FLOOD PROOFING TECHNOLOGY

In The Tug Fork Valley

US Army Corps of Engineers
Flood Proofing
NATIONAL FLOOD PROOFING COMMITTEE

April 1994

Front Cover Photographs:

Top: **House on the right during April 1977 flood.**
Middle: **Same house during flood proofing project.**
Bottom: **Flood proofing completed.**

Note: The house was modified by removing the small gable roof above the porch before it was raised.

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PREFACE

For three days in April 1977, the Tug Fork Valley was subjected to torrential rains and a subsequent flood of monumental proportions. The Tug Fork Valley was no stranger to floods having experienced 37 damaging flood events during a 50-year period. However, the April 1977 flood was the flood of record, exceeding the 500-year flood event in many of the heavily populated areas of the Valley. In a matter of a few hours, 600 homes were completely destroyed and another 5,000 structures were heavily damaged by the raging flood waters.

Miraculously, there were no fatalities during the flood, but hundreds of families were left homeless during an unusually cold spring month and the Valley's basic infrastructure and industrial base were rendered useless for several months. A massive emergency aid and clean-up program involving the Corps of Engineers, the Federal Disaster Assistance Administration, the American Red Cross, West Virginia and Kentucky National Guard units and State Emergency Services followed the receding water into the Tug Fork Valley.

As the Valley's residents struggled to regain their foothold on life, the seeds of an unique flood damage reduction plan were being sown by the Huntington District of the Corps of Engineers. Aided by the passage of unique legislation, the Corps of Engineers waded into the flood-soaked Tug Fork Valley, and developed a multi-faceted plan destined to change the development pattern of the Tug Fork Valley forever. This report presents the features of that plan as they were constructed and focuses on the application of flood proofing technology in the Tug Fork Valley to reduce future flood damages.

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Introduction

For many years, federal, state, and local agencies associated with flood control and flood plain management have expounded on the merits of nonstructural measures as a method of reducing flood related damages. The nonstructural measures available include flood proofing, flood plain relocations, flood plain zoning regulations, purchase of easements and transfer of development rights. The use of flood proofing has long been regarded as a relatively inexpensive method of providing protection to structures in the flood plain.

The April 1977 flood in the Tug Fork Valley provided the impetus for formulating a flood damage reduction plan which used both structural and nonstructural measures to achieve a cost effective and socially acceptable solution to the flooding problems in the valley.

Tug Fork Flooding History

The Tug Fork Valley is located on the border of southern West Virginia and north-eastern Kentucky. The Tug Fork, a tributary of the Big Sandy River, begins in the coal fields of McDowell County, West Virginia, and flows northwest through a rugged mountainous landscape on its way to the Ohio River. The Tug Fork Basin is shown on *figure 1*.

The earliest recorded damaging floods in the Tug Fork Valley occurred in 1875. Since that time, at least 50 damaging floods have ravaged the Valley. The April 1977 flood of record in the Tug Fork Valley also caused severe flood damages in the Levisa Fork (a tributary of the Big Sandy River) and the Upper Cumberland River Basins in Kentucky. Flood damages in the Tug Fork Basin amounted to 250 million dollars during the April 1977 flood. More recent flooding in May 1984 resulted in flood damages amounting to 117 million dollars in the Tug Fork Valley.

Project Authorization

As a result of the April 1977 flood, Congress enacted legislation within the Energy and Water Development Act of 1980 (P.L.96-367). Section 202 of the Act addressed the areas impacted by the 1977 flood and was unique for the following reasons.

1) Section 202 provided legislative approval to implement whatever measures were deemed by the Chief of Engineers to be necessary and advisable to reduce flood damages in the areas affected by the April 1977 flood.

2) Section 202 provided for the needed work to be accomplished at full Federal expense (without cost-sharing by a local sponsor).

3) Section 202 specified the April 1977 flood as the target level of protection for flood damage reduction measures.

4) Section 202 specified that the benefits of implementing such a flood damage reduction program would exceed the costs of the program. In effect, this provision eliminated the normal requirement for determining whether a project generated a positive benefit/cost ratio.

5) Section 202 provided that the projects constructed under this authority would be operated and maintained by a local project sponsor.

In effect, Section 202 of the Act provided a fertile legislative environment for the formulation and implementation of an array of both structural and nonstructural measures in the Tug Fork Valley.

Project Formulation

The initial formulation process was applied to a 140-mile section of the main-stem of the Tug Fork and its tributary streams affected by the April 1977 flood. Under the Section 202 legislation, project formulation was based upon:

1) cost-effectiveness of reducing damages for each structure or group of structures;

2) effectiveness in reducing flood damages;

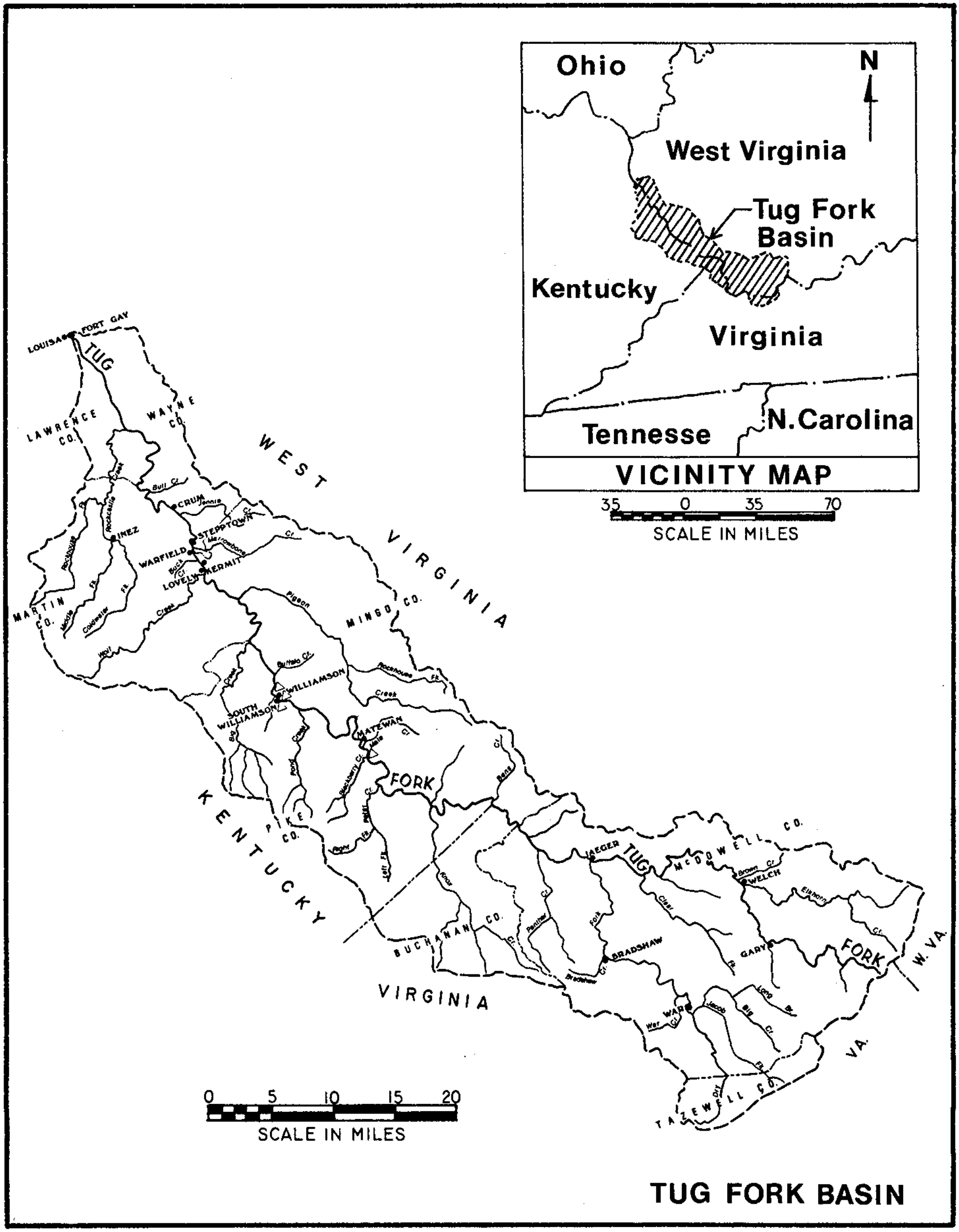
3) social acceptability;

4) environmental suitability.

The application of these formulation parameters resulted in a program featuring structural floodwalls at several densely developed urban areas and the use of flood proofing and permanent flood plain evacuations in the scattered linear communities along the river. To reduce the sociological impacts of flood plain relocations in an area where suitable housing is in short supply, the program included the development of several Housing and Community Development (H&CD) sites for construction of replacement housing.

Environmental Compliance

In conjunction with the formulation of the flood damage reduction program, the potential environmental impacts of constructing the structural floodwalls and the sociological impacts of relocating large numbers of flood plain residents were addressed in a basin-wide environmental impact statement (EIS). This analysis resulted in the inclusion of several key features of the overall plan including the


Ohio
N
West Virginia
Tug Fork Basin
Kentucky
Virginia
Tennesse
N.Carolina
VICINITY MAP
35 0 35 70
SCALE IN MILES
LOUISA
FORT GAY
TUG
LAWRENCE CO.
WAYNE CO.
WEST VIRGINIA
CRUM
INEZ
STEPPTOWN
WARFIELD
KERMIT
LOVELY
MARTIN CO.
MINGO CO.
WILLIAMSON
SOUTH WILLIAMSON
MATEWAN
FORK
KENTUCKY
PIKE CO.
BUCHANAN CO.
VIRGINIA
IAEGER
TUG
McDOWELL CO.
WELCH
BRADSHAW
GARY
FORK
W. VA.
WAR
VA.
TAZEWELL CO.
0 5 10 15 20
SCALE IN MILES
TUG FORK BASIN
Figure 1.

use of textured surfaces and graphics on the floodwalls, use of the evacuated flood plain areas for replacement of wildlife habitat lost during construction of the floodwalls, landscaping of floodwall easements, and provision of the nonstructural measures to eligible flood plain residents on a strictly voluntary basis. These features have been very successful in the implementation of the Section 202 program in the Tug Fork Valley.

Project Implementation

Upon completion, the comprehensive basin-wide plan was submitted to the Office of the Assistant Secretary of the Army for Civil Works for review and approval in 1982. Based upon that review, the comprehensive plan was divided into 15 separate, geographically defined project areas that could be independently approved, funded and implemented. Since that time, three of the 15 project areas (Williamson and Matewan, West Virginia, and South Williamson, Kentucky) have been approved for implementation and are in various stages of construction.

A total of 946 structures including 689 residences and 257 commercial structures are being protected by structural floodwalls in these project areas. Another 470 structures including 400 residences and 70 commercial structures are being protected by nonstructural measures in these three project areas.

In accordance with the provisions in the Section 202 legislation, a local cooperation agreement (LCA) was executed with the local sponsor prior to the implementation of each approved project area. The LCA required that:

1) the local sponsor operate and maintain the constructed project;

2) the local sponsor participate in the National Flood Insurance Program and enforce the required ordinances;

3) the local sponsor operate an approved Flood Warning and Emergency Evacuation Plan in the project area; and

4) the local sponsor manage evacuated flood plain lands set aside for wildlife habitat in accordance with a jointly prepared management plan.

Nonstructural Planning

As discussed above, the nonstructural program consisted of the flood proofing of eligible structures and the acquisition of flood plain structures which could not be flood proofed under the program criteria. Both of these options were provided on a voluntary basis to flood plain residents in approved project areas. In all cases of the nonstructural program, potential participants were provided with the option of not participating in the program and maintaining their existing flood plain residence under the local flood plain management ordinance.

In an effort to inform the public about the features of the plan and the options available under the nonstructural program, a series of workshop meetings and public hearings were held at churches and schools throughout the Tug Fork Valley during the formulation process. The ongoing success of the overall plan and the participation rates experienced in the nonstructural program have been a direct result of those early public involvement activities.

Flood Proofing Options

Under the nonstructural program, structures located in the flood plain that would suffer damages to the first habitable floor during a recurrence of the April 1977 flood were eligible for either voluntary flood proofing or acquisition. Eligibility for flood proofing required that:

1) the structure would suffer damages to the first floor or to mechanical systems below the first floor during a recurrence of the April 1977 flood;

2) the structure not be located within the regulatory floodway (the channel of a river or other water course and the adjacent land areas that must be reserved to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height);

3) raising the structure to an elevation 1 foot above the April 1977 flood level would not place the first floor more than 12 feet above the ground surface; and

4) the structure was physically sound and could be raised safely.

The method chosen for flood proofing was based upon engineering feasibility and cost-effectiveness. The options available for flood proofing included the following:

1) elevation on a solid masonry wall foundation or wood post/beam foundation or masonry pier foundation;

2) construction of a waterproofed veneer wall against the structure with sealed openings at entrances;

3) construction of floodwalls or levees around an individual or group of structures; or

4) construction of a replacement flood proofed structure on-site.

Although all of these options were available in the program, only options 1 (elevation), 2 (veneer wall), and 4 (replacement flood proofed structure) were implemented in the program. Only structure elevation and the veneer wall project are discussed in this report. Based upon research of flood proofing techniques, it was decided that elevated structures would allow flooding of the enclosed area beneath the raised first floor.

In those cases where the cost to flood proof an eligible residential structure, plus the standard relocation benefits, exceeded the value of the structure and property, the homeowner was presented with an offer for the purchase of the structure and property in lieu of flood proofing. Since these homeowners were not eligible to relocate to a Corps of Engineers constructed H&CD site and in an effort to reduce the social impacts of relocations, homeowners who chose not to accept the purchase offer were allowed to retain the flood proofing option and have their structure flood proofed. However, the attractiveness of this purchase option resulted in approximately 40 percent of the residences eligible for flood proofing being voluntarily sold to the Corps of Engineers by the owners.

This economic evaluation process was modified for use with commercial structures. Commercial owners were not presented with a choice of flood proofing or acquisition, but were offered the most cost-effective option based upon a comparison of acquisition costs and flood proofing costs. The flood proofing costs were based upon the most cost-effective, feasible flood proofing option available for each structure. This resulted in 85 percent of the commercial owners choosing the voluntary acquisition option. The remaining 15 percent chose other options for their commercial structure.

