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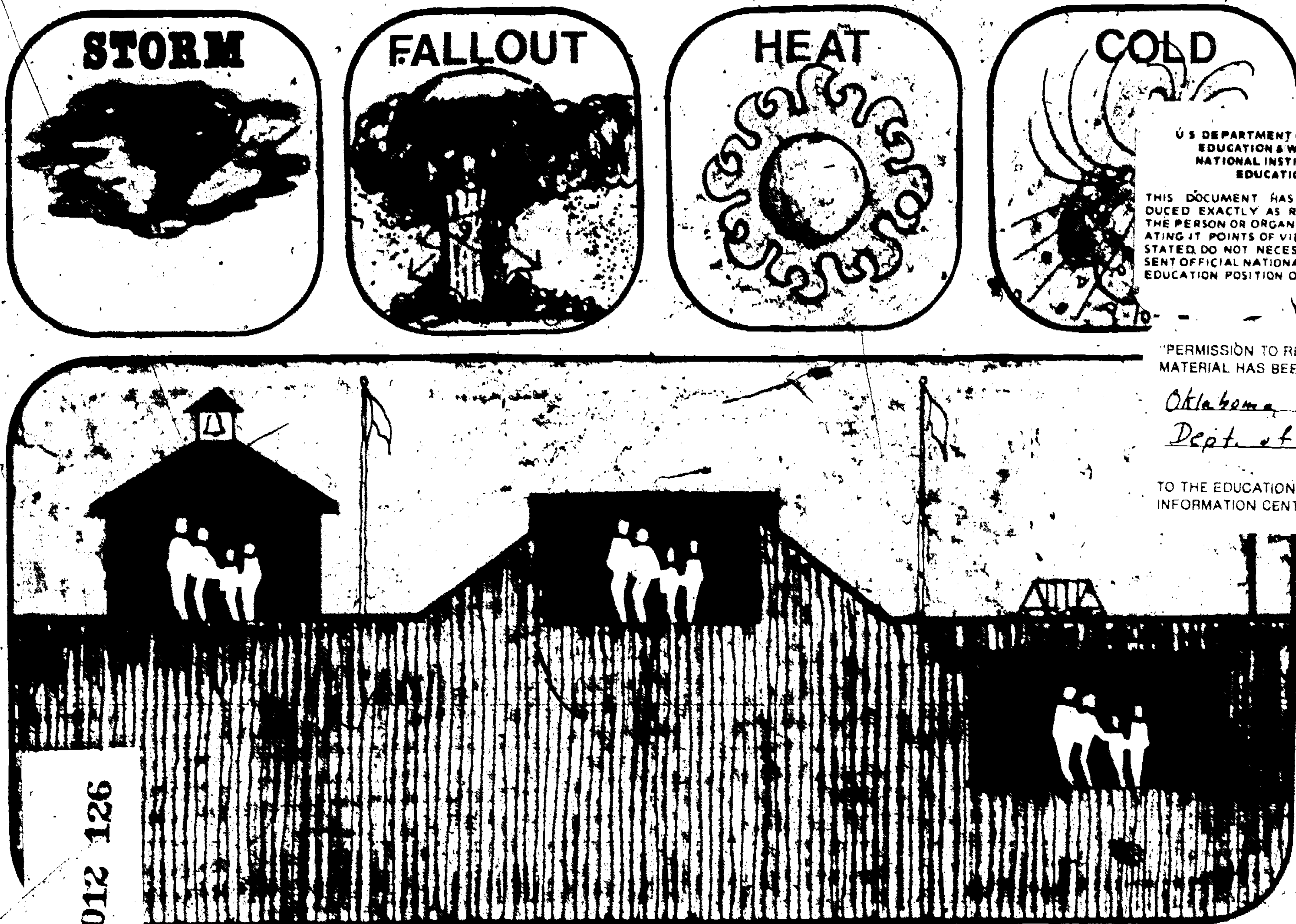
ABSTRACT

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 shools 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



Oklahoma State Department of Education

Leslie Fisher, Superintendent

A Case For Underground Schools

Prepared For

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Department of Defense

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By

School Plant Services
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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 certianly 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

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Insurance

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 structual 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.

Real Estate

Real estate was studied from the perspectives costs and savings. Real estate costs include acquisition, but do not extend into taxes. Savings consider utilization and maintenance.

Land has been acquired by (1) dedication at statehood, (2) gift, and (3) purchase. Although there have been differences in acquisition costs, these differences appear to be related to the swing of the economy and the urban or rural location of the land rather than for its intended usage. In regard to current land value, no difference was found between land on which conventional buildings would be built from land where underground schools would be built. Although cheaper land(shallow soil, grade, high water content) would be a consideration for construction purposes, both types of structure use the same engineering considerations. That makes the land cost decision hinge on the location of students to be served more than on one type of land.

There are possibilities for some savings in utilization. Landscaping for above-ground buildings usually involves more expense to esthetically 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

SCHOOL	SITE SIZE (ACRES)	CURRENT * LAND VALUE	COST PER ACRE
CONTROL SCHOOLS (CONVENTIONAL)			
Davis Jr. High	16.5	$160,429	$9,723
Mangum	2.0	10,000	5,000
McLoud	40.0	120,000	3,000
Highland East	20.0	100,000	5,000
BERMED SCHOOLS			
Longfellow	20.0	$ 68,000	$3,400
Tupelo	2.2	11,000	5,000
Washington	14.0	25,200	1,800
UNDERGROUND SCHOOLS			
Bethel	10.0	$ 20,000	$2,000
Blanchard	16.0	16,000	1,000
Davis	16.5	160,432	9,723
Duke	6.2	6,200	1,000
Hydro	20.0	36,000	1,800
John Glenn	5.0	100,000	20,000
Prague	30.0	90,000	3,000
Seiling	20.0	20,000	1,000
Weleetka	30.0	60,000	2,000
Wellston	10.0	55,000	5,500

*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.

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DESIGN COST DATA

SCHOOL	YEAR BUILT	TOTAL COST	GROSS FLOOR AREA SQ. FT.	COST PER SQ. FT.
CONTROL SCHOOLS (CONVENTIONAL)				
Davis Jr. High	1976	$ 23,100	19,890	1.16
Mangum	1961	14,880	33,507	0.44
McLoud	1975	22,740	24,800	0.92
Highland East	1977	82,497	46,927	1.76
BERMED SCHOOLS				
Longfellow	1973-74	50,519	36,062	1.40
Tupelo	1978	26,600	16,750	1.59
Washington	1972-73	17,700	18,067	0.98
UNDERGROUND SCHOOLS				
Bethel	1973	26,100	11,550	2.26
Blanchard*	1968	9,000	8,140	1.11
Blanchard*	1974	10,800	8,140	1.33
Davis	1967	12,000	12,500	0.96
Duke	1965	16,825	22,760	0.74
Hydro	1975	14,700	10,000	1.47
John Glenn	1967	6,494	9,840	0.66
Prague	1967	15,219	7,540	2.02
Seiling	1966	9,000	6,815	1.32
Weleetka*	1972	14,100	12,514	1.13
Weleetka*	1978	27,240	12,514	2.18
Wellston	1967	7,080	8,400	0.84

*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 above-ground 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.

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CONSTRUCTION COST DATA

SCHOOL	YEAR BUILT	TOTAL COST	GROSS FLOOR AREA SQ. FT.	COST PER SQ. FT.
CONTROL SCHOOLS (CONVENTIONAL)				
Davis Jr. High	1976	$ 385,000	19,890	$19.36
Mangum	1961	248,000	33,507	7.40
McLoud	1975	379,000	24,800	15.31
Highland East	1977	1,374,952	46,927	29.30
BERMED SCHOOLS				
Longfellow	1973-74	841,981	36,062	23.35
Tupelo	1978	442,782	16,750	26.43
Washington	1972-73	295,000	18,067	16.33
UNDERGROUND SCHOOLS				
Bethel	1973	435,000	11,550	14.05
Blanchard*	1968	150,000	8,140	18.43
Blanchard*	1974	180,000	8,140	22.11
Davis	1967	200,000	12,500	16.00
Duke	1965	280,418	22,760	12.32
Hydro	1975	245,000	10,000	24.50
John Glenn	1967	108,240	9,840	11.00
Prague	1967	253,645	7,540	33.64
Seiling	1966	150,000	6,815	22.01
Weleetka*	1972	235,000	12,514	18.79
Weleetka*	1978	454,000	12,514	36.28
Wellston	1967	118,000	8,400	14.05

*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 undergound 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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ENERGY CONSUMPTION DATA—ANNUAL INDEXES

SCHOOL	PERCENTAGE UNDERGROUND	ELECTRICAL MBTU/FT²	NATURAL GAS MBTU/FT²	TOTAL USAGE MBTU/FT²	TOTAL COST $/FT²
CONTROL SCHOOLS					
Mangum	0	14.9	75.8	90.7	0.38
McLoud	0	20.6	73.6	94.2	0.34
Davis Jr. High	0	21.0	26.7	47.7	0.23
Highland East	0	40.0	47.0	87.0	0.47
BERMED SCHOOLS					
Longfellow	0	26.6	27.0	53.6	0.31
Washington	0	35.5	– –	35.5	0.33
UNDERGROUND SCHOOLS					
Bethel	15%	36.9	20.5*	57.4	0.46
Blanchard	45%	39.9	—	39.9	0.41
Davis	100%	48.2	—	48.2	0.46
Duke	66%	29.2	—	29.2	0.25
Hydro	19%	20.6	22.1	42.7	0.26
John Glenn	16%	29.0	38.4	67.4	0.35
Weleetka	25%	25.9	36.3	62.2	0.35
Wellston	10%	22.0	13.8	35.8	0.24

*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 on against tornadoes, highwinds, 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 quantitave 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), but there is a better alternative for emergencies. With a system such as depicted in Fig. 1, the super imposed load capability becomes that listed in column 5. 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:

o Several of the schools already have some soil cover. The figures in table refer to total soil cover.

o Neither bermed school provides good shelter from tornadoes that pass directly overhead, because their roofs might be lifted off.

o 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.

o 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

Name of School	Superimposed Load to Equal Design Load (psf)	Additional Soil Required to Provide PF 1000(1) (in.)	(psf)	Soil Loading Allowable in an Emergency(2) (in.)	(psf)	Maximum Superimposed Load when Strengthened(3) (psf)	Blast Protection when Strengthened and Upgraded to PF 1000 (psi)
Arnett	145	28	280	19	190	1080	5.6
Bethel (4)	277	29	290	29	290	1780	10.3
Blanchard	75	19	190	15	150	2265	14.4
Blanchard (4) Addition	100	19	190	19	190	2600	16.7
Davis	167	30	300	19	190	840	3.8
Henry Wadsworth(5) Longfellow (bermed)	35	33	330	4	40	240	0
Hydro	100	29	290	11	110	680	2.7
John Glenn(6)	245	19	190	19	190	4570	30.4
Prague	200	30	300	23	230	1360	7.4
Seiling	110	30	300	19	190	1900	11.1
Washington (5) (bermed)	30	36	360	4	40	150	0
Weleetka (6)	330	29	290	29	290	2140	12.8
Wellston (6)	300	18	180	18	180	5440	36.5

(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 sturcture 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.

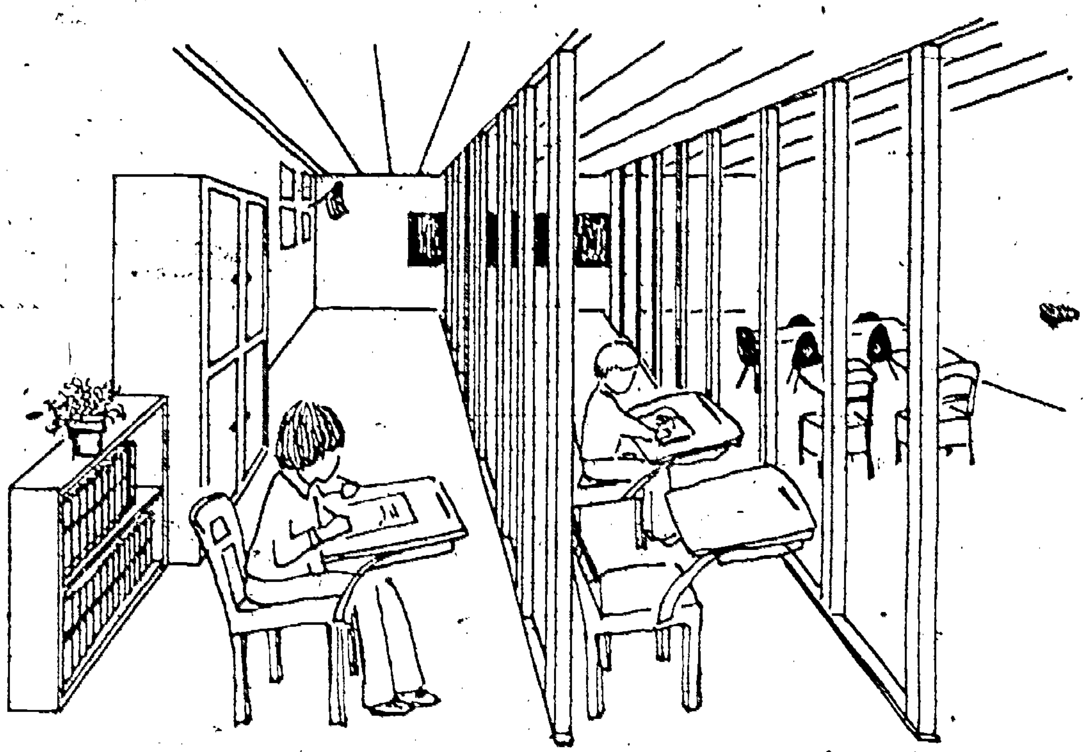


Figure I

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."

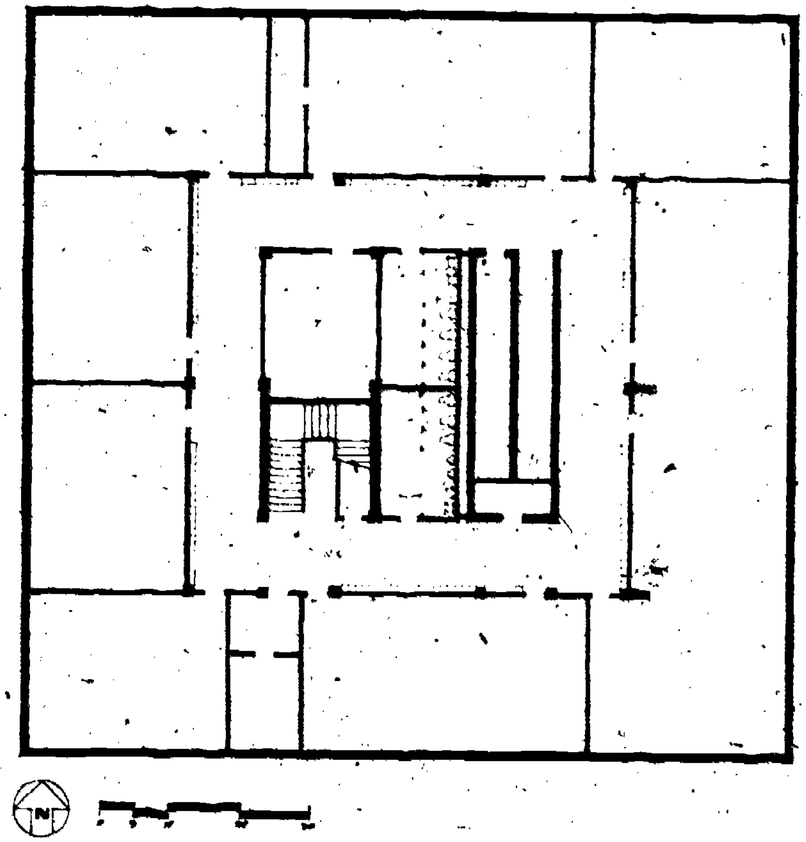
PHYSIOLOGICAL EFFECTS - Physiological effects were addressed in terms of specific complaints such as headaches, blurred vision, fatigue, nausea, and behavioral changes. One educator mentioned that students in one underground school had become lethargic in the afternoons because of improper ventilation.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

BETHEL HIGH SCHOOL

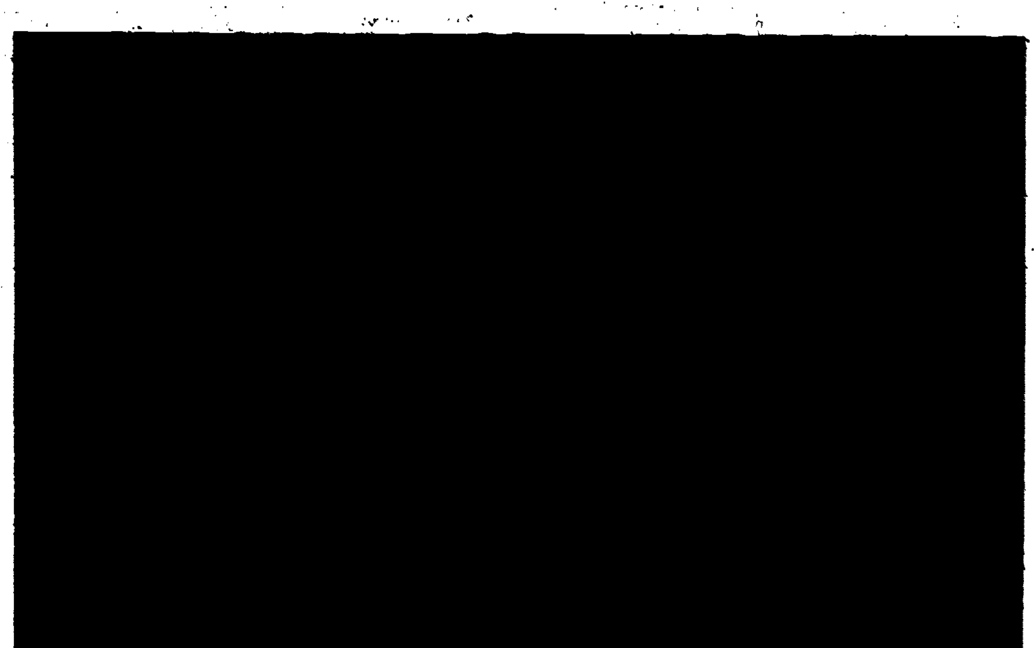
Location:	Shawnee, Oklahoma
District:	Bethel Independent District
Superintendent:	Belvin Cantrell
Architect:	Richard Dunham, AIA
Completed:	1973
Capacity:	315 Students–Grades 10-12
Floor Area:	11,550 Sq. Ft.
Construction:	$37.66 per Sq. Ft.



