cavities, and non-brittle
i. these characteristics imply that the granite will inhibit water from collecting within from either the atmosphere or soil
b. disadvantage: not expected to last 10,000 years under certain atmospheric conditions
4. SYNROC B
a. advantage: expected to last 20,000 to 2,000,000 years

II. Marker location

A. Factors to consider when designing the markers
1. Natural events
a. seismic activity
b. flooding
c. soil erosion
d. wind

e. climactic change
f. damage by vegetative growth

2. Human actions
    a. future land use near the repository
    b. distance to be detected from
        i. aerial - call attention to the site
        ii. ground-level - warns people once they have decided to investigate the area

III. Marker Design

A. Perimeter Markers
1. Shape
    a. rectangular
    b. triangular
    c. monolithic
2. Size
    a. needs to be high enough in order to prevent being buried by shifting sand and to prevent removal by humans
    b. recommended between 25 and 33 feet
3. Marker distance
    a. close enough so that the marker on the right and left can be seen from the middle marker
4. Message (see handouts)
    a. text
    b. symbols
    c. map of entire area

B. Earthwork
1. Aerial detection
    a. can also be placed on mountain side
    b. consider environmental impact
    c. consider effects of natural events
2. Hazardous waste symbol
3. Size depends on the distance desired for detection

C. Interior Markers
1. Type of design (see handouts)
    a. four monoliths with vault under earth mound
    b. central markers with document vaults with reinforced concrete base mat below
2. Message (see handout)
    a. text
    b. symbols

D. Vault
1. Design
    a. rectangular box
        i. under or above ground

ii. if below ground, must dig to get to the vault

b. pyramid

i. more difficult to remove or vandalize

2. Contents
   a. maps
   b. detailed information about the site
   c. maps about other hazardous waste sites
   d. small replica of design to be placed in a museum

E. Natural Features on Site
   1. Rock outcroppings such as the Sphinx
   2. The societal value may protect them from human interference

Aldersey-Williams, Hugh. 1993. Creating monument to folly. I.D. 40:16.

Sandia National Laboratories in Albuquerque, New Mexico, assigned two teams of consultants to develop a marker design which would deter human intrusion. One member of the team, architect Michael Brill, suggests that the marker should not have any artistic merit which would call unnecessary attention to the repository site as a possible tourist attraction. The marker should appear hostile in nature as opposed to a place of shelter or protection.

Berry, Warren. 1983. Durability of marker material for nuclear waste isolation sites. ONWI-474. Office of Nuclear Waste Isolation. Batelle Memorial Institute. Columbus, OH.

Berry approaches various notions for marker material. He considers metals, natural stone, man-made materials, and plastics. When discussing each material, he takes into account various environmental conditions in both the atmosphere and soil and a deterioration rate of one millimeter in 10,000 years. Berry notes that moisture can be the most damaging environmental factor. Therefore, arid or semi-arid regions are the most suitable areas for the marker material. In the next 10,000 years, however, the climate is expected to change from interglacial to glacial. An increase in flooding and flash flood is anticipated. This will cause "the filling of dry basins with water, increased slope erosion and landslides, and accumulation of wind-blown loess and sand." His final recommendations are based on archaeological data and extrapolations of the deterioration rates obtained from field or lab experiments.

The advantage to metal is that it can be worked, it is tough, and it can withstand extreme temperatures or thermal shock. The disadvantage to metal is that some deteriorate under a variety of environmental conditions, and metal can be recycled. Of the metals, the titanium and Hastelloy C-276 are recommended since they are likely to survive the 10,000-year requirement in both atmospheric and soil conditions, and of the metals, they have the least amount of economic value. The effects of welding on titanium have not been studied; however, due to the process used to weld, Berry does not believe that it will affect the 10,000 service life. Hastelloy C-276 is a highly alloyed nickel-based alloy. There are other metals that would survive in the above-ground conditions (stainless steels and aluminum), but they would not last in the soil conditions.

The author does not suggest any of the natural stones. Most likely they will deteriorate enough to destroy the message, but they will survive well enough in order to be able to support other materials. Berry believes that granite is not a durable material; however, he cites an example of a granite surface found in the Sierra Nevada which has "retained the polish and scratches formed by glacier ice thousands of years ago." It has been documented that some granites have not deteriorated in over 200 years, whereas others have in 50 years. The extreme temperatures in arid desert regions can cause deterioration with little or no weathering.

