State of New Jersey
Department of Conservation and Economic Development,
Division of Water Policy and Supply.

SPECIAL REPORT 11

ELIZABETH RIVER FLOOD CONTROL

In the Counties of

ESSEX AND UNION

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April, 1951

520 East State Street
Trenton, New Jersey

STATE OF NEW JERSEY
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

Charles R. Erdman, Jr., Commissioner

DIVISION OF WATER POLICY AND SUPPLY

Howard T. Critchlow, Director

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LETTER OF TRANSMITTAL

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Hon. Charles R. Erdman, Jr., Commissioner
Department of Conservation and Economic Development

Dear Sir:

I am transmitting herewith a report on the problem of the control of floods on the Elizabeth River in Essex and Union Counties, New Jersey, prepared by the Division of Water Policy and Supply in cooperation with the various municipalities and county agencies located within the Elizabeth River basin. Investigations of the causes and prevention of floods are an important part of the duties of the Division. This report is one of a series of studies which the Division is making on small rivers in the northern metropolitan area of New Jersey in cooperation with local agencies as time and funds permit.

The report presents a Master Plan for the alleviation of floods on the main channel of the Elizabeth River by the development of three dry detention basins located upstream of the City of Elizabeth, with channel improvements upstream and downstream thereof. The recommended plan offers an economical and practical solution of the flood problem on the Elizabeth River. Where practical, dual benefits are developed by coordination of flood control improvements with the county park system.

Flood control involves many complex and interrelated engineering, legal, politico-social, and economic problems. The report presents brief discussions of those questions and provides sufficient data on design and benefits to enable the local authorities to estimate costs, determine justification, and develop a program for construction of the plan in steps, either now or at some future time.

I therefore recommend that a limited edition of this report on the flood problem of the Elizabeth River be published as a special report of the Division of Water Policy and Supply.

Respectfully submitted,

Howard T. Critchlow

Howard T. Critchlow,
Director

April 30, 1951

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INTRODUCTION

The most serious flood of recent years throughout the Elizabeth River basin was produced by the storm of July 23, 1938. However, the magnitude of this flood has been exceeded by at least four floods of record, in 1897, 1901, 1903, and 1915, and equaled once at Irvington and once at Elizabeth within the past six years. In addition to the damages and inconveniences caused by these major floods, smaller floods occurring at frequent intervals have resulted in inundation of some lands of the basin, property damage, and considerable interference with communication, transportation, and the habits of living. These floods, which have been termed by some as "nuisances" since the flood waters quickly subside, cause, on the one hand, minor or no damage but give rise, on the other hand, to discontent, ill-feeling, and a generally dissatisfied populace. When no protective measures are taken, whatever the extent of flooding, the area suffers a severe loss in community spirit and income as property values depreciate and people move out of the affected areas.

While damages and inconveniences suffered during floods of the past have been sufficient to warrant public expenditure of funds for protection against recurrences, the real seriousness of the flood control problem on the Elizabeth River, particularly on the lower reach through the City of Elizabeth, is potential and cannot be based upon records of past floods. As the Elizabeth River basin continues to develop, as it surely will, located as it is in a vital and convenient sector of the expanding metropolitan area, floods of considerably greater magnitude than have been experienced in the past will occur at more frequent intervals.

The development of a rural area into an urban community creates, of necessity, an increase in surface runoff. The construction of houses, streets, gutters, and storm sewers, and the elimination of wooded and other natural surface storage areas all decrease the amount of storm rainfall which can be absorbed by the ground. This resultant increase in flood runoff, which cannot be avoided, will not in itself create too difficult a flood problem if the natural drainage channels are adequately protected and properly developed. The riparian property owner, however, in his desire to obtain the most use of his lands, too often fills in not only the flood plain which nature provided for the temporary storage of excess flood waters, but in many cases part of the main channel required for the passage of flood waters.

In 1938 the necessity for a comprehensive plan for control of floods on the rapidly-growing Elizabeth River basin was brought vividly to the attention of the governing bodies of municipalities and other interested agencies by the large flood of July 23 of that year. It was apparent that the past practice of alleviating local flooding by the enclosure or improvement of stream channels through the individual efforts of numerous municipalities was aggravating the problem by providing relief at the expense of neighboring communities. Furthermore, it was recognized that unless adequate measures were taken in the near future to provide for increased flood runoff, a critical flood problem would be created on the lower reach of the river which could only be remedied with difficulty and extreme cost.

