

3. Projects will not be located on Federal or state designated scenic rivers or protected areas, nor on the main stem of the Delaware River.
4. Projects which are part of the Level "B" Comprehensive plan, and are designated for water supply, are considered unavailable to provide protection unless they have additional capacity to add-on flood control.
5. Projects cannot require such an "extensive" relocation of major roads, railways, or structures which makes them "obviously" economically infeasible.
6. Environmentally and socially sensitive areas would not preclude further consideration in itself but would reinforce other negative findings. However, sites which have been previously eliminated or deferred for environmental, social or cultural reasons will automatically be eliminated.
7. Projects cannot be economically feasible as a single purpose flood control project if they are already infeasible as a flood control component of a multipurpose project. The advantages of a multipurpose project would preclude this; however, the concepts were reviewed for any abnormal situations.

158. Only two projects, Aquashicola and Cherry Creek, remained after the screening process. It is emphasized that all of these projects were evaluated with a primary purpose of flood control and conclusions are made solely for flood control. Conclusions may not be valid for other purposes or considerations such as using the sites for water supply or hydropower alone or jointly with flood control.

159. Aquashicola, as a single-purpose flood control impoundment, has a relatively small capacity and would control only Lehigh River flows entering the Delaware River at Easton, Pennsylvania, well below much of the study area. It was therefore eliminated from further consideration as a means of reducing main stem flood damages. Cherry Creek, being an off-line flood skimming project requiring main stem diversion by pumping stations and tunnels, was eliminated because of its small flow reduction potential and prohibitively high costs.

#### EVALUATION OF NONSTRUCTURAL ALTERNATIVES

160. The wide range of nonstructural flood damage reduction measures can be grouped into two categories. The first category contains those individual nonstructural measures designed to limit flood damages to particular structures and properties that are subject to flooding. These measures, applied either alone or in combination, include floodproofing, individual floodwalls, elevating, and buying of structures. The second category consists of areal measures including flood plain management and flood warning and preparedness plans. As stated previously, both elements of this second category would be included in any flood damage reduction plan, and therefore, the development and evaluation of basic nonstructural plans focused on those measures that are applied to individual structures.

161. Because of the individuality of most of the nonstructural measures and the different characteristics between and among the land uses in a damage reach, different mixes of nonstructural measures had to be evaluated. The analysis was based on an optimization procedure which analyzed each reach for

each stage of flooding and applied the least expensive measure for each structure at that stage. The benefit analyses were conducted with the Structural Inventory of Damages (SID) and Equivalent Annual Damages (EAD) computer models. The cost analyses was accomplished with a Nonstructural Cost (NSC) computer model which was developed for this study.

162. The purpose of the NSC program is to determine the most cost effective combination of nonstructural measures in order to estimate the cost of implementation. The program accesses SID data files to obtain information such as use, size, elevations and construction type of each structure. A library of nonstructural cost curves was preprogrammed for various types of structures. These curves relate stage with respect to first floor to a cost per square foot for nonstructural application. At each stage the cost entered is for the least expensive measure for that construction type and protection level relative to the first floor. The output for each reach and each stage within the reach includes the number of structures of each land use type to which each measure is applied, the total number of structures, the number not receiving nonstructural protection, and the average annual cost.

163. A brief description of each of the nonstructural measures evaluated is presented below. The results of the nonstructural screenings are summarized in the following paragraphs. Details are presented in the Formulation Appendix.

- No Action - applicable to structures which are receiving no nonstructural measures since they are not prone to flooding at the selected level of protection.
- Minor Floodproofing - selected when the level of protection is greater than a basement elevation but less than a Zero Damage Elevation (ZDE). It is mostly applied to structures with brick or masonry walls which are prone to basement seepage problems or nuisance type flooding. It generally involves the use of sealants for exterior and interior walls, valves to prevent sewer backup, sump pumps, and other methods of floor pressure relief.
- Major Floodproofing - applicable to structures where the level of protection varies from the basement floor elevation to three feet above the first floor. This type of protection includes temporary and permanent closures and shields for doorways and windows, large pumps, and hydrostatic protection. Considerations include the physical feasibility of closing all openings below the selected level of protection, the impermeability of exterior walls and whether the structure is capable of withstanding the anticipated hydrostatic pressure including buoyancy.
- Individual Floodwalls - applicable to structures where the level of protection rises from the Zero Damage Elevation (ZDE) to a maximum of four feet above the first floor. Floodwalls are considered when minor and major floodproofing cannot be applied because the hydrostatic pressure directly against the walls causes possible slab uplift, wall collapse, and/or flooding.
- Elevate Structure - selected for structures where the level of protection varies from three feet to seven feet above the first floor. Although any structure can be raised it is more appropriate for single and two-story frame structures on raised foundations as

