- Moderate flooding with low velocities and short duration;
- Individual solutions without collective action or where collective action is not possible; and
- Activities dependent on flood plain locations, thereby requiring some degree of protection.

144. Previous investigations, such as the Madigan-Praeger Report, have indicated that as little as 15 percent of the existing structures in a flood plain lend themselves to a floodproofing solution. However, flood problem areas throughout the study area do exist which have high zero damage elevations (ZDE) and development characteristics suitable for floodproofing. The potential for "blanket application" was never expected but partial application was expected; therefore, floodproofing was considered for all structures.

145. <u>PERMANENT FLOOD PLAIN EVACUATION</u>. The objective of permanent evacuation is to remove people and damageable property from the flood hazard area. Not only is evacuation applicable for entire or partial sectors, it is also very effective for completing a total plan for flood protection by application to outlying structures that cannot be incorporated with the other measures of the plans.

146. With the removal of flood-susceptible buildings, an opportunity exists for increasing open space, park, and recreational development; for promoting natural and conservation areas; and for advancing compatible utilization such as parking, transient storage or pedestrian malls for commercial development. Permanent evacuation, if not part of a more comprehensive community plan, can have a positive impact on a community. On the other hand, the removal of property can upset a neighborhood; decrease the communities' tax base; and, in general, have adverse social and economic effects. Effective and implementable plans will undoubtably include tradeoffs in zoning and uses with nonfloodplain lands and require a general review of community long term objectives and future plans. Unfortunately, it often becomes obvious that flood control benefits are secondary. They are not as great as the benefits which could be realized from other purposes or uses. In these cases, flood control benefits should be considered as strong secondary or additional benefits for areas being considered for other purposes such as redevelopment, open spaces, conservation, or recreational development.

147. The practicality of evacuation depends upon the frequency and severity of flooding and upon the value of the property. Many of the structures which were flooded in 1955 have either been abandoned or demolished and removed. Yet, past investigations have estimated that a maximum of approximately 20 percent of the structures that are subject to relatively frequent flooding could be purchased and the occupants permanently evacuated. Flood plain evacuation was investigated but solely from the perspective of flood control project investment; not as a secondary purpose.

EVALUATION OF STRUCTURAL ALTERNATIVES

148. Based on the rationale presented in the preceding paragraphs, levee/floodwall systems and flood water storage impoundments were the only structural measures selected for further consideration. These were evaluated through a screening process for each of the damage reaches. The number of screenings for each damage reach was determined by the potential for economic

justification and technical feasibility after each screening. With each successful screening the data used was more refined and the methods and analytical tools used for evaluation were more sophisticated. The level of detail increased with each screening but with an assurance that any inherent inaccuracies or uncertainties always favored benefits. In this way, a potential measure was not prematurely eliminated. This increasing detail was brought to a level which was sufficient to insure that the measure was suitable for incorporation into alternative plans.

LEVEES AND FLOODWALLS.