Within practical economic limits, compensation for this increase in flood runoff is provided by the hydraulic design recommended in this report, which has the support of the Union County Flood Control and Park Development Committee and its Joint Engineering Committee, with whom full details have been discussed during the preparation of the design.

Authority

This report on control of floods on the Elizabeth River is the result of studies initiated in 1939 by the State Water Policy Commission, predecessor of the present Division of Water Policy and Supply of the State Department of Conservation and Economic Development. Under Chapter 266, Laws of 1939, the Legislature of the State of New Jersey approved a special appropriation for that Commission authorizing it to prepare comprehensive plans for control of floods on the Elizabeth and Rahway Rivers. At the same time, the Board of Chosen Freeholders of Union County authorized an appropriation to provide additional personnel to assist in the preparation of these plans. Similar action was taken by the Board of Chosen Freeholders of Essex County in making available personnel from its engineering staff.

On July 26, 1939 a conference was held with the Essex and Union County Engineers to consider a joint program of cooperation for comprehensive studies of the flood control problems in these two basins. This conference adopted a cooperative program for the preparation of basic surveys and the installation of additional rain gages, stream gaging stations, and tide gages to remedy deficiencies in basic hydrological data, and defined in terms of frequency the flood for which protection should be provided. Methods of flood control were also considered. It was decided that preference would be given to the Elizabeth River basin and that the program would include a comprehensive investigation of all hydrological data on these two basins, including storm rainfall, in order to provide basic data for improved methods of estimating flood runoff for problems of this type. During the course of these hydrological studies and during the subsequent period of flood control design for the Elizabeth River, numerous additional conferences were held with the governing bodies of the interested counties and municipalities, and with the Joint Engineering Committee composed of engineers representing these governmental agencies.

Legislation supporting such participation of State and local agencies in a program of flood control and long-range planning is provided by the law creating the State Water Policy Commission and three encroachment laws, whereby:

1. The Commission is authorized to conduct investigations of the water resources of the State and to complete comprehensive studies for specified public uses and purposes, one of which is the prevention of floods. (Revised Statutes 58:1-11)

2. The State is given power to control and curb future abuse of stream channels through the issuance of permits for new structures and the renewal of existing structures located within the ordinary high water mark. (Revised Statutes 58:1-26 and 27)

3. The counties are authorized to cooperate with municipalities in flood control and channel improvement projects and to assist financially as they may deem proper. (Revised Statutes 40:29-3 to 6)

4. The municipalities are given authority to construct improvements, remove obstructions, and establish encroachment lines to define the limits of the stream channel, subject to the approval of the State as to the flood-carrying capacity to be provided. (Chapter 229, Laws of 1938 Amending Revised Statutes 40:46-1)

Under the above legislation, the State's cooperation in a flood control project is limited to the hydrological studies required to determine the economical safe size of flood for which protection should be provided and to the hydraulic design necessary to insure satisfactory operation and coordination of the comprehensive improvement.

Hydrological studies of rainfall and runoff of the Elizabeth and Rahway River basins were started in September 1939 under the terms of the co-operative agreement established in the joint conference of July 26, 1939, and were practically completed when interrupted, first by lack of funds, and then by the demands of World War II. After a six-year interruption, the designs have been carried to conclusion by the Flood Control Unit organized in 1946 to make hydrological studies and prepare hydraulic designs for the alleviation of floods.

Scope of Report

The intent of this report is to present to the governing bodies of all interested municipalities, counties, and other agencies pertinent facts, engineering data, and hydraulic designs as a general guide to the complex problems involved in the control of floods on the Elizabeth River. Detailed designs are to be developed and submitted for approval to the Division of Water Policy and Supply in accordance with standard procedures as and when construction is undertaken.

The scope of the report is four fold:

1. To establish the size of the flood for which protection is to be provided when the basin is fully developed and the control works and other improvements have been completed.

