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Hazard Mitigation Potential of Earth-Sheltered Residences

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Accounting for
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Institution

A

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EXECUTIVE SUMMARY

Earth-sheltered housing, which has become popular in recent years for energy conservation, offers the potential for production of a great deal of fallout shelter space. The purpose of this study is to explore some of the technical and institutional issues which must be addressed if this potential is to be realized.

During a prosperous year the housing industry may construct as many as two million conventional units. It is interesting to note that if all of these were earth-sheltered structures of average size, this could produce enough fallout shelter space for the entire population of the United States. Even if only a small fraction of the units built each year were earth-sheltered, a significant addition to the nation's inventory of fallout protection could be realized in a few years.

Earth-covered residences give fallout protection greatly superior to the basements of frame dwellings. With careful attention to design and making relatively inexpensive modifications, earth-sheltered residences also can provide very high-grade fallout protection over much of their floor area. With the same design modifications, they provide very high protection from a wide variety of natural disasters.

For some additional expense, an earth-sheltered residence can be modified at no loss of floor area or function to be upgradable in a few days to resist one to two atmospheres of blast overpressure. Carrying out this operation in a crisis involves the movement of many tons of earth. Either excavation equipment or a large labor force would be required.

Many examples of attractive earth-sheltered residences exist. It has been amply demonstrated that they can be designed and constructed to have quite pleasing interior environments and exterior appearance.

The largest problem preventing widespread adoption of earth-sheltered housing is that construction costs are 20-40% more than comparable aboveground conventional frame housing. This cost can be partially offset by the energy savings inherent in good earth-sheltered housing design. Properly designed, such homes can save 20-60% of the energy used even by well-designed frame houses. The energy costs make the life-cycle cost of earth-sheltered residences more nearly competitive with conventional frame construction. The life-cycle cost of a home is forcefully apparent to the owner in his combined monthly mortgage payment and utility bills.

Housing developments of earth-sheltered, single-family residences offer the potential of reduced lot sizes and, hence, reduced land costs over what would otherwise be required for aboveground construction. In high-cost suburban areas the saving in land may amount to a significant fraction of the total cost of the home.

Recent very high mortgage rates (14-16%) have amplified the effect of the cost disadvantage of earth-sheltered housing on the relative monthly costs. A decline of mortgage rates to more traditional levels would ameliorate this disadvantage.

Modern technologies of concrete construction, particularly the use of reusable, modular, metal, concrete forms and portable scaffolding, can further erode the cost disadvantage of earth-sheltered structures. The material cost of a concrete structure is not markedly different from that of a frame structure. Much of the extra cost of concrete construction is the labor and materials in the single-use, custom wood forming, which is comparable to the labor and materials required for the whole house of frame construction.

As part of the study, an example of a hazard-resistant design of an earth-sheltered residence was developed. The design is a 137.5-m² (1480-ft²), solar-heated, elevational type which in its peacetime configuration provides complete protection against tornadoes, forest

fires, power outages in cold weather, and radiological ground contamination. After upgrading in a day or two during a severe international crisis, the example design will protect the occupants against one atmosphere blast overpressure.

In order to realize the maximum shelter potential from this type of construction, the institutional factors affecting its wide-spread adoption must be addressed. The identification of institutional considerations and policy options is based on a review of the literature on the diffusion of innovation, policy implementation, earth-sheltering and impact assessment. It has further depended on an identification and evaluation of institutional issues and barriers viewed by a panel of experts as most important to the adoption and use of earth-sheltered structures. A summary of these issues and those policy options appearing to offer the most promise for the rapid diffusion of earth-sheltered structures, and a brief outline of a potential implementation analysis is offered.

The most important institutional issues associated with hazard-mitigating earth-shelters fall into two categories: issues related to the desire to use these structures and issues related to the ability to purchase them. In the first category, the issues of livability, aesthetics, and soundness of investment are most crucial; in the second, the critical issue is the availability of mortgage money at attractive rates. Moderately important issues are much more numerous, and include the issues of conformity to a socially accepted image, innovation in the construction industry, financing of construction loans, access to (and egress from) the structure, and societal impacts arising from policy initiatives taken to stimulate earth-sheltering.

The most important institutional issues associated with crisis-upgradeable earth-sheltered structures, in addition to those identified above, relate to the desire to use, the ability to upgrade, and the

issue of emergency use for evacuees. Vital issues related to the desire to use this type of structure concern safety and the perceived threat of nuclear war. The issue related to upgrading is the availability of specialized equipment (or large numbers of workers). The issue of emergency use for evacuees concerns legal and social problems. Two moderately important issues relate to the community-wide effects of using crisis-upgradable structures.

A total of nine issues associated with the development of earth-sheltered, neighborhoods or communities are identified as most important. Under issues related to the desire to use earth-sheltered structures, neighborhood esthetics is extremely significant. The availability of mortgage money and the ability of earth-sheltered neighborhoods and communities to reduce costs are both critical issues related to the purchase of earth shelter. The most important issues related to construction are the financing of construction loans and the difficulty in building an entire neighborhood or community as planned. Finally, vital issues related to the community-wide effects of the adoption of earth-sheltered structures are the issues of housing density, urban form neighborhood concept and changes in the image of the city. Moderately important issues are those on land use regulations and the limited experience of planners and regulators, both related to the construction of earth-sheltered buildings.

A number of specific policy options have been identified as offering the most promise for addressing the goals of adopting an earth-sheltered program. This selection was based on an evaluation by a panel of experts and on the option's ability to score favorably on a number of evaluation criteria.

Education and financial incentives appear to be the most promising policy options for each of the component goals. Educational programs may need to be targeted to potential adopters (i.e., home buyers) and to critical elements of the infrastructure (e.g., the financial community,

builders and developers, appraisers, and real estate firms). The substance of the education programs include verification of the livability and aesthetics of hazard-mitigating, earth-sheltered structures and information regarding financial considerations, including the existing availability of loan money and resale opportunities. Such a program might include the development, validation and dissemination of housing plans, the dissemination of financial information, and actual demonstrations of such facilities for those potential adopters requiring personal experience with earth-sheltered structures. Information regarding the hazard-or crisis-mitigating features of earth-sheltered housing is not considered to be an important element of such a program; in fact, it might be counter-productive.

Among the financial incentives considered (tax credits or, deductions) low-interest, assumable loans; and construction loans) are the most viable options. Among these, construction loans might be favored because of ease of administration. It will be necessary to assure that, whatever financial incentives are selected, these policies do not inequitably impact different population segments. This is particularly the case when the program deals with the provision of protection from potential natural or man-made hazards or crises.

For crisis-upgradable structures it may also be important to assist in the provision of resources for upgrading (e.g., materials, equipment, labor) and supplies (e.g., food, water, and medical supplies) for the use of such structures in the event of crisis (e.g., food, water, and medical supplies). While local governments might assume the lead responsibility for planning for and implementing the provision of such resources, the federal and state governments might assist through bulk procurement policies.

Finally, in addition to education and financial incentives for the development of earth-sheltered neighborhoods and communities, it may be useful for local governments to revise existing land use regulations to allow greater housing density for such applications. This would allow reduction in unit cost and enhance the ability to develop integrated community or neighborhood housing plans.

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CONVERSION FACTORS FOR SI UNITS

English units have been retained in the body of this report. The report is directed principally to the construction industry, and refers to commercially available materials and sizes commonly expressed in English units. The report quotes extensively from earlier work expressed entirely in English units. Conversion factors for SI units are given below:

<u>To Convert From:</u>	<u>To:</u>	<u>Multiply By:</u>
Foot (ft)	Meter (m)	0.3048
Square Foot (ft ²)	Square Meter (m ²)	0.0929
Cubic Feet (ft ³)	Cubic Meter (m ³)	0.0283
Inch (in.)	Meter (m)	0.0254
Mile (mi)	Meter (m)	1.609
Square Foot (ft ²)	Meter (m)	.0929
Pound-Force/in ² (psi)	Kilopascal (kPa)	6.894
Atmosphere (14.7 psi)	Kilopascal (kPa)	101.4
Gravity (32.2 ft/sec ²)	Meter/sec ²	9.8

HAZARD MITIGATION POTENTIAL OF EARTH-SHELTERED RESIDENCES

ABSTRACT

Earth-sheltered residences have become popular in recent years for their energy conservation and environmental advantages. Those with earth covered roofs and walls offer great inherent protection against many natural and man-made hazards including especially tornadoes, power outages in cold weather, forest fires and radioactive fallout. U. S. residential construction in a single good year can produce 200 million m^2 of floor space. If only a few percent of this were earth-sheltered, in a few years a significant addition to the nation's inventory of fallout protection could be realized. Slight modifications of the designs can enhance fallout protection at negligible cost and provide blast protection at moderate cost. Drawings of an example of such a design are included in the report.

The principal disincentive for earth-sheltered construction is the 20 to 40% increase in cost per unit area over conventional frame construction. Methods to reduce this include volume production, smaller lots, use of precast units, and reusable forms.

In addition to cost, important institutional issues affecting the homebuyer's decision to purchase an earth-sheltered residence are the structure's livability, aesthetics, and soundness of investment and the availability of suitably-trained and equipped contractors and mortgage money at attractive rates.

The most promising policy options for promoting the adoption of earth-sheltered structures are education and financial incentives. Educational measures include verification of the livability and aesthetics of hazard-resistant, earth-sheltered structures and information on existing availability of loan money and resale opportunities. A program to implement these policies might include validation and dissemination of housing plans and financial information and demonstration construction.

1. INTRODUCTION

1.1 Program Goals

In recent years, earth-sheltered structures have been the object of considerable favorable attention, largely because of their energy saving attributes. Another strength of this type of structure is its ability to protect the occupants from hazards, both natural and man-made. It is this combination of attributes, particularly the latter, which has stimulated the interest of the Federal Emergency Management Agency (FEMA) in earth-sheltered structures. Specifically, FEMA is interested in exploring ways to increase the inventory of individual earth-sheltered structures and entire neighborhoods that will provide effective protection for occupant while avoiding the need for significant federal expenditures.

FEMA's interests in earth-sheltered structures are actually three-fold. The Agency is interested in exploring ways to accomplish the following

1. Encourage private sector adoption of hazard-mitigating earth-sheltered structures. Such structures are resistant to peacetime hazards (like tornadoes, earthquakes, or brush fires) and provide protection against radioactive fallout without upgrading. Many of the earth-sheltered houses built in recent years provide similar levels of natural hazard protection and could have been made to provide protection from radioactive fallout as well with some small design modifications.
- 2) Encourage private sector adoption of crisis-upgradable earth-sheltered structures in areas where this level of protection is considered necessary. A crisis-upgradable structure is defined as one that is resistant to peacetime hazards and can be upgraded in roughly one day's time to withstand an explosion-induced overpressure or one to two atmospheres.

- 3) Encourage private sector development of entire earth-sheltered neighborhoods or communities.

In order to effectively encourage private sector adoption of earth-sheltered structures, it will be helpful to review technical attributes of the building type, the institutional issues¹ that may inhibit its adoption and use, and those public policy options with the potential to remove any significant barriers. These subjects were the focus of a study conducted over the last year by staff at Oak Ridge National Laboratory (ORNL), and will compose the substance of this report. The primary emphasis of this study was on the use of earth-sheltered structures in the residential sector, placed at low to moderate densities. Where the relevant issues and options vary with the different goals identified above, this will be noted.

1.2 Report Outline

Following this introduction, this report is organized into eight major sections. Section Two presents background information in earth-sheltered housing, including its historical development and the current state-of-the-art. In Section Three, a technical review of earth-sheltered housing is given, focusing on hazard mitigation potential, the advantages of earth-shelter, critical design parameters, a cost comparison with conventional residential structures and various cost reduction strategies. Section Four identified hazard-mitigating techniques that might be incorporated at moderate cost and provides a sample design. In Section Five, the focus shifts from the technical aspects of earth-sheltering to a brief discussion of the process of adoption and diffusion by which a new technology becomes accepted by

¹Institutional issues are broadly defined here as those issues related to the social institutions and interactions necessary for adoption of a technology, as opposed to those technical issues directly related to the physical characteristics of the technology itself. Examples of institutional issues that are important to the adoption of earth-sheltered structures are the availability of mortgage money at attractive rates and the effects of land use regulations promulgated by local governments.

society. This is followed by a discussion of major institutional issues associated with program goals, and their relative importance to the adoption process. In Section Seven, a set of criteria for evaluating policy options is presented, followed by a discussion of the most promising policy options that can be used to meet program goals. Section Eight presents some information on the major organizations likely to be involved in policy implementation, and the report ends with a brief set of conclusions and recommendations.

2. BACKGROUND OF EARTH-SHELTERED HOUSING

2.1 HISTORICAL DEVELOPMENT

The use of underground space for defense purposes dates back to prehistoric times and has continued in many forms throughout recorded history. Many ancient civilizations used buried structures or spaces carved out of solid rock to protect their valuables, including their gods and their temples. In many areas of the world, people have used and are using rock caverns and other earth-covered structures as homes for the living and the dead. Examples abound, especially around the Mediterranean: Egypt, Greece, Italy, Turkey, Saudi Arabia, and Iran. India and China also have many such structures. There is an underground Roman villa in France and underground Roman Legion barracks in Italy. Closer home, we have extensive cliff dwellings used by the ancient Indians in the United States.

In the early days of this country, settlers used underground structures (cellars) to store their produce or vegetables. As the pioneers moved westward, they encountered sandstorms and tornadoes. The root cellars quickly became storm shelters. Although modern refrigeration has reduced the number of cellars being used for food storage, many cellars still exist and could be used for shelter in emergencies.

Military development of underground structures following the development of the artillery shell has a particularly long and successful history. Therefore it was natural for civil defense planners to look to underground structures to protect civilians, first from enemy bombs and then from nuclear weapons.

2.2 STATE OF THE ART

The popularity of earth-sheltered construction has been increasing in the United States. In 1972 only a few earth-sheltered structures



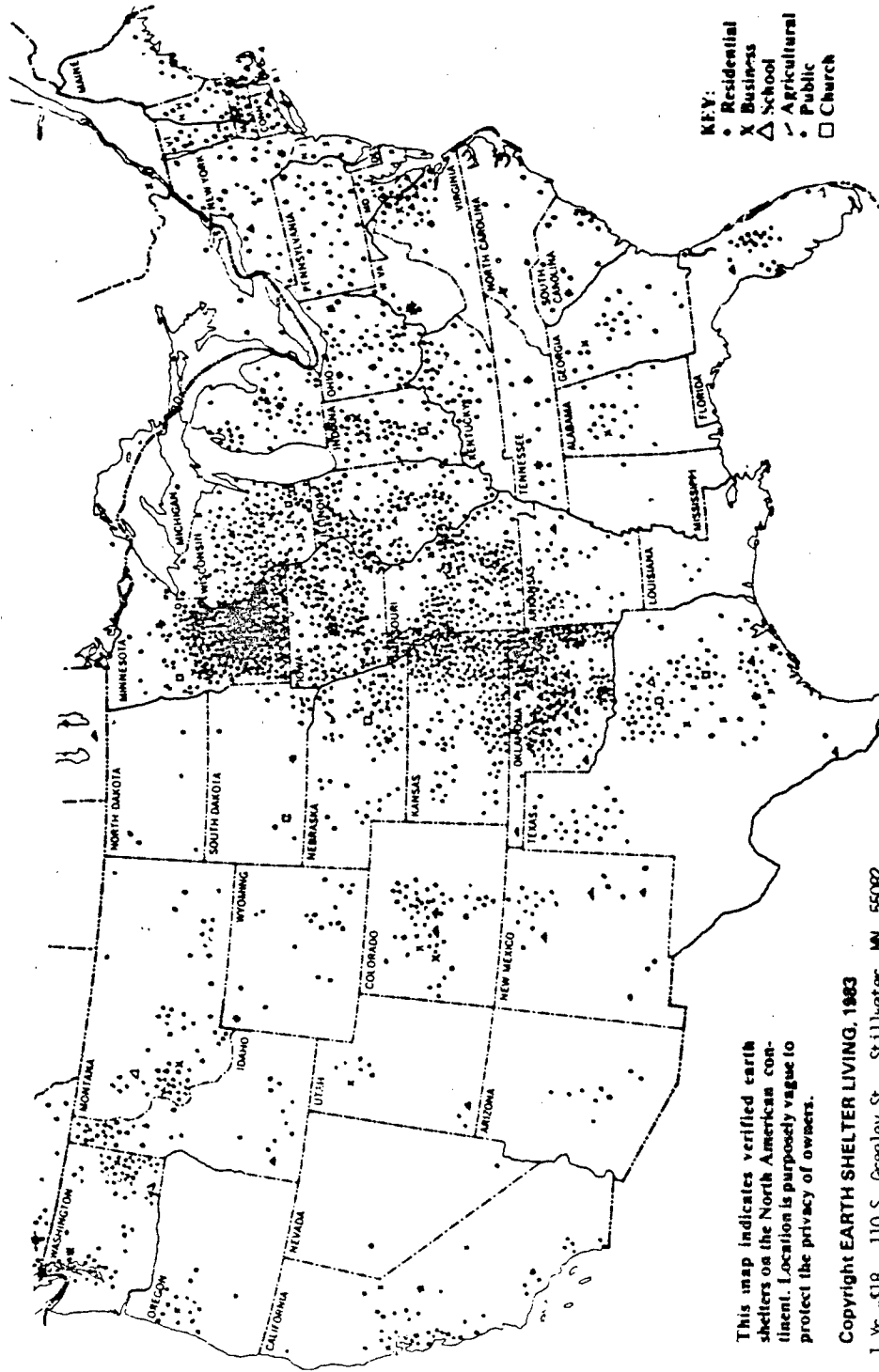
were reported, while in 1982 Earth Shelter Digest & Energy Report had approximately 2500 earth-sheltered structures listed in their data bank. Some observers claim that less than half of the existing structures are in this data bank. Figure 1 indicates that earth-sheltered structures have been built in almost every state in the United States, and most are residential structures. The majority of these structures are located in the Midwest where climate conditions are relatively severe. These areas are subjected to very cold winters and/or experience frequent destructive tornadoes. Citizens concerned with the abuse of land and calling for "gentle architecture" gave the earth-sheltered housing movement additional momentum.

Various materials have been used in the construction of present-day structures. Concrete is the most widely used material because of its load-bearing capacity and resistance to decay and corrosion. The concrete may be poured in place, prefabricated at the factory or on site, or in the form of concrete blocks. Some less conventional designs rely entirely on wood for structure as well as finishing. Attempts to lower the cost have resulted in the use of steel culverts, gunnited steel forms, and fiberglass tubes.

Only a small percentage of the designs is other than residential. Construction is mostly in rural areas, though the impact on energy saving and land preservation would be more significant in metropolitan (suburban) communities. The designs of these dwelling are tailored to fit any imaginable lifestyle from a "\$50 and up" wood-log shack covered by polyethelene for waterproofing to very expensive residences. The designs are generally one-family residences. Figure 2 depicts the floor plan of a typical one-family, earth-sheltered home. Multiple unit structures have also been built. One example is a 20-unit structure built into the hillside for use as an off-campus dormitory (Earth Shelter Digest, 1981). The structure was built with concrete, steel beams, and precast roof planks set in place. The facade was finished

Earth Shelters — North America

Fig. 1



This map indicates verified earth shelters on the North American continent. Location is purposely vague to protect the privacy of owners.

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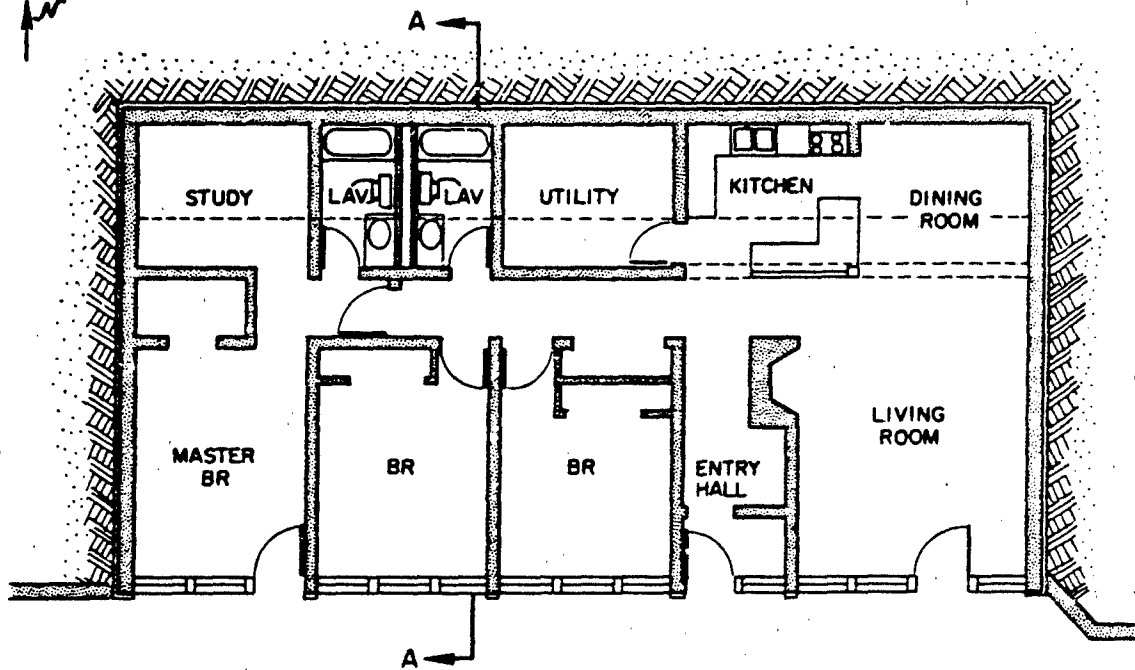


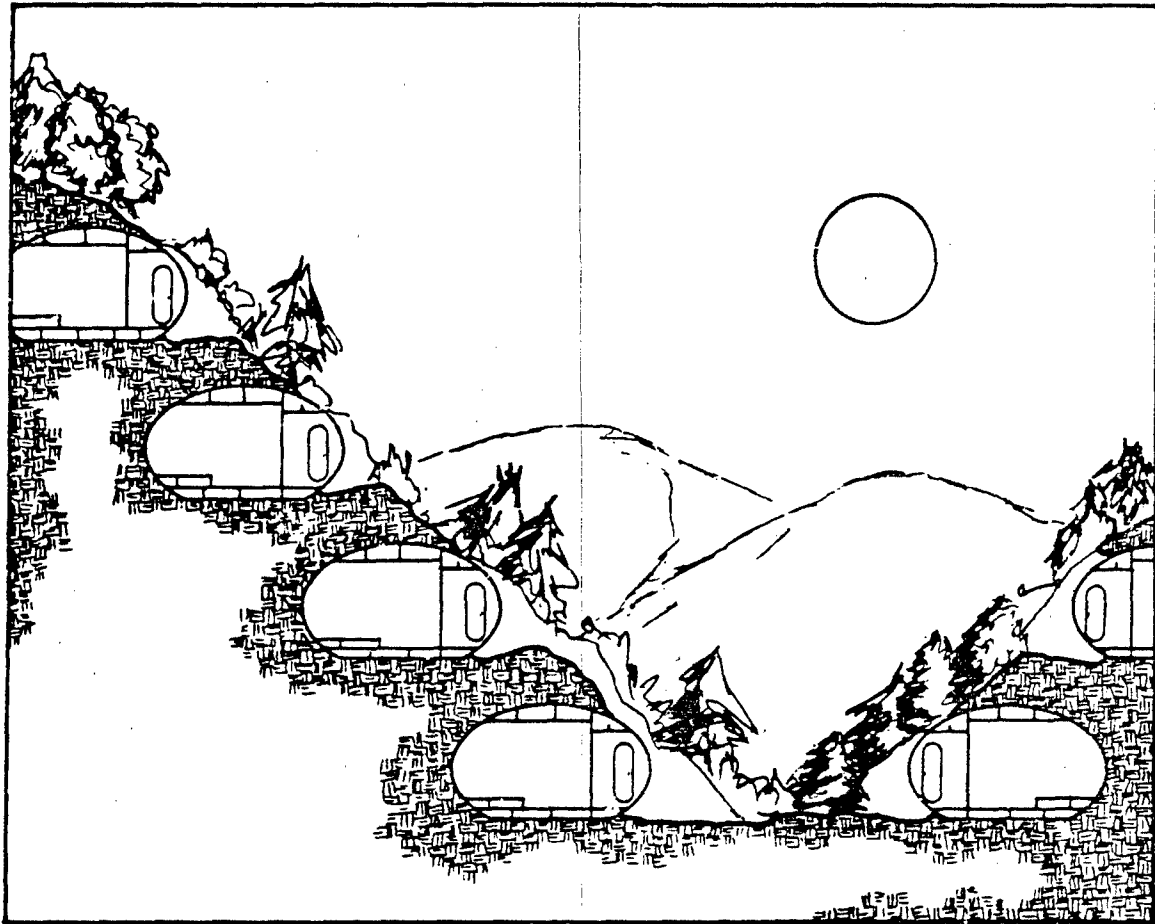
Fig. 2 Typical Floor Plan - ORNL Concept

with wood, enclosing some greenhouse areas in the south face. A 47-unit development is underway in St. Pierre, France. This ArchiterraTM underground construction employs precast concrete panels for some side walls and roof (Sterling et al., 1981). In Minneapolis, Minnesota, townhouses were built next to a very busy interstate highway. The 12-unit structure faces the road to the north and only the entrances are visible (Earth Shelter Living, 1983).

The multipurpose, portable, pod-shaped house in Fig. 3 (called the My-My) is being marketed in Japan by Taisei Construction Company as a shelter from disasters. Originally, it was designed to be used for a holiday home but later became quite popular due to the decreasing availability of land for building in Japan (Taisei Construction Company).

Regardless of size, these homes all fit the general taxonomy illustrated in Fig. 4. Earth-sheltered structures are divided into two basic groups: berm (on the left in Fig. 4) means that the new earth level has been raised above the existing grade to accommodate the new structure; chamber (on the right in Fig. 4) means that space for the building was excavated beneath the existing grade. The chamber type is less intrusive on the landscape. These two groups are divided into four similar subgroups:

- (1) True underground (top two) with spaces isolated from the outside.
- (2) Courtyard or atrium, surrounded by interior space and used for entry as well as being a light and air source.
- (3) Elevational, in which three walls and the roof are covered by earth and the fourth wall is exposed with a multitude of windows. This style is the most popular today since it can collect solar energy as well as permit a view of the surroundings.
- (4) Side wall penetration, which allows expansion in the future.



Figs. 3 My-My Pods

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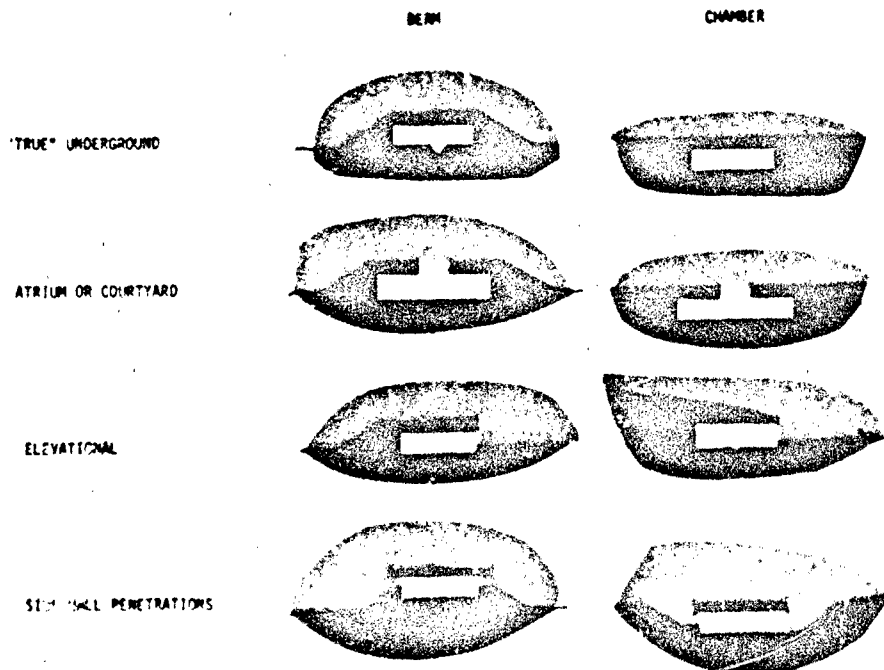


Fig. 4 A Simple Taxonomy of Terratechtural Types

With increased interest in earth-sheltering, a number of companies (Earth Shelter Corporation; Terra-Dome Corporation; Tri-Steel Structures) are providing franchise services including:

- (1) Construction training for builders;
- (2) Licensing contractors to build the franchiser's designs;
- (3) Design and construction services which may include preliminary feasibility studies, cost estimates, site planning, detailed architectural and structural designs, drawings and specifications, and on-site construction supervision;
- (4) Marketing; or,
- (5) Mail serve sales of earth-sheltered designs.

Federal, state, and private funds have supported research at several organizations around the country. Structural techniques have been investigated in efforts to reduce the cost of earth-sheltered designs. The research has also focused on earth heat transfer, passive solar means of space heating, materials (construction materials as well as waterproofing and insulation), code and zoning laws, cost and social issues, and data validation and experience in the earth-sheltered environment. Lead work was performed by the Underground Space Center, University of Minnesota. The research done by or subcontracted by this center has lead to numerous books, reports, and articles dealing with codes, finances, energy analysis, construction practice and lists of do's and don'ts in earth-sheltered designs (all included in the Bibliography). The Center for Natural Energy Design, School of Architecture, Division of Engineering, Oklahoma State University, Stillwater, Oklahoma has also been involved in research dealing with earth-sheltered buildings.

Two major contributions to the earth-sheltered program activity resulted from work done at ORNL (Shapira & Barnes, 1980; Shapira et al., 1983) -- the Joint Institute for Heavy Ion Research (JIHIR) and a report Cost and Energy Comparison Study of Above- and Belowground Dwellings were sponsored by the Innovative Structures Program and the Passive and Hybrid Heating and Cooling Program in the U.S. Department of Energy.

To date a vast amount of information and literature exists. A bibliography is included at the end of this report. Seminars have been offered by universities and private contractors for some time. Several conventions have been devoted solely to earth-sheltering (see Bibliography).

3. TECHNICAL REVIEW

3.1 HAZARD MITIGATION

Earth-covered construction, as presently practiced, provides a great deal of protection against many, if not most, natural and technological disasters. Surrounding the structure and covering its roof with earth protects it from the dynamic pressure of wind of any velocity, extremes of heat and cold, and ionizing radiation. A completely buried structure is spared some of the shear stresses generated by the horizontal shaking of an earthquake.

Earth-covered structures must be stronger than frame construction to bear the pressure of the surrounding soil, and are usually constructed with considerable margins of safety in design strength. The material of construction is usually reinforced concrete in the U.S., although steel has been used, as well as self-supporting excavations in soft rock. The greater strength of the structures provides protection against exterior loads and impacts from explosions or vehicles that would destroy a conventional structure.

The earth cover and non-combustible structure provide great protection against external fires whether of natural or human origin.

Earth-covered structures usually have very low air infiltration rates and can be made almost leak-tight. This is advantageous in reducing heat loss in cold weather or designing a filtration system to exclude undesirable particulate matter (e.g., pollen) but requires the installation of controlled ventilation to control humidity, accumulation of toxic vapors, and radon.

Earth-covered structures usually have limited access points (doors and windows) which makes it easy to protect them against forcible entry.

The feature motivating most earth-covered construction is its very low heat loss in cold weather. This coupled with the very large heat capacity of concrete structures make underground, concrete homes ideal candidates for passive solar heating through skylights or a partially exposed south wall.

The degree of protection afforded by earth-sheltered residences against natural and technological hazards is summarized in Table 1.

The heading "Conventional Design" refers to an undefined representative of current practice in earth-sheltered residential construction. The term "Hazard Resistant Design" refers to an earth-sheltered design slightly modified as indicated in the subsequent discussion to cope with that hazard. Five levels of protection are identified:

- (1) Complete:
No reasonably expected severity of the hazard could be expected to result in death or injury to the occupants if they behave prudently. (e.g., stay away from windows).
- (2) High:
Death or injury to occupants only from unlikely severity of hazard and/or improbable failure of structure.
- (3) Moderate:
Significant protection compared with frame construction, but death or injury likely from moderate level of hazard.
- (4) Low:
Some protection compared with frame construction afforded at low levels of hazard.
- (5) None;
No protection afforded at any level of hazard without radical redesign.

3.1.1 Natural Hazards

3.1.1.1 Moving Air (Explosion, Tornado, Hurricane Winds, and Thunderstorms)

Earth-covered walls simply do not experience any dynamic loads from winds of any origin. The effect of transient overpressure from explosions on earth-covered, vertical walls is attenuated by the earth.

Table 1. Hazard Protection Afforded by
Earth-sheltered Residences

Type Hazard	Protection Afforded by	
	Conventional	Hazard-Resistant
----- Natural Hazards -----		
Tornado	High	Complete
Hurricane Wind	Complete	Complete
Thunderstorm Gust	Complete	Complete
Hail	Complete	Complete
Lightning	Complete	Complete
River Flood	None	None
Hurricane Tide	None	None
Dam Failure	Low	Low
Tsunami	Low	Low
Avalanche	Moderate	High
Landslide	Low	Low
Mudslide	Low	Low
Earthquake	Moderate	High
Volcanic Ash Fall	Low	Low
Volcanic Lava Flow	Low	Low
Forest or Brush Fire	High	Complete
----- Technological Hazards -----		
Aircraft Accident	Moderate	High
Liquid Fuel Spill and Fire	Low	Moderate
House Fire	Moderate	High
Loss of Power in Cold Weather ice storm, blizzard, blackout, oil embargo coal strike	High	Complete
Toxic Vapor	Low	Low
Toxic Aerosol	Low	High w/abs filter
Reactor Accident		
Radioactive Aerosol	Low	High w/abs filter
Ground Contamination	High	Complete
Nuclear Weapon Fallout	Moderate	High
Blast	Low	Moderate

The negative pressure developed in a tornado is resisted by the weight of earth on the roof and by ties between the roof and the walls. (Negative pressure is responsible for much of the damage to conventional buildings from tornadoes.)

Hurricane winds and thunderstorm gusts seldom exceed 120 mph and are much less of a hazard than the 300-mph winds believed to occur in severe tornadoes.

Elevational earth-sheltered structures with an exposed exterior wall are more vulnerable to winds, and particularly wind-driven missiles, than are completely buried or atrium structures. However, the only damage likely is to glass. The strength of the concrete wall required to support the roof and the prestressing of that wall by the weight of the roof and soil cover make any structural damage from wind highly unlikely. The danger from glass makes it advisable for occupants to move to interior rooms during violent winds that come from the direction where windows are located.

Storm shutters for the exposed windows could be installed if an owner wants complete protection from storm winds.

Earth-covered structures provide complete protection against lightning.

3.1.1.2 Moving Water (Flood, Hurricane Tide, Dam Failure and Tsunami)

Rising water is one hazard against which earth cover affords little protection. In fact, the incentive to get the floor elevation as low as possible to reduce earth moving costs aggravates the flooding hazard in coastal and other areas subject to flooding. Earth-sheltered structures should not be built in such areas. Completely belowgrade residences should not be built on extensive flat terrain subject to heavy rainstorms. A foot of standing water which is an inconvenience in abovegrade construction is a catastrophe in belowgrade construction without very careful and expensive designing to cope with it.