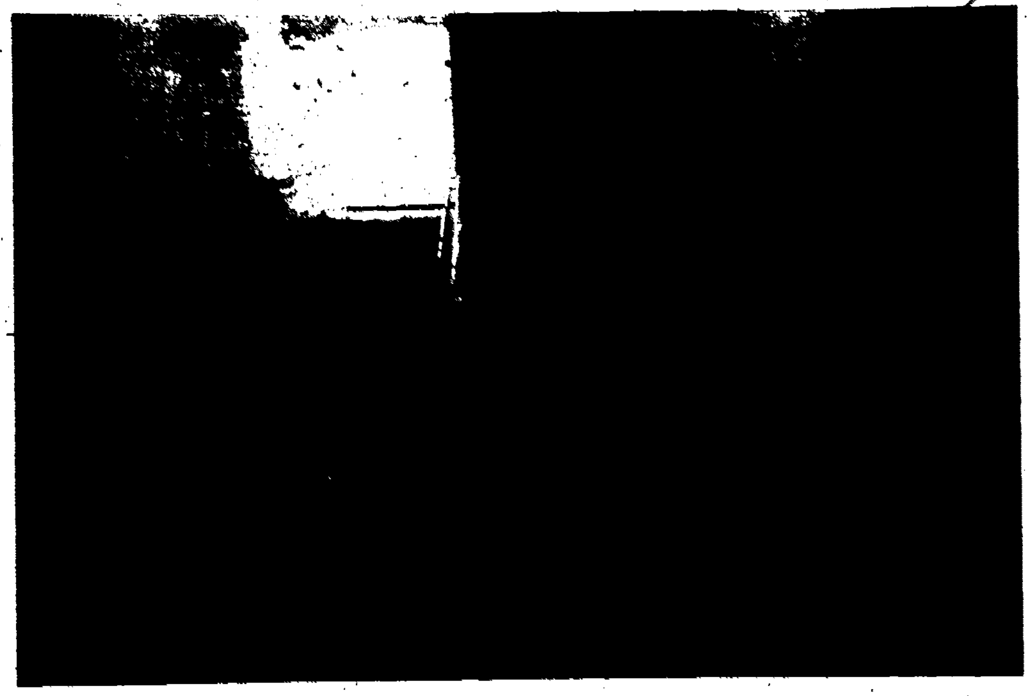
Floor Plan

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.

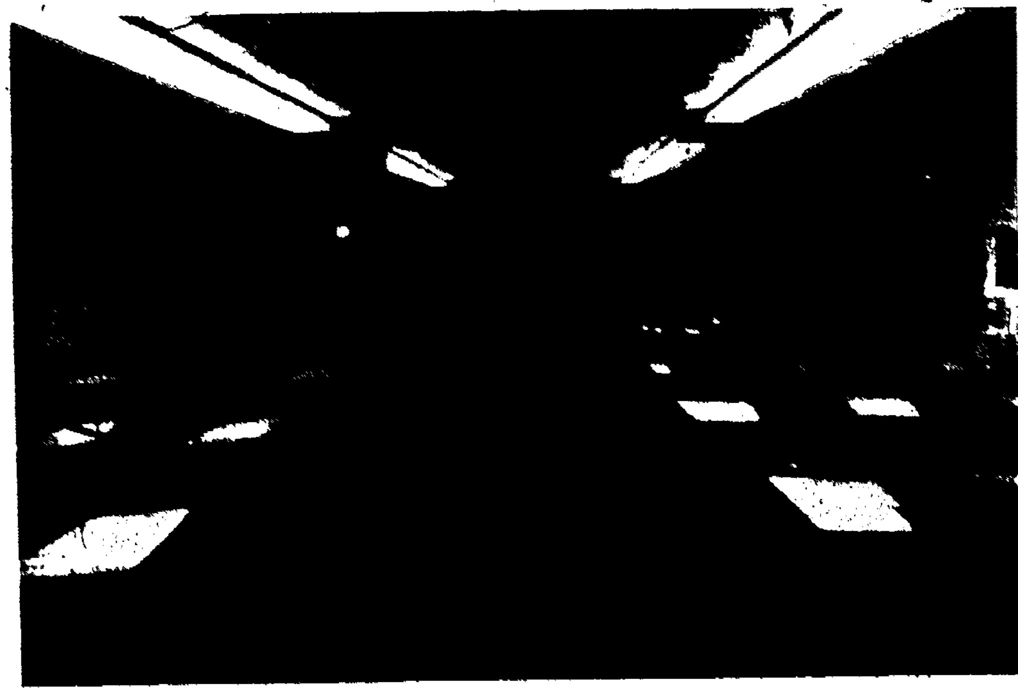
A 1977 addition added additional above ground classrooms on top of the belowground classrooms and surrounding the initial entry core.



Front Entrance

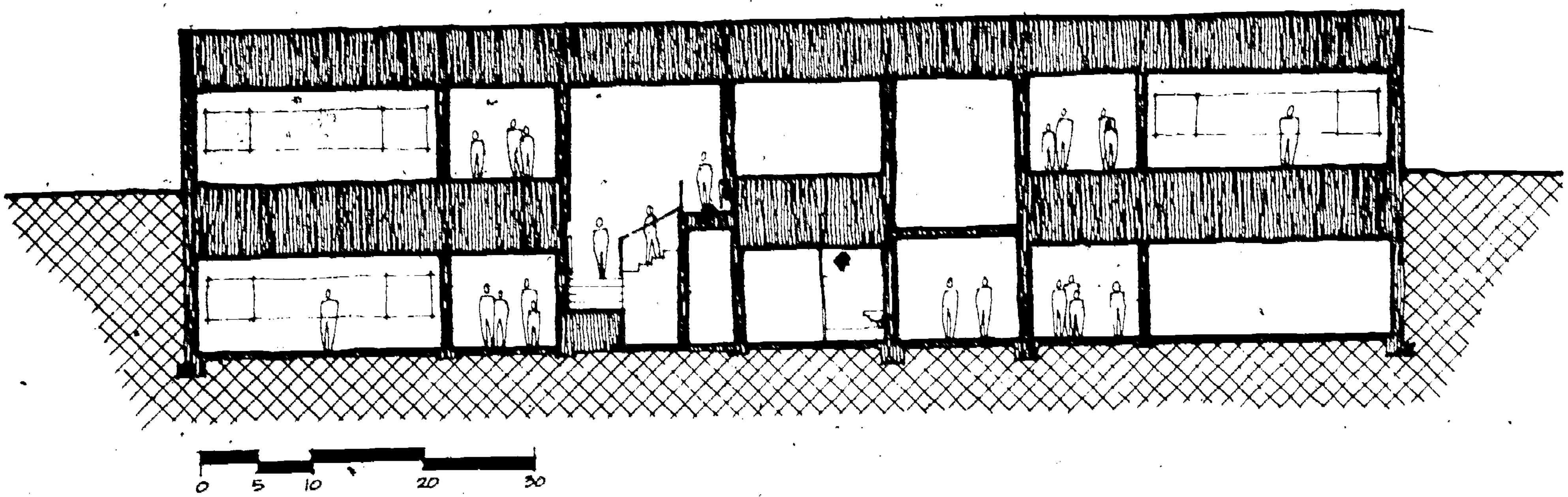


Ramp



Classroom

BETHEL



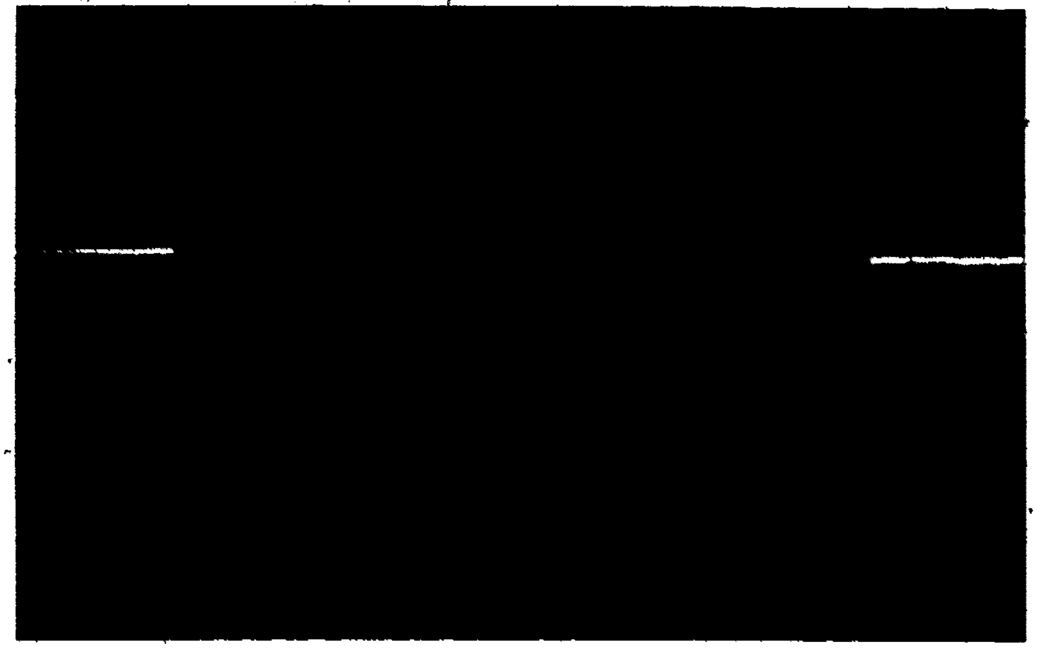
Section

BLANCHARD JR-SR HIGH SCHOOL

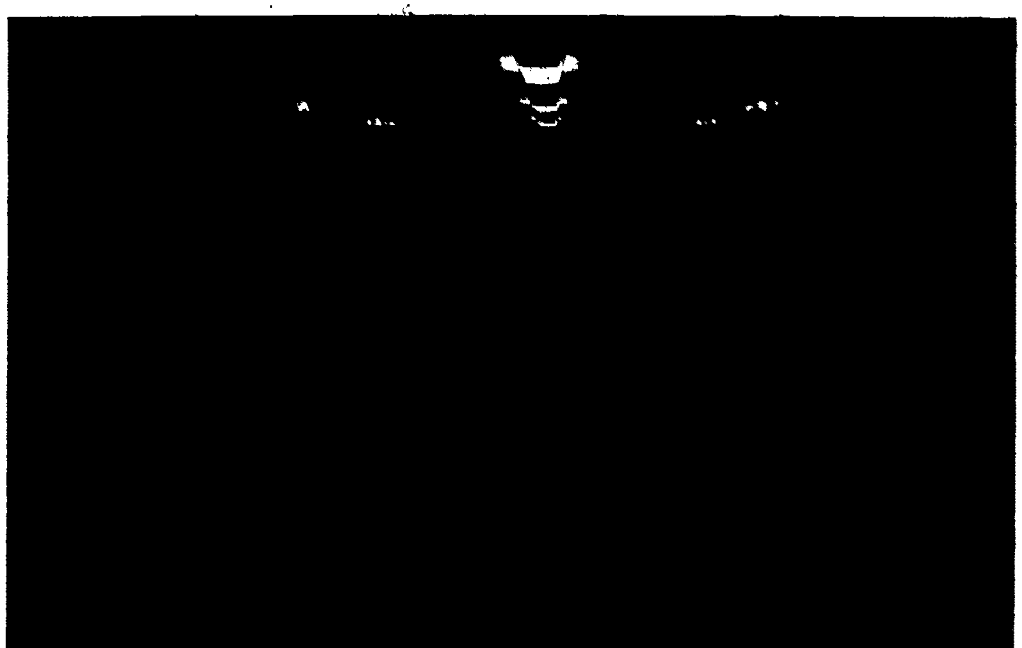
Location:	Blanchard, Oklahoma	
District:	Blanchard Independent District	
Superintendent:	G. Pruitt Lewis	
Architect:	Hudgins, Thompson & Ball Oklahoma City, Oklahoma	
Completed:	A:	1968
	B:	1974
Capacity:	A:	300 Students--Grades 7-9
	B:	300 Students--Grades 10-12
Floor Area:	A:	8,140 Sq. Ft.
	B:	8,140 Sq. Ft.
Construction:	A:	$18.43 per Sq. Ft.
	B:	$22.11 per Sq. Ft.

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.