2. To develop a comprehensive master plan of hydraulic designs for channel improvements, detention basins, and control works to provide the desired relief uniformly along the main river from the Newark storm sewer system in Irvington, Essex County, to the Arthur Kill in Elizabeth, Union County.

3. To recommend a long-range construction program whereby the desired relief can be obtained economically and efficiently by step construction as and when required.

4. To submit for use in similar problems on comparable streams such hydrologic data and procedures as have been developed by these studies for determining flood runoffs of uniform desired frequency for fully developed urban areas.

Working in close cooperation with local officials and engineers, a comprehensive plan has been developed, the general details of which are shown on Plate 3. The magnitude of the design flood for which protection is to be provided is summarized in Table 4. Hydraulic design data on type and width of improved channels, improved stream bed grades, and design flood high water flow lines are presented on continuous profiles, Plates 8, 9, and 10. Details on bridge and utility reconstruction are summarized in Tables 6 and 7. Hydraulic designs for inlet and outlet control works for the three detention basins are given in Drawings I to IV, inclusive, submitted as a supplement to the report. No grading plans for the detention basins have been prepared. The storage requirements for these basins are defined by capacity-area curves, Plates 5, 6, and 7. Detailed park development plans and construction working drawings will be prepared by local agencies as required. The proposed plan is flexible so that changes in details may be made to meet unexpected developments.

Statements of physical conditions affecting floods and their relief, and of the extent of past floods are presented. Details of the hydrologic investigations of storm-rainfall and flood-runoff records on the Elizabeth and Rahway River basins are summarized. Procedures developed for estimating design floods on the Elizabeth River basin are described for use in similar problems on comparable streams. Design data are presented on unit hydrograph and retention capacity relations for fully developed, storm sewered urban areas of Essex and Union Counties; and for storm rainfall relations, including frequency, intensity duration, depth-area, and type of critical storms.

No estimates of construction costs or of benefits to be derived are included in the report of this Division. The report does, however, present facts and engineering data on which such estimates and working drawings can be prepared by the interested local cooperating officials. Brief discussion on the question of benefits and real estate acquisition is presented to complete information on all facts pertaining to this problem. The control of floods on the Elizabeth River, as on every

other stream in the State, is primarily a local problem. The population of the area affected by the flooding of the stream must weigh the facts and decide for themselves whether they will continue to pay the damages and suffer the inconveniences of repeated flooding or spend the money necessary to construct flood control works. No consideration has been given to the development of a financial plan for carrying out the recommended construction and for the allocation of costs and benefits. These questions can best be solved by local officials most directly affected by damages and cost of relief.

Conclusions

1. Floods have occurred in the Elizabeth River basin at intervals sufficiently close to warrant public expenditures for the purpose of protecting property and persons affected thereby.

2. Serious flooding has been experienced at numerous points in the basin; notably above Lyons Avenue and Mill Road and along the Newark Flume in Irvington, at Baldwin Place and on Lightning Brook in Union, and on Union Avenue between West Grand and West Jersey Streets and below Trotters Lane in Elizabeth.

3. Flood conditions in Irvington between the outlet of the Newark Flume and Mill Road have been greatly relieved by channel improvements already completed.

4. Magnitude of flood peaks in Irvington is limited by the capacity of the storm sewers which enclose the headwaters of the Elizabeth River and its major tributaries.

5. Frequency and magnitude of floods in Union County have been increased by the construction of the Irvington Flume.

6. The most serious flood of record in this valley was produced by the storm of July 23, 1938.

7. The size of that flood has been exceeded by at least four floods, 1897, 1901, 1903, and 1915, and has been equaled once at Elizabeth and once at Irvington within the past six years.

8. As the drainage basin develops and as the channels are improved by walled and paved flumes or are enclosed in storm sewers, floods will increase both in magnitude and frequency.

9. The fully developed and storm sewered headwaters of the Elizabeth River in East Orange and Newark above the Irvington stream gaging station at Valley Street is representative of ultimate development of the entire basin.

10. Loss of natural flood storage in Hillside and Union by continuation of channel improvement would create a flood problem on the lower river that could be remedied only with difficulty and at extreme cost.

