CHAPTER VI

TYPICAL APPLICATIONS OF FLOODPROOFING TECHNIQUES

A. INTRODUCTION

This chapter presents examples of non-residential floodproofing plans that have been designed and implemented in three cities within the United States. These examples have been included to illustrate the applicability of the techniques presented in this manual.

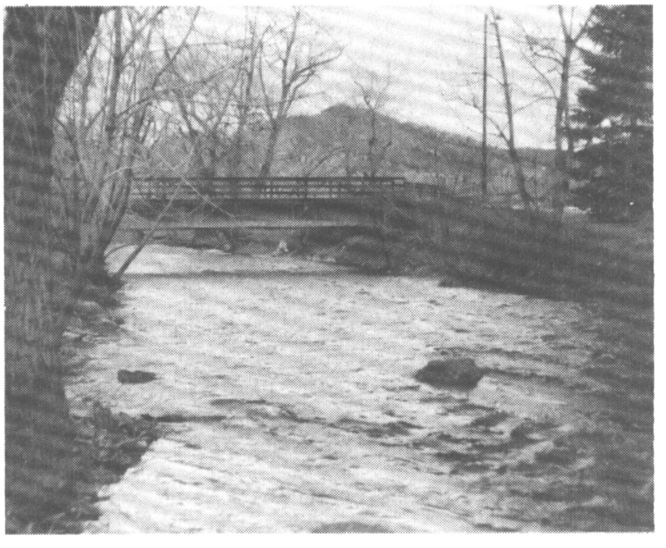
The three cities that were selected for study include Boulder, Colorado; Bristol, Connecticut; and Lock Haven, Pennsylavania. These cities are similar in that they each have a history of major flooding and extensive flood damages that has resulted in an interest in floodproofing techniques. Each city is participating in the National Flood Insurance Program, which requires floodproofing or elevation of all new non-residential construction in the floodplain in addition to all existing non-residential flood-prone structures that are substantially improved. The flood insurance studies conducted for these areas represented a major source of hydrologic data that was used in the design of floodproofing plans.

B. BOULDER, COLORADO

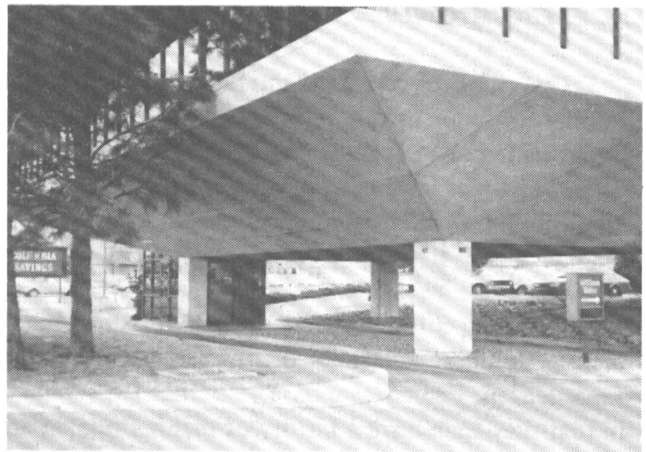
Boulder, Colorado was established in 1859 at the mouth of Boulder Canyon along Middle Boulder Creek. Floodplains in the area are subject to frequent and severe flash flooding associated with intense rainfall that occurs over a large, steeply sloped watershed. Floodwater velocites and floating debris content are relatively high in the area.

Boulder has experienced rapid development over the last few decades, with little or no floodplain management controls. A major flood in 1965 provided local residents with the incentive to participate in the National Flood Insurance Program and to develop and adopt floodplain regulations and an emergency warning system and evacuation plan. The flood warning system includes provisions for low cost radio activated alarms that can be placed at an individual structure. In addition, warning sirens are provided at neighorhood fire stations. This system allows the use of flood shields and other contingent floodproofing methods in certain areas of the city. The city also created a storm drainage and flood control utility district.

In 1969, following another major flood, the State of Colorado created an Urban Drainage and Flood Control District to coordinate flood damage abatement programs and provide technical and financial assistance to communities. Boulder was selected as a pilot study area for the District. This program has resulted in the design and construction of a significant number of floodproofed structures in the Boulder area. Seven examples of these floodproofing efforts are briefly described on the following pages. Floodproofing techniques that are illustrated include the use of elevation, flood shields, and levees.



Columbia Savings and Loan
Boulder, Colorado



Area beneath the building provides sheltered space for automatic bank teller facility.

The Columbia Savings and Loan building is an attractive concrete and glass facility with a metal roof. The 5,055 square foot building is elevated on four main columns. The use of floodproofed space below the structure for a drive-through teller facility reduced total site size requirements and associated land acquisition costs. The first floor level has been elevated 14 feet above the ground, one foot above the base flood elevation. Elevation represented the only feasible floodproofing option at this site due to the significant flooding depth.

The cost of elevating this structure was approximately $77,000 (1970) which included the columns, stairs, elevator, utility extensions, and surfacing the bottom of the elevated floor area.

The entire structure is elevated with the exception of glass entry areas.

Emily Lawrence, Ltd.
Boulder, Colorado

Anticipated flood depths at the Emily Lawrence, Ltd. site were less than 3 feet, with floodwater velocites of 2 feet per second. It was determined that elevation on fill was the most cost effective and desirable floodproofing alternative for the site. The 5,500 sq. ft. brick veneer building is constructed on a concrete slab foundation. The first floor level has been elevated approximately 2.5 feet above the base flood elevation. The location of the building on the edge of the floodplain fringe allowed final grading that provides direct access to the first floor in the front of the building. A combination of grassed embankments and retaining walls were used to accommodate a relatively steep grade transition at the back of the structure. Floodproofing costs, including delivery and compaction of the fill material and additional site preparation, were approximately $15,000 (1980).

Site grading provides direct access to first floor elevation at the front of the structure.

Combination of grass embankments and retaining walls to accommodate grade change at rear of the structure.

JLS Professional Building
Boulder, Colorado

The JLS Professional Building is a two-story structure constructed of glass, steel, concrete and brick veneer. The building was elevated on walls and columns to provide parking space and to protect against flood damage. The first floor elevation is about 6 feet above the base flood elevation. Expected flood depths at this site are 3 feet with flow velocities of 2 feet per second. Elevation increased the cost of the building by 20-35%, however the benefits associated with parking space below the structure compensated for this cost increase. The total structure cost was approximately $500,000 (1980). The first floor area of this building is approximately 4,750 square feet.

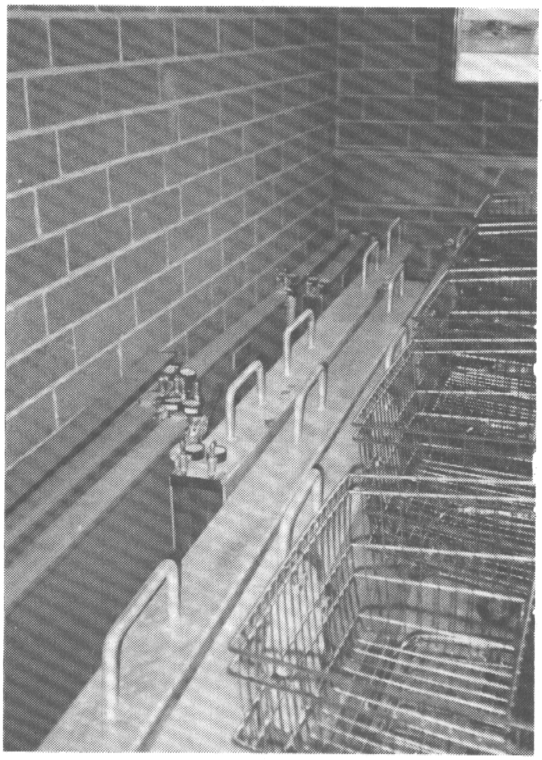
Extensive parking space has been provided beneath this elevated structure.