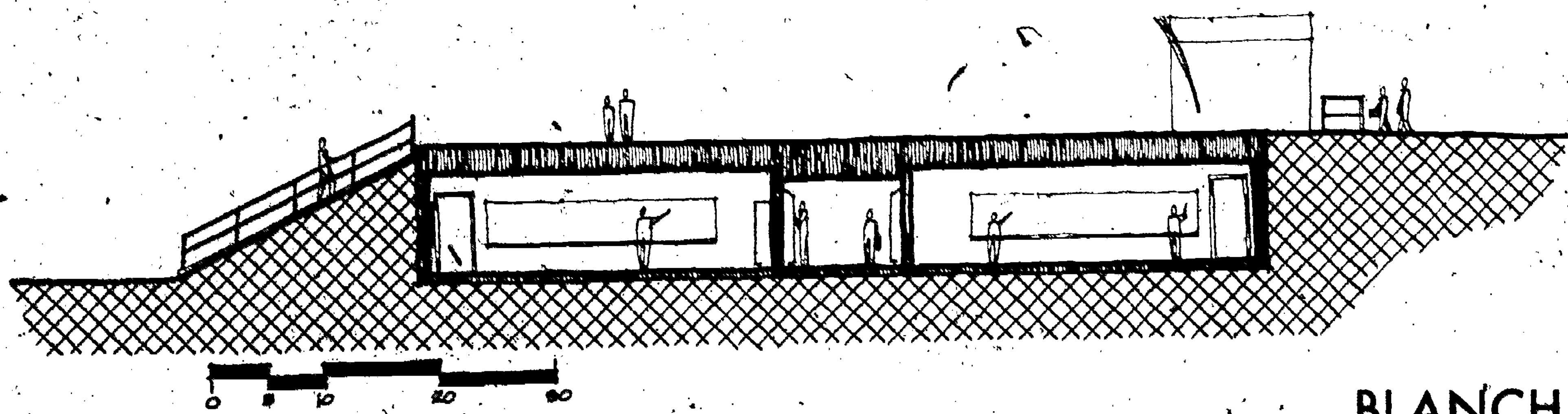


Side Entrance

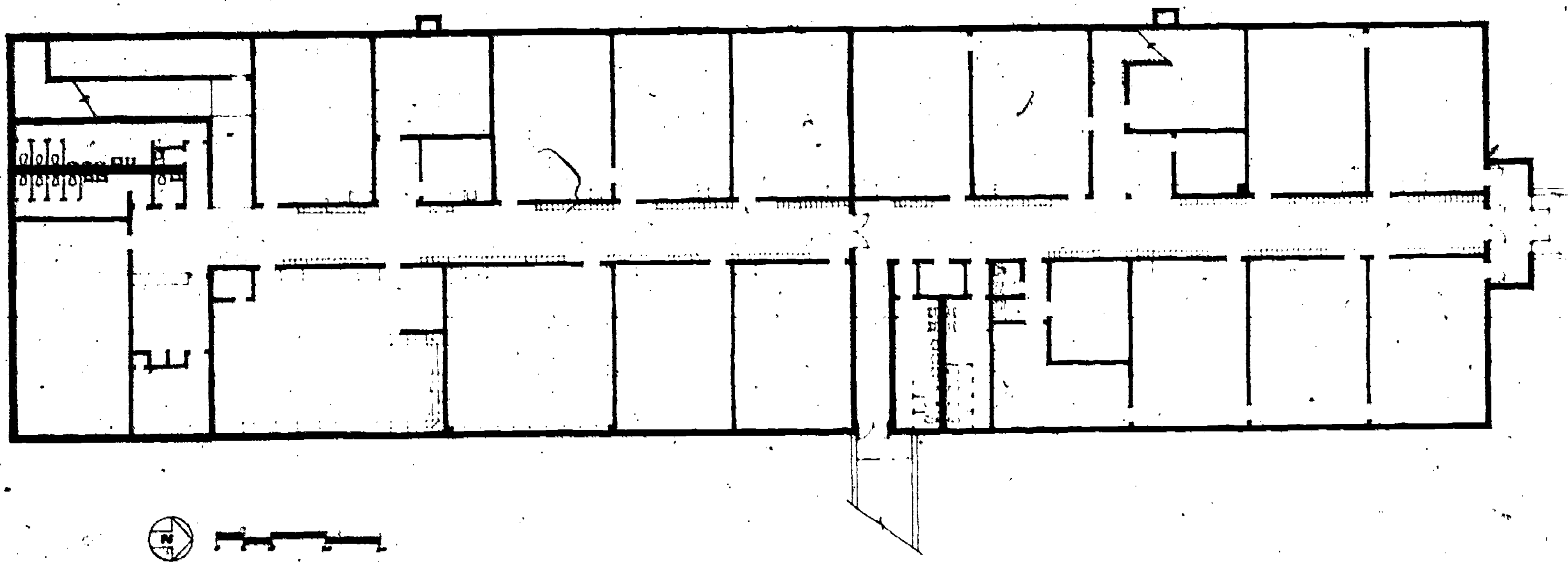


Hallway

BLANCHARD



Section



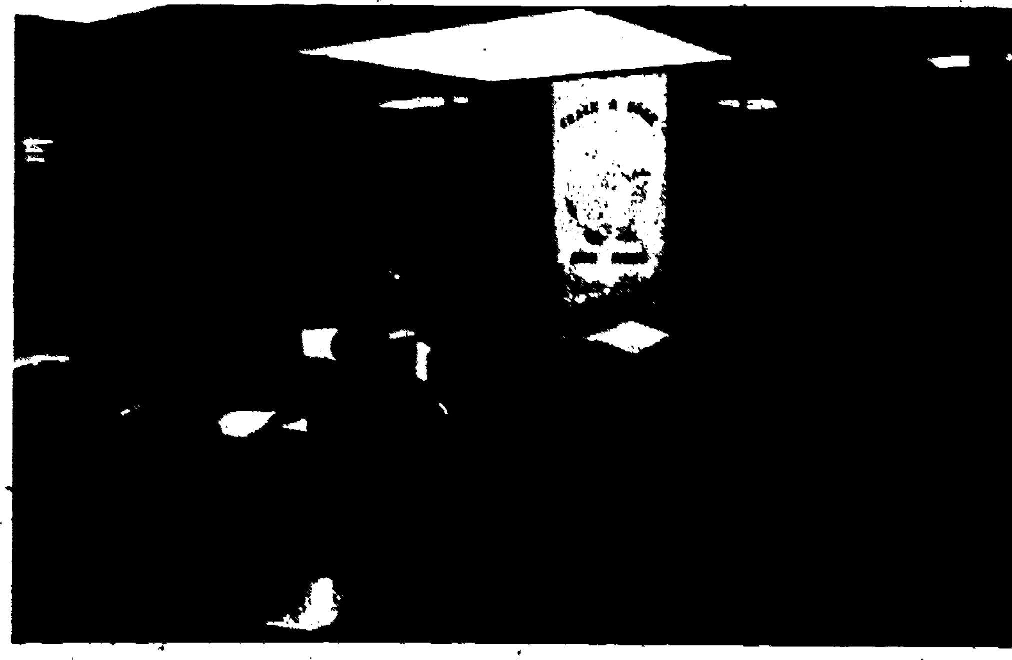
Floor Plan

DAVIS ELEMENTARY SCHOOL

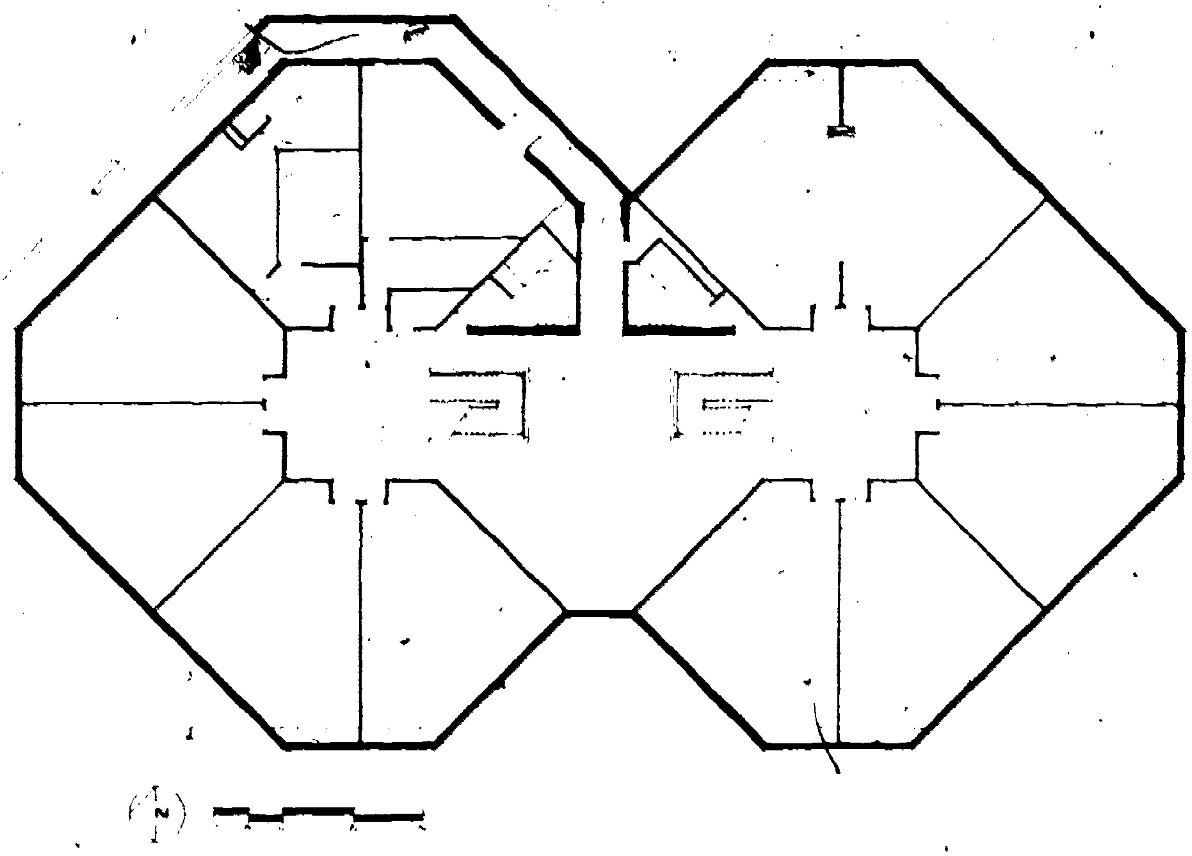
Location:	Davis, Oklahoma
District:	Davis Independent District
Superintendent:	E. Wayne Byrd
Architect:	Locke, Wright & Foster Oklahoma City, Oklahoma
Completed:	1967
Capacity:	380 Students--Grades 1-6
Floor Area:	12,500 Sq. Ft.
Construction:	$16.00 per Sq. Ft.

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.



Library



Floor Plan

31

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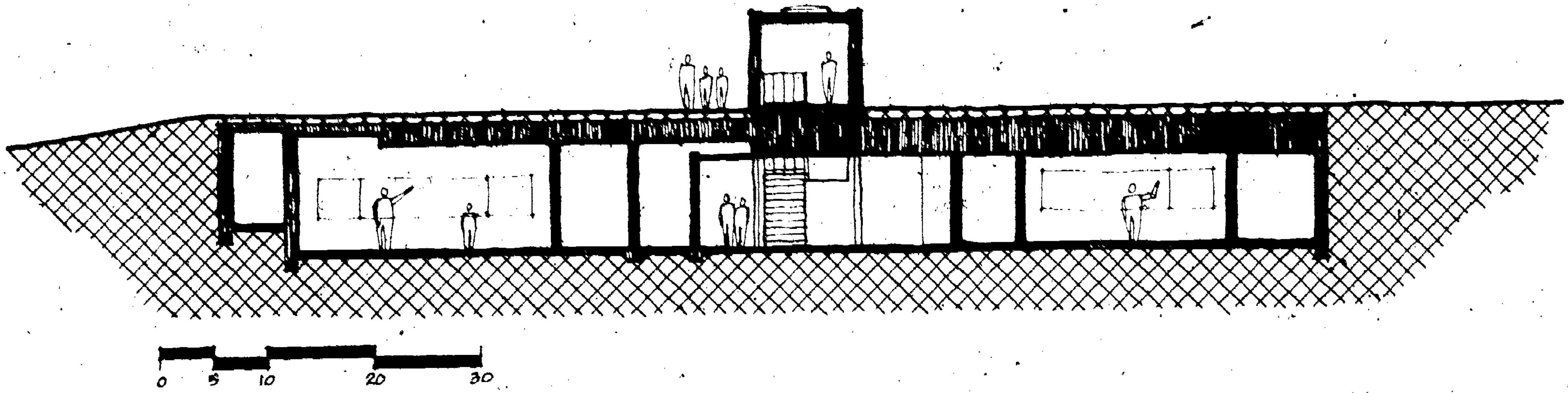


Section

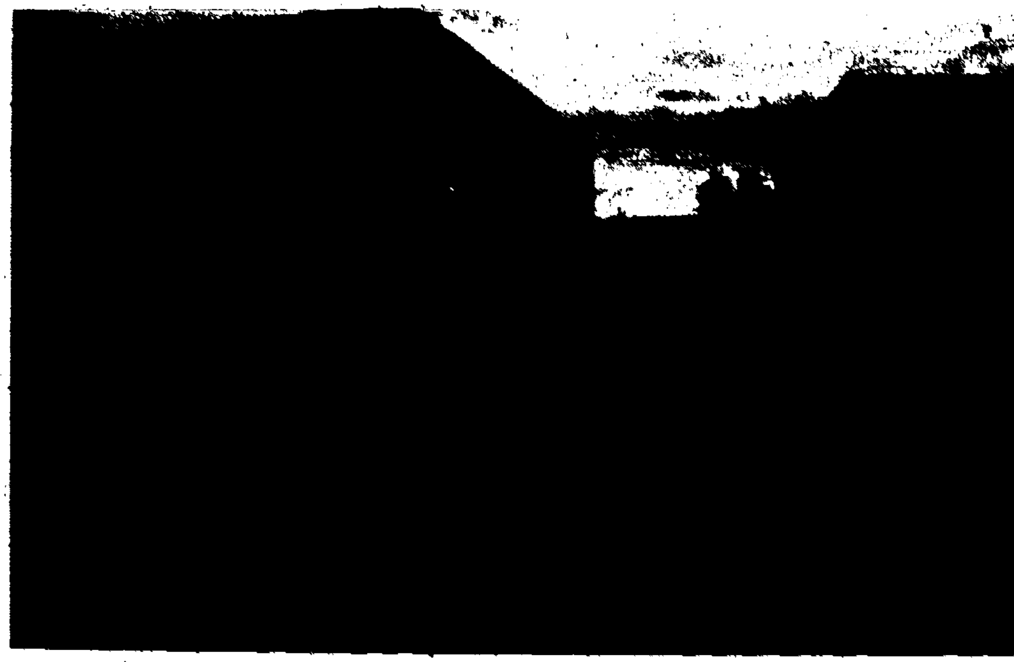
DAVIS

Entrance to School

Play Area Above Underground School

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.

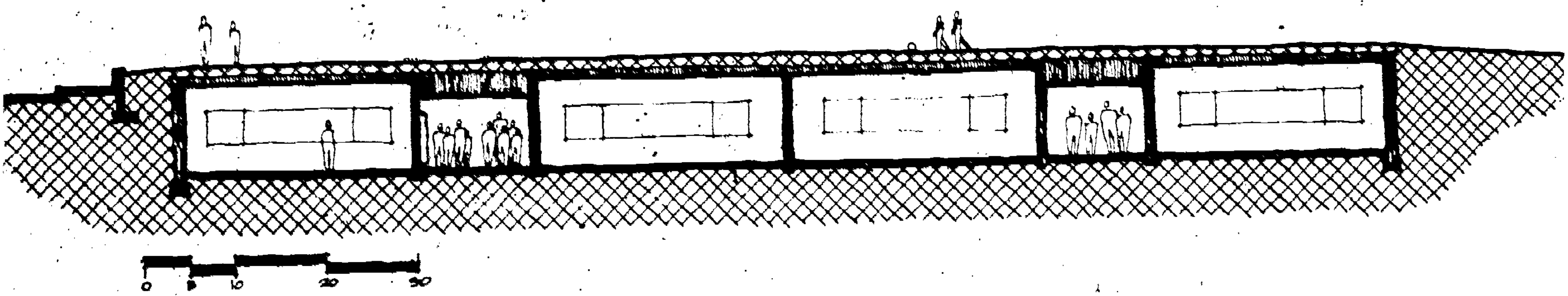


Buildings Above Underground School

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.