No residence of any kind should be built on a river flood plain. On flat terrain, berm-type earth-sheltered construction should be used, with the floor higher than the surrounding grade. Earth-sheltered structures should be built only on ground higher than the level of likely flooding.

The strength of the earth-sheltered structure can provide more resistance, relative to conventional structures, to being washed away by a transient water flow such as from a dam failure or tsunami.

3.1.1.3 Moving Earth (Avalanche, Landslide, Mudslide, Earthquake, or Volcano)

Earth-sheltered construction of proper design can provide great protection against rock avalanches and complete protection against snow avalanches. Proper design includes: no openings facing upslope, adequate strength of closures of roof penetrations, and provision of access areas for the reestablishment of ventilation and escape tunnels.

Earth-sheltered construction, by virtue of its strength and anchoring in the soil, provides more protection against landslide and mudslide than conventional construction. However, it is far from absolute protection. The structure is less likely to collapse from smaller slides, or near the edge of a slide than is a frame dwelling. However, at the center of a big slide the forces developed can greatly exceed the strength of the structure.

Built to existing seismic codes, earth-sheltered structures can provide almost complete protection against earthquakes, provided they are not engulfed in a large quake-caused slide. It should be noted that, if seismic construction is decided upon, attention should be given to potential internal hazards generated by the quake. Care must be taken to assure that bookcases and cabinets are properly anchored, lighting fixtures are protected, and interior partitions are of proper construction.

Volcanoes, in addition to causing landslides and mudslides, can also cause mud flows, ash falls (meters deep sometimes), lava flows, and toxic vapor clouds. Very marginal protection is provided against these effects by earth-sheltered construction. On warning of impending eruption within 10 miles, especially upwind, prudence would dictate temporary evacuation.

3.1.1.4 Forest and Brush Fire

The earth cover and non-combustible structure provides complete protection against most natural fires. Temporary difficulties could be experienced with smoke in structures high on a steep hill above a large fire, if the wind has just the wrong direction and velocity. In general, most forest and brush fires could sweep right over properly designed earth structures without any danger to the occupants. When designing for an area subject to natural fire hazards, some common sense must be used to avoid exposed combustible insulation, ventilatory acrylic skylights, and wood trim and doors. Landscaping and planting in these areas should be designed with fire in mind, to avoid large accumulations of vegetation next to windows, doors, skylights, and ventilation intakes.

3.1.2 Technological Hazards

3.1.2.1 Aircraft Accident

The hazard on the ground from aircraft accidents is from the impact of debris and fire from the fuel. By far, the major hazard is from fire. If the aircraft doesn't impact directly on the earth-sheltered residence, the fire from the crash should pose little hazard to the structure. Conventional earth-sheltered construction offers more resistance to impact than frame construction, but not enough to guarantee safety. High-strength construction designed for earthquake

resistance or blast protection will protect against everything except impact by very heavy debris (large jet engines, for example) or debris moving horizontally against exposed windows in elevational designs.

3.1.2.2 Liquid Fuel Spill

Earth-covered construction is greatly superior to conventional construction, but not absolute in its protection against large fires from transportation accidents. In particular, those resulting from spills of liquid fuel from a plane crash, train derailment, tank truck accident, or pipeline rupture can present a severe hazard if the spill engulfs the structure. The hazard will be reduced if the precautions mentioned above have been observed and, in addition, the soil surface is graded to slope away from any exposed opening into the structure.

3.1.2.3 House Fire

Earth-covered structures provide as little protection against the hazards of an internal fire fed by contents and furnishings as has been afforded by so-called "fireproof" hotels in catastrophes in the last several years. Only sprinkler or other extinguishing systems can provide protection against this hazard. Limited openings for egress and ventilation can complicate escape from and the fighting of an internal fire in an earth-covered structure.

3.1.2.4 Loss of Power in Cold Weather (Ice Storm, Blizzard, Power Blackout, Oil Embargo, Coal Strike)

Loss of power is not a severe hazard to residences, nor is cold weather; but the combination, especially if persistent, can be dangerous. It is against this hazard that earth-sheltered structures are really designed. Their very low heat loss rates and surrounding soil temperatures assure that pipes will not freeze if the doors and windows are kept closed and ventilation minimized. A wood-burning stove

or fireplace can easily maintain a shirt-sleeve environment in much of the structure as long as the wood supply lasts. A properly designed structure employing passive solar heating will remain comfortable indefinitely even with numerous cloudy days.

Drifting snow can develop into an egress problem if entrances haven't been properly designed. Open atria can be completely filled with snow. Exposed south walls can be completely covered with drifts, blocking egress and solar heating. If built in snowy areas, atria should be covered (at least in winter) and elevational structures need to be protected by snow fences or tree plantings. In any case, emergency exits through skylights should be provided.

3.1.2.5 Toxic Vapor and Toxic Aerosols

The very low uncontrolled infiltration rate characteristic of earth-sheltered structures (and very well-constructed, modern, conventional structures) offers the possibility of some protection from airborne toxic materials. Appropriate filtration equipment can be installed in the ventilation system to be switched on if there is some reason to fear airborne toxic materials.

Toxic vapors such as ammonia, chlorine, phosgene, radioiodine, or sulfur dioxide require expensive charcoal filters. To be effective against high vapor concentrations, a lot of charcoal is required. Transportation and industrial accidents releasing such vapors have been handled by evacuating the surrounding population.

Toxic aerosols can be removed very effectively and inexpensively with high-efficiency particulate filters. The toxic materials can be radiological, biological or chemical poisons released by industrial accident or malevolent act. To some people, ragweed and other pollens are toxic airborne biological aerosols.

3.1.2.6 Reactor Accident

The hazards to people from reactor accidents are from inhalation of radioactive airborne materials and from external irradiation from airborne and deposited radioactive materials. Airborne materials may be vapors and gases (iodine, xenon, and krypton) and radioaerosols (all the

other fission products). Outside plant boundaries, inhalation of rare gases does not present any real threat to health. Iodine is a potentially serious problem. It can be removed by charcoal air filters. Its danger to humans can be reduced at least two orders of magnitude by ingestion of 100 mg of potassium iodide, minutes or hours before exposure.

The major danger from reactor accidents is inhalation of radio aerosols. The same considerations apply as for toxic aerosols mentioned above: a little protection is obtained by a relatively airtight structure, but almost complete protection can be obtained by connecting an absolute filter into the ventilating system.

High protection against external radiation from a reactor accident is offered by almost any earth-sheltered structure. This is due to the fact that very high levels of ground contamination are not expected outside plant boundaries. An earth-sheltered residence designed for fallout protection will protect occupants adequately against lethal external radiation from any conceivable reactor accident.

3.1.2.7 Nuclear Weapon Fallout

The earth-covered roof and sides of earth-sheltered residences provide some inherent protection from fallout radiation, much superior to frame houses. However, exposed walls and large windows in elevational design may reduce the fallout protection factor below 40 in areas in the front rooms.

By putting planters along the exposed wall and sloping the ground away from the wall, exposure from this direction can be greatly reduced. Arrangement of load-bearing solid walls inside to shield rear rooms can provide sizable areas of the structure with a protection factor approaching 1000 in their day-to-day configuration. If the structure is designed to be crisis-upgradable, very high protection factors can be achieved. Designing the patio blocks so they may be stacked in the windows, and making other provisions for piling mass against the front wall can result in protection factors of several thousand over the entire floor area.

3.1.2.8 Nuclear Weapon Blast

Conventional earth-sheltered construction, due to its covered walls, prestressing load on exposed walls, and safety factor in roof strength, is somewhat more blast-resistant than abovegrade frame structures. Experience with nuclear weapons effects on conventional and reinforced masonry residences in Operation Teapot in 1955 (Randall, 1961) suggests that unmodified, earth-sheltered construction should survive 6-7 psi, compared with 1-2 psi for frame structures. However, although the structure may survive 7 psi, large window openings would result in injuries to occupants in the adjacent rooms. If the windows are designed to be covered as part of a crisis-upgrading procedure, this danger can be greatly reduced.

At relatively low additional cost, the reinforced concrete structure can be made significantly stronger by some increase in thickness of critical walls and the addition of some steel reinforcement. If the roof is designed for the addition of columns to reduce span length as part of a crisis-upgrading procedure, very significant blast hardness can be achieved, in the range of one to two atmospheres (15-30 psi). Any exposed walls must be designed for corresponding horizontal loads and piled with earth as part of this crisis-upgrading procedure. A concept employing these techniques is described later in this report as an example. This concept will be referred to throughout this report as a crisis-upgradable structure as opposed to hazard-mitigating and conventional earth-sheltered structures.

3.2 ADVANTAGES

The following description gives some of the important advantages that are attributed to earth-sheltered construction (Chester et al., 1979).

3.2.1 Reduced Requirements for Heating and Cooling of the Enveloped Space

The thermal-tempering effects are derived from two phenomena - the earth has lower seasonal and diurnal temperature fluctuation than the ambient air (see Fig. 5) and the average earth temperature lags behind the average ambient temperatures depending on the depth of earth cover. In the event of a power failure during extremely cold weather with no solar input, the temperature in an earth-sheltered building will drop only a few degrees (e.g., from 58°F to 52°F in 24 hours). On the other hand, the temperature in an aboveground dwelling under similar conditions can drop below freezing in the same time (see Fig. 6).

3.2.2 Acoustical Isolation from the Outdoors

Earth-covered walls and roofs have enormous acoustical impedances. Earth-sheltered structures have been used for very noisy sites such as adjacent to busy airport runways and interstate highways. With proper acoustical design of ventilation intakes and entrances (e.g. use of vestibules), an earth-covered structure can be made effectively soundproof. Interior noise levels are usually due entirely to the ventilation system and occupant activities.

3.2.3 Less Interference with the Surrounding Landscape

With all or most of the structure below grade, visual obstruction of the landscape is greatly reduced. Roof contour and planting can be selected to make the landscape appear completely undisturbed when viewed from most directions.

3.2.4 Increased Privacy Compared to Conventional Dwelling

The acoustical and visual isolation available with most earth-sheltered designs can greatly reduce the disturbance of one neighbor by the activities of another, even in developments with very small lots. It is very easy to avoid housing arrangements which have windows of one house looking right into those of the neighbors, which is so common in housing developments.

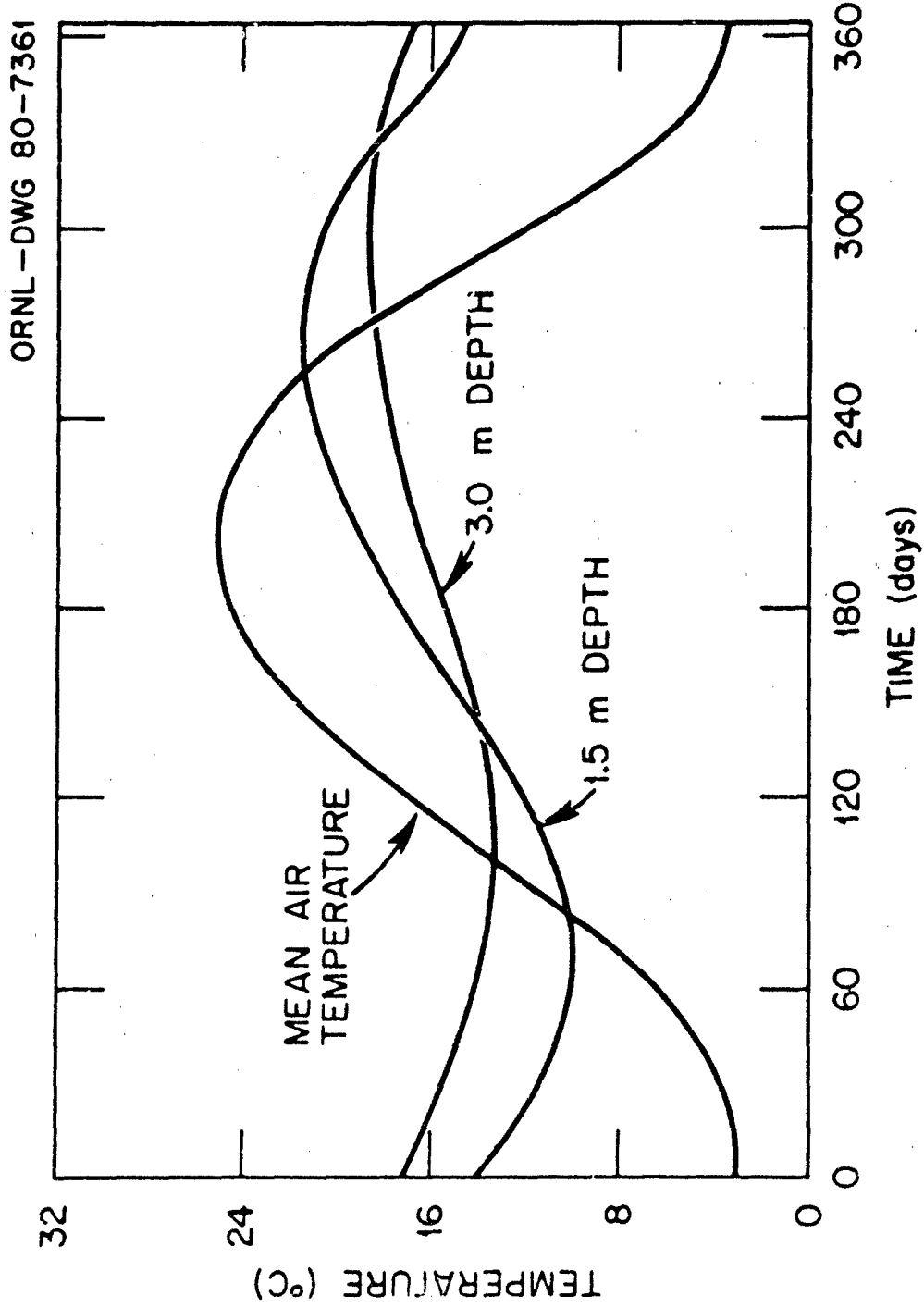


Fig. 5 Approximate Mean Daily Temperatures for
Oak Ridge, TN.

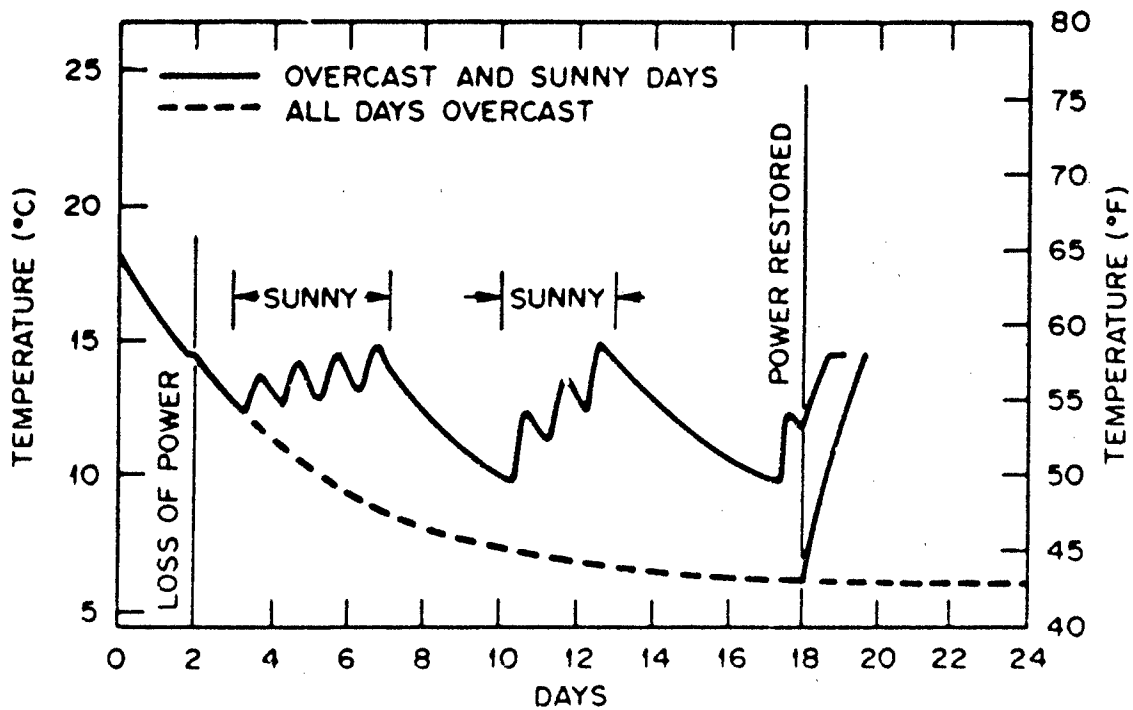
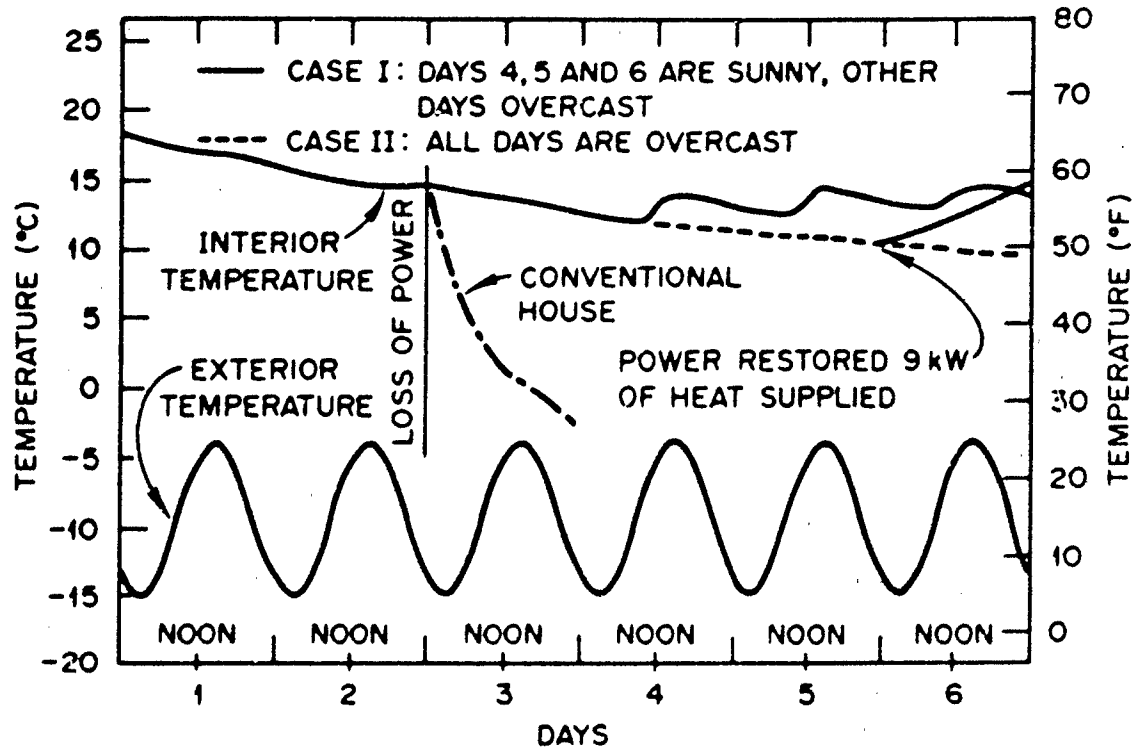


Fig. 6. Performance of the Structure During Power Failure.

3.3 DESIGN AND CONSTRUCTION PROBLEMS

Some problems, if not dealt with, could make earth-sheltered structures physically, aesthetically, or psychologically unattractive. The techniques for solving most of these problems do exist.

3.3.1 Psychological Fear

There is a common negative reaction to the idea of underground living. Exposure to good designs will undoubtedly erase misconceptions people have about earth-sheltered buildings. People who actually experience living or working in properly designed underground space almost invariably are enthusiastic about it. This has been the experience with the JIHIR and the Kansas City Underground.

3.3.2 Lack of Visual Depth

The lack of visual depth to the facade can be compensated by use of proper combinations of finish facade material well blended with the adjoining landscaping.

3.3.3 Lack of Natural Light

Many earth-sheltered designs lack sufficient lighting. However, today many designs integrate direct gain space heating and therefore employ large amounts of south facing windows. Proper interior arrangement of rooms can provide adequate lighting for all interior rooms.

3.3.4 Low Infiltration Rate

Low air infiltration rates cause problems that affect weathertight, energy-efficient, aboveground homes as well as earth-sheltered houses. This can create potentially hazardous air contamination, undesirable odors, and high levels of humidity. The inclusion of interior circulation, natural ventilation, and mechanical or forced-air ventilation will produce an acceptable quality of indoor air.

3.3.5 Condensation

Condensation has been a problem. In many cases this can be traced to situations in regions with humid summers where earth-sheltered walls were uninsulated. Condensation occurs when warm humid air strikes the cool uninsulated walls. Insulation of the walls will usually prevent this problem. In very severe humidity, mechanical airconditioning to the extent present in most homes today will be required.

3.3.6 Water Leakage

Weatherproofing deserves serious attention. Leaking can be a problem in any type of structure; however, locating and repairing a leak source belowground is more tedious and expensive. Waterproofing must be reliable. Careful site planning and landscaping will control the sources of water. In the first place, sites located in flood plains are to be avoided, as should high-water-table and low-lying sites. Proper landscaping, contours, plantings, drainage, and backfilling will reduce water concentration at building walls. Waterproofing must also include a proper skin for the building and very careful details for any penetration (e.g., vents, skylights, etc.). See Earth-Sheltered Structures Fact Sheets 03 and 04 on waterproofing. (University of Minnesota, 1980, 1981.

3.3.7 Loads on Walls and Roof

Structural engineering must account for additional lateral and vertical loads. Most basements are not adequately designed and cannot be used as examples of earth-sheltered design.

3.3.8 Cost

Although light, commercial underground structures can be directly competitive with equivalent aboveground structures, earth-sheltered dwellings invariably cost more than equivalent aboveground wood-frame houses. How much more is still hotly debated among enthusiasts in the

field. This additional cost is usually partly offset by the substantially lower heating and airconditioning costs of the earth-sheltered structures. See Section 3.4 following.

3.4 COST COMPARISON: ABOVEGROUND VS EARTH-SHELTERED

The assertion that earth-sheltered structures cost less or only a little more than above ground structures is often made by promoters of earth-sheltered structures. We believe that commercial or institutional earth-sheltered structures can, under proper conditions, compete with aboveground structures when life-cycle costs are compared. This position is hard to support, however, when a massive (concrete), single-family, earth-sheltered house is compared with the more conventional, light (wood frame), single-family home. A study (Shapira et al., 1983) recently completed at ORNL, concluded that under present market conditions, if aboveground and underground dwellings of equal size and quality are built on equal lots, the construction cost of the earth-sheltered structure compares poorly with that of the aboveground structure. Lowered operation and maintenance costs, including lower fuel bills, are outweighed by the higher interest charges on the higher capital cost which causes the monthly payments to be higher.

The ORNL Cost and Energy Comparison Study differs from other economic/cost studies in that it is a side-by-side analysis. For each one of the five selected representative localities "identical" aboveground and earth-sheltered houses were designed. The earth-sheltered structure (which incorporates direct gain space heating) has the same sizes, number, and quality of rooms and storage areas as the above ground home. Naturally, the floor plan differs in that the earth-sheltered home has only south facing windows and the unfinished space or the parking facility is not necessarily in the basement area. But, for the home buyer, the exterior style of the house, the general interior arrangement and the finishing materials are the same for each region in the aboveground and earth-sheltered structures. The only differences are features inherent to energy conservation -- earth-sheltering, direct-gain space heating, etc.

Both the aboveground basic unit (i.e., living space with no additional basement, garage, etc.) and the earth-sheltered basic unit (Fig. 7) have approximately 1480 square feet (138 square meters) of floor space. Depending on the region, a basement, an attached garage, or other space may be added to both the aboveground and earth-sheltered basic units. Details of construction and final finish are location specific.

3.4.1 Costing

Finished sets of blueprints and construction specifications were prepared and sent to an A/E (Architectural/Engineering) firm that provided a detailed cost analysis (Table 2). The initial construction costs of the earth-sheltered dwellings are greater than the "about 10% or more" usually claimed by the promoters of the concept. This is probably due to the fact that other "studies" compared designs with the same number of bedrooms but neglected storage or unfinished space (Sterling and Shurcliff, 1981). In other cases, the earth-sheltered homeowners who served as their own contractors failed to include their labor and profit in the cost figure.

3.4.2 Energy Analysis

Table 3 lists the annual energy consumption for one earth-sheltered, one energy-efficient aboveground, and one new conventional home. In one case an older, poorly insulated home was included in the comparison. The energy savings are significant. In the Minneapolis earth-sheltered structure, a saving of 48% in energy consumption was realized compared to the energy-efficient, aboveground design and a saving of 65% compared to a standard aboveground house. In Salt Lake City, the respective savings were 58% and 86%.

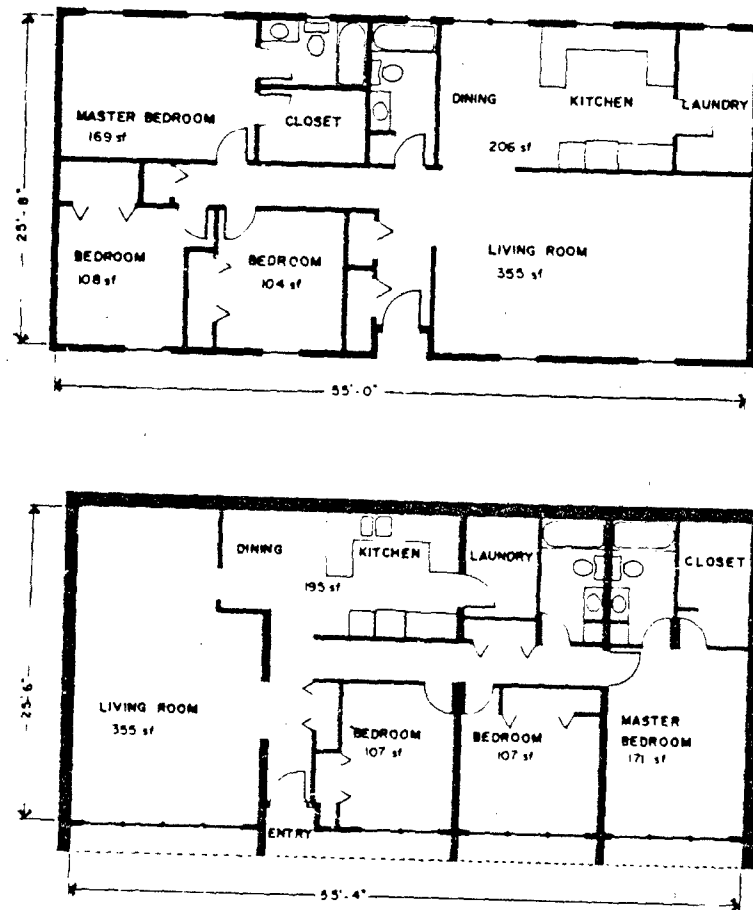


Fig. 7 Floor Plan from Comparison Study

Table 2. Estimated Construction Cost for the Conventional
Aboveground and Earth-Sheltered Structures,
January 1981

Location	Aboveground Cost (dollars)		Earth-Sheltered Cost (dollars)		Additional Earth- Sheltered Cost	
	Subtotal ^a	Total ^b	Subtotal ^a	Total ^b	Subtotal	Total
Minneapolis/ St. Paul	72,099	97,099	107,144	132,144	49%	36%
Boston	79,044	102,044	112,882	135,882	43%	33%
Salt Lake City	62,603	84,103	81,530	103,030	30%	23%
Knoxville	59,313	71,313	77,514	89,514	31%	26%
Houston	60,597	73,347	86,337	99,087	42%	35%

^aIncludes shell, interior finishes, plumbing, electrical, HVAC, site improvements subcontractor and contractor's overhead and profits.

^bTotal cost has land purchase costs added to subtotal.

Table 3. Annual Energy Consumption of Earth-Sheltered
and Aboveground Residences

Location	Annual Energy Consumption as Calculated by					
	SOLEST			BLAST		
	Heating (million Btu)	Cooling (million Btu)	Total (million Btu)	Heating (million Btu)	Cooling (million Btu)	Total (million Btu)
Minneapolis						
1 Earth-sheltered	35.3	1.7	37.0	49.4	5.3	54.7
2 Aboveground, efficient	-	-	-	67.1	4.6	71.7
3 Aboveground, standard	92.4	9.4	101.8	-	-	-
4 Aboveground, uninsulated	172.0	12.0	184.0	-	-	-
Boston						
1 Earth-sheltered	16.3	1.0	17.3	26.7	3.6	30.3
2 Aboveground, efficient	-	-	-	30.0	3.1	33.1
3 Aboveground, standard	83.8	9.6	93.4	-	-	-
Salt Lake City						
1 Earth-sheltered	14.6	0	14.6	27.9	3.8	31.7
2 Aboveground, efficient	-	-	-	24.3	10.3	34.6
3 Aboveground, standard	85.0	18.5	103.5	-	-	-
Knoxville						
1 Earth-sheltered	5.7	6.6	12.3	13.4	2.2	15.6
2 Aboveground, efficient	-	-	-	12.5	12.8	25.3
3 Aboveground, standard	60.8	30.0	90.8	-	-	-
Houston						
1 Earth-sheltered	0	9.9	9.9	3.7	5.7	9.4
2 Aboveground, efficient	-	-	-	5.2	9.6	14.8
3 Aboveground, standard	25.7	55.8	81.5	-	-	-

3.4.3 Life-Cycle Costing

The only fair way to compare two proposed investments that vary significantly in initial expenditure and in operating costs is to compare life-cycle costs. This method is not in general use by homeowners but has become widely accepted by commercial and industrial enterprises. Present methods of life-cycle cost analysis provide two equivalent measures of life-cycle cost, the "Present Value" and the "Annual Cost" methods. Life-cycle analyses were made on each of the designs. Using 1981 construction and conventional loan mortgage rates (14% to 16%), it is difficult for the earth-sheltered homes to compete economically with either the standard or the energy efficient aboveground houses if initial construction, annual maintenance and energy costs are the dominant comparison parameters (see Table 4). Lowered operation and maintenance costs, including lower fuel bills, are outweighed by the current high interest rates which causes the mortgage payments to be so much higher that they offset the savings derived from the energy-conserving features of the earth-sheltered, passively heated residence.

Cost added by earth-sheltered construction must be kept at or below 10% in order to compete with the aboveground home with the mortgage rates now in effect. It may turn out that 14-15% mortgage rates were a temporary economic aberration. If mortgage rates fall below 10% and consumer prices remain around their present levels, especially for gas and electricity, life-cycle costs of earth-sheltered residences may become much more competitive with conventional construction.

It should also be pointed out that earth-sheltered homes carry a wide range of price tags. For those who are interested in the benefits of earth sheltering, an earth-sheltered home that has a price tag to suit their budget exists. Buying this earth-sheltered house rather than a conventional aboveground home carrying the same price tag means: (a) some reduction in square footage, (b) loss of a dining room or den, (c) omitting an unfinished basement, or (d) reducing the number of bedrooms.

Table 4. Present Value/Life-Cycle Cost for Earth-Sheltered, Aboveground Efficient
and Standard Aboveground Homes

City	Discount Rate	Property Tax	Income Tax	Interest Rate	"Penalty" Points	Earth Sheltered	Above Ground Efficient	Above Ground Standard
Minneapolis	12%	9.9%	34%	11%	2.0	\$99,226	\$84,916	\$87,321
Boston	10.6%	34%	33%	11%	2.0	109,384	88,294	97,429
Salt Lake City	10.0%	6.9%	35.8%	11%	2.0	83,005	74,051	78,962
Knoxville	11.5%	10%	28%	11%	2.0	72,965	63,355	68,061
	11.5%	10%	20%	11%	1.0	72,248	62,784	67,530
Houston	11.3%	3.5%	20%	11%	3.5	81,969	65,361	67,110
	11.3%	3.5%	20%	11%	1.0	79,993	63,894	65,743

NOTE: 40% resale value after 30 years is included in calculations.

The results would be very different if comparison were made in the commercial, institutional sector where the construction costs for the earth-sheltered versions are not significantly different from those of the aboveground; and, over the life of the structure the earth-sheltered structure offers both comfort and monetary advantages. The materials used for conventional commercial buildings are similar in most cases to those used in earth-sheltered construction. For example, commercial buildings are largely built of masonry and concrete materials rather than of wood as is the case with most residential construction. The contractors in the commercial sector possess both the knowledge and the heavy equipment needed for most earth-sheltered construction. These factors are significant in reducing the cost differences between aboveground and earth-sheltered commercial designs.

So far the discussion has covered only the cost of "conventional" earth-sheltered structures which, though they provide good protection from natural hazards, must be improved to give the high degree of radiation and blast protection from nuclear weapons effects. The modifications can take place within the existing structure with no added space required. The conventional design needs to be modified slightly as discussed in Section 4.1 so that crisis upgrading can take place with a minimum of materials and effort. Dual use of space (i.e., for peacetime and for crisis upgrading) affords a shelter at minimal added construction cost. The corresponding added value is not usually included in life-cycle cost analyses. Over the conventional earth-sheltered structure the added cost for dual use as a crisis upgradable shelter for 100 people would be approximately \$6000 (See Section 4.2).

3.5 COST REDUCTION

There are several ways that the premium cost of an earth-sheltered structure can be reduced. These include innovative use of land and employing innovative construction techniques and materials. The following paragraphs present a selection of the ones we feel have the best potential for cost reduction.

3.5.1 Suburban Subdivisions

In suburbs of larger communities the price tag attached to each parcel of land is very high. Earth-sheltered homes reduce very little the amount of open space both visually and physically (Fig. 8). By dividing the lots in a subdivision in a manner more suitable for earth-sheltered buildings (e.g., long narrow lots along contours), the size of each lot can be significantly reduced without sacrificing the amount of "grass and garden." For example, in 1981 in a Minneapolis subdivision, a 120x220 ft lot sold for \$27,900. (Minneapolis Real Estate Agents, 1981). That subdivision had excellent orientation and could have been divided into lots uniquely suited to earth-sheltering and produced two to three times the number of lots. This would have yielded a net cost reduction for each homesite of at least \$14,000. Another advantage of constructing earth-sheltered homes in small communities is the saving that can be realized by bringing in the necessary heavy equipment for essentially "volume production." An encouraging start on such developments is the proposed "Rural Earth-Sheltered Energy Park" (Ellsworth et al., 1981) being planned by the Cumberland Development Corporation in Cumberland, Wisconsin. The planning phase was funded by the U.S. Department of Energy.

3.5.2 Mass Production

Mass production techniques have been used with great success in the building of our "mobile homes" as well as our automobiles. Mass production of modules in factory settings can materially reduce costs and improve quality control. Even "mass production" on-site is possible. Precut, precast members and modules can be assembled on site much more economically than is possible with the traditional building techniques. One prerequisite for these reductions is a standardization of specifications and designs which can come only from a concentrated community or government effort.