11. Unless measures are taken to provide some degree of protection, damages and inconveniences will increase rapidly with the further development of the basin.

12. Protection against the largest floods, which occur on the average at extremely long intervals, is not considered necessary or economically advisable.

Recommended Plan

The integrated hydraulic design presented in this report as a solution to the flood problem on the Elizabeth River involves (1), the construction of three shallow flood detention basins above Elizabeth in Union and Hillside Townships on land now owned or to be owned by the Union County Park Commission and (2), channel improvements upstream and downstream thereof. The plan is one of cooperation with nature, maintaining and increasing where possible the natural storage of the basin.

Detention basins will be of the dry type. Except for relatively short periods of infrequent flooding, these basins will be empty and the lands available for recreation and other purposes. The basins will be located on existing lowlands now subject to flooding. Dual benefits will be derived from the proposed sites by incorporating them into the Union County Park Commission system. Control works will be located at existing bridges on State Highway Route 29 and Salem Road and at the existing Ursino Dam. Flood waters will be impounded in these basins and temporarily stored therein to reduce flood peak discharges on the lower reach of the river through Elizabeth. For design conditions, flood waters will be confined to high water levels experienced during the flood of July 23, 1938, except immediately upstream of the Route No. 29 and Salem Road controls where the depth has been increased to provide more effective storage.

However, despite the increased flood storage provided above Elizabeth, the required channel improvement on the lower reach of the river through that City will be extensive and expensive. In order to provide for satisfactory storm water drainage on streets throughout Elizabeth, existing channels will have to be enlarged and eventually walled for the entire distance of 3.9 miles from the mouth at Arthur Kill to Ursino Dam. Twelve of the existing 24 bridges will ultimately need to be rebuilt to provide single-span crossings conforming to the improved channel sections. In addition, abandonment of bridges at Crane and Murray Streets and relocation of South Street bridge is recommended. For the tidal reach, walls are to be carried one foot above the probable extreme high tide. Modification of the recommended rectangular walled channel cross-section may be possible through the Elizabeth River Parkway and Mattano Park. For the upper reach in Elizabeth, above head of tide, the recommended channel improvement will approximately double the safe carrying capacity of the present channel.

Upstream of the proposed detention basins the improvement will be both less extensive and expensive. A considerable portion of the work on this reach has been completed by Irvington and the improved channel has adequate capacity except at certain critical sections. The Newark Flume, extending 2730 feet into Irvington downstream of the Newark line at Valley Street, will require reconstruction to enlarge the waterway so as to confine flood waters in that area. Extension of the Irvington walled and paved flume, from the County line at Mill Road through Hillside and Union Townships to the Route No. 29 Detention Basin below Union Avenue, is also recommended. Modification of certain portions of the Irvington Flume will eventually be required. Reconstruction of the more critical of these points at Chancellor Avenue and Mill Road will be incorporated in the proposed river crossings of Route No. 4 Parkway.

Protection against the largest flood of record or the maximum probable flood is not considered economically justified. Through the City of Elizabeth and the detention basins the plan is designed to provide protection uniformly along the main river against the probable future flood which can be expected to be equaled or exceeded, on the average, once in 25 years when the basin is fully developed and the control works and other improvements have been completed. Protection against sudden release of flood waters impounded in the detention basins by failure of the control works will be provided by emergency provisions in their design for the safe passage of floods 65 to 95 percent in excess of the 25-year design. Above the detention basins, where much of the improvement has been completed and damage due to floods in excess of design will be less extensive, the plan will provide protection against a flood of lesser frequency, once in 15 years.

For the lower river, protection will be limited to design flood discharges occurring at high tide elevation 4.0 or less, or with extreme high tide at elevation 7.0 and no appreciable flood runoff. Combinations of floods and high tides in excess of these limits may create flood conditions beyond the scope of the recommended plan. The probable frequency of such combinations, however, is considered in excess of the 25-year frequency limitations imposed on this design.