Following owner application for the program and approval of a flood proofing design by the Corps of Engineers for the structure, the flood proofing construction was supervised and inspected by state housing agencies under a cooperative agreement with the Corps of Engineers. A construction contract, reflecting the approved design and negotiated cost, was executed between the homeowner and the contractor. For those structures where elevation was the most cost-effective option, the owner was required to execute an agreement, prior to start of construction, that restricted future use of the foundation area under the elevated first floor. Future enforcement of owner operation and maintenance of the flood proofing construction and owner compliance with the restrictive agreements was transferred to the local sponsor following the final construction inspection.

Acquisition Options

The voluntary acquisition program was made available for those structures located within the regulatory floodway limits, or which needed to be raised more than 12 feet, or which were physically unsound or where the cost of flood proofing exceeded the value of the real property. Under this program, eligible structure owners could sell their flood plain property and structure and relocate to a site of their choice above the elevation of the 1977 flood under the Uniform Relocation Assistance and Real Property Acquisition Act of 1970, (P.L. 91-646) or relocate to a Corps of Engineers constructed H&CD site. Housing benefits in excess of P.L. 91-646 relocation benefits were provided to flood plain residents choosing the Corps of Engineers' H&CD site to encourage clearing of the flood plain and to maximize use of the new subdivisions. The evacuated flood plain land was dedicated, depending on its physical characteristics, to either the replacement of wildlife habitat or disposal through the General Administrative Services (GSA) for future development under the existing local flood plain management ordinances. The April 1977 flood was used as the design flood for construction on the tracts transferred to GSA for disposal. The 1977 flood elevation was higher than the 100-year flood elevation at these tracts and, therefore, was used as the controlling flood elevation.

Flood Proofing Design Parameters

A series of design parameters were developed for the flood proofing program to determine the feasibility of flood proofing individual or groups of structures and to guide the flood proofing design process. These parameters included:

1) **The design flood:** Established by the Section 202 legislation as the April 1977 flood. In those areas of the Valley where the 100-year flood was higher than the April 1977, the 100-year flood level was used as the design flood.

2) **Freeboard:** Generally, 1 foot of freeboard was added when elevating structures. The freeboard was measured from the elevation of the design flood to the bottom of the subfloor material or floor slab of the first floor. One foot of freeboard was used on the design of the veneer wall project.

3) **Waterproofed Veneer Wall Design:** The maximum height for the design of a veneer wall is dependent upon the strength of the existing structure walls and the soil conditions around the structure. Previous testing has indicated that generally a 3-foot wall height is the maximum advisable for flood proofing of structural veneer walls.

4) **Height of Raise:** The height limit for elevating structures was determined after an analysis of the problems associated with structure access, foundation design, aesthetics and the programmatic costs of relocating a substantial number of the affected structures in the Valley. In the Tug Fork project, it was determined that elevating structures up to 12 feet from the ground surface was technically feasible, socially acceptable and economically justifiable. Setting the height limit at 12 feet resulted in a substantial savings in program costs by reducing the number of structures for which acquisition/relocation was the only option.

5) **Flood Water Velocity:** Based upon hydrologic and

engineering studies for foundation designs, it was determined that flood proofing structures by elevation or veneer walls would only occur where flood water velocities did not exceed 8 feet per second.

6) **Structure condition:** Since many of the structures in the Tug Fork Valley were built in the absence of building codes and were flooded repeatedly, damages to floor systems, foundations, and walls were extensive. Structures found to be deteriorated beyond a point where limited rehabilitation would not permit safe elevation, were placed in the voluntary relocation program.

7) **Adjacent Structures:** In many urban locations where construction occurred in the absence of building codes or ordinances, structures were erected very close to each other. Although the location of adjacent structures did not result in the acquisition of any structures in lieu of flood proofing, the costs of elevation were increased due to the limited working area. In some situations, portions of adjacent structures were temporarily demolished in order to place lifting steel for raising the structure to be elevated. In these cases, adjacent structure owners were encouraged to execute formal written agreements outlining the extent of the demolition and required reconstruction prior to construction. Justified temporary demolition costs were reimbursed as a part of total construction costs. Requests for variances from existing building codes or revision of subdivision covenants were required to flood proof several structures in urban project areas.

Flood Proofing Test Program

In an effort to evaluate the cost-effectiveness of the proposed flood proofing criteria, design parameters and construction methods prior to initiation of a full program, the Corps of Engineers implemented a flood proofing test program. The two-phase test program elevated a total of 18 carefully selected structures in the project area. The evaluation of the test program data formed the basis for the criteria and methods used throughout the remaining flood proofing program. The test program also served to educate the contractors and to promote public interest in the flood proofing program. Participation in the program increased dramatically as eligible structure owners viewed the raised "model" structures in their community.

Applied Flood Proofing Technology

Foundation Design

The choice of a particular foundation for an elevated structure and the basic design of that supporting foundation were critical cost and coordination elements in the flood proofing program. Several factors influenced the basic design and application of foundations in the Tug Fork Valley including:

1) flood plain location of the structure and the inherent hydraulic characteristics of that location;
2) height of raise required to reach the design flood elevation with freeboard;
3) type of building construction such as frame or masonry;
4) use and condition of the structure;
5) architectural character of the structure, and
6) cost effectiveness of the solution.

Generally, three main types of supporting foundations were used to raise the structures in the Tug Fork Valley. Those three types included: reinforced solid masonry wall, wood post and beam, and masonry pier construction. Table 1 shows the distribution of structures by foundation type in the three project areas.

Table 1.
Distribution of Flood Proofed Units by Foundation Type

	Number of Flood Proofed Units In			
Foundation Type	Williamson	Matewan	South Williamson	Total
Masonry Wall	53	1/ 23	51	127
Masonry Pier	1	0	0	1
Wood Post/Beam	0	6	2	8
Totals	54	29	53	136

1/ One concrete veneer wall constructed at a church in Matewan Project area.

Masonry Wall Foundation

The majority of structures completed in the first three approved phases of the Tug Fork Valley project were raised on reinforced masonry wall foundations. The decision to use this type of foundation was based upon the architectural styles of structures located in those project areas and the increased support strength needed in higher flood water velocity locations.

Normally, existing foundations and footings on eligible structures were deteriorated due to repeated flooding or unsuitable as a base for the new walls due to poor construction. For this reason, most if not all portions of the existing footing and foundation walls were demolished during the raising process. Where possible, the existing footing and portions of the existing foundation walls were used as a base for the extended masonry wall.

The basic design of the reinforced masonry wall foundation *(see figure 2)* consisted of a continuous perimeter wall of concrete block (8x8x16 or 8x12x16-inch block) resting upon an appropriately sized (12x18 or 12x24-inch) reinforced concrete footing. The masonry wall contained vertical steel reinforcing grouted into every third cell of the concrete block *(see figure 3)*.

The vertical steel was placed in 2 feet lengths with 12-inch lap splicings. All concrete block cells were grouted solid below grade and block sealer was applied to the exterior block face below grade to prevent moisture penetration. The exterior surface of the block was painted with a coating of block filler and two coats of latex paint (owner's choice of colors). The vertical steel was tied to the footing reinforcing and a continuous bond-beam course positioned near the top of the foundation wall. *Figure 4* shows the fourth course below the brick face to be the bond-beam course for this structure. Generally, #4 steel rebar was used in the footing, as vertical reinforcing and in the bond-beam course.

In addition to the vertical reinforcing, steel reinforcing (standard truss "dur-o-wal") was added to alternating horizontal mortar joints. Steel anchor bolts were extended in grouted block cells from the bond-beam course to the new sill plate or steel strapping was included in the grouted block cells and attached to the existing joists for anchoring the first floor to the new foundation *(see figure 2)*.

In those limited cases where the existing footing was suitable as a base for the new foundation, the existing footing was drilled, new #4 steel reinforcing bars were grouted in, and a strip footing cap was poured on top of the old footing before laying new foundation block. A continuous grout layer was placed on top of all footings before laying the initial block course.

In cases where the structure had an existing below-

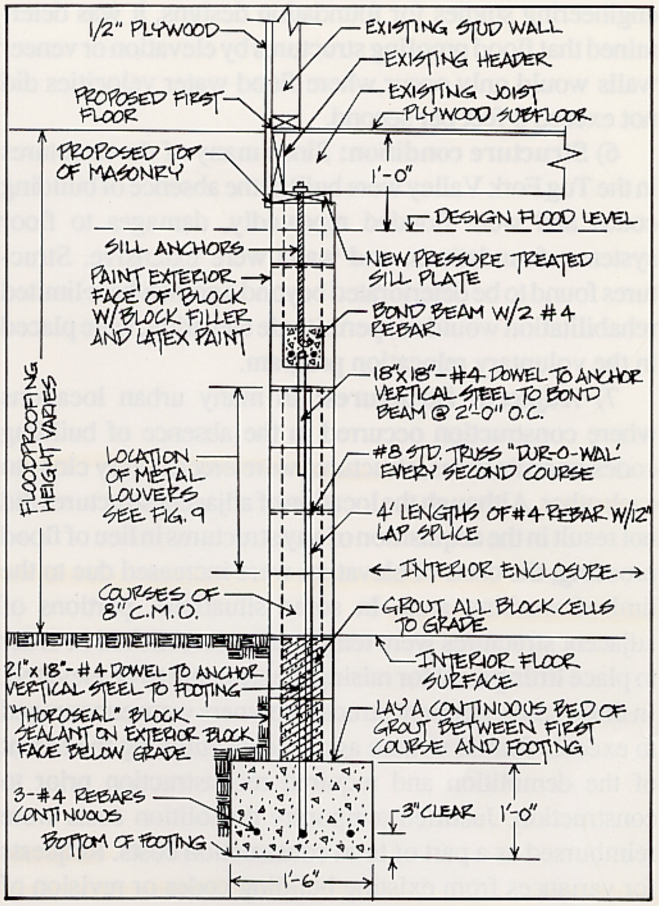


Figure 2.—Typical Wall Section

Figure 3.—Reinforced Masonry Wall Foundation

Figure 4.—Bond Beam Placement

grade basement, the existing basement wall was removed 2 feet below grade and a new footing was constructed on top of the existing wall before laying the new foundation block. The existing basement floor was fractured and the basement area was filled with compacted free-draining material to the elevation of the exterior grade. Interior supporting masonry or steel pipe columns, when required, were founded on unfractured portions of the existing basement floor or on new footings and extended to the required design height *(see figure 5)*.

Flood Louvers

An integral part of the solid wall foundation design was the equalization of hydrostatic water pressures between the interior enclosure and the exterior flood heights. With the exception of using a veneer wall to "dry" flood proof a church, the entire Tug Fork Valley flood proofing program was based upon elevation with flooding below the first floor.

In the case of the solid masonry wall foundation system, openings to allow filling and drainage of the enclosed area were designed with one square inch of free opening per one square foot of enclosed floor space. The design used on 88 percent of the structures elevated on masonry wall foundations was a 2 x 2-foot square galvanized sheet metal louver, providing 50 percent free opening with alternating louvers for both filling and drainage of the enclosure with no human intervention required *(see figure 6)*.

Louvers were placed within 8 inches of the interior grade and at least two louvers were used in each enclosure regardless of the enclosed square footage *(see figure 7)*. Owners were allowed to press-fit 1-inch thickness styrofoam panels into the louvered opening from the interior to reduce cold air penetration into the enclosed area beneath the first raised floor *(see figure 8)*. In the event of flooding, these panels would dislodge at low water pressures and permit hydraulic equalization to occur.

In the case of the other foundation designs (wood post/beam and masonry pier) the area beneath the first floor was not entirely enclosed or enclosed with wood lattice, allowing free passage of flood water both into and out of the space without louvers.