opposed to structures with slab on grade foundations or structures with basements. Structure elevation is selected when economic, hydrostatic and/or aesthetic conditions warrant it.

- Buy - applicable to structures where the level of protection exceeds seven feet above the first floor. Buying a structure at market value does not include costs associated with relocation, such as new land or the actual relocation activity.

#### FIRST SCREENING

164. In the first screening, at each selected stage for each reach in the study area average annual least costly nonstructural combinations were developed from the NSC computer model and compared to the average annual benefits from the EAD computer model. The combination resulting in the maximum net average annual benefit (i.e. average annual benefits minus average annual costs) was designated as the selected nonstructural policy elevation at the index location for the entire reach.

165. In order to minimize the risk of rejecting an economically feasible nonstructural measure, average annual benefits were intentionally overstated. Similarly, a benefit-cost ratio of 0.80 or greater was selected as the criteria for a reach to advance to the next screening.

#### SECOND SCREENING

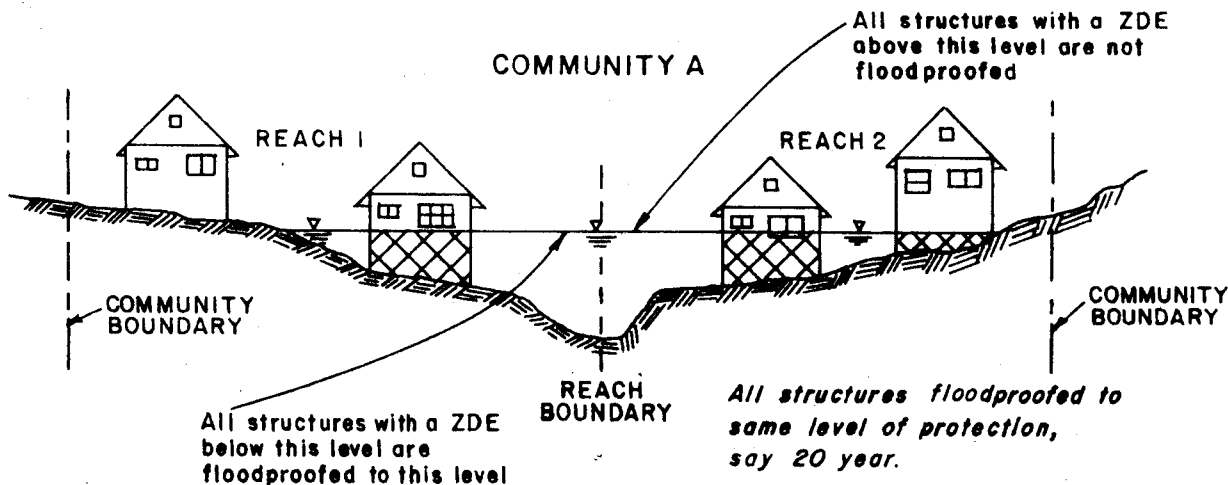
166. The second screening concentrated on increasing the accuracy of estimated benefits and costs. This was accomplished by removing benefits from the computer models which cannot be claimed for nonstructural measures. These benefits include: transportation (roads and bridges), agriculture, and emergency costs. Benefits and costs for each reach were further scrutinized for overall reasonability. It should be emphasized that even with this increased accuracy which generally lowered benefits, the benefits were still intentionally overestimated although less so than in the first screening. This was in keeping with the philosophy that at this stage of the formulation, nonstructural measures should not be eliminated prematurely. As in the first screening, a BCR of 0.80 or greater was selected as the minimum economic viability for progressing to the third screening.