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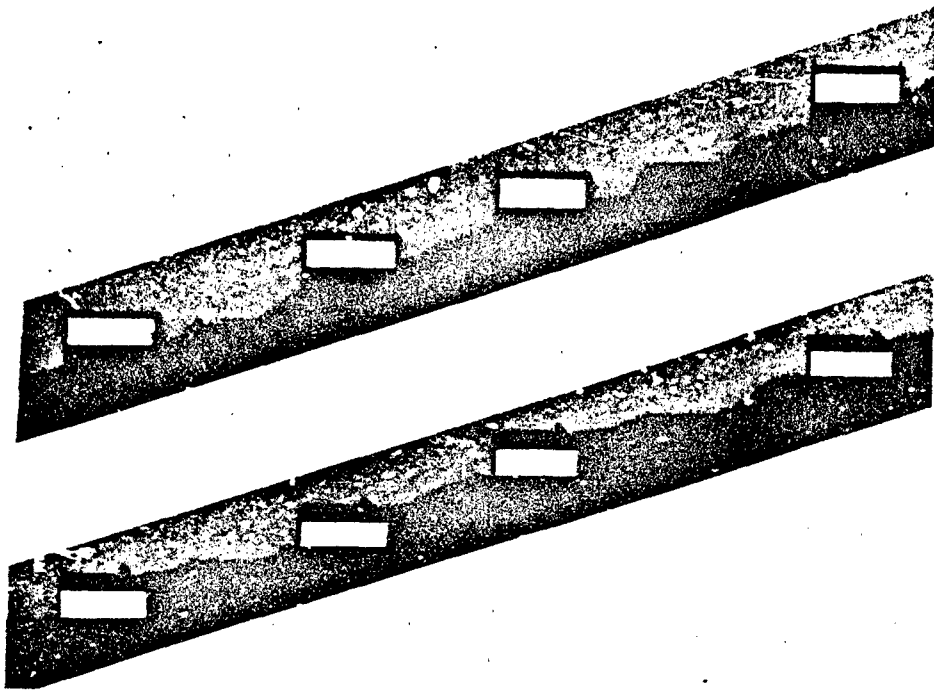


Fig. 8 Arrangement of Conventional and Earth-Covered Structures

3.5.3.2 Tilt-up Construction

This is a technique (Nelson, 1981) developed to use the construction site as a prefabrication area. The flat slab floor is poured in place, cured, and then sprayed with a chemical sealer and bond breaker. Next, the wall panels are laid out on the finished floor. The size of wall panel is limited only by the capacity of the crane that is available. Forms for the panels are installed on the floor, using 2x6 lumber. Lifting inserts are installed at the top of each panel. The concrete is placed, vibrated, and trowelled to a smooth finish. The wall panels can be poured in stacks wherever convenient. After the panels are poured and cured, a crane is brought in to erect them. This method saves much labor and materials and reduces the complexities of the formwork. In addition, quality control of such wall panels can be much better than vertically poured walls and can be less porous to water, making waterproofing more dependable.

3.5.3.3 Use of Reusable Forms and Scaffolding

Large-scale contractors are able to save costs for their clients by stocking forms that can be reused. This requires a large investment in equipment and standardization of the design of concrete panels. There are a few equipment suppliers that now can provide reusable forms and scaffolding on a rental basis. The success of this as a method of reducing costs depends upon wide acceptance of the techniques. This is one area where government assistance could make a difference.

3.5.3.4 Innovative Forms

An inflatable form system is available (Earth Shelter Living, 1982). It results in unconventional dome shapes but could save considerable labor and material.

3.5.3.5 Collaborative Construction

The alternate energy movement in the United States seems to have generated a camaraderie similar to that displayed by the rural communities of the Midwest during the last century, where it was

customary for farmers to help each other build their barns. Some of the earth-sheltered-living fans have initiated informal collaborative groups that help each other build earth-sheltered houses (Earth Shelter Living, 1982). With the help of a number of franchisers who are in the market with structures suitable for such groups (e.g., U.S. Gypsum, U.S. Steel, and Terra-Dome), local groups could learn the necessary skills and help each other build homes. Since the contractor's profit and overhead sometimes account for 20 to 30% of the cost of a new home, cooperatively built homes should cost that much less.

3.5.4 Innovative Structural Materials

3.5.4.1 Concrete Arch Systems

A system that was developed in Switzerland for tunnel lining in 1968 has been adapted for use in earth-sheltered homes by a Florida architect (Dr. John B. Langley) and the Metal Products Division of United States Gypsum Company. It is a patented system called the "BERNOLD PLATE" system. It has been used in at least 16 earth-sheltered homes. The system uses steel plates punched out of 14-gauge steel. The plates are assembled to form an arch which serves the dual functions of form and reinforcing. The plates are approximately four feet square and weigh 40 to 50 pounds each. A two-person crew with only ordinary carpenter's skills can assemble them in place ready for the concrete cover even without the use of a crane. After the arch is in place it is covered on both sides by ShotcreteTM. The arched shape provides a much stronger roof than a flat slab. This method saves all the forming costs, uses less concrete, and avoids the need for heavy construction machinery. The shotcrete operation can be continuous after the arch is in place. The curved sections are rolled to the specific curvature required by the individual project. U.S. Gypsum Company is planning to provide several standard radii as stock items if the demand becomes large enough. Details of the method are given in a handbook (Langley, 1980).

3.5.4.2 Prefabricated Modular Shapes

The My-My pods mentioned earlier could be used to produce many earth-sheltered homes rapidly by some company holding a license from the Taisei Construction Company to build them in America. Or some company in the U.S. could develop a comparable product for mass production.

3.5.4.3 Preformed Culvert Sections

Although this method has not been sufficiently tested yet, we believe that quite satisfactory earth-sheltered homes can be economically built using standard commercially available structural plate arches. These are available in gauges (10) in useful widths (25-40 ft) which withstand complete burial. Great savings in erection labor can offset the higher material cost. When fully buried with 5 ft of cover with sufficiently dilatant backfill, structures of this type have withstood nuclear weapon overpressure as high as 100 psi, due to earth arching.

3.5.4.3 Surface-bonding Agents

This method of strengthening a concrete block wall shows some promise of reducing the cost of concrete walls. The method consists of trowelling the surface bonding agent (e.g., Surewall™) on the surface of a concrete wall laid up without mortar. A builder using this method could use much less skilled labor than required for an ordinary concrete wall, would require no forms, and would be almost as strong as a poured in place concrete wall ((Mother Earth News, 1981). The method has not been sufficiently tested yet, so some additional research would be needed to verify the projected savings.

4. AN EXAMPLE OF HAZARD RESISTANT DESIGN

4.1 MODIFICATIONS TO THE "KNOXVILLE" EARTH-SHELTERED DESIGN

If below-grade construction of a habitable space can be justified by energy and/or land conservation, (or for any other reason for that matter), there are techniques for converting it to blast shelter in a crisis at moderate cost, especially if the structure has been designed from the beginning to be crisis-upgradable.

The Knoxville earth-sheltered design (Fig. 9) employs the following features:

- (1) slab-on-grade floor,
- (2) three poured-in-place steel reinforced concrete perimeter walls,
- (3) hollow concrete-block interior walls,
- (4) wood stud/sheet rock partition walls (parallel to the south facade),
- (5) a south-facing "window-wall,"
- (6) prefabricated hollow core ceiling panels of SpandekTM,
- (7) the three "earth-contact" walls are carefully waterproofed,
- (8) thermal insulation boards provide mechanical protection of the waterproofing, and
- (9) attached garage with partly earth-covered walls and uncovered roof.

The "Knoxville design" emphasizes cost and energy conservation. To maximize hazard mitigation, some changes have been made in the design, shown in Figs. 10 and 11 and in the working drawings in Appendix E.

The major change is the greater use of load-bearing interior walls and cast-in-place (CIP) roof. These eight-inch reinforced walls can be either cast-in-place concrete or grouted retaining-wall block. They are arranged to provide more uniform support of the roof, reducing unsupported roof spans, and in conjunction with the solid portions of the front wall, provide more protection from radiation and wind-driven missiles for the rear areas of the house. The room designated "study"

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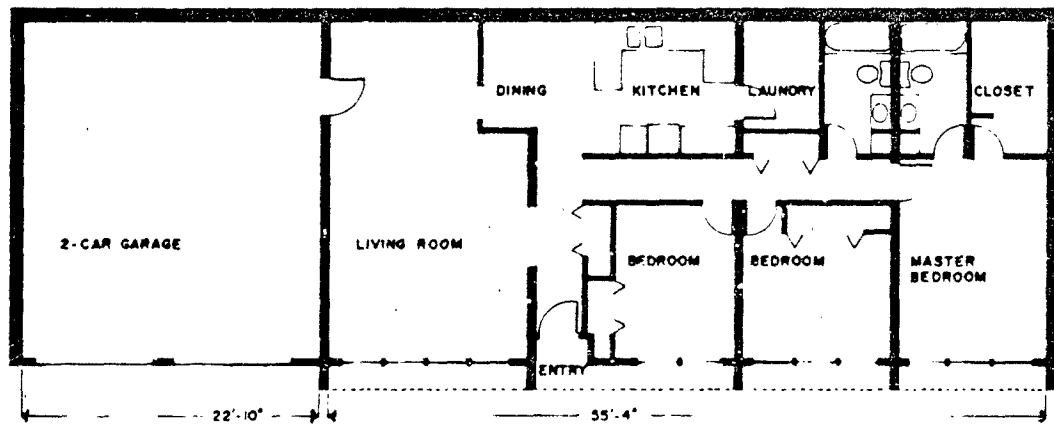
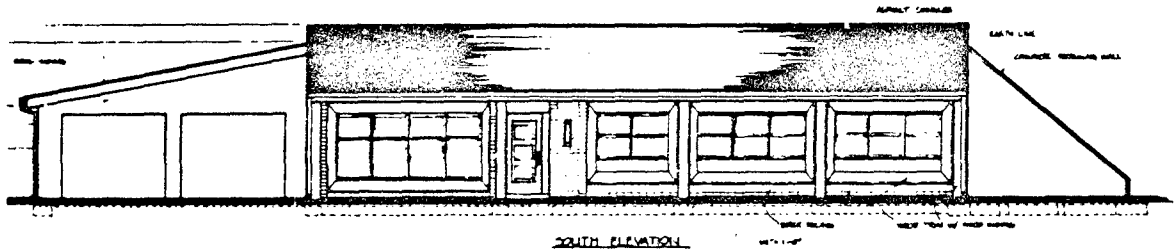


Fig. 9 Knoxville Earth-Sheltered Design



Fig. 10. Hazard Resistant (Crisis Upgradeable) Design.

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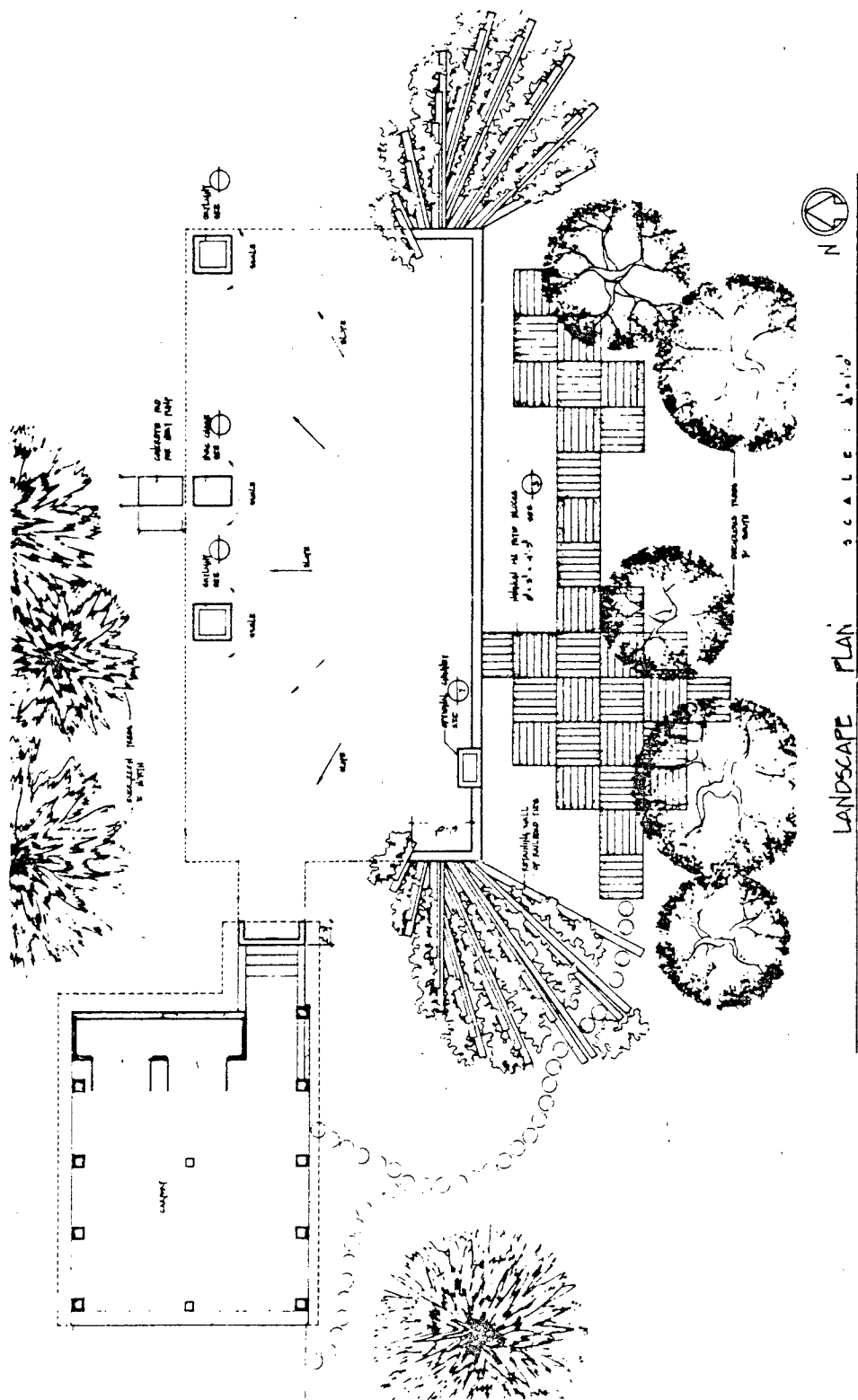


Fig. 11. Landscape Plan

is designed to have a radiation protection factor of several hundred and complete protection from wind-driven missiles in the peacetime configuration of the house. The smaller windows in the bedrooms would have external planters or be in front of the solid walls under them to provide additional fallout protection and incidentally a little more thermal insulation.

The garage in the Knoxville design with its difficult-to-protect doors and expensive walls has been moved away from the house so the west wall can be bermed. To reduce cost, the garage can be a carport. The green earth-sheltered motif of the house can be retained for the carport at a minimum cost by the use of trellises and appropriate plantings.

The columns on the front wall have been designed to take the horizontal loads from a one-atmosphere blast overpressure. The openings for the windows are designed to be protected against blast by stacking the patio paving blocks in front of the glazing as part of a crisis-upgrading procedure. For the maximum protection, earth from the banks on either side of the house can be piled against the front wall after the window closures are in place. This operation would require either construction equipment (front-end loader or bulldozer) or a great amount of hand labor to move the required 60-100 m² of earth. However it would provide a fallout protection factor of at least 1000 over the entire area of the house, and eliminate the danger of pressure amplification in re-entrant angles from blast waves approaching from the direction of the exposed walls.

The roof is specified as cast-in-place concrete rather than prefabricated concrete planks (e.g., SpandeckTM). The cost of the two approaches is a tradeoff unless labor costs are extraordinarily high, which is generally not the case in rural or suburban areas around smaller cities. The CIP roof has the advantage of much greater ductility and toughness, much better anchorage at the walls, much more punch resistance if extra support columns are used, and better radiation shielding from the same bearing capacity. The eight-inch-thick roof is designed to resist one atmosphere overpressure functioning as a two-way slab. One support column is required in the center of the living room

as part of the upgrading procedure. By putting four columns in the living room and adding one column at the center of each of the other seven structural bays, the roof would resist overpressures in excess of three atmospheres.

A depth of cover on the roof of three feet, or at least one-fifth the span, is specified. If the earth used has a large angle of internal friction (more than 35°), earth arching to the walls and columns will occur under blast loading, providing another factor of two protection against long-duration overpressures, and several times this against short duration blasts (as from kiloton range weapons).

The skylights are designed to serve multiple functions as ventilators and emergency exits. In the peacetime configuration they would have an acrylic weather cover, and provision for ventilation and emergency egress, and winter insulation. Part of the crisis-upgrading procedure would be replacement of the peacetime closures with a blast door and an expendable/replaceable weather canopy. Figure 12 shows the structure in its upgraded posture.

4.2 COST COMPARISON

The changes made in the "Knoxville Design" earth-sheltered structure in the interest of both hardenability and cost containment in the "crisis upgradable design" have made a cost comparison between the two ambiguous. To identify more clearly the costs of hardening, another design, the "Knoxville Economy ESS", has been introduced which has the cost-saving features of the crisis upgradable ESS but not the hardening. The economy structure is the Knoxville design with the garage replaced by separate carport and the concrete retaining walls replaced with slopes stabilized with railroad ties.

In addition to the carport, the use of ceramic tile in the bath and fabric-backed gypsum interior wall covering was identified as a cost option, but is included in the final totals.

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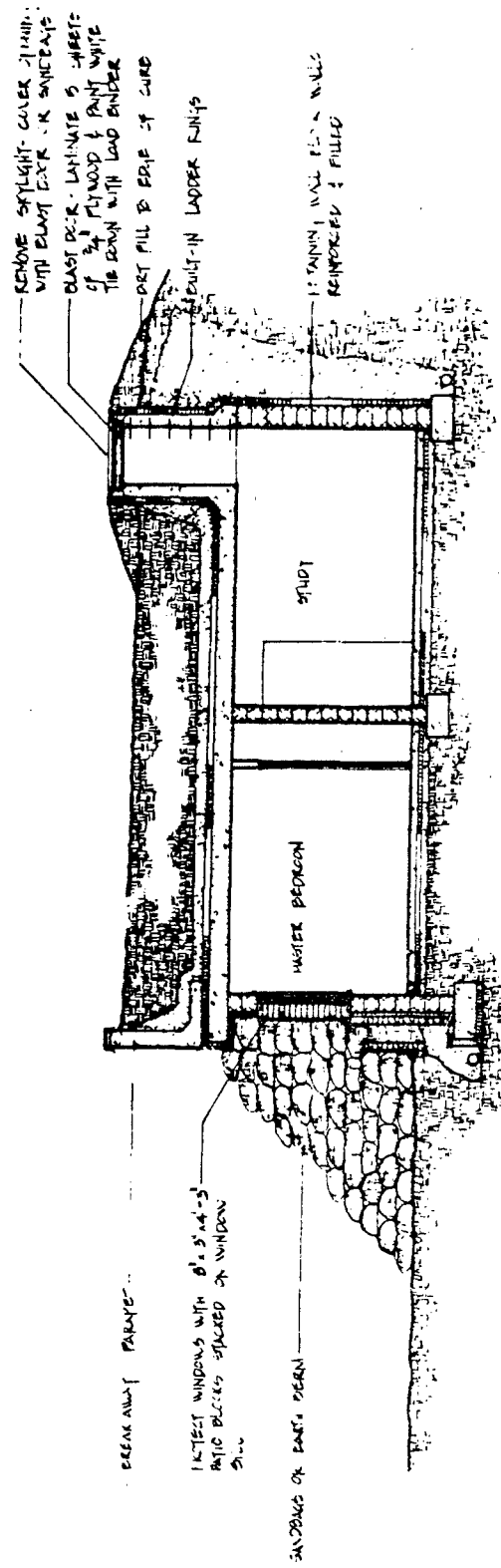


Fig. 12. Upgraded Posture

The costs of four structures are compared in Table 5. The first two columns are the Knoxville aboveground design and the Knoxville Earth-Sheltered Design from the Cost and Energy Comparison Study (Shapira 1983) with the prices corrected for 15% inflation from January 1981 to January 1983. The Knoxville Economy ESS and Crisis Upgradable Structure in the third and fourth columns are as previously described, with the costs estimated for early 1983 (when costs were quite stable). All costs include materials, labor, and 10% contractor's overhead and profit.

The bottom line in Table 5 is the percentage increase in the cost of each structure which must be added to buy a crisis-upgradable structure which can be hardened to one atmosphere blast overpressure. The cost due purely to hardening (a little over 6 percent) can be seen from comparison between the Knoxville Economy ESS and the crisis upgradable ESS. This cost is due principally to the strong columns in the south wall, and the increased cost of running the electrical wiring in conduit in the floor, solid walls and roof. It is much cheaper to run wiring in hollow block or stud walls, and a hollow concrete plank roof. The cast-in-place roof is not too much more expensive than precast plank.

The cost increase over aboveground design, 33%, is due principally to going underground and replacing frame construction with reinforced masonry or concrete construction. Once the cost of going underground has been accepted, the additional cost of blast hardening is minor, and could be offset by foregoing or deferring other amenities.

TABLE 5. COMPARISON OF 1983 COSTS FOR CRISIS UPGRADEABLE
AND OTHER EARTH-SHELTERED STRUCTURES

	Knoxville Aboveground Fig. 7	Knoxville Comparison ESS Figs. 7 & 9	Knoxville Economy ESS Figs. 9 & 11	Crisis Upgradeable ESS Figs. 10 & 11
Basic House Cost	\$68,210	\$89,141	\$78,943	\$84,116
Comparability Package				
Carport	Included	Included	4726 2047	4726 2047
Interior Finish	Included	Included	<u>\$85,716</u>	<u>\$91,089</u>
% Cost Increase To Go To Upgradeable	33.5	2.19	6.26	

5. INTRODUCTION TO TECHNOLOGY ADOPTION AND DIFFUSION PROCESSES

In addition to the technical features of earth-sheltering discussed earlier, it is important to understand the adoption and diffusion processes by which a "new" technology like this is tried and eventually accepted by society. Research on the diffusion of innovations has addressed three basic areas - inventive activity, or the development of an idea into a marketable product or service; the diffusion process itself; and the impacts of innovation diffusion (Brown, 1981). In turn, research on the diffusion process has consisted of two major research traditions - the adoption perspective and the market and infrastructure perspective. Although these two orientations emphasize different aspects of the process, as discussed below, in combination they offer substantial guidance regarding what can be done to gain widespread adoption of an innovation.

5.1 THE ADOPTION PERSPECTIVE*

The basic premise of this perspective is that the adoption of an innovation is primarily the outcome of a learning or communications process (Rogers and Shoemaker, 1971). If an individual learns about an innovation, if that innovation is compatible with his or her social, economic, and psychological characteristics, and if that innovation satisfies a felt need better than existing alternatives, he or she will adopt the innovation.

The ability of innovation proponents to induce adoptions through information flows has been shown to be quite limited. Among the five stages of the adoption decisionmaking process as identified by Rogers and Shoemaker (i.e., awareness, interest, evaluation, trial and adoption), impersonal sources of information, such as mass media, professional journals and untargted information dissemination programs

*Much of this discussion derives from Berry and Bronfman (1980).



may affect the first two, awareness and interest; later stages of the process usually require the influence of social interactions, opinion leaders, and other market-pull forces (Berry and Bronfman, 1980).

The compatibility of an innovation with a potential adopter's social, economic, and psychological characteristics has been measured in terms of the characteristics of innovations and of their adopters. Innovations have been characterized along numerous "objective" dimensions, including relative advantage, complexity, trialability or devisibility, observability or communicability, cost, return on investment, efficiency, risk, and numbers of gatekeepers, among others (Zaltman, et al., 1973; Hough, 1975; Rogers and Shoemaker, 1971; and Warner, 1974). Many researchers stress that however objective these attributes may appear, it is the potential adopter's perception of attributes that determines adoption.

5.2 THE MARKET AND INFRASTRUCTURE PERSPECTIVE

The market and infrastructure perspective on the diffusion process posits that "the opportunity to adopt is egregiously and in many cases purposely unequal" (Brown, 1981, p. 7) and focuses on the process by which innovations and conditions favorable to adoption are made available to potential adopters. Three major activities compose the diffusion process - the establishment of diffusion agencies or outlets through which the innovation is to be distributed; the development of implementation strategies by these agencies for inducing adoption within their markets or service areas; and finally, the actual adoption of the innovation (Brown, 1981). Brown's emphasis on the supply side of diffusion, in contrast to the adoption or demand side characterized by Rogers and Shoemaker, seems particularly germane to those institutions interested in inducing diffusion. This view places responsibility for diffusion success on the diffusion agency rather than on the adopter, uses existing distribution systems rather than creating new ones, and actively incorporates commonly used business and marketing strategies in the diffusion process.

The concept of a technology delivery system or innovation delivery system is a particular variant of the market and infrastructure perspective (Berry and Bronfman, 1980). This system has a number of components, including (1) research-performing institutions; (2) manufacturing institutions; (3) product-distribution institutions; and (4) lending institutions that make funds available to other components of the technology delivery system and, potentially, to adopters as well. According to Ezra (1975), all of the components of the technology delivery system must be in place and be ready to accept a new technology before it can penetrate the marketplace. Financing such a system can be achieved through a variety of mechanisms, including outright federal funding; cost-sharing; loan-guarantees or loan insurance; construction grants; and indirectly through codes, standards and regulations.

5.3 IMPLICATIONS OF ADOPTION AND DIFFUSION PROCESSES FOR EARTH-SHELTERED RESIDENCE ADOPTION

In order for a program encouraging the adoption and diffusion of earth-sheltered structures to be successful, it is important to pay close attention to what is currently known about adoption and diffusion processes. Although there are no general predictive models or theories of diffusion that can be applied directly to the problems of inducing adoption and diffusion and forecasting diffusion rates, as the divergence of the two research traditions indicates, the literature does suggest a number of principles that might guide the development of policies intended to encourage adoption and diffusion of earth-sheltered residences.

5.3.1 Market Identification and Segmentation

It is important to characterize the potential market for earth-sheltered structures early in the policy development process. The diffusion literature has identified ideal types of adopters - the "innovators" who are venturesome; the "early adopters" who are respectable opinion leaders and help to evangelize the innovation; the

"early majority" who follow opinion leaders with deliberate willingness but seldom lead; the "late majority" who are skeptical and must be dragged into the market; and the "laggards" who, due to strong ties with traditional ways of doing things are the last to adopt a new technology (Rogers and Shoemaker, 1971). The question becomes one of identifying segments of the population who are likely to lead the market. In the case of earth-sheltering, the innovators already exist, and the task is to develop policies that will affect the behaviors of opinion leaders and those willing to examine and evaluate purposefully the desirability of earth-sheltering. Who are these people, and where do they live? Can the innovation (i.e., earth-sheltering) be characterized as compatible with their values and objectives? What, if anything, needs to be done to make the innovation compatible with their values and goals?

5.3.2 Use of Existing Information and Communications Networks

Potential adopters operate within existing social structures that have existing communications networks. They attend to diverse information sources, from the mass media to their colleagues at work. Equally important, and congruent with the market and infrastructure perspective on diffusion, they tend to seek information from traditional sources. In the case of making housing investments, they are likely to communicate with real estate firms, appraisers, builders and developers, and lending institutions as well as the mass media (e.g., real estate listings) and their friends and colleagues. Putting information in the right sources is, then, perhaps as important as the content of the information itself.

5.3.3 Infrastructure Development

In addition to information, diffusion agencies need the resources and the will to induce adoption. If, as Brown maintains, individuals make choices within a constraint set, it is important for adoption and diffusion proponents to ease the constraints potentially limiting

adoption. This implies that the conditions favorable to diffusion need to be designed to be sensitive to the existing institutional environment, taking full advantage of the knowledge, expertise, and power residing in those institutions. This also implies that existing institutional resources need to be supplemented where they are deficient.

5.3.4 Identification of Specific Institutional Issues or Barriers

Given the diverse range of potential barriers to the adoption and diffusion of earth-sheltered structures, it is useful to develop policies that address specific barriers in specific market segments at specific times in the adoption process. For instance, early initiatives might address a specific issue (see Section 6) that affects acceptance of earth-sheltered mortgages by the financial community when influential persons are considering making personal investments in such housing options.

5.3.5 Adoption and Diffusion Monitoring

Whatever diffusion options are implemented, it will be important to monitor and evaluate their results so that midcourse revisions and corrections might be made. This would especially be critical when the diffusion agency has limited resources and wants to support the most cost-effective elements of a multi-dimensional diffusion strategy.

5.4 SUMMARY

The diffusion literature suggests careful attention to demand and supply dimensions of innovation adoption. Central to both of these dimensions is the identification of those specific issues that may impede optimal behavior by potential adopters and the relevant infrastructure. The following Section presents a comprehensive list of such issues and presents an evaluation of those that are deemed most important to the adoption and diffusion of earth-sheltered residences.

6. INSTITUTIONAL ISSUES

Issues arising from the institutional and organizational interactions necessary for the adoption of a new technology are very important to consider when exploring ways to encourage the private sector development of earth-sheltered residences and communities. This section will focus on those issues expected to be important in the adoption of earth-sheltering by the residential sector. Institutional issues unique to public, commercial, and other non-residential structures were not studied, but the likelihood of major similarities and differences between the residential and non-residential sectors will be discussed briefly.

Data on institutional issues and options affecting the adoption of earth-sheltering housing were gathered in two basic ways. In the first phase of the study, an in-depth review of the literature on earth-sheltered structures was conducted and a preliminary list of institutional issues and relevant policy options was compiled. In the second phase of the study, additional information was obtained through a review of the relevant literature and the use of questionnaires completed by a panel of 16 experts. This panel included experts in the areas of earth-sheltered structures, diffusion of innovation, disaster research, housing, law, policy analysis, and planning. The data collected during Phase II was then analyzed by ORNL staff to produce the findings presented here and in subsequent chapters.

Table 5 presents a broad range of institutional issues that could affect the development of earth-sheltered houses and communities. Over 40 issues were identified and grouped in five general categories. The first category contains issues related to the desire to use earth-sheltered residences. These issues involve the perceived attributes of earth-sheltered dwellings and how they influence the behavior of potential adopters. This focus is compatible with the popular "adoption perspective" on innovation diffusion, which centers on the process by which individuals decide to adopt a new technology (Rogers and Shoemaker, 1971).

Table 6 Complete Listing of Institutional Issues Affecting
the Utilization of Earth-Sheltered Residences

Issues Related to the Desire to Use Earth-Sheltered Residences

- Aesthetics
- Livability
- Safety
- Soundness of Investment
- Conformity to Socially Accepted Image
- Expression of Personal Values
- Response to the Threat of Nuclear War^a

Issues Relating to the Construction of Earth-Sheltered Structures

- Building Regulations
- Land Use Regulations
- Restrictive Covenants
- Limited Experience of Planners and Regulators
- Availability of Inexpensive Designs and Plans
- Financing of Construction Loans
- Innovation in the Construction Industry
- Difficulty in Building Neighborhood/Community as Planned^b

Issues Related to the Ability to Purchase Earth-Sheltered Residences

- Availability of Suitably Trained and Equipped Contractors
- Availability of Mortgage Money at Attractive Rates
- Ability of Earth-Sheltered Neighborhoods/Communities to Reduce Costs^b

Issues Related to the Use of Earth-Sheltered Residences

- Interior Environmental Quality
- Maintenance of Structure
- Access to Structure
- Energy Use
- Taxation
- Insurance
- Resale
- Emergency Use of Earth-Sheltered Structures
- Ease of Interaction with Neighboring Units
- Protection from Intrusion or Vandalism
- Legal Liability Imposed under Doctrine of Attractive Nuisance
- Need for Access to Specialized Equipment (or Large Numbers of People) and Materials to Allow Crisis Use^a

^aIssues related exclusively to the adoption of crisis-upgradable earth-sheltered structures.

^bIssues related exclusively to the development of earth-sheltered neighborhoods or communities.

Table 6 (continued)

Issues Related to Community-Wide Effects of Using Earth-Sheltered Structures

- Housing Density
 - Urban Form
 - Environmental Protection
 - Energy Consumption
 - Disaster Protection
 - Public Access to Earth-Sheltered Dwellings in Case of Disaster
 - Neighborhood Concept
 - Changes in the Image of the City
 - Changes in Existing Building Industry
 - Societal Impacts Arising from Policy Initiatives to Stimulate Earth-Sheltering
-

In contrast, the next set of issues focuses on the organizational arrangements whereby earth-shelters are built, an area of vital importance in assuring that potential adopters will have something to adopt. The major actors involved here are builders, developers, designers, lenders, and regulators. The type of issue treated here is compatible with the "supply side" or "market and infrastructure" perspective from the diffusion of innovation literature (Brown, 1982). Also compatible with this perspective are those issues related to the ability to purchase earth-sheltered dwellings, which fall into the third major category identified in this study. While the ability to purchase is clearly influenced by an individual's socioeconomic status, the focus here is on those institutional factors (like the availability of suitably trained and equipped contractors) which help determine the market price of an earth-covered dwelling. Again, the emphasis is on the infrastructure which determines the ability of an individual to take advantage of an innovation.

Issues related to the use of earth-sheltered dwellings arise after an individual or family purchases and moves into such a dwelling. These issues are important both for their impacts on those who have already adopted this technology and for their potential influence on future adopters, whose decisions can be strongly influenced by the experience of early innovators (Shama, 1982). While this set of issues is important from both the adoption as well as the "impacts" perspective, the final category of issues identified is important solely from the perspective of its impacts. Issues related to the community-wide effects of using earth-sheltered residences focus on how the adoption of a new technology will affect society at large. Relatively neglected in the diffusion of innovation literature, with the notable exception of the recent writings of L. A. Brown (1982), the effects of new development have long been of interest in the fields of technology assessment (Coates, 1974) and social impact analysis (Finsterbusch and Wolf, 1977).

All the issues identified in the five categories discussed above were examined for their importance in affecting the adoption and use of earth-sheltered residences. The remaining sections will focus on those issues judged to be significant relative to each of FEMA's three major interests, presented in Chapter 1. Section 6.1 presents important issues associated with the adoption of hazard-mitigating earth-sheltered structures; Section 6.2 contains those issues associated with crisis-upgradable earth-shelters; and Section 6.3 describes important issues associated with the development of earth-sheltered neighborhoods or communities. Those issues judged as most important in affecting the utilization of earth-shelters are discussed in some detail, while issues classified as moderately important are treated much more briefly (for a more complete discussion of those issues rated as moderately and least important, see Appendices A and B). A preliminary discussion of institutional issues associated with the adoption and use of non-residential earth-sheltered structures can be found at the end of Section 6.1. Before we begin the discussion of specific issues, however, a brief definition of terms is in order.

The issues presented below were selected from a preliminary list of issues (Table 5) compiled as the result of an extensive literature review in the area of earth-sheltering. The most significant issues from among those in the initial listing have been chosen with the help of a subsequent search of the diffusion of innovation literature and the responses to a questionnaire (Appendix C) distributed to experts (Appendix D) on earth-shelters, innovation diffusion, and other relevant subjects. To allow the prioritization of issues, "most important" issues are defined as those most likely to have an immediate or near-term effect on the adoption and use of earth-sheltered building technology (most often by presenting a significant barrier to utilization) and likely to require some type of timely response (e.g., a government policy initiative) to stimulate utilization. "Moderately important" issues, while expected to play a significant role in the diffusion of

earth-sheltered building technology, will have less immediate impact on adoption and use and will require less direct intervention. Issues classified as "least important" are expected to have limited significance in the diffusion process and will not be discussed in the body of this report.