Berry also suggests SYNROC B (hot pressed at 1300 °C). The natural stones that are comparable to SYNROC B are reported to have lasted 20,000 to 2,000,000 years under a variety of geochemical environments.

Berry's final recommendation for a material to use for the marker is synthetic sapphire (Al_2O_3). It has been suggested that it would survive in ambient conditions for over 260,000 years with little or no deterioration.

As for material to use in the library, Berry does not believe that presently there is a material suitable for surviving 10,000 years (paper, magnetic tape, floppy disks, or microfilm). He suggests that the information contained in the library should be inscribed or embossed on metal such as titanium or Hastelloy C-276.

Dold, Catherine. 1992. From the twentieth century, with love. Discover 13:22-23.

Two teams of experts were formed to address the topic of a surface marker to warn future generations of the dangers associated with the repository site. The teams were set up to confront the conditions which exist just outside Carlsbad, New Mexico, at the Waste Isolation Pilot Plant (WIPP). The two teams agree that redundancy is important in the design of the marker; however, they differ in opinion as to whether the marker should be beautiful or ugly. Team B's design resembles Stonehenge which consists of a circle of granite monoliths enclosing a rock shelter located at the center of the site. One member of team A agrees with Team B in that if the marker is beautiful, then the marker will instill a feeling of pride and admiration which may decrease the chance of the marker being torn down. The other members of Team A believe the marker should be ugly. Michael Brill suggests that the vertical markers should be slanted and resemble thorns or jaggered teeth. In addition, the earthworks should be menacing and chaotic.

El-Baz, Farouk. 1981. Desert builders knew a good thing when they saw it. Smithsonian 12:116-121.

The author suggests that the Egyptians modeled their ancient structures after natural formations found in the desert. The conical shapes of their structures, such as Imhotep's Step Pyramid, mimic several natural conical structures found throughout Egypt, such as a natural step pyramid made out of sandstone. The conical shapes allow the wind to travel upslope to the peak where the power of the wind dissipates. Although man-made pyramids have sides, the structure and design still does not deteriorate due to wind. In addition, the Sphinx may have been modeled after a small hill made out of limestone which was previously shaped by the wind. It is believed by some that some of the ancient structures, such as the Great Pyramid, were built over existing hills. The author suggests that the people of these times had an understanding of the relationship between the structure of their monuments and nature.

Isbell, William. 1978. The prehistoric ground drawings of Peru. Scientific America. 239:140-153.

Isbell discusses the various interpretations of the Nazca Lines along with other ground drawings found around the world. As the author points out, the meaning or intentions of the drawing cannot be determined by the drawings alone. The Nazca lines have remained for so many years due to the strong south winds which blew away most of the sandy surface soil, leaving behind rocks and pebbles. Over time, this has created a desert pavement. Because of the low annual rainfall, the erosive effects on the desert pavement have been minimal. If the wind and rain conditions are similar in other desert areas, then the chances of a ground drawing enduring would increase. Most of the ground drawing can only be seen from air; however, there is one chalk figure found in Britain. The drawing is on a hillside which is visible from the ground.

Kaplan, Maureen. 1982. Archaeological data as a basis for repository marker design. ONWI-354. Office of Nuclear Waste Isolation. Batelle Memorial Institute. Columbus, OH.

Kaplan, an archaeologist on the WIPP panel developed to design a marker system, identifies four levels of information that need to be conveyed by the repository marker design. Level I: attention getter; Level II: attention getter and warning; Level III: basic information; Level IV: full record of information. All of these levels should be conveyed on the site. In addition, off-site messages should be left in several areas in order to increase the probability for the survival of the warning.

Some of the criteria to follow when designing the marker are that the marker system: 1) should be designed to make the removal or destruction undesirable or difficult; 2) take into account indirect affects caused by humans, i.e., acid rain; 3) should withstand natural occurrences, i.e., flooding, earthquakes, etc.; and 4) should not require additional maintenance since it cannot be guaranteed in the future. The author suggests that sight, as opposed to our other senses, should be the only means of detection.

