Case for Underground Schools.

Oklahoma State Dept. of Education, Oklahoma City.
Defense Civil Preparedness Agency (DOD), Battle Creek, Mich.

[79]

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Space Utilization; Thermal Environment; *Underground Facilities; *Windowless Rooms

*Oklahoma

The underground school offers several advantages. Preliminary studies in Oklahoma have shown that these schools perform exceptionally well as learning environments. The lack of noise and distractions helps teachers keep the attention of their students. Underground structures can protect people against a broad range of natural and man-made disasters, and schools offer the additional advantage that they are generally located central to the highly populated regions where emergency shelters may be most needed. In many cases, these schools were built with the understanding that the schools would provide sanctuary for the community in the event of tornadoes. There are indications that revenue requirements for energy and maintenance of underground schools are likely to be significantly less than requirements for comparable above ground schools. There are possibilities of making dual use of available land by building underground. Case studies of 12 schools show capacity, construction costs, floor plans, and photographs. (Author/MLF)
A CASE FOR UNDERGROUND SCHOOLS

STORM

FALLOUT

HEAT

COLD

Oklahoma State Department of Education
Leslie Fisher, Superintendent
A Case For Underground Schools

Prepared For

Defense Civil Preparedness Agency
Department of Defense

Contract Number DCPA01-78-C-0265
Work Unit 1151 E

By

School Plant Services
Bob Martin, Administrator

In Cooperation With

Oklahoma Civil Defense
Hayden Haynes, Director
Foreword

School administrators are faced with significant problems in providing desirable learning environments due primarily to the continued growth of school population and the general obsolescence of older buildings. These problems are compounded with concerns about special features required by the Federal Government, storm protection, and rising energy costs. Building underground may be a viable alternative to the more conventional approach.

The Underground School offers several advantages. Preliminary studies by our staff at the State Department of Education have shown that these schools perform exceptionally well as learning environments. Both teachers and principals alike have commented on the lack of noise and distractions and the ease with which they could keep the attention of their students. Underground schools are highly valued for storm protection. In many cases, these schools were built with the understanding that the schools would provide sanctuary for the community in the event of tornadoes. This is particularly important in Oklahoma since an average of 54 tornadoes are sighted on the ground each year. There are indications that revenue requirements for energy and maintenance of underground schools are likely to be significantly less than requirements for comparable above ground schools. There are possibilities of making dual use of available land by building underground. For example, the land over an underground school could be used as playground areas.

I want to stress, however, that the safety and energy efficiency of underground schools depend crucially on their design. Sound engineering principles and techniques need to be applied by experienced architects and engineers.

Leslie Fisher
State Superintendent
of Public Instruction
Commentary by the State Civil Defense Director

This publication was prepared using funds provided by the Defense Civil Preparedness Agency with the State Civil Defense in the capacity of financial manager.

Primary mission of civil defense is to save lives and protect property in any type of catastrophe, man made, nuclear or from natural causes. Preparedness is one of the keys to safeguard ourselves and our property. The construction of protected schools, whether underground or bermed, would certainly provide safety for our school children.

I urge you to seriously consider constructing your next school using a "protected" design.

Hayden Haynes
Director
Oklahoma Civil Defense
Acknowledgments

SCHOOL PLANT SERVICES
- Bob Martin, Administrator
  - Dr. Charles Holleyman, Assistant Administrator
  - Jim Hodges, Architect, AIA
  - Paul Hallett, P.E.

CURRICULUM SECTION
- Dr. Earl Garrison, Administrator

BETHEL SCHOOL DISTRICT
- Belvin Cantrell, Superintendent

BLANCHARD SCHOOL DISTRICT
- G. Pruitt Lewis, Superintendent

DAVIS SCHOOL DISTRICT
- E. Wayne Byrd, Superintendent

DUKE SCHOOL DISTRICT
- Bill Morgan, Superintendent

NORMAN SCHOOL DISTRICT
- Dr. Wm. D. Anderson, Jr., Superintendent
  - Don Dillon, Staff Assistant for Facilities