Building materials include combination of glass, steel, concrete and brick veneer.

Safeway Building
Boulder, Colorado

The Safeway building has a brick veneer exterior with a standing metal seam roof. All windows are located above the base flood elevation, which is approximately equal to the finished floor elevation. Therefore, flood shields only designed to protect only the doors. Flood velocities in the area are approximately 2 feet per second. The shields are equipped with a pneumatic watertight sealing system, and vary in size from 40 inches to 166 inches wide by 26 inches high. The shields are stored near the front of the store behind the shopping cart storage area where they are convenient in case of flooding. The 8 shields provided for the site were manufactured by the Presray Corporation for a total cost of $22,650 (1981).

Existing Safeway Building has been retrofitted with flood shields to protect against flood depths up to 2 feet above the 1st floor elevation.

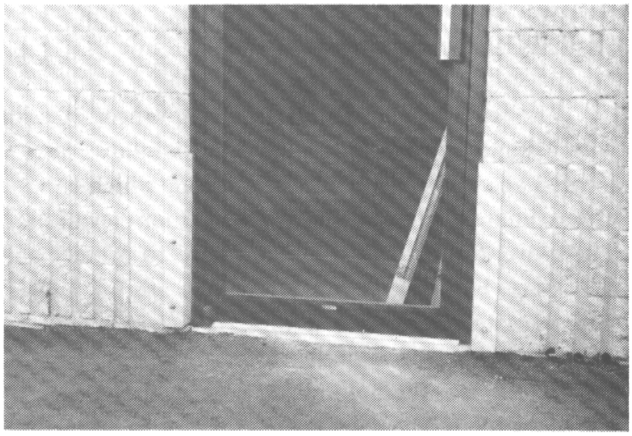


Stored flood shields (Note pneumatic seal valves).

Detail of frame used for mounting shield at front door.

Eastpark Building
Boulder, Colorado

The Eastpark is a fluted concrete block building used for manufacturing and storing office furniture. The finished floor level is approximately equal to the base flood elevation, and flood velocities are estimated at 2 feet per second. All windows at the site are well above the flood level; therefore only doors have been fitted with flood shields. Bolt-on shields were fabricated by a local metal working firm (Boulder Steel) to floodproof this existing structure. A total of 18 shields are required to protect the structure. Ten of these shields are 3 feet wide, and 8 of the shields are 10 feet wide. All shields are 3 feet in height. The total cost of the shields was $3,400 (1980).



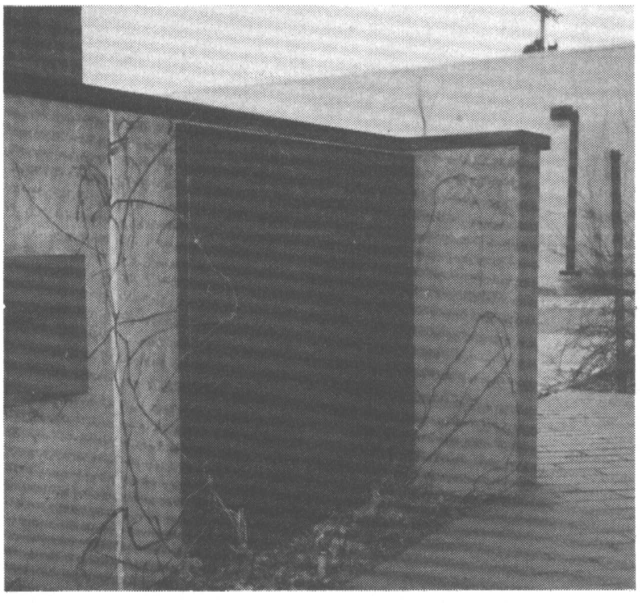
Door frames for mounting flood shields at personnel door.

Floodproofing requires installation of 18 flood shields to protect 8 vehicular entrances and 10 personnel doors.

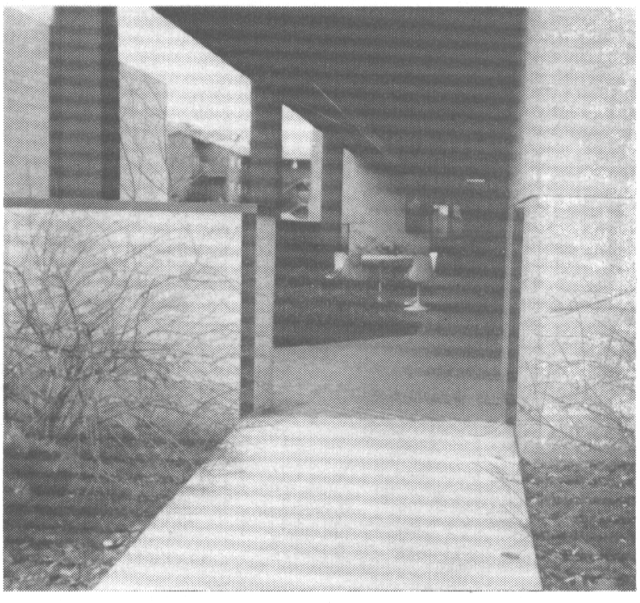
Commonwealth Office Building
Boulder, Colorado

The Commonwealth Office building is a three-story stuccoed precast concrete structure. The finished floor level at this site is approximately 3 feet below the base flood level. Floodproofing of this existing structure required 5 flood shields. The shields are 48 inches high and range from 3-4 feet in width. The shields are designed to withstand 3 feet of flooding depth. The shields were manufactured by Boulder Steel. The total cost of shields at this site was $1,750 (1978).

Structure can be floodproofed with a total of 5 flood shields.



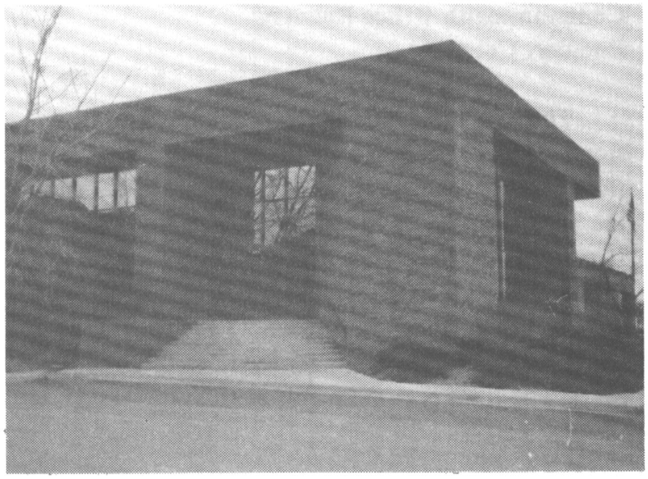
Small courtyard area is protected by combination of precast concrete wall and flood shield at door opening.



Flood shield in storage position adjacent to opening it is designed to protect.