When deciding upon the message comprehensibility, the designers need to consider that the society, culture, and languages may change drastically in 10,000 years. In addition, the message should be not only understandable but also believable. The designers do not want to convey a message of the contents in the site as being desirable vs. undesirable, such as with King Tut's tomb. Some guidelines to follow when designing a message are to use several messages in order to increase the chances that at least one will be translated or recognizable; use current, widespread languages; and do not use jargon. The messages can be conveyed in three different ways: symbols, pictures, and language. Kaplan believes that English will evolve; however, unlike her contemporaries on the panel for WIPP, she believes that an effort toward translating the text will be made as long as some people can read ancient languages.

The author's proposed marker system design involves three parts: 1) A series of granite monoliths should define the perimeter of the repository site and possibly a buffer zone. The perimeter markers should define the area to avoid when drilling in order to avoid bringing the waste to the surface. Kaplan suggests natural stone over metal due to the recyclability of metals. The reason for using monoliths is that if mortar is used, then upkeep is required in order to maintain the integrity of the marker. The perimeter markers should provide Level III information. On the front face of the monolith (8 feet wide), there should be three symbols: the hazardous waste symbol created by the Human Interference Task Force, radioactive material symbol, and a picture of a person digging with a line drawn across it. Then below is "DANGER," "RADIOACTIVE WASTE," and "DO NOT DIG DEEPLY HERE." These simple words are then repeated in the six languages of the United Nations (English, French, Arabic, Spanish, Russian, and Chinese) in order to increase the chances of being translated. On one side of the monolith, a brief description of the repository in text form provides who, what, when, why, what to avoid, where to find more information, and marker replacement. Again, this information should be provided in the languages of the United Nations. On the other side, the same information should be given but in symbols instead of text. Three of the sides will provide information while one side remains blank. The purpose is to give information as to where the entire marker system should be viewed. Leaving the interior side blank and the front portion with symbols and text should demonstrate to the viewer that he/she is standing outside of the repository area. The message should be carved into a flat surface, and the remaining surface should be polished in order to minimize areas where rain can collect which would eventually cause corrosion and deterioration. To minimize the deterioration due to wind, the message can be protected by a raised band around the edge of the panel. Then the spacing of the markers should allow a person to see the adjacent markers on each side while standing at one marker. The design of the perimeter markers should be able to be deciphered even if some of the markers are removed or destroyed. Kaplan suggests the total height of the markers should be 25 feet with 5 feet in the ground which leaves 20 feet exposed to the atmosphere. Unlike Stonehenge, the markers should have a broad base (8 ft. x 5 ft.) and be rectangular in order to create more stability. The top's dimensions should be 6 ft. x 4 ft. This shape will reduce wind resistance, and rain will run off the face. To increase stability, shaped packing stones can be placed at the base of the monolith.

2) An earthwork in the form of the hazardous material warning symbol. This should be made if the goal is to call attention to the site and if it is to be seen from the air. This may trigger an investigation at the site which was not previously planned. The earthwork should be at least six feet high, but the height should be determined by the rate of surface erosion for the specific

repository site. To decrease vegetative growth, crushed stone can be packed on top as in the Nazca Lines which create a desert varnish. This type of marker only conveys Level I type of information and possibly Level II. The size of the symbol depends on the height from which you want the symbol to be seen. This type of message entails the greatest amount of environmental impact.

3) A marker at the center of the site is needed for added redundancy and to provide level IV information. The information given here should also be provided at an off-site storage area. The information is stored in an underground vault which is immediately surrounded by a series of monoliths. The vault should be underneath an earth mound which resembles an ancient burial mound. With the information being kept in the vault and underneath the earth mound, a more stable environment is created, protected from wet/dry and freeze/thaw cycles which can deteriorate the marker material. The series of four monoliths surrounding the mound are used to draw attention to the vault placed in the center of the site. The message given should say that more information is located below the mound in the vault and then repeated in all of the languages. Excavation of the mound probably will occur before the monoliths are taken or damaged. These monoliths should be shaped differently from the perimeter monoliths. The height and shape should be different while the tapered base is still maintained for stability. The information in the vault should be carved onto either stone or fired clay. They seem to be the most suitable materials. The information provided in the vault should state a full record of information - plans, drawings, maps, environmental impact statements, etc. In addition, the message should include that the information provided in the vault should be translated into the current language, placed on durable material, and replaced in an on-site marker.