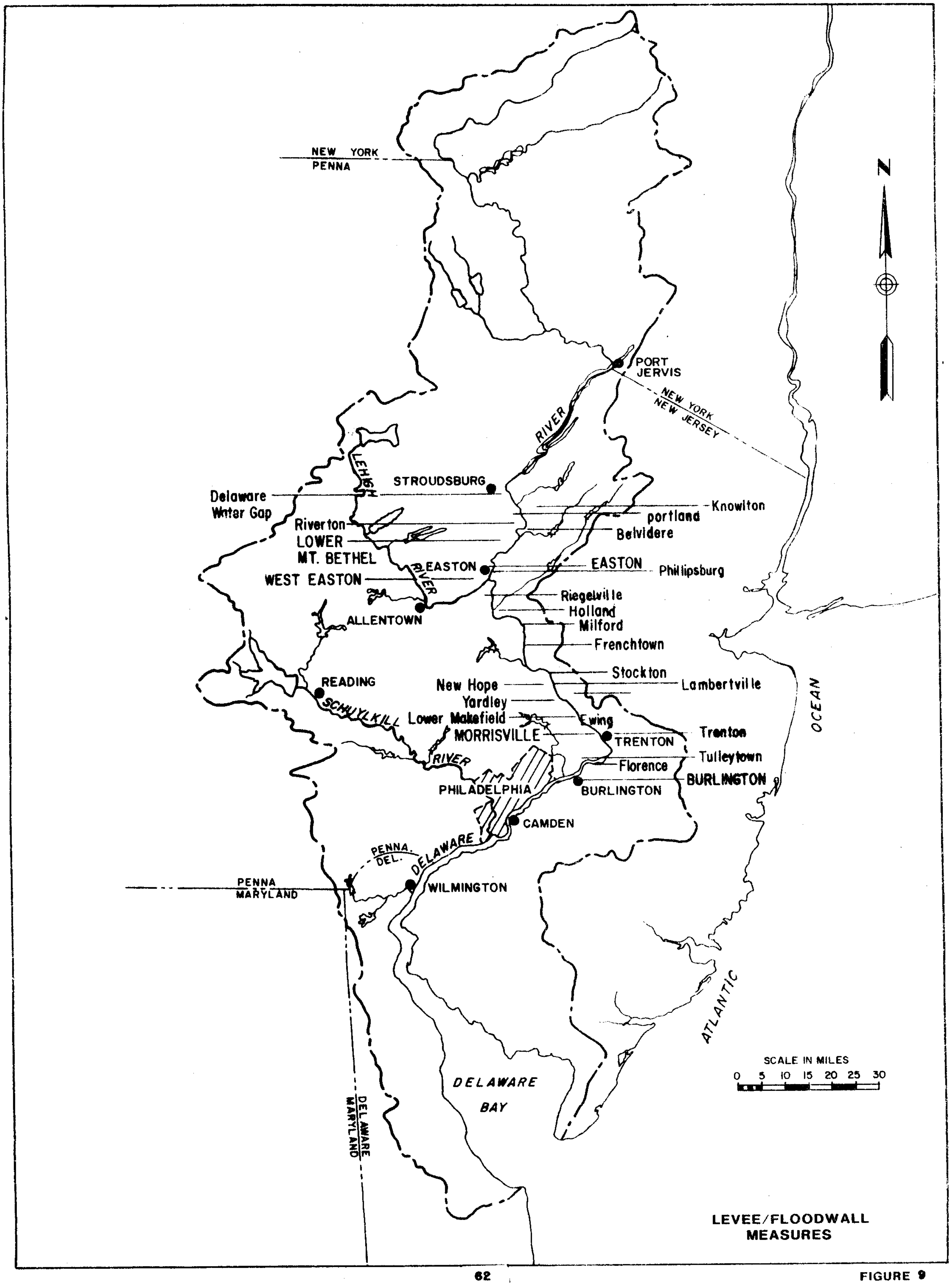
149. All areas which had a concentration of floodprone structures or major individual plants or facilities were reviewed for levee/floodwall protection. Because of the large number of potential levee/floodwall applications, a series of three screenings was conducted with an increase in the depth of analysis with each sucessive screening. In this manner, areas for which levee/floodwall projects could not be justified were methodically eliminated.

150. The initial screening of levees and floodwalls consisted of a comparison of average annual damages (AAD) with the length, height, and complexity of protective works which would be required. Areas in which the magnitude of AAD was such that it obviously would not support the costs of levee/floodwall projects were eliminated. The areas which were considered beyond the initial screening are shown in Figure 9.

151. The second screening used AAD directly as an intentional overestimate for average annual benefits (AAB) and a "cost curve" approach for estimating average annual cost (AAC). A level of protection equal to the SPF was initially analyzed. Sensitivity runs were then conducted with costs being reduced by first 25 percent and then 50 percent. This was done to insure that possible cost variances were not critical and to serve as a proxy for multiple analyses at lower levels of protection. Even with those inflated benefits and lower costs, BCR's are much less than unity for many of the areas investigated. It was concluded that no variations of design would be economically justified for those areas that did not survive the second screening

152. The third screening of levee/floodwall measures was conducted for the remaining areas. Initially, SPF projects were investigated using AAD for benefits with more detailed cost estimates. Once these results were reviewed, levee/floodwall systems for a 100-year level of protection were investigated at selected areas. Once again, sensitivity runs were conducted. Since better cost estimates were developed for these measures, only the sensitivity of a 25 percent reduction in total cost was tested. However, because of the complexity of interior drainage requirements, the sensitivities of reducing interior drainage by first 25 percent and then 50 percent were tested.