#### THIRD SCREENING

167. Of the 440 original reaches, only 24 remained after the first two screenings, and these were analyzed in a third screening comprised of two steps. The first step further refined benefit and cost estimates and deleted those benefits (reduction of residential landscaping costs, pumping costs, etc.) which were designed to prevent premature elimination by overstating the damages reduced by nonstructural measures. The second step aggregated the 24 reaches into their 19 respective communities and evaluated all the reaches in each community at the selected level of protection for the viable reach. Each community's level of protection was developed by determining the frequency (in

years) of the selected protection level for the economically viable reach or reaches within each specific community and using this frequency as the target level of protection for the entire community. In effect, only those structures with a zero damage elevation (ZDE) at or below the target level will receive nonstructural floodproofing measures. This approach provides a uniform level of protection throughout a community (see figure below). The nonstructural measure applied depends on the protection level with respect to the first floor, and the construction and land-use type of each structure.

### FLOODPROOFING TO SPECIFIED FLOOD TARGET LEVEL



**NOTE:** Cross hatched area represents amount of floodproofing for each structure

168. The results of the screening analysis of the nonstructural measures are summarized in Table 16. Seven of the nineteen communities analyzed in the third screening had a BCR less than unity and were therefore eliminated from further evaluation.

#### COMMUNITIES REMAINING AFTER THIRD SCREENING

169. There were 12 communities which met the screening criteria (BCR equal to or greater than unity) and therefore surpass a minimum level of economic justification. Those communities are listed in Table 17 with the types of nonstructural measures evaluated and the number of structures requiring each type of measure. A discussion of each of those twelve communities follows.

#### BUCKS COUNTY, PENNSYLVANIA

- . Bridgeton Township. The nonstructural analysis yielded a BCR of 1.6 at a 22-year level of protection at a total cost of approximately \$422,000. The structures requiring the application of nonstructural protective measures are irregularly and loosely grouped in a rural area along the Delaware River.

- . Bristol Borough. The analysis yielded a BCR of 2.2 at a 66-year level of protection at a total cost of approximately \$109,000. Of those structures requiring the application of nonstructural protective measures, eleven

TABLE 16

SUMMARY OF NONSTRUCTURAL SCREENINGS<sup>4/</sup>

COMMUNITY	NUMBER OF STRUCTURES (SPF BOUNDARY)	STRUCTURES REQUIRING PROTECTION (PERCENT)	LEVEL OF PROTECTION (FREQUENCY IN YEARS)	AVERAGE ANNUAL BENEFITS (\$000)	AVERAGE ANNUAL COSTS (\$000)	BENEFIT COST RATIO	SCREENING <u>1/</u>
BUCKS COUNTY, PA							
Bensalem Twp	121	73	<u>2/</u>	9.84	31.42	0.31	2
Bridgeton Twp	152	33	<u>22</u>	52.80	33.20	1.60	3
Borough of Bristol	66	79	66	18.95	8.56	2.20	3
Bristol Twp	136	16	50	47.40	20.60	2.30	3
Durham Twp	25	40	<u>2/</u>	0.14	5.97	0.02	1
Falls Twp	4	100	<u>2/</u>	57.68	479.36	0.12	2
Lower Makefield Twp	639	46	<u>2/</u>	1.27	39.25	0.03	2
Borough of Morrisville	33	85	<u>2/</u>	3.05	32.66	0.09	2
Borough of New Hope	278	7	22	66.16	33.89	1.95	3
Nockamixon Twp	6	16	50	0.56	1.56	0.36	3
Plumstead Twp	16	12	28	31.62	6.41	4.93	3
Borough of Reigelsville	197	26	<u>2/</u>	0.49	6.70	0.07	1
Solebury Twp	97	63	<u>167</u>	78.39	153.60	0.51	3
Tinicum Twp	211	9	13	85.80	36.80	2.33	3
Borough of Tullytown	17	94	333	7.38	22.06	0.33	3
Upper Makefield Twp	304	9	22	29.83	34.15	0.87	3
Borough of Yardley	328	37	35	97.41	148.27	0.66	3
NORTHAMPTON COUNTY, PA							
City of Easton	260	22	50	98.66	152.87	0.64	3
Forks Twp	71	63	<u>2/</u>	1.66	12.47	0.13	1
Lower Mt. Bethel Twp	202	5	17	24.04	13.42	1.79	3
Borough of Portland	37	89	<u>2/</u>	5.47	53.15	0.10	1
Upper Mt. Bethel Twp	122	41	<u>2/</u>	6.81	50.30	0.14	2
Williams Twp	117	20	<u>2/</u>	1.89	8.28	0.23	2
MONROE COUNTY, PA							
Borough of Delaware Water Gap	35	72	<u>2/</u>	1.35	6.93	0.19	2
Smithfield Twp	141	50	<u>2/</u>	84.25	658.14	0.13	2