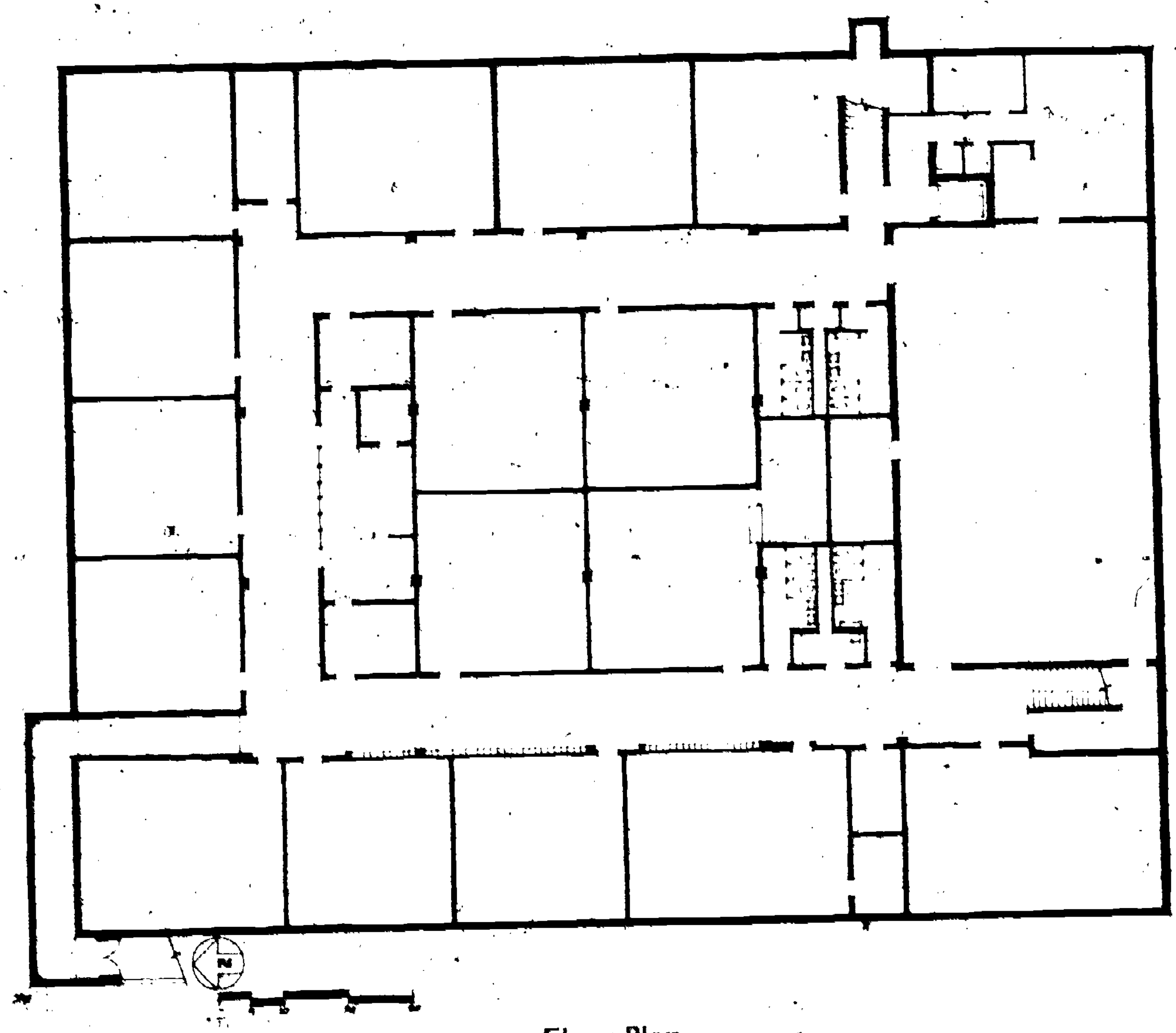
The underground design offers a number of advantages which include more compact floor plans, no distractions from outside noise, reduced maintenance and energy costs.

Classroom



Section

DUKE



Floor Plan

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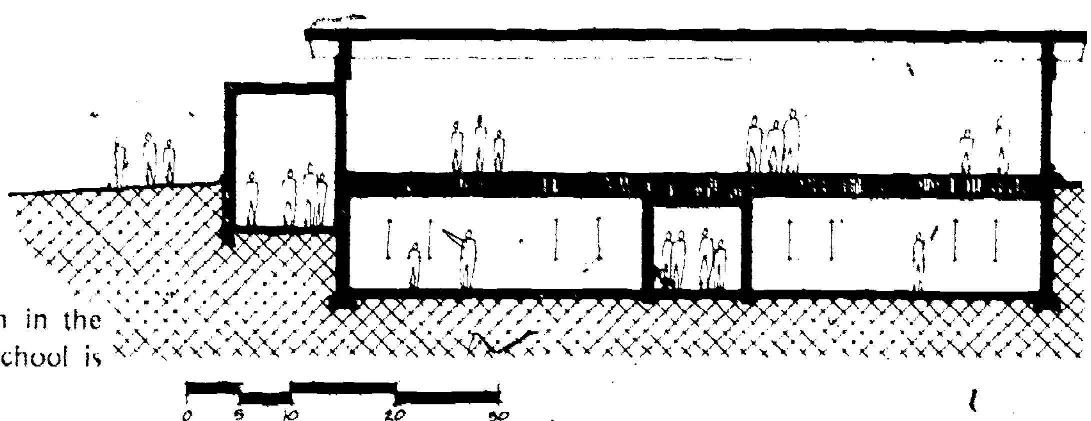
JOHN GLENN ELEMENTARY SCHOOL

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.

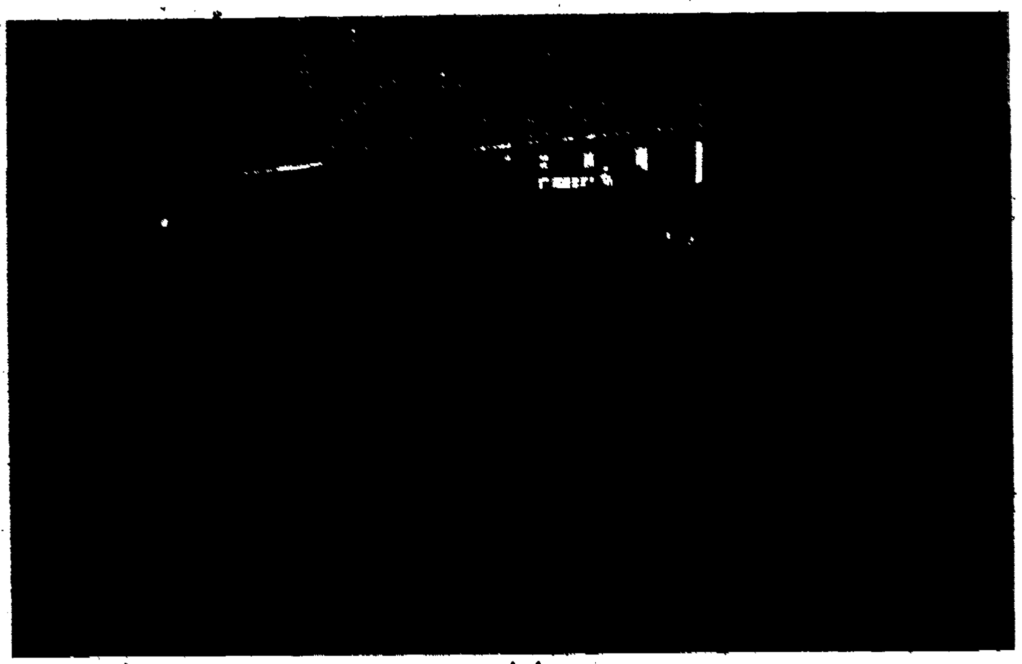
Front View

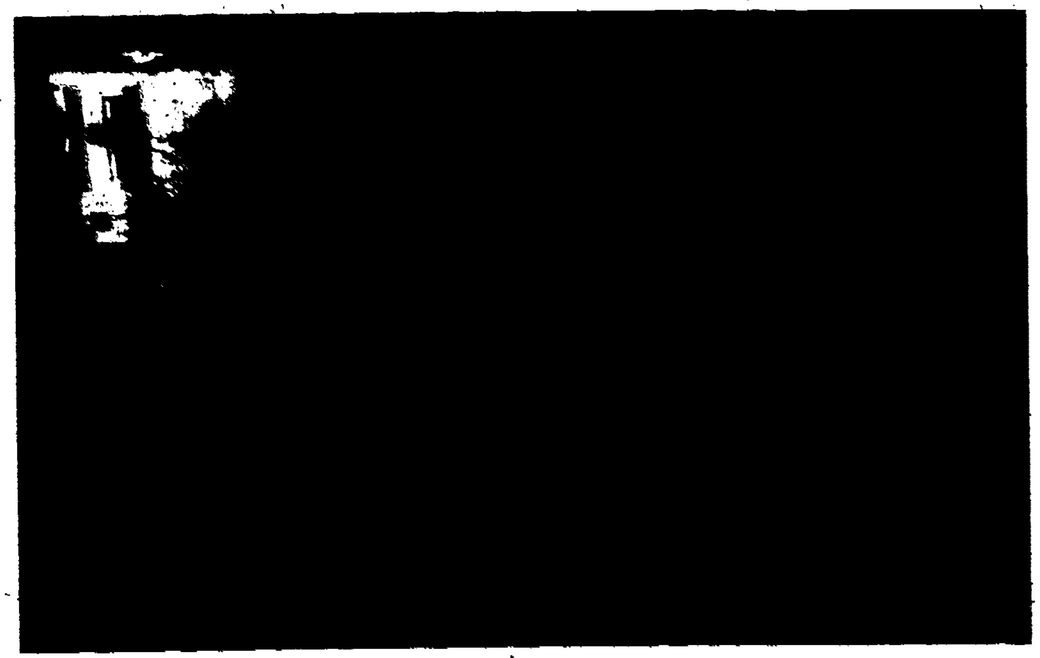
Land conservation was the primary consideration in the decision to build this underground school. The school is also used as a community storm shelter.



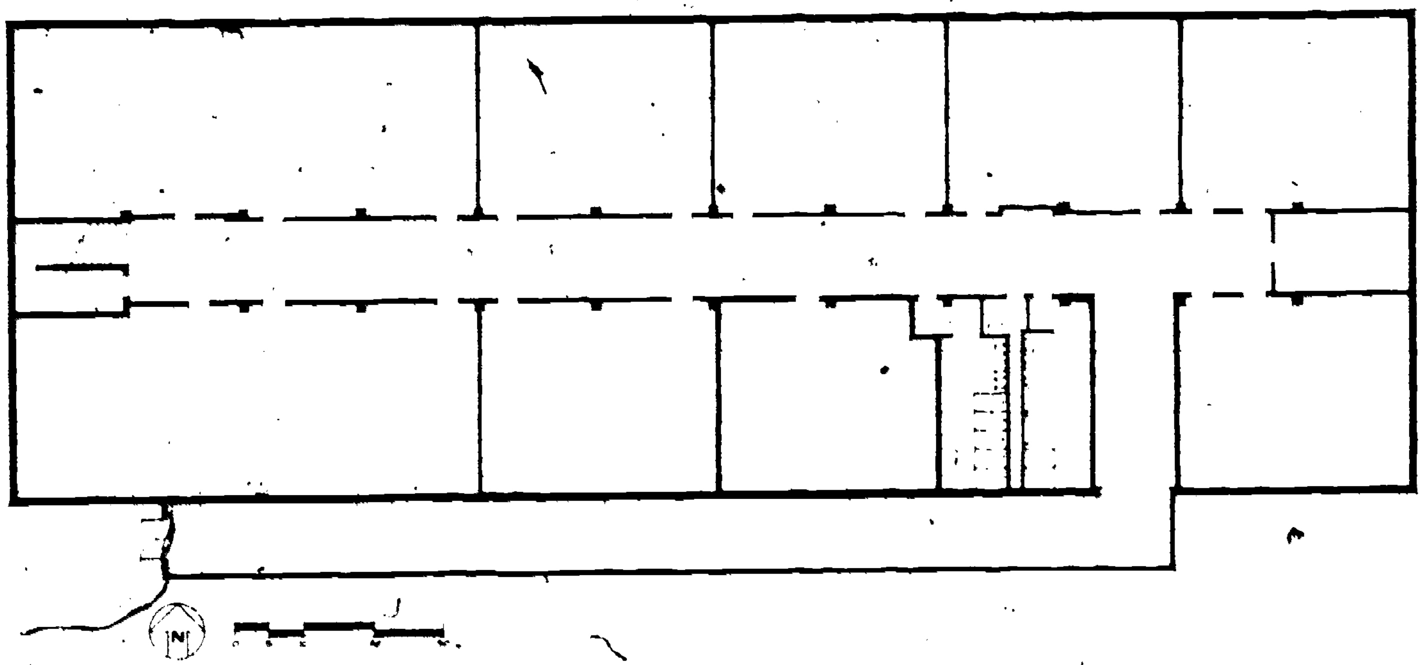
Section

37


Playground Area


Entrance Ramp

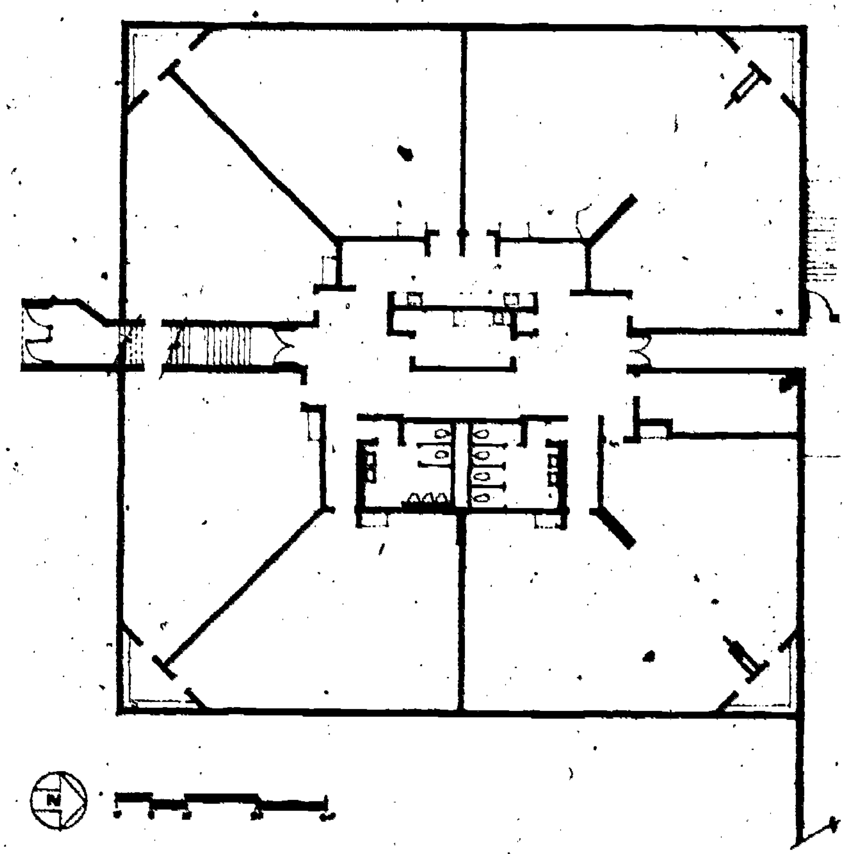
JOHN GLENN


Floor Plan

38 39

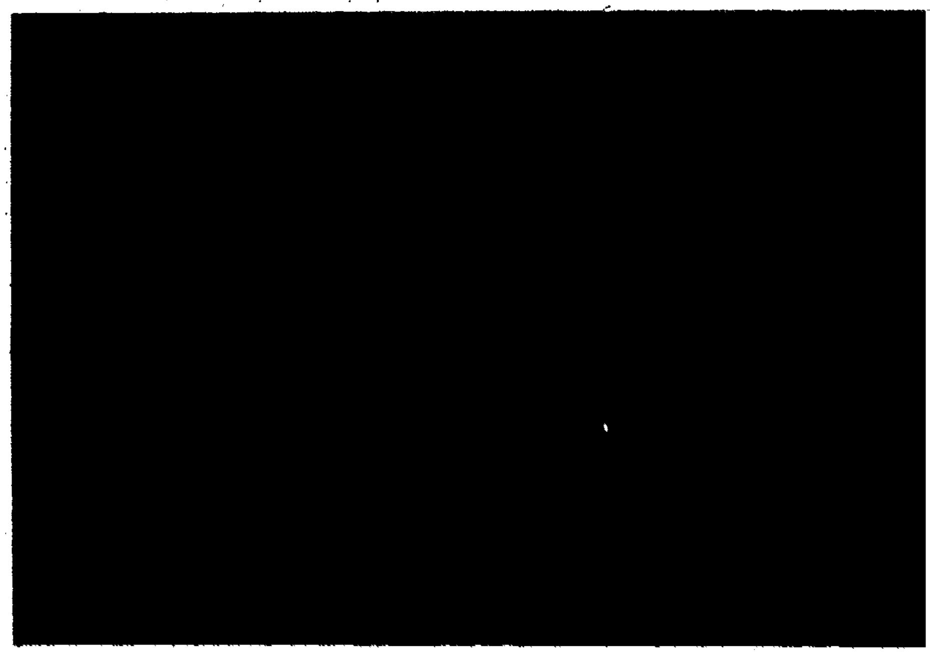
HYDRO ELEMENTARY SCHOOL

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.