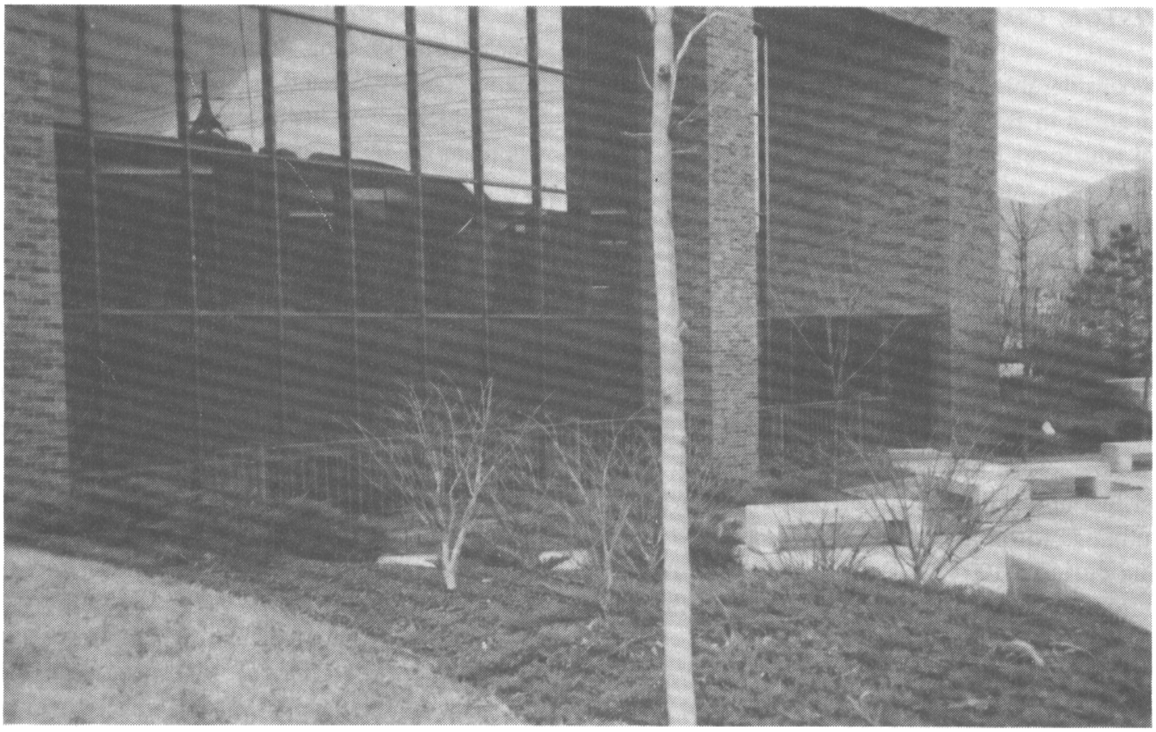
Moore and Company
Boulder, Colorado

The Moore and Company building is located in an area that presented an opportunity to floodproof with an earthen levee. Secondary benefits were derived from the landscaping features incorporated in the design of the levee and building. The base flood elevation at this site is approximately 8 feet above the finished basement floor level, however the levee provides protection to an elevation 2 feet above the base flood level. Therefore, the levee protects both the basement and first floor (a total of 9,800 square feet). The three-story brick veneer building has a walkout basement that opens onto a courtyard that is enclosed by the levee. Access to the front of the building is provided by concrete steps that provide the same level of flood protection as the levee. The total cost of the levee on three sides of the building was approximately $5,000 (1980).

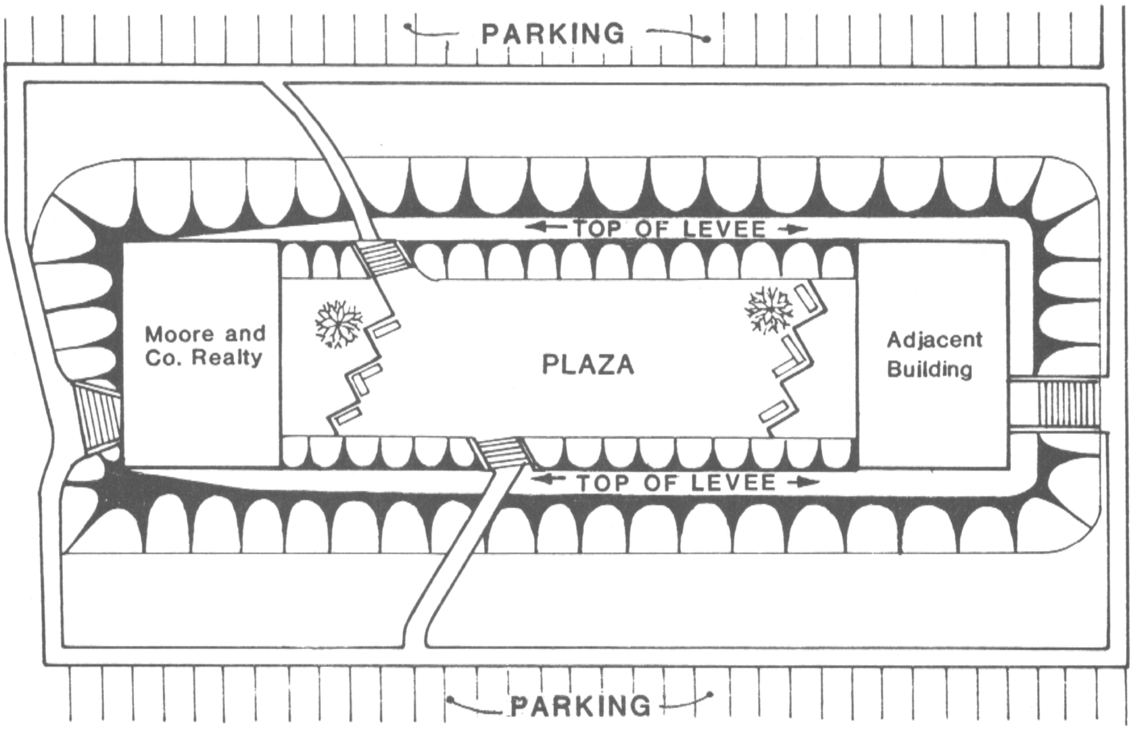


Front entrance is protected from flooding by concrete steps.

The skillful mixing ground cover and grass planting reduce the visual impact of the levee structure.



View of Moore and Company plaza area from top of levee.



Site plan for Moore and Co. Realty. Note that levee protects two structures and provides a heavily landscaped and enclosed central plaza area.

C. BRISTOL, CONNECTICUT

A considerable number of structures have been floodproofed in Bristol, Connecticut. However, this manual will focus on the Wallace Barnes Steel Company. This site was selected because of the company's interest in floodproofing techniques, which has resulted in the construction of a broad range of floodproofing techniques throughout the plant.

A portion of the Pequabuck River channel was diverted in 1946, and the Wallace Barnes facilities have been constructed on the old river bed. During normal flow levels, portions of the plant are only 5 vertical feet above the relocated river water surface; and buildings within the area are subject to 2-4 feet of flooding during a 100-year flood. In 1955 and 1975 major floods resulted in extensive damage to the steel plant.

Recognizing that plant relocation was not economically feasible, the Wallace Barnes Steel Company retained the firm of Anderson-Nichols to perform a floodproofing feasibility study for the complex. The study identified a wide range of permanent, contingent, and emergency floodproofing techniques that could be used to reduce flood damages. Suggested techniques included the use of floodwalls, earthen levees, flood shields, drainage systems, sump pumps, utility system protection, permanent closures, and elevation. The advantages and disadvantages of alternative approaches were identified in the study, in addition to the cost of proposed techniques.

After some modification to the initial floodproofing plans Wallace Barnes management adopted and began to implement a floodproofing program. The selected measures included permanent closure of two coal loading bins, floodwalls designed to protect open spaces between buildings and a below-grade doorway, bolt-on flood shields to protect a total of 61 openings, and replacing an old wooden wall in one building with a 4 foot high concrete wall topped with a frame wall with metal siding. Also, a new addition to the plant was elevated above the base flood level, and a foundation drainage system was installed to relieve uplift pressure on the existing concrete slab floors.

All flood shields and openings have been clearly labeled with symbols that are classified by color and shape. This classification system specifies the location of all shields, and installation priorities. The code numbers are illustrated on a graphic master plan that is maintained by all plant supervisors.