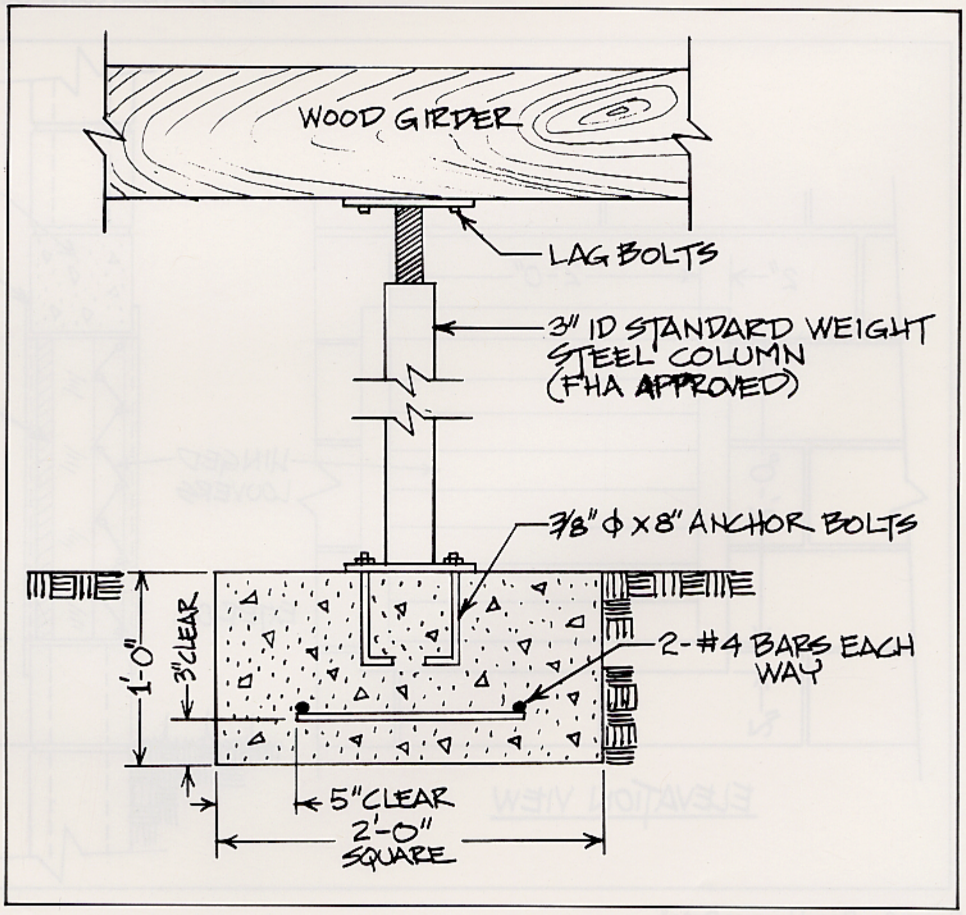


Figure 5.—Interior Column

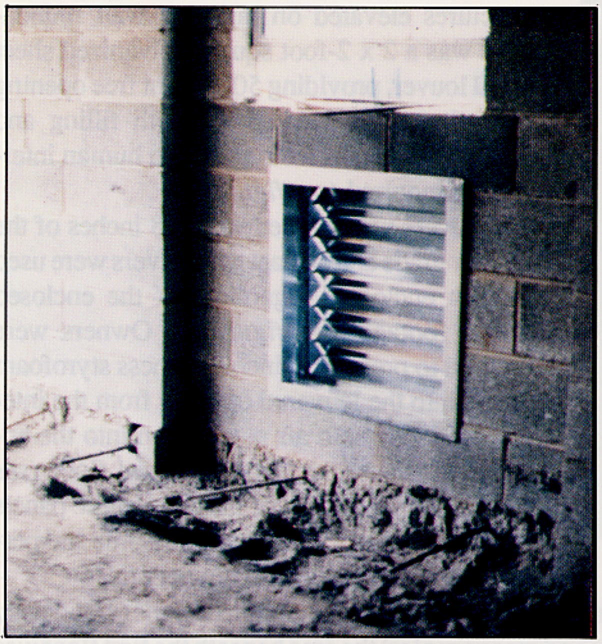


Figure 6.—Flood Louver Inside

Figure 7.—Flood Louver Outside

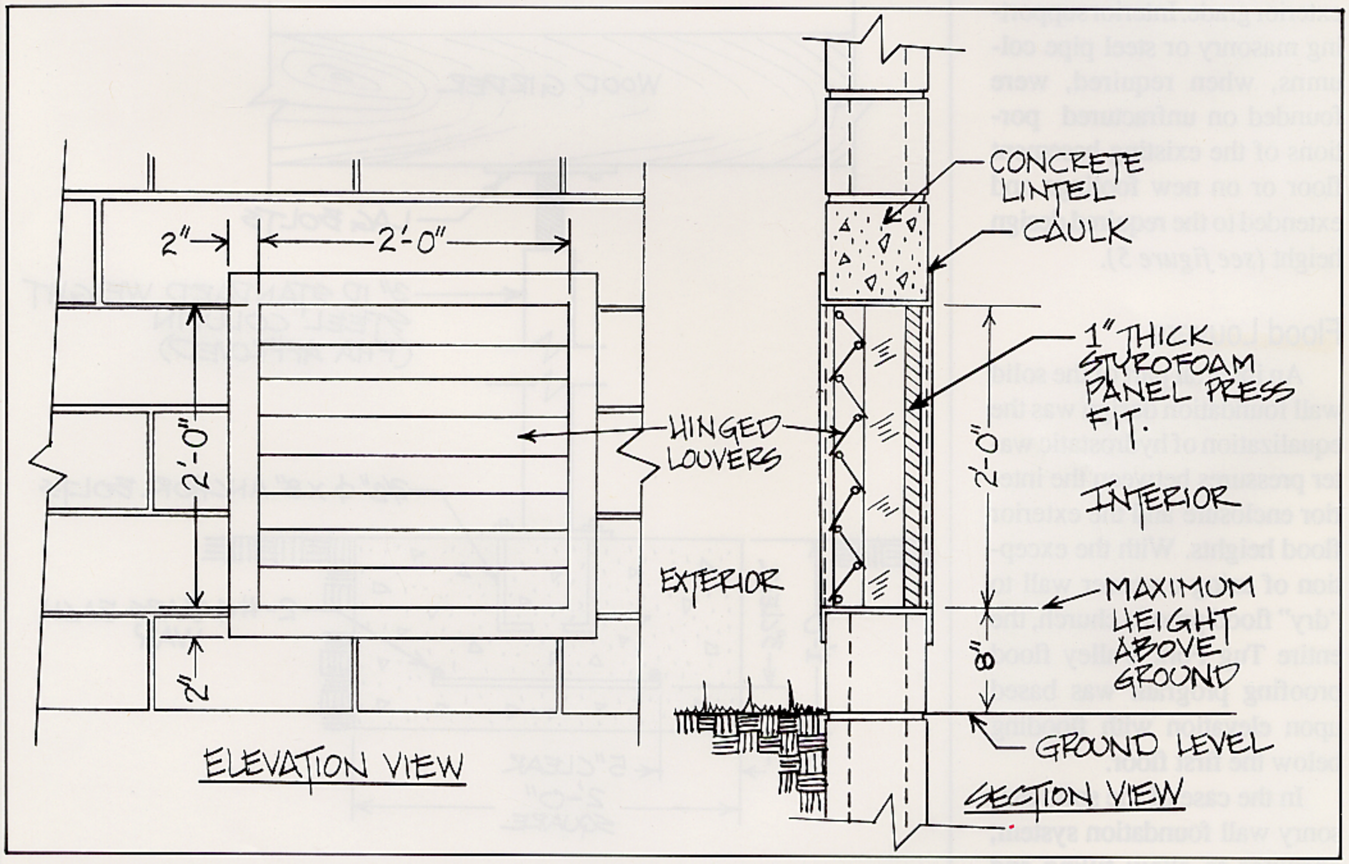


Figure 8.—Flood Louver Detail

Masonry Pier Foundation

In limited cases where the structure character permitted use of a foundation other than the solid masonry wall, a masonry pier design was used to support the raised structure. As shown in *figures 9* and *10*, a residence in the Tug Fork Valley program was raised about 11 feet on masonry piers. A steel frame structure was designed to span the masonry piers and support the existing floor system which was in poor condition from past flooding damages *(see figure 11)*. All of the masonry piers were individually designed to fit the structure and the expected hydrostatic and hydrodynamic loading at the site.

The piers were constructed of 8x8x16-inch concrete block founded on concrete footings. All cells of the block pier were grouted solid. Vertical reinforcing was placed in all piers with ladder style masonry joint reinforcing in alternating horizontal joints. Number 5 reinforcing steel bars were used for footings and vertical reinforcing as shown in *figure 12*.

Utilities were collected into insulated pipe chases constructed to resist the effects of cold weather *(see figures 13 and 14)*. The structure floor was fully insulated to reduce the increased heating demands caused by unimpeded air flow beneath the structure. The perimeter of the masonry pier foundation was clad with treated wood

Figure 9.—House Elevated On Masonry Piers

Figure 10.—House Elevated On Masonry Piers

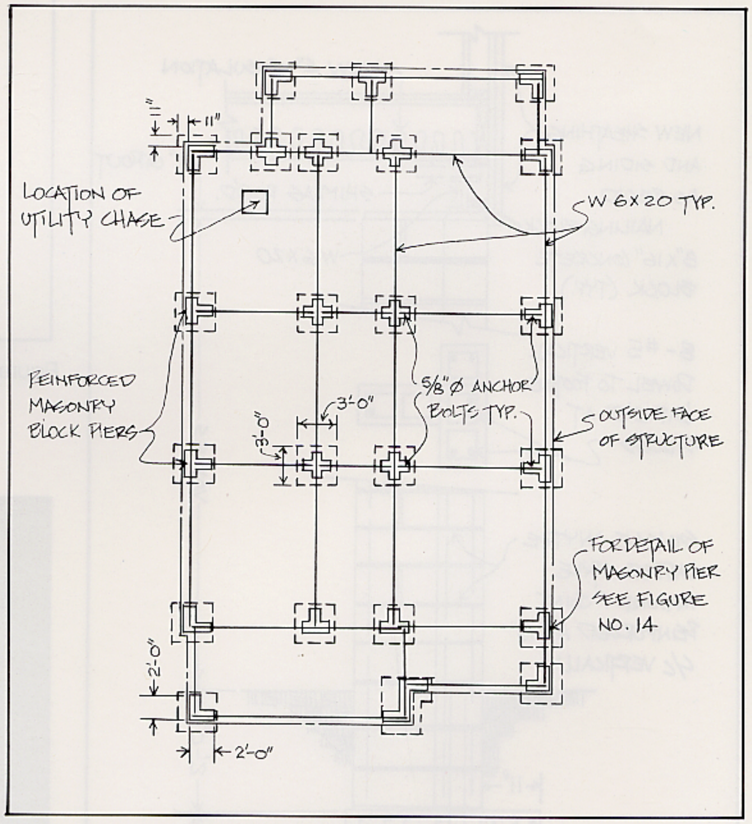


Figure 11.—Masonry Pier Plan

planking and wood lattice to reduce the visual impacts of this design *(see figure 15)*.

Although the masonry pier foundation design was proposed for several frame structures in the Tug Fork Valley flood proofing program, only one structure was eventually elevated on this design. The remaining structures were purchased under the voluntary acqusition program in lieu of flood proofing *(see FLOOD PROOFING OPTIONS, page 3)*. When compared to the solid masonry wall design, the chief **advantages** of the masonry pier design are:

1) the reduced impedance of flood water flows around the structure; and
2) a slight reduction in construction costs.

The **disadvantages** of the masonry pier design include:

1) limited use in supporting structures with masonry walls or masonry veneers;
2) limited use of the lower area for storage and vehicle parking due to the reduced security of the lower area;
3) increased costs for insulation of floors and utilities;
4) increased costs for aesthetic treatment; and
5) increased Operations and Maintenance (O & M) costs.

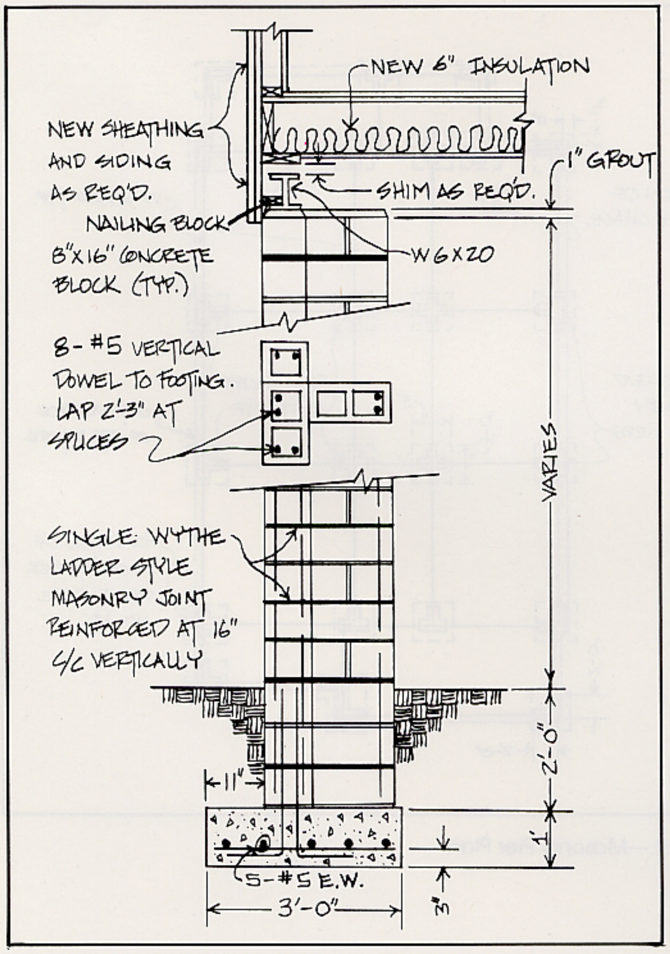


Figure 12.—Masonry Pier Detail Section

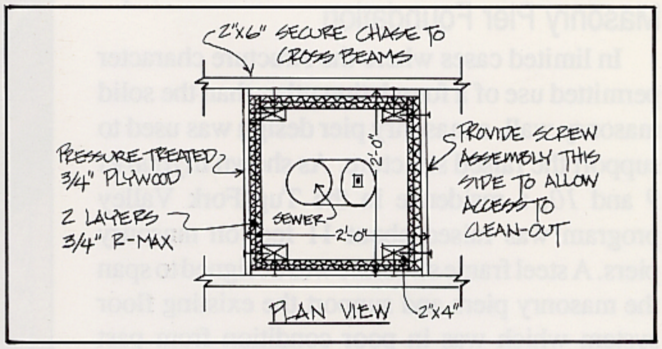


Figure 13.—Insulated Utility Pipe Chase

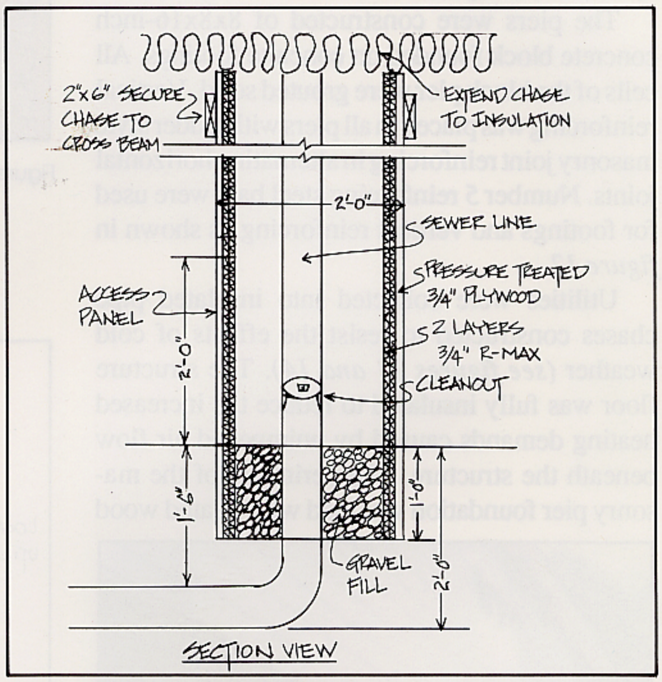


Figure 14.—Pipe Chase Detail Section


Figure 15.—Wood Lattice Panels

Wood Post and Beam Foundation

The housing stock located in the Tug Fork Valley flood plain is composed mainly of one- and two-story frame and masonry homes (800-1,800 square feet). These types of homes account for about 80 percent of all housing in the Valley. The remaining 20 percent are modulars and mobile homes featuring either wood or structural steel framing. Supporting foundations consisted of masonry wall, masonry veneer, and wood post/beam construction. Based upon data from the publication *MANUFACTURED HOME INSTALLATION IN FLOOD HAZARD AREAS* (FEMA 85/ September 1985), a basic design for wood post/beam supporting foundations was developed for use in the Tug Fork Valley. This design was used to elevate two frame residences and six mobile homes *(see MANUFACTURED STRUCTURES, page 21).*

The basic design uses 8-inch diameter or square pressure-treated wood posts founded at least 4 feet deep with a continuous 6-inch concrete encasement below grade. Spacing of posts is dependent upon structure size and configuration, size and number of support beams required, soil bearing capacity, and uses of the area below the raised first floor in compliance with local flood plain requirements. *Figure 16* shows the post spacing for a small one-story frame structure being elevated 9 feet.