Kliewer, Gary. 1992. The 10,000-year warning: alerting future generations about our nuclear waste. The Futurist 26:17-19.

A committee of experts was developed in order to design a marker which would warn people about the radioactive material that was going to be placed into the Waste Isolation Pilot Plant in Carlsbad, New Mexico. The 12-person panel consisted of three anthropologists, an archaeologist, two linguists, two material scientists, two astronomers, a psychologist, an architect, and an artist. The questions which the panel addresses are the following: How do you make a sign that will never fade away? What languages do you use? What surface do you write the messages on? How do you relay a clear message to an audience so distant in time that its culture, politics, level of technology, and religion are unknown? Frank Drake, an astronomer on the panel, discusses that the vandalism of the marble from the Great Pyramid has taught us not to make the marker "pretty." The panel suggests that the marker should have a variety of ways to convey the warning. They advise that an enormous earthwork surround the site. Then the designers should use "ugly granite obelisks" which stand 50 feet high so that the shifting sands do not bury the obelisks. At the surface, rooms should be placed with chambers below which would contain detailed information about the site and what is buried there. Inside the chamber, maps of other radioactive waste sites should be stored along with a small replica of the main markers in order to be stored in museums as a global record of the site. In addition to the textual information, the message should be conveyed pictorially. Drake suggests that the pictures include "a cartoon strip of people digging into the thing and dying." The periodic table of elements, with the radioactive elements contained at the site pointed out, should be displayed in the chamber.

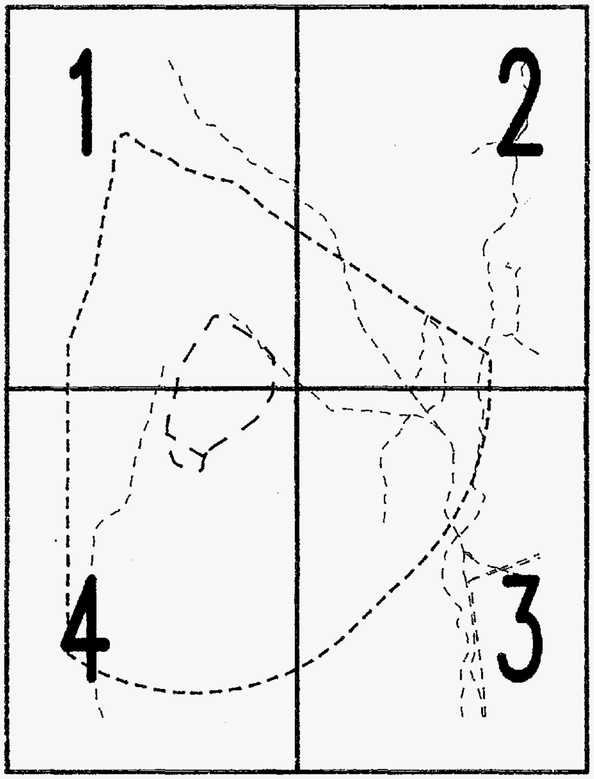
In addition, history suggests that the languages of religion are more likely to survive than currently spoken languages. For example, there still are many people who understand the Arabic written in the Koran, but a relatively few number of people understand Old English. Drake believes that the current spoken languages will evolve, transform, or disappear.

Redundancy should be an overall theme throughout the marker. They recommend that millions of glass markers about the size of coins be buried in the soil. They suggest glass since it will never decay, and there is no economic value. Therefore, there would be no motivation to vandalize these small markers.