Floor Plan

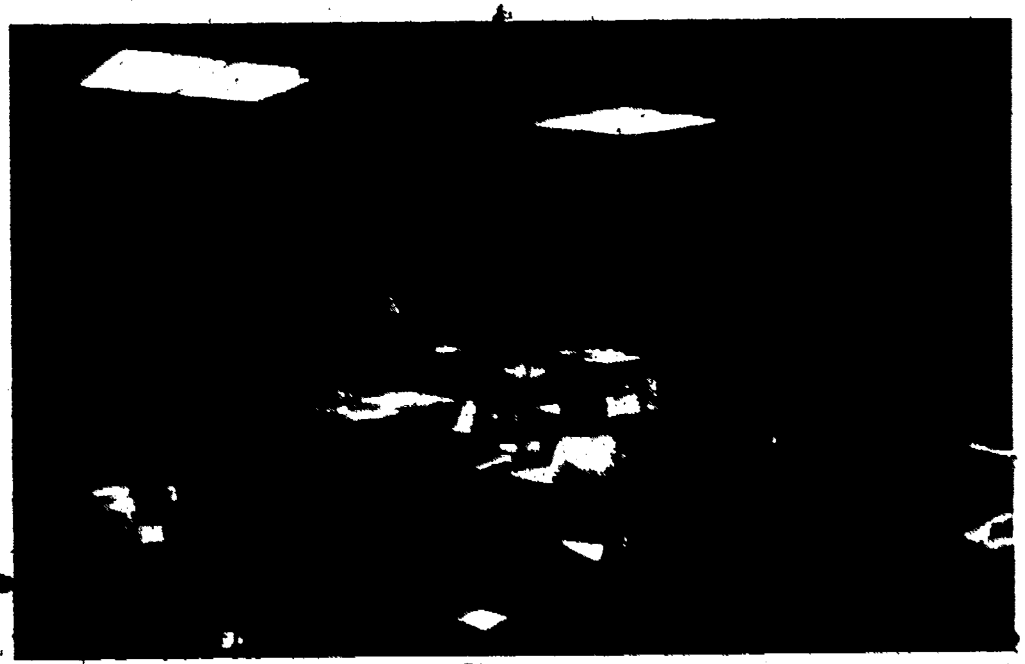
The school administration's concern for student safety, energy conservation and controlled environment were the primary reasons for building underground.



Entrance

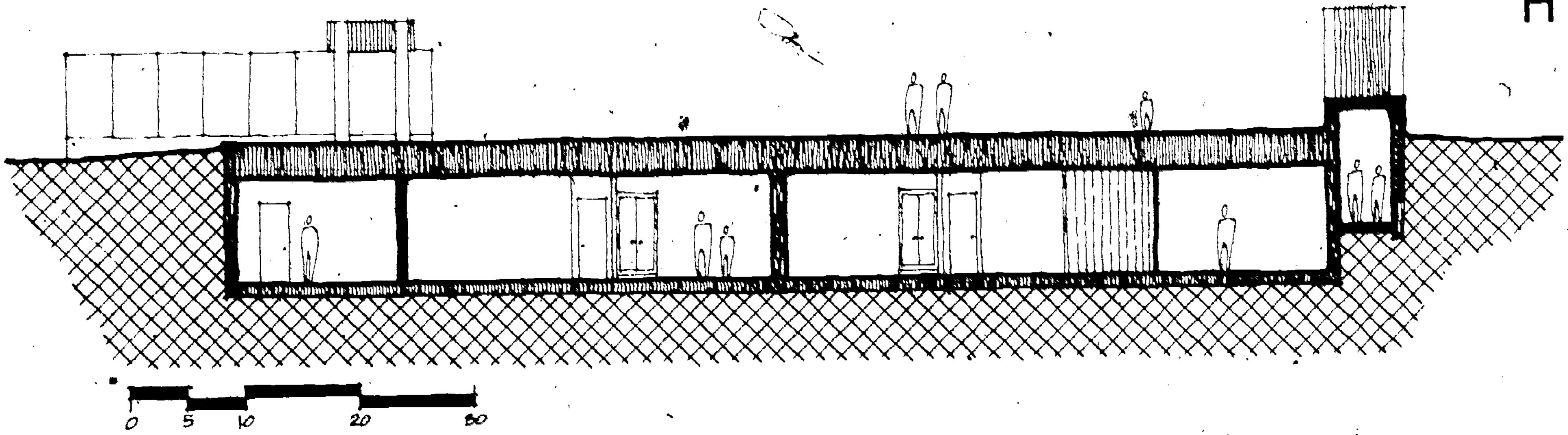
40

Playground Above Underground School



Classroom

HYDRO



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Section

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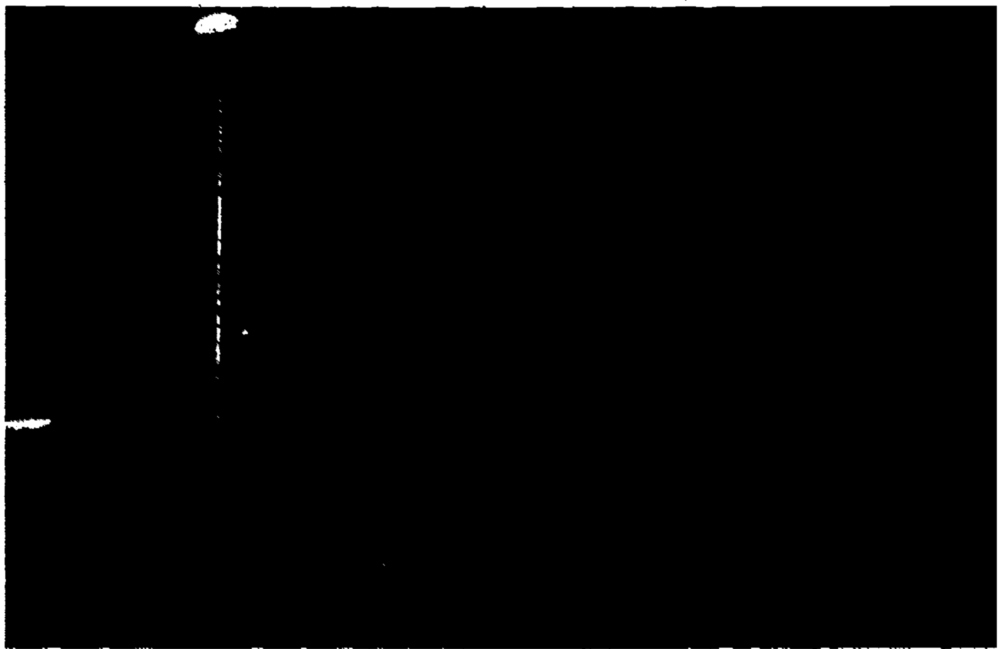
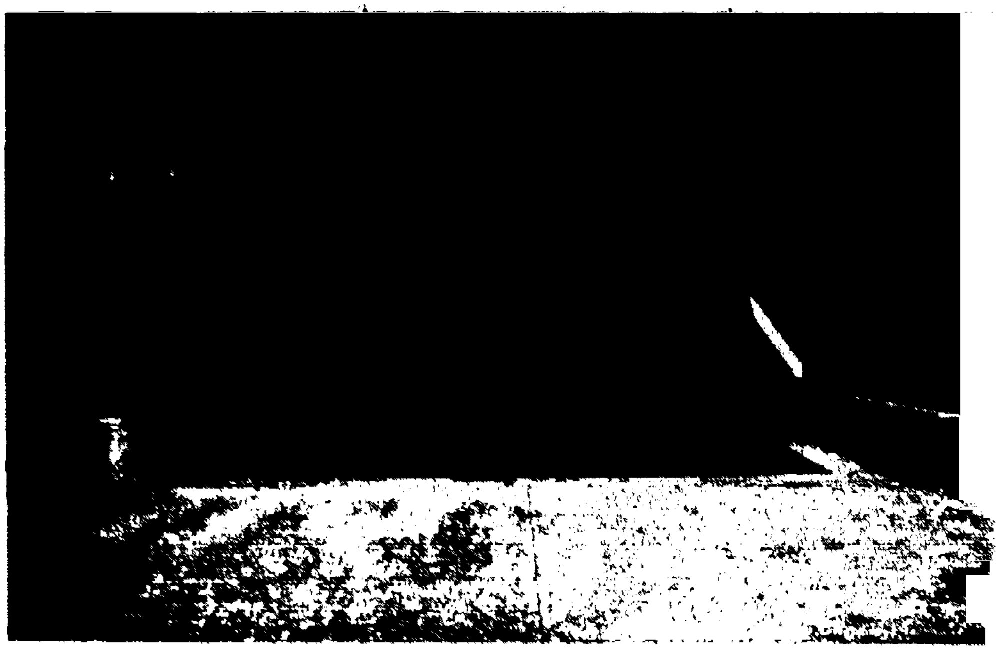
LONGFELLOW MIDDLE SCHOOL

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.

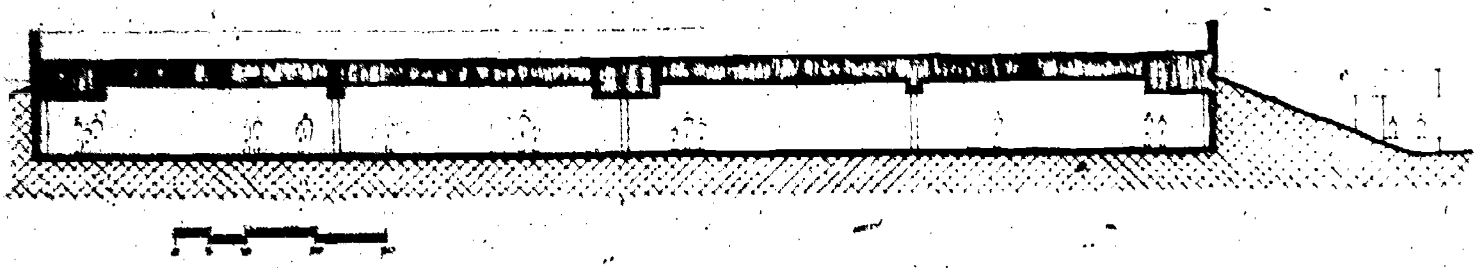


Side View

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 chances of water seepage, little or no vandalism, and an elimination of the need for sewer lifts.