TABLE 16 (Continued)

SUMMARY OF NONSTRUCTURAL SCREENINGS<sup>4/</sup>

COMMUNITY	NUMBER OF STRUCTURES (SPF BOUNDARY)	STRUCTURES REQUIRING PROTECTION (PERCENT)	LEVEL OF PROTECTION (FREQUENCY IN YEARS)	AVERAGE ANNUAL BENEFITS (\$000)	AVERAGE ANNUAL COSTS (\$000)	BENEFIT COST RATIO	SCREENING <u>1/</u>
BURLINGTON COUNTY, NJ							
City of Beverly	No Structures		<u>2/</u>				2
City of Bordentown	2	50	<u>2/</u>	0.91	0.38	0.95 <sup>3/</sup>	2
Bordentown Twp	No Structures		<u>2/</u>				1
City of Burlington	2966	81	<u>2/</u>	790.42	3188.38	0.25	2
Burlington Twp	13	93	<u>2/</u>	14.96	99.15	0.15	2
Delanco Twp	45	15	<u>7</u>	13.67	3.27	4.18	3
Delran Twp	73	100	<u>2/</u>	16.15	188.33	0.09	1
Edgewater Park Twp	No Structures		<u>2/</u>				1
Borough of Fieldsboro	2	0	<u>2/</u>				1
Florence Twp	1	100	<u>2/</u>	0.02	4.36	0.01	2
Mansfield Twp	2	100	<u>2/</u>	0.39	1.38	0.28	2
Riverside Twp	163	7	<u>25</u>	22.78	9.82	2.32	3
HUNTERDON COUNTY, NJ							
Alexandria Twp	47	86	<u>2/</u>	8.67	43.04	0.20	2
Delaware Twp	20	60	<u>2/</u>	7.97	15.78	0.51	2
Borough of Frenchtown	206	30	<u>2/</u>	1.50	20.11	0.17	2
Holland Twp	37	16	<u>35</u>	12.00	8.43	1.42	3
Kingwood Twp	70	38	<u>95</u>	17.35	32.91	0.53	3
City of Lambertville	450	55	<u>2/</u>	108.45	166.45	0.65	2
Borough of Milford	90	44	<u>2/</u>	0.85	24.58	0.04	2
Borough of Stockton	140	39	<u>2/</u>	0.37	17.42	0.02	1
W. Amwell Twp	4	100	<u>2/</u>	0.47	14.32	0.03	2
MERCER COUNTY, NJ							
Ewing Twp	200	65	<u>2/</u>	21.25	151.91	0.14	1
Hamilton Twp	10	70	<u>50</u>	67.81	22.82	2.97	3
Borough of Hopewell	98	15	<u>2/</u>	4.70	13.40	0.35	2
City of Trenton	646	84	<u>2/</u>	113.65	858.58	0.13	2

TABLE 16 (Continued)