YUCCA MOUNTAIN AND IMMEDIATE VICINITY
NYE COUNTY, SOUTHERN NEVADA

Potential areas for location of Surface Markers within the CCA

- Conceptual Controlled Area
- Proposed Repository Outline
- Existing Roads
- Topography, 20' Contour Interval
- Stream Courses with 100' Radius Buffer
- Faults with 50' Radius Buffer
- Alluvium covered areas
- Bedrock/Alluvium Data Unavailable
- Suitable bedrock areas

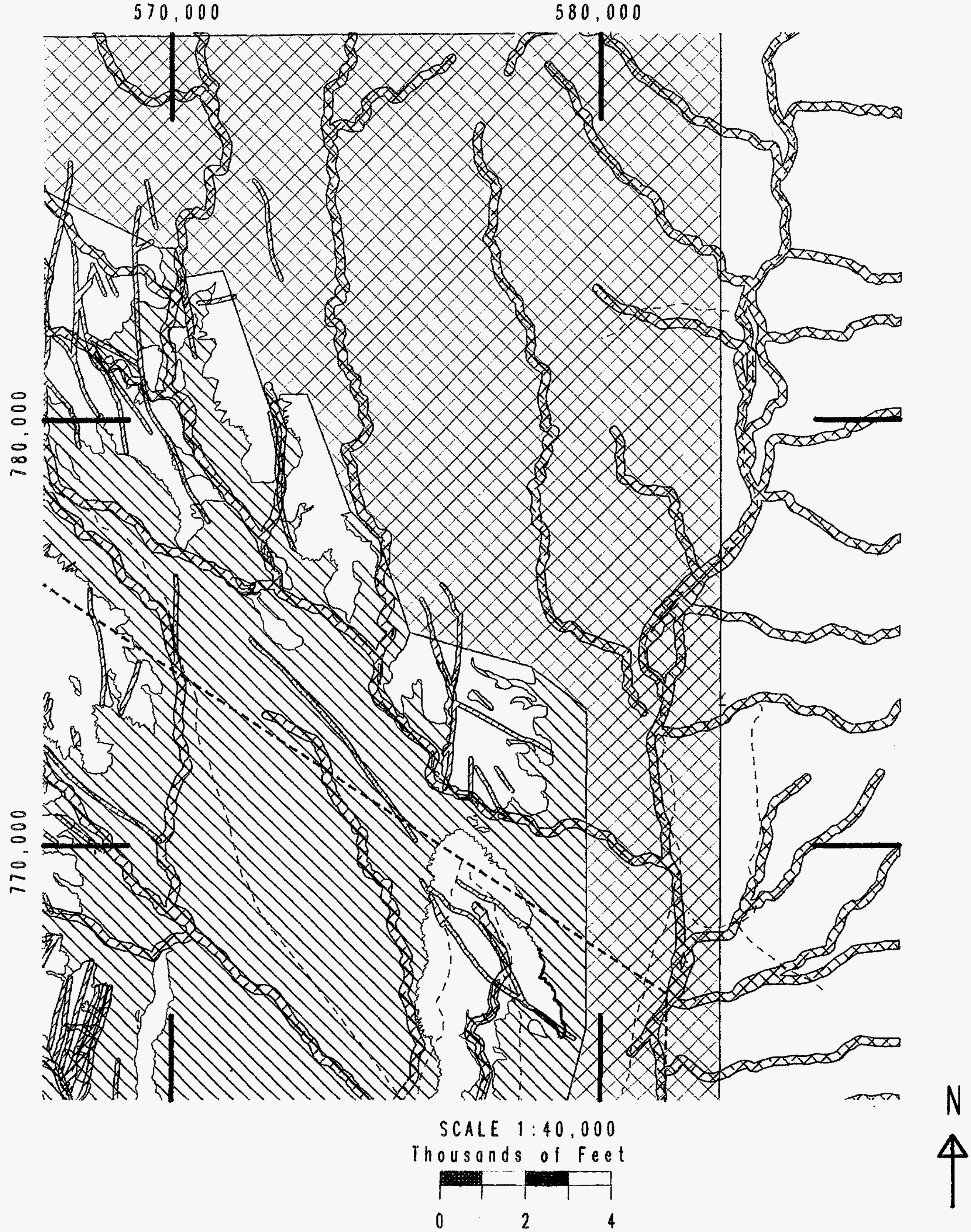


This page is a key for, and the location map to the left shows the relationship of, the four quadrant maps (1-4) that follow of the Conceptual Controlled Area (CCA). The location map shows the CCA, Proposed Repository Outline, and existing roads for reference. A large-scale detail map of the Proposed Repository Outline is also provided.