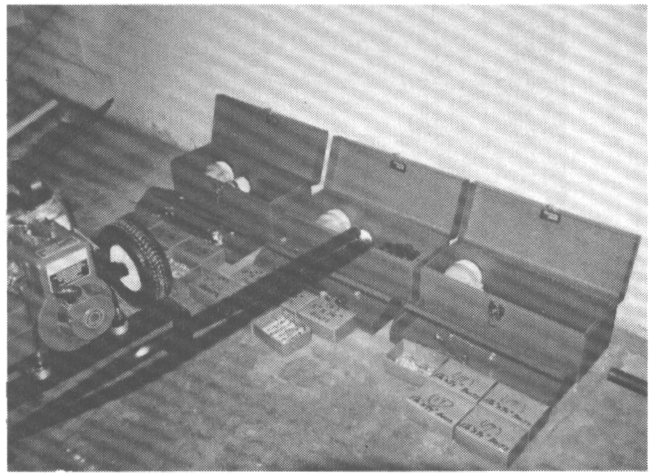
Several locations have been designated throughout the plant for floodproofing component and equipment storage. Sandbags are stored on raised pallets that can be transported by fork lift equipment. Emergency gasoline powered pumps are also stored at these locations and a routine maintenance program assures that all systems are operational. The floodshields for individual openings are stored as close to the openings as possible and the tools for mounting them are stored at a common site.

To assure that sufficient personnel are available to implement the floodproofing measures, Wallace Barnes conducts regular training sessions for all supervisors and maintenance people. All supervisors maintain a copy of the Floodproofing Operations Manual which shows all implementation requirements and material storage locations. Because there are maintenance personnel in the boiler building near the river, the monitoring of the river staff gage is assigned as a routine task during potential flood conditions. The floodproofing measures have been prioritized so that the installation crew can implement the plan in phases as required to protect against various flooding conditions.

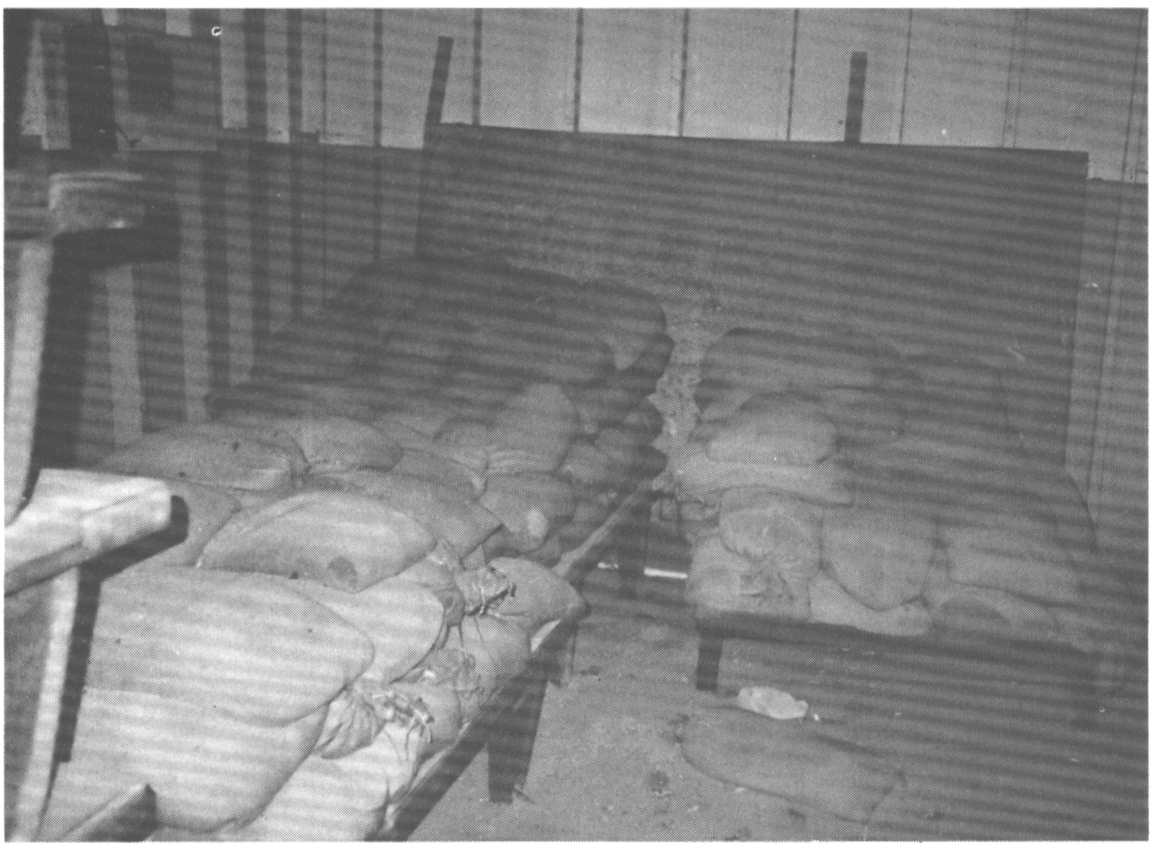
There has been one flood at the Wallace Barnes site since the floodproofing improvements were completed. This flood occurred on June 5, 1982. The event resulted in flooding of only two non-floodproofed buildings within the complex. Maintenance personnel in the boiler building began to monitor the river staff gage at 12:00 p.m. At 6:00 p.m., company management decided to implement appropriate floodproofing measures. A four man crew installed all system components by 8:00 p.m., the river peaked at 10:00 p.m., and floodwaters subsided by 12:00 p.m. Test ports were monitored throughout the flood, but hydraulic pressure beneath the floors was not elevated to significant levels since the floodwaters receded very quickly. Therefore, it was not necessary to close floor drain valves, or to activate the pumps connected to the foundation drainage system.

This flood did not result in any damages to the Wallace Barnes site with the exception of minor exterior cleanup requirements. For comparison purposes, it is significant to note that a brass rolling mill is located near the Wallace Barnes site. Operations at this facility are comparable to those at Wallace Barnes, and the brass rolling mill was subjected to comparable flood depths. Because the mill did not have any provisions to reduce flood damages, the facility sustained close to $1 million in flood damages.

With the exception of engineering services, the total cost of floodproofing measures at the Wallace Barnes site was approximately $250,000 (1980). The company has been able to recover this cost through reduced flood insurance rates, and damages prevented during the June 5, 1982 flood.



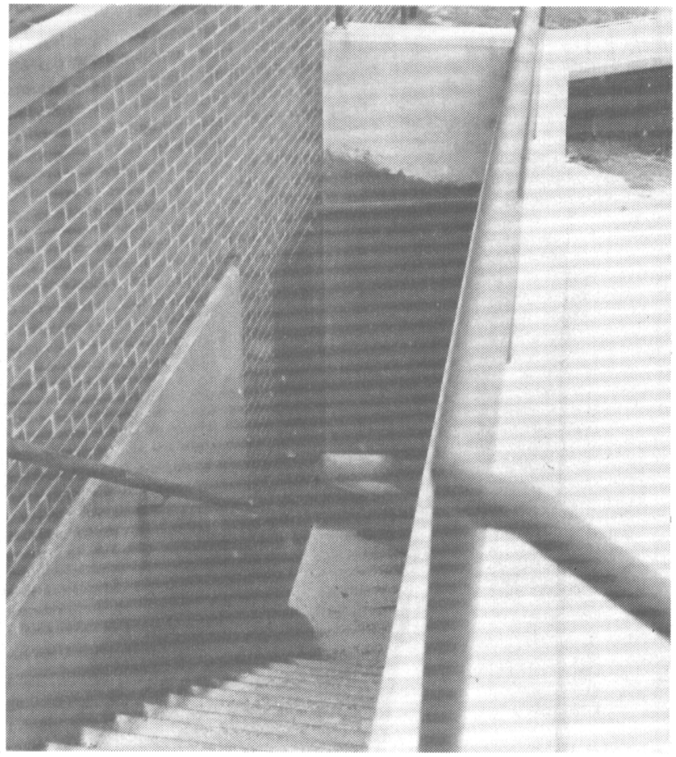
Tools, parts, and portable gas powered pumps required to install flood shields and remove any seepage that may occur.