153. Relatively high zero-damage stages, relatively steep and narrow flood plains, past individual self-help efforts and community flood plain management efforts in the areas evaluated have resulted in lowering average annual damages (AAD) and, consequently, lowering potential average annual benefits (AAB). At the same time, older urban communities have very complex infrastructures along potential project alignments which result in very high relocation and construction costs. These factors have resulted in the infeasibility of levee and floodwall protection. The only levee/floodwall



LEVEE/FLOODWALL MEASURES

FIGURE 9

measure demonstrating even marginal feasibility is the SPF protection project for Morrisville, Pennsylvania. Even that project has a BCR less than unity.

154. A summary of the evaluation of levee/floodwall measures is presented in Table 13. This table contains the location, first cost, average annual cost (AAC), average annual benefits (AAB), benefit-cost ratio (BCR), sensitivity BCR (when the costs are for the second screening and 25 percent for the third screening) reduced by 50 percent, and the screening in which the project was eliminated.

IMPOUNDMENTS.

155. All forms of impoundments and all potential impoundment sites for controlling flood waters were reviewed. They included new sites, increasing existing flood control capacity, and the addition of flood control storage at new or existing multipurpose and single purpose projects. "Dry dams", as well as permanent pool projects and off-line flood skimming projects were all reviewed. From the beginning it was obvious that the difficulty with impoundments lies in developing enough control to significantly lower stages along the main stem of the Delaware River without use of a main stem reservoir. Although it was the optimum main stem project, the Tocks Island project discussed earlier in this report was rejected primarily because it would impound one of the last major free flowing rivers in the northeast. For these reasons main stem impoundment was not considered further.

156. The objective of this review was to evaluate all previously identified potential impoundment sites under present-day conditions. Reservoir locations that were previously identified by the Corps of Engineers or other agencies were reviewed. The site locations were obtained from House Document 522, the Madigan-Praeger Report, TAMS reports, the Delaware River Basin Electric Utility Group (DRBEUG), the DRBC and the Level "B" Study. The locations of these sites are shown on Figures 10 and 11. It is considered highly unlikely that after more than 30 years of study, additional impoundment locations exist that could potentially make a measureable contribution to flood control along the main stem Delaware River.

157. Because of the large number of sites and multiple variations at each site, a series of screenings was conducted. Each screening concentrated on one or two criteria. The screening criteria are discussed below and summaries of the screening analysis for the impoundments shown on Figures 10 and 11 are displayed in Tables 14 and 15, respectively. The numbers below indicate the screening step for which the criteria was used.

1. Projects should be located above the City of Trenton, New Jersey, to be considered as having any real contribution to the study area. Below Trenton, floods are caused by a combination of fluvial and tidal influences.

2. Projects should have as a minimum 20,000 acre-feet of storage available for flood control. Conventional storage projects should control a minimum drainage area of 50 square miles which is currently uncontrolled. Projects were considered further if the potential exists to pump water into the reservoir and, therefore, control a much larger drainage area.

TABLE 13
BENEFIT/COST SUMMARY
LEVEE/FLOODWALL MEASURES
SECOND AND THIRD SCREENING
(March 1983 Dollars and Conditions)