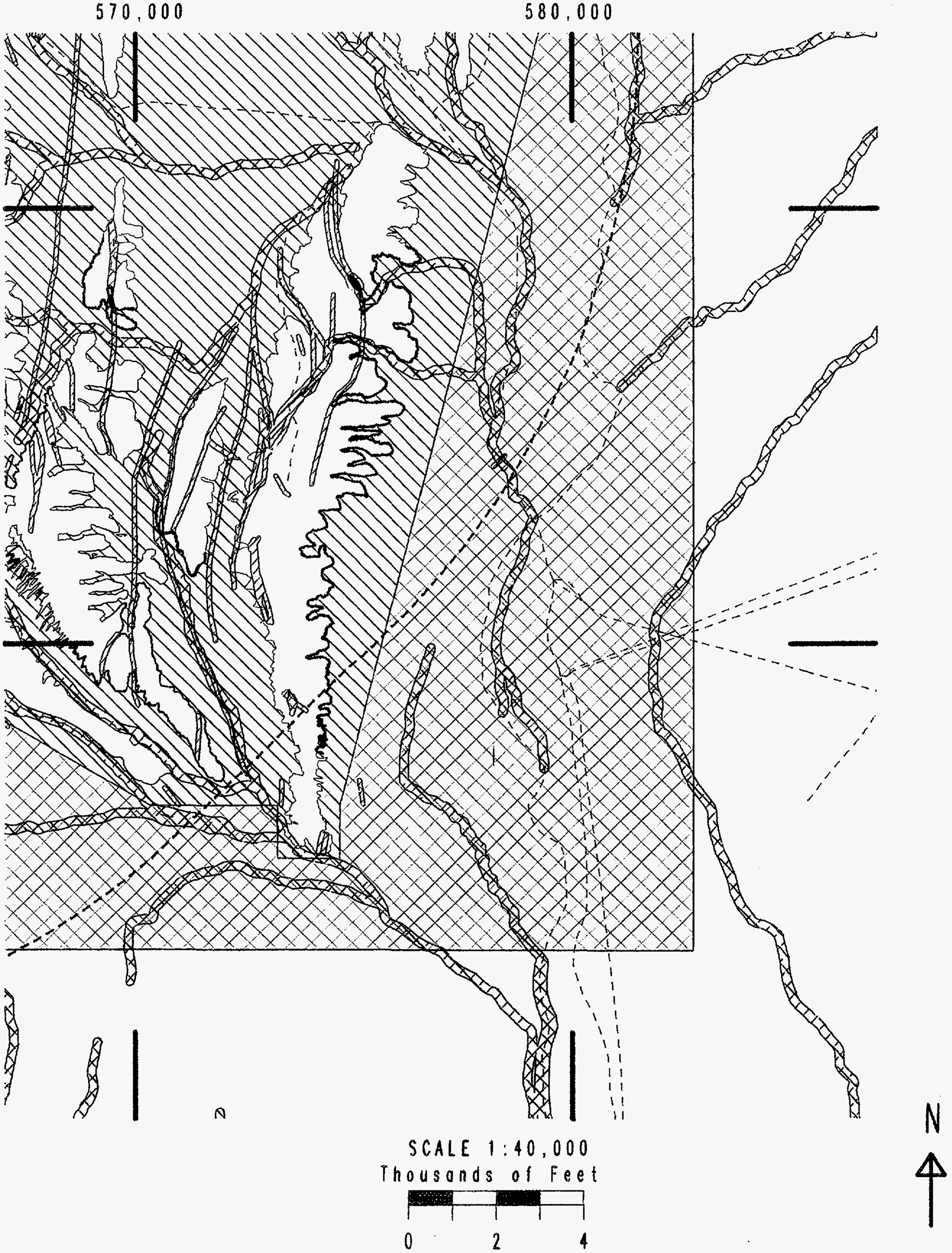
PROPOSED REPOSITORY OUTLINE DETAIL

1. NW QUADRANT

2. NE QUADRANT



3. SE QUADRANT



4. SW QUADRANT