It is important to note that the prioritization of issues presented here is likely to change over time, with different issues assuming different degrees of importance as one stage in the adoption process yields to the next (Friesma, 1982). It should also be noted that the importance of these issues has been judged largely on their expected potential for influencing the adoption and use of earth-sheltered residences. Were the focus of attention shifted from issues affecting adoption and use to those societal issues engendered by the widespread utilization of this type of structure, the relative importance assigned to the various issues here could be considerably different. Government policymakers must be aware that if they choose to implement measures designed solely to encourage the utilization of this type of structure, they may be failing to address other issues that could be critical for society as a whole.

6.1. ISSUES ASSOCIATED WITH THE ADOPTION AND USE OF HAZARD-MITIGATING EARTH-SHELTERED RESIDENCES

Hazard-mitigating earth-sheltered structures are characterized by the protection they offer occupants against a variety of natural and man-made disasters, including radioactive fallout. These structures are similar in design to many elevational earth-sheltered dwellings built in recent years. This indicates that the same degree of protection might be available to a sizable proportion of the earth-sheltered market without the necessity for substantial change in designs or in established earth-sheltered building practices. Working against this,

however, is the fact that increasing numbers of earth-sheltered dwellings are being built with conventional, exposed roofs (Sterling, 1982), lowering costs somewhat but removing many of the safety advantages traditionally associated with earth-covered buildings.

A complete listing of important institutional issues associated with the adoption and use of hazard-mitigating, earth-sheltered structures is presented in Table 6. The most important issues will be discussed in Section 6.1.1 and moderately important issues will be treated in Section 6.1.2. A brief discussion of non-residential issues will be presented in Section 6.1.3.

6.1.1 Most Important Issues

Two general types of issues emerge as most important in affecting the adoption and use of earth-sheltered residences. They are: (1) issues related to the desire to use such structures, and (2) issues related to the ability to purchase them. Three specific issues are singled out as being most important from the first set of issues, and two are seen as most critical from the second.

6.1.1.1 Issues Related to the Desire to Use Earth-Sheltered Residences

This type of issue is important in the adoption of a variety of new technologies; however, it is likely to be especially critical for earth-sheltering because of the negative connotation associated with "living underground" by many potential home buyers.

Livability. Both the psychological and physical comfort offered by earth-sheltered structures are important to potential customers. Living and working underground is likely to be difficult for some people but not for others. Different studies have revealed widely divergent reactions to the underground environment (Lutz, 1975). The most interesting finding is that a psychological aversion to inhabiting earth-covered buildings may be more a product of negative bias toward the underground than a result of the actual physical attributes of surface space (Hollon, 1980). In order to compete with aboveground

Table 7. Important Institutional Issues Associated with the Adoption and Use of Hazard-Mitigating Earth-Sheltered Residences.

MOST IMPORTANT ISSUES

Issues Related to the Desire to Use Earth-Sheltered Residences

- o Livability
- o Aesthetics
- o Soundness of Investment

Issues Related to the Ability to Purchase Earth-Sheltered Residences

- o Availability of Suitably Trained and Equipped Contractors
- o Availability of Mortgage Money at Attractive Rates

MODERATELY IMPORTANT ISSUES

Issues Related to the Desire to Use Earth-Sheltered Residences

- o Expression of Personal Values
- o Conformity to Socially Accepted Image

Issues Related to the Construction of Earth-Sheltered Residences

- o Building Regulations
- o Land Use Regulations
- o Restrictive Covenants
- o Availability of Inexpensive Designs and Plans
- o Innovation in the Construction Industry.
- o Financing of Construction Loans

Issues Related to the Use of Earth-Sheltered Residences

- o Resale
- o Interior Environmental Quality
- o Access to Structure
- o Energy Use

Issues Related to the Community-Wide Effects of Using Earth-Sheltered Residences

- o Housing Density
 - o Urban Form
 - o Neighborhood Concept
 - o Changes in the Image of the City
 - o Energy
 - o Changes in the Existing Building Industry.
 - o Societal Impacts Arising from Policy Initiatives to Stimulate Earth-Sheltering
-

buildings, however, the warmth, dryness, and light that are typically associated with conventional structures must be available in earth-sheltered structures. Also, the image of the underground as damp, musty, and dark - markedly undesired in most modern earth-sheltered dwellings - must be dispelled.

Aesthetics. The appearance of earth-sheltered structures and their aesthetic appeal to potential consumers can strongly influence the desire to purchase and reside in this type of dwelling. Differences in height and other dissimilarities in appearance between earth-shelters and more conventional structures could be considered a negative factor by many potential customers. According to Roessner (1982), potential buyers will be very reluctant to deviate from accepted values of aesthetics or livability without a very powerful reason to give up those values. This problem could be addressed, however, through designs that attempt to imitate conventional dwellings with a traditionally styled front elevation or, conversely, that successfully develop a unique earth-sheltered aesthetic that emphasizes the warmth, security, and strength of building underground (Metz, 1980).

Soundness of investment. Perceptions of the purchase price and operating costs of an earth-sheltered structure relative to those of a comparable aboveground structure, the rate of value appreciation, and the ease of resale can all be important in influencing the desire to purchase this type of dwelling.

6.1.1.2. Issues Related to the Ability to Purchase Earth-Sheltered Residences

These institutional issues are of great importance because the way in which they are resolved will directly affect the costs of the earth-sheltered structures and the subsequent ability of potential buyers to afford them.

Availability of suitably trained and equipped contractors. The experience and efficiency of builders engaged in earth-sheltered construction will be directly reflected in the cost of earth-sheltered dwelling units they construct (Sterling, Aiken, and Carmody, 1980).

As the industry matures, skill levels increase, the number of trained contractors rises and competition increases, the importance of this issue should decline and the prices charged for earth-sheltered housing units should decrease. This, in turn, is likely to encourage greater sales.

Availability of mortgage money at attractive rates. To allow the widespread adoption of earth-sheltered housing, mortgage money must be readily available at rates that will appeal to significant numbers of potential buyers (Ziebarth, 1982). This is important for any type of dwelling, but especially critical for earth-shelters with their higher initial costs. The willingness of lending institutions to make such money available is determined by several important factors. The availability, or lack thereof, of mortgage insurance is one such factor; the risk to lending institutions in case of default on an earth-sheltered mortgage would be greatly reduced if mortgage insurance were routinely given on loans for this type of structure. The ease with which earth-sheltered mortgages can be resold on the secondary market, thus maintaining the liquidity of the original lender, can be another important determinant of a lending institution's willingness to finance this type of building (Korell, 1978). Other important factors are the ability of lender to appraise the current and projected resale value of an earth-sheltered unit (Sterling et al., 1980), and whether or not life-cycle costing is used to determine the ability of a prospective home buyer to repay a loan (Patterson, 1978).

6.1.2. Moderately Important Issues

Issues of several different types fall into the moderately important category and will be listed below. For more detailed discussion of these issues, see Appendix A.

6.1.2.1. Issues Related to the Desire to Use Earth-Sheltered Residences

Two issues emerge as moderately important in this area. One is the issue of personal values, or more precisely how these are expressed in one's choice of a dwelling unit. This issue could be important in the

early stages of the adoption process but should diminish as the market matures (Roessner, 1982). The other issue is the closely related one of conformity to a socially accepted image, and how the desire to conform is translated into the decision to purchase a particular type of structure (Moreland, 1983).

6.1.2.2. Issues Related to the Construction of Earth-Sheltered Residences

Several issues of this type have moderate importance for the adoption and use of earth-sheltered residences. They include building regulations and their effects on allowable kinds of buildings; land use regulations; restrictive covenants; the availability of inexpensive designs and plans; innovation in the construction industry and its consequences in terms of the abilities of architects, builders, and developers; and the financing of construction loans, which may be resolved when permanent financing is widely available (Moreland, 1983).

6.1.2.3. Issues Related to the Use of Earth-Sheltered Residences

Of moderate importance here are the issues of resale when an owner's use of an earth-sheltered structure draws to a close; interior environmental quality, access and emergency egress from the structure; and energy use.

6.1.2.4. Issues Related to the Community-Wide Effects of Using Earth-Sheltered Residences

While these issues are only of moderate importance at this time in influencing the adoption and use of earth-sheltered structures, they can be very important in terms of their impact on society. Policymakers can elevate the current importance of these issues by predicating any support for earth-sheltering on the societal outcomes likely to result from the widespread utilization of this technology. Specific issues of importance include the effect of earth-sheltering on housing density within the community; potential impacts on urban form, neighborhood concept, and the image of the city; the energy implications of using

energy-efficient, earth-sheltered structures, possible changes in the existing building industry; and the societal impacts arising from any policy initiatives taken to encourage earth-sheltering. This last issue is of particular importance because of the direct role played by government policies in causing these impacts, which include the acceleration of the community-wide effects described previously, plus the possible encouragement of different rates of involvement and adoption among different segments of society.

6.1.3. Potential Issues for Non-Residential, Earth-Sheltered Structures

While the primary focus of this report is on issues associated with the adoption and use of earth-sheltered residences, a brief word is in order on those issues that may arise in conjunction with commercial, institutional, or other non-residential, earth-covered buildings. Those issues identified in our study as important for earth-covered residences were examined for their potential significance in the non-residential arena. The findings of this very preliminary analysis are presented below. Issues that did not arise in the course of our residence-focused study are not treated here, but further analysis is called for in order to identify any uniquely non-residential issues that may be expected to accompany that type of construction.

As in the residential sector, issues related to the desire to use earth-sheltered structures are expected to be most important in affecting the adoption and use of this type of building for non-residential purposes. Soundness of investment is likely to be the most critical consideration here, but aesthetics, comfort/livability, and possibly safety are also likely to be important.

Issues related to the ability to purchase earth-sheltered structures, among the most important in the residential sector, are expected to be much less significant for non-residential buildings. These issues are not likely to be at all important where only natural hazard mitigation and fallout protection are provided. Where a level of blast protection is provided comparable to that offered by crisis-upgradable residences, the issue of availability of mortgage money may then assume

moderate importance due to the higher construction costs that may be engendered by a need for additional materials and labor. Most of the other issues in this area are not expected to be relevant since there is currently a great deal of contractor, designer, and lender experience with massive concrete and steel construction for commercial, institutional, and other non-residential purposes.

Several issues related to community-wide effects of using earth-sheltered structures should be moderately important from a societal perspective. The issues of disaster protection and public access to earth-shelters in case of disaster should both be significant because of the potential for this type of building to provide public protection in times of crisis. Changes in the image of the city are also a possibility, but only if the designs of non-residential earth-shelters are substantially different from those currently used in this field. The impacts of any government policies on various segments of society must also be considered.

Issues related to construction are expected to be among the least important, with only the financing of construction loans and, less likely, the issues of building regulations and industry innovation showing any potential for significant impact. Also of minor importance are issues related to the use of earth-shelters. In this category, only emergency use and possibly resale are expected to be genuine issues.

6.2. ISSUES ASSOCIATED WITH THE ADOPTION AND USE OF CRISIS-UPGRADABLE EARTH-SHELTERED RESIDENCES

Crisis-upgradable, earth-sheltered structures are resistant to peacetime hazards without modification and can also be upgraded in a relatively short time to withstand a weapons-induced overpressure of one to two atmospheres. This section will deal with those institutional issues that are expected to be important in influencing the adoption and use of this type of structure. Virtually all of the issues identified as important in conjunction with hazard-mitigating earth-shelters will also be important here; however, only those issues that are significant in notably different ways or whose importance is unique to this area will be discussed below.

6.2.1 Most Important Issues

Table 7 lists those issues judged to be important relative to the adoption and use of crisis-upgradable earth-shelters. Five specific issues emerge as most important. Two of these are issues related to the desire to use earth-sheltered structures; one is an issue related to the ability to purchase this type of structure; and two are issues related to the use of earth-shelters.

6.2.1.1 Issues Related to the Desire to Use Earth-Sheltered Residences

Safety. This issue, particularly as it relates to fire safety and indoor air quality, has been mentioned over the years in the earth-shelter literature but was not identified by our panel of experts as being especially important in influencing a potential consumer's decision to buy a typical earth-covered residence. In the case of crisis-upgradable earth-shelters, however, the issue of safety in the event of nuclear war is likely to be a significant one to those individuals willing to spend extra for this type of structure. Still, the lack of importance attributed to safety by our experts indicates that this segment of the market may be relatively small.

Response to preparation for nuclear war. Because crisis-upgradable earth-sheltered residences are clearly designed to provide protection against the effects of nuclear war, an important issue for prospective adopters will be their response to preparation for such an eventuality. For some, the idea of planning for future safety in the event of war will stimulate a positive emotional response but, for many others, the direct connection between crisis-upgradable buildings and war is likely to stimulate an avoidance reaction to this type of structure.

6.2.1.2. Issue Related to the Ability to Purchase Earth-Sheltered Residences

This issue was discussed earlier as very important to the adoption of hazard-mitigating earth-shelters. It is expected to be even more important for crisis-upgradable structures because of the higher costs required for their construction.

TABLE 8. Important Institutional Issues Associated with the Adoption and Use of Crisis-Upgradable Earth-Sheltered Residences^a

MOST IMPORTANT ISSUES

Issues Related to the Desire to Use Earth-Sheltered Residences

- Safety
- Response to Preparation for Nuclear War

Issues Related to the Ability to Purchase Earth-Sheltered Residences

- Availability of Mortgage Money at Attractive Rates

Issues Related to the Use of Earth-Sheltered Residences

- Need for Access to Specialized Equipment (or Large Numbers of People) and Equipment to Allow Crisis Use
- Emergency Use of Earth-Sheltered Structures

MODERATELY IMPORTANT ISSUES

Issues Related to the Community-Wide Effects of Using Earth-Sheltered Residences

- Disaster Protection
 - Public Access to Earth-Sheltered Structures in Case of Disaster
 - Societal Impacts Arising from Policy Initiative to Stimulate Earth-Sheltering
-

^aThe issues identified here are expected to be important specifically because of the crisis-upgradable nature of the structures under consideration. Those issues identified in Table 3.2 as important in the adoption of more conventional earth-sheltered structures are likewise expected to be important here.

6.2.1.3 Issues Related to the Use of Earth-Sheltered Residences

In order to upgrade the kind of earth-sheltered structure described in Section 4 so that it will provide blast protection, substantial amounts of concrete and earth will have to be moved into position in front of the exposed south wall. This will require access to earth-moving equipment of the kind not generally kept by homeowners, or the availability of large numbers of strong people to move the materials by hand. Once crisis-upgrading is accomplished, additional materials (e.g., food, water, medical supplies, sewage facilities) will be needed to allow safe and effective use by the occupants. This issue is critical for crisis-upgradable structures because it directly affects the ability to use this type of building for its intended purpose in case of emergency.

6.2.2 Moderately Important Issues

Three issues, all of them related to the community-wide effects of using earth-sheltered structures, have been identified as moderately important in connection with the adoption and use of crisis-upgradable earth-sheltered residences. While of limited importance in influencing adoption and use, these issues can be very significant from a societal perspective. The issue of disaster protection can be significant because of the potential benefits resulting from the availability of crisis upgradable structures in times of emergency. The issue of public access to earth-shelters in case of disaster is important because of the likelihood that non-residents will seek shelter in this type of structure in the event of an impending crisis. Societal impacts arising from government policy initiatives to stimulate the use of such structures also deserves mention here. Because of the life-and-death implication of owning, or not owning, a crisis-upgradable unit in case of nuclear attack, any policies that have the effect of encouraging different levels of adoption by different socioeconomic groups would be difficult to justify.

6.3 ISSUES ASSOCIATED WITH THE DEVELOPMENT OF EARTH-SHELTERED NEIGHBORHOODS OR COMMUNITIES

Important issues associated with the development of entire earth-sheltered neighborhoods, subdivisions, or communities will include most of those issues identified in Section 6 plus a set of additional issues stemming from the unique circumstances associated with development at this scale. Those issues peculiar to earth-sheltered development of this magnitude are listed in Table 8 and discussed briefly below.

6.3.1 Most Important Issues

Nine issues are identified as being most important in affecting the adoption and use of earth-sheltered neighborhoods or communities. These fall into four separate categories: issues related to the desire to use earth-sheltered structures; issues related to the ability to purchase earth-shelters; issues related to the construction of such structures; and issues related to the community-wide effects of using them.

6.3.1.1. Issues Related to the Desire to Use Earth-Sheltered Residences

While the appearance of individual earth-sheltered buildings was discussed earlier as influencing the adoption of this type of structure, the issue of aesthetics on a neighborhood scale emerges as important when we shift our focus from single structures to entire subdivisions or communities. Not only is the appearance of the individual home under consideration likely to be of significance to a potential buyer, but the combined aesthetic appeal of all the houses and associated open spaces for an entire block or subdivision is likely to influence the decision to buy. The related subject of "neighborhood concept" and "changes in the image of the city" will be discussed later in this section under community-wide issues.

TABLE 9. Important Institutional Issues Associated with the Development of Earth-Sheltered Neighborhoods or Communities*

MOST IMPORTANT ISSUES

Issues Related to the Desire to Use Earth-Sheltered Residences

- Aesthetics

Issues Related to the Ability to Purchase Earth-Sheltered Residences

- Availability of Mortgage Money at Attractive Rates
- Ability of Earth-Sheltered Neighborhoods/Communities to Reduce Costs

Issues Related to the Construction of Earth-Sheltered Residences

- Financing of Construction Loans
- Difficulty in Building Neighborhood/Community as Planned

Issues Related to the Community-wide Effects of Using Earth-Sheltered Residences

- Housing Density
- Urban Form
- Neighborhood Concept
- Changes in the Image of the City

MODERATELY IMPORTANT ISSUES

Issues Related to the Construction of Earth-Sheltered Residences

- Land Use Regulations
 - Limited Experience of Planners and Regulators
-

^aThe issues identified here are expected to be important specifically because of the neighborhood/community scale of the development under consideration. Those issues identified in Table 3.2. as important in the adoption of individual earth-sheltered structures are likewise expected to be important here.

6.3.1.2 Issues Related to the Ability to Purchase Earth-Sheltered Residences

Availability of mortgage money at attractive rates. Once more this issue emerges as among the most important for adoption. It is mentioned here to point out that if an earth-sheltered structure is part of an entire neighborhood or community of similar structures, this is likely to be a factor in the decision of the lending institution reviewing the potential buyer's loan application.

Ability of earth-sheltered neighborhoods/communities to reduce costs. There are a number of ways in which building earth-sheltered dwellings at the neighborhood or community scale can help reduce total costs. Land costs per unit can be less than for more conventional units because of the potential for building at higher densities (Section 6.3.1.4). Construction costs can also be controlled when building at this scale by distributing management expenses and other fixed costs over a large number of units. In all these ways, the development of earth-sheltered buildings on a large scale can result in lower costs for potential consumers.

6.3.1.3 Issues Related to the Construction of Earth-Sheltered Residences

Financing of construction loans. Obtaining construction loans is extremely important for prospective builders and developers, yet financing may be difficult to arrange because of the financial community's current lack of experience with earth-sheltered buildings and neighborhoods (Sterling, Aiken, and Carmody, 1980). This issue is expected to be especially important at this scale because of the large amounts of money that will be needed to develop entire earth-sheltered subdivisions and communities.

Difficulty in building neighborhood/community as planned. Once the decision has been made to build on the neighborhood or community scale, a developer may still encounter problems in implementing his or her plan. The need for good south-facing slopes, where passive-solar elevational designs are used, may present difficulties, as might the need to protect

solar access on a large scale (Jaffee and Erley, 1979). Another potential problem arises where the developer sells lots to individual builders or owners wishing to construct their own residences. In such a case, there may be difficulties in assuring that earth-sheltered buildings compatible with the rest of the development are actually built.

6.3.1.4 Issues Related to the Community-Wide Effects of Using Earth-Sheltered Residences

The issues of housing density, urban form, neighborhood concept, and image of the city are considered extremely important at this scale of development for two reasons. First, when earth-sheltered structures are placed in entire neighborhoods or communities, these issues can play a significant role in influencing the desire of individual consumers to use this type of building. Secondly, the potential for community-wide impacts becomes much more obvious at this scale, so the argument for considering them important should be more compelling despite our original orientation toward issues affecting adoption and use.

Housing density. In practice, earth-sheltered dwellings have frequently been located on large lots in suburban or rural locations. In theory, however, earth-covered construction offers the possibility of placing dwelling units at higher-than-average residential densities in single-family and some kinds of multi-family developments without adverse community effects (Moreland, 1975, 1983). This is possible because of the greater visual privacy and sound insulation offered by earth-shelters, the fact that less surface space is required per unit, and the opportunity afforded by earth-covered structures for building on steep slopes (Thorsen and Rue, 1980) and other normally undesirable lots.

Urban form. In addition to allowing higher residential densities, the widespread use of earth-sheltered structures could also lead to other modifications in urban form. Because the greatest part of an earth-sheltered structure is located beneath the surface, the opportunity for multiple uses within the same development is much

greater with earth-sheltered than with conventional construction. Open space and residential uses can both be optimized (Sterling, Aiken, and Carmody, 1980; Wells, 1976), and historic structures can be preserved by placing new development underground (Fairhurst, 1976). Mixed land uses may be acceptable in earth-sheltered developments, because of the natural sound and site buffers provided. Finally, the higher densities allowed through earth-sheltering can encourage greater public use of mass transit and reduce the demand for local streets and highways (Barker, 1980).

Neighborhood concept. It has been suggested that the greater privacy afforded by earth-sheltered development can erode residents' "sense of neighborhood" by reducing visual contact between neighboring structures and lots. Opportunities for interaction and the ability to "keep an eye" on neighbors' properties can diminish. If the cohesion of neighborhoods does, in fact, decline, the importance of the town center may increase correspondingly to help fill residents' need for community. It can also be posited, however, that neighborliness could actually increase through the provision of common open areas atop houses and in yards that promote a stronger sense of shared neighborhood space.

Changes in the image of the city. Without the prominent house profiles associated with conventional aboveground construction, earth-sheltered communities may become less "imageable" (Lynch, 1960), presenting a weaker and less impressive image of the city for its occupants. On the other hand, it is also possible that the greater emphasis on natural contours and vegetation that is likely to accompany extensive earth-sheltered development could strengthen the city's image, particularly in areas with striking natural features that could be blunted by more conventional construction practices. At the same time, by burying our housing units, the visual announcement of status differentials among houses and neighborhoods may be reduced.

6.3.2 Moderately Important Issues

Two issues related to the construction of earth-sheltered residences are considered moderately important in terms of the development of earth-sheltered neighborhoods or communities. Land use regulations were mentioned earlier as a potential barrier to the construction of individual earth-sheltered structures, but they are cited again in this context because of the difference in scale. The second issue of interest is the limited experience of planners and regulators, particularly at this large scale, which can result in a lack of positive guidance to builders and developers and a limited willingness to approve this kind of development.

In this section we have discussed a broad range of important institutional issues associated with the adoption and use of earth-sheltered structures, focusing primarily on those issues influencing adoption and use but also pointing out the societal implications of earth-sheltering. In the next section, potential policy options will be examined that can be used to address the issues highlighted here.

7. POLICY OPTIONS FOR EARTH-SHELTERING

The identification and evaluation of policy options or instruments are conventionally guided by a number of critical factors including the goals, objectives, or desired outcomes of the sponsor, the feasibility of implementing the option, and the anticipated direct impacts of implementation. In the present case, where the generic goal is to encourage private sector adoption of earth-sheltered (ES) residence, an additional evaluative criterion is the ability of the option to enhance adoption. Following an elaboration on useful criteria for evaluating policy alternatives, this section sequentially identifies, evaluates and characterizes those policy options and associated implementation programs that appear to be most promising in terms of achieving the three component goals of an ES residence adoption program (i.e., encourage the private sector adoption of hazard-mitigating ES residences; encourage the private sector adoption of crisis-upgradable residences; and encourage the development of entire ES neighborhoods and communities).

7.1 CRITERIA FOR EVALUATING POLICY OPTIONS

Selection of appropriate policy options should be based on the simultaneous consideration of multiple criteria. One policy instrument might be favored solely in terms of one criterion but score poorly on other, equally important criteria; in such a case this policy option would not be nominated as one for further consideration unless feasible ways exist to mitigate or ameliorate its scoring poorly on the other criteria.

7.1.1 Institutional Issue or Barrier

As noted in the previous section there are a number of institutional issues that appear to present barriers of varying degrees of importance to the realization of the goals of an ES residence adoption program. Clearly it is important to select policy options that address

the most serious of these barriers to the adoption of ES residences. At the same time, care must be taken to ensure that a policy mechanism that may successfully address one barrier does not aggravate others. Although the key institutional issues have already been identified (see Section 6), it is important here to note that as we move from the most conservative to the most radical goal (i.e., from the adoption of hazard-mitigating ES residences to the development of ES neighborhoods or communities), the number of important or moderately important institutional issues or barriers increases substantially. In the former case, issues related to the desire to use ES residences and the ability to purchase ES residences are deemed most important; in the case of developing ES neighborhoods or communities, these issues are joined by issues related to the construction of ES neighborhoods and the community-wide effects of such development. It is also important to note that the range of important issues is extremely diverse, limiting the effectiveness of any single policy option. For instance, a single policy instrument cannot simultaneously ensure the availability of suitably trained and equipped contractors and guarantee the soundness of one's investment in ES residences. Both concerns need to be addressed but no single instrument is capable of resolving both issues.

The winnowing of institutional issues found in Section 6 helps in the identification and evaluation of policy options in a dual sense. It limits and prioritizes issues for which policy options need to be identified and, more importantly, it provides a substantive context for the design of policy options. Thus, in Sections 7.3 through 7.5 we concentrate our attention on policy options addressing the most important issues related to each of the three programmatic goals and do not identify policy options for less important issues.

7.1.2 Ability to Enhance Adoption

Since the generic goal is to enhance the adoption of ES residences it is important to develop policy instruments that meet this goal. Thus, the policy instruments should be sensitive to those features of

adoption and diffusion processes (noted in Section 5) that appear to be related to successful adoption:

- (1) early and comprehensive identification and segmentation of the the market;
- (2) use of existing information and communications networks appropriate to the different stages of the adoption process;
- (3) development of innovation supply capabilities or of the innovation delivery system;
- (4) development of policy initiatives and strategies that address specific institutional issues or barriers (see Section 7.2.1) in specific segments of the market at specific times in the adoption process; and
- (5) introduction and maintenance of ongoing evaluations of the success or failure of the policy instrument, to identify appropriate modifications.

While the diffusion literature at present offers no general models that can be used to guide the development of appropriate policy instruments for ES residence adoption (for the reasons identified in Section 5), the design of measures based on these five principles will strongly influence the potential success of any adoption program.

7.1.3 Feasibility of Policy Implementation

The eventual selection of policy instruments should also be constrained by the feasibility of their implementation. Recent research regarding policy implementation indicates that policy and program implementation is a very complex process with multiple opportunities for failure (Mazmanian and Sabatier, 1981; Mann, 1982, Ingram and Mann, 1980; Pressman and Wildavsky, 1973; Bardach, 1977; and Jones, 1975). This literature also identifies a fairly consistent set of variables explaining why implementation fails or succeeds. Mazmanian and Sabatier, for instance, specify three generic factors that affect implementation - the tractability of the problem; the ability of the

decision or other policy output to structure the implementation process favorably; and the effect of various political and economic variables on support for program objectives. Others concentrate on the importance of identifying, early on, all of the affected interests and their stakes and structuring the program or policy to take these interests into account, particularly if one or more of these interests can effectively veto or sabotage the entire effort (Lowi, 1975; Carnes, 1982). Yet other evaluation frameworks indicates that options should be based on factors such as cost, their administrative complexity, and their flexibility.

This literature in general, then, tells us that policy instruments should be selected on the basis of their ability to address tractable problems, demand the support of multiple and occasionally competing constituencies, and be cognizant of existing and projected dominant social, political, and economic values in society. They should enjoy the support of potential adopters and innovators (particularly within the innovation delivery system--contractors, lenders, developers, and regulators), and should address those segments of society most likely to innovate and lead others toward the adoption of ES residences.

7.1.4 Impacts of Implementing Policy Options

Policy options should also be selected on the basis of the indirect impacts of their implementation. If, for example, two policy instruments are likely to result in equivalent levels of ES residence adoption (i.e., the direct impact) and be equally feasible in terms of implementation, the option should be chosen that results in the most favorable and least unfavorable indirect impacts.

The kinds of indirect impacts that can result from policy or program implementation are varied. It is useful to categorize them according to the substance of the impact (e.g., economic, environmental, social and political), the recipient of the impact (e.g., geographic region, and class or group of individuals), and the expected time frame

of the impact (e.g., immediate, midterm, and long term). For instance, it has been suggested that policymakers should be sensitive to and evaluate the economic and institutional impacts of a major ES adoption initiative on the local building industry in various regions of the country. Some regions and their conventional housing industries might be better able to innovate and market ES residences than others, and some might be adversely impacted by such an initiative, leading to other economic and political problems (Morony, 1983). A tax credit policy option, to take another example, may implicitly target middle- and upper- middle-class individuals and families and lead to a perception by those less fortunate that they are expendable in time of natural hazard or man-made crisis, even if other elements of a comprehensive civil defense program attend to their protection; it may well be that differential perceptions of the quality of protection (e.g., being in a single-family residence rather than an institutional protective structure or being relocated) may lead to feelings of inequitable treatment and result in significant societal impacts.

7.1.5 Scoring by Panel of Experts

An important part of the research performed in this study involved an evaluation of various policy instruments by a panel of experts (see listing in Apperdix D). While these experts were not asked to evaluate these instruments in light of all of the criteria noted here, they were asked to identify those policy options that were the most likely to be successful in encouraging the adoption and use of ES housing. This evaluation served as a check upon our own evaluation and acted as an important input in our subsequent analyses.

7.1.6 Composite Scores of Policy Suitability

The foregoing criteria, taken together, provide a mechanism for evaluating a diverse range of policy options. Table 9 summarizes these

TABLE 10. Criteria for Evaluating ES Policy Options

Institutional Issues or Barrier Addresses

Most Important and Moderately Important Issues (See Tables 6-8)

Ability of Policy to Enhance Adoption

Degree of Market Segmentation
Use of Existing Networks
Development of Delivery System Infrastructure
Specificity of Issue or Barrier Addressed
Opportunity for Policy Revision

Feasibility of Policy Implementation

Tractability of the Problem
Ability to Structure Implementation
Compatibility with Existing Values and Practices
Stakeholder Groups/Implementing Groups
Implementation Complexity and Cost

Direct and Indirect Impacts of Policy Implementation

Substance of Policy Impact
Recipient of Policy Impact
Time Frame of Policy Impact

criteria. As can be seen, these criteria are often interactive. The conventional home building industry, for example, would likely be a key actor in the ES residence adoption process and would occupy a variety of roles. It is one of the most important segments of the existing infrastructure essential to the adoption process, particularly in terms of its ability to enter and sustain a position in the market; it certainly could be impacted differentially by alternative policy options; and it would undoubtedly play a key role in developing policy options and help to structure that policy's implementation.

The remainder of this section sequentially identifies and discusses those policy options that are judged to be most promising in terms of achieving the three component goals of an ES residence adoption program. These options have been culled from the original comprehensive listing of policy options evaluated by our expert panel (see Table 10). Further, for each programmatic goal, only those options that address the most important institutional issues or barrier (see Tables 6-8) are identified and discussed.

7.2 POLICIES TO ENHANCE ADOPTION OF HAZARD-MITIGATING EARTH-SHELTERED RESIDENCES

It has previously been noted that the most important institutional issues or barriers associated with the adoption of hazard-mitigating earth-sheltered residences are related to the desire to use and the ability to purchase such structures. More specific issues within these broad categories include the real or perceived livability and aesthetics of ES residences and the availability of sufficient mortgage money at attractive rates to allow potential buyers to adopt ES residences.

It was generally agreed by our panel of experts that, from among the lengthy list of potential policy options, education and financial incentives were the policy programs most likely to be successful in enhancing the adoption of ES residences. Within these two broad programs, specific instruments need to be developed that are compatible with the evaluative criteria previously established.

Table 11. Complete Listing Of Potential Policy Options
To Encourage the Adoption and Use of Earth-
Sheltered Residences

-
1. Educate all Sectors of Society about Earth-Sheltered Residences
 - a) Educate the public concerning the advantages of earth-sheltering (I)^a
 - b) Construct demonstration facilities for hands-on experience with earth-sheltered structures (I)
 - c) Educate builders concerning the competitive advantage offered by large-scale construction with minimum management costs and profits per unit (II,III)
 - d) Educate public in earth sheltered construction techniques in order to encourage owner-built structures and the reduction of front-end costs (III)
 - e) Educate financial community on advantages of earth-sheltering (III)
 - f) Develop public education programs on proper maintenance and ventilation (IV)
 - g) Compile and disseminate resale information (IV)
 - h) Disseminate information on the use and availability of earth-sheltered structures for disaster protection(V)
 - i) Educate local planning boards on advantages and organization of underground space (V)
 2. Enhance the Skills of Builders and Regulators in the Area of Earth-Sheltered Construction
 - a) Develop programs to retool builders and regulators (II)
 - b) Distribute "certified" builder training programs (III)
 3. Utilize the Taxing Power to Increase the Attractiveness of the Earth-Sheltered Option
 - a) Subsidize contractors through tax credits (II)
 - b) Encourage "do-it-yourself" construction through tax credits to individuals and/or builders (III)
 - c) Subsidize buyers through income tax credits (III)
 - d) Increase taxes on conventional fuels (IV)
 - e) Pass preferential property tax rates (IV)

^aNumbers in parentheses indicate the Institutional Issues which the policy options addresss, where I is the desire to use ES structures, II is related to the construction of ES structures, III is the ability to purchase ES structures, IV is the use of ES structures, and V is the community-wide effects of using ES structures.

Table 11 (continued)

-
4. Promote the Development of Building Standards and Regulations that will Encourage the Further Use of Earth-Sheltering
 - a) Establish earth-shelter safety and comfort standards (I)
 - b) Extend model building codes and HUD Minimum Property Standards (II)
 - c) Develop licensing requirements for builders and trainers (II)
 - d) Promulgate stringent energy-use standards for all structures (V)

 5. Promote Land Use Planning and Regulation that will Encourage Earth-Sheltering
 - a) Create model earth-sheltered land use controls (II)
 - b) Develop and disseminate model solar access protection measures (IV)
 - c) Encourage community designs that optimize neighborhood cohesiveness (IV)
 - d) Encourage inclusion of underground space in community development plans (V)
 - e) Develop model plans for earth-sheltered neighborhoods (V)
 - f) Encourage greater urban density (V)
 - g) Pass stricter environmental controls for above-ground buildings (V)
 - h) Require Environmental Impact Statement for large development projects (V)

 6. Use the Direct Expenditure of Government Funds to Stimulate the Increased Use of Earth-Sheltered Residences
 - a) Build government facilities, including public housing, on ES basis (I,V)
 - b) Build earth-sheltered residences for sale or lease to private users (II)
 - c) Purchase materials in bulk for resale to individual builders in order to minimize cost (III)
 - d) Provide direct subsidies for occupants agreeing to share their earth-sheltered dwellings in case of emergency (V)
 - e) Provide grants to communities for useful facilities that would double as shelters (V)

 7. Increase the Amount of Money Available for Loans on Earth-Sheltered Residences at Attractive Rates
 - a) Provide low-interest, assumable loans to promote resale (I & III)
 - b) Expand loan insurance programs (III)
 - c) Provide construction loans (II)
 - d) Establish loan insurance programs for construction loans (II)
 - e) Encourage purchase of earth-sheltered mortgages on secondary market (III)

Table 11 (continued)

-
8. Assure the Availability of Attractive Insurance Policies for Earth-Sheltered Residences
 - a) Provide insurance to cover construction-period liability (II)
 - b) Encourage preferential insurance policies for building owners (IV)
 9. Assure the Availability of Building Materials, Techniques, and Plans for High-Quality, Cost-Effective Earth-Sheltered Residences
 - a) Aid developers in design refinements (I)
 - b) Sponsor research and development to facilitate earth-sheltered construction (II)
 - c) Develop and disseminate proven standardized plans for earth-sheltered structures (II & III)
-

7.2.1 Education

There was general agreement that many segments of the public need to be educated about ES residences before any expeditious, effective, and efficient penetration of the market can occur. These include the general public as the nominal consumers and, equally important, members of those institutions that affect the provision or supply of housing - builders, planners, the financial community, and real estate firms, among others.