Under ultimate conditions of development and completion of all recommended improvements, the design peak discharge suppressed by detention basin storage will vary through Elizabeth from 5300 cubic feet per second below Trotters Lane to 6260 cubic feet per second at Arthur Kill. Corresponding flood discharges under present conditions vary from approximately 2900 to 3400 cubic feet per second. Elimination of the detention basin system by channel improvement through the Townships of Union and Hillside would result in discharges in excess of 10,000 cubic feet per second through Elizabeth under ultimate conditions of development. Major suppression will be provided by the Route No. 29 and Salem Pond Detention Basins which reduce inflow flood peaks, respectively, from 6440 to 5110 cubic feet per second and from 6190 to 4660 cubic feet per second.

For the upper reach, above the detention basins, the design flood varies from 1800 cubic feet per second at the outlet of the storm sewer system on Valley Street, Newark, to 3470 cubic feet per second at the inlet of Route No. 29 Detention Basin below Union Avenue. No great increase in existing flood discharge will be experienced in this area, which is now practically fully developed and storm sewered. The flood of 1800 cubic feet per second at Valley Street, representing the peak discharge from the storm sewer system which completely encloses the headwaters of the Elizabeth River in fully developed sections of Newark, East Orange, and Irvington, has been experienced twice in the 17-year period of record at the Irvington gaging station. Had the capacity of this storm sewer system been adequate to carry these floods without surcharge and temporary retention of surface runoff in streets, gutters, and catch basins of the tributary area, discharges of nearly 2700 cubic feet per second would have been experienced at the Irvington gaging station.

Immediate construction of the complete plan is not necessary or advisable. The plan, however, should be approved officially by all interested parties to provide a "Master Plan for the Elizabeth River," and a program of long-range construction adopted to relieve flooding as and when required. Immediate measures should be taken to secure all lands required for the detention basins and improved channel right-of-ways, and to control private building operations, pipe crossings and other obstructions affecting the recommended plan. Completion of the detention basins will provide the greatest protection and is recommended as the first step to be undertaken. Priority should be given to the Route No. 29 and Salem Pond Basins. Local flooding should be relieved as required by rebuilding critical points in conformity with the Master Plan. Where practical, channel improvements should be made in steps as flood runoff increases. All bridges which do not conform to the plan should be modified or rebuilt when adjacent channel improvements warrant such work.

Merits of Recommended Plan

The plan recommended herein offers the most economical solution to the flood problem of the Elizabeth River. It provides a program not only for the alleviation of present flooding but, in addition, an orderly approach to the flood control problems which will arise in the future as the area develops, tributaries are enclosed in storm sewers, and channel improvements are made. Conservation of the natural storage areas of the Elizabeth River is of primary importance and must be accomplished at once, and certain modifications should be made now to relieve present flooding at critical sections of the river channel. However, the major portion of the work recommended, especially in the lower reach of the river through the City of Elizabeth, may be deferred until such time as increased flood discharges warrant such expenditures of funds. By adopting this long-range program, the total cost of the project may be distributed over a long period of time with accrued benefits of sufficient value to finance much of the expensive latter construction.

Features of the plan which warrant the full support of the Union County portion of the Elizabeth River basin are as follows:

1. For the City of Elizabeth the two primary items are reduction of the required width of improved channel and deferment of expensive channel improvement. Loss of flood storage in the proposed detention basins would require such material widening of the river channel as to seriously affect private property adjacent to the river. Under the recommended plan, the required channel width is confined, for the most part, to the top of existing banks. Reduction of flood discharges by the detention basin storage will defer the time when expensive channel improvement on the lower river must be constructed.

2. For the Townships of Union and Hillside the primary benefits are the increase of recreational facilities, the elimination of waste swamp lands, and increase in adjacent upland values resulting from the development of the detention basin areas as part of the Union County Park System. The history of park development has conclusively proven that the initial cost and loss in ratables are rapidly offset by the increase in land values surrounding the park lands, and that parks more than pay for themselves in a short time. In addition, the Townships will be released from the necessity of ultimately constructing expensive channel improvements to protect low private lands from flooding.

3. While Union County at large will benefit to some degree from the above items, the major item is the material reduction in the cost of county bridge reconstruction, which will ultimately be required on the lower reach of the river through Elizabeth.