Sand bags stored on pallets that can be moved to site by fork lifts.

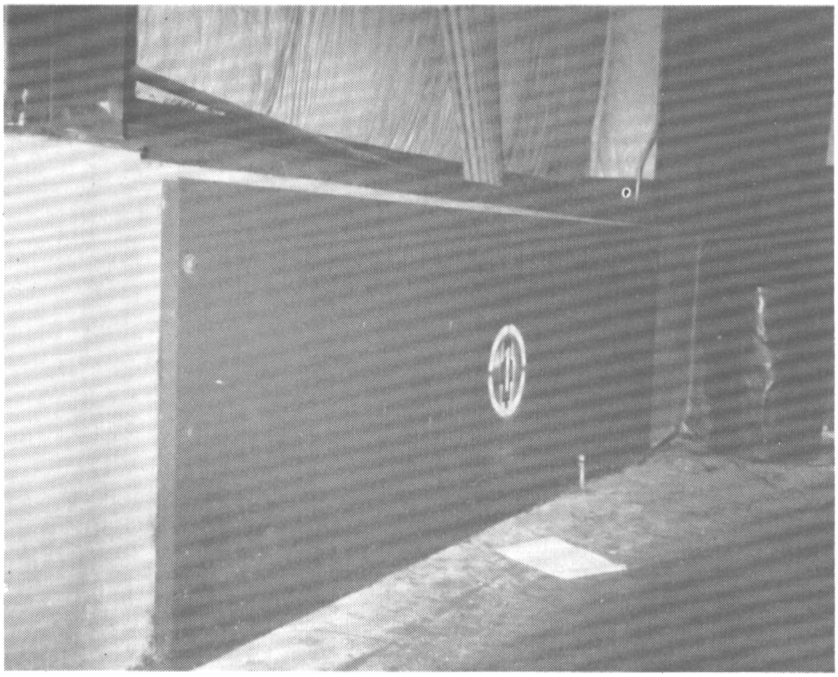
Floodproofed on-site gasoline pump to provide fuel for portable pumps and other equipment.

Concrete cap used to seal abandoned coal loading chute.

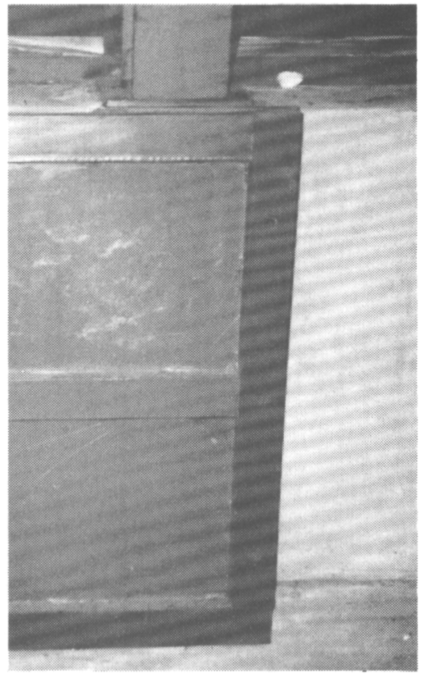


Reinforced concrete wall to protect below grade door (steps extend to top of the wall and down to Ground level).

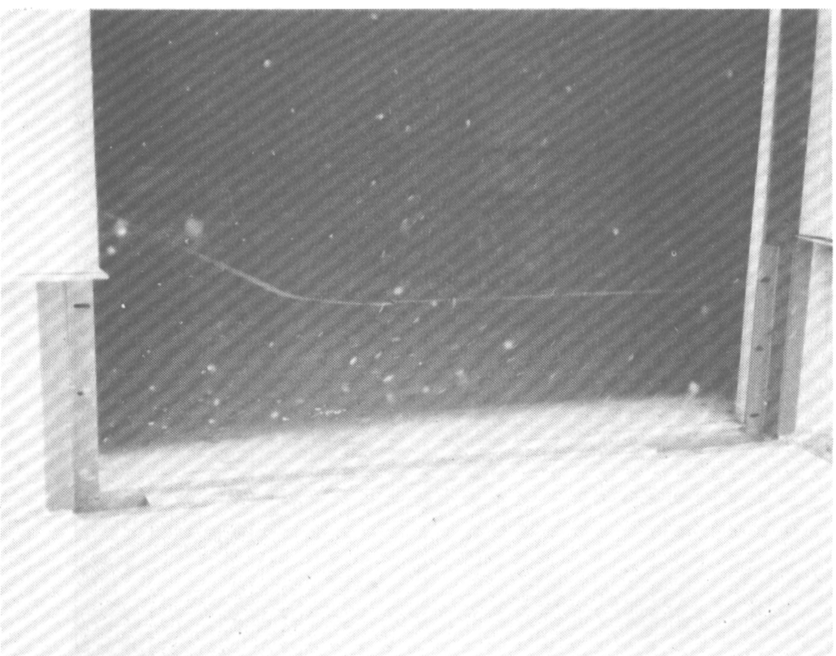
Flood shield are maintained in place over seldom-used openings.



Flood shield in stored position. Can be raised to protect large loading dock door.