To the extent that consumers, or potential consumers, are even aware of ES housing, they are believed to be most concerned about the livability and aesthetics of ES housing as well as the soundness of an investment in such unconventional housing. Moreover, they appear to be relatively unaware of limited existing policies permitting or encouraging the purchase of ES housing, such as the Department of Housing and Urban Development's (HUD's) instruction to field offices to look for ways to approve earth-sheltered structures rather than to turn them down (Morony, 1982).

Educating the public about the livability and aesthetics of unconventional housing, such as ES, will not be easy. One of our experts noted that consumers need to see, to feel, and to get hands-on experience before they will be convinced that ES housing is suitable for them (Thomas, 1982). Thomas recommended support for demonstration homes at events such as state fairs where tours and visits would impart first-hand experience with ES housing. In addition to such demonstrations, plans of existing ES homes that are livable and aesthetically pleasing might be disseminated through existing networks (e.g., home builders associations, real estate firms and associations), and other plans might be developed and tested for eventual dissemination (e.g., Tennessee Valley Authority's "Solar Homes for the Valley". It is important in this case to develop plans that would be attractive to those segments of the market most likely to innovate - the young and well-educated who are fairly well off but who are also likely to have limited investment capital. Some of our experts noted that educating potential customers about

the hazard-mitigating features of an ES house might actually have an adverse effect in terms of enhancing adoption, presumably because of the negative connotations some people may have about taking positive action to mitigate the effects of disasters, both natural and man-made (Courville, 1982; Roessner, 1982; Sterling, 1982). It should be noted that the dissemination of such information might be useful in some regions that are prone to particular types of disasters (e.g., tornadoes in the Midwest), as an element of an overall education program, however, such information may be counterproductive.

Educating the public regarding the soundness of an investment in ES housing is also likely to be difficult. While a national ES housing loan data bank (Sterling, 1982) would be somewhat useful in this regard, there is a good chance that consumers will be more sensitive to ES housing activity in their particular region. They may require assurance that their homes will be marketable to others like them in their area and may not be convinced by the marketability of ES housing in other regions. Local and regional ES housing loan data banks, including information on loans, house sales, resales, appraisals, and time on the market might help to alleviate the concerns of potential consumers regarding the soundness of an investment in ES housing. Such programs might be modeled on the existing efforts at the University of Minnesota's Underground Space Center.

In addition to educating the potential consumer, it is important to educate persons in the relevant infrastructure. Our panel of experts generally agreed that the financial community, architects, builders and developers, planners, appraisers, and real estate firms need to be educated about ES housing and how its development would affect and could be affected by their institutions and actions. It should be acknowledged that governmental leverage over these institutions is somewhat limited. In the interest of using existing institutional networks, perhaps they should develop their own education programs with technical assistance, where needed, from appropriate governmental agencies (e.g., HUD, the Department of Energy, and FEMA). Builders, for instance, might wish to support such programs so that their efforts have a better chance

of being productive in terms of actual sales. The financial community might educate its loan officers about ES housing attributes normally omitted from the loan decision-making process, such as energy costs and, in the current case, the hazard-mitigating (and thus, cost-avoidance) elements of ES construction.

Educational programs are relatively easy to design and implement. Although there is not a likely role for state and local governments (Mosen, 1982), both the federal government and trade associations have a stake in enhanced adoption and have substantial experience with education programs to influence consumer decisions. Targeting such programs toward the home buying public and toward the supply infrastructure would likely be more productive than a generalized nationwide publicity campaign. Such programs would include providing sufficient demonstration units to allow hands-on experience for those perceiving earth-shelters as dank, dark, and depressing ("like caves") and disseminating plans of aesthetically pleasing and livable ES houses and information related to the existing and projected costs and resale opportunities of ES houses. Plans might be developed and tested for ES homes of variable cost and size so that, in spite of higher initial first costs, they might be available to a broader segment of the home buying public. The direct and indirect impacts of educational programs are likely to be relatively benign. While the direct impacts of education, taken alone, may not be substantial in terms of enhancing adoption, adoption is not likely to work without education. The most significant indirect impacts are likely to be twofold: the opportunity costs of such a program and the potential perception held by nonadopters that the allocation of government funds for such a program is unwise at best and discriminatory at worst. In the latter case, it would be especially important to demonstrate that the federal government has active programs for protecting non-ES residence adopters from the ravages of natural hazards. Education programs could be implemented in a relatively short time period (3-6 months) and have long as well as short-term effects.

7.2.2. Financial Incentives

There was also general agreement among our experts that, given the high costs of ES housing and the depressed condition of the home building and buying industry, it is important to provide financial incentives for consumers and the supply infrastructures to invest in ES housing. Specific policy instruments include the provision of income tax credits and/or deductions for consumers, low interest assumable loans for consumers, construction loans, loan insurance programs and purchase of ES mortgages on the secondary markets.

Tax credits or deductions are the most obvious incentives and already exist at the federal level for active solar and conservation (Energy Tax Act of 1978, P.L. 95-618) and in some states for diverse applications. This option clearly addresses a major institutional barrier, is relatively easy to administer as a generic policy instrument, and, depending on its size, could result in substantial adoption of ES housing. Tax credits or deductions have the further advantage of targeting the exact audience under consideration, the home buyer, whose aggregate actions could lead to increased demands for ES housing. It might also be expected that a tax credit or deduction would lead to the development of a more active infrastructure that would advertise the availability of the tax credit or deduction and promote increased demand.

One possible problem with the use of tax credits or deductions is the determination of what expenditures should properly qualify. Should they include all of the incremental costs of earth sheltering or merely the incremental costs of providing hazard-mitigating elements to the earth-sheltered residence? Once a general policy is made with respect to that issue, it would be necessary to determine how specific criteria should be established and who should establish them. For instance, should there be regional variation for the criteria (i.e., the federal government would probably not wish to induce the adoption of tornado-resistant ES homes that are potentially dangerous in flood-prone areas)? State and local governments, however, might be able to resolve

this regional variation problem through more site-specific tax credit or deduction programs. What absolute maximum credit or deduction might be allowed so as to optimize penetration and not, at the same time, appear to reward some socioeconomic groups at the expense of others?

An additional potential problem with the use of tax credits or deductions is that it would reduce governmental revenues at a time of significant budget deficits. This factor, alone, might make a tax credit an unlikely or infeasible policy option at this time.

Loan programs have traditionally not worked as effectively as credits or deductions in enhancing adoption (R'UPI, 1977), but they may hold a greater attraction for ES home market penetration under current conditions. Although earth-sheltered buildings are specifically included as a solar energy system qualifying for the loan program set up under the Solar Energy and Energy Conservation Act of 1980 (P.L. 96-294), current authorizations and appropriations by Congress are substantially below those initially authorized for appropriation. The Department of Housing and Urban Development, which administers the Solar Energy and Energy Conservation Bank, made \$30.4 million available in financial assistance throughout the country for FY 1983, compared with the \$1.025 billion authorized by Congress for this year in 1980. Equally important, under the original law, loans for solar energy systems applications, including earth-sheltering, were to constitute a minority of total program expenditures (i.e., 33 percent in FY 1981; 24 percent in FY 1982; and 22 percent in FY 1983). In short, if a new loan program were to be established for ES residences it would likely require more significant funding than currently exists, a stronger presence in the Solar Energy and Energy Conservation Bank, or both.

Prior experience indicates that loans are expensive to administer for relatively low-cost items; in the case of more expensive purchases such as ES homes the per unit cost of the loan should be less and would make the loan option more attractive. As with tax credits or deductions, it would still be necessary to determine what proportion of the costs would be available for the subsidized loan and to design a loan program that would be equitable in its impacts. In the latter case it

might be possible to tailor loans for particular size and cost of unit, including smaller, low-cost homes, to avoid or minimize the equity problem.

Another financial incentive might be the provision of loan money to the home building and construction industries. This option would be targeted more tightly, and yet cost savings could be passed on to the eventual consumer. Moreover, it would be possible to stipulate that loans would be made for a specified number of homes of predetermined size and cost. In short, construction loans could facilitate the development of an important part of the infrastructure, could be structured to achieve predetermined objectives (e.g., penetrate particular segments of the overall and regional markets), and could be relatively easily refined as the effectiveness of the option is demonstrated or as new objectives emerge. The obvious disadvantage of construction loans is the appearance of pork barrel for a particular industry, even when the benefits might actually accrue throughout society.

Finally, financial incentives might be offered through government-financed loan insurance programs, like VA, FHA, and FMHA, and secondary mortgage market programs such as FNMA and FHLMC. Already, the FHA has instructed field offices to encourage ES housing (Morony, 1982). Such "instructions" may be perceived as inforce and for greater ES penetration may require the implementation of quantitative goals, quotas, or other incentives. In the secondary mortgage market, FNMA has no policy on ES structures, per se, but there is a concern with their appraisal and marketability in case of foreclosure. The federal charter of FNMA requires that all mortgages purchased be generally acceptable on the commercial mortgage market (Burshein, 1982). FHLMC, also a federally-chartered private corporation with responsibility to its stockholders, cannot change its basic policies without explicit changes in its charter. Amendments to existing charters or their interpretation for secondary mortgage market entities may be needed to allow preferential treatment to emerging technologies such as earth-sheltering or the establishment of a specific secondary market entity within the Solar

Energy and Energy Conservation Bank (Reiger, 1981). One of the chief disadvantages with changes in the federal governments' loan insurance and secondary mortgage market institutions is the opportunity cost associated with such a change, particularly in a tight loan market; special programs for earth-sheltering could draw money away from other needy areas such as low-income family assistance or urban housing programs. Special programs favoring earth-sheltered home loans would also be difficult to implement for some of the agencies, such as FNMA which purchases its mortgages in an auction process.

7.3 POLICIES TO ENHANCE ADOPTION OF CRISIS-UPGRADABLE, EARTH-SHELTERED RESIDENCES

The education and financial incentives policy options identified for enhancing the adoption of hazard-mitigating ES residences are also applicable, with some modification, for crisis-upgradable ES residences. There are some additional options, however, that may be necessary to respond to the most important institutional issues or barriers for crisis-upgradable ES residences as identified in Sect. 6.3, especially those issues related to the crisis-upgrading process and the emergency use of ES residences during times of crisis.

Many of the same kinds of educational programs and policies identified in Sect. 7.2.1 are applicable for crisis-upgradable ES residences. As in the case of hazard-mitigating elements of ES structures, some of our experts noted that educating the public about the benefits of crisis-upgradable ES residences in the event of a man-made disaster (e.g., nuclear war) could have a chilling effect on the market and reduce rather than enhance the adoption of such structures (Sterling, 1982; Roessner, 1982; Courville, 1982). Given the nationwide demand for protection against nuclear war and the geographic constraints on ES residences generally and crisis-upgradable ES residences in particular (Morony, 1982), educating the public about crisis-upgradable ES residences could be problematic from an equity

perspective unless those constrained from using the ES option are informed about equivalent protective actions being taken in their regard. Educating the homeowner about how to share his residence with strangers as well as neighbors would be particularly difficult.

Financial incentives will be particularly important for the adoption of crisis-upgradable ES residences, because of their substantial incremental cost. Many of the same instruments identified as potentially useful for hazard-mitigating ES residences may be appropriate here, with the same caveats. Equity concerns are again most problematic and would require substantial attention during the design of the policy option. For that reason, carefully designed and regulated loans to the construction industry may be the most successful of the financial incentives options.

It will also be important to develop policy instruments to guarantee access to resources both for the crisis-upgrading process itself and for the effective use of crisis-upgradable residences during the time of crisis. Although it is likely beyond the scope of the federal government to make such guarantees, it could play a significant role in assisting state and local governments in their efforts to make such guarantees.

The crisis-upgrading process, as currently characterized, would require the emplacement of some additional columns and lintels within the structure and the movement of materials (e.g., earth and concrete) to protect areas exposed to potential blast. The procurement and storage of columns and lintels, the storage and maintenance of earth-moving equipment and gasoline for emergency use, and/or the assignment of municipal staff to move earth manually during time of emergency may well be within the emergency powers of state and local governments. The ability of local governments, however, to absorb such planning, capital, and operating costs may not exist uniformly. The federal and state governments might offer technical and financial assistance to local governments embarking on such ventures.

The provision of resources for the effective use of crisis-upgradable residences in the event of crisis may be even more problematic. Resources that would be necessary minimally include food, water, sewage, and medical supplies. Procuring, storing, and maintaining resources over potentially long periods of time and transporting them to ES residences at the time of crisis is clearly beyond the responsibility of the homeowner and, given substantial deployment of ES housing, could be beyond the fiscal and institutional capabilities of local governments. Again, the federal government might provide technical and financial assistance (e.g., in the form of bulk procurement of food and medical supplies passed on to local governments) while leaving the design and implementation of actual resource delivery systems to local governments.

7.4 POLICIES TO ENHANCE THE DEVELOPMENT OF EARTH-SHELTERED NEIGHBORHOODS AND COMMUNITIES

Education and financial incentives may also be important policy options to encourage the development of ES neighborhoods and communities. It may also be important to alter land use regulations and ordinances to allow greater housing density than is normally the case.

Educational programs would likely address the aesthetics of earth-sheltered neighborhoods and communities and would deal with the issues of urban form, neighborhood and the image of the city. Since little information on such large-scale development currently exists, it would be important to design, test, and disseminate plans for such developments (Sterling, 1982). The development of such a program would not be easy and straightforward; it would have to validate the possibility of demand for such a development and characterize that demand in terms of likely ownership patterns, regional location, and housing mix. Working through existing design centers such as the University of Minnesota's Underground Space Center or Oklahoma State University's School of Architecture and with existing infrastructure, the federal government might sponsor a demonstration prototype that would both educate and allow for ongoing institutional research (Lambright, 1982). This option might, however, be identified with

pork barrel and should, thus, likely be awarded on a competitive basis. It is also possible that if such a prototype is associated with disaster protection and is seen as benefitting a relatively privileged segment of society, charges of inequity might be made.

Financial incentives are also important for the development of ES neighborhoods and communities, but in different ways than for the other two programmatic goals. The risk in this case is much greater for the builder/developer and potentially somewhat less for the individual homebuyer. The cost of an individual unit could be somewhat less in a neighborhood or community development project for reasons of economies of scale and, potentially, less land area per unit (assuming the permission of greater housing density). For builders and developers (and the financial community), the costs and risks are greater absent a guaranteed demand for the units. For this reason it may be particularly important to target loan money toward those institutions involved in construction of the ES development. Given the higher cost of ES housing, it may still be important to make mortgage money available at attractive rates to individual consumers through government - subsidized and guaranteed loans.

One of the premises of an ES neighborhood or community may be the ability of the builder and developer to site a greater number of units per acre than is allowed by existing regulation. Revision of this regulation by local governments may be justified on the grounds of the greater land use efficiency of earth-sheltering. While wholesale revisions of land use regulations are no. easy to obtain and may, in fact, be perceived as a threat by many vested interests in a locale, applications for earth-sheltered planned unit developments (PUD's) may be acceptable in many areas if they are professionally developed and are sensitive to local inputs.

7.5 SUMMARY

The foregoing discussion has identified and briefly evaluated a number of options to encourage the adoption of hazard-mitigating and crisis-upgradable ES residences and the development of ES neighborhoods or communities. This evaluation, based on a consideration of several

generic criteria (i.e., institutional issue addressed, ability to enhance adoption, feasibility of implementation, and policy impacts) and the results of a survey of a panel of experts, indicates that education and financial incentives are the policy options most likely to lead to increased adoption of ES residences. It has been suggested that the design of particular policy instruments should be guided by cognizant institutions and that special attention should be paid to equity considerations, particularly with respect to potential disaster protection. The policy options outlined in this section require additional specification and analysis so that their feasibility and effectiveness can be better anticipated. The next section addresses what kinds of public and private sector groups would likely be involved in implementing these various options.

8. MAJOR ACTORS IN POLICY IMPLEMENTATION

In order to ensure effective implementation of public policies to encourage earth-sheltering, it is important for any agency or organization taking the lead role in this endeavor to identify all the major actors to be involved and to achieve willing and active participation by these parties. The identification of major actors and their involvement in the implementation process should be initiated as early as possible, preferably during the policy development stage when general parties at interest become apparent but before specific policy measures have been chosen. It is expected that all levels of government as well as the private sector can make significant contributions to the policy design and implementation processes, but special attention is given to the federal role because of the broad range of powers available at this level. Assuming the federal government chooses to play a lead role as policy initiator, the cooperation of other major actors can be ensured by convincing them that the encouragement of increased use of earth-sheltered residences will be mutually advantageous, by providing incentives such as subsidies to make their participation more attractive, by promulgating rules and regulations to mandate their involvement, or by some combination of these. In the remainder of this section, the potential role of each major actor in implementing the most promising policy options identified in Chapter 4 (e.g., education and financial incentives) will be discussed.

8.1 FEDERAL ROLE

The role of the federal government in stimulating the adoption and use of earth-sheltered residences is potentially very important. In terms of subject matter, federal interest in the areas of housing, energy, and public safety are well established. In terms of power to act, the federal establishment has the authority and the means (though the latter are becoming increasingly strained) to directly provide



educational services and financial assistance to prospective earth-sheltered consumers and suppliers. Federal agencies also have a great deal of leverage to influence the actions taken by state and local governments as well as by the private sector. This ability to guide the activities of others is particularly important in light of admonitions in the earth-sheltered literature to utilize existing networks and institutions, where possible, that are appropriate to the different stages of the adoption process. Finally the federal government is in a strong position to monitor the societal implications of various policies and see that inequitable outcomes are avoided.

In the field of education, federal agencies can build demonstration units, both on an individual and possibly a block or small subdivision scale, to help familiarize the home-buying public and the building industry with this technology. The federal government can also fund the development and testing of plans for such buildings and communities and disseminate this information, directly or through existing private sector networks of marketing, trade, and professional associations. Assistance to developers, lenders, and other important segments of the "supply-side" infrastructure can also be proffered. A national earth-sheltered loan/data bank can be established, or financial and technical assistance provided to establish a number of such entities at the state or regional level. To enhance the potential of earth-sheltered structures for use in time of crisis, aid can be given to local governments to allow these units of government to assist earth-sheltered occupants with crisis-upgrading and shelter usage, if needed.

Turning to financial incentives, the federal establishment is once more well-equipped to act. The federal level is the most appropriate for the provision of income tax credits and deductions, although massive deficits make this option less feasible at this time than may have been the case in previous years. Loan assistance to potential consumers can be provided through a well-funded Solar Energy and Energy Conservation Bank or similar institution but, once more, budgetary constraints may

inhibit the immediate use of this option. Construction and development loans, very important both for individual residences and larger scale developments, could also be backed by the federal government although, again, better fiscal conditions are probably a necessary pre-condition. Private sector financing can be stimulated through a concerted federal effort to tailor the policies of federal loan insurance programs and secondary mortgage market entities to favor loans on earth-sheltered residences. To help adopters of crisis-upgradable residences use their unit optimally in the event of crisis, federal agencies could offer financial assistance to local governments that would then provide the necessary support, such as the provision of earth-movers.

8.2 STATE ROLE

Much fewer resources, both financial and technical, are available at this level for the implementation of policies aimed at increasing the use of earth-sheltered structures. The states do generally have a good understanding, though, of housing needs and building conditions within the state.

One promising state educational action would be to establish a state loan/data bank at the statewide or sub-state level to inform potential buyers, builders, and lenders concerning the soundness of an earth-sheltered investment. Other possibilities include the development of plans for earth-sheltered houses, the actual construction of demonstration units, and the provision of technical assistance to local governments on crisis-upgrading and shelter use, but these may require resources that are currently beyond the means of many state governments.

In the area of financial assistance, those states with a personal income tax can provide credits for purchasers of earth-sheltered residences, but the fiscal drawbacks cited earlier for the federal government would be at least as germane here. A more likely state activity is to disseminate federal money provided by the Solar Energy

and Energy Conservation Bank as currently structured, but the amounts available are currently too small to have a wide-spread effect. A final state role may be to use the familiarity with its own territory to help the federal government determine where to target federal assistance programs.

8.3 LOCAL GOVERNMENT ROLE

Local government agents traditionally deal with builders and developers directly in such matters as the issuance of building permits and the review of conformity with various land use regulations. Because of this ongoing contact, local officials have a good understanding of the needs of local developers and a unique opportunity to informally educate the building industry concerning the advantages of earth-sheltering and how one can go about entering the field. Local governments may also have the opportunity to encourage the shared use of earth-sheltered houses during crises through more focused local education programs.

The ability to provide direct financial assistance is extremely limited among local governments, but these units can channel federal resources that will allow crisis-upgrading and crisis-use by the occupants of earth-sheltered structures. As with the state, local governments can also use their unique knowledge of their own jurisdictions to help the federal government determine where, and at what level of funding, other financial assistance programs are needed.

8.4 PRIVATE SECTOR ROLE

Like the federal government, the private sector is expected to play an extremely significant role in stimulating the adoption and use of earth-sheltered structures. Major actors of importance in this sector include builders and developers, architects and designers, building suppliers, financial institutions, real estate firms and appraisers, and trade and professional associations. The importance of these players,

who together compose the building supply-side infrastructure, stems from their crucial role in providing those structures demanded by the public. In order to change the type of building which these actors design, finance, and erect, new ways of doing business will have to be communicated to this complex network. This can be accomplished by government policies and programs which attempt to have an impact on crucial behaviors, as discussed above, as well as by the efforts of key actors changing things from within, which is the focus of this section. In the area of education, the private sector shares a dominant role with the federal government. Earlier, it was suggested that the private sector can use its internal communication networks to disseminate information produced at the federal level. In addition, the major private sector trade and professional associations can develop their own materials on earth-sheltered specifications, advantages, and "how-tos" targeted at their own peers as well as the home-buying public. The ongoing educational efforts of these groups - like conferences, workshop, publications, and building shows - are ideally suited for the distribution of such informational materials to the appropriate audiences. Demonstration units could also be provided as a "hands-on" educational aid.

The primary private sector actors in the provision of financial incentives are expected to be lending institutions and private mortgage insurers and secondary mortgage buyers. Lending institutions are capable, if properly motivated, of making large amounts of money available for earth-sheltered loans to builders and home-buyers, either by developing new formulas to determine borrower eligibility that take energy costs into account or by simply establishing preferential approval policies for this type of loan. In order for this to occur, however, lenders will have to be strongly convinced of the profitability of these transactions, possibly through the provision of government subsidies. As for private mortgage purchasers and loan insurers, their endorsement of earth-sheltered residences would be helpful but pursuing this is not likely to be as fruitful as focusing on large government loan insurers like FHA or federally chartered, secondary mortgage market entities like FNMA.

From the foregoing discussion, the important role of both the federal government and the private sector in stimulating the adoption and use of earth-sheltered residences becomes apparent. Further narrowing and refinement by interested agencies of the policy options discussed here and an in-depth examination of similar efforts is required to allow final identification of the specific actors needed and their individual roles. The last section will summarize the most important issues and options presented in this report and will briefly discuss those steps that can be taken by government entities interested in policy selection and implementation.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 TECHNICAL CONSIDERATIONS

Earth-sheltered housing, which has become popular in recent years for energy conservation, offers the potential for the production of a great deal of fallout shelter space. During prosperous years, the housing industry may construct as many as two million units. If these were earth-sheltered structures of average size, at the present standard of 10 square feet per space, each unit could provide on the order of 100 fallout shelter spaces. In theory, at least, space for the entire population of the United States could be constructed each year. Even a small fraction of this potential, realized year after year for several years, could make a very significant addition to the nation's inventory of fallout protection.

Earth-sheltered structures with earth-covered roofs give fallout protection greatly superior to conventional frame dwellings and superior to the basements of frame dwellings. With relatively inexpensive modifications and careful attention to the design, earth-sheltered residences can provide very high-grade fallout protection over much of their floor area. With design modifications, they provide very high protection from a very wide variety of natural disasters.

For some additional expense, an earth-sheltered residence can be modified at no loss of floor area or function to be upgradable in a few days to resist one to two atmospheres of blast overpressure. Carrying out this operation in a crisis involves the movement of many tons of earth, but much less than for conventional structures. Either excavation equipment or a large labor force would be required.

Many examples of very attractive earth-sheltered residences exist. It has been amply demonstrated that they can be designed and constructed to have very pleasing interior environments and exterior appearance.

Given general acceptance of the concept, not now established, the largest problem preventing widespread adoption of earth-sheltered housing is that it costs from 20-40% more than comparable aboveground,

conventional frame housing. This cost can be partially offset by the energy savings inherent in good earth-sheltered housing design. Properly designed, such homes can save 20-60% of the energy used even by well-designed frame houses. The energy costs make the life-cycle cost of earth-sheltered residences more nearly competitive with conventional frame construction. The life-cycle cost of a home is forcefully apparent to the owner in his combined monthly mortgage payment and utility bills.

Housing developments of earth-sheltered, single-family residences offer the potential of reduced lot sizes and, hence, reduced land costs over what would be required for aboveground construction. In high-cost suburban areas, the saving in land cost may amount to a significant fraction of the total cost of the home.

Recent very high mortgage rates (14-16%) have amplified the effect of the cost disadvantage of earth-sheltered housing on the relative monthly costs. A decline of mortgage rates to more traditional levels would ameliorate this disadvantage.

Modern technologies of concrete construction, particularly the use of reusable, modular, metal concrete forms and portable scaffolding, can further erode the cost disadvantage of earth-sheltered structures. The materials cost of a concrete structure is not markedly different from that of a frame structure. Much of the extra cost is the labor and materials in the single-use, custom wood forming, which is comparable to the labor and materials required for frame construction.

9.2 INSTITUTIONAL CONSIDERATIONS

The identification of policy options to realize the hazard-mitigation potential of earth-sheltered structures has relied on the conjunction of diverse literatures, including diffusion of innovation, policy implementation, earth-sheltering and impact assessment. It has further depended on an identification and evaluation of institutional issues of barriers viewed by a panel of experts as most problematic to the adoption and use of earth-sheltered structures. Following a summary

of these issues and those policy options appearing to offer the most promise for the rapid diffusion of earth-sheltered structures, a brief outline of a potential implementation analysis process is offered.

9.2.1 Most Important Institutional Issues

In Chapter 6 a number of important issues were identified in conjunction with the adoption and use of hazard-mitigating earth-sheltered structures and crisis-upgradable earth-shelters, and the development of entire earth-sheltered neighborhoods or communities. Those issues with the greatest likelihood of having a substantial effect on adoption and use at this time and requiring a timely response to stimulate utilization were classified as "most important." Other issues, while significant for adoption and use, are expected to have less of an immediate effect and require less intervention and were labelled "moderately important." Our prioritization of issues reflects this study's primary focus on those issues influencing the adoption and use of earth-sheltered structures as opposed to those societal issues resulting from such adoption.

From this perspective, the most important issues associated with hazard-mitigating earth-shelters fall into two categories, issues related to the desire to use those structures and issues related to the ability to purchase them. In the first category, the issues of livability, aesthetics, and soundness of investment are most crucial; in the second, the critical issues are the availability of suitable trained and equipped contractors and the availability of mortgage money at attractive rates. Moderately important issues are much more numerous, numbering eighteen in all from four of our five major categories (See Table 3.2), and include the issues of conformity to a socially accepted image, innovation in the construction industry, financing of construction loans, access to (and egress from) the structure, and societal impacts arising from policy initiatives taken to stimulate earth-sheltering.

The most important issues associated with crisis-upgradable earth-sheltered structures, in addition to those identified above and (which also apply here), fall into three basic categories. Vital issues related to the desire to use this type of structure relate to safety and the response to preparations for nuclear war. The availability of mortgage money is the one critical issue from among those related to the ability to purchase. Under issues related to the use of these structures, the need for access to specialized equipment (or large numbers of people) to allow crisis use is singled out, as is the issue of emergency use. There are also two moderately important issues both related to the community-wide effects of using crisis-upgradable earth-sheltered structures.

Turning to those issues associated with the development of earth-sheltered neighborhoods or communities, a total of nine are identified as most important. Under issues related to the desire to use earth-sheltered structures, neighborhood aesthetics is extremely significant. The availability of mortgage money and the ability of earth-sheltered neighborhoods and communities to reduce costs are both critical issues related to the purchase of earth-shelters. The most important issues related to construction are two, the financing of construction loans and the difficulty in building an entire neighborhood or community as planned. Finally, there are four vital issues related to the community-wide effects of the adoption of earth-sheltered structures; these are the issues of housing density, urban form, neighborhood concept, and changes in the image of the city. Moderately important issues are those of land use regulations and the limited experience of planners and regulators, both related to the construction of earth-sheltered buildings.

It should be noted again that the preceding prioritization of issues reflects a strong interest in those factors that can influence adoption and use. From a societal perspective, however, issues stemming from the widespread adoption of earth-sheltered structures and from those policy initiatives taken to encourage it may be substantially more important than indicated here.

9.2.2 Most Promising Policy Options

From the comprehensive list of policy options considered initially (see Table 4.2), a number of specific policy options have been identified as offering the most promise for addressing the goals of an earth-sheltered structure adoption program. This selection was based on an evaluation by a panel of experts and on the option's ability to score favorably on a number of evaluative criteria.

Education and financial incentives appear to be the most promising policy options for each of the component goals. Educational programs may need to be targeted to potential adopters (i.e., home buyers) and to critical elements in the infrastructure (e.g., the financial community, builders and developers, appraisers, and real estate firms). The substance of the educational programs may vary somewhat, depending on which goal is being addressed, but common elements might include verification of the livability and aesthetics of hazard-mitigating, earth-sheltered structures and information regarding financial considerations, including the existing availability of loan money and resale opportunities. Such a program might include the development, validation and dissemination of housing plans, the dissemination of financial information, and actual demonstrations of such facilities for those potential adopters requiring personal experience with earth-sheltered structures.

Among the financial incentives considered, tax credits or deductions, low-interest, assumable loans, and construction loans are considered to be the most viable options. Among these, construction loans might be favored in terms of ease of administration. It will be important to ensure that, whatever financial incentives are selected, these policies do not inequitably impact different population segments. This is particularly the case when the program deals with the provision of protection from potential natural or man-made hazards or crises.

For crisis-upgradable structures it may also be important to assist in the provision of resources for upgrading (e.g., materials, equipment, labor) and for the use of such structures in the event of crisis (e.g., food, water, and medical supplies). While local governments might

assume the lead responsibility for planning and implementing the provision of such resources, the federal and state governments might assist through bulk procurement policies.

Finally, in addition to education and financial incentives for the development of earth-sheltered neighborhoods and communities, it may be useful for local governments to revise existing land use regulations to allow greater housing density. This would allow reductions in unit cost and an enhanced ability to develop integrated community or neighborhood housing plans.

9.3 FUTURE RESEARCH NEEDS

9.3.1 Technical Requirements

9.3.1.1 Hazard Mitigating Design Development

This study has explored only one design of a hazard-mitigating earth-sheltered residence. Other designs and floor plans should be developed. In particular, an earth-sheltered structure of the atrium type should be studied for crisis-upgrading potential.

The all-important factor of cost reduction needs further work. Designs tailored for the use of reusable modular forms should be developed.

9.3.1.2 Field Test of Hazard-Mitigating Features

Crisis-upgradable designs should be field-tested in DNA-sponsored blast tests. In particular, means to protect the exposed wall in elevational designs must be tested. Other areas of uncertainty are egress closures, especially in the skylites, and ventilation intakes.

9.3.1.3 Cooperative Test Building

Practical experience with actual construction of hazard-mitigating designs must be acquired. Real-world problems with cost, and getting a contractor to produce a satisfactory structure with some unconventional features at an acceptable price must be experienced. The experience

might be acquired at lowest cost to the government through cooperative agreement with a prospective home owner who wants a hazard-mitigating or crisis-upgradable earth-sheltered residence. An agreement might be sought where in exchange for plans and advice, the owner would permit photo-documentation of construction and share cost information. Ideally, this activity should be continuing and iterative, with problems encountered in one design addressed in the next.

9.3.1.4 Earth-Sheltered Housing Development

There is an almost total lack of experience with earth-sheltered communities or housing developments in the United States. It would be very desirable to find out if the cost savings posited for earth-sheltered communities through serial production and higher housing density can be achieved.

9.3.2 Policy Implementation Analysis

It seems clear that definite opportunities exist to enhance the adoption and use of hazard-mitigating, earth-sheltered housing. Prior to the formal enunciation and implementation of such policies, however, it is important to analyse potential policy options in considerably greater detail than was allowed in this effort. Such an analysis would permit a careful structuring of the implementation process and increase the probability of favorable and intended program impacts. An implementation analysis would address and resolve a number of concerns, each of which is dealt with briefly below.

9.3.2.1 Selection of Policy Options

The ultimate selection of policy options should be guided by the following considerations:

Final specification and clarification of program goals. Successful implementation depends substantially on the particular goals and objectives that are meant to be achieved. What are the relative

priorities of an earth-shelter adoption program--to saving energy, conserving land, or mitigating the impacts of potential disasters?

Identification of target audience. What is the target audience and where do they reside? Regional deployment objectives and their scale would be critical to the final design of educational or financial incentive policy options. These objectives are clearly policy questions (i.e., beyond the scope of objective analysis) that must be factored in the formulation of policy options.

Cost benefit analysis of potential options. The options presented in this analysis could be implemented at varying costs, depending on the scale of the objective to be achieved. A detailed cost analysis of the options, accompanied by projections of potential market penetration, would facilitate the final design of policy options.

Policy impact mitigation analysis. If cost-effective policies result in the introduction of significant unintended adverse effects, it may be possible to design cost-effective ways to mitigate these effects.

Consider other options. Other non-earth-sheltered and/or non-residential earth-sheltered policy options may address and achieve policy objectives more effectively, efficiently and expeditiously. Roessner (1982), Morony (1982), Mosen (1982), Sterling (1982), and Labs (1982) all had some questions regarding the goals of a hazard-or crisis-mitigating, residential, earth-shelter structure adoption program, particularly with respect to its ability to yield significant protection in a cost or socially productive fashion. Some felt that earth-sheltered commercial or institutional buildings would offer greater protection more easily than residential applications; others favored relocation over sheltering as a general, crisis-mitigating strategy. In short, the effectiveness of an earth-sheltered residential option needs to be compared with other options, including a mix of residential with commercial and institutional.

Selection of specific programs. Whatever policies are ultimately selected, specific programs will need to be designed so that a structured implementation can occur. These programs would likely have multiple components, each achieving some part of the overall policy objective.