MANGUM SCHOOL DISTRICT
- Ray Garton, Superintendent

McLOUD SCHOOL DISTRICT
- J.E. Walker, Superintendent

MOORE SCHOOL DISTRICT
- Joe Lindsey, Superintendent
  - Dick Corbitt, Assistant Deputy Superintendent

PRAGUE SCHOOL DISTRICT
- Roy Grissom, Superintendent

SEILING SCHOOL DISTRICT
- Gerald Daugherty, Superintendent

WASHINGTON SCHOOL DISTRICT
- John Pryor, Superintendent

WELEETKA SCHOOL DISTRICT
- David Puckett, Superintendent

WELLSTON SCHOOL DISTRICT
- Frank Duke Bryant, Superintendent

WESTERN HEIGHTS SCHOOL DISTRICT
- Dr. William E. Hodges, Superintendent
  - Don Anderson, Assistant Superintendent
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
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<td>Real Estate</td>
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<td>Case Studies</td>
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</table>
The Insurance Service Office in Oklahoma reports that there is no difference in insurance rates for underground buildings and identically constructed above ground buildings. The reasons given are twofold. First, there is no established rating classification system specifically for underground structures. Second, rates for underground buildings are based on the same judgement factors applied to conventional schools. In the case of fire insurance, the major factors are: construction type, occupancy, exposure and municipal protection.

**FIRE INSURANCE**—There are definite possibilities of savings on fire insurance premiums by building underground. The lower premium would be based primarily on the higher quality of underground construction. The type of construction generally employed for underground buildings is classified as fire resistive. This means that all structural members, including walls, partitions, columns, floors, and roofs are made of non-combustible materials. Fire rating authorities will assess penalty charges for any deficiencies such as unprotected steel, substandard wall thickness and inferior wall materials.

**EXTENDED COVERAGE**—Rating officials often provide lower rates for underground buildings because these structures have a lower exposure to surface hazards such as tornadoes, hail, and ice storms. Rates for extended coverage are mostly dependent on anticipated losses and underground schools should eventually get better rates as insurance companies compile experience data.

**VANDALISM**—Vandalism is not a problem in Oklahoma. Minor offenses reported such as paint scuff marks and Halloween pranks have negligible costs. The underground school appears to be less attractive to vandals because there are limited exposed walls. Also, the vandal may be fearful of being trapped underground with no convenient means of escape.

There are possibilities for some savings in utilization. Landscaping for above-ground buildings usually involves more expense to aesthetically balance the view. Underground buildings usually have a grass or play area without extensive landscaping. Because of this difference, more grounds maintenance appeared to be involved in the control schools, but records were not available to establish cost differentials.

On a unit for unit comparison (without considering one level to multilevel comparisons, high-rise to depth extension, etc.) savings might be generated by using the land over the underground structure as an activity area. This could reduce the need for purchasing more land to expand play areas. Again cost relationships probably would not be the major factor in most areas of Oklahoma for this decision, but the need for activity space. Some schools found that constructing a gymnasium above an underground school produced noise problems. To avoid this, more depth would be necessary, thus adding to the cost.
# REAL ESTATE COST DATA

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*Current value of land was determined from recent transactions in the same area or by acceptable rates of appreciation.*
Design

Most of the underground schools in Oklahoma were designed to provide protection from high winds and tornadoes. For example, when plans were conceived for a new school in Wellston, Oklahoma, it was decided to build the entire school underground rather than build a conventional school with a much needed but little used underground storm shelter.

The underground design offers a number of advantages. Below ground space is almost always the safest location for shelter from high winds and tornadoes. Another advantage is that thermal properties of soil can be used to optimize heat gain and loss thus conserving energy. Building underground makes better utilization of available land since the space above ground structures can be used for playground areas and other conventional buildings. With three feet of earth cover, underground structures offer significant security from nuclear fallout. The underground design also minimizes vandalism problems in schools by limiting exposed walls.

The safety afforded by underground schools depends crucially on their design. This holds for tornado safety as well for radiation shielding and blast protection. Several of the schools studied are very lightweight and do not afford significant blast protection. These schools may also perform poorly under tornado loading. Energy efficiency also has to be designed in. Schools, underground or not, will only be as energy efficient as they are designed to be.