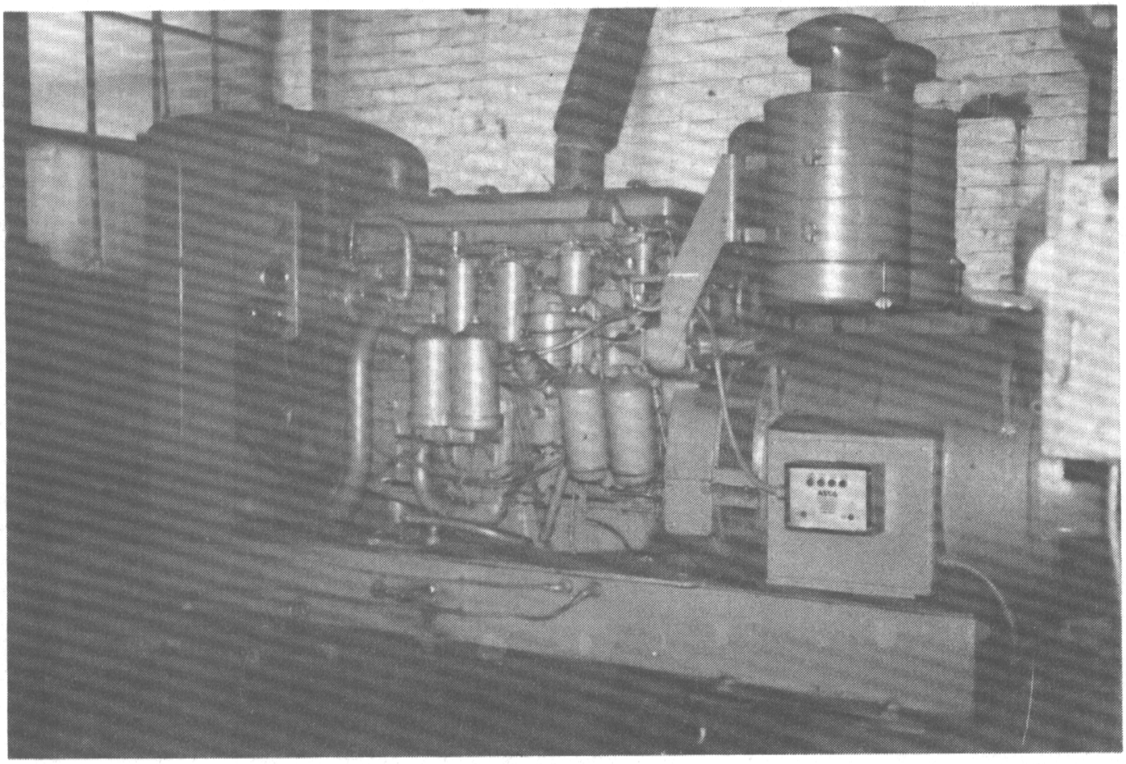


Shield Detail

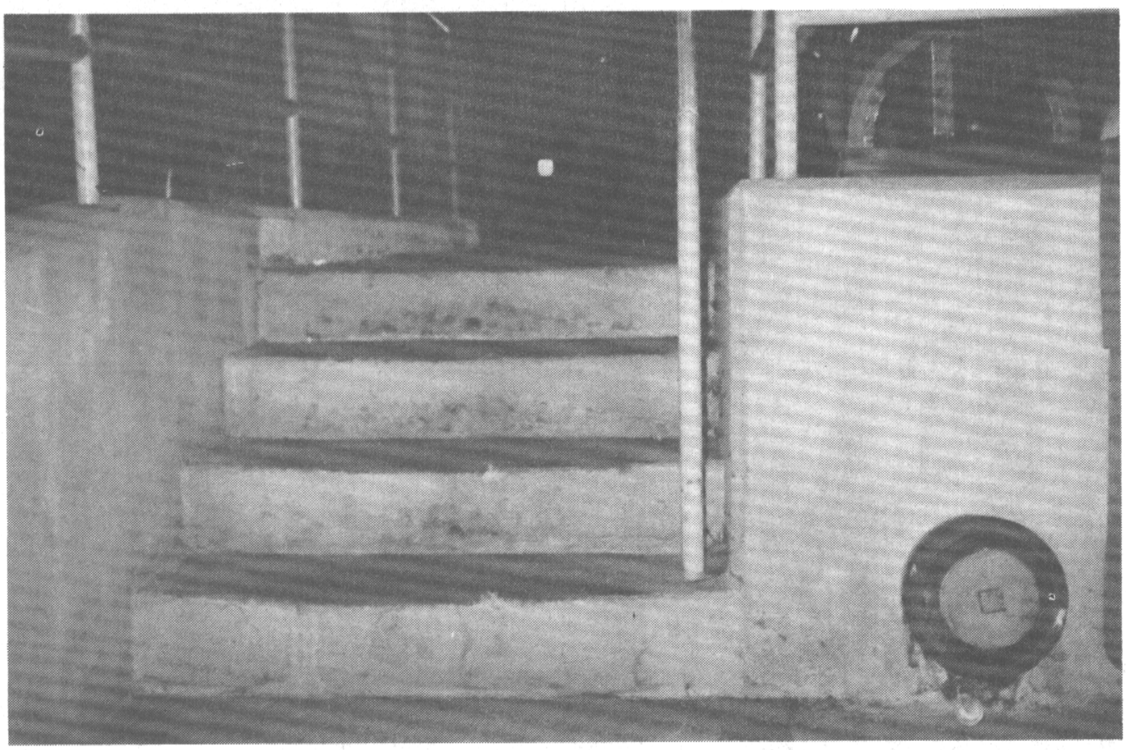


Frame for mounting flood shield on loading dock door. A 4″ x 4″ piece of timber is used to facilitate traffic over a slot designed to receive and seal the flood shield.

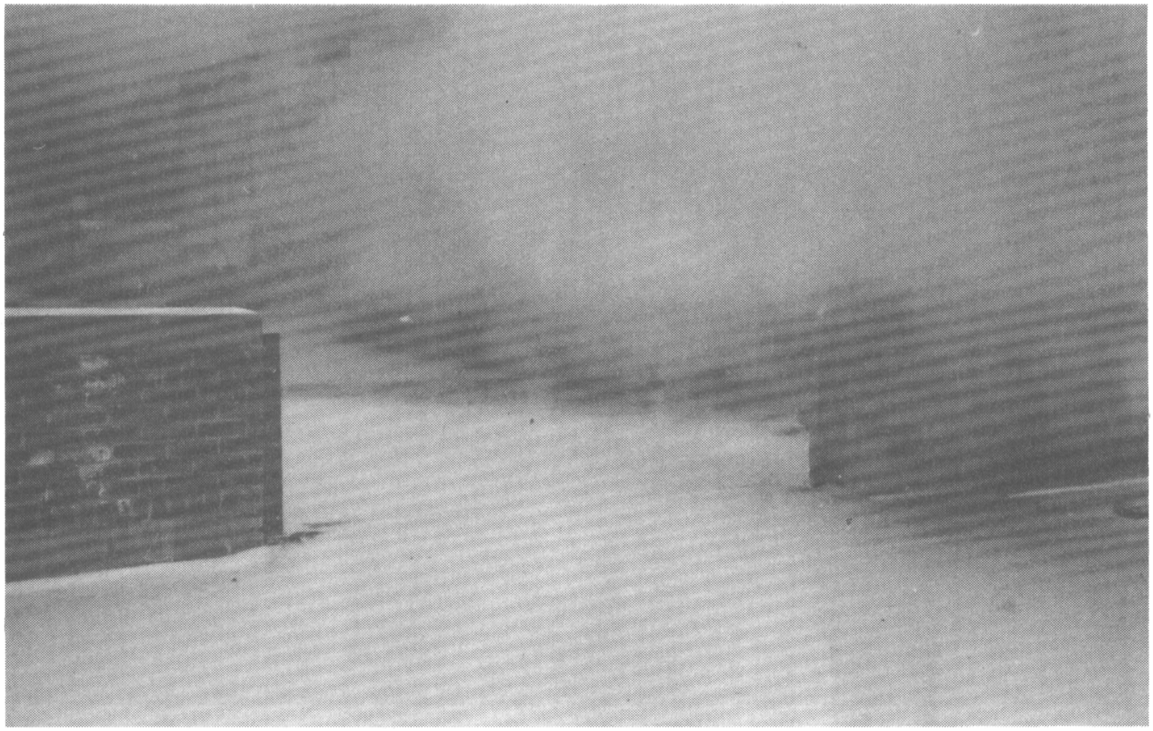
Frame Detail



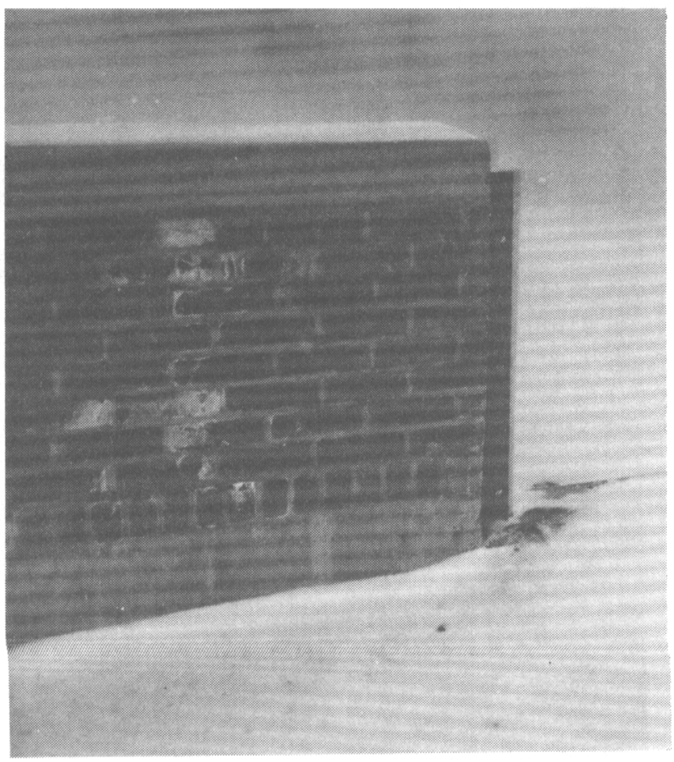
Diesel pump which can be used to dewater seepage within the plant and from a below grade collector system on the perimeter of the plant that is designed to reduce uplift forces on the floor system.