9.3.2.2 Refinement of Chosen Policies

Once a preferred policy or set of policies is chosen and a preliminary identification of specific programs to allow implementation is made, a process of refinement is likely to be required. Based on past experiences with the implementation of similar policies, a thorough examination of the institutional realities involved, and a good measure of creative thinking, detailed programs appropriate to the case at hand should be designed. In order to maximize the feasibility of the measures that are ultimately designed, this design process should be carried out by the lead agency in close consultation with those actors identified as most likely to be involved in implementation.

9.3.2.3 Final Identification of Major Actors

Once policies and detailed programs to encourage the adoption and use of earth-sheltered structures are developed, a final identification can be made of those actors best equipped to manage different aspects of implementation. A preliminary listing of potential actors would be made much earlier, but at this later time sufficient program details should be available to allow a final choice of all major participants. As with the previous tasks, this task should be completed through an examination of past experience with similar situations and an analysis of the current institutional and organization milieu.

9.3.2.4 Identification of Necessary Resources for Implementation

With a detailed understanding of the specific policies and programs to be implemented and the cast of actors responsible, the lead agency can identify those resources that will be required to accomplish the

desired goals. Necessary commitments of staff, time, money, and materials must all be known, to the extent possible, in order to assure that the desired policy measures can be carried out as planned.

Performance of the implementation analysis described above could be expected to greatly enhance chances for successful implementation of policies intended to increase the adoption and use of earth-sheltered structures. Although the various stages of the proposed analysis are presented sequentially, it is expected that it will actually be carried out in an iterative fashion, with the information received from each step used to update the findings from others and to allow mid-course corrections as the likely effects of various policy decisions become apparent. With an effective analysis leading to well-planned and carefully implemented policies and programs, a substantial step will have been taken toward increasing the rate of adoption and use of earth-sheltered structures in a manner that would maximize the benefits of this technology and minimize any adverse consequences.

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EVALUATION: A valuable update of an important work, for both homeowner and architect.

Chalmers, L. S., Jones, J. A., Homes in the Earth [1980.] Design Concept Associates. \$9.95
KEYWORDS: Earth-Sheltered; Underground; Designs; Design Concept Associates.
ABSTRACT: A compendium of earth-sheltered housing (40 examples). Authors give readers permission to use the designs under their own responsibility.
EVALUATION: Excellent drawings.

Wells, M., Underground Designs. 87 pages. [1977
KEYWORDS: Design; Site; Codes; Waterproofing; Insulation.
ABSTRACT: Plans and 170 illustration of 18 of Wells' underground designs.

I. BOOKS

E. Public Policy

1. Earth Sheltered Communities

Sterling, R.L., Carmody, Elnicky, G., "Architerra"
Earth-Sheltered Community Design [1981.] Underground
Space Center, Univ. of Minn.

2. Market Penetration

Brown, L.A., Innovative Diffusion: A New Perspective [1981.] Methuen

Hough, G.W., Technology Diffusion: Federal Programs and
Procedures [1975.] Mt. Airy: Lomond Books

Rogers, E.M., Shoemaker, P., Communication of Innovation [1971.] New York: Free Press

Zaltman, G., Duncan, R. Holbeck, J., Innovations and
Organizations [1973.] New York: John Wiley

3. Policy Implementation

Bardach, E., The Implementation Game [1977.] Cambridge,
MA: MIT Press

Carnes, S.A., "Confronting Complexity and Uncertainty:
Implementation of Hazard Waste Management Policy"
Environmental Policy Implementation [1982.] Lexington,
MA: Lexington Books

Ingram, H.M., Mann, D.E., Why Policies Succeed and Fail [1980.] Beverly Hills, CA: Sage Publications

Lowi, T., Ginsberg, E., et al, Poliscide [1975.] New York:
Macmillan Publishing Co, Inc.

Mann, D.E., Ed., Environmental Policy Implementation [1982.] Lexington, MA: Lexington Books

Mazmanian, D.A., Sabatier, P.A., Effective Policy
Implementation [1981.] Lexington, MA: Lexington Books

Pressman, J., Wildavsky, A., Implementation [1973.]
Berkeley: Univ of California Press

Reiger, A.J., "The Solar Bank: A New Energy Incentive"
Incentives to Stimulate Solar Energy Use - A Proceeding of
the Second Seattle Workshop [1981.] Pacific Northwest
Laboratory

I. BOOKS

E. Public Policy

4. Impact Assessment

-----, Federal Incentives for Solar Homes: An
Assessment of Program Options [1977.] Cambridge, MA:
BUPFI, Inc.

Finsterbusch, K., Wolf, C.P., eds, Methodology of Social
Impact Assessment [1977.] Stroudsburg, PA: Dowden,
Butchinson and Ross

Lynch,, The Image of the City [1960.] Cambridge, MA:
The MIT Press

I. BOOKS

F. General Treatment

....., Earth Sheltered Residential Design Manual. [1981..] HUD/Underground Space Center, Univ. Minn.
KEYWORDS: Design; Construction.

Baum, G.T., Boer, A.J., MacIntosh, J.C.Jr., Earth Shelter Handbook. 224 pages. [1980.] Tri/Arch. Associates, Milwaukee: Tech/Data Publications (\$12.95)
KEYWORDS: Design; Sketches; Environmental Impact; Codes; Expansive Clay; Structure.
ABSTRACT: A primer for the do-it-yourselfer in earth sheltered houses. Oriented toward the Great Lakes region.
EVALUATION: Primer basically for the "Do-It-Yourself" types.

Campbell, S., Underground House Book. 208 pages. [1980.] Garden Way Publishing Co., Charlotte, VI., \$9.95.
KEYWORDS: Design; Site Development; Cost; Loans; Waterproofing; Insulation.
ABSTRACT: A guide for do-it-yourselfers. Chapter topics include land, financing, site development, heat, interior decoration. Many drawings and diagram are included.
EVALUATION: Good general guide for novices.

Frenette, E. R., Holthusen, T. L., ed., Earth Sheltering: The Form of Energy and the Energy of Form. Pergamon Press, \$35, paperback. Lib. Cong. CC NO 81-8643 245 pages. [1981.] Underground Space Association
KEYWORDS: Design Competition; Residential; Commercial; Research.
ABSTRACT: Design drawings of 51 examples of earth-sheltered designs submitted to the 1981 American Underground Space Association's design competition. There were 14 awards in 4 categories - single family, non-residential, multifamily and research.
EVALUATION: Gives a fair view of present state of the art as seen by professors of architecture.

Jones, C.O., Clean Air [1975.] Pittsburgh: Univ. of Pittsburgh Press

Lane, Anderson., Builders Manual on Earth Sheltered Construction. [1982..] Concrete Construction Publications.
KEYWORDS: Design; Construction.

Scalise, J.W., Earth Integrated Architecture. 300 pages. [1975.] College of Architecture, Univ. of Ariz, Tempe, AZ.
KEYWORDS: Design.
ABSTRACT: A workbook. Consists of designs from student research and design projects on earth integrated architecture. Emphasis on southwest climate.

I. BOOKS

F. General Treatment

Scott, R. G., How to Build Your Own Underground Home: A Complete Guide to Planning, Designing, Building and Living Comfortably in a Geothermic Home. TAB Books, Blue Ridge Summit, PA. 256 pages. [1979

KEYWORDS: Do-It-Yourself; Design; Evaluation.

Stauffer, T., Underground Utilization: A Reference Manual of Selected Works in 8 Volumes. [1978..] Dept. of Geosciences, Univ. of Mo, Kansas City, MO., \$52.50

KEYWORDS: Design; Construction.

ABSTRACT: A combination of many reprinted and new articles on all aspects of underground construction.

Sterling, R. Editor., Earth Sheltered Housing Design: Guidelines, Examples and References. 310 pages. [1978.] Underground Space Center, Univ. of Minn \$11.00

KEYWORDS: Earth Sheltered; Underground; Design; Energy Conservation; Insulation; Waterproofing; Code Requirements; Zoning.

ABSTRACT: A definitive exploration of all facets of earth sheltered-housing, design and construction. The report is intended to assist people in the layout and design of earth-sheltered houses and covers public policy issues like codes, zoning and finance. Plans and sections of 20 earth-sheltered houses are included.

EVALUATION: The most significant single contribution to the literature of earth-sheltered housing during the 70's.

II. Technical Reports.

A. Construction Practice

1. Site Development

Means, R.E., Soil Investigation for Building Foundations. Publication No. 94. [1955.] Oklahoma Engineering Experiment Station, OSU, Stillwater, OK.
KEYWORDS: Site Development.

2. Structural Design

....., Manual for the Construction of Residential Basements in Non-coastal Flood Environs. HUD, Federal Insurance Administration.
KEYWORDS: Basements; Design; Insulation; Waterproofing.

Means, R.E., Parcher, J.V., Foundations for Small Houses in Oklahoma. Publication No. 99. [1958.] Oklahoma Engineering Experiment Station, OSU, Stillwater, OK.
KEYWORDS: Design; Foundation.

Spears, R. E., Constructing Earth Sheltered Housing with Concrete. 36 pages. [Undated.] Portland Cement Association, Building Div.
Sponsored by: U.S. Department of Housing and Urban Development. (Contract H-S 235)
KEYWORDS: Concrete; Design.

3. Cost

Mixel, G., "Energy and Construction Costs of Earth Sheltering." [1981.] Setter, Leach and Linstrom, Inc./Underground Space Center. Univ. of Minnesota.

Shapira, H. B., Cristy, G. A., Bright, S. E., Yost, M. B., "Cost and Energy Comparison Study of Above and Belowground Dwellings" OBNL/CON-91 [Feb. 1983.] Oak Ridge National Laboratory

II. Technical Reports.

B. Hazard Mitigation

1. Structural Design

Foyer, L.L. Ed., "Building Design for Environmental Hazards." Multiprotection Design Manual. Vol. IV. [Dec. 1973.] Defense Civil Preparedness Agency (DCPA)
Sponsored by: DCPA/DOD, Washington, D.C.

Cristy, G. A., Expedient Shelter Survey, Final Report - CRNL-4860 250 pages. [July, 1973.] Oak Ridge National Laboratory
Sponsored by: Atomic Energy Commission
KEYWORDS: Expedient Shelter

Cristy, G. A., Kearny, C. H., Expedient Shelter Handbook. CRNL-4941 300 pages. [Aug. 1974.] Oak Ridge National Laboratory
Sponsored by: Energy Research and Development Agency (ERDA)
KEYWORDS: Expedient Shelter

House, C., Architectural Design Techniques for Fallout Protection and Energy Conservation TR-86 [Sept. 1978.] Howard University, School of Architecture and Planning.
Sponsored by: DCPA/DOD
KEYWORDS: Design; Fallout; Energy Conservation.

Kimel, W.B. (Ed.), Radiation Shielding TR-40 [Nov. 1966.] Kansas State University, Manhattan, KS.
Sponsored by: OCD/DOD, Washington, D.C.
KEYWORDS: Shielding; Fallout.

Kummer, R.E., Sprankle, R.B., Multiprotection Design - Wind, Ground Motions, Environmental. TR-20, Vol. 6 [Dec. 1973..] Defense Civil Preparedness Agency (DCPA)
Sponsored by: DCPA/DOD, Washington, D.C.
KEYWORDS: Design; Protective Construction; Wind; Earthquake; Environment.

Moreland Associates, Earth Covered Buildings: An Exploratory Analysis for Energy and Hazard Performance. 286 pages. [1981
Sponsored by: Federal Emergency Management Agency (FEMA)
KEYWORDS: Earth Covered Buildings; Hazard Mitigation; Economics.

Ward, D. B., Building Design for Radiation Shielding and Thermal Efficiency. TR-85 44 pages. [Dec 1977.] Defense Civil Preparedness Agency (DCPA)
Sponsored by: DCPA
KEYWORDS: Fallout; Shielding; Energy conservation; Design.

II. Technical Reports.

B. Hazard Mitigation

1. Structural Design (CONTINUED)

Wright, R., Kramer, S., Culver, C. (Eds.), Building Practices for Disaster Mitigation BSS46 [Feb. 1973.] National Bureau of Standards, Washington, D.C.

KEYWORDS: Disaster Mitigation; Building Practices

2. Upgrading Techniques

Tansley, R. S., Bernard, R. D., Shelter Upgrading Manual: Key Workers Shelter 127 pages. [May 1981.] Scientific Services Inc.. (SSI)

Sponsored by: Federal Emergency Management Agency (FEMA)

KEYWORDS: Key Workers; Upgrade; Expedient

ABSTRACT: One of a series being developed to support CRP. Manual is intended for planners and plant personnel in risk areas. Presents methodology for evaluating basement areas and expedient shelters. Tables and charts for closing and shoring small openings. Format is looseleaf. Expedient shelters considered: buried tanks, rail cars, storm drains, concrete utility vaults, fiberglass cylinders.

EVALUATION: Pretty sketchy but a reasonable first cut.

Tansley, R. S., Gabrielsen, B. L., Cugner, C. J., Upgrading of Existing Structures. Phase III. Shelter Design Options. [May 1981.] Scientific Services, Inc. (SSI)

Sponsored by: Federal Emergency Management Agency (FEMA)

KEYWORDS: Upgrading; CRP; Failure Prediction.

ABSTRACT: Results of an investigation of blast upgrading of existing shelters by developing failure prediction methodologies for various structure types and verifying these by full-scale load tests. Upgrading schemes designed for use in support of CRP. Structure types included: wood, steel, and concrete floor and roof systems. A program summary includes charts and data for design.

EVALUATION: Fairly thorough but some structures were not tested.

3. Civil Defense

....., Fallout Radiation Shielding TR-20 (Vol. I) [June, 1976

Sponsored by: DCPA/DOD, Washington, D.C.

KEYWORDS: Fallout Shelter; Radiation Shielding; Civil Defense; Design

II. Technical Reports.
 B. Hazard Mitigation

3. Civil Defense
 (CONTINUED)

....., Domestic Nuclear Shelters. Technical Guidance. A Home Office Guide. [1981.] Home Office (U.K.)

KEYWORDS: Design; Classification Strategy; Supplies; Permanent; Improvised

ABSTRACT: Comprehensive guide for shelter planning and design. Sections on effects of nuclear weapons, design requirements, shelter strategy and supplies. designs for permanent and for improvised shelters.

EVALUATION: Very good

-----, Protective Construction TR-39 [Aug. 1981.] Federal Emergency Management Agency (FEMA), Washington, D. C.

KEYWORDS: Civil Defense; Protection

Randall, P.A., "Damage to Conventional and Special Types of Residences Exposed to Nuclear Effects" Operation Teapot Project 31.1 WT 1194 [1961.] Civil Effects Test Group, USAEC

Sponsored by: Housing and Home Financing Agency; Federal Civil Defense Agency

II. Technical Reports.

C. Energy Related

1. Heat Transfer

Dill, R. S., Robinson, W. C., Robinson, H. E., Measurement of Heat Losses from Slab Floors. RMS 103 National Bureau of Standards, Washington, D.C.
KEYWORDS: Heat Transfer; Insulation.

Kersten, M. S., Thermal Properties of Soil. Vol. LII No. 21 94 pages. [June 1, 1949.] Minnesota Engineering Experiment Station.
KEYWORDS: Heat Transfer; Insulation.

Kusuda, T., Earth Temperatures Beneath Five Different Surfaces. National Bureau of Standards Report 10313. [Feb. 1971.]
KEYWORDS: Ground Temperatures.

2. Insulation

Claesson, J., Eftring, B., Optimal Thermal Insulation and Ground Heat Losses. Report by Lund Institute of Technology. [Aug 1979.] Dept. of Mathematical Physics, Lund, Sweden
KEYWORDS: Insulation; Heat Transfer

Kaplar, C. W., Studies of Moisture Effects on Thermal Conductivity of Rigid Insulation. CRREL International Report No. 207 [1969..] U.S. Army CRREL, Hanover, N.Y.
KEYWORDS: Insulation; Moisture.

Schaefer, D., Water Absorption of Insulation in Protected Membrane Roofing Systems. CRREL Technical Note. [Jan. 1974..] U.S. Army CRREL, Hanover, N.Y.
KEYWORDS: Insulation; Moisture; Roofing.

3. Passive Solar

Labs, K., Regional Analysis of Ground and Aboveground Climate for Architectural Design. [1981.] Sponsored by: Oak Ridge National Lab/ DOE Innovative Structures Program.
KEYWORDS: Microclimate; Temperature; Regions.

II. Technical Reports.

D. Psychological and/or Physiological

1. Daylighting

....., How to Predict Interior Daylight Illumination.. [Undated.] Libbey-Owens-Ford Company, Toledo, Ohio.
KEYWORDS: Daylighting; Predicting.

Collins, B.I., Windows and People: A Literature Survey; Psychological Reaction to Environments with and without Windows. BSS 70. Vol. 70 [June 1975.] National Bureau of Standards, Washington, D.C.
KEYWORDS: Daylighting; Psychological Factors.

Hopkinson, R.G., Architectural Physics: Lighting. [1963.] HMSO, London.
KEYWORDS: Daylighting.

2. Acceptability

-----, Potential Use of Underground Space. Vol. 1 75 pages. [Feb. 1975.] Dept of Civil and Mineral Engineering, Univ. of Minn.
Sponsored by: University of Minnesota.
KEYWORDS: Underground Space; Use.

-----, Preliminary Design Information for Underground Space Vol.2 [Aug. 1975.] Department of Civil and Mineral Engineering, Univ. of Minn.
Sponsored by: University of Minnesota.
KEYWORDS: Design; Underground Space.

Bergman, M., The Potential for Underground Industrial, Commercial and Storage Facilities in Minnesota. 183 pages. [Undated.] Underground Space Center, Univ. of Minn.
KEYWORDS: Underground Storage; Underground Commercial; Use.

Lutz, F. W., Lynch, P. D., Lutz, S. B., ABO Revisited: An Evaluation of the ABO Elementary School and Fallout Shelter. pp 1-30. [June, 1972.] Defense Civil Preparedness Agency (DCPA)
Sponsored by: DCPA
KEYWORDS: School; Evaluation; Psychological Effects; New Mexico.

ABSTRACT: The first underground school in the world was opened in 1963 at Artesia, New Mexico. The effects of operating underground for a period of nine years were studied. The conclusions were that there had been no detrimental effects on students or teachers. The underground school was somewhat more costly to light and cool than aboveground schools but was better lighted and cooled. It was less costly to heat.
EVALUATION: Very good.

II. Technical Reports.

D. Psychological and/or Physiological

2. Acceptability (CONTINUED)

Robinette, G.O., Plants, People, and Environmental Quality.
[1972.] U.S. Dept of Interior, National Park Service,
Wash, D.C.
KEYWORDS: Landscaping; Site Development.

3. Public Policy.

....., Legal, Economic, and Energy Considerations in the
Use of Underground Space. NSF/RA/S-74-002 [Sept.
1974..] U.S. National Committee on Tunneling Technology.
Sponsored by: National Science Foundation.
KEYWORDS: Public Policy; Legal Issues; Economic Issues;
Energy.

Ferry, L.G., Bronfman, L.M., "Research on Noneconomic
Factors Relevant to the Diffusion of Solar Total Energy
Systems" ORNL/TM-7297 [1980.] Oak Ridge National
Laboratory

Carnes, S.A., Copenhaver, E.D., Reed, J.H., et al,
"Incentives and the Siting of Radioactive Waste Facilities"
ORNL-5880 [August, 1982.] Oak Ridge National Laboratory

Jaffee, H., Erby, D., Protecting Solar Access for
Residential Development: A Guidebook for Planning Officials
[1979.] Washington, D.C.: U.S. Government Printing Office

Sterling, R., Aiken, R., Carnody, J., Earth Sheltered
Housing: Code, Zoning, and Financing Issues. [April
1980.] Univ. of Minn. Underground Space Center.
Sponsored by: U.S. Dept of Housing and Urban Development.
KEYWORDS: Public Policy; Building Codes; Zoning; Financing.

4. Financing.

....., Earth Sheltered Home Financing: An Introduction
for Lenders and Appraisers. ORNL/SUB-70513V-2 [Sept.
1981 (Draft).] Oak Ridge National Lab.
Sponsored by: U.S. Dept of Energy.
KEYWORDS: Public Policy; Financing; Lenders; Appraisers.

II. Technical Reports.

E. Examples

1. Experience

Boyer, L. I., Grondzik, W. T., Human Comfort and Energy Conservation in Earth Sheltered Buildings. [1980.] Architectural Extension, Okla. State Univ., Stillwater, OK.
KEYWORDS: Earth Coupling; Energy conservation.

Grondzik, W. T., Johnston, T. L., Boyer, L. I., Monitoring of Earth Sheltered Residences in Okla., Project Report. [1981
Sponsored by: Control Data Corporation
KEYWORDS: Ground Coupling; Monitoring

II. Technical Reports.

F. General Treatment

....., Design and Analysis of Earth Integrated Buildings.
[1981.] Architectural Extension, OSU, Stillwater, OK.

KEYWORDS: Design; Analysis

ABSTRACT: A Technical Seminar Workbook.

Eligh, T. P., "Building Underground" Building Systems
Design 22 pages. [Oct/Nov, 1976

KEYWORDS: Energy Saving; Communities; Designs

ABSTRACT: Underground and earth-covered construction offers significant opportunity for saving energy, reducing building costs and preserving land values. These methods lend themselves to mass production techniques without endless repetition and can effect energy savings of 75% or more.

Labs, K., The Architectural Use of Underground Spaces:
Issues and Applications. 160 pages. [1975.]

Thesis (M.Arch.), Washington University, St. Louis, MO.

KEYWORDS: Design, Issues; History.

ABSTRACT: The thesis discusses the advent of underground architecture. It covers potential implications of underground design practice, issue in design and use of underground, specific problems related to structure, regional suitability, environment, and landscaping.

COMMENT: Also available from Ken Labs., 147 Livingston St.
New Haven CT. 06511

III. Articles and Papers.

A. Construction Practice.

1. Innovative Techniques.

....., "Advertisement." Earth Sheltered Digest and Energy Report. No. 18 [Nov/Dec, 1981.] U. S. Gypsum Metal Products Division

KEYWORDS: Products; "Bernold"; Concrete Forms; Gunitite.
 ABSTRACT: The "Bernold" system forms the shell and serves as permanent reinforcement. Combines punched and formed steel with Shotcrete or Gunitite. Produced by U.S.Gypsum Metal Products Division.
 EVALUATION: Good.

....., "Precast Gives Glimpse of Future." Earth Sheltered Digest and Energy Report. No. 17 pp 46-47. [Sept/Oct, 1981

KEYWORDS: Techniques; Precast Concrete; Economics; Prefab Modules.
 ABSTRACT: David Iash's masters thesis at Mass. Inst. of Tech. "Opportunities and Limitations for the Use of Precast Concrete in Earth Sheltered Housing", deals with "Industrialization of Earth Sheltering". He gives perspective to the precast industry. Includes a post WWII history of housing in Europe and America.
 EVALUATION: Worth reading

-----, "My Mother's House - The Walls Go Up" Mother Earth News Vol. 70 pp 106-108. [July/Aug 1981

-----, "Collaborative Learns Building Skills" Earth Shelter Living pp 4-5. [Sept/Oct 1982

Iunde, M.R., "Precast Would Make Good Walls." Earth Sheltered Digest & Energy Report. pp 16-17. [1981
 KEYWORDS: Precast Components; Roofs; Walls.
 ABSTRACT: Redesign of a residence for a Minnesota Energy Agency grant required careful analysis of cost effectiveness, energy impact and on-site coordination difficulties. The material of choice for roofs in the Minnesota area is precast concrete. A significant market for precast basement and underground walls exists but there are no suppliers.

Nelson, J., "Tilt-up Done On Site" Earth Sheltered Digest and Energy Report. No. 18 pp 6-9. [Nov/Dec, 1981
 KEYWORDS: Techniques; Tilt-up; Nebraska.
 ABSTRACT: Procedure for tilt-up method is explained in detail. A crane is required to lift the panels after they have cured but all other work can be done manually. Costs not reported. Builder is James Nelson of River City Builders.
 EVALUATION: Very informative.

III. Articles and Papers.

A. Construction Practice.

2. Site Development.

Elifrits, C. D., Augenbaugh, N. B., "Geotechnical Aspects of Site Selection and Evaluation for Earth-Sheltered Type Housing." Proceedings Underground Space Conference and Exposition, Kansas City, MO [June 1981
KEYWORDS: Structural Problems; Soils

Jones, D. E., JR., "The Expansive Soil Problem" Underground Space Vol. 3 No. 5 [Mar/Apr, 1979
KEYWORDS: Structural Problems; Expansive Soil

Wirth, T. E., "Landscape Architecture Above Buildings." Underground Space Vol. 1 [1977.] Underground Space Association. / Pergamon Press
KEYWORDS: landscape.

3. Waterproofing.

....., "Soil Considerations in Subgrade Waterproofing." Building Research. [Nov/Dec 1964
KEYWORDS: Soil; Site Development.

Lane, C. A., "Waterproofing Earth Sheltered Homes." Fine Homebuilding. [April/May 1981.] Taunton Press, Newtown CT.
KEYWORDS: Waterproofing

McGroarty, B. M., "Waterproofing." Earth Sheltered Digest & Energy Report. Vol. 10 No. 13 [1980-1981
KEYWORDS: Waterproofing.

4. Structural Design.

Bunker, D., "Designed For Deep Texas" Rodales New Shelter pp 27-30. [Jan 1982
KEYWORDS: Case study; Frank Moreland; Decatur, TX.; North-facing; Poured Concrete.
ABSTRACT: House designed by Moreland has poured concrete shell, 10-in.-thick walls. Roof is precast, prestressed 8-in. concrete planks, topped by another poured layer. Roof has 3 in. of rigid high-density polystyrene insulation covered by 3 ft of earth. The house faces north to give better cooling. A 2-ton heat pump provides both heating and cooling. Cost of 2176-sq-ft house was \$120,000 (\$55/sq-ft) including Italian tile.
EVALUATION: Example of use of north-facing windows.

III. Articles and Papers.

A. Construction Practice.

4. Structural Design.

(CONTINUED)

Metz, D., "Heavy Loads" Rodale's New Shelter [Jan 1982.] Rodale Press

KEYWORDS: Roof Design; Concrete Footings; Polystyrene, Urethane; Thermal Breaks.

ABSTRACT: Technical discussion of structural problems and various solutions. Problems include concrete, footings, walls, and insulation. Compares reinforced concrete walls with concrete block walls, poured in place concrete slab roofs with precast concrete plank roofs and heavy timber roofs. Cost and performance of urethanes, extruded polystyrenes, and expanded polystyrenes are compared. "Heat bleeding" and the need for thermal breaks are discussed.

EVALUATION: Very informative.

5. Cost.

....., "Study Shows Lower Energy and Construction Costs from Earth-Sheltering." Underground Space. pp 197-198. [Jan/Feb 1981.

KEYWORDS: Computer Model; Life-cycle Cost; Construction Costs.

ABSTRACT: A study performed by an architectural firm assisted by the Underground Space Center at Univ. of Minn. based on computer models, found construction costs for bermed structures to be less than for conventional buildings but costs for fully buried structures were higher than conventional. The study claims that the payback for bermed structures is immediate for all climates but that the additional cost for fully covered structures was not justified in the milder climates.

....., "Resales Set Market Values." Earth Shelter Digest & Energy Report. pp 37-38. [May-June, 1981

KEYWORDS: Cost; Value; Resale; Commercial.

Jones, L. S., "Non-traditional Military Uses of Underground Space." Underground Space Vol. 2 No. 3 pp 153-158. [April, 1978

KEYWORDS: Military Uses; Medical Facilities; Storage; Quarters; Cost.

ABSTRACT: Underground construction can be very advantageous to military establishments for such things as storage facilities of all kinds, medical facilities, and even housing for administration and quarters. Initial costs estimated about 11% above surface construction. Life cycle costs are comparable to aboveground structures.

EVALUATION: Good discussion of uses of underground structures.

III. Articles and Papers.

A. Construction Practice.

5. Cost.

(CONTINUED)

Lane, C.A., "An Essay - Frequently asked Questions on earth-sheltered Housing." Underground Space. Vol. 4 No. 3 [1979.] Underground Space Center, Univ. of Minn.
KEYWORDS: Waterproofing

Lunde, M.R., "Thermal and Earth Covered Roof Costs Compared." Earth Sheltered Digest and Energy Report No. 18 pp 18-20. [Nov/Dec., 1981
KEYWORDS: Economics, Thermal roof, Bermed, Earth-covered
ABSTRACT: Costs of "Thermal Roof" (flat) house - \$87968, earth-sheltered, sloped roof - \$99,447. Advantages and disadvantages of bermed and earth sheltered houses compared. Related articles on Nos. 14 and 15 ESD & ER.
EVALUATION: Valuable comparison. Summary depends on related articles (q.v.).

Lunde, M.R., "Efficiency Compared: Earth Covered and Thermal Roof." Earth Sheltered Digest and Energy Report No. 15 pp 26-29. [May/June, 1981
KEYWORDS: Economics; Thermal Roof; Bermed
ABSTRACT: Two houses identical except for roof structures are compared for heat loss: One is an underground house with 12" to 15" earth cover; The other is a bermed house with a "thermal roof". Calculated heat loss in Minneapolis weather was 2% less for the "thermal roof". See related articles in ESD&ER No. 14, pp 28-29.; No 18, pp 18-19.
EVALUATION: Only part of the story. See related articles.

Lunde, M.R., "Covered vs Conventional - "Thermal Roof" is Introduced." Earth Sheltered Digest and Energy Report No. 14 pp 28-29. [Mar/Apr, 1981
KEYWORDS: Thermal Roof; Economics; Bermed.
ABSTRACT: earth-bermed structures without soil on the roof are cheaper than earth covered. Martin Lunde & Associates developed a "Thermal Roof" for cost and energy comparisons. Comparisons are continued in No. 15 (May/June) and No. 18 (Nov./Dec).
EVALUATION: Only part of story see continuation articles.

Muller, C.A.. Taylor, R.A., "No Cause for Apprehension about Costs of Insuring Earth-Sheltered Homes." Underground Space. Vol. 5 pp 28-30. [1980
KEYWORDS: Public Policy; Costs; Insurance; Financing.

III. Articles and Papers.

B. Hazard Mitigation.

1. Structural Design.

....., "Disasters Point Way to Earth Shelters." Earth Sheltered Digest & Energy Report. pp 11-14. [Mar./Apr. 1980

KEYWORDS: Public Policy; Hazard Mitigation.

Echn, C., "The Underground Tube Home." Home Energy Digest and Wood Burning Quarterly. [Fall 1978

KEYWORDS: Steel Culvert; Prefabricated; Design.

ABSTRACT: Gives a design using prefabricated steel culverts. No technical information. Architect was Michael McGuire of Steelwater, Minnesota. Manufacturer was Modular Technology Corporation. P.O.Box 6, Plato Center, IL, 60170

2. Civil Defense.

....., "'Egg' is Fallout Shelter, Vacation Home" Emergency Planning Digest pp 18-19. [Oct/Dec, 1981

KEYWORDS: Prefab; Fallout Shelter; Fiberglass.

ABSTRACT: The "Egg" is a reinforced fiberglass structure designed as a fallout shelter and a vacation home. It sells for \$30,000 completely installed. It has an emergency exit built in. The unit is furnished and equipped with cabinets, cushions, cooking utensils, shovel, batteries, lamps, TV and radio. A 470 gallon tank for water is provided.

EVALUATION: A new idea that may have promise in some (limited) applications.

....., "In the Event of Catastrophe." Underground Space. Vol. 5 No. 6 pp 344-355. [May/June 1981

KEYWORDS: Public Policy; Catastrophe.

Chester, C. V., "Incorporating Civil Defense Shelter Space in New Underground Construction." Proceedings of Underground Space Conference and Exposition, K.C., Mo. pp 31-47. [June 8-10, 1981

KEYWORDS: Underground Construction; Blast Shelter.

Sisson, G.M., "Underground for Nuclear Protection." Underground Space. Vol. 4 No. 6 pp 341-348. [May/June 1980

KEYWORDS: Civil Defense.

III. Articles and Papers. C. Energy Related.

1. Heat Transfer.

Houghten, F.C., Taimuty, D.I., Gutherlet, C., Brown, C.J.,
"Heat loss Through Basement Walls and Floors."
Transactions ASHRAE No. 1213 pp 369-384. [1942
KEYWORDS: Heat Transfer; Insulation.

Kusuda, T., Achenbach, P.R., "Earth Temperature and Thermal
Diffusivity of Selected Stations in the United States."
Transactions ASHRAE Vol. 71 pp 61-75. [1965
KEYWORDS: Ground Temperature; Thermal Diffusivity; Climate.

Iatta, J.K., Boileau, G.G., "Heat Losses from House
Basements." Canadian Buildings. Vol. 10 No. 10 p 4.
[Oct. 1969, .] National Research Council of Canada.
KEYWORDS: Heat Transfer; Insulation; Basements.

Baff, S. J., "Ground Temperature Control" Underground
Space Vol. 3 No. 1 pp 35-44. [1978
KEYWORDS: Comfort; Ground Heating; Plastic Ground Cover.
ABSTRACT: Control of underground temperature to hold near
comfort zone was investigated. Covering the ground with
glass or clear plastic can achieve this goal at depths of 5
meters or more. Faving and south slope can get within 5
degrees.
EVALUATION: Effective but expensive. There are better and
cheaper ways.

Shipp, P.H., Meixel, G.D., Ramsey, J.W., "Analysis and
Measurement of the Thermal Behavior of the Walls and
Surrounding Soil for a Large Underground Building."
Underground Space. Vol. 5 No. 2 [Sept/Oct 1980
KEYWORDS: Heat Transfer; Insulation.

Speltz, J.J., Meixel, G.D., "Computer Simulation of the
Thermal Performance of Earth Covered Roofs." Underground
Space. Conf. and Expo - Proceedings. Pergamon Press. [
June 8-10, 1981
KEYWORDS: Heat Transfer; Insulation.

2. Insulation.

Ambrus, T., Komoly, T., "Moisture Movements Under Combined
Effects of Temperature and Vapor Pressure Gradient."
Refrigeration Journal. [July, Aug, Sept, Oct. 1968.
KEYWORDS: Insulation; Moisture.

III. Articles and Papers.

C. Energy Related.

2. Insulation.

(CONTINUED)

Eait, J., "Getting Into It: Umbrella Modifies Soil Temperature." Earth Shelter Living 27 pp 8-9. [May/June 1983

KEYWORDS: Underground Insulation.

ABSTRACT: A new look at insulation configurations underground.

EVALUATION: Has possibilities.

Hedin, C.P., "Moisture Gains by Foam Plastic Roof Insulation Under Controlled Temperature Gradients." Journal of Cellular Plastics [Sept/Oct. 1977

KEYWORDS: Insulation; Moisture.

Joy, F.A., "Thermal Conductivity of Insulation Containing Moisture." Thermal Conductivity Measurement and Application of Thermal Insulation. ASTM Special Technical Publication 217 [1957.] ASTM

KEYWORDS: Insulation; Moisture; Conductivity.

Kaplar, C.W., "Moisture and Freeze-Thaw Effects on Rigid Insulation." Technical Report No. 249 [April 1974..] U.S. Army CEREL, Hanover, N.Y.

KEYWORDS: Insulation; Moisture.

Levy, M.H., "Moisture Vapor Transmission and its Effects on Thermal Efficiency of Foam Insulation." Journal of Cellular Plastics. [Jan. 1966

KEYWORDS: Foam Plastics; Moisture; Thermal Efficiency.