State law limiting the level taxation for new school construction in Oklahoma has a major impact on underground school design. This law often favors less-expensive building technologies and may be an inhibiting factor with respect to decisions to build underground since underground buildings often cost more to build than conventional buildings. However, school administrators believe that the long-term economy of underground buildings justifies a greater construction cost.

Architects have been very competitive in design costs with fees averaging 6% of building costs (see Design Cost Data Table). The fees are the same for conventional aboveground buildings. The only variations noted apply to small projects or major renovations.
## DESIGN COST DATA

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*School was constructed in two different phases.
Construction

Oklahoma has constructed twenty-seven schools with some portions of the buildings underground and fifteen more with earth bermed walls. In most cases, protection from tornadoes was the primary reason for building underground. Many of the schools also serve as community storm shelters.

Construction costs have increased dramatically since 1965 for both aboveground and underground schools. (See Construction Cost Data Table.) Construction costs are site-specific and not easily generalized. However, the data indicates that the costs for underground buildings are slightly higher than for comparable surface structures. For example, the Superintendent from Duke Schools reported that their underground school was completed in 1965 for $1 to $2 more per square foot than a similarly constructed aboveground school. The Prague school was completed in 1967 for $4 to $6 more per square foot on the bid price.

The higher construction costs are attributed to increased requirements for excavation, concrete framework, roof structure, ventilation and underground drainage. In some instances, building contractors also add contingency fees as a means of protecting themselves against the possibility of weather delays and hard to reach water leaks. It is generally believed, however, that underground construction costs will become more competitive with conventional building costs as architects and engineers gain experience with this type of construction.

While the initial costs are higher, School administrators believe that these higher costs are offset by long term savings. The long term savings come primarily from decreased costs of maintenance, operation and repair of underground buildings. Over the years, the Duke system has experienced reduced costs of both interior and exterior maintenance. A further benefit was that losses due to vandalism have been practically non-existent.

Although administrators are generally satisfied with the performance of their underground schools, there are some changes they would like to see. The air handling system should be specifically designed to ensure its compatibility with underground construction. Better techniques should be applied to improve thermal efficiency and waterproofing.
<table>
<thead>
<tr>
<th>SCHOOL</th>
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<th>GROSS FLOOR AREA</th>
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*School was constructed in two different phases.
Energy Consumption

Most administrators of underground schools were confident that their schools were more energy efficient than other schools. Unfortunately, the amount of reduction was not often known. In many cases, the underground school was metered along with an above ground facility.

One administrator stated that their cooling unit, installed in 1966, did not operate efficiently and that installation of a newer unit would show marked reductions in energy costs. The Superintendent from Duke Elementary and High School related that he paid an unscheduled visit to his school during the Christmas vacation. Even though the school had not been operated for one week, the inside temperature was 68° to 69° while it was 0° outside.

An analysis of utility billing information for the school year 1977-78 provides some evidence to support the belief that underground and bermed schools are more energy efficient than comparable above ground schools. This evidence is not conclusive because of mixed metering with above ground buildings and the varying percentages of the total floor area below grade. (See Energy Consumption Data Table.) It should be noted that even though the bermed and underground schools appear to use less energy per gross square foot per year, this lower usage is not generally reflected in lower annual energy costs per square foot primarily because of the increased use of electrical energy.