The superstructure consisted of pressure-treated wood beams positioned to support the main bearing walls of the structure. Pressure-treated wood sill plates were placed between the post/beam framework and the structure's floor system. The beams were connected to the dapped (notched) posts using galvanized bolts, washers and nuts. Additional lateral and horizontal wood bracing was added to resist lateral wind and flood water loading. *Figure 17* shows the basic design elements of the wood post/beam foundation.

As in the case of the masonry pier design, it was imperative that the first floor of the home be well insulated

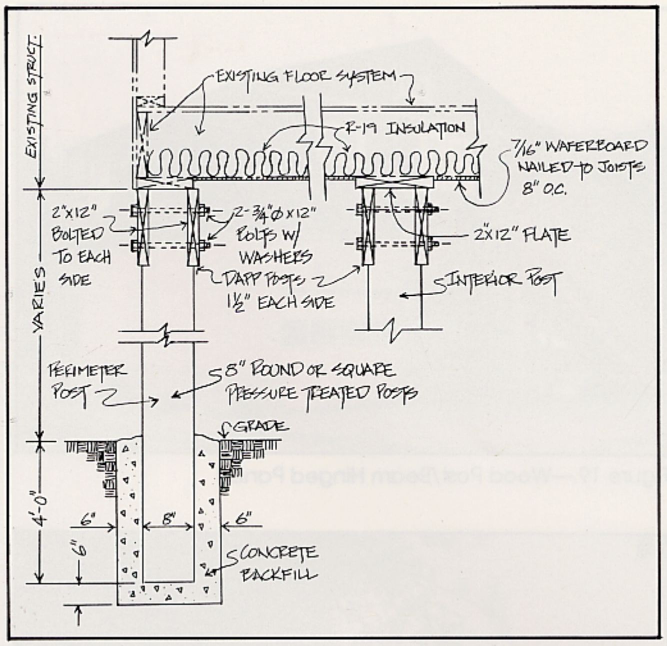


Figure 17.—Wood Post/Beam Detail Section

to reduce the increased heating demands caused by the new open "cold space" beneath the structure *(see figure 18).*

Also, as in the case of the masonry pier design the visual impact of the wood post/beam foundation was reduced by addition of pressure-treated wood panels or wood lattice.

In both cases, the materials used for aesthetic treatment were resistant to water damage and did not impede high water flows. *Figure 19* shows the addition of wood panels to a wood post/beam foundation. The panels were hinged at the top. Break away pins located at the bottom allowed the panels to swing in the direction of the flood flow. This reduced the hydrodynamic loading on the foundation, which reduced obstruction of floodwaters, operation and maintenance costs for the owner, and collection of debris.

Figure 20 shows the addition of wood lattice panels to a mobile home with a wood post/beam foundation.The wood post/beam design proved to be effective for use on

Figure 16.—Wood Post/Beam Post Spacing

Figure 18.—First Floor Insulation

Figure 19.—Wood Post/Beam Hinged Panels

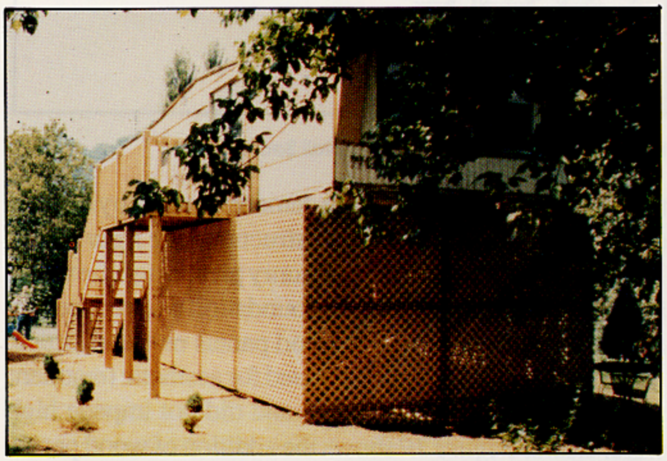


Figure 20.—Wood Post/Beam Lattice Panels

mobile homes and smaller wood-frame structures. The design proved not to be useful for masonry or masonry veneer structures. The advantages of this design included reduced impedance of flood flows around the structure, and reduced costs compared to the solid masonry wall design. The disadvantages of the design include increased costs for insulation of floors and utilities, reduced security of the new foundation area, limited application to a variety of architectural styles, increased O&M costs, and increased costs for aesthetic treatment.

Use of Flood Resistant Materials

Flood waters may contain various chemicals, solvents, acids, and penetrants which when combined with waterborne sand, gravel and silts can scour, stain, corrode, abrade, and deteriorate materials used in normal building construction. For this reason materials used in the elevation of structures must be capable, either by their own surface qualities or by the addition of sealants or coatings, of resisting damage due to these waterborne contaminants and abrasives.

As described in *FLOOD PROOFING OPTIONS* on page 3, foundation walls beneath elevated structures would be subject to both interior and exterior flooding. For this reason both interior and exterior materials used in the foundation areas would be inundated by flood waters. Using the classification system described in Chapter 4 of the Corps of Engineers publication *FLOOD PROOFING REGULATIONS* (March 1992), the spaces beneath the first floor elevation would be classified as W4 (flooded with flood water) for the interior spaces and W5 (Non-Flood Proofed) for all exterior areas. Based upon these classifications, only materials listed as Class 4 or 5 were used for construction below the first floor elevation. The only addition to this listing under the Tug Fork Valley program was the use of pressure-treated lumber for floor systems, steps, platforms, wood post supports, and aesthetic lattice and solid wood panels. All wood materials used in areas classified as W4 and W5 were pressure-treated in accordance with Federal Specification (TT-W-581).

Foundation Aesthetics

Prior to the initiation of the flood proofing program, the Corps of Engineers' Huntington District graphically analyzed the visual impacts of elevating residential structures to various heights. The results of that study indicated that the aesthetics of elevating residential structures could be improved by several methods including:

1) use of textured masonry units on solid foundation walls;

2) use of foundation paint colors which complement the house;

3) use of fill material to reduce the amount of wall exposed above ground;

4) inclusion of windows and doors in the foundation walls; and

5) use of planting materials to mask the exposed foundation walls.

Figures 21, 22, and *23* show a selection of the foundation treatments used for solid masonry walls in the program. In addition to painting the wall surfaces, the addition of access doors, garage doors, and windows in the solid masonry wall design shown in *figures 24* and *25* significantly improved the look of the elevated structure.

The use of fill material, although visually effective in reducing the amount of exposed wall surface, was found not to be practical in densely developed areas due to the limited lot sizes and local flood plain management ordinance requirements regarding the extent and grades of fill slopes in the flood plain.

Aesthetic treatments for the masonry pier and wood post/beam foundations were limited to wood lattice and hinged wood panels. Both of these treatments were found to be cost-effective methods for reducing the visual impacts of elevating structures on these types of foundations. In all cases, the lattice and panels were constructed of pressure-treated wood with galvanized metal connectors. Examples of these foundation treatments are shown in *figures 19* and *20*.

In addition to the aesthetic foundation treatments mentioned above, landscape plantings used to screen the new foundation system proved to be a cost-effective solution in several areas. *Figure 26* shows one instance where the use of landscape plantings was effective in screening the new foundation.

Figure 21.—Visual Aesthetics Painted Finish

Figure 22.—Visual Aesthetics Painted Finish

Figure 23.—Visual Aesthetics Textured Block

Figure 24.—Visual Aesthetics Structural Features

Figure 25.—Visual Aesthetics Structural Features/Landscape Plantings

Figure 26.—Visual Aesthetics/Landscape Plantings

Structural Rehabilitation

Due to poor construction, age and flooding, most of the structures included in the flood proofing program exhibited damages to the floor systems, first floor walls, foundation walls and footings. For these reasons, most of the structures elevated in the program required some rehabilitation of the building.

In most structures, the sill plates, header boards, and many of the joists and beams had been severely deteriorated by repeated flooding and were replaced with pressure-treated wood during elevation of the structure. *Figure 27* shows a situation where the existing deteriorated floor system was replaced to allow safe elevation of the structure. The replacement of floor systems was limited to repair of flood damages necessary to elevate the structure. In those cases where the existing floor system was inadequately designed or constructed with undersized timbers, the homeowner was required to finance that portion of the rehabilitation related to inadequate design or poor construction.

Figure 27.—Structure Damage Deteriorated Floors

The foundation systems of most of the eligible structures were in very poor condition due to age and repeated flooding as shown in *figure 28*. Concrete and mortar in footings, masonry foundation walls, interior columns and chimney supports were deteriorated to such an extent that use as a base for new construction was impossible. Most existing footings were removed due to deterioration from flooding and were replaced during construction of the new foundation.

Figure 29 is an example of a structure used to show the combination of damages which were so severe that the structure was acquired in lieu of flood proofing.

Figure 28.—Structure Damage Deteriorated Foundation

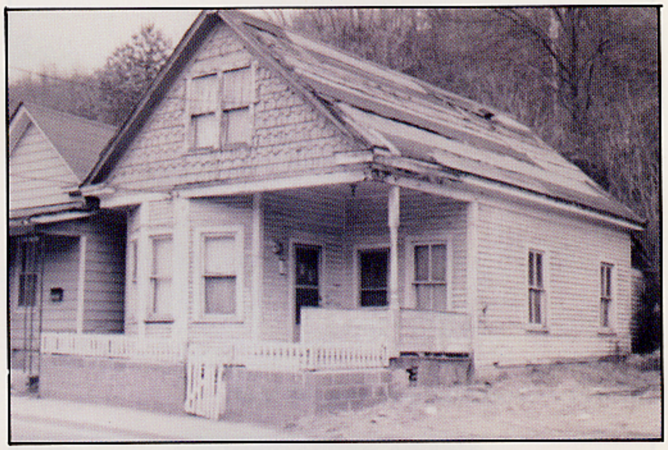


Figure 29.—Structure Damage From Age And Flooding

Structure Access

One of the most important aspects of elevating structures is assuring safe and convenient access to the elevated first floor. Eligible structures displayed a myriad of existing access systems including attached masonry or wood porches, decks, landings, patios, and breezeways. In addition, many of the eligible structure owners were handicapped or otherwise disabled requiring alternative methods of access.

Generally, residential access was accomplished by construction of pressure-treated wood decks and steps connected to existing walkways and driveways *(see figure 30)*.

In some cases, an existing masonry porch was physically attached to the structure in a manner which required lifting the porch with the structure and construction of a new foundation under the raised porch *(see figure 31)*.

For structures with multiple first floor entrances, engineering analyses determined that connection of the entrances with elevated walkways leading to a central stairway was more cost-effective than multiple stairways *(see figure 32)*.

Figure 30.—Access By Pressure-Treated Decks And Steps

Figure 31.—Masonry Porch Raised With Steps

Figure 32.—Central Stairway Multiple Entrances

In those cases where the existing structure had an attached garage and the structure was being elevated at least 8 feet, the garage entrance was replaced in the solid masonry wall foundation *(see figure 33)*.

In cases where the structure owner or members of the owner's family were physically handicapped (required

Figure 33.—Garage Added On First Floor

physician's written confirmation), access facilities were provided in the form of wood ramps, or mechanical chair lifts, to at least one entrance of the elevated structure. Access ramps were designed to meet federal standards for slope and size and were constructed of pressure-treated wood *(see figure 34)*. The use of ramps was limited due to the amount of elevation needed on many structures and the lack of available lot space in which to construct the ramp.

Where ramps were not technically feasible, a mechanical chair lift was installed to provide handicapped access. The lifts were normally installed on the interior access stairway, *(see figure 35)* to reduce the exposure of the lift system to the weather, but some systems were installed on an exterior stairway *(see figure 36)*.

Handicapped access was made available to commercial structures provided that such access existed prior to initiation of the program. For those commercial structures not having existing handicapped access, such access was added at the owner's request and expense during the flood proofing process. All public buildings (post offices, government offices, etc.) determined eligible for the program, were provided handicapped access when elevated.

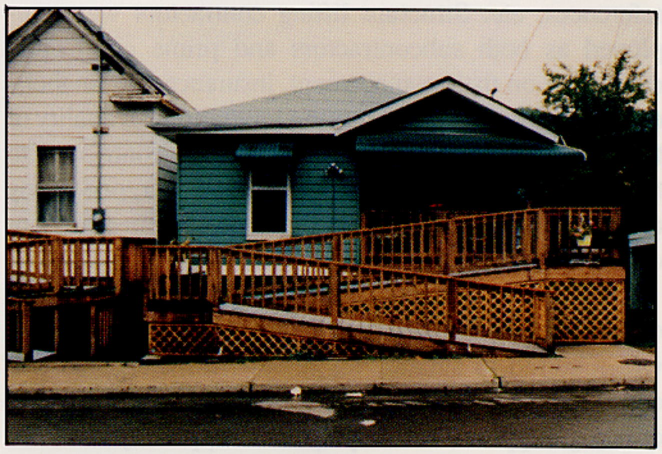


Figure 34.—Handicapped Access By Wood Ramps

Figure 35.—Handicapped Access By Interior Chairlift

Figure 36.—Handicapped Access By Exterior Chairlift

Structure Lifting Process

One of the most important and relatively expensive elements in elevating structures is the process of physically lifting the structure to the design elevation. Due to the opportunities for catastrophic failure and subsequent litigation, contractors selected for lifting structures were carefully scrutinized regarding past experience, insurability, references, etc. Structure lifting contractors were employed as both subcontractors and prime contractors depending on their management, insurance and financial capabilities in the flood proofing program. The quality of the lifting contractors proved to be a major contributor to the overall success of the program. However, one lifting contractor was removed from the flood proofing program due to failure to perform.