Meixel, G.D., Shipp, P.H., Bligh, T.P., "The Impact of Insulation Placement on the Seasonal Heat Loss Through Basement and Earth Sheltered Walls." Underground Space Vol. 5 No. 1 [July/Aug 1980

KEYWORDS: Heat Transfer; Insulation; Basement.

Vadnis, K., "Truths May Be Buried in Insulation." Earth Sheltered Digest and Energy Report. No. 18 pp 10-12. [Nov/Dec., 1981

KEYWORDS: Polystyrene; Styrofoam; Insulation; R-values; Compressive Strength; Water Absorption.

ABSTRACT: Problems with polystyrene insulation. Blue board (styrofoam) produced by Dow and pink board (formular) by U.S. Gypsum are extruded. All white board is expanded. Quality control of white board is not dependable. Performance standards have not been developed. R-values are manufacturer's data. No third party testing available. Compressive strength and water absorption are advertised by manufacturers.

EVALUATION: Important Caveats.

III. Articles and Papers.
C. Energy Related.

3. Passive Solar.

Baggs, S. A., "Effects of Vegetation on Earth Cooling Potential." Proceedings of Earth Shelter Performance and Evaluation. Tulsa, OK. [Oct. 1981
KEYWORDS: Earth Coupling; Vegetation.

Boyer, L. L., Grondzik, W. T., Weber, M. J., "Passive Energy Design and Habitability Aspects of Earth Sheltered Housing in Oklahoma." Underground Space Vol. 4 No. 6 [1980
KEYWORDS: Earth Coupled Cooling; Disaster Protection; Energy.

Boyer, L. L., Grondzik, W. T., "Habitability and Energy Performance of Earth Sheltered Dwellings." Proceedings of Third International Conference on Alternate Energy Sources. [Dec. 1980
KEYWORDS: Ground Coupled Cooling; Energy Savings.

Boyer, L. L., "Evaluation of Energy Savings Due to Daylighting" Proc. Intl. Passive Cooling Conf. AS/ISES, Miami Beach. [Nov. 1981
KEYWORDS: Daylighting; energy savings.

Ezra, A. A., "Technology Utilization: Incentives and Solar Energy." Science Vol. 187 pp 41-78. [1975

Kusuda, T., Achenbach, P. R., "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States." ASHRAE Transactions 71. Part 1 [1965
KEYWORDS: Earth Temperature; Thermal Diffusivity.

Iabs, K., "Underground Building Climate" Solar Age Vol. 4 p 10. [1979
KEYWORDS: Earth Coupling.

Iabs, K., Watson, D., "Regional Suitability of Earth Tempering." Proceedings of Earth Shelter Performance and Evaluation. Tulsa, OK. [Oct., 1981
KEYWORDS: Earth Tempering

Murdoch, J. B., "A Procedure for Calculating the Potential Savings in Lighting Energy from Use of Skylights." J. Illum. Engr. Soc., Vol. 6 No. 4 [1977
KEYWORDS: Daylighting; Skylights; Energy Savings.

Weber, M. J., Boyer, L. L., Grondzik, W. T., "Implications for Habitability Design and Energy Savings in Earth Sheltered Housing." Proceedings of Earth Shelter Design Innovations, Okla. City. [April, 1980
KEYWORDS: Earth Coupling.

III. Articles and Papers.
C. Energy Related.

3. Passive Solar.
(CONTINUED)

Wylie, J., "Gardening in Earth Shelters." Earth Shelter
Living. No. 27 pp 28-30. [May/June 1983

KEYWORDS: Growing Plants; Passive Solar.

ABSTRACT: Owners must decide if they want to grow plants or
supplement the heating system. They cannot do both.

EVALUATION: A seldom heard point of view.

III. Articles and Papers.

D. Psychological and Physiological

1. Daylighting

....., "Recommended Practice of Daylighting." Lighting Design and Application. Vol. 9 No. 2 [1979
KEYWORDS: Daylighting; Design Practice.

....., "Underground Houses - 8 Works." Process: Architecture Vol. 21 [Jan 1981.
KEYWORDS: Daylighting.

Bennett, E., Eljadi, D., "Solar Optics: Projecting Light into Buildings." AIA Journal [March 1980
KEYWORDS: Daylighting; Solar Optics.

Boyer, L.I., "Subterranean Designs Need Daylighting." Earth Sheltered Digest & Energy Report. Vol. 1 No. 4 [1979
KEYWORDS: Daylighting.

Boyer, L.I., "Daylighting in Subterranean Spaces." Proceedings - Going Under to Stay on Top. [Nov. 1979.]
Underground Space Center, Univ. of Minnesota.
KEYWORDS: Daylighting

Boyer, L.I., "Daylighting Designs Presented." Earth Sheltered Digest and Energy Report. No. 18 pp 13-15. [Nov/Dec., 1981
KEYWORDS: Daylighting; Glare; Shadows; Skylights.
ABSTRACT: Problems of daylighting are listed: fewer windows, more glare, harsh shadows, poor light distribution. Skylights have problems. "Flashlight" beam, solar penetration in summer. Daylighting factors discussed.
EVALUATION: General interest.

Flynn, J.E., "The ISES Approach to Recommendations Regarding Levels of Illumination." Lighting Design and Applications. Vol. 9 No. 9 [1979
KEYWORDS: Daylighting; Lighting Standards.

Villecco, M., Selkowitz, S., Griffith, J.W., "Strategies of Daylight Design." AIA Journal. [Sept. 1979
KEYWORDS: Daylighting; Design.

Wells, M., "North Light Admitted" Earth Sheltered Digest and Energy Report No. 18 pp 11. [Nov/Dec., 1981
KEYWORDS: Daylighting; North windows; Periscope.
ABSTRACT: North openings prevent glare, give cross ventilation. Periscope effect used to provide panoramic view without serious heat leak.
EVALUATION: An interesting innovation.

III. Articles and Papers.

D. Psychological and Physiological

2. Indoor Air Quality.

Lord, D., "Interior Environmental Quality in Earth Shelters." Proceedings Earth Shelter Performance and Evaluation, Tulsa, OK., Oct. 1981. [Oct. 1981
KEYWORDS: Air Quality.

May, H., "Ionizing Radiation Levels in Energy-Conserving Structures." Underground Space. Vol. 5 No. 6 pp 384-391. [May/June 1981
KEYWORDS: Public Policy; Air Quality; Radon.

Oswald, B.A., "Tight House Can Seal in Pollution." Earth Shelter Living No. 27 pp 36-37. [May/June 1983
KEYWORDS: Radon; Ventilation.
ABSTRACT: Tight houses need controlled ventilation to keep radon levels down. A radon measuring device is illustrated.
EVALUATION: Very good summary of the dangers.

3. Acceptability.

....., "Multi-Units Attract Students." Earth Sheltered Digest & Energy Report. pp 24-29. [Sept./Oct. 1981
KEYWORDS: Public Policy; Acceptability.

-----, "Townhouses for Sale." Earth Shelter Living. No. 26 pp 10-11. [March/April 1983

Hellon, S.D., Kendall, F.C., Morsted, S., Watson, D., "Psychological Responses to Earth-Sheltered, Multilevel, and Above Ground Structures With and Without Windows." Underground Space. Vol. 5 No. 3 pp 171-178. [Nov./Dec. 1980
KEYWORDS: Public Policy; Psychological Response; Windows; Windowless Space.

McKown, C., Stewart, K.K., "Consumer Attitudes Concerning Construction Features of an Earth-Sheltered Dwelling." Underground Space. Vol. 4 No. 5 pp 293-295. [Mar./Apr. 1980
KEYWORDS: Public Policy; Acceptability; Design.

Moreland, F., "Earth Covered Habitat, an Alternative Future." Underground Space Journal Vol. 1 pp 295-307. [1977
KEYWORDS: Design; Acceptability.

III. Articles and Papers.

D. Psychological and Physiological

3. Acceptability. (CONTINUED)

Sterling, B., Surcliff, W. pp. "Sterling and Shurcliff Debate: Earth-Sheltered Homes: Weighing the Advantages." Underground Space. pp 200-204. [Jan/Feb 1981
KEYWORDS: Advantages; Disadvantages.
ABSTRACT: Written debate between Sterling (an advocate of underground homes) and Shurcliff (an advocate of super-insulated homes).

Stewart, K. K., McKown, C., Peck, C., "Consumer Attitudes Concerning an Earth-Sheltered House." Underground Space. Vol. 4 No. 1 pp 11-15. [July/Aug. 1979
KEYWORDS: Public Policy; Attitudes; Acceptability.

Wells, H., "Why I Went Underground." The Futurist p 22. [1976

4. Public Policy.

....., "Federal Activities in Earth-Sheltered and Underground Constction." Underground Space. Vol. 5 No. 5 pp 275-278. [Mar/Apr. 1981
KEYWORDS: Federal Activities; Public Policy.

....., "Tax Laws Make Pass at Passive." Earth Sheltered Digest & Energy Report. p 64. [Mar./Apr. 1981
KEYWORDS: Public Policy; Tax; Passive Solar.

Parker, H. B., "Earth-Sheltered Construction: Thoughts on Public Policy Issues." Underground Space. Vol. 4 No. 5 pp 283-288. [March/April 1980
KEYWORDS: Public Policy.

Costes, J. F., "Some Methods and Techniques for Comprehensive Impact Assessment." Technological Forecasting and Social Change. Vol. 6 pp 341-357. [1974

Cocgan, A. H., "Classification and Valuation of Subsurface Space." Underground Space. Vol. 3 No. 4 pp 175-186. [Jan./Feb. 1979
KEYWORDS: Public Policy; Valuation; Classification

EgenKolk, J. G., "Fire Protection for Underground Buildings." Underground Space. Vol. 6 No. 2 pp 93-95. [Sept./Oct. 1981.
KEYWORDS: Fire Protection; Public Policy.

III. Articles and Papers.

D. Psychological and Physiological

4. Public Policy.

(CONTINUED)

Duffaut, P., "Site Reservation Policies for Large Underground Openings." *Underground Space*. Vol. 3 No. 4 pp 187-193. [Jan./Feb. 1979
KEYWORDS: Public Policy; Site Reservation.

Ellsworth, D.A. et al, "The OASIS 2000 Model: A Rural Earth-Sheltered Energy Park." *Underground Space* Vol. 6 pp 153-159. [1981

Fairhurst, C., "Going Under to Stay on Top." *Underground Space*. Vol. 1 No. 1 pp 71-86. [1976
KEYWORDS: Public Policy; Cost.

Jansson, B., "City Planning and the Urban Underground." *Underground Space*. Vol. 3 No. 3 pp 99-115. [Nov./Dec. 1978
KEYWORDS: Public Policy; City Planning.

Jabs, K., "Underground Development, Zoning, and You." *Earth Shelter Digest & Energy Report*. pp 4-7. [Jul./Aug. 1979
KEYWORDS: Public Policy; Zoning; Development.

Larbert, B., "Planning for Energy Needs: A Look at Three New Communities." *Underground Space*. Vol. 5 No. 6 pp 362-369. [May/June 1981
KEYWORDS: Public Policy; Energy Needs.

Lanier, E., "Assessing Environmental Impact of Earth Covered Buildings." *Underground Space*. Vol. 1 No. 1 pp 309-315. [1977
KEYWORDS: Public Policy; Environmental Impact.

Lanier, E., Moreland, F., "Earth-Sheltered Architecture and Land Use Policy." *Underground Space*. Vol. 1 No. 1 pp iii-iv. [1977
KEYWORDS: Public Policy; Land Use.

Moe, R.D., "Technology and the Legislator: The Value of Communication." *Underground Space*. Vol. 4 No. 1 pp 1-10. [Jul./Aug. 1979
KEYWORDS: Public Policy; Legislation; Communication.

Mundale, S., "Energy Park: A Comprehensive Project to Address Urban Problems." *Underground Space*. Vol. 6 No. 2 pp 100-104. [Sept./Oct. 1981
KEYWORDS: Public Policy; Energy Park.

III. Articles and Papers.

D. Psychological and Physiological

4. Public Policy. (CONTINUED)

Scott, D.H.Ed., "The Earth Experience of Codes, Zoning Ordinances, Financing, Incentives, and Attitudes." Proceedings of the SUN 1980 Solar Update. [Sept. 24-26, 1980

Sponsored by: U.S.Dept. of Energy

KEYWORDS: Public Policy; Zoning; Financing; Incentives.

Shasa, A., "Speeding the Diffusion of Solar Energy Innovations" Energy Vol. 7 No. 8 pp 705-715. [1982

Sterling, R., Carnody, J., "Cost and Code Study of Underground Building: A report to the Minnesota Energy Agency." Underground Space. Vol. 4 No. 3 pp 119-136. [Nov/Dec. 1979

KEYWORDS: Public Policy; Cost; Building Codes.

Svenson, G.S., "Zoning Ordinances as Obstacles to Earth Sheltered Housing: A Minnesota Perspective." Underground Space. Vol. 3 No. 4 pp 165-174. [Jan./Feb. 1979

KEYWORDS: Public Policy; Zoning.

Thomas, W.A., "Ownership of Subterranean Space." Underground Space. Vol. 3 No. 4 pp 156-163. [Jan./Feb. 1979

KEYWORDS: Public Policy; Ownership.

Thorsen, G.W., Rue, B.L., "High Bank Instead of High Rise - An Earth-Sheltered Approach to Medium Density Housing." Underground Space. Vol. 5 No. 3 pp 149-151. [Nov./Dec. 1980

KEYWORDS: Public Policy; Medium Density Housing.

Warner, K.E., "The Need for Some Innovative Concepts of Innovation: An Examination of Research on the Diffusion of Innovations." Policy Sciences Vol. 5 pp 433-451. [1974

Wingquist, T., "How Can Society Encourage Appropriate Use of Underground Space?" Underground Space. Vol. 5 No. 4 pp 219-223. [Jan./Feb. 1981

KEYWORDS: Public Policy.

III. Articles and Papers.

D. Psychological and Physiological

5. Financing.

....., Financing an Innovative Energy Conserving Home: A Borrower's Guide. ORNL/SUB-70513V-1 [Sept. 1981 (Draft).] Oak Ridge National Lab.
Sponsored by: U.S. Dept. of Energy
KEYWORDS: Public Policy; Financing; Energy Conserving.

Korell, M.L., "Financing Earth-Sheltered Housing: Issues and Opportunities." Underground Space. Vol. 3 No. 6 pp 297-301. [May/June 1978
KEYWORDS: Public Policy; Financing; Issues; Opportunities.

Machowski, B., "Builders Report Healthy Spec. Market." Earth Sheltered Digest & Energy Report. pp 15-17. [Sept./Oct. 1981
KEYWORDS: Public Policy; Market; Builders; Speculative Construction.

Vadnais, K., "Insurance Study Favors Earth-Sheltering." Earth Shelter Living No. 26 pp 26-27. [March/April 1983
KEYWORDS: Insurability.
ABSTRACT: After two years of research sponsored by the National Association of Mutual Insurance Companies, underground housing is heralded as the wave of the future.
EVALUATION: Looks like good work.

III. Articles and Papers.

E. Examples.

1. Experience.

....., "My Mother's House." Mother Earth News. No. 70
pp 106-108. [July/Aug 1981

KEYWORDS: Mother Earth News; Dry Stacked Block; "Surewall";
Surface Bonding.

ABSTRACT: The first in a series on the earth-sheltered
house being built at Mother Earth News' Eco-village in
North Carolina. The house faces 5 degrees east of south.
The back of the cut into the hillside left a 13 1/2-ft
bank. A 14-ft retaining wall made with 12-in. concrete
blocks, laid dry and surface bonded with "Surewall" mastic
forms the back wall of the split level house.

EVALUATION: Interesting.

....., "My Mother's House." Mother Earth News. No. 72
[Nov/Dec, 1981

KEYWORDS: Waterproofing; "Surewall"; Surface Bonding.

ABSTRACT: Describes the building and waterproofing of
Mother Earth News' house. Waterproofing is rubber on the
roof, Bentonite on the walls.

EVALUATION: Interesting description of surface bonding
technique.

....., "Fire HQ Covered for 23 years." Earth Sheltered
Digest and Energy Report. No. 18 pp 4-5. [Nov/Dec,,
1981

KEYWORDS: Case Study; Early Example; Government Building.

EVALUATION: Historical interest.

....., "Team Accepts Design Challenge" Earth Sheltered
Digest and Energy Report No. 18 p 28. [Nov/Dec, 1981

KEYWORDS: Cost; Design; Casey, IL.

ABSTRACT: Design details of a 2400-sq-ft earth sheltered
house in Casey, IL. Cost was 10 to 15% higher than similar
conventional houses which average \$50/sq-ft. Architect was
Tom Miller of Chicago. Electric bill was \$349.45 annually.

EVALUATION: Fair.

....., "Restaurant Successful Underground." Earth
Sheltered Digest and Energy Report No. 18 pp 38-39. [
Nov/Dec,, 1981

KEYWORDS: Case study; Restaurant; Greentown, IN.; Cost

ABSTRACT: A 2800-sq-ft restaurant in Greentown, IN. Energy
use is less than half the National Restaurant Association
average energy per meal. Cost \$120,000.

EVALUATION: Indicates public acceptance of underground
space.

III. Articles and Papers.

E. Examples.

1. Experience.

(CONTINUED)

....., "Museum is Out of Sight" Earth Sheltered Digest and Energy Report No. 18 p 40. [Nov/Dec., 1981
 KEYWORDS: Case study; Museum; Multistory; Des Moines, Ia.
 ABSTRACT: Design of a 4 story 150,000-sq-ft underground museum for the Iowa State Historical Museum in Des Moines. Designed by Brown, Healy, Bock of Cedar Rapids, Ia. The project is expected to cost \$11 million.
 EVALUATION: Good example of multistory use.

....., "Cutting Costs" Rodale's New Shelter p 22 (box). [Jan 1982
 KEYWORDS: Techniques; Economy; Surface Bonding; Franchises; Building Plans
 ABSTRACT: Rob Roy tells in "Underground Houses: How to Build a Low-cost Home" (Sterling Publications) how he built his subsurface house for less than \$8000. Two of his alternate building techniques are: 1) Surface bonded concrete block walls; and 2) Wooden plank-and-beam roofs. Standard underground house plans are available for \$500 from Elliscn Design and Construction, Minneapolis. Plans for "Earthtech 6" designed by Don Metz are available for \$150.
 EVALUATION: Some of the shortcuts suggested are dangerous.

Davis, A., "My Cave" Underground Space Vol. 2 No. 3 pp 151-152. [April, 1978
 KEYWORDS: Case Study; Davis Cave; Franchise.
 ABSTRACT: Built in 1975. Davis was so impressed with its superior qualities and low cost (not reported) that he is offering franchises for others to build.
 EVALUATION: Strictly advertising.

Machowski, B., "Berm Shelter Ozark Development." Earth Sheltered Digest and Energy Report. No. 18 pp 54-57. [Nov/Dec, 1981
 KEYWORDS: Case Study; Wood Roof; Atrium; Concrete Wall; Highlandville, MO.
 ABSTRACT: Bermmed on three sides with an insulated wood roof. House in Highlandville, MO. cost \$25/sq ft (exclusive of land). Mono-poured walls are 8 in. thick; poured slab is 5 in. thick. Wall insulation is 1 in. rigid board polystyrene over the top. Rccf is supported by commercial trusses made with 2x4s and covered by 5/8-in. plywood.
 EVALUATION: Interesting case study.

III. Articles and Papers.

E. Examples.

1. Experience.

(CONTINUED)

Rawlings, R., "Dig It Yourself" Rodale's New Shelter pp 23-26. [Jan 1982

KEYWORDS: Case study; Poured walls; Elastomer Membrane ; Waterproofing; Cost.

ABSTRACT: Bob and Margaret Scott - do it yourselves - built a poured wall, concrete plank roof, earth sheltered house with the help of a consulting engineer and several contractors. Insulation is sprayed on urethane foam with 4 in. on the roof (R-30). Walls have 4 in. at top, tapering to 2 in. (R-16). Two layers of polyurethane elastomer membrane was used for waterproofing. The Scotts want to try tilt-up walls next.

EVALUATION: Good example of some real problems that can complicate earth shelter

Scott, M., "Moving Underground" Earth Sheltered Digest and Energy Report No. 18 pp 22-27. [Nov/Dec., 1981

KEYWORDS: Case Study; Concrete Walls; Concrete Pumping; Financing.

ABSTRACT: Two articles on a 1735-sq-ft earth covered home at Coeur d'Alene, Idaho. Troubles included financing, excessive interest costs, a concrete pump that wouldn't pump, and collapse of the concrete chute.

EVALUATION: Interesting.

Vitt, J.E., "Developing Kansas City's Underground Space." Underground Space. Vol. 4 No. 5 pp 284-292. [

Mar/Apr. 1980

KEYWORDS: Public Policy; Case Study; Kansas City, MO.

III. Articles and Papers.

F. General Treatment.

Labs, K., "The Architectural Underground" Underground Space Vol. 1 No. 1 pp 1-8. [1976

KEYWORDS: Underground Space; History; Caves; Religion; Cliff Dwellings; Kiva; Dugouts; Climate Control; Civil Defense.

ABSTRACT: Underground space has been useful for thousands of years. Historical examples are given. Recently a new interest has evolved and a number of new types have emerged.

EVALUATION: Excellent.

IV. Bibliographies.

....., "OSU Research Papers and Reports on Earth-Sheltered Buildings." 3 pages. [Dec 1980.] Oklahoma State University, Stillwater, OK.

KEYWORDS: Bibliography

ABSTRACT: A list of OSU research papers and reports on Earth-Sheltered buildings available from Architectural Extension at CSU,

EVALUATION: 17 papers listed.

-----, "Earth Shelter/ Underground Bibliography." 17 pages. [1979.] Earth Shelter, Inc.

KEYWORDS: Bibliography; Information; Planning; Construction.

Jones, L.K., "Underground Construction" p 15. [Nov. 1, 1979.] Oklahoma State University, Stillwater, OK.

KEYWORDS: Bibliography

ABSTRACT: Contains approximately 250 references to articles and other publications on underground construction,

EVALUATION: Comprehensive.

Keehn, P. A., Earth-Sheltered Housing: An Annotated Bibliography and Directory. CPL-43 [Jan. 1981.] Council of Planning Librarians.

KEYWORDS: Bibliography; Author Index; Architects; Builders.

ABSTRACT: Contains 232 earth-sheltered housing abstracts, with author index. Lists 13 earth-sheltered housing conferences, 38 architects and builders of earth-sheltered structures, and 4 booksellers.

EVALUATION: Helpful but not complete.

Peter, A., Soil Thermal Properties, An Annotated Bibliography. [1962.] The Franklin Institute, Philadelphia, PA.

KEYWORDS: Bibliography.

V. Proceedings

-----, Earth Shelter 2: Collected Papers Presented at Earth Sheltered Conference and Exhibition, Minneapolis, MN. [April 9-11, 1980
Sponsored by: Univ. of Minn Underground Space Center.
KEYWORDS: Detailing; Performance; Ground; Climate; Legal; Cost; Environment.

-----, Proceedings of Passive and Hybrid Cooling Conference. Miami, FL. [1981.] American Section/ International Solar Energy Society (ISES).
KEYWORDS: Earth Coupling; Passive cooling.

Ecyer, L. I., Ed., Proceedings: Earth-Sheltered Building Design Innovation. Second National Technical Conference. 132 pages. [April, 1980
KEYWORDS: Innovations; Earth sheltered; Design; Construction; Acceptability; Livability; Energy Conservation; Results; Data.
ABSTRACT: A technical conference held in Oklahoma City in April 1980. Half of the papers were authored by architects, one third by engineers, the rest by contractors and researchers.
EVALUATION: Good quality technical information.

Foyer, L. I., Ed., Proceedings: Earth Sheltered Performance and Evaluation, Second National Technical Conference. Tulsa, OK. [Oct. 16-17, 1981.
Sponsored by: Architectural Extension, Okla. State Univ.
KEYWORDS: Earth Environment; Design; Modeling; Analysis; Passive Solar.

Holthusen, T. L., Ed., The Potential of Earth Sheltered and Underground Space.: Today's Resource for Tomorrow's Space and Energy Viability. Pergamon Press, \$48. 503 pages. [June 1981
KEYWORDS: Civil Defense; Subways; Commercial; Residential.
ABSTRACT: Papers presented at a symposium held in Kansas City in June 1981.
EVALUATION: Wide range of subjects.

Moreland, F., Higgs, Shih, Eds. ., "Earth Covered Buildings and Settlements. CONF-7805-138 part 1 and part 2" Proceedings of Conference: "Alternatives in Habitat: The Use of Earth Covered Buildings and Settlements". Two volumes [May 1978..] Univ. of Texas, Arlington, TX.
Sponsored by: Dept. of Energy/Innovative Structures Program.
KEYWORDS: Earth Environment Design; Modeling; Analysis; Passive Solar.

V. Proceedings

Moreland, F., Ed., Alternatives in Energy Conservation: The Use of Earth Covered Buildings. Proceedings and Notes of a Conference Held in Ft. Worth, TX. July 9-12, 1975.

NSF-RA-760006 [July , 1975

Sponsored by: National Science Foundation - RANN

KEYWORDS: Earth-covered; Energy Conservation.

COMMENT: Available from U.S. Government Printing Office, Washington, D.C. 020402 Stock No. 038-000-00286-4. \$3.25.

VI. Fact Sheets.

-, "Site Investigation" Earth Sheltered Structures Fact Sheet 01 ORNL/SUB-7849/01 p 8. [Dec 1981.]
Underground Space Center, Univ. of Minn.
Sponsored by: ORNL/U.S DOE, Office of Buildings and Community Systems Buildings Division.
KEYWORDS: Surroundings; Climate; Topography; Geology; Soil; Ecology.

--, "Planting Considerations" Earth Sheltered Structures Fact Sheet 02 ORNL/SUB-7849/02 6 pages. [Nov 1981.]
Underground Space Center, Univ. of Minn.
Sponsored by: ORNL/ U.S. DOE, Office of Buildings and Community Systems, Buildings Division
KEYWORDS: Landscaping; Planting; Shrubs; Trees; Garden.

---, "Waterproofing Techniques" Earth Sheltered Structures Fact Sheet 03 ORNL/SUB-7849/03 p 4. [Dec 1980.]
Underground Space Center, Univ. of Minn.
Sponsored by: ORNL/ U.S. DOE, Office of Buildings and Community Systems, Buildings Division .
KEYWORDS: Waterproofing; Site planning; Drainage; Membranes

----, "Waterproofing Considerations and Materials." Earth Sheltered Structures Fact Sheet 04 ORNL/SUB-7849/04 12 pages. [Sept 1981.]
Underground Space Center, Univ. of Minn
Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division.
KEYWORDS: Waterproofing; Site; Soil; Climate; Cost; Lifespan; Applications; Materials.

-----, "Insulation Principles" Earth Sheltered Structures Fact Sheet 05 ORNL/SUB-7849/05 8 pages. [May 1981.]
Underground Space Center, Univ. of Minn.
Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division.
KEYWORDS: Insulation; Heat leak; Climate; U-Value.

-----, "Insulation Materials and Placement." Earth Sheltered Structures Fact Sheet 06 ORNL/SUB-7849/06 5 pages. [May 1981.]
Underground Space Center, Univ. of Minn.
Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division.
KEYWORDS: Insulation; Materials; Selection; Placement.

-----, "Daylighting Design." Earth Sheltered Structures Fact Sheet 07 ORNL/SUB-6974 IV-01 5 pages. [Aug 1981.]
Underground Space Center, Univ. of Minn.
Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division.
KEYWORDS: Daylighting; Natural light; Energy; Glare; Shading.

VI. Fact Sheets.

-----, "Indoor Air Quality" Earth Sheltered Structures Fact Sheet 08 ORNL/SUB-69741V-01 6 pages. [Aug 1981.] Underground Space Center, Univ. of Minn. Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division. KEYWORDS: Pollutants; Ventilation; Humidity; Filtration.

-----, "Earth Coupled Cooling Techniques." Earth Sheltered Structures Fact Sheet 09 ORNL/SUB-69741V-03 6 pages. [Aug 1981.] Underground Space Center, Univ. of Minn. Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division. KEYWORDS: Earth coupled; Cooling; Comfort; Climate.

-----, "Disaster Protection" Earth Sheltered Structures Fact Sheet 10 04 6 pages. [Sept 1981.] Underground Space Center, Univ. of Minn. Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division. KEYWORDS: Storms; Tornadoes; Earthquakes; Civil Defense.

-----, "Building in Expansive Clays" Earth Sheltered Structures Fact Sheet 11 ORNL/SUB-69741V-05 6 pages. [Sept 1981.] Underground Space Center, Univ. of Minn. Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division. KEYWORDS: Expansive Clay; Structural integrity.

-----, "Passive Solar Heating" Earth Sheltered Structures Fact Sheet 12 ORNL/SUB-69741V-06 6 pages. [Sept 1981.] Underground Space Center, Univ. of Minn. Sponsored by: ORNL/U.S.DOE, Office of Buildings and Community Systems, Buildings Division. KEYWORDS: Passive Solar; Direct Gain; Trombe Wall; Design.

VI. Fact Sheets.

....., Home Blast Shelter 6 pages. [May 1978.]
 Defense Civil Preparedness Agency (DCPA)
 Sponsored by: Defense Civil Preparedness Agency.
 KEYWORDS: Underground; Concrete; Shelter.
 ABSTRACT: A pamphlet giving a design of a blast shelter for individual homes.
 EVALUATION: Design should be improved to reduce cost.

....., Earth Integrated Building Construction. 24 pages.
 [June 1979..] Portland Cement Association. Skokie, IL.
 KEYWORDS: Planning; Design; Construction; Examples.
 ABSTRACT: Contains background information on earth sheltering and gives examples of projects in the planning and completed stages. References to other sources of information.

....., Windstorm Protection Design (3 Booklets)
 TR-83; TR-83A; TR-83B [July 1975; Sept. 1975; April 1976.] Defense Civil Preparedness Agency (DCPA); DCPA/DOD, Washington, D.C.
 Sponsored by: DCPA/DOD
 KEYWORDS: Windstorm Protection; Protective construction; Design; Structures

Simmons, L. B., Passive Solar Earth Sheltered Housing. 10 pages. [April, 1981.] Simmons and Sun.
 KEYWORDS: Poured-in-place Concrete; Post-Tensioned Concrete; Code Frictions; Financing.
 ABSTRACT: A discussion of some problems and their solutions for passive solar, earth-sheltered houses.
 EVALUATION: Good.

APPENDIX A

Moderately Important Institutional Issues
Affecting the Utilization of Earth-Sheltered
Residences

APPENDIX A

Moderately Important Institutional Issues Affecting the Utilization of Earth-Sheltered Residences

In the body of this report, a number of issues are identified as important in relation to three different types of earth-sheltered development: hazard-mitigating, earth-sheltered residences; crisis-upgradable earth shelters; and entire earth-sheltered neighborhoods or communities. It is possible that an issue can be most important in relation to one or more of these types of development and moderately important in relation to another. This Appendix presents a discussion of those issues identified in the text as moderately important in relation to the adoption and use of one or more of the above types of earth shelters and not discussed in more detail elsewhere as most important relative to another type.

Issues Related to the Desire to use Earth-Sheltered Residence

Expression of Personal Values. To many homeowners, the choice of a dwelling unit can be a statement of personal values. For some, the purchase of an earth shelter constitutes a positive assertion of the buyer's innovativeness, environmental concern, and energy awareness. The evolving symbolism associated with earth-sheltering and future trends in national values is likely to affect public response to this residential option.

Conforming to Socially Accepted Image. While some potential home buyers are interested in making a statement about their independence and innovativeness by their choice of a dwelling unit, many others are interested in projecting an image more in conformity with mainstream tastes and values. For this latter segment of the home buying public, earth-sheltered housing may be unacceptable to the extent that its

external appearance departs from more conventional dwelling units (Moreland, 1983). This barrier to the adoption of earth-sheltering can be addressed in the short term by the design of structures which depart as little as possible from aboveground structures, possibly through the use of traditionally-styled front elevations and exposed roofs. In the longer term, the issue of conformity could dissolve as a barrier to adoption if earth-sheltered dwellings become widely accepted by society at large.

Issues Related to the Construction of Earth-Sheltered Residences

Building Regulations. Building regulations are frequently cited as major obstacles to the construction of earth-sheltered dwellings. Specifically, the model building codes that are widely adopted by local governments throughout the country have come under fire, as have the HUD Minimum Property Standards (MPS) which are used to judge the eligibility of residential structures for federal loan insurance programs. Major provisions that are found in at least one model code or in the MPS and that can block earth-sheltered construction are: 1) the requirement for a direct means of egress from living and sleeping areas to the outside; 2) the requirement for windows opening to the outside in every habitable room for light and ventilation; and 3) requirements for structural integrity which don't address the unique characteristics of earth shelters. Without prescriptive standards that are specifically geared to earth-covered housing, developers choosing to build underground will have to prove equivalent performance to conventional structures through the "Alternate Methods and Materials Provisions" contained in most codes. These provisions do allow innovation, but proving equivalence is frequently time-consuming and expensive (Sterling, Aiken, and Carmody, 1980).

Land Use Regulations. The local zoning ordinance is the land use regulation most frequently cited as a potential barrier to earth-sheltered construction. Zoning ordinances are generally much less standardized than are building codes, but there are several problem characteristics which appear in many different codes. These include: 1) minimum height requirements; 2) minimum floor area requirements that don't count basement space; 3) maximum lot coverage requirements; 4) minimum setbacks; and 5) outright prohibition of living underground (Sterling, Aiken, and Carmody, 1980). On the positive side, natural resource protection ordinances which limit the impermeable surfaces allowed in a given development can actually encourage earth-sheltered development.

Restrictive Covenants. Certain aspects of these binding agreements, which are written into individual property deeds, can present a barrier to the construction of earth-sheltered buildings. Prohibitions against living in basements and requirements that all building plans be reviewed by an architectural review board for compatibility with existing dwellings can be particularly troublesome (Ziebarth, 1980).

Limited Experience of Planners and Regulators. Those individuals charged with designing and overseeing community development may not understand the important physical factors, like geology and hydrology, which affect the feasibility of building underground. They may also be unfamiliar with the design principles governing this type of development, particularly at the neighborhood or community scale. This lack of understanding can prevent planners and regulators from giving positive guidance to prospective builders of earth-sheltered structures and, at the same time, can limit their willingness to approve this kind of dwelling.

Availability of Inexpensive Designs and Plans. The availability of relatively inexpensive designs and plans for earth-covered structures could reduce developers' need for expensive architectural and engineering services and increase their familiarity with the type of building. Wide-spread availability of plans for earth-covered structures can increase the likelihood that they will be taken seriously by the building community, as well as boosting awareness of this building type among the home buying public.

Innovation in the Construction Industry. The construction industry is generally reputed to be very conservative, a characteristic that manifests itself in a slowness to adopt new building practices. It is unlikely that, without intervention, the willingness to innovate will be any greater in the case of earth-sheltered housing than it has been in the past. Indeed, there are some strong forces pulling against rapid acceptance of earth-sheltered construction, including the need for conventional builders to learn new construction skills, to invest in new equipment, and to employ additional architectural and engineering services, at least during the learning process (Sterling, Aiken, and Carmody, 1980).

Issues Related to the Use of Earth-Sheltered Residences

Resale. When an owner's use of an earth-sheltered structure draws to a close, he or she faces the issue of resale. There is very little information on the resale value of earth-sheltered houses (Korell, 1978), although the little data there are indicate that at least some units have sold at good prices (Earth-Shelter Digest, 1981). Still, the overriding uncertainty of resale value can have a negative impact on both lenders and prospective buyers.