All forms of energy are not provided at the same cost. Electric energy has been generated, transported and delivered in a clean and very versatile form. This is reflected in its cost, which is relatively high on the basis of dollars per million BTU since it includes cost elements for fossil or nuclear energy, energy conversion losses, transmission line losses, and others.
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</tr>
<tr>
<td>Bethel</td>
<td>15%</td>
<td>36.9</td>
<td>20.5*</td>
<td>57.4</td>
<td>0.46</td>
</tr>
<tr>
<td>Blanchard</td>
<td>45%</td>
<td>39.9</td>
<td>39.9</td>
<td></td>
<td>0.41</td>
</tr>
<tr>
<td>Davis</td>
<td>100%</td>
<td>48.2</td>
<td>48.2</td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>Duke</td>
<td>66%</td>
<td>29.2</td>
<td>29.2</td>
<td></td>
<td>0.29</td>
</tr>
<tr>
<td>Hydro</td>
<td>19%</td>
<td>20.6</td>
<td>22.1</td>
<td>42.7</td>
<td>0.26</td>
</tr>
<tr>
<td>John Glenn</td>
<td>16%</td>
<td>29.0</td>
<td>38.4</td>
<td>67.4</td>
<td>0.35</td>
</tr>
<tr>
<td>Weleetka</td>
<td>25%</td>
<td>25.9</td>
<td>36.3</td>
<td>62.2</td>
<td>0.35</td>
</tr>
<tr>
<td>Wellston</td>
<td>10%</td>
<td>22.0</td>
<td>13.8</td>
<td>35.8</td>
<td>0.24</td>
</tr>
</tbody>
</table>

*Propane

1 MBTU = 1,000 BTU
Disaster Protection

It is disaster protection, against tornadoes, that has provided impetus for design and construction of underground schools in Oklahoma. However, underground structures can protect people against a broad range of natural and man-made disasters; and schools offer the additional advantage that they are generally located central to the highly populated regions where emergency shelters may be most needed.

Quite simply, the ability of a structure to provide shelter against physically disruptive forces such as tornadoes, hurricanes, hailstorms, or high winds is related to the loading the structure can withstand. Placing a structure underground enables the strength of the structure to be augmented by the strength of the soil around it. If the structure is also strong enough to support a soil cover of two feet, that will be sufficient to hold the roof against tornadoes, high winds, etc., and to protect against hailstones and falling objects. Moreover, a structure that will support a soil cover of three feet will be very effective against fallout radiation and could be made effective against a nuclear attack.

The table on the facing page provides a quantitative summary of the disaster protection currently afforded as well as what could be provided in an emergency for each of the underground schools.

Column 2 gives the total additional load that can be superimposed on each structure without exceeding the design value. This superimposed load might be concrete, soil, or people. Column 3 gives the superimposed soil load that, if added to the bare structure, would provide disaster protection sufficient to meet nearly all circumstances (tornadoes, radiation, etc.). This soil load is given in both inches and pounds per square foot.

Comparison of the data in columns 2 and 3 shows that only three schools can support the recommended soil cover load safely and permanently, as built. Two additional schools could carry this load as a temporary emergency measure (column 4 vs. column 3). Under such an emergency expedient, it is seen (column 5 vs. column 3) that all but the two bermed schools could be safely covered with soil to the depth indicated in column 3. With the temporary emergency strengthening and the soil cover added to obtain a PF 1000 radiation protection, the strength remaining could resist the blast loadings indicated in column 6.

A few important points and findings should be noted:

- Several of the schools already have some soil cover. The figures in table refer to total soil cover.
- Neither bermed school provides good shelter from tornadoes that pass directly overhead, because their roofs might be lifted off.
- For those schools where a PF 1000 can be attained without exceeding the design load (corresponding to the underlinings in column 2), a total soil cover as indicated in column 3 would be a desirable permanent disaster protection measure.
- Had a disaster protection analysis and appropriate design changes been made before construction, any of the underground or bermed schools could have been built to provide PF 1000 (and immunity to tornadoes passing directly overhead, as a consequence). The added cost would total somewhere between $0.50 and $1.00 per square foot (less than 3% of total cost, in most cases).
## Radiation and Blast Protection Capability of Underground Schools Studied