Newly constructed computerized rolling mill area has been elevated above the base flood elevation.



Floodwall to protect large area between two buildings.



Frame for mounting flood shield at access point through floodwall.

D. LOCK HAVEN, PENNSYLVANIA

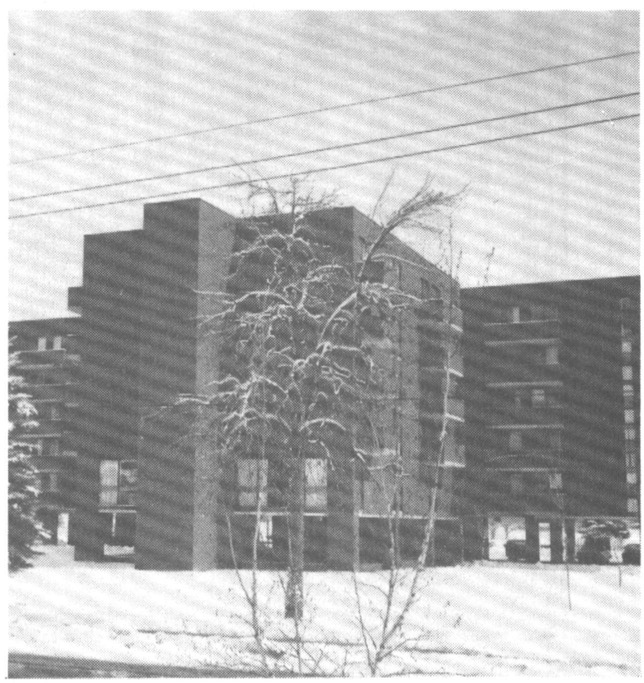
The city of Lock Haven is located in Clinton County in central Pennsylvania. The West Branch of the Susquehanna River flows through the north portion of the city, and Bald Eagle Creek flows through the south section. The combined drainage area of these two watersheds is approximately 3,117 square miles. Previous flood studies have shown that approximately 60% of the town lies within the 100-year floodplain. Futhermore, a large percentage of development within the floodplain is located in the floodway where depths exceed 8 feet, and velocities exceed 3 fps. The city has been flooded 19 times in the past 130 years. The flood of record occurred in 1972 as a result of Tropical Storm Agnes (estimated as a 140-year flood) in Lock Haven.

As a result of obvious flood hazards, the City of Lock Haven and Clinton County have initiated a floodplain management program. Historical flood problems which were highlighted by Tropical Storm Agnes led to the involvement of a complex network of government agencies at the Federal, State, regional and local levels, all working toward means of reducing flood damages in Lock Haven. The result has been the floodproofing of a considerable number of both residential and non-residential structures in the area.

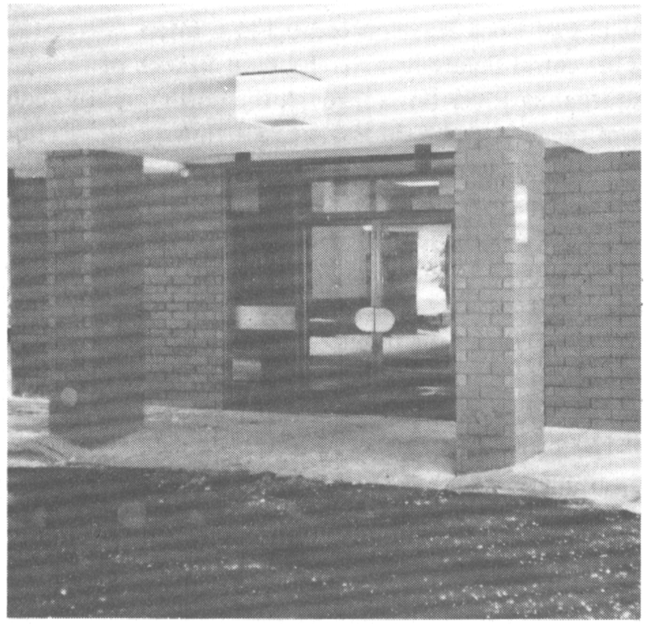
In response to extreme flood depths, the most common floodproofing technique that has been applied in Lock Haven is structure elevation. The floodproofing examples shown in this chapter illustrate the flexibility of elevation as it applies to several building types in an area that is subjected to extreme flood hazards. The sites described below illustrate that elevated structures can be functional, cost effective, and aesthetically pleasing.

Kephart Plaza
Lock Haven, Pennsylvania

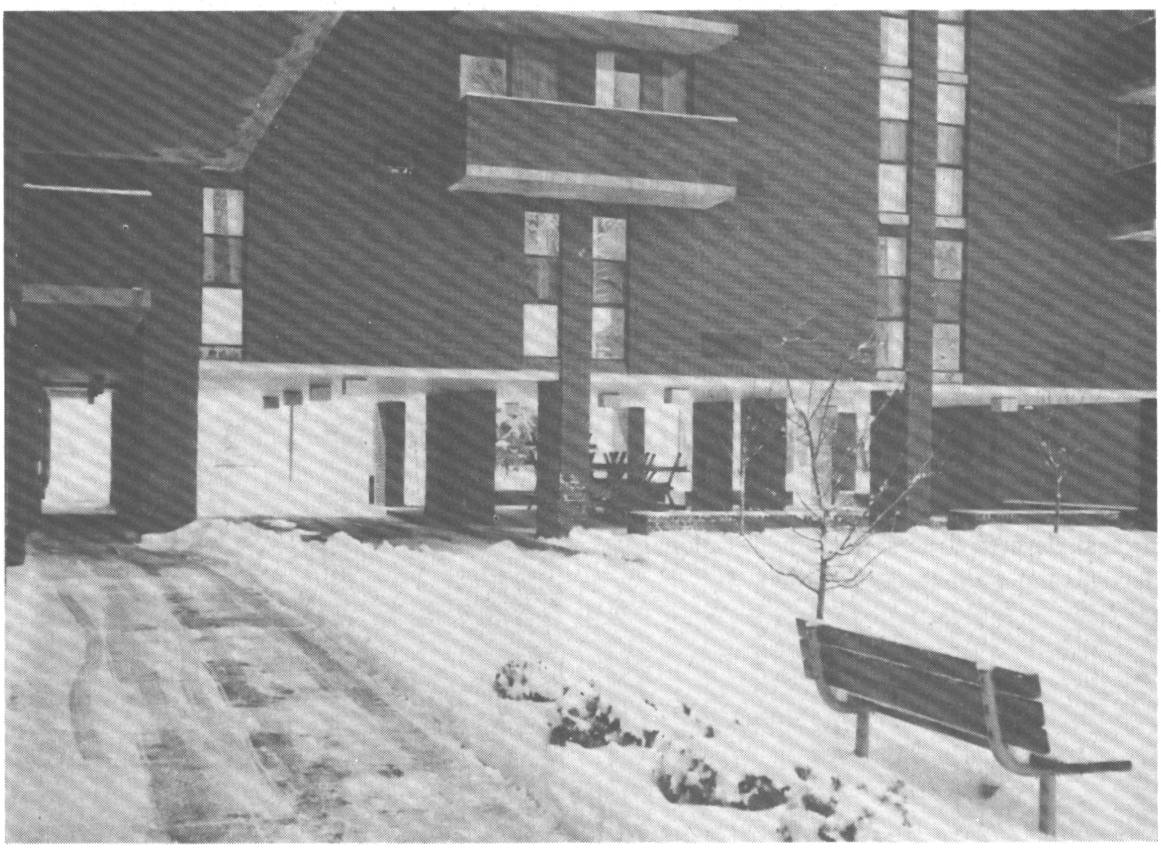
The Kephart Plaza is a five-story cast-in-place concrete structure with a brick veneer exterior. Base flooding depth associated with the 100-year flood is approximately 9 feet. The ground elevation at the site is 557 msl and the finished floor elevation is 567 msl which places it about 1 foot above the base flood elevation. All utilities have been elevated to the first floor and access to the building is provided by stairs and an elevator. Floodproofing costs, including elevation of the utilities, was about $100,000 (1979) or 5% of the total project cost. The open space beneath the building is utilized for parking, storage and picnic facilities. Flood warnings at this site are issued from warning sirens at a nearby fire station.