Interior Environmental Quality. "Indoor air pollution" can be a problem for the occupants of earth-sheltered residences due to the tightly-sealed nature of the typical earth shelter. Some observers have also pointed to the potentially hazardous concentrations of radioactive radon gas that can occur in some earth-covered buildings (May, 1981). These problems can be addressed through the provision of adequate ventilation systems, intelligent building operations, and the prudent choice of building materials.

Access to Structure. Access to the buried walls and roof of an earth-covered structure for any needed repairs or remodeling could be difficult and costly. Access to the structure for the performance of emergency services like fire protection could also be more difficult than for aboveground houses, as could be the related function of emergency egress. These potential problems could diminish the attractiveness of earth-covered dwellings.

Energy Use. The energy needed for space conditioning is likely to be much less for an earth shelter than for a conventional structure, particularly if passive solar heating is utilized (Earth-Sheltered Housing Design, 1978). The resulting lower energy bills are expected to be very attractive to residents and also to increasing numbers of lenders.

Issues Related to the Community-Wide Effect of Using Earth-Sheltered Residences

Energy Consumption. As discussed earlier, energy required for space conditioning is likely to be much less in earth-sheltered than in conventional structures, especially where passive solar heating is provided. The consequent reduction in energy demand should have benefits for the society at large as well as for the individual occupants. Greater energy independence is widely accepted as a

worthwhile social goal, the benefits of which range from increased autonomy at the community level to strengthened national security. In addition to saving energy normally required for space conditioning, additional savings could be realized in the transportation sector if higher residential densities lead to increased use of mass transit, and also in the area of embodied energy as higher densities result in shorter street and utility lines.

Changes on Existing Building Industry. Should the use of earth-sheltered housing become widespread, there are likely to be significant effects for the existing building industry. It is expected that the builders of conventional aboveground structures will see their business decline unless they acquire the skills and equipment needed for subterranean construction. At the same time, those builders and developers with capabilities in this area should see their activities increase. Similar impacts are likely among building material suppliers, as well.

Social Impacts Arising from Policy Initiatives to Stimulate Earth-Sheltering. Government policy initiatives taken to encourage the use of earth-sheltering hold the potential for causing unintended impacts to society. At the least such initiatives, by speeding the diffusion of innovation can accelerate those societal impacts likely to result from the widespread adoption of earth-covered residences. In addition, these policies could encourage different rates of adoption among different socioeconomic groups, thus resulting in varying degrees of benefit for distinct segments of society. Government policy initiatives could also encourage more involvement, and hence greater profits for one type of contractor or supplier (e.g. small or large residential or commercial) than another. The equity implications of such differential benefits resulting from government-sponsored actions will have to be closely examined by prospective policy-makers.

Disaster Protection. It is expected that hazard-mitigating and crisis-upgradable, earth-sheltered structures can offer significantly greater hazard protection than do conventional, aboveground residences. The societal benefits resulting from the decreased loss of life and property in case of a natural or man-made disaster could be significant.

Public Access to Earth-Sheltered Dwellings in Case of Disaster. In the event of an impending disaster, individuals other than the actual occupants may desire the protection afforded by crisis-upgradable structure. Important questions that arise, therefore, are "What can be done to encourage the owners of such structures to share their homes with others during an emergency?" and, conversely, "What can be done to protect an owner's right not to share?" It is expected that these questions may be addressed at the state or local, rather than the federal, level of government.

APPENDIX B

Least Important Issues Affecting the Utilization
of Earth-Sheltered Residences

APPENDIX B

Least Important Institutional Issues Affecting the Utilization of
Earth-Sheltered Residences

This Appendix presents a discussion of those issues that, while potentially significant, are considered least important relative to the other issues identified in effecting the adoption and use of individual earth-sheltered dwellings and entire neighborhoods and communities. None of the issues described below were discussed in the body of the report or in Appendix A.

Issues Related to the Use of Earth-Sheltered Residences Maintenance of Structure. The limited area of exposed exterior walls and roofs in earth-sheltered structures could make these units require less maintenance, thus increasing their attractiveness to users (Sterling, Aiken, and Carmody, 1980). On the other hand, any failure in exterior water-proofing could be extremely problematic.

Taxation. As long as the initial costs of earth-sheltered structures are higher than for conventional structures, property taxes based on housing value will provide a disincentive, though not necessarily a major one, for potential adopters.

Insurance. There has been little research on the costs of insuring earth-covered housing and whether they would differ from the costs for conventional structures. The costs for earth-sheltered insurance could well be lower because of the fire resistant nature of this type of structure (Muller and Taylor, 1980). On the other hand, there is a slight chance that insurance costs could be somewhat higher, at least initially, because of the possibility of difficulties with access and egress in case of fire. In any case, the difference in cost between

insurance for belowground and aboveground structures can be expected to be relatively small compared to all the other expense of home ownership

Ease of Interaction with Neighboring Units. Because of the submerged nature of earth-sheltered dwellings, interaction among neighboring units could be diminished. This could bring increased privacy, but it could also lead to decreased opportunities for "neighboring."

Protection from Intrusion or Vandalism. Because they have fewer exposed surfaces, it is expected that earth-sheltered houses could afford greater protection against intrusion (Muller and Taylor, 1980) and certain forms of vandalism, increasing the appeal for present and prospective users. On the other hand, earth-sheltered rooftops and their vents and chimneys are often exposed on-grade, making them accessible for various kinds of mischief.

Legal Liability Under Doctrine of Attractive Nuisance. According to one of our respondents (Ziebarth, 1982), earth-sheltered dwellings, particularly those with landscaped roofs adjacent to substantial drop-offs, can present a potential legal liability for the owners.

Issues Related to the Community-Wide Effects of Using Earth-Sheltered Residences

Environmental Protection. Substantial use of earth-sheltered structures could result in significant positive effects to the natural environment. Open space can be preserved and wildlife communities can thrive, even in built-up areas, through careful earth-covered design and construction. Urban heat islands can be lessened, and air pollution and carbon dioxide emissions can be minimized because of the reduced need to burn conventional fuels to heat earth-sheltered structures. Urban run-off and consequent water pollution can also be greatly reduced and ground water recharge increased because fewer impermeable surfaces are created

in earth-sheltered developments (LaNier, 1977). On the negative side is the possibility of subsidence or changes in drainage patterns resulting from construction, but these are likely to be avoided by careful planning and design.

Appendix C

QUESTIONNAIRE

Institutional Factors and Policy Options Related to the Utilization of Earth-Sheltered Structures

Under the sponsorship of the Federal Emergency Management Agency (FEMA), we are seeking to increase our understanding of the institutional issues¹ affecting private-sector adoption of earth-sheltered structures and of those policy options that can be used to address these issues and encourage the use of this building type. Specifically, we are interested in those issues that are likely to arise in conjunction with the private sector development of hazard-mitigating earth-sheltered structures² and crisis-upgradable earth-shelters,³ as well as from the development of entire earth-sheltered neighborhoods and communities and the use of privately-owned structures to provide community protection in times of crisis.⁴ Your help is needed in identifying and evaluating potential institutional issues and policy options in these areas. While FEMA is interested in encouraging all kinds of earth-sheltered structures, the primary emphasis of this study is on low to moderate density residential developments.

¹Institutional issues are broadly defined here as those issues related to the social institutions and interactions necessary for adoption of a technology, as opposed to those technical issues directly related to the physical characteristics of the technology itself. Examples of institutional issues that are important to the adoption of earth-sheltered structures are the effects of land use regulations promulgated by local governments and the ability of the construction industry to adopt new building techniques and materials.

²A hazard-mitigating earth-sheltered structure is one that provides protection from natural hazards like tornadoes and earthquakes, and possibly some protection from nuclear weapons effects as well, modification.

³A crisis-upgradable earth-sheltered structure is one that provides protection from the hazards mentioned above and can also be upgraded in roughly one day's time to withstand a weapons-induced pressure of 15 to 30 pounds per square inch (PSI). Such a structure would be distinguished from a typical elevational earth-sheltered building by having more massive front walls, a few extra bearing walls internally, places inside for expedient columns and lintels, and movable landscaping components like paving blocks and planters that can be stacked in front of the structure for added protection.

⁴These structures would have an every-day use, as a residence or business for example, and a crisis use as a cooperative shelter. As much of the structure as possible should be usable as shelter space.

Institutional Issues

A set of institutional issues that could arise in conjunction with the utilization of earth-sheltered structures is presented below. The first page present five major types of issue which were identified during a preliminary study. Subsequent pages list specific issues that could arise in each of these general areas.

Please read through the entire list and answer these two questions:

1. Are there any important institutional issues that could accompany the adoption of earth-sheltered buildings that are not included here? If so, please list and explain.
 2. Of all the issues, which do you consider most important and which least important in affecting the adoption and use of earth-sheltered structures? Please explain.
- Indicate your response directly on the list of issues or on the blank pages provided at the end of this questionnaire.

It should be noted that the institutional issues listed here were identified primarily from a study of the development of individual hazard-mitigating earth shelters that could provide community protection in times of crisis. Little effort was made during this preliminary study to identify issues arising from the construction of crisis-upgradable shelters or the development of earth-sheltering on the neighborhood or community scale. Issues related to this type of development might, therefore, deserve extra attention in your review.

INSTITUTIONAL ISSUES AFFECTING THE UTILIZATION OF
EARTH-SHELTERED STRUCTURES

- I. Issues Related to the Desire to Use Earth-Sheltered Structures
- II. Issues Related to the Construction of Earth-Sheltered Structures
- III. Issues Related to the Ability to Purchase Earth-Sheltered Structures
- IV. Issues Related to the Use of Earth-Sheltered Structures
- V. Issues Related to the Community-Wide Effects of Using Earth-Sheltered Structures

INSTITUTIONAL ISSUES AFFECTING THE UTILIZATION OF
EARTH-SHELTERED STRUCTURES

- I. Issues Related to the Desire to Use Earth-Sheltered Structures
 - A. Aesthetics
 - B. Livability
 - C. Safety
 - D. Soundness of Investment
 - E. Expression of Personal Values
- II. Issues Relating to the Construction of Earth-Sheltered Structures
 - A. Building Regulations
 - B. Land Use Regulations
 - C. Restrictive Covenants
 - D. Limited Experience of Planners and Regulators
 - E. Financing of Construction Loans
 - F. Innovation in the Construction Industry
 - G. Legal Liability During Construction
 - H. Provision of Utilities
 - I. Ownership of Underground Space
- III. Issues Related to the Ability to Purchase Earth-Sheltered Structures
 - A. Availability of Suitably Trained and Equipped Residential Contractors
 - B. Availability of Inexpensive Designs and Plans
 - C. Appraisal of Earth-Sheltered Structures
 - D. Use of Life-Cycle Costing in Loan Decisions
 - E. Mortgage Insurance for Earth-Sheltered Structures
 - F. Resale of Earth-Sheltered Mortgages
- IV. Issues Related to the Use of Earth-Sheltered Structures
 - A. Maintenance of Structure and Interior Environmental Quality
 - B. Access To Structure
 - C. Energy Use
 - D. Taxation
 - E. Insurance
 - F. Resale
 - G. Emergency Use of Earth-Sheltered Structures
 - H. Ease of Interaction with Neighboring Units
 - I. Protection from Intrusion or Vandalism

V. Issues Related to Community-Wide Effects of Using Earth-Sheltered Structures

- A. Housing density
- B. Urban Form
- C. Environmental Protection
- D. Provision of Utilities
- E. Energy Consumption
- F. Disaster Protection
- G. Public Access to Earth-Sheltered Dwellings in Case of Disaster
- H. Neighborhood Concept
- I. Changes in the Image of the City

Policy Options

A set of potential policy options to address the institutional issues listed previously and encourage the utilization of earth-sheltered structures is presented below. The first page presents nine general policy directions identified during a preliminary study and the subsequent pages list a number of focused policies that could be enacted in each of these general areas.

Please read through the entire list and answer these three questions:

1. Are there any important policies that could be used to encourage earth-sheltering that are not included here? If so, please list and explain.
 2. Of all the policy options, which do you consider to have the greatest near-term chance of success and which should be least successful in stimulating the use of earth-sheltered structures? Please explain.
 3. (OPTIONAL) What do you anticipate will be the major societal impacts of implementing those policies which you consider most promising? Please pay particular attention to impacts that may be unintended or unanticipated.
- Indicate your response directly on the list of policy options or the on blank pages provided at the end of this questionnaire.

Again, it should be noted that the policy options listed below were developed primarily to encourage the development of individual hazard-mitigating earth-shelters that can also provide community protection. Little effort was made during the preliminary study to identify policies specifically designed to stimulate the construction of crisis-upgradable earth-shelters or to promote earth-sheltering on the neighborhood or community scale. Policies to serve these latter two purposes might, therefore, deserve extra attention in your review.

POTENTIAL POLICY OPTIONS

TO ENCOURAGE THE UTILIZATION OF EARTH-SHELTERED STRUCTURES

1. Educate all Sectors of Society about Earth-Sheltered Structures.
2. Enhance the Skills of Builders and Regulators in the Area of Earth-Sheltered Construction.
3. Utilize the Taxing Power to Increase the Attractiveness of the Earth-Sheltered Option.
4. Promote the Development of Building Standards and Regulations That Will Encourage the Further Use of Earth-Sheltering.
5. Promote Land Use Planning and Regulation That Will Encourage Earth-Sheltering.
6. Use the Direct Expenditure of Government Funds to Stimulate the Increased Use of Earth-Sheltered Structures.
7. Increase the Amount of Money Available for Loans on Earth-Sheltered Structures at Attractive Rates.
8. Assure the Availability of Attractive Insurance Policies for Earth-Sheltered Structures.
9. Assure the Availability of Building Materials, Techniques, and Plans for High-Quality, Cost-Effective Earth-Sheltered Structures.

POTENTIAL POLICY OPTIONS
TO ENCOURAGE THE UTILIZATION OF EARTH-SHELTERED STRUCTURES

1. Educate all Sectors of Society about Earth-Sheltered Structures
 - a) Educate the public concerning the advantages of earth-sheltering (I)*
 - b) Educate builders concerning the competitive advantage offered by large-scale construction with minimum management costs and profits per unit (II, III)
 - c) Educate public in earth-sheltered construction techniques in order to encourage owner-built structures and the reduction of front-end costs (III)
 - d) Educate financial community on advantages of earth-sheltering (III)
 - e) Develop public education programs on proper maintenance and ventilation (IV)
 - f) Compile and disseminate resale information (IV)
 - g) Disseminate information on the use and availability of earth-sheltered structures for disaster protection (V)
 - h) Educate local planning boards on advantages and organization of underground space (V)
2. Enhance the Skills of Builders and Regulators in the Area of Earth-Sheltered Construction
 - a) Develop programs to retool builders and regulators (II)
 - b) Distribute "certified" builder training programs (III)
3. Utilize the Taxing Power to Increase the Attractiveness of the Earth-Sheltered Option
 - a) Subsidize contractors through tax credit (II)
 - b) Encourage "do-it-yourself" construction through tax credits to individuals and/or builders (III)
 - c) Subsidize buyers through income tax credits (III)
 - d) Increase taxes on conventional fuels (IV)
 - e) Pass preferential property tax rates (IV)

*Numbers in parentheses indicate the Institutional Issues which the policy options address.

4. Promote the Development of Building Standards and Regulations that will Encourage the Further Use of Earth-Sheltering
 - a) Establish earth-shelter safety and comfort standards (I)
 - b) Extend model building codes and HUD Minimum Property Standards (II)
 - c) Develop licensing requirements for builders and trainers (II)
 - d) Promulgate stringent energy-use standards for all structures (V)
5. Promote Land Use Planning and Regulation that will Encourage Earth-Sheltering
 - a) Create model earth-sheltered land use controls (II)
 - b) Develop and disseminate model solar access protection measures (IV)
 - c) Encourage community designs that optimize neighborhood cohesiveness (IV)
 - d) Encourage inclusion of underground space in community development plans (V)
 - e) Develop model plans for earth-sheltered neighborhoods (V)
 - f) Encourage greater urban density (V)
 - g) Pass stricter environmental controls for above-ground buildings (V)
 - h) Require Environmental Impact Statement for large development projects (V)
6. Use the Direct Expenditure of Government Funds to Stimulate the Increased Use of Earth-Sheltered Structures
 - a) Build earth-sheltered structures for sale or lease to private users (II)
 - b) Purchase materials in bulk for resale to individual builders in order to minimize cost (III)
 - c) Provide direct subsidies for owners agreeing to share their earth-sheltered dwellings in case of emergency (V)
7. Increase the Amount of Money Available for Loans on Earth-Structures at Attractive Rates
 - a) Provide low interest assumable loans to promote resale (I & III)
 - b) Expand loan insurance program (III)
 - c) Provide construction loans (II)
 - d) Establish loan insurance programs for construction loans (II)
 - e) Encourage purchase of earth-sheltered mortgages on secondary market (III)

8. Assure the Availability of Attractive Insurance Policies for Earth-Sheltered Structures
 - a) Provide insurance to cover construction-period liability (II)
 - b) Encourage preferential insurance policies for building owners (IV)
9. Assure the Availability of Building Materials, Techniques, and Plans for High-Quality, Cost-Effective Earth-Sheltered Structures
 - a) Aid developers in design refinements (I)
 - b) Sponsor research and development to facilitate earth-sheltered construction (II)
 - c) Develop and disseminate proven standardized plans for earth-sheltered structures (II & III)

Thank You Very Much for Your Cooperation.

APPENDIX D

Panel of Experts

Appendix D

Panel of Experts

L. J. Atkison
Architect
Edgerton, Missouri

Ronald J. Morony
Building Technology Division
Office of the Assistant Secretary
for Policy Development and
Research - Dept. of Housing
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Michael B. Barker
American Institute of Architects
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David Mosena
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Stillwater, Oklahoma

David Roessner
Technology and Science
Policy Program
School of Social Science
George Institute of Technology
Atlanta, Georgia

George Courville
Oak Ridge National Laboratory
Oak Ridge, TN

Raymond L. Sterling, Director
Underground Space Center
University of Minnesota
Minneapolis, Minnesota

H. Paul Friesema
Department of Political Science
Northwestern University
Evanston, IL

William A. Thomas
American Bar Foundation
Chicago, Illinois

Kenneth Labs
Undercurrent Design Research
New Haven, Connecticut

Kathleen Vadnais
Editor
Earth Shelter Living
St. Paul, Minnesota

Harold Lambright
Syracuse Research Corporation
Syracuse, New York

Donald Watson
American Institute
Architects
Guilford, Connecticut

Frank Moreland
Earth-Covered Structures, Inc.
Fort Worth, Texas

Allan M. Ziebarth
President
Earth Shelter, Inc.
Omaha, Nebraska

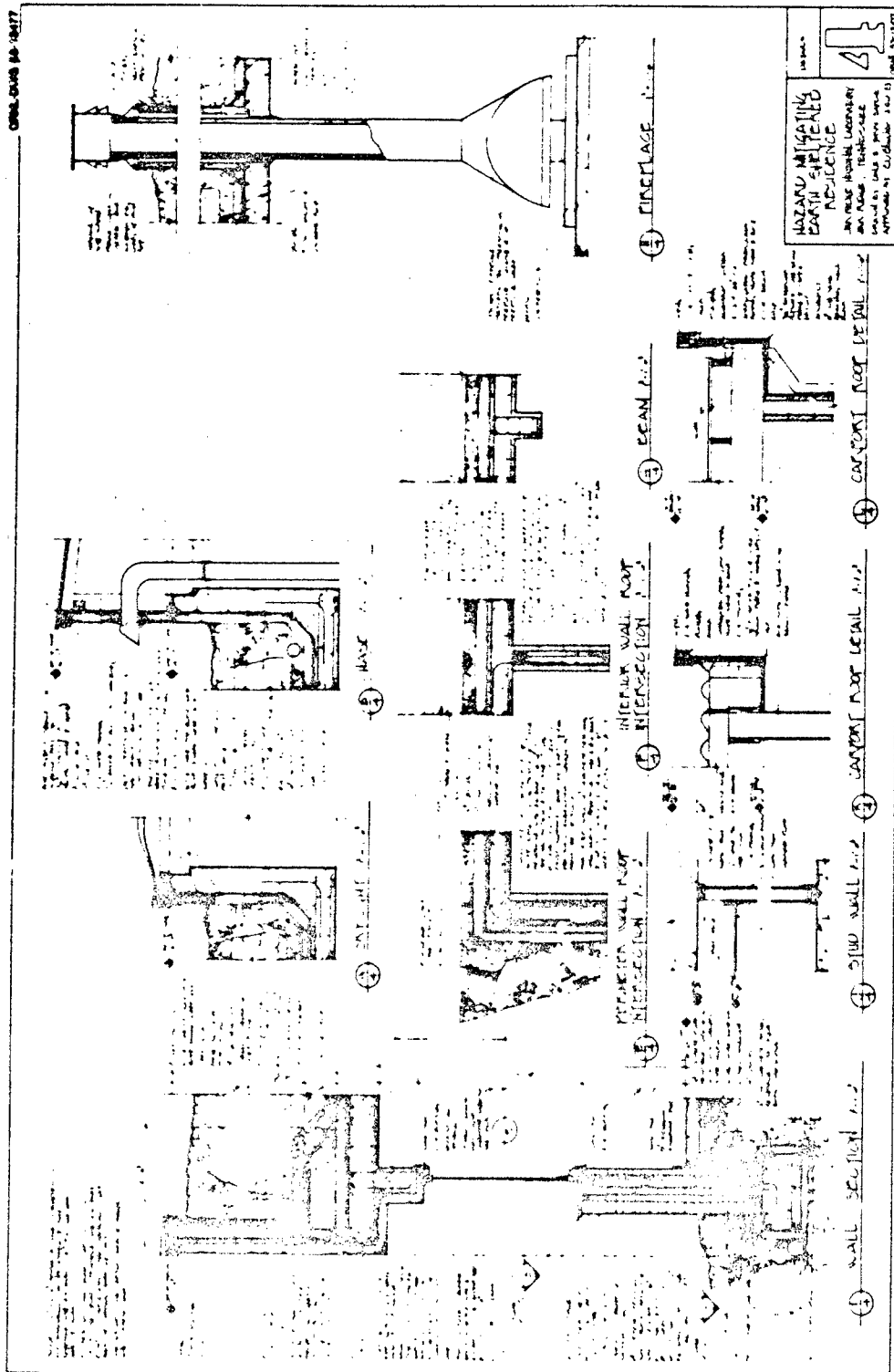
APPENDIX E

Construction Drawings of Hazard-Mitigating
Earth Sheltered Residence

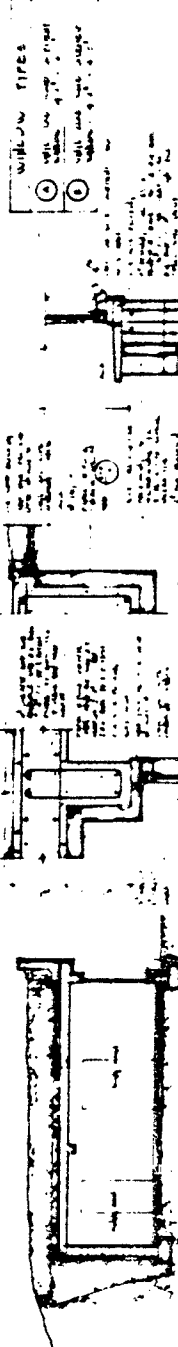
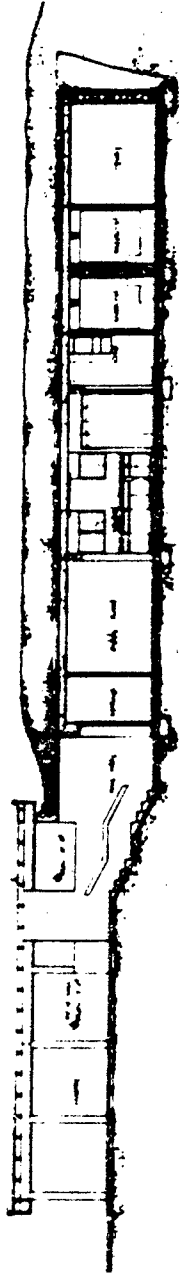
These eight reduced reproductions of working drawings of a Hazard-Mitigating Earth Sheltered Residence are too small to be usable as construction drawings. Full-sized copies of the construction drawings suitable for reproduction have been submitted to Publications Management, Federal Emergency Management Agency, POB 8181, Washington, DC 20024.

The drawings have been carefully checked but the structure has not been test built at the time of this writing.



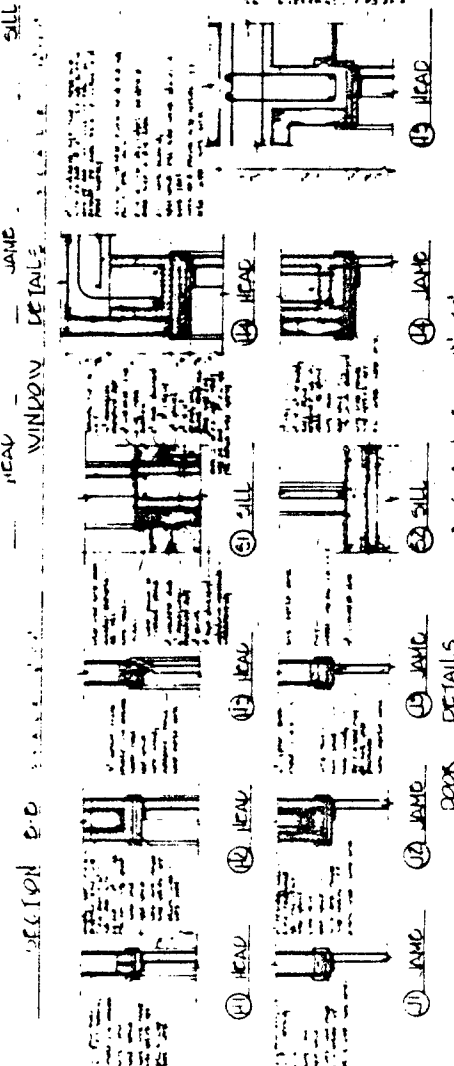


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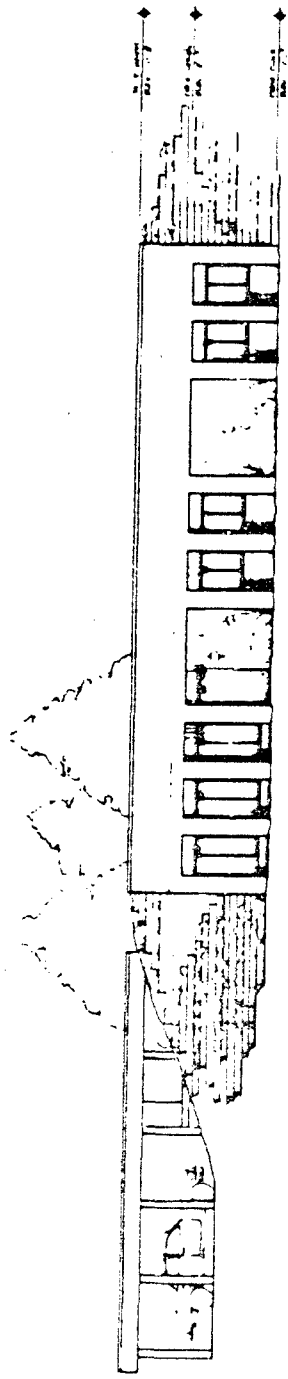
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HAZARD MITIGATING
EARTH-SHAKING
RESISTANCE
ONE STORY BUILDING
30 PAGES
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SOUTH ELEVATION

SCALE 1/4" = 1'-0"



WEST ELEVATION

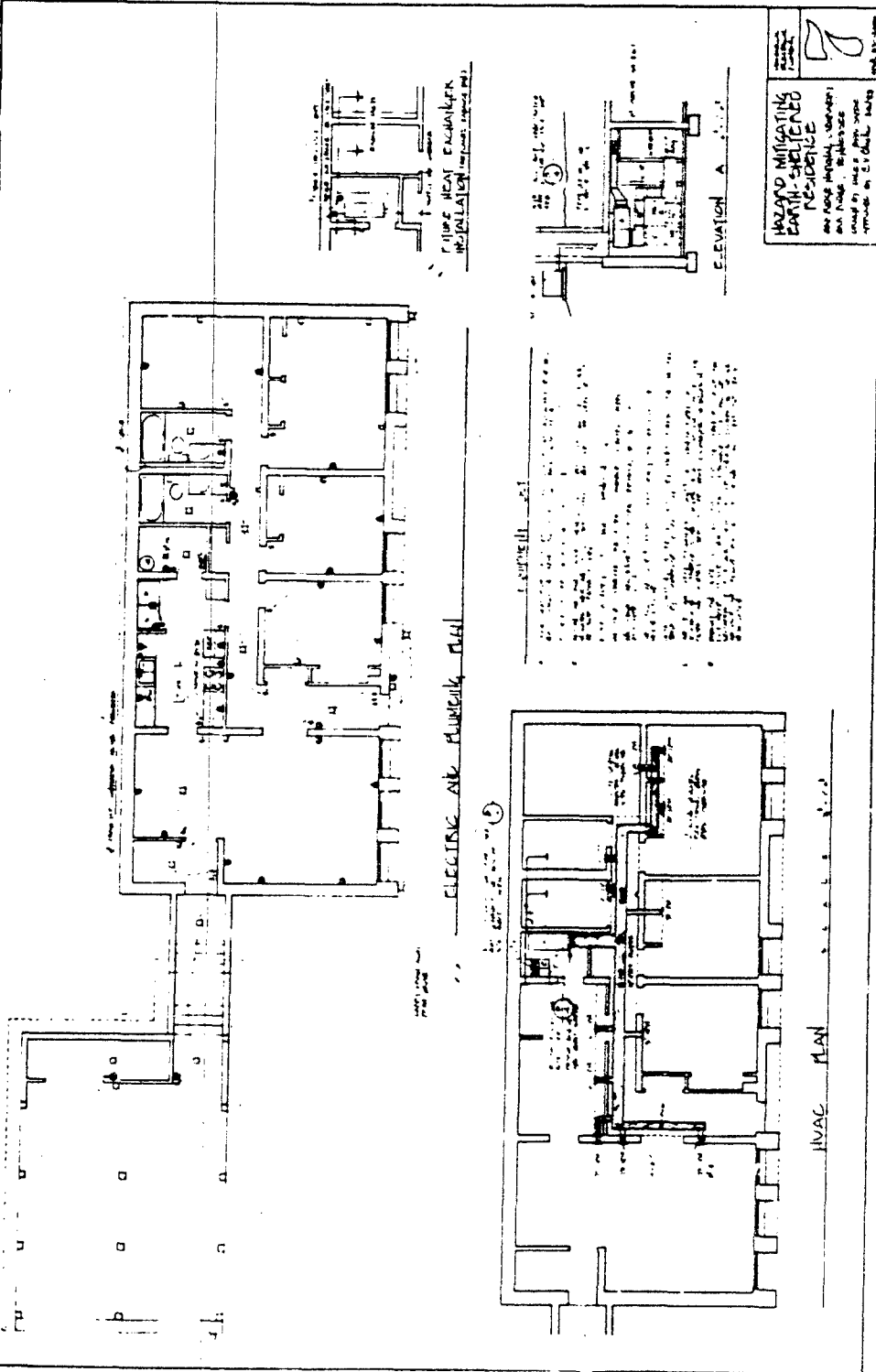
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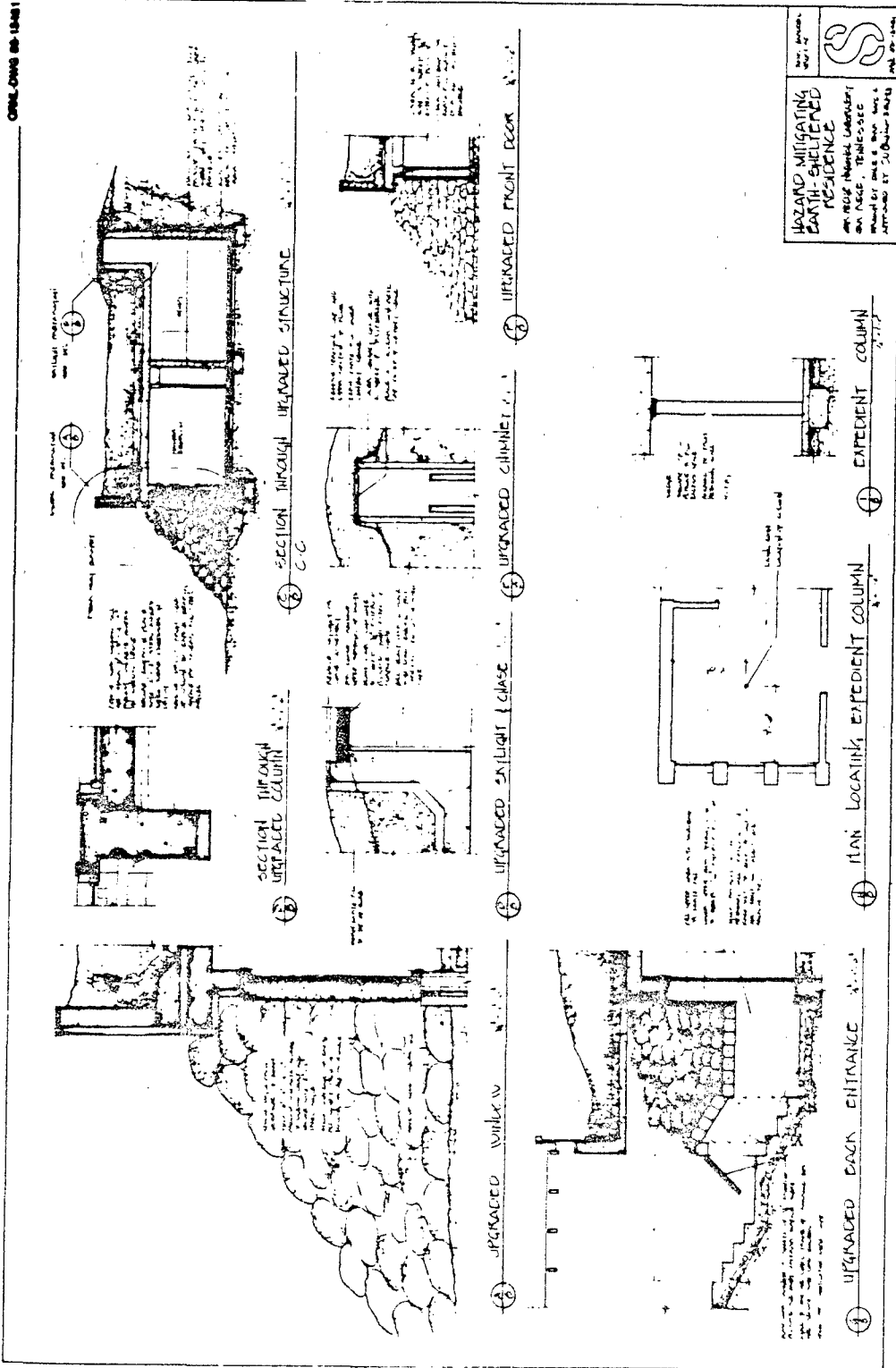
EAST ELEVATION

SCALE 1/4" = 1'-0"

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	6
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