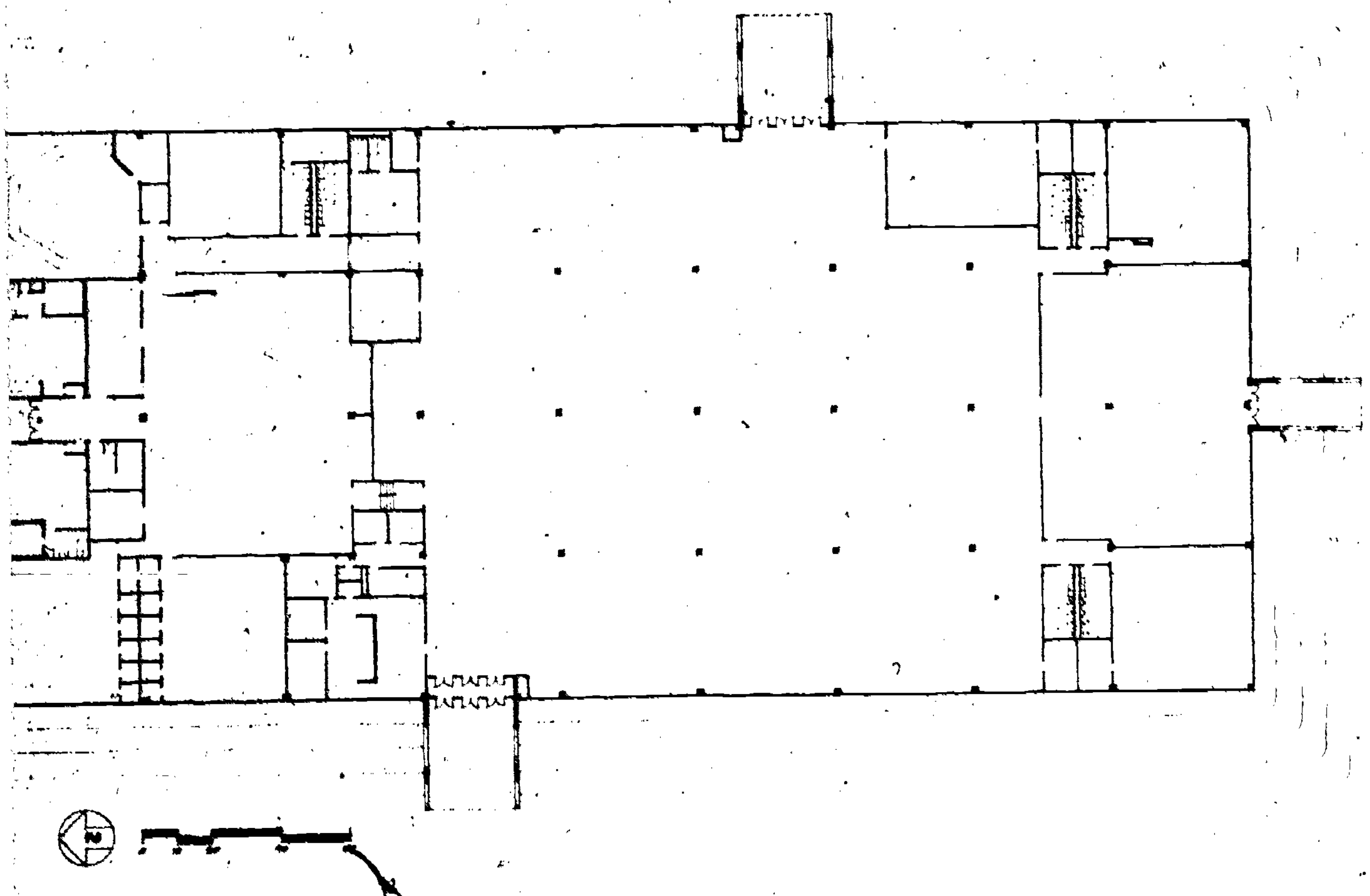


Entrance



Section

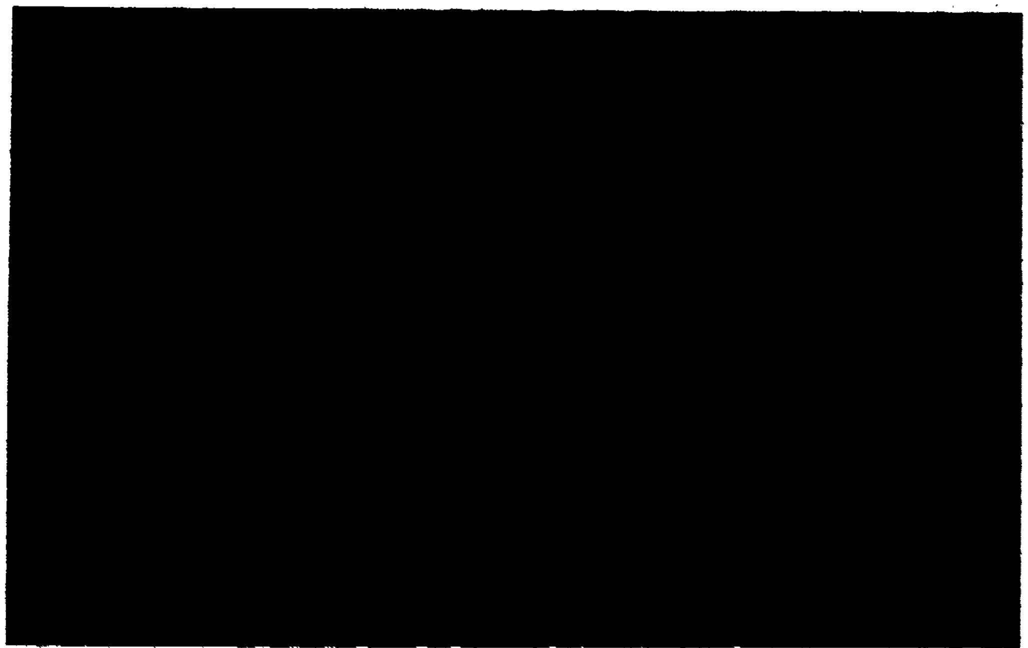
LONGFELLOW



Floor Plan

PRAGUE ELEMENTARY SCHOOL

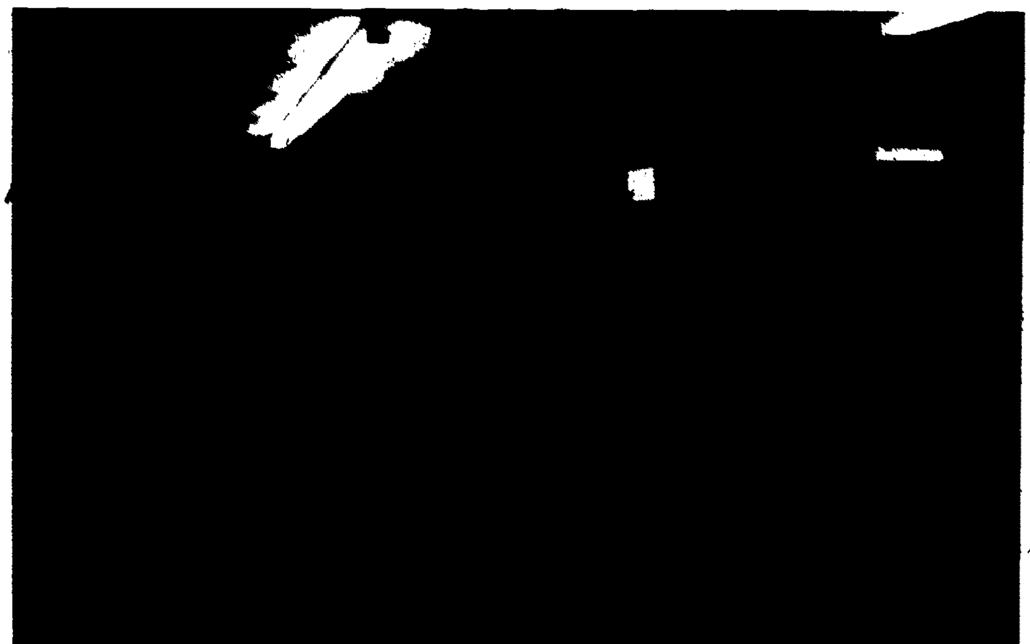
Location:	Prague
District:	Prague Independent District
Superintendent:	Roy L. Grissom
Architect:	Bowman-Nicek, AIA Oklahoma City, Oklahoma
Completed:	1967
Capacity:	165 Students--Grades 1-2 and Special Education.
Floor Area:	7,540 Sq. Ft.
Construction:	$33.64 per Sq. Ft.



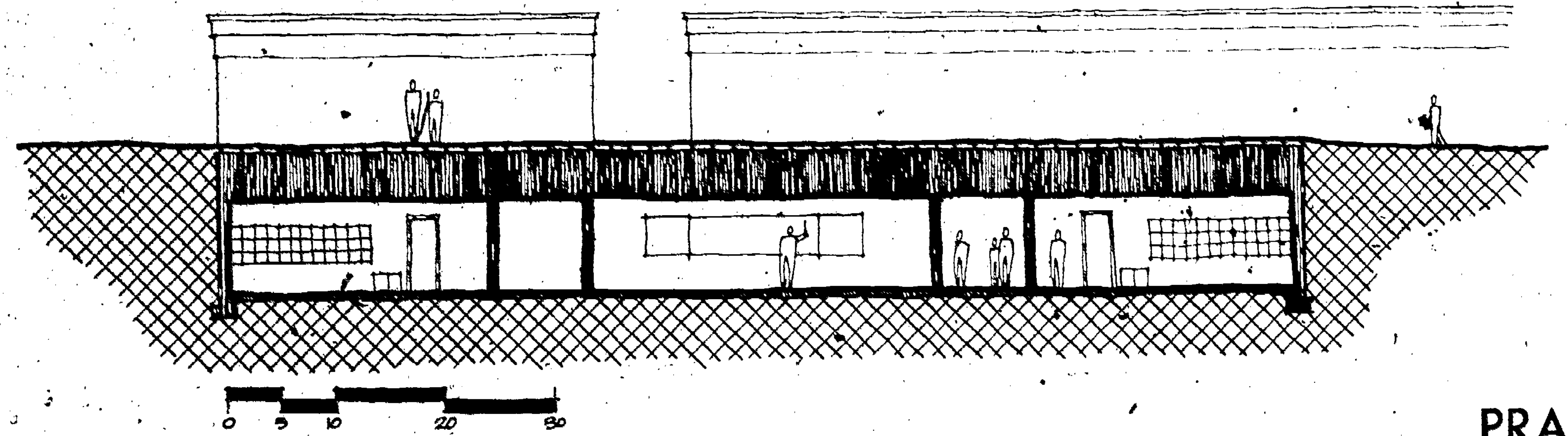
Entrance

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.

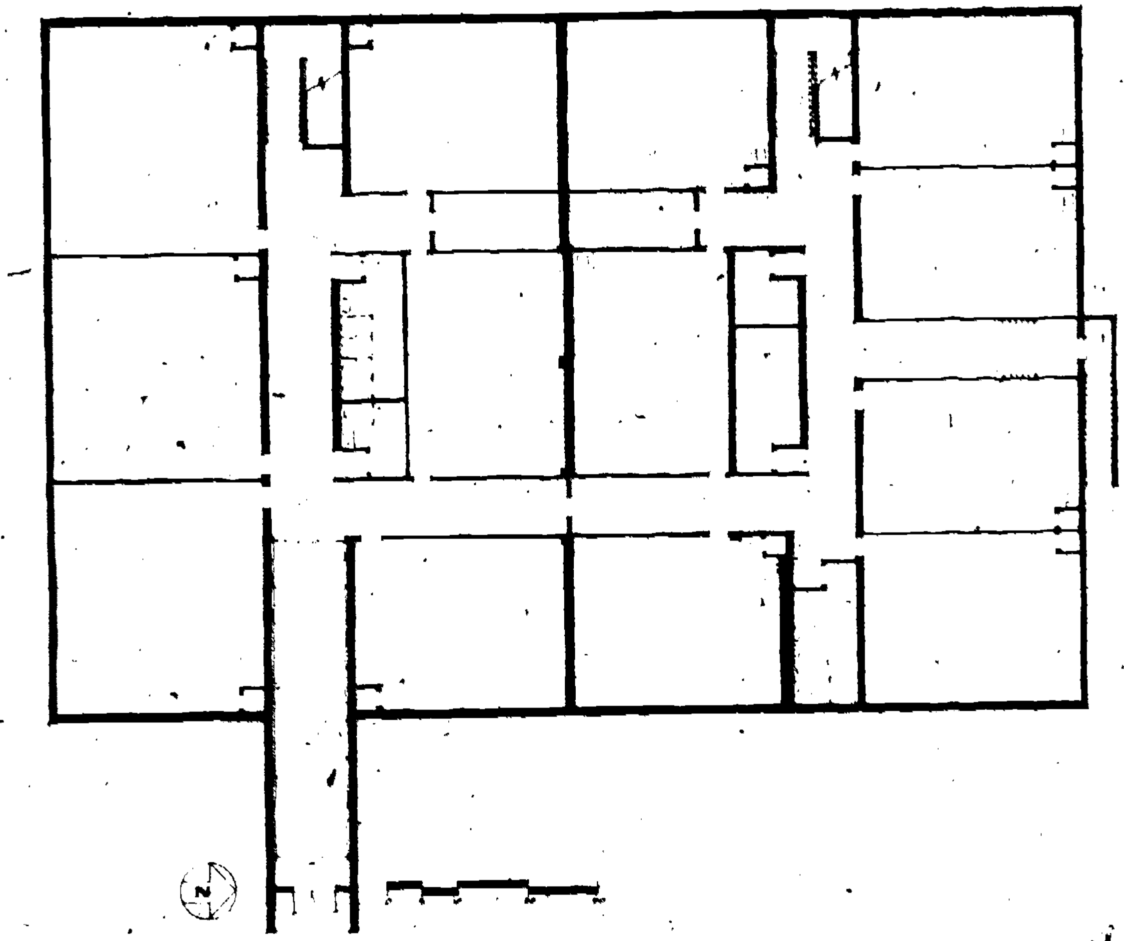


Stairway



Section

PRAGUE

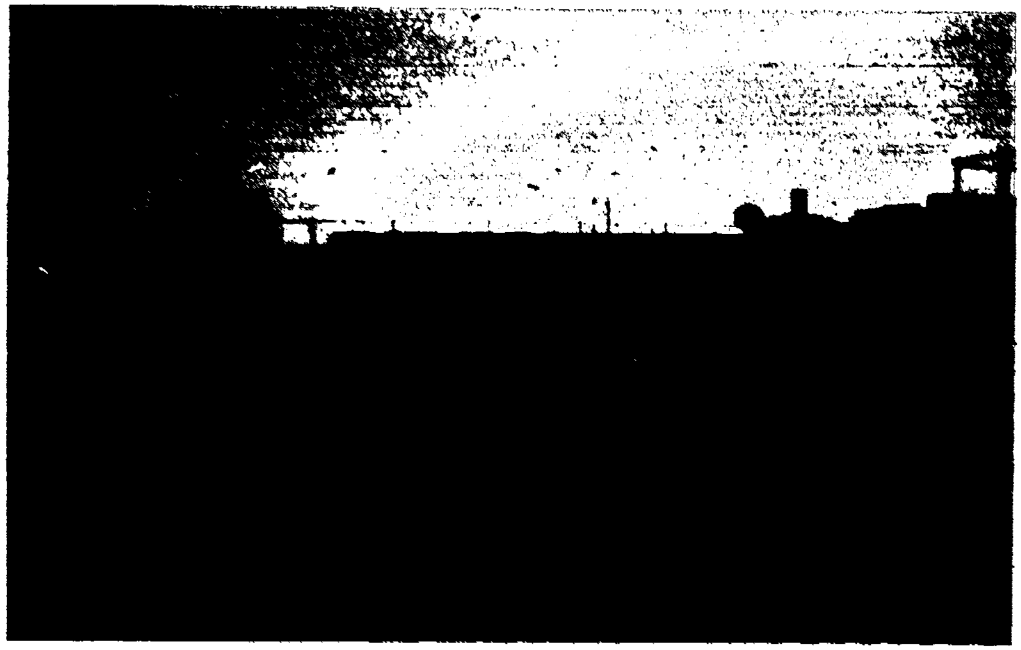


Floor Plan

Playground Area

SEILING ELEMENTARY SCHOOL

Location:	Seiling, Oklahoma
District:	Seiling Independent District
Superintendent:	Gerald Daugherty
Architect:	Hudgins, Thompson & Ball Oklahoma City, Oklahoma
Completed:	1966
Capacity:	150 Students--Grades 4-6
Floor Area:	6,815 Sq. Ft.
Construction:	$22.01 per Sq. Ft.

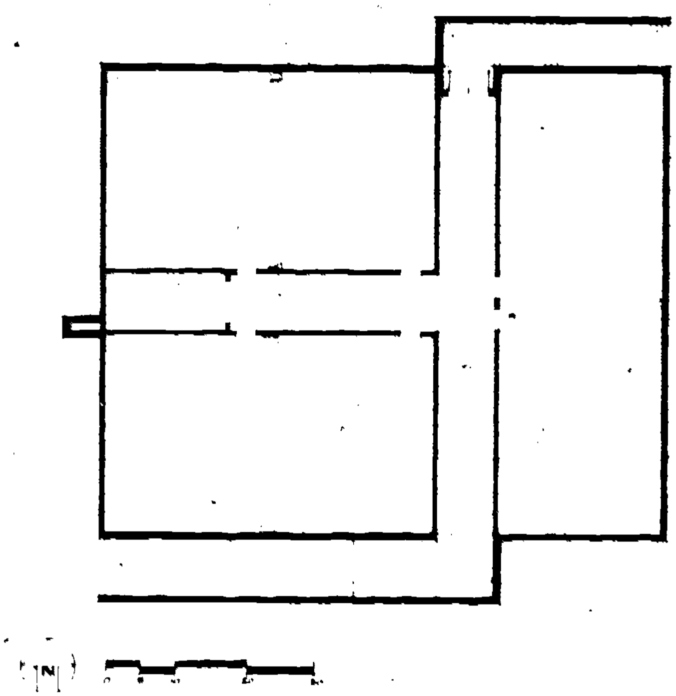


Playground Area

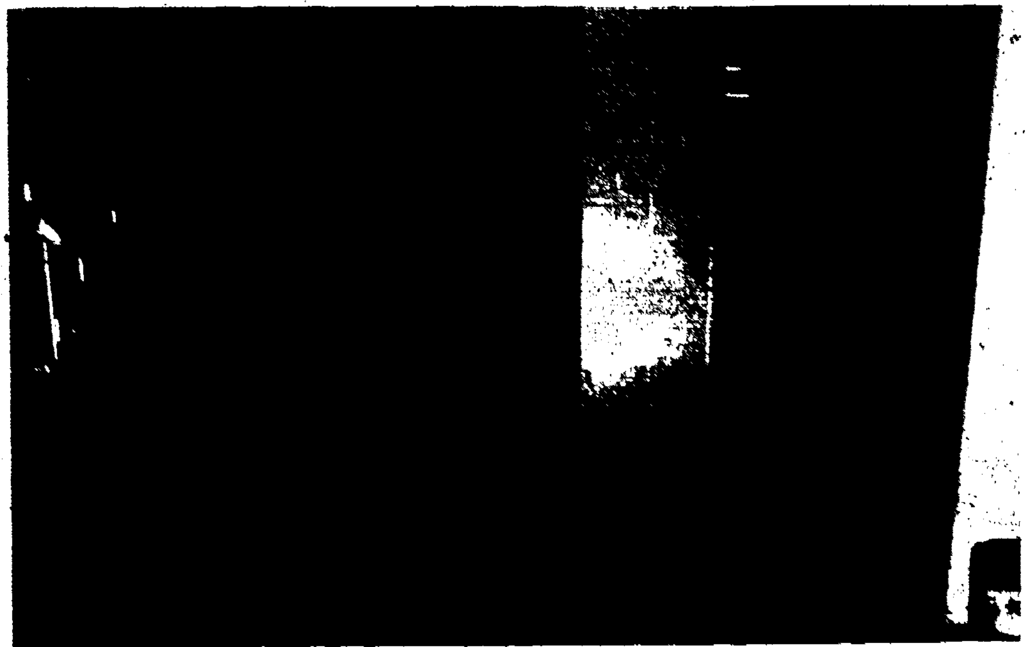
The school administration's concern for student and staff safety, the need for all of their outdoor activity space, and the attractiveness of a completely controlled classroom environment, led to the construction of an underground school.

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

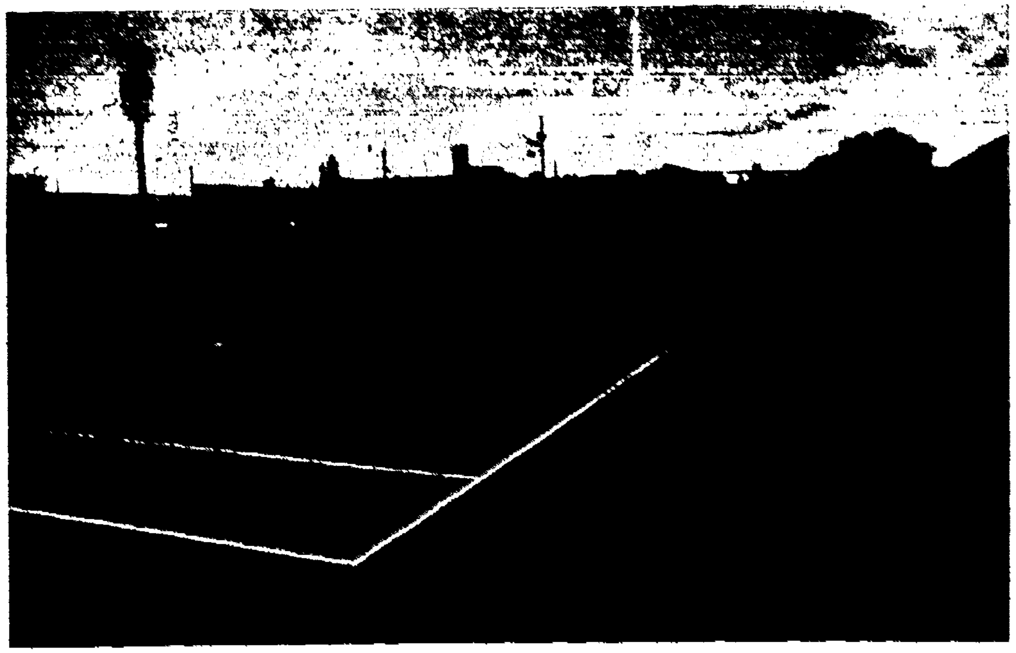
By building underground and covering the structure with two feet of dirt, Seiling was able to build three tennis courts on top of the underground building.