Several elements contribute to the successful elevation of structures in the program. First, each lifting contractor was required to submit, for review, a lifting plan that described the numbers and placement of support beams, cribbing supports, and any special support systems for porches or building additions required to raise the structure *(see figure 37)*. The correct placement of the support cribbing and steel beams proved to be critical in reducing damages to the structure and its contents. Where failures occurred, resulting in either external or internal cracking of walls and floors, placement of cribbing supports and/or size and number of steel lifting beams were determined to be the cause.

In one case, failure of a cribbing base located adjacent to a footing excavation nearly resulted in the collapse of an elevated structure. This event led to excavation of all cribbing bases in order to avoid the consequences of bank failure *(see figure 38)*.

Prior to lifting a structure, a survey was made of the structure interior to locate critical stress points and concentrated weights. Critical areas in residences included bathrooms, kitchens, interior supporting walls, floor slabs, fireplaces, chimneys, and room additions. Each of these areas received special attention in the lifting plan due to the presence of non-flexible wall and floor coverings, which were subject to cracking from supporting beam flexure, or the concentration of heavy fixtures or supporting structures.

Figure 37.—Raised Structure On Cribbing

Figure 38.—Placement Of Cribbing Supports

These areas required placement of cribbing supports or additional steel beam supports. Critical areas in commercial structures included heavy equipment rooms, interior supporting walls, storage and stock areas, and concrete slab floors. Also required in the lifting plan was the proposed lifting system. Most lifting contractors used a unified hydraulic jacking system which allowed collective or individual control of hydraulic jacks located within the cribbing supports *(see figure 39)*.

These systems were operated from a central control panel on the hydraulic unit, allowing the operator to elevate and level the structure in one operation *(see figure 40)*. In many cases, the leveling process resulted in the closing of existing masonry wall cracks when the structure was lowered to the newly leveled foundation.

As a by-product of the elevation process, the unified hydraulic jacking system determined the weight of the structure which proved useful in foundation design. Use of the unified hydraulic jacking system facilitated the elevation of most structures in the program to the design flood height in a single work day.

Two additional factors that required consideration in the elevation process were weather and safety. Weather related problems including rain, wind and freezing temperatures affected the flood proofing program. Once the structure was raised to the design height and construction had begun on the new footing and foundation walls, rain, snow and cold weather created a number of serious problems. Excavated trenches for new footings became rain-filled resulting in bank failures. High winds increased the chances of collapsing a structure elevated on cribbing supports. Wind related collapse was especially critical for mobile homes during the lifting process. Cold weather affected concrete pours and the laying of masonry block walls and columns.

Weather related problems were solved, in part, by installing plastic skirting around the bottom of the raised structure, as shown in *figure 41*. Once the plastic skirting was installed, the area beneath the structure was protected from precipitation and could be heated to a temperature that protected utilities and allowed concrete and mortar work to proceed.

Safety was most important during the construction activities of the flood proofing program. Considering the types of activities involved in elevating structures and constructing new foundations beneath the raised structure, a number of safety measures were instituted to reduce the overall risks. Contractors, inspectors, Corps of Engineers personnel and the staff of state housing agencies were informed of the inherent construction dangers. Standard precautions regarding the use of personal safety equipment (helmets, safety footwear, eye and ear protection, etc.), the use and storage of potentially hazardous solvents and fluids, fire protection, use of heavy equipment and power tools, and control of the job site perimeter were discussed frequently with contractors.

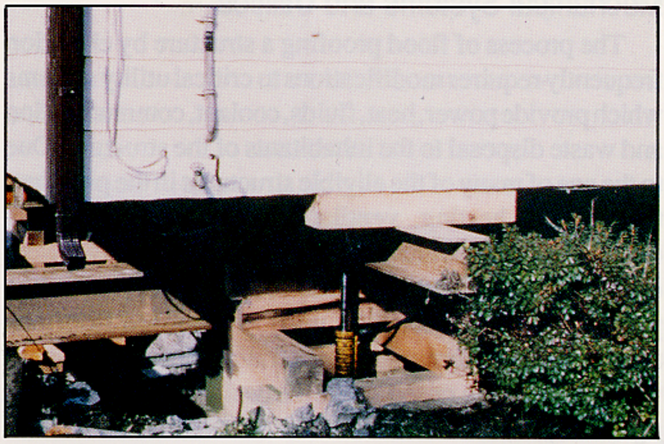


Figure 39.—Placement Of Hydraulic Jacks

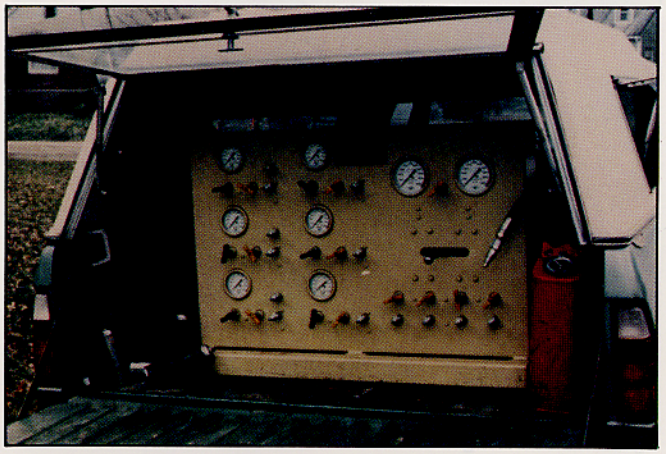


Figure 40.—Control Unit For Hydraulic Jacks

Figure 41.—Weather Protection Plastic Skirting

The safety efforts of the Corps of Engineers, the state housing agencies, and the contractors resulted in the successful flood proofing of 136 structures without a single fatality or serious injury.

Mechanical Systems and Utilities

The process of flood proofing a structure by elevation frequently requires modifications to critical utility systems which provide power, heat, fluids, coolant, communication and waste disposal to the inhabitants of the structure. Due to the age of many of the eligible structures in the program, the existing heating, ventilation, and air conditioning (HVAC) systems were antiquated and in many cases were difficult to raise with the structure. Many homes in the project area were heated by up-flow gas-fired floor furnaces, which under program criteria and local ordinances were needed to be raised above the design flood height *(see figure 42)*.

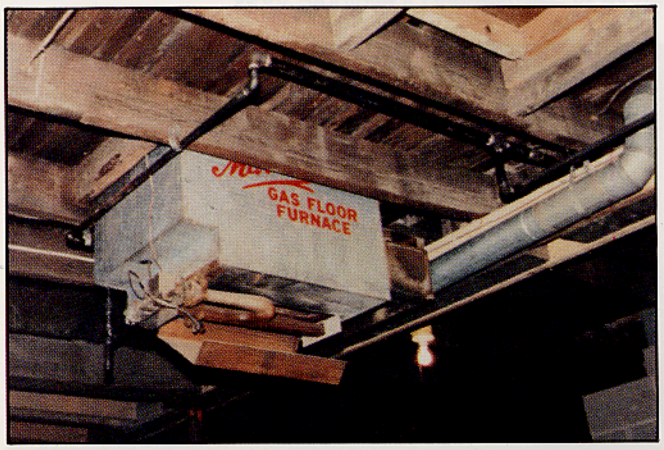


Figure 42.—Heating Unit Raised With Structure

Depending upon the type and size of the floor furnace, a decision to protect the existing furnace in-place required elevating the entire structure at least two or three feet higher than required to protect the first floor. For larger structures (greater than 1,200 square feet), the costs associated with this additional elevation, such as additional block wall, increased column height, additional stairway height, and increased extension of utilities, exceeded the cost of installing a replacement heating system in the structure.

Therefore, several new HVAC systems were installed during the flood proofing program to reduce the overall program costs. Structure owners were required to fund system betterments beyond the minimum replacement required. Similar situations occurred where coal-fired furnaces were encountered in basements.

Generally, other types of HVAC systems such as hot-water, forced-air, and heat pumps and their various component parts were raised by relocation into existing available spaces such as closets or utility rooms within the first floor, relocation into a new utility room raised to the same elevation as the structure *(see figure 43)* or relocation onto an elevated exterior platform *(see figures 44 and 45)*.

Figure 43.—Elevated Utility Room

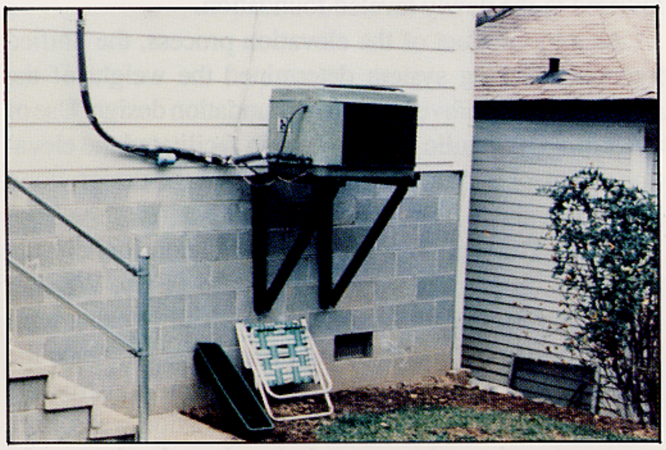


Figure 44.—Compressor Unit On Suspended Platform

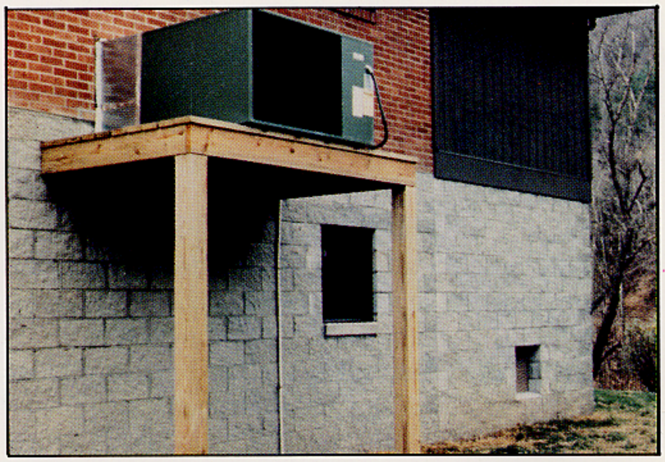


Figure 45.—Compressor Unit On Elevated Platform

Hot-water heaters, water-softening systems, and other mechanical systems critical to the functioning of the structure were raised into first floor spaces or relocated into new elevated utility rooms. In those cases where mechanical systems were relocated into new, elevated utility rooms, additional space was provided for existing appliances such as clothes washers, dryers, freezers and other storage items. All additions to the basic structure for relocating utilities or habitable replacement basement space were constucted to code standards and were fully insulated. Efforts to match the architectural style of the new additions to the existing structure were negotiated during the flood proofing design stage.

In addition to the mechanical systems affected by the elevation process, all of the utility lines servicing the structure including water, sewer, electric, telephone, cable television, and gas were affected by the elevation of the structure. The underground service lines (gas, water, sewer) entering the structure were disconnected prior to the elevation process. The utility lines were extended and reconnected as a part of the flood proofing construction contract. Extended utility lines (water, sewer and drains) were individually insulated or placed into insulated pipe chases *(see figure 13)*. In those cases where the existing underground lines had deteriorated or did not meet code requirements, additional costs to repair the lines were the responsibility of the structure owner.

Aerial service lines such as electric, telephone, and cable television that crossed above the structure's roof were raised or relocated to meet service company and building code requirements. This operation normally necessitated moving the service mast on the structure or extending the service mast to reach the required clearances. Also, in the process of elevating the structure, provisions were made to relocate the electric service meters above the design flood height onto an access deck or platform as shown in *figure 46*. In addition to the incoming service lines, flood damages to the existing electric fuse or breaker boxes required replacement of the distribution boxes during the service reconnection work.

Costs for replacement of these electric service components not directly related to flood damages such as undersized breaker boxes or unsafe wiring were the responsibility of the owner. Similar arrangements were undertaken for other aerial service lines such as telephone and cable television.

Figure 46.—Service Meter Relocated Onto Deck

Garages and Chimneys

Many of the structures in the project area were constructed with attached garages and chimneys. The nonstructural program criteria excluded detached garages, outbuildings and storage buildings from the flood proofing program. Only garages or out-buildings that had been converted to living space were eligible for the flood proofing program under Section 202, Public Law 96-367 *(see figure 47)*.

The decision to raise attached garages on any individual residence was based upon several factors including roof and wall construction connecting the garage and the residence, the need for an elevated utility room or basement replacement space, and the ability to construct a new foundation for the elevated section of the residence in

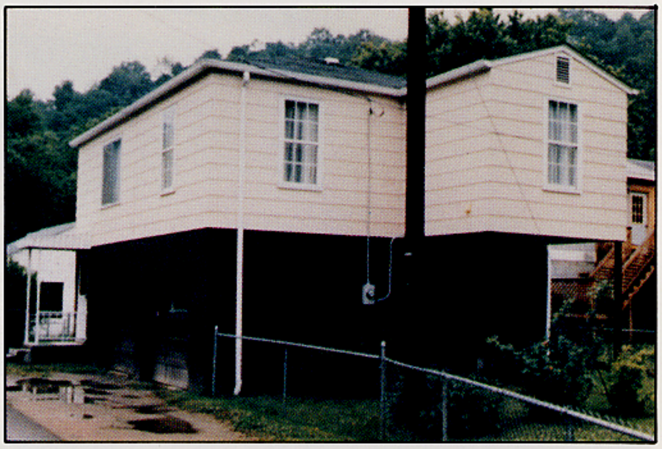


Figure 47.—Converted Garage Elevated

proximity to the existing garage structure. In those cases where replacement space was required or when flood-prone mechanical systems or utilities were elevated with the residence, the attached garage was separated from its concrete slab floor and elevated with the residence and the interior garage space was enclosed. The garage door opening was closed, a bay window installed, and a new floor was constructed converting the area to living space *(see figure 48)*.