SUMMARY OF NONSTRUCTURAL SCREENINGS<sup>4/</sup>

COMMUNITY	NUMBER OF STRUCTURES (SPF BOUNDARY)	STRUCTURES REQUIRING PROTECTION (PERCENT)	LEVEL OF PROTECTION (FREQUENCY IN YEARS)	AVERAGE ANNUAL BENEFITS (\$000)	AVERAGE ANNUAL COSTS (\$000)	BENEFIT COST RATIO	SCREENING <u>1/</u>
WARREN COUNTY, NJ							
Town of Belvidere	191	83	<u>2/</u>	24.08	179.76	0.13	1
Harmony Twp	175	11	<u>10</u>	23.77	13.10	1.81	3
Knowlton Twp	140	32	<u>2/</u>	4.59	47.20	0.10	2
Lopatcong Twp	1	0	<u>2/</u>				2
Pahaquarry Twp	2	0	<u>2/</u>				1
Town of Phillipsburg	118	52	<u>2/</u>	4.82	115.68	0.04	2
Pohatcong Twp	113	25	<u>2/</u>	1.16	30.17	0.04	2
White Twp	60	45	<u>2/</u>	4.78	13.91	0.34	2

1/ The screening indicated is the last screening to which the community progressed. A community did not advance to the next screening if it had a BCR less than 0.8 (1.0 in third screening).

2/ Nonstructural analysis in screenings 1 and 2 was done exclusively on a reach by reach basis. Therefore the level of flood protection of a community eliminated in the 1st and/or 2nd screenings varies by reach within the community because the selected level of protection is the optimum level for each reach and therefore not consistent throughout the community.

3/ Only one structure received nonstructural action within the community and because of this constraint the community did not advance to the next screening.

4/ March 1983 price level. Discount rate of 7 7/8%.

TABLE 17

DELAWARE RIVER BASIN STUDY - NONSTRUCTURAL ANALYSIS  
NONSTRUCTURAL ACTIONS

Community	No Action (No Protection Required)	Minor Floodproof	Major Floodproof	Individual Floodwall	Elevate	Buy
<u>BUCKS COUNTY, PENNSYLVANIA</u>						
Bridgeton Twp	101	6 (Res)	25 (Res) 2 (Com)	4 (Res) 1 (Ser)	13 (Res)	0
Bristol Boro	14	11 (Com)	40 (Res) 1 (Ser)	0	0	0
Bristol Twp	114	0	2 (Res)	15 (Res) 1 (Pub)	4 (Res)	0
New Hope Boro	257	1 (Res) 1 (Com)	2 (Res) 4 (Com)	1 (Res) 5 (Com)	7 (Res)	0
Plumstead Twp	14	0	0	1 (Res)	0	1 (Res)
Tinicum Twp	192	1 (Res)	3 (Res) 1 (His)	7 (Res) 1 (Ser)	2 (Res)	3 (Res) 1 (Com)
<u>NORTHAMPTON COUNTY, PENNSYLVANIA</u>						
Lower Mt. Bethel Twp	193	1 (Res)	0	4 (Res)	4 (Res)	0
<u>BURLINGTON COUNTY, NEW JERSEY</u>						
Delanco Twp	38	1 (Com)	3 (Res)	1 (Res) 1 (Com)	1 (Res)	0
Riverside Twp	152	0	3 (Res) 2 (Com)	6 (Res)	0	0
<u>HUNTERDON COUNTY, NEW JERSEY</u>						
Holland Twp	31	0	1 (Res)	3 (Res)	1 (Res)	1 (Res)
<u>MERCER COUNTY, NEW JERSEY</u>						
Hamilton Twp	3	0	1 (Com)	1 (Com) 1 (Ind)	1 (Com)	1 (Com) 2 (Ind)
<u>WARREN COUNTY, NEW JERSEY</u>						
Harmony Twp	156	5 (Res)	5 (Res)	5 (Res)	3 (Res)	1 (Com)



commercial establishments and one municipal garage are loosely grouped at the mouth of a small tributary to the Delaware River. The remaining structures are apartments in a complex in an urbanized area along the Delaware River.

. Bristol Township. The analysis yielded a BCR of 2.3 at a 50-year level of protection at a total cost of about \$261,000. The structures requiring protective measures are irregularly and loosely associated in groups of not more than eight in an urbanized area along the Delaware River and Neshaminy Creek.

. New Hope Borough. The nonstructural analysis yielded a BCR of 2.0 at a 22-year level of protection at a total cost of about \$430,000. The structures requiring protective measures are loosely grouped along the Delaware River in the urbanized area of downtown New Hope.