Floor Plan

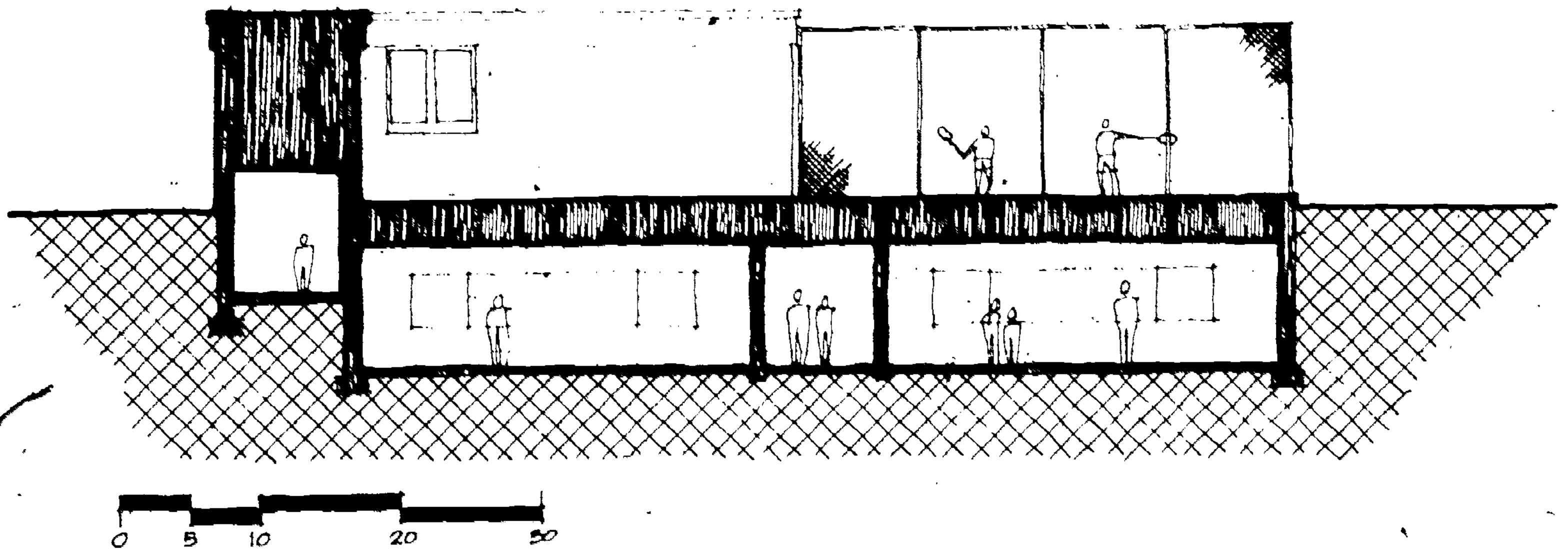


Ramp



Tennis Courts Above Underground School

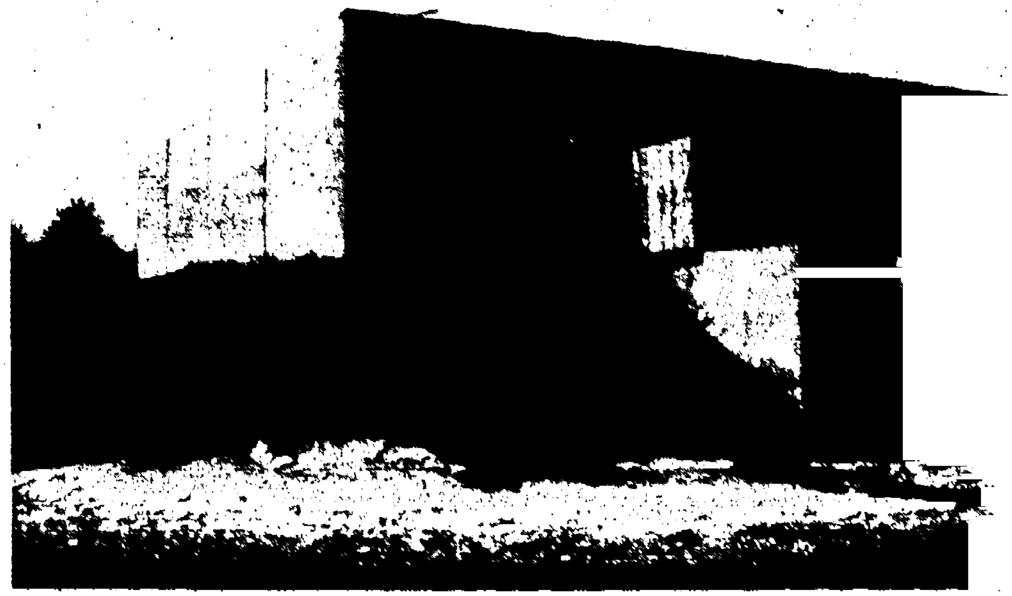
SEILING



Section

TUPELO HIGH SCHOOL

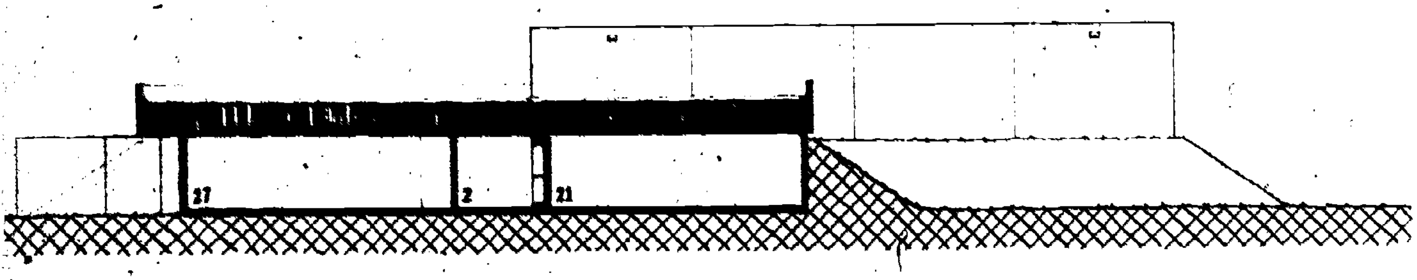
Location:	Tupelo, Oklahoma
District:	Tupelo Independent District
Superintendent:	Paul Fortner
Architect:	Ben Graves and Associates, AIA, Norman, Oklahoma
Completed:	1978
Capacity:	350 Students--Grades 7-12
Floor Area:	16,750 Square Feet
Construction:	$26.43 per Sq. Ft.


Berm

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.

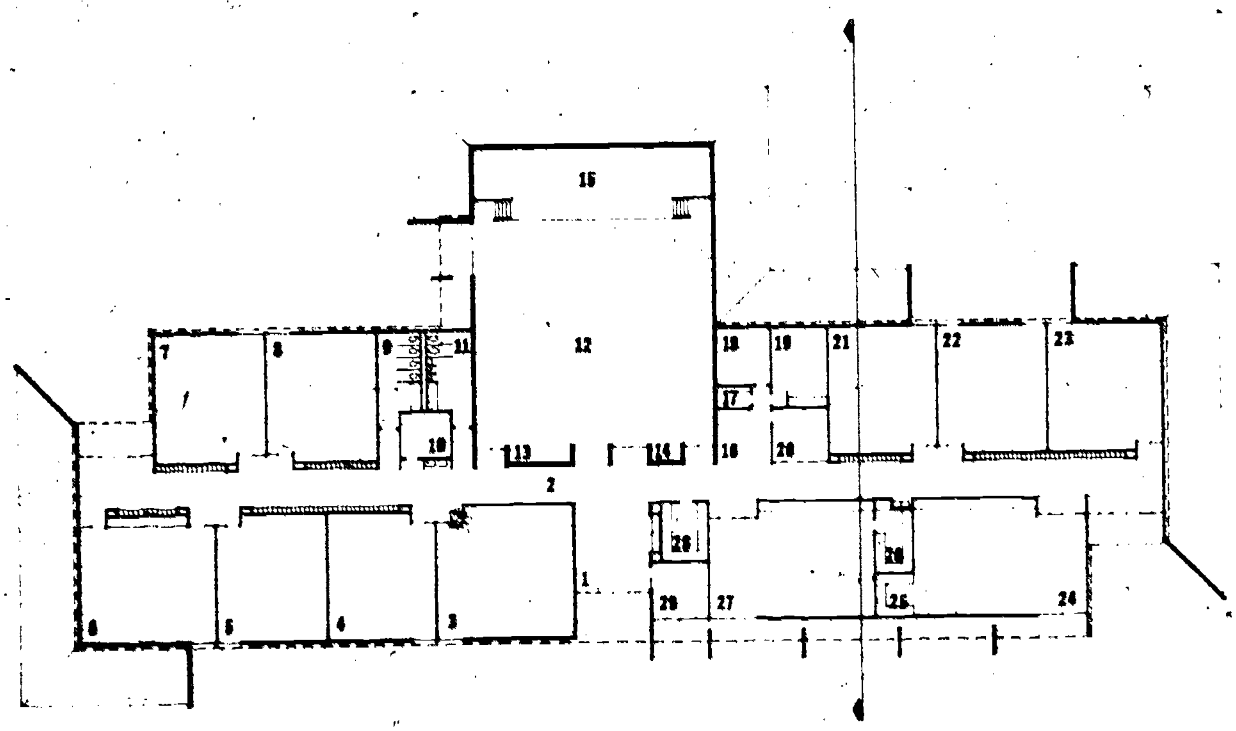

Hallway

51



Section

TUPELO



Floor Plan

WASHINGTON HIGH SCHOOL

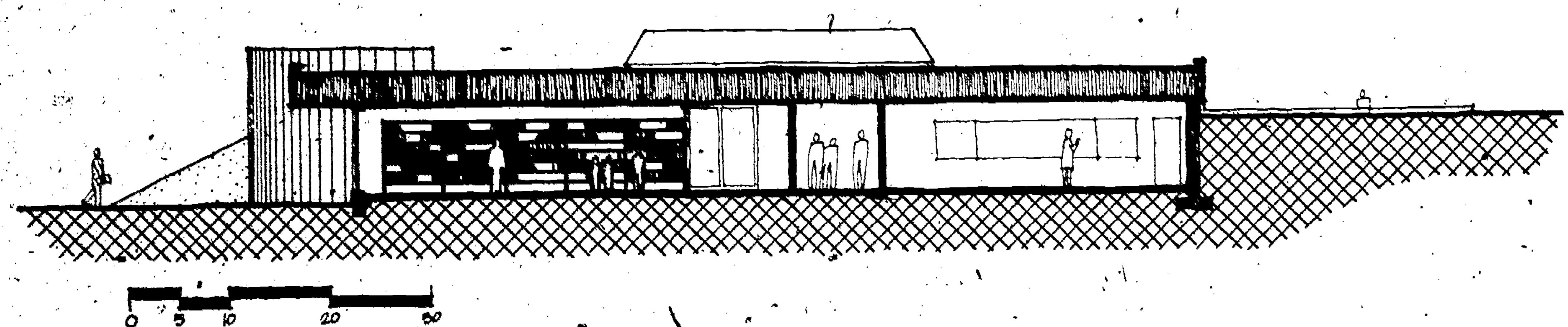
Location:	Washington, Oklahoma
District:	Washington Independent District
Superintendent:	J.W. Pryor
Architect:	Reid Architectural Firm Oklahoma City, Oklahoma
Completed:	1973
Capacity:	280 Students--Grades 9-12
Floor Area:	18,067 Sq. Ft.
Construction:	$16.33 per Sq. Ft.

Front View

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.

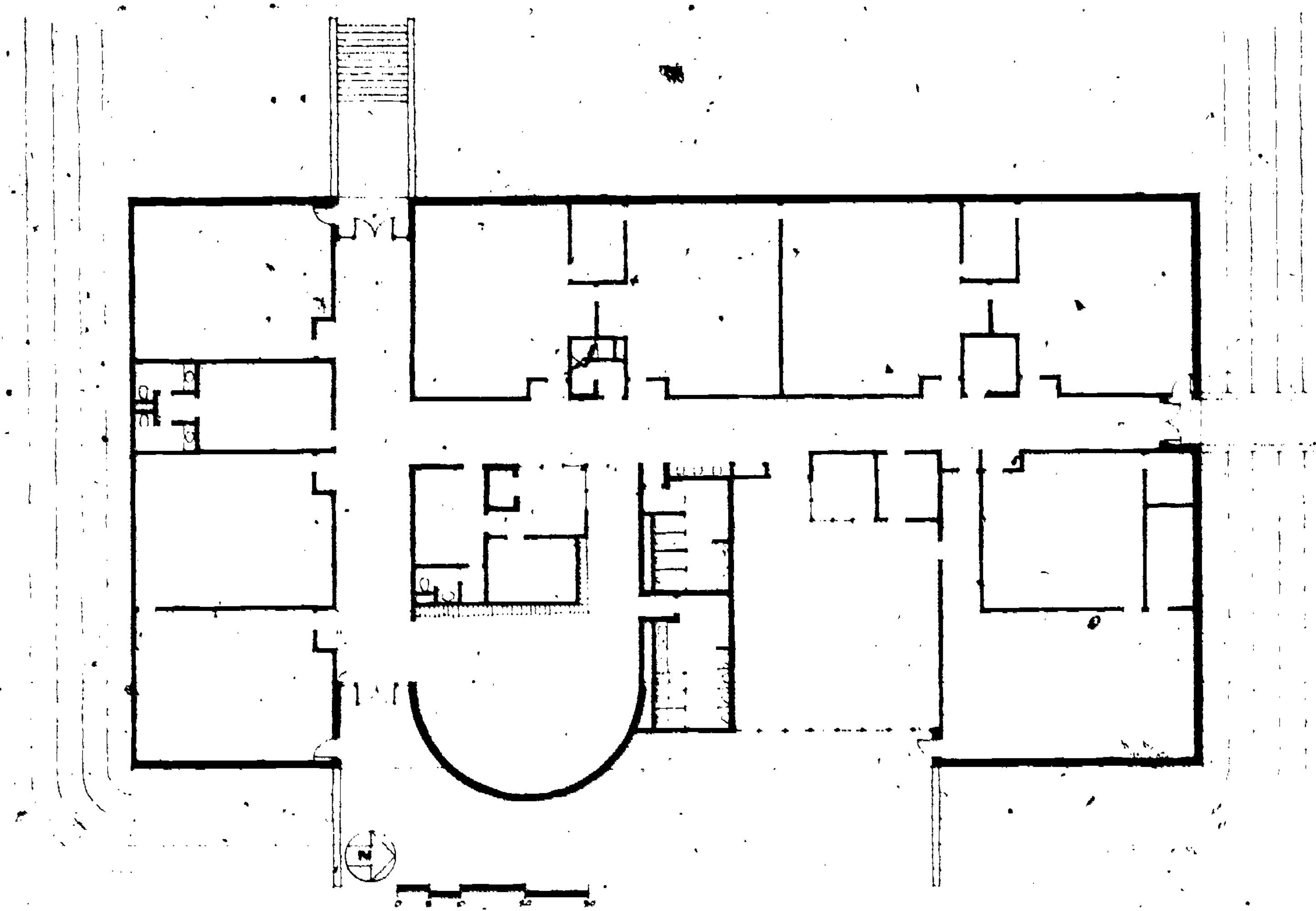
The school administration finds that the problems with the exposed roof and the additional cost of an underground structure might prevent them from building another underground building.