Structure elevated on columns and walls



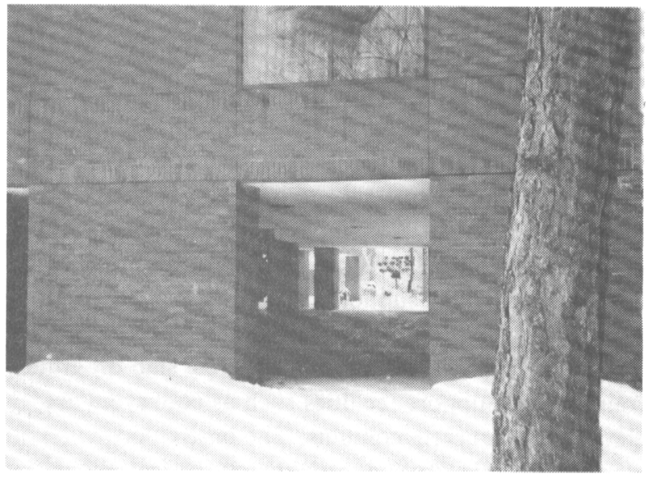
Front entrance at Kephart Plaza.



Area under the structure is used for outdoor activities and storage.

Ross Library
Lock Haven, Pennsylvania

The Ross Library building is a 2-story cast-in-place structure with a brick veneer exterior. Because of the need in this case to reduce the impact of building placement on the floodwater depth or flow, the front and one side of the building have been elevated on walls and the balance of the structure is supported by columns. The first finished floor has been elevated approximately 12 feet, 7 feet above the base flood elevation, to reflect the severe losses that would be incurred at the library if a flood exceeded the 100-year level. The cost of elevation was approximately $100,000 (1978).

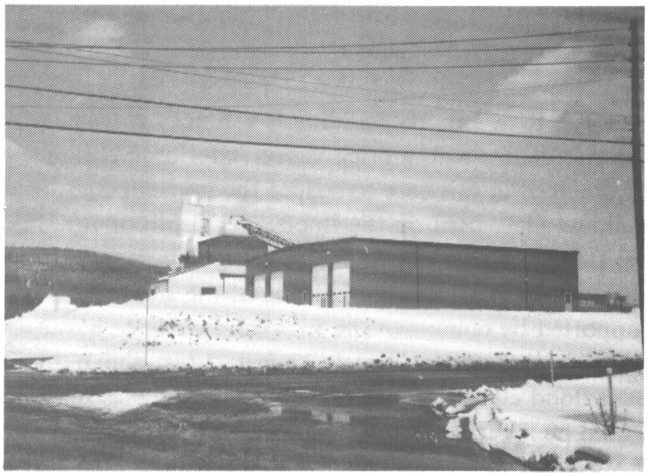


Combined use of wall and columns minimize visual impacts of 12 foot elevation height.

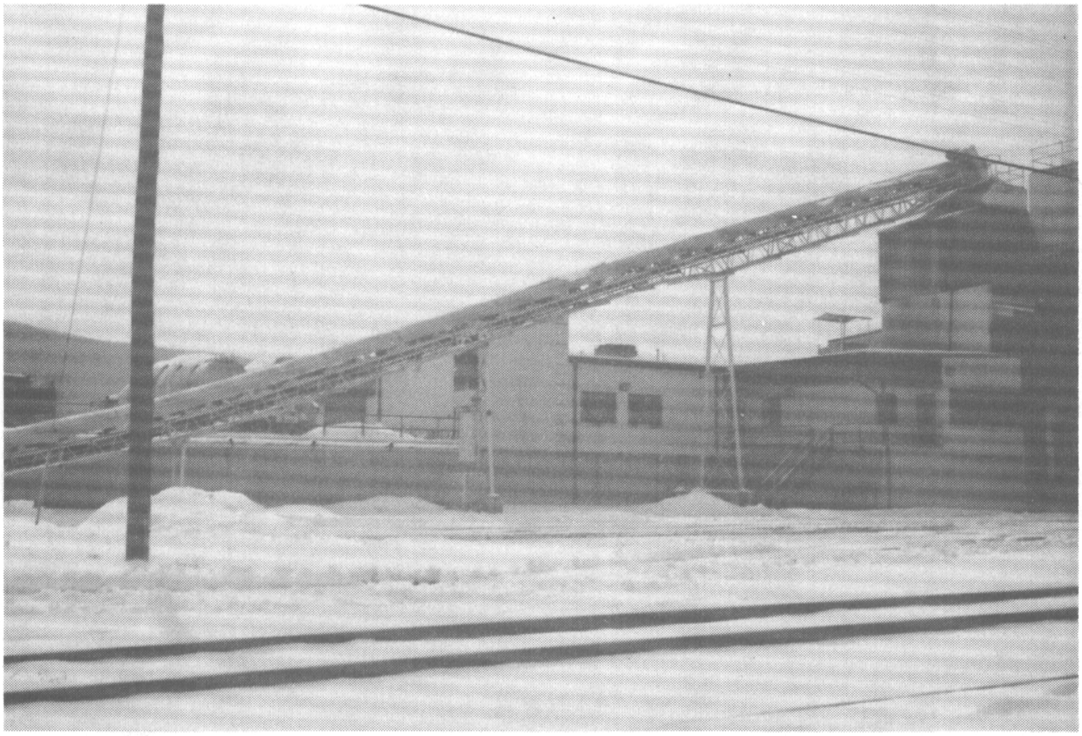
Structure has been elevated 7 feet above the base flood level in recognition of potential damage from floods that exceed the regulatory flood level.

Centre Concrete
Lock Haven, Pennsylvania

The Centre Concrete Company is located in the flood fringe. Two buildings have been constructed on fill at the Centre Concrete site including a 6,150 square-foot control building and a 6,400 square-foot garage. The control building is of concrete block construction and is supported by fill which has been placed behind a concrete retaining wall. The garage is a four-bay metal building on a concrete slab-on-grade foundation. Support facilities such as conveyors are elevated on concrete columns. The base flood elevation at this site is approximately 10 feet above the original ground elevation. The cost of additional fill for the site was $6.00 per cubic yard for a total cost of approximately $120,000 (1981)



Garage structure elevated on earth fill.



Control building is elevated on earth fill that is enclosed by concrete retaining walls. This technique minimizes space requirements because areas for slope transition are not required.

ELEVATION ON FILL

American Legion Hall
Lock Haven, Pennsylvania

The American Legion Hall in Lock Haven is a concrete block building that has been elevated approximately 10 feet on fill. The finished floor is located one foot above the base flood elevation. Earth fill was delivered to the site at a cost of $2.00 per cubic yard for a total cost of $4300 (1979), or 3% of the total building cost of $150,000 (1979).

Structure elevated approximately 10 feet on earth fill for approximately 3% of the total project cost.