LOCATION	FIRST COST ($000)	AAC ($000)	AAB ($000)	BCR	SENSITIVITY BCR 1/	ELIMINATED IN SCREENING
BUCKS COUNTY, PA						
Lower Makefield Twp	10269	934	239	0.26	0.51	2
Morrisville Boro 2/	3578	292	64	0.22	0.26	3
Morrisville Boro 3/	5195	424	291	0.69	0.78	3
New Hope Boro 2/	4208	381	166	0.44	0.87	2
New Hope Boro 3/	7159	637	58	0.09	0.18	2
Rieglesville Boro	6851	623	45	0.07	0.15	2
Tullytown Boro 2/	1140	103	9	0.09	0.17	2
Tullytown Boro 3/	3293	298	14	0.05	0.09	2
Yardley Boro 2/	10860	984	141	0.14	0.29	2
Yardley Boro 3/	18593	1684	238	0.14	0.28	2
NORTHAMPTON COUNTY, PA						
Easton City 3/	25869	2115	130	0.06	0.08	3
Lower Mt. Bethel Twp 2/	2565	233	7	0.03	0.06	2
Lower Mt. Bethel Twp 3/	6016	492	20	0.04	0.06	3
Portland Boro	2649	239	31	0.13	0.26	2
West Easton Boro 3/	19895	1627	55	0.03	0.05	3
MONROE COUNTY, PA						
Delaware Water Gap Boro	1619	146	47	0.32	0.64	2
BURLINGTON COUNTY, NJ						
Burlington City 2/	19475	1593	82	0.05	0.07	3
Burlington City 3/	26031	2128	238	0.11	0.14	3
Florence Twp	1770	161	3	0.02	0.04	2
HUNTERDON COUNTY, NJ						
Frenchtown Boro	8680	786	70	0.09	0.18	2
Holland Twp	5990	534	120	0.22	0.45	2
Lambertville City 2/	2674	242	20	0.08	0.17	2
Lambertville City 3/	7465	676	255	0.38	0.75	2
Milford Boro 2/	2946	292	88	0.30	0.60	2
Milford Boro 3/	32276	266	73	0.27	0.55	2
MERCER COUNTY, NJ						
Ewing Twp	4936	477	50	0.11	0.22	2
Trenton City	9321	844	232	0.27	0.55	2
WARREN COUNTY, NJ						
Belvidere Twp	3300	299	15	0.05	0.10	2
Knowlton Twp	6983	633	24	0.04	0.08	2
Phillipsburg Twp	5148	466	10	0.02	0.04	2

1/ 50% Reduction in Costs for 2nd Screening
25% Reduction in Costs for 3rd Screening
2/ 100-year protection
3/ SPF protection