In all cases, this approach was determined to be more cost-effective than the construction of a new elevated addition for these uses and preserved the architectural quality of the structure by not separating the roofline. Structure owners were responsible for interior finishing beyond basic wallboard, paint and plywood subfloor. A floor slab and garage door opening were provided in the new foundation for replacement of the elevated garage area *(see figure 49)*. In several cases, the attached garage was separated from the residence prior to raising and was left at the original elevation *(see figure 50)*.

Figure 48.—Garage Converted To Living Space

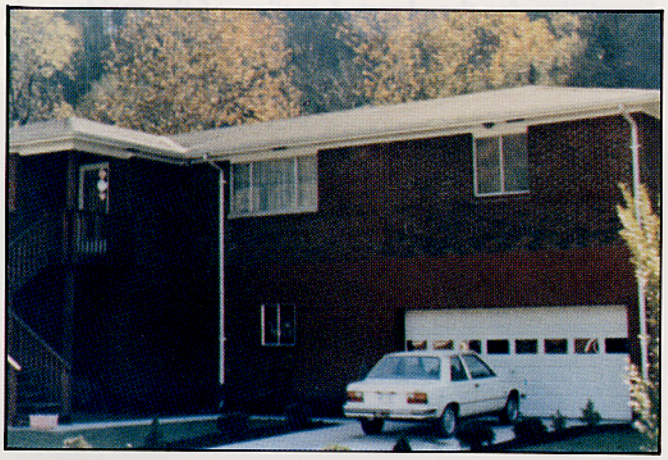


Figure 49.—Garage Replacement In Ground Floor Area

Figure 50.—Garage Separated Before House Elevation

Chimneys were present on many structures eligible for the flood proofing program. Interior and/or exterior chimneys were evaluated by the design engineer prior to elevating the structure. The decision whether to raise, replace or remove the chimney(s) during the raising operation was based upon structural qualities, cost-effectiveness, condition and present use of the chimneys. Many chimneys were raised with the structure by bracing the base and, if necessary, the top of the chimney. A new masonry wall foundation was constructed under the chimney *(see figure 51)*.

Several unstable, but operational chimneys were replaced with cost-effective metal flue systems *(see figure 52)*. Replacement of existing chimneys with metal flue systems was standard practice in masonry pier and wood post/beam foundations. In cases where the existing chimney(s) were not operational, they were removed during flood proofing construction, and not replaced.

In several residences, the interior chimneys were unstable, not operational and structurally tied to each floor. This

Figure 51.—Chimney Elevated With Structure

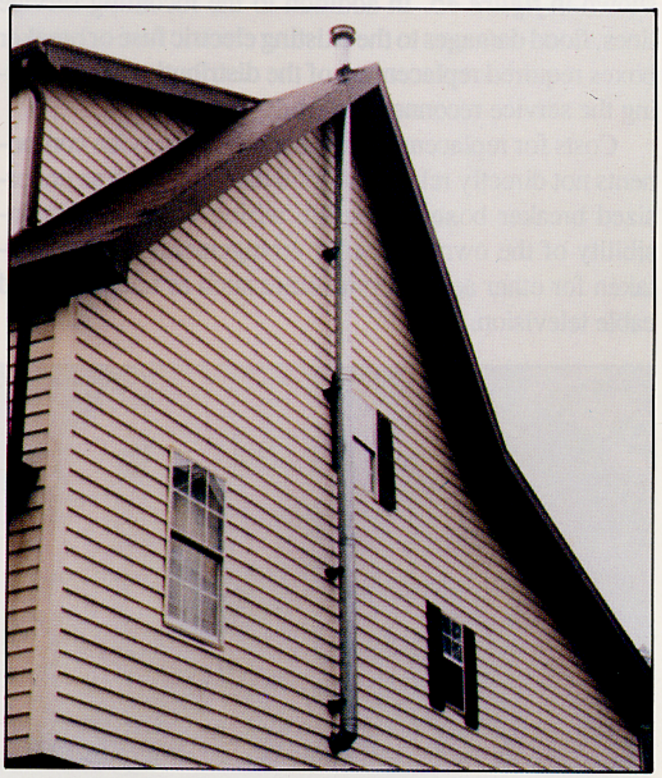


Figure 52.—Chimney Replaced With Metal Flue

increased the risk of overall catastrophic failure of the residence during the elevation operation. These chimneys were removed prior to elevation, and not replaced. The resultant openings in the walls and floors were modified as closets for storage.

Modular and Mobile Structures

A significant number of modular and mobile homes were placed within the project flood plain area following the April 1977 and May 1984 floods. These structures were identified prior to the initiation of the nonstructural program and several program criteria were developed to determine when the flood proofing option would be used. Those criteria required that:

1) the structure was owner-occupied (not a rental unit);
2) the structure owner held title to the tract;
3) the structure was considered as real property (not personal property); and
4) the structure was placed on a permanent foundation.

As in the case with standard stick-built structures, all requirements regarding floodway location, height of elevation and structure condition applied to modular and mobile structures. As a result of the application of the above criteria, a total of 17 units were found eligible for flood proofing in the project area. Of that total, six have been raised using the methods described below. The remainder were converted to the acquisition program.

The basic wood post/beam foundation design was derived from Chapter 4 of the publication *MANUFACTURED HOME INSTALLATION IN FLOOD HAZARD AREAS* (FEMA 85/ September 1985). Design considerations for the foundation structure included lateral stresses by floodwater and wind, scour, structure size, access, future replacement of the structure, utilities, insulation, and aesthetics. The structural features of the foundation are shown in *figures 53, 54,* and *55.*

Additional items such as structure tie-down anchors were added to the wood post/beam foundation for manufactured structures. The lateral spacing of wood posts and size of supporting beams were increased to accommodate future replacement of the structure. Actual elevation of the structure was accomplished using either hydraulic jacking systems or mobile cranes. After installation of the posts outside and around the existing structure walls, the structure was lifted by jacks or by crane while the cross-beams and bracing were bolted in place.

Since the posts and beams were all pre-measured and pre-notched, the structure could be lifted, lowered and tied-down onto the new foundation within a single work day. This method of installation reduced the construction time, costs, risks of wind related collapse, provided for future structure replacement and significantly reduced the amount of temporary housing needed for the structure owner.

Access to the raised unit was accomplished by pressure-treated wood steps and decks. In cases where manufactured units had existing decks, those decks were raised with the structure *(see figure 56).* Where handicapped access was required, mechanical chair lifts were installed on the exterior access steps. The placement of existing and new decks provided platforms for raised mechanical HVAC systems and electric meters. In other cases the mechanical HVAC system was raised on a separate platform adjacent to the manufactured unit.

Utilities such as water and sewer were extended to the elevated unit within insulated pipe chases. Aerial utilities such as electric, telephone and cable television were modi-

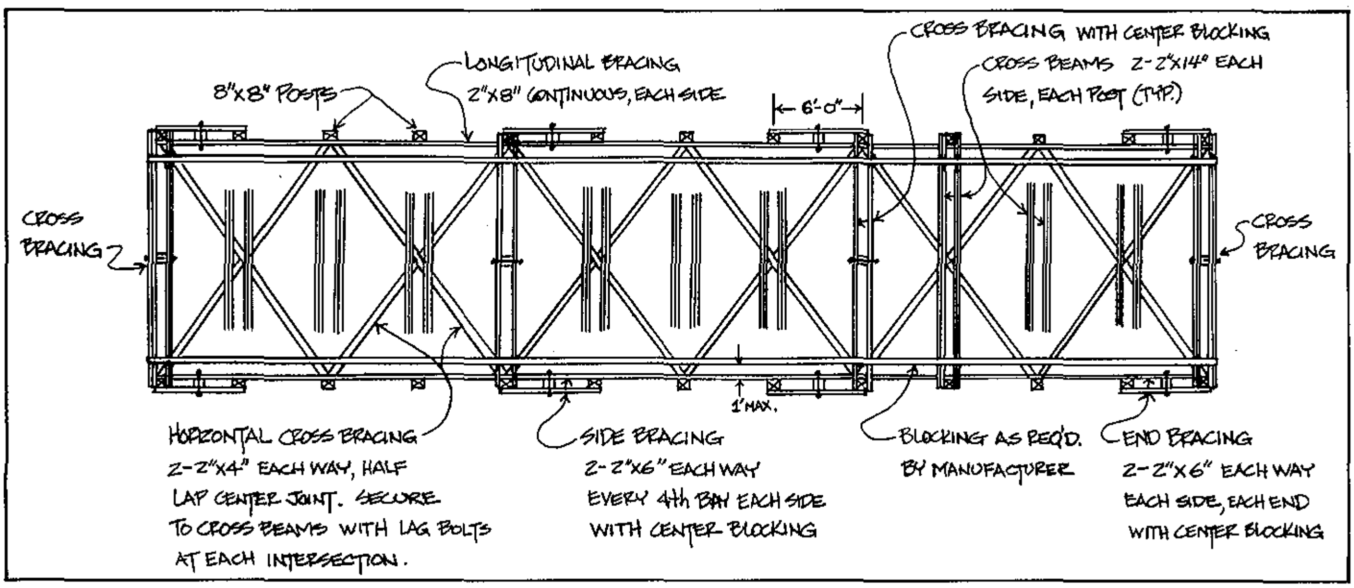


Figure 53.—Foundation Plan View

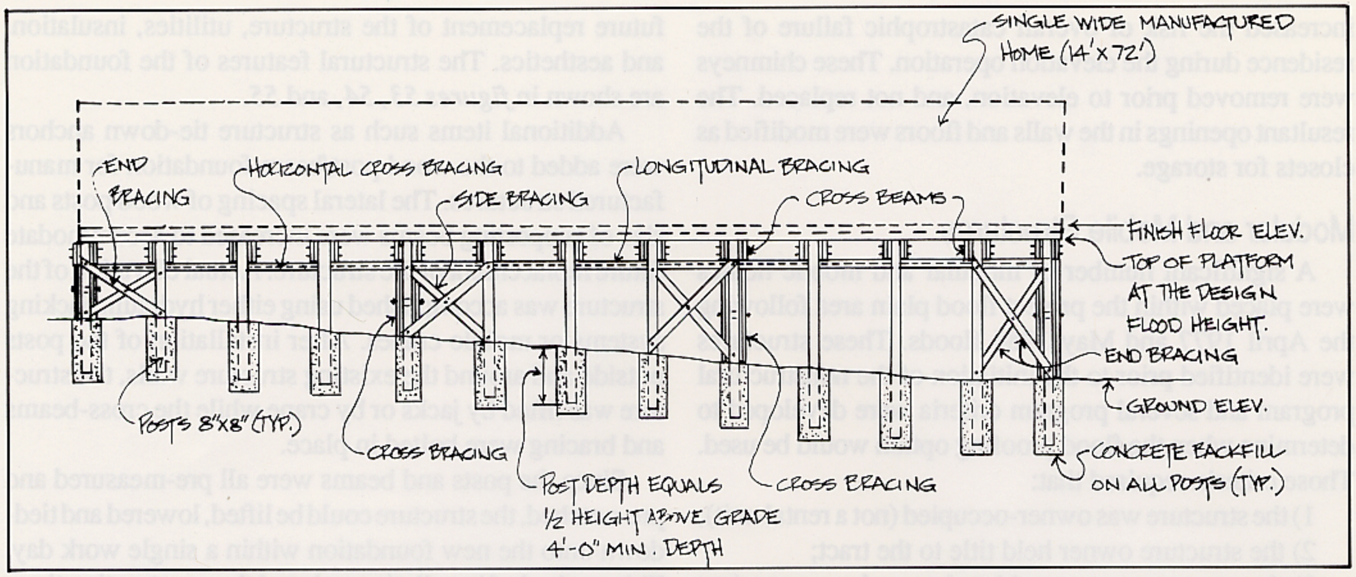


Figure 54.—Foundation Side Elevation

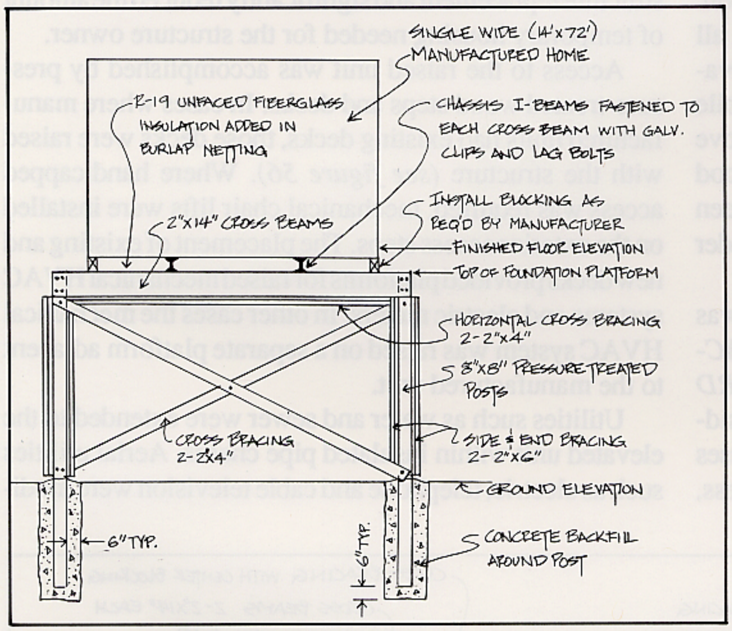


Figure 55.—Foundation End Elevation

fied as described in *MECHANICAL SYSTEMS AND UTILITIES*, page 18.

Of prime concern to the owners of modular and mobile units was the final appearance of the elevated structure. As described in *FOUNDATION AESTHETICS* on page 12, the aesthetic quality of units elevated on the masonry pier or wood post/beam foundation was increased by the addition of wood lattice covering the new foundation structure.

The wood lattice was painted in a color of the owner's choice or treated with wood preservatives. Generally, this form of aesthetic treatment was accepted.