Entrance



Section

WASHINGTON



Floor Plan

54

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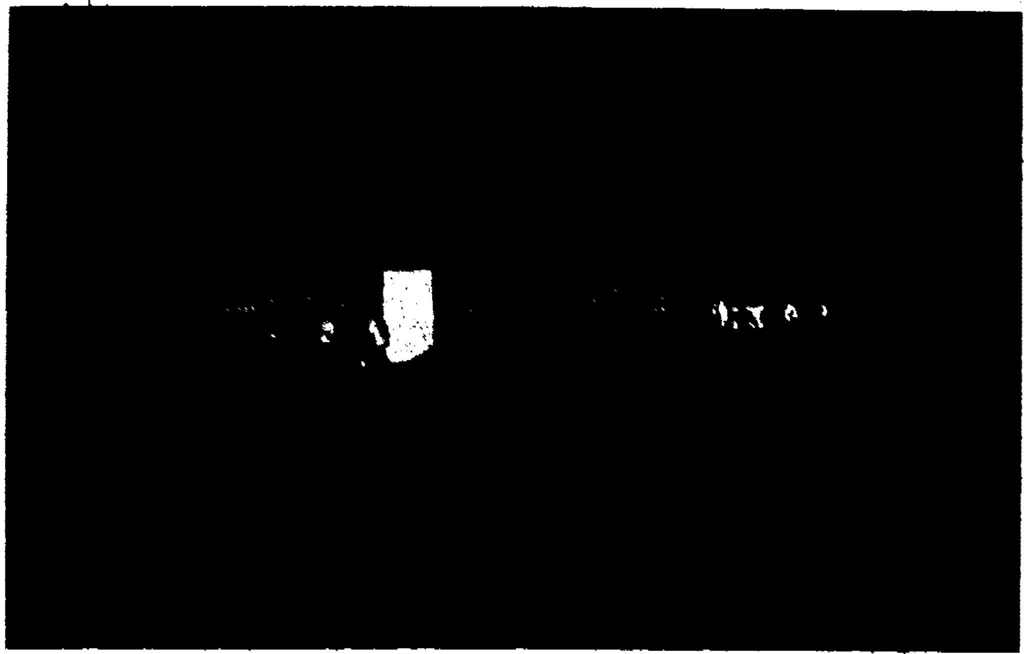
WELEETKA ELEMENTARY SCHOOL

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.

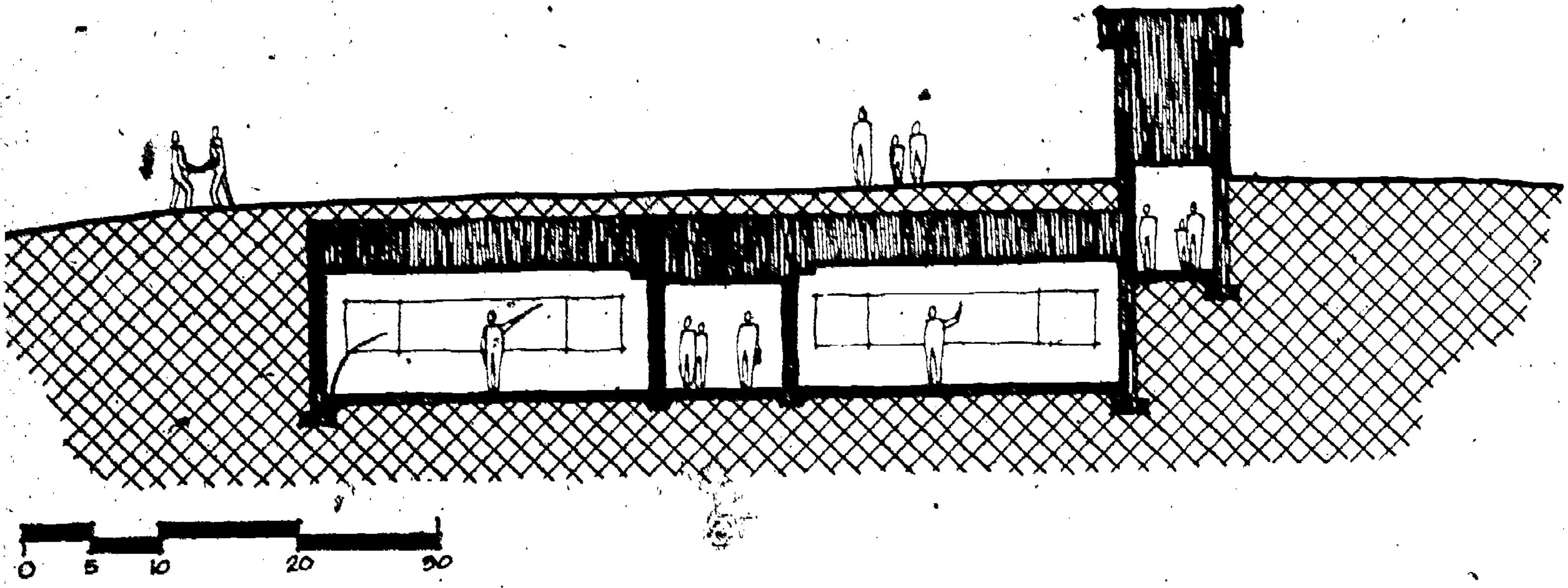


Entrance

Ramp

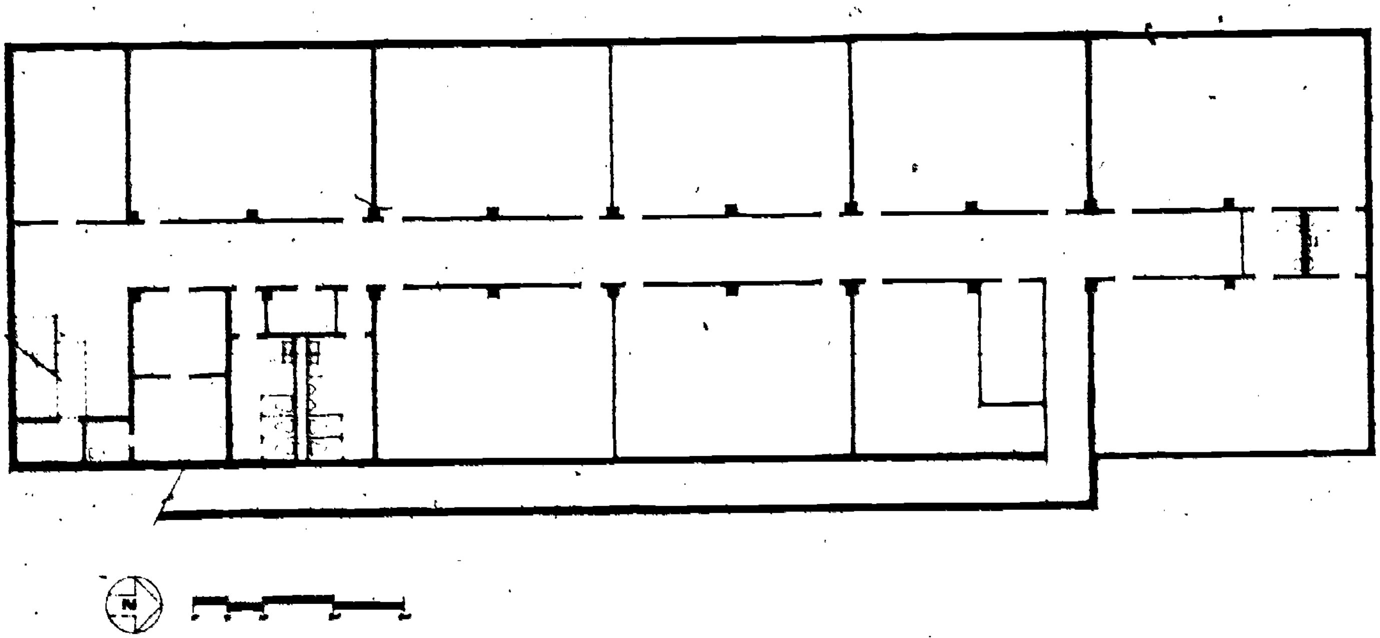
Safety of the children from tornados, controlled environment, energy savings, and limited school site space were the prime factors in determining the first underground structure at Weleetka.

The school was built in two phases, Project A completed in 1972, Project B in 1978.



Section

WELEETKA



Floor Plan

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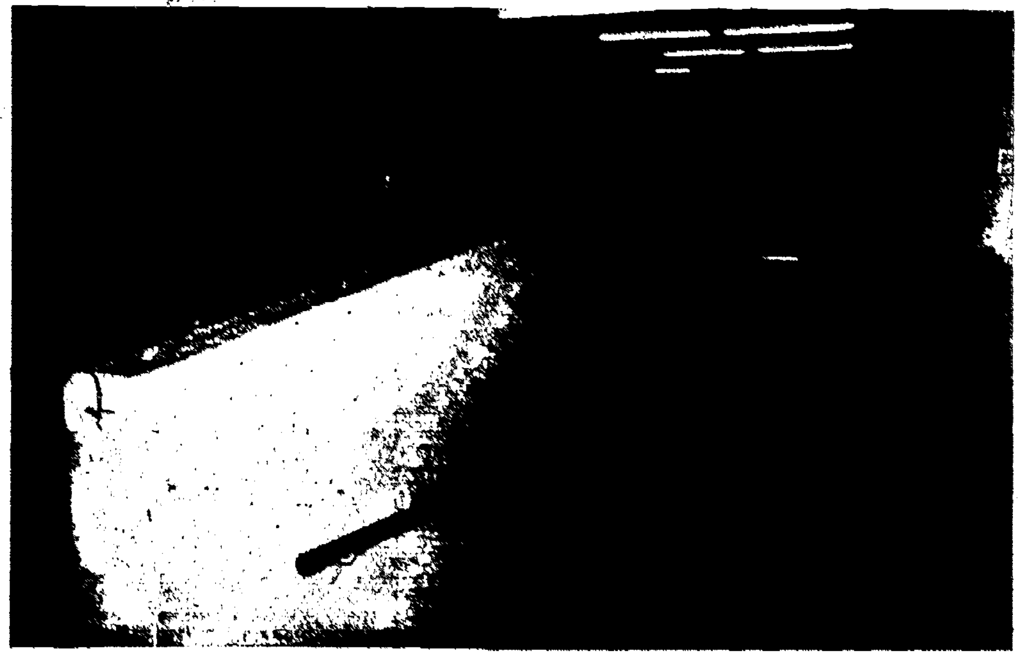
WELLSTON ELEMENTARY AND JR HIGH SCHOOL

Location:	Wellston, Oklahoma
District:	Wellston Independent District
Superintendent:	Frank Duke Bryant
Architect:	Richard Dunham, AIA Oklahoma City, Oklahoma
Completed:	1972
Capacity:	190 Students--Grades 5-8
Floor Area:	13,000 Sq. Ft.
Construction:	$14.05 per Sq. Ft.

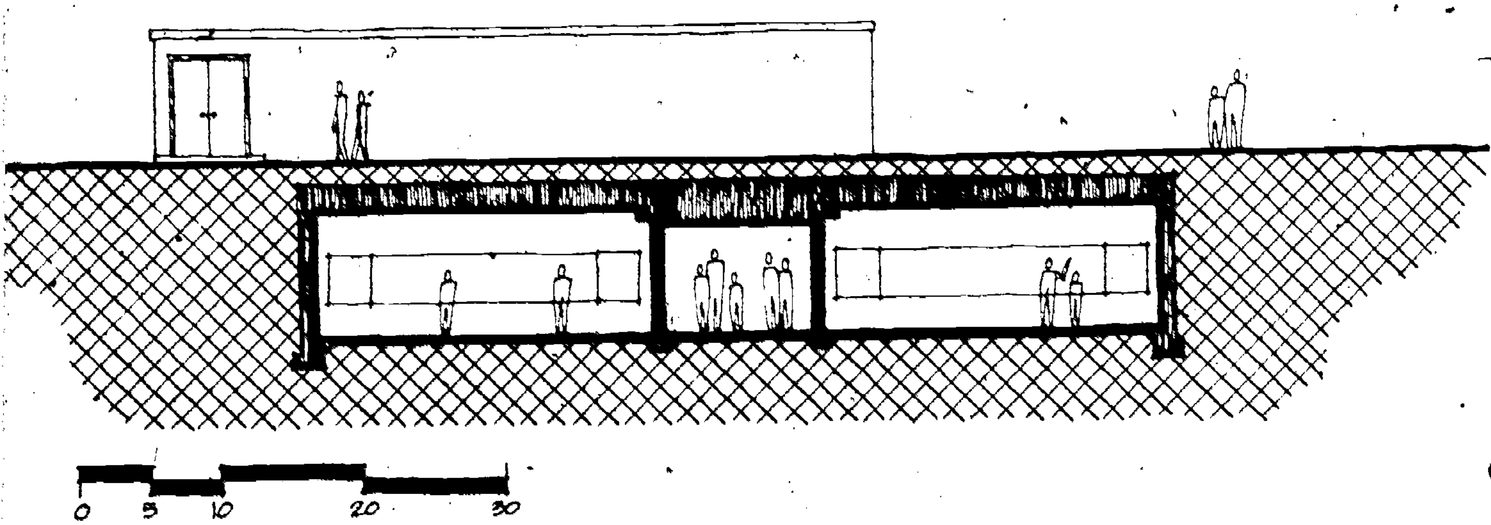


Ramp

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.

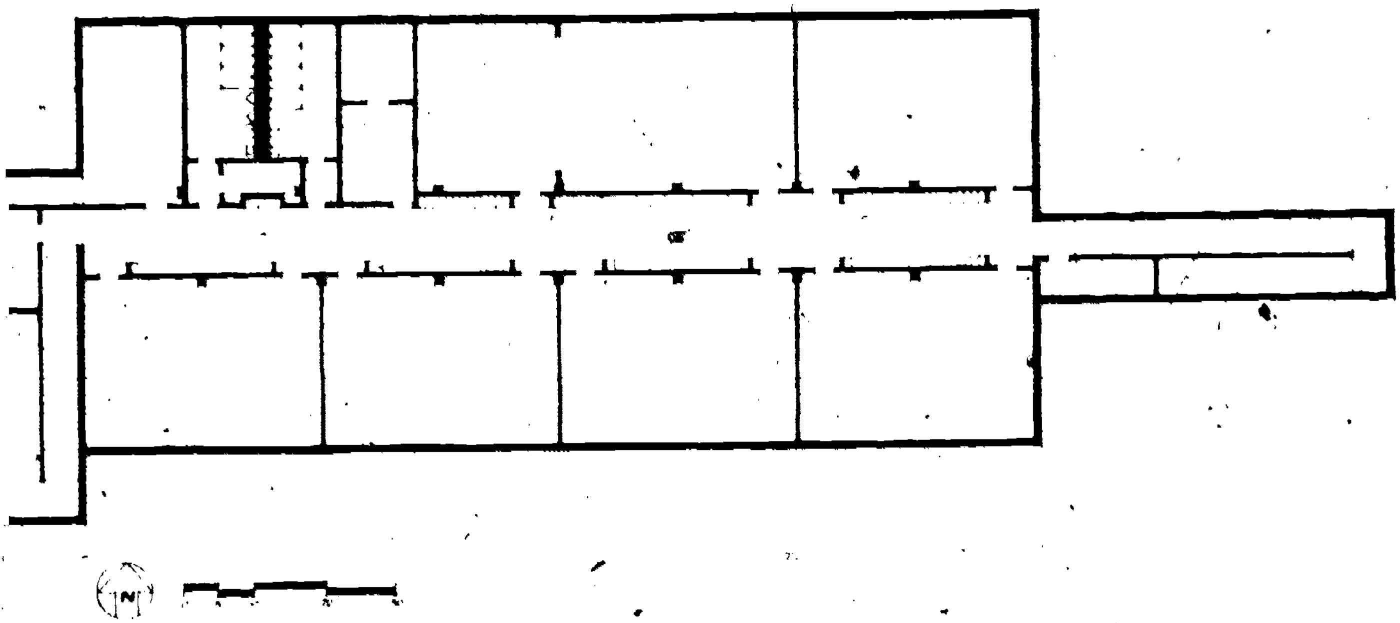
Wellston is often subject to wind storms and tornadoes. When plans for the new school were conceived, it was decided that rather than build a conventional, above-ground school with a much needed but little used storm shelter underground, it would be most economical to put the entire structure below the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

Classroom



Section

WELLSTON



Floor Plan

5.)

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