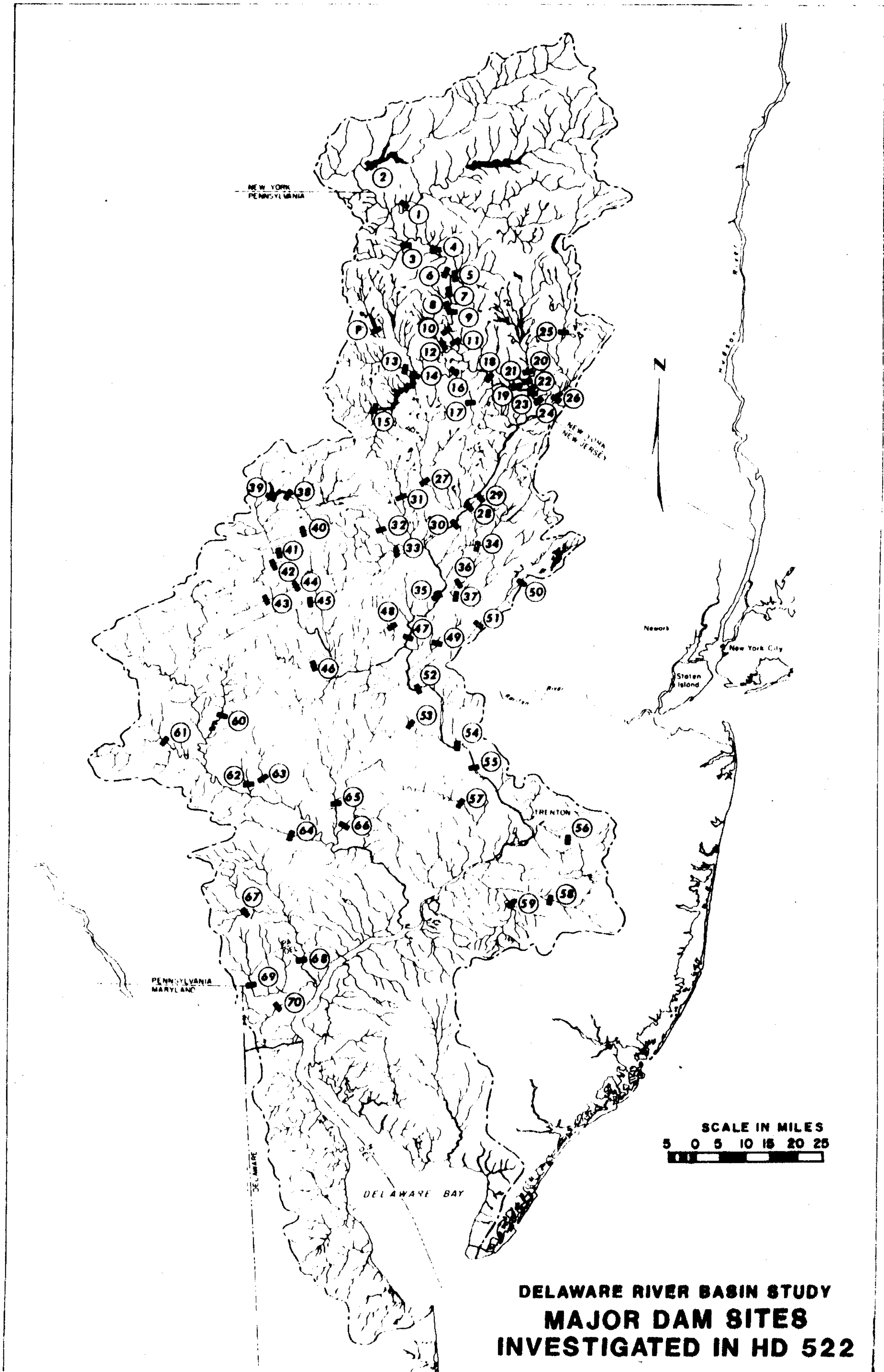

NEW YORK
PENNSYLVANIA
NEW YORK
NEW JERSEY
Newark
New York City
Staten Island
TRENTON
PENNSYLVANIA
MARYLAND
DELAWARE
DELAWARE BAY
SCALE IN MILES
5 0 5 10 15 20 25
DELAWARE RIVER BASIN STUDY
MAJOR DAM SITES
INVESTIGATED IN HD 522