<table>
<thead>
<tr>
<th>Name of School</th>
<th>Superimposed Load to Equal Design Load (psf)</th>
<th>Additional Soil Required to Provide PF 1000 (1) (in.)</th>
<th>Soil Loading Allowable in an Emergency (2) (in.)</th>
<th>Maximum Superimposed Load when Strengthened (3) (psf)</th>
<th>Blast Protection when Strengthened and Upgraded to PF 1000 (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arnett</td>
<td>145</td>
<td>28</td>
<td>19</td>
<td>1080</td>
<td>5.6</td>
</tr>
<tr>
<td>Bethel (4)</td>
<td>277</td>
<td>29</td>
<td>29</td>
<td>1780</td>
<td>10.3</td>
</tr>
<tr>
<td>Blanchard</td>
<td>75</td>
<td>19</td>
<td>15</td>
<td>2265</td>
<td>14.4</td>
</tr>
<tr>
<td>Blanchard (4)</td>
<td>100</td>
<td>19</td>
<td>19</td>
<td>2600</td>
<td>16.7</td>
</tr>
<tr>
<td>Addition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davis</td>
<td>167</td>
<td>30</td>
<td>19</td>
<td>840</td>
<td>3.8</td>
</tr>
<tr>
<td>Henry Wadsworth (5)</td>
<td>35</td>
<td>33</td>
<td>4</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>Longfellow (bermed)</td>
<td>33</td>
<td>330</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydro</td>
<td>100</td>
<td>29</td>
<td>11</td>
<td>680</td>
<td>2.7</td>
</tr>
<tr>
<td>John Glenn (6)</td>
<td>245</td>
<td>19</td>
<td>19</td>
<td>4570</td>
<td>30.4</td>
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<tr>
<td>Prague</td>
<td>200</td>
<td>30</td>
<td>23</td>
<td>1360</td>
<td>7.4</td>
</tr>
<tr>
<td>Selling</td>
<td>310</td>
<td>30</td>
<td>19</td>
<td>1900</td>
<td>11.1</td>
</tr>
<tr>
<td>Washington (5) (bermed)</td>
<td>30</td>
<td>36</td>
<td>4</td>
<td>.150</td>
<td>0</td>
</tr>
<tr>
<td>(bermed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weleetka (6)</td>
<td>330</td>
<td>29</td>
<td>29</td>
<td>2140</td>
<td>12.8</td>
</tr>
<tr>
<td>Wellston (6)</td>
<td>300</td>
<td>18</td>
<td>18</td>
<td>5440</td>
<td>36.5</td>
</tr>
</tbody>
</table>

1. PF refers to Protection Factor, from nuclear radiation. A PF 1000 is likely to be adequate for almost any eventuality.
2. Only in an extreme emergency will it be valid to exceed the Design Load (column 2) without first strengthening the structure.
3. An example of a temporary (expedient) option for strengthening is given in Fig. 1. Only five of the schools could be upgraded to PF 1000 without first strengthening the structure.
4. In an extreme emergency, these two schools could be upgraded to PF 1000 without first strengthening the structure (columns 3 vs 4).
5. These bermed structures could not be upgraded to PF 1000 even with temporary strengthening of the structure (columns 3 vs 5).
6. These three structures could safely be upgraded immediately and permanently and not exceed the design load (columns 3 vs 2).
The Seiling school is used here to provide an example of how to implement expedient structural upgrading. Note that several desks and two students have been left in the picture of the modified school room to provide perspective. The subdivided spaces will be generally about one third of the open space area. Though obviously more confining, the temporary inconvenience may be far outweighed by the benefit gained as an emergency shelter.

The upgrading concept applied is basically simple. In a typical structure above ground, a 2 psi loading over the surface of a wall will collapse it. In an underground structure, where the walls are protected by the soil around them, the roof is the vulnerable element and "shoring" (such as shown in the figure) will strengthen the roof and hence, the entire structure significantly. In an emergency, shores can be cut from wood posts and beams and assembled in a matter of hours. The calculations summarized in columns 5 and 6 of the table were based on this kind of emergency strengthening of the roofs in the underground schools.
Sociological and Psychological Attitudes

This section of the report summarizes a conference held in Oklahoma City on February 22, 1979. The purpose of the conference was to explore trends and experiences in Oklahoma underground schools. Conference participants included twelve school district superintendents, principals, and teachers, who related their experiences with underground schools.

The participants focused on their observations of student behavior and on community attitudes toward underground schools. Comments are summarized in the following notes:

**LEARNING ENVIRONMENT** - Teachers and principals alike believe that their underground schools provide a superior learning environment due primarily to a lack of noise and distractions. Teachers can also make better use of classroom walls to stimulate learning since there are no windows.