. Plumstead Township. The nonstructural analysis yielded a BCR of 4.9 at a 28-year level of protection at a total cost of about \$81,000. The structures requiring protective measures consist of two residential properties in a rural area along the main stem Delaware River.

. Tinicum Township. The nonstructural analysis yielded a BCR of 2.3 at a 13-year level of protection at a total cost of approximately \$427,000. The structures requiring protective measures are irregularly and loosely associated in groups of not more than eight in a mostly rural area along the main stem Delaware River.

#### NORTHAMPTON COUNTY, PENNSYLVANIA

. Lower Mount Bethel Township. The analysis yielded a BCR of 1.8 at a 17-year level of protection at a total cost of about \$170,000. The structures requiring protective measures, located in a rural area along the Delaware River, consist of a group of six residential properties with the rest of the structures scattered throughout the township.

#### BURLINGTON COUNTY, NEW JERSEY

. Delanco Township. The nonstructural analysis yielded a BCR of 4.2 at a 7-year level of protection at a total cost of about \$41,000. The structures requiring protective measures are located in an urban area along both the Delaware River and Rancocas Creek.

. Riverside Township. The analysis yielded a BCR of 2.3 at a 25-year level of protection at a total cost of approximately \$125,000. The structures requiring protective measures are scattered throughout the urbanized area at the mouth of Rancocas Creek.

#### HUNTERDON COUNTY, NEW JERSEY

. Holland Township. The analysis yielded a BCR of 1.4 at a 35-year level of protection at a total cost of about \$107,000. The structures requiring protective measures are located along the Delaware River in a mostly rural area.

## MERCER COUNTY, NEW JERSEY

. Hamilton Township. The nonstructural analysis yielded a BCR of 3.0 at a 50-year level of protection at a total cost of about \$290,000. The structures requiring protective measures are located within a complex of a group of six oil companies and distributors, made up of small office buildings and oil storage tanks, and a small marine repair shop in a rural area along the Delaware River.

## WARREN COUNTY, NEW JERSEY

. Harmony Township. The nonstructural analysis yielded a BCR of 1.8 at a 10-year level of protection at a total cost of approximately \$166,000. The structures requiring the application of protective measures are located in a rural area along the main stem Delaware River in a group of 5 residential properties and a loosely associated group of 13 residential properties, including some cottages, and a commercial establishment.

170. In aggregate and on a community basis at a survey level of analysis, the application of nonstructural protective measures is economically justified for 223 structures (or approximately 1.9 percent) of the over 12,000 structures inventoried in the floodplain (as defined by the SPF) of the 105 river miles of the main stem Delaware River from Stroudsburg, Pennsylvania, to Burlington, New Jersey. These structures are distributed among 12 of the 58 communities in that reach. The total cost of the nonstructural protection of these 12 communities is approximately \$2,629,000. Before a nonstructural protection plan could be implemented, however, a more detailed analysis would be required.

## DESIGNATION OF THE NATIONAL ECONOMIC DEVELOPMENT (NED) PLAN

171. Application of nonstructural measures to selected structures within the communities listed in Table 17 is the NED plan. Of all the measures evaluated for this study, this plan would provide the maximum net benefits with minimal environmental effects.

## FUTHER STUDIES REQUIRED

172. Further detailed studies remain to be done before any nonstructural measures could be implemented. Those studies would include, but not be limited to, a more accurate determination of flood plain limits, engineering studies of each structure affected and a more precise determination of costs and potential benefits. Giving due consideration to the estimated construction costs and comparison of anticipated remaining study costs to potential project benefits, it may be appropriate that further studies be conducted in accordance with the provisions of Section 205 of the 1948 Flood Control Act. That Act, as amended, authorizes the Secretary of the Army to construct small projects for flood control and related purposes not specifically authorized by Congress when in the opinion of the Chief of Engineers such work is advisable. A non-Federal entity that is interested in sponsoring further studies must be identified before further action can be taken under the cited authority. Local officials for each of the 12 communities listed in Table 17 and for each of the Counties in which those communities are located were contacted to ascertain non-Federal interest in sponsoring further studies. Those contacts and results are discussed in the following section.