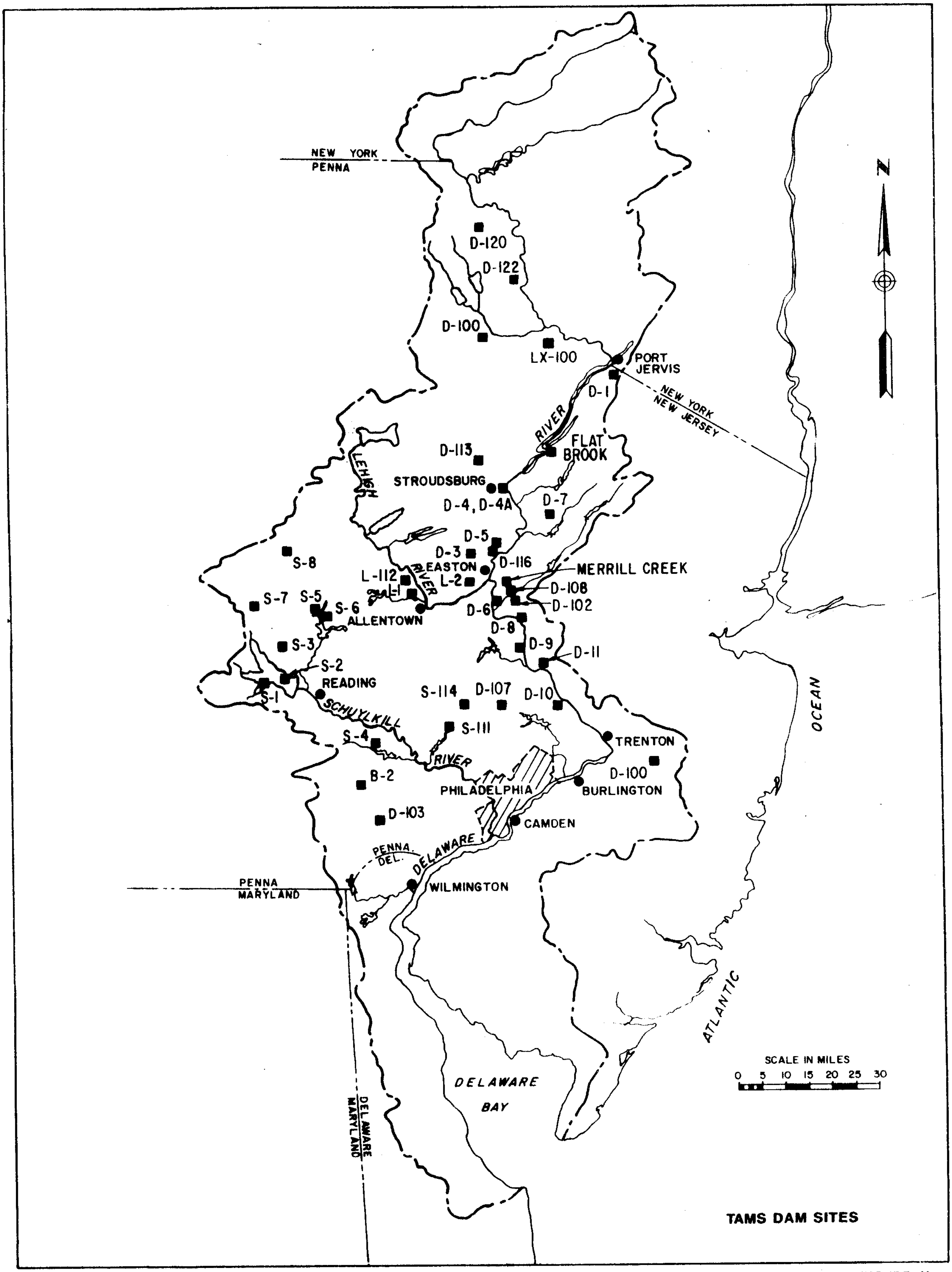
FIGURE 10

TABLE 14
IMPOUNDMENT SITES
PREVIOUSLY IDENTIFIED
HD522 SUMMARY

Index #	Project	Location	Eliminated in Screening
1	Hawk Mountain	East Branch Delaware River	5
2	Connorsville	West Branch Delaware River	4
3	Equinunk	Equinunk Creek	3
4	Hankins	Delaware River	3
5	Callicoon	Callicoon Creek	5
6	Callicoon River	Delaware River	3
7	Cochecton	Delaware River	3
8	Milansville	Calkins Creek	2
9	Skinners Falls	Delaware River	3
10	Narrowsburg	Delaware River	3
11	Tusten	Delaware River	3
12	Masthope	Masthope Creek	2
13	Hawley	Middle Creek	5
14	Wallenpaupack	Wallenpaupack Creek	5
15	Sterling	Wallenpaupack Creek	4
16	Lackawaxen	Lackawaxen Creek	5
17	Shohola Falls	Shohola Creek	5
18	Barryville	Delaware River	3
19	Knights Eddy	Delaware River	3
20	Rio	Mongaup River	4
21	Delaware	Mongaup River	2
22	Mongaup	Delaware River	3
23	Hawks Nest	Delaware River	3
24	Sparrow Bush	Delaware River	3
25	Bridgeville	Neversink River	5
26	Basherkill Stream	Neversink River	5
27	Girard	Bushkill Creek	5
28	Wallpack Bend	Delaware River	3
29	Flat Brook	Flat Brook	3
30	Tocks Island	Delaware River	3
31	Pine Mountain	Brodhead Creek	5
32	Bartonsville	Pocono Creek	2
33	McMichael (4A)	McMichael Creek	5
34	Paulina	Paulins Kill	5
35	Belvidere	Delaware River	3
36	Sarapta	Beaver Brook	2
37	Pequest	Pequest River	5
38	Tobyhanna	Lehigh River	2
39	F.E. Walter	Lehigh River	4
40	Mud Run #1	Mud Run	2
41	Stoney Creek #2	Stoney Creek	2
42	Bear Creek #3	Bear Creek	2
43	Mahoning	Mahoning Creek	2
44	Beltzville	Pohopoco Creek	4
45	Aquashicola	Aquashicola Creek	