**PSYCHOLOGICAL EFFECTS** - Conference participants were asked to relate any instances of phobia, apprehension, or psychological disturbance on the part of students that could be in any way related to being underground. There were none. One teacher commented that "I never really knew I was underground and neither did the children."

**PHYSIOLOGICAL EFFECTS** - Physiological effects were addressed in terms of specific complaints such as headaches, blurred vision, fatigue, nausea, and behavioral changes. One educator mentioned that students in one underground school had become lethargic in the afternoons because of improper ventilation. The problem was solved after proper ventilation levels were established.

Lack of dust in underground schools provided a positive physiological effect in the relief of chronic allergy symptoms. The superintendent of the Duke underground school reported that a student in the school had said that she loved coming to school because it was the only place she could breathe.

**COMMUNITY ATTITUDES** - A central attitude that emerged was the sense of security felt by community members in knowing that they have a shelter from tornadoes. Participants also reported that for some residents, underground schools may not be easily identified as a community landmark.
The primary considerations in deciding to build this underground school were conservation of land area, storm protection, reduced energy usage and controlled learning environment. Other advantages which have emerged are lower insurance rates and a negligible amount of vandalism.

A 1977 addition added additional above ground classrooms on top of the belowground classrooms and surrounding the initial entry core.
Parts of the above ground school were destroyed by a tornado and school administrators were primarily concerned for student safety. Energy conservation, controlled environment, and shortage of activity space were also influencing factors in the decision to build this underground school.

The school was built in two phases, Project A completed in 1968, Project B in 1974.
Davis Elementary School

Location: Davis, Oklahoma
District: Davis Independent District
Superintendent: E. Wayne Byrd
Architect: Locke, Wright & Foster
Oklahoma City, Oklahoma
Completed: 1967
Capacity: 380 Students--Grades 1-6
Floor Area: 12,500 Sq. Ft.
Construction: $16.00 per Sq. Ft.

This school district was faced with a choice between playground space and construction of a new school. They found that they could have both by building underground. The school provides five classrooms, learning center, and administrative office.

Administrators believe their school performs exceptionally well. Several advantages that have emerged deal directly with the absence of vandalism and underground school injuries, lower insurance rates, tornado protection and controlled learning environment.
DUKE ELEMENTARY AND HIGH SCHOOL

Location: Duke, Oklahoma
District: Duke Independent District
Superintendent: Bill E. Morgan
Architect: William Appleby, AIA
Altus, Oklahoma
Completed: 1965
Capacity: 300 Students--Grades K-12
Floor Area: 22,760 Sq. Ft.
Construction: $12.32 per Sq. Ft.

The Duke School was built to replace the previous school which was destroyed by fire in April, 1964. It was designed to also serve as a community fallout and tornado shelter for 1,950 persons.

The underground design offers a number of advantages which include more compact floor plans, no distractions from outside noise, reduced maintenance and energy costs.
JOHN GLENN
ELEMENTARY SCHOOL

Location: Oklahoma City, Oklahoma
District: Western Heights
Superintendent: Dr. William E. Hodges
Asst. Supt.: Don Anderson
Architect: Bill Appleby, AIA
Completed: 1967
Capacity: 250 Students-Grades 5-6
Floor Area: 9,840 Sq. Ft.
Construction: $11.00 per Sq. Ft.

Land conservation was the primary consideration in the decision to build this underground school. The school is also used as a community storm shelter.
HYDRO ELEMENTARY SCHOOL

Location: Hydro, Oklahoma
District: Hydro Independent District
Superintendent: Charles Grambrell
Architect: Larry Anderson, AIA
Oklahoma City, Oklahoma
Completed: 1975
Capacity: 250 Students—Grades K-6
Floor Area: 10,000 Sq. Ft.
Construction: $24.50 per Sq. Ft.