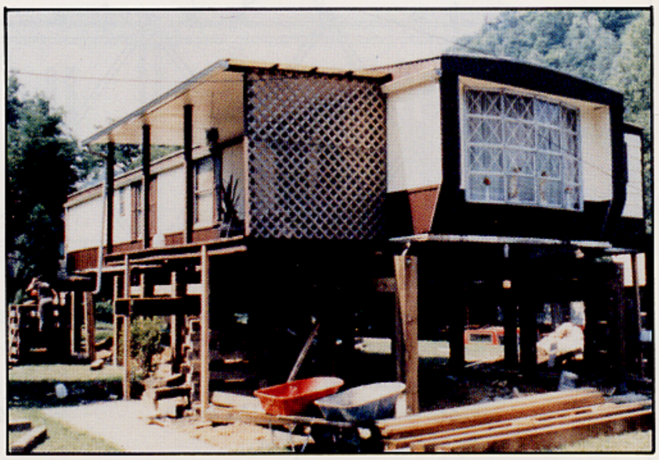


Figure 56.—Deck Raised With Manufactured Unit

Veneer Wall Alternative

As discussed in FLOOD PROOFING OPTIONS on page 3, one of the alternatives made available to protect structures was the construction of a waterproofed veneer wall. This type of perimeter wall is included under the category of "dry" flood proofing. In this category, water is prevented from entering the first floor of the structure by the use of veneers, closures, and sealants. Areas so protected are included under the classification W1 (completely dry space) listed in *FLOOD PROOFING REGULATIONS* (Corps of Engineers, March 1992). Several factors limit the use of veneer walls for protecting structures including:

1) the inherent strength of the structure's existing perimeter walls;

2) the depth of flooding at the structure;

3) flood water velocity at the structure;

4) size and number of closures needed to service the structure;

5) the structure owner's capabilty to operate and maintain the flood proofing system; and

6) Under NFIP requirements, a veneer wall is only allowed for non-residential buildings.

Based upon these five factors, most structures in the Tug Fork Valley proved incapable of being protected by a veneer wall. However, one structure located in the Matewan nonstructural project area and determined eligible for the flood proofing program met the criteria needed for construction of a veneer wall. The structure, a two-story church of 1,920 square feet was located within the floodway fringe and experienced only 1.82 feet of flooding in the first floor area during the 1977 flood. The first floor of the church was constructed with masonry walls and the second story was wood frame construction. Flood water velocity at the church site was between two and three feet per second.

A detailed engineering analysis of the structure's walls, closures and utilities determined that the structure could be "dry" flood proofed by constructing a veneer wall attached to the existing first floor masonry wall. The owners of the church exhibited a willingness and capabilty to operate and maintain the veneer wall, closures, and utilities to prevent future flood damages to the structure.

The veneer wall was constructed of reinforced poured concrete. The wall was six inches thick and extended from the existing footing to an elevation one foot above the design flood *(see figure 57)*. The wall was attached to the existing masonry wall with metal anchors *(see figure 58)* and formed rubber waterstops were installed between all concrete joints. Aluminum flashing was installed along the top of the wall to prevent rainwater from seeping

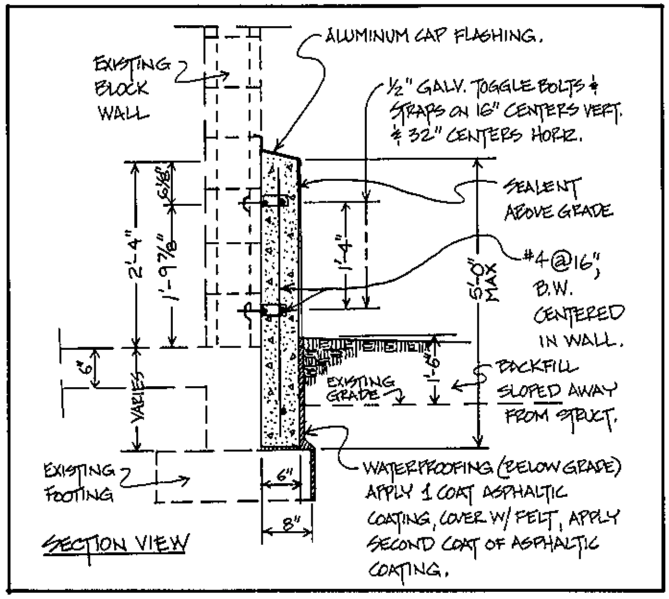


Figure 57.—Veneer Wall Detail Section

between the veneer wall and the existing masonry wall *(see figure 59)*.

Asphaltic waterproofing was applied to the veneer wall surface below ground and a waterproof silicone sealant was applied to the veneer wall surface above the exterior grade *(see figure 57)*.

Only one entrance to the first floor required a closure. The remaining door accessed an equipment room on the first floor and was shortened to avoid the need for a second closure in the veneer wall. A 3-by 2-foot solid aluminum panel with perimeter seals and lock bolts was used to seal the closure *(see figure 60)*. The second floor was accessed by exterior concrete steps and interior steps.

An exterior air-conditioning unit was relocated onto a raised pressure-treated wood platform *(see figure 45)*. A

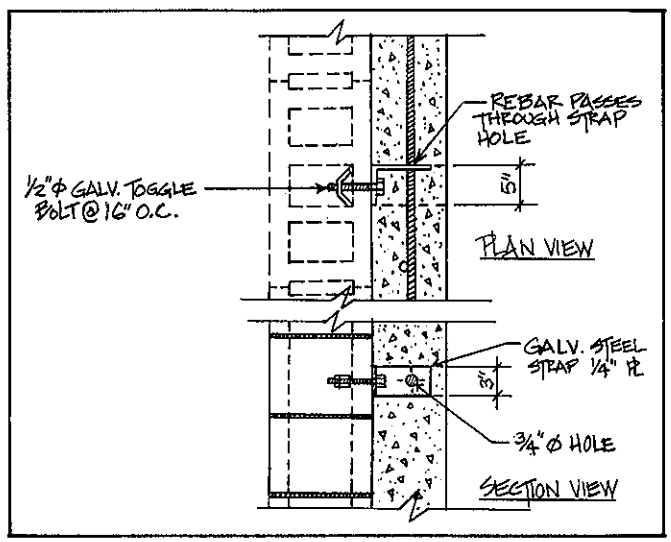


Figure 58.—Veneer Wall Metal Anchor Detail Section

water line was relocated to avoid penetration of the veneer wall and a valve box and gate valve were installed on the underground sewer line to prevent backflows into the first floor area.

Detailed instructions regarding the operation and maintenance of the veneer wall, closure and utility valve were placed on wall placards both on the exterior wall next to the closure and inside the church. These items were included in the agreement executed between the church owners and the Corps of Engineers. *Figures 61* and *62* show the veneer wall during construction.

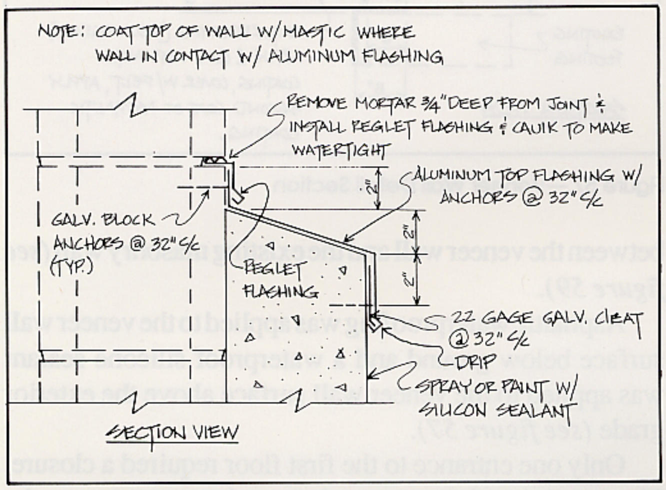


Figure 59.—Aluminum Flashing Detail Section

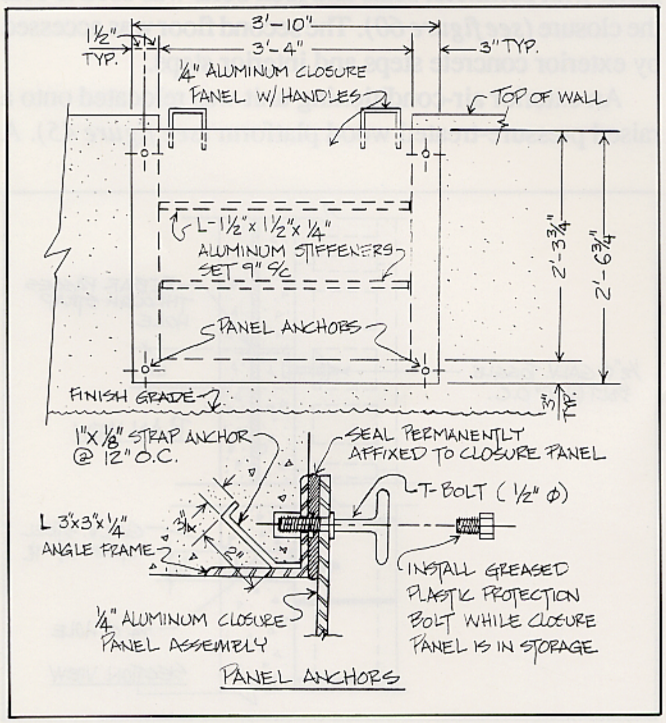


Figure 60.—Watertight Closure

Figure 61.—Veneer Wall Construction Views

Figure 62.—Veneer Wall Construction Views

Flood Proofing Costs

Flood proofing existing structures by elevation or constructing a veneer wall around the structure is a complicated and labor intensive process. The factors described in *FLOOD PROOFING DESIGN PARAMETERS* on page 4, all contribute to the cost of elevating an existing structure or the cost of constructing a veneer wall around a structure. The key factors influencing the cost of flood proofing by elevation include:

1) size, condition and construction type (frame or masonry) of the structure;

2) the height of elevation required and the type of foundation needed to support the structure;

3) the need for structure rehabilitation;

4) the type, condition and location of mechanical and utility systems.

5) requirements for structure access including handicapped access.

Key factors which influence the construction cost of veneer walls include:

1) height of design flood at the structure;
2) type and condition of the structure walls;
3) type, extent and condition of structure footing;
4) number and size of structure access closures needed;
5) number, size and location of underground utilities entering the structure; and
6) permeability and bearing capacity of soils at the structure.

Additional factors which influence the cost of flood proofing include the availability of skilled contractors and competitively priced building materials. *Tables 2* and *3* show the percentage contribution that each major flood proofing work item has on the total cost to elevate a structure or to construct a veneer wall (dry flood proofing) against the structure.

Table 2
Flood Proofing Cost
Structure Elevation

Construction Items	Percent of Total Construction
Structure Lifting	27
Foundations	21
Mechanical and Utilities	9
Carpentry and Finishings	14
Site Work, Mobilization, and Cleanup	29

Table 3
Flood Proofing Cost
Dry Flood Proofing
Veneer Wall

Construction Items	Percent of Total Construction
Site Work, Mobilization, and Cleanup	40
Concrete and Masonry	24
Metals (Aluminum Flashing/Rebar)	26
Carpentry and Finishes	7
Mechanical and Electrical	3

Relocation Alternatives

The nonstructural program consisted of voluntary flood proofing for those structures found eligible and voluntary acquisition for those remaining structures which could not be flood proofed under the program criteria. Structures placed in the acquisition program were acquired under the Section 202 authority and processed by the Corps of Engineers' Huntington District under the provisions of P.L. 91-646. Residential owners were allowed to salvage their flood plain home and to relocate the home to a flood-safe site *(see figure 63)* or they could purchase a new comparable home at a Corps of Engineers H&CD site. Also, residential owners could purchase an existing home of their choice located outside of the April 1977 flood plain.

The acquisition component of the program required the identification of comparable replacement housing in the project area before the acquisition program could be initiated. As a result of the April 1977 and subsequent May 1984 floods, many comparable replacement structures were determined to be unusable due to their flooding susceptibility.

In an effort to identify new housing resources in the project area, the Corps of Engineers prepared a comprehensive study of potential replacement housing sites throughout the Tug Fork Valley. This study identified 44 individual sites for construction of new replacement housing (single-family and multifamily units) to meet the Section 202 program relocation needs in the Tug Fork Valley.

The potential housing sites located in the project areas were prioritized based upon:

1) cost-effectiveness based on an average cost per developed lot;

2) convenience to the relocated parties;

3) O&M potential by qualified local sponsors; and

4) aesthetic/environmental quality.

In addition to this analysis, the sites were coordinated with the local sponsor, the potential relocatees (in workshop meetings), the state housing agencies and the Federal Housing lending institutions (Farmers Home Administration, Veterans Administration, and Federal Housing Administration). A total of three H&CD sites in the Tug Fork Valley have been approved for construction by the Office of the Assistant Secretary of the Army for Civil Works. Those three sites include Valley View and Mate Creek in West Virginia and Pond Creek in Kentucky. Between the three sites a total of 103 single-family units and 16 multifamily units (townhouses) will be accommodated.

The H&CD sites are being designed and constructed in accordance with site development standards promulgated

Figure 63.—Structure Being Relocated

by Farmers Home Administration, Housing and Urban Development, and the state housing agencies. Adherence to these standards assured that relocatees and future owners would have access to federally insured mortgage financing. Design and construction of utilities and streets were coordinated with state and local entities to assure future operation and maintenance of the sites by the local sponsor. Future land-use at each site is further controlled by site covenants filed with the official plat map.

The Valley View H&CD site, which contains 56 single-family housing sites, is located adjacent to the incorporated limits of Williamson, West Virginia, where the majority of flood plain relocations are occurring *(see figure 1)*. This location will facilitate the annexation of the site by the city of Williamson and recovery of a portion of the relocated tax base. Upon completion of the site construction in 1989, the West Virginia Housing Development Fund, acting as the local sponsor and under contract to the Corps of Engineers, initiated the construction of comparable replacement residences for eligible flood plain parties at the Valley View site. The Valley View H&CD site is shown in *figure 64*. The Pond Creek H&CD site which was designed

Figure 64.—Valley View Housing Site

to accommodate 21 single-family lots is located in the unincorporated South Williamson, Kentucky, area *(see figure 1)*. Site construction was completed in 1991 and the construction of comparable replacement residences is being administered by the Kentucky Housing Corporation under contract to the Corps of Engineers. Construction of replacement homes at this site for flood plain relocated parties in the South Williamson project area was completed in 1992 *(see figure 65)*.