TABLE 14 (Continued)
IMPOUNDMENTS
HD522

Index #	Project	Location	Eliminated in Screening
46	Trexler	Jordan Creek	5
47	Chestnut Hill	Delaware River	3
48	Belfast	Bushkill Creek	2
49	Washington	Pohatcong Creek	2
50	Hackettstown	Musconetcong River	4
51	New Hampton	Musconetcong River	5
52	Holland	Delaware River	1
53	Tohickon	Tohickon Creek	1
54	Eagle Island	Delaware River	1
55	Goat Hill	Delaware River	1
56	Crosswicks	Crosswicks Creek	1
57	Newtown	Neshaminy Creek	1
58	Birmingham	North Branch Rancocas Creek	1
59	Ergrestown	South Branch Rancocas Creek	1
60	Maiden Creek (Moselem)	Maiden Creek	1
61	Blue Marsh	Tulpehocken Creek	1
62	Monocacy	Monocacy Creek	2
63	Fancy Hill	Manatawny Creek	1
64	French Creek	French Creek	1
65	Spring Mountain	Perkiomen Creek	1
66	Evansburg	Skippack Creek	1
67	Buck Run	Buck Run	1
68	New Castle	Brandywine Creek	1
69	Newark	White Clay Creek	1
70	Christiana	Christina River	1



TAMS DAM SITES

FIGURE 11

TABLE 15
IMPOUNDMENT SITES
PREVIOUSLY IDENTIFIED
TAMS STUDY SUMMARY

TAMS #	Project	Location	Eliminated in Screening
D-1	Clove Brook	Clove Brook	5
D-3	Bushkill Creek	Bushkill River	5
D-4	Cherry Creek #1	Cherry Creek	5
D-4A	Cherry Creek #2	Cherry Creek	
D-5	Little Martin's Creek	Little Martin's Creek	4
D-6	Lower Pohatcong Creek	Lower Pohatcong Creek	5
D-7	Beaver & Muddy Brooks	Beaver & Muddy Brooks	5
D-8	Hakihokake Creek	Hakihokake Creek	5
D-9	Tinicum Creek	Tinicum Creek	5
D-10	Pidcock Creek	Pidcock Creek	5
D-11	Wichecheake Creek	Wichecheake Creek	5
D-100	Crosswicks #1	Crosswicks Creek	1
D-102	Bloomsbury	Musconetcong Creek	5
D-107	Bridgepoint	Neshaminy Creek	1
D-108	Old Greenwick	Pohatcong Creek	2
D-113	Pocono Mountains	Paradise Creek	2
D-116	Martin's Creek	Martin's Creek	2
D-120	Equinunk Creek	Equinunk Creek	3
D-122	Milanville Creek/Pumping	Calkins Creek	2
L-1	Hokendauqua Creek	Hokendauque Creek	5
L-2	Shoeneck Creek	Shoeneck Creek	5
L-112	Kreidersville	Hokendauqua Creek	5
Lx-100	Hawley/Pumping	Middle Creek	5
S-1	Spring Creek	Spring Creek	1
S-2	Plum Creek	Plum Creek	1
S-3	Irish Creek	Irish Creek	1
S-4	Pigeon Creek	Pigeon Creek	1
S-5	Pine Creek	Pine Creek	1
S-6	Stoney Run	Stoney Run	1
S-7	Red Creek	Red Creek	1
S-8	Locust Creek	Locust Creek	1
S-111	Lederach	East Branch Perkiomen Creek	1
S-114	Tylersport	East Branch Perkiomen Creek	1
B-2	Marsh Creek	Marsh Creek	1
B-103	Sconneltown	East Branch Brandywine Creek	1
	Flat Brook/Pumping	Flat Brook	3
	Merrill	Merrill	4

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 becasue 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