The school administration's concern for student safety, energy conservation, and controlled environment were the primary reasons for building underground.
LONGFELLOW MIDDLE SCHOOL

Location: Norman, Oklahoma
District: Norman Independent District
Superintendent: Dr. William D. Anderson, Jr.
Architect: Bozalis and Roloff
Oklahoma City, Oklahoma
Completed: 1974
Capacity: 608 Students--Grades 6-8
Floor Area: 36,062 Sq. Ft.
Construction: $23.35 per Sq. Ft.

This is a typically bermed school. The berms were raised to within 4 feet of the roof to limit direct access. Bermed schools have several advantages. Among the pluses are: safety, energy conservation, a reduction in the chance of water seepage, little or no vandalism, and an elimination of the need for sewer lifts.
The Prague School was originally designed as a conventional above ground school. This was changed to an underground school when a tornado struck the town. Small school site and a desire for controlled classroom environment also influenced the decision to build underground.

School administrators are pleased with the controlled environment and are planning to build a second underground school.
The school administration's concern for student and staff safety, the need for all of their outdoor activity space, and the attractiveness of a completely controlled classroom environment, led to the construction of an underground school.

Six underground classrooms house 3rd, 4th and 5th grades and provide shelter for the entire student body and staff.

By building underground and covering the structure with two feet of dirt, Seiling was able to build three tennis courts on top of the underground building.
Ramp

Tennis Courts Above Underground School

Section
TUPELO HIGH SCHOOL

Location: Tupelo, Oklahoma

District: Tupelo Independent District

Superintendent: Paul Fortner

Architect: Ben Graves and Associates, AIA, Norman, Oklahoma

Completed: 1978

Capacity: 350 Students--Grades 7-12

Floor Area: 16,750 Square Feet

Construction: $26.43 per Sq. Ft.

Faced with the growing national need for energy conservation, the local need for a community storm shelter, and a limited budget, Tupelo's new high school was constructed above ground with a tilt-up, sandblasted reinforced concrete structure. Earthen berms cover seventy percent (70%) of the exterior surface area. This combination provided a storm secure structure with an approximate sixty percent (60%) reduction in heating costs during the coldest winter ever recorded in Oklahoma.
WASHINGTON HIGH SCHOOL

Location: Washington, Oklahoma

District: Washington Independent District

Superintendent: J.W. Pryor

Architect: Reid Architectural Firm
          Oklahoma City, Oklahoma

Completed: 1973

Capacity: 280 Students-Grades 9-12

Floor Area: 18,067 Sq. Ft.

Construction: $16.33 per Sq. Ft.

Safety, due to the fact a tornado had destroyed part of the town, and the extreme shortage of space on the school site were the prime factors in Washington's building and underground school.

The school administration finds that the problems with the exposed roof and the additional cost of an underground structure might prevent them from building another underground building.
### WELEETKA ELEMENTARY SCHOOL

**Location:** Weleetka, Oklahoma

**District:** Weleetka Independent District

**Superintendent:** David Puckett

**Architect:** Richard Dunham, AIA
Oklahoma City, Oklahoma

**Completed:**
- A: 1972
- B: 1978

**Capacity:**
- A: 163 Students--Grades 4-6
- B: 163 Students--Grades K-3

**Floor Area:**
- A: 12,514 Sq. Ft.
- B: 12,514 Sq. Ft.

**Construction:**
- A: $18.79 per Sq. Ft.
- B: $36.28 per Sq. Ft.

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Safety of the children from tornados, controlled environment, energy savings, and limited school site space were the prime factors in determining the first underground structure at Weleetka.

The school was built in two phases: Project A completed in 1972, Project B in 1978.
The school is located 18 ft. underground. All that is visible at ground level is the entry way to the 13,000 sq. ft. subterranean structure.

Wellston is often subject to wind storms and tornadoes. When plans for the new school were conceived, it was decided that rather than build a conventional, above-ground school with a much needed but little used storm shelter underground, it would be most economical to put the entire structure below the surface and make full use of all space.


22. Rowan, Jan C. "The Earth" - Special Issue, Progressive Architecture, Apr. 1967, pp 125-184


42. Wells, Malcolm B.: Down With Architecture, Printed and distributed by Malcolm Wells, Aug 75.


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