The Mate Creek site is located in Matewan, West Virginia, and is scheduled for completion in 1995 in conjunction with the Matewan, West Virginia, Local Protection Project. This project is a structural component of the Section 202 program. The construction of 26 single-family and 16 multifamily units in the Mate Creek housing site is expected to be completed in 1996 in cooperation with the West Virginia Housing Development Fund *(see figure 66)*.

Figure 65.—Pond Creek Housing Site

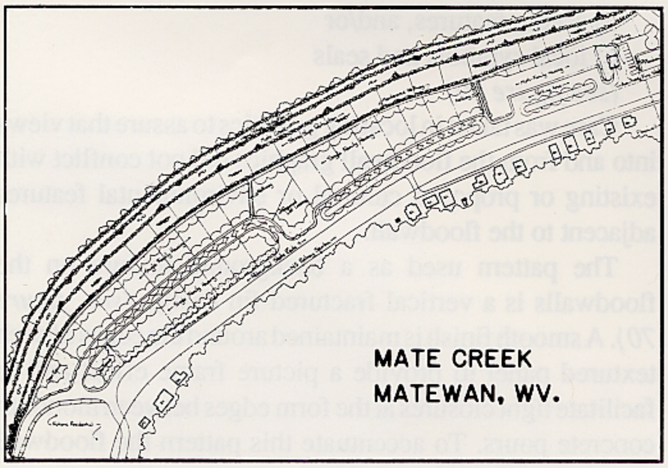


Figure 66.—Mate Creek Housing Site

Relocation Costs

The acquisition/relocation program for the Section 202 Tug Fork Valley was administered under the provisions of P.L. 91-646. In accordance with those provisions, residential and nonresidential property owners determined to be eligible only for acqusition were offered the fair market value for their real property (structures and land). In addition to the fair market value of their flood plain property, residential owners who did not relocate to a Corps of Engineers H&CD site were offered standard relocation benefits under P.L. 91-646 to assist in the purchase of a comparable replacement home of their choice located out of the April 1977 flood plain area.

When necessary, additional funds in excess of the fair market value of the flood plain property and standard relocation benefits provided under P.L. 91-646 were made available for residential owners choosing to construct new comparable replacement homes in the Corps of Engineers H&CD sites. These additional funds were paid directly by the Corps of Engineers to the building contractor at the closing for the new replacement home in the H&CD site.

For those residential owners who were determined originally to be eligible for flood proofing and subsequently chose to sell their property to the Corps of Engineers in lieu of flood proofing, relocation benefits for replacement housing were limited to standard benefits under P.L. 91-646. All homeowners were provided moving expenses in accordance with P.L 91-646 to relocate furnishings to the replacement home regardless of its location.

Nonresidential owners were offered standard relocation benefits and moving benefits under P.L. 91-646 in addition to the fair market value of their flood plain property.

Evacuated Flood Plain Uses

The acquisition and relocation of eligible flood plain structures to the H&CD sites and other private market sites, results in the evacuation of significant acreages of flood plain land. The EIS prepared for the Section 202 Tug Fork Valley project identified adverse project related impacts associated with the construction of structural floodwalls at the major urban centers in the valley.

Coordination of these findings with the United States Fish and Wildlife Service and the natural resources agencies from West Virginia and Kentucky resulted in negotiation of a mitigation plan which provided a dependent relationship between the structural and nonstructural components of the overall plan. Basically, the mitigation plan consisted of replacing each acre of disturbed habitat at the structural floodwalls with an acre of evacuated flood plain habitat acquired under the nonstructural program. Preacquisition planning between the Corps of Engineers and coordinating state natural resources agencies identified those flood plain tracts which would be most suitable for replacement mitigation habitat *(see figure 67)*.

Figure 67.—Evacuated Tracts For Mitigation

Once the evacuated tracts have been restored with landscaping and seeding, they are conveyed to the local sponsor for future operation and maintenance under the terms of the Section 202 legislation and the local cooperation agreement. The future care and administration of the mitigation lands is guided by a management plan jointly prepared by the Corps of Engineers, natural resources agencies and the local sponsor.

Other flood plain tracts acquired under the nonstructural program, but found to be unsuitable for habitat mitigation are transferred to the GSA for disposal. This process results in the reintroduction of developable flood plain lands into the private market for development compliant with local flood plain management ordinances. Under this process, a portion of the community's relocated commercial and residential tax base and employment opportunities are replaced.

Structural Floodwall Aesthetics

The Tug Fork Valley EIS addressed the visual impacts of high floodwalls constructed in densely populated areas. In each of the four communities (Williamson, West Williamson and Matewan in West Virginia and South Williamson in Kentucky) where floodwalls were proposed, the floodwall alignments were highly visible and created structural intrusions into each community.

In an effort to reduce these visual impacts, the EIS mitigation plan included recommendations that the floodwall surfaces be textured and tinted and that, where appropriate, graphics be cast into the concrete wall surfaces. The use of wall texturing and graphics was approved in subsequent floodwall design memoranda for the Section 202 structural projects listed above.

Generally, the use of textured concrete (fractured-fin pattern) on vertical walls creates an ever-changing series of shadows and color changes depending on the amount and angle of direct sunlight striking the wall surface *(see figure 68)*. However, use of this in situ graphic process on Corps of Engineers constructed floodwalls is not a standard practice and examples of this process on large wall surfaces are uncommon.

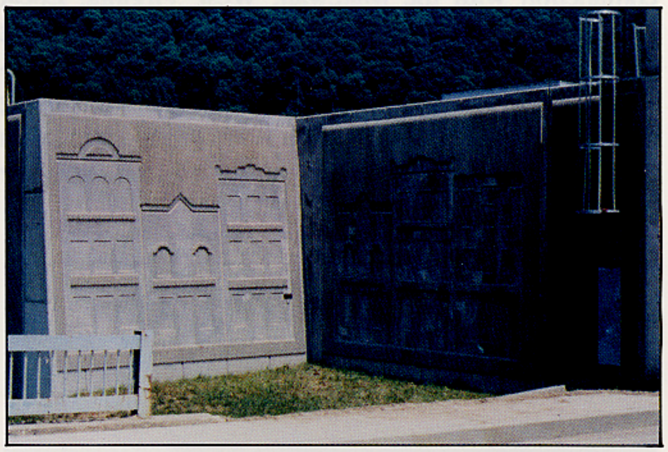


Figure 68.—Floodwall Aesthetics

The Corps of Engineers prepared preliminary sketch designs for various graphic schemes at the four floodwall locations and coordinated those designs with the local sponsors. In each case, a graphic theme or concept was developed reflecting the entire community or parts of the community. Graphic themes were based upon:

1) historical events,
2) cultural icons,
3) sporting events,
4) environmental features,
5) scenic features, and/or
6) local symbols and seals

(see figure 69).

Care was taken in locating graphics to assure that views into and from the floodwall graphics did not conflict with existing or proposed cultural or environmental features adjacent to the floodwall.

The pattern used as a background texture on the floodwalls is a vertical fractured-fin design *(see figure 70)*. A smooth finish is maintained around the edges of each textured panel to provide a picture frame effect and to facilitate tight closures at the form edges between monolith concrete pours. To accentuate this pattern the floodwall was designed without coping.

Figure 69.—Floodwall Graphics

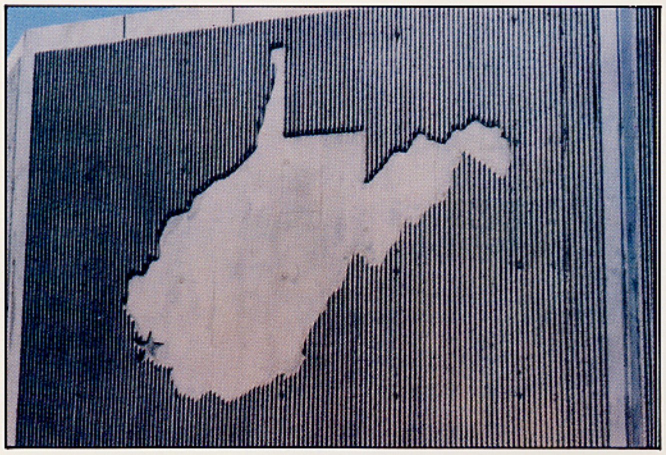


Figure 70.—Vertical Fractured-Fin Design

The polyurethane elastomeric form liners (fractured fin-pattern) were prepared with plywood backing *(see figure 71).*

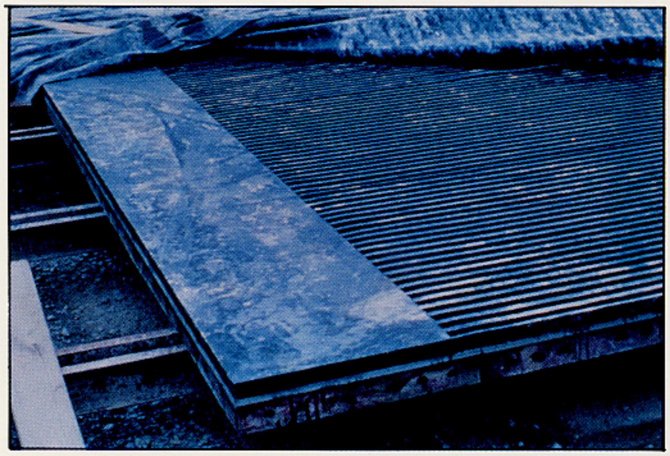


Figure 71.—Graphic Form Liners

The graphic patterns, cut from plywood or particle board, were nailed to the surface of the form liner in reversed, negative position *(see figure 72)* and the voids behind the graphic panels were filled in with styrofoam to prevent concrete leakage into the graphics.

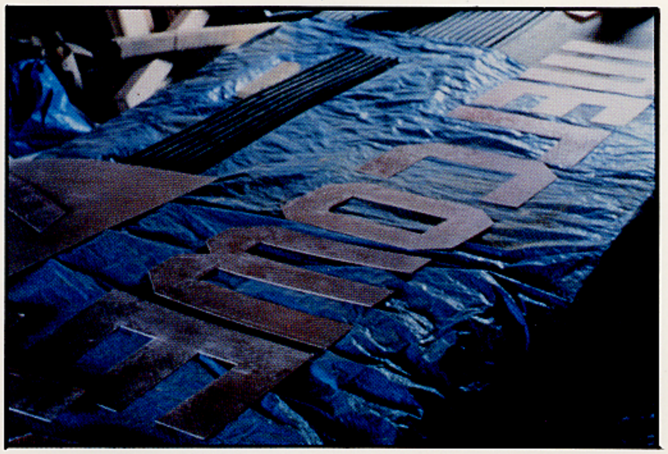


Figure 72.—Graphic Patterns

The entire graphic assembly was tied to the steel floodwall forms. Tie rods were carefully positioned to avoid conflicts with the graphics and the fractured-fin texture. The panels were filled with concrete and allowed to set. The forms were removed from the wall surface and the graphic surfaces and framed edges of the monoliths were sack-rubbed with white cement to fill voids and further accentuate the graphics *(see figure 73).*

The combination of contrasting textures and colors with interesting and familiar graphic forms provides a winding mural throughout the community that residents perceive as a positive effect on adjoining private property values.

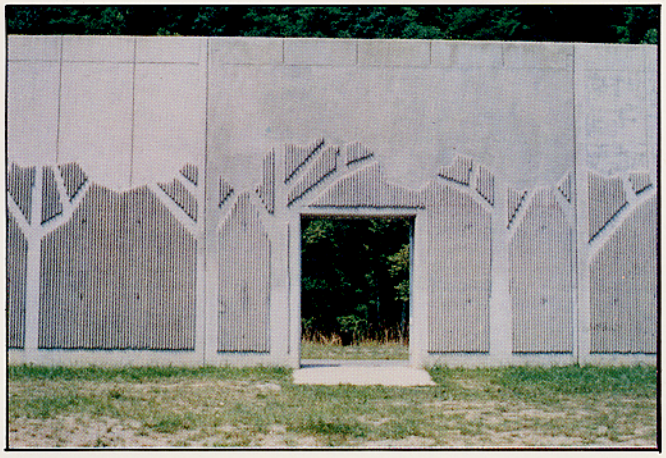


Figure 73.—Sack-Rubbed Finish On Graphics

Summary

Since its beginning in November 1985, the Tug Fork Valley Nonstructural Flood Proofing Program has elevated all or parts of 135 structures, and protected one structure with a veneer wall using the technology described in this report.

The Section 202 Flood Proofing Program has experienced a 90 percent participation rate from eligible structure owners. Generally, structure owners involved in a post-project interview have been pleased with flood proofing. They have expressed their emotional and psychological relief with the significant reduction of the flood risks to their homes.

A number of lessons were learned during the implementation of the Tug Fork Valley flood proofing program, including the following:

1) Voluntary participation in the flood proofing program is necessary for its success;

2) Involve the public in the decision-making process through workshop meetings or public meetings.

3) Coordinate the flood proofing program with the local flood plain ordinance manager and FEMA.

4) Coordinate with and involve local or state housing agencies in the program.

5) Prepare a flood warning and emergency evacuation plan for the flood proofing program.

6) Use a Contractor/Owner contractual process to construct flood proofing.

7) Implement a prototype or test flood proofing program to educate contractors and the public and to advertise the program.

The flood plain acquisition/relocation program has acquired 334 structures with 85 of those already relocated or to be relocated into Corps of Engineers constructed H&CD sites. The voluntary acquisition program has experienced an 80 percent participation rate. This rate of participation substantiated earlier contentions that the combination of a voluntary program with provision of convenient replacement housing would be successful in luring residents away from historically "prime," but hazardous flood plain locations. Flood plain residents reacted in a positive and enthusiastic manner when given the opportunity to freely select from a range of alternative relocation options and provided with sufficient relocation funds.

Relocated residents, contacted in a post-project interview, expressed their overall satisfaction with the relocation program and their emotional relief in being removed from the effects of future flooding.

REFERENCES

Energy & Water Development Act of 1980, Section 202
(P.L. 96-367)

Uniform Relocation Assistance and Real Property Acquisition Act of 1970
(P.L. 91-646)

National Flood Insurance Program and Related Regulations
October 1, 1989 and 1990

Manufactured Home Installation in Flood Hazard Areas
(FEMA 85/ September 1985)

Flood Proofing Regulations
U.S. Army Corps of Engineers - March 1992

Federal Specification
(TT-W-581)