Existing Reports

The flood situation on the Elizabeth River has been under study for many years by municipal, county, state, and private agencies. During this time two reports have been published:

1. In October, 1940 the Joint Engineering Committee published Report No. 1 entitled "Control of Floods on the Elizabeth River, Section No. 1, Salem Road-County Line (Mill Road), Union County." This report was issued for the primary purpose of presenting to the governing bodies of all interested municipalities and other agencies the necessity for immediate acquisition of the property required for the construction of flood detention basins on the lowlands in the Townships of Hillside and Union above Salem Road and Route No. 29. While comprehensive plans for the control of floods on the Elizabeth River had not at that time been completed in detail, sufficient progress had been made to define the extent of land required for these two detention basins. On November 13, 1940 a conference of the governing bodies, with their engineers and attorneys, of the State Water Policy Commission, Union County Park Commission, County of Union, City of Elizabeth, and Townships of Hillside and Union was held to consider Report No. 1. The engineering features were adopted and a committee known as the Union County Flood Control and Park Development Committee was appointed, with Commissioner F. V. Lowden

of the Water Policy Commission as Chairman, to develop a policy for carrying out the recommendations of this report. Excellent progress has been made in securing lands for the construction of the Route No. 29 and Salem Pond Detention Basins. At present, approximately 90 percent of the required acreage between Salem Road and Union Avenues has been acquired by the Union County Park Commission.

2. In June, 1921 James H. Fuertes, Consulting Engineer, submitted his "Report to the Board of Public Works, Elizabeth, N. J. on the Improvement of the Sewerage of Elizabeth and the Abatement of Nuisances in the Elizabeth River." This report included a survey of all existing sanitary and storm drains, and established by a system of bench marks a much needed reference datum for the City of Elizabeth. It recommended that all combination sanitary and storm drains be rebuilt as separate systems, and that sewage discharge into the Elizabeth River be entirely eliminated. In addition, the report included a study of the flood situation within the City of Elizabeth. It recommended increasing the capacity of channels by widening and deepening, walling certain reaches, aligning the river as required to reduce sharp bends, and establishing a program for the replacement of all bridges of inadequate capacity. Mr. Fuertes' estimate of the design flood through the City of Elizabeth is 30 percent less at the City line than the 25-year design flood used in our present studies, and 14 percent less at the Arthur Kill. Considering the limitations of available hydrological data in 1921, revisions of plans for the development and improvement of the Elizabeth River basin above the City of Elizabeth during the past 30 years, and a probable difference of interpreting the size of flood considered economical for design purposes, this difference in flood discharge estimates is readily understandable.

DESCRIPTION OF BASIN

The Elizabeth River is one of the smaller coastal streams of the Piedmont Plain in the State of New Jersey. With headwaters located in East Orange, it flows in a southerly direction, as shown on Plate 1, for a distance of 11.9 miles from the densely populated and fully developed municipalities of Essex County into Union County; and thence between the rapidly growing Townships of Hillside and Union, through the center of the congested urban development of Elizabeth into the tidal estuary of the Arthur Kill below South Broad Street, Elizabeth.

Geologically, the Elizabeth River basin is located on the Newark group of the Triassic Brunswick Formation of sedimentary rock consisting of soft red shale with sandstone beds. In Union County stratified drift and recessional moraines deposited by the late glacial age overlie much of this formation.

Elevations varying from 180 feet at the extreme limits of the basin in East Orange to mean sea level at the Arthur Kill reach maxima of 280 feet in the Lightning Brook drainage area of Maplewood on the west side and 210 feet in the Elizabeth River Storm Sewer drainage area of Newark on the east side of the basin.

For the upper basin in Essex County, slopes are steep and natural flood retention storage is insignificant. As shown on Plate 2, both the main channel and its tributaries, except for part of Lightning Brook, have been either enclosed in storm sewers or improved by walled and paved flumes.

In Union County, and especially in Union Township, the slopes of both the main channel and the tributaries are flat. Large natural storage exists on the main river between Ursino Dam and Union Avenue. Additional natural storage was available on Lightning Brook and the East and West Branches, but due to development of these areas, much of this storage has been lost. On the West Branch, a large part of this natural storage has been preserved by the Galloping Hill Golf Course of the Union County Park Commission and the Hummocks well field of the Elizabethtown Water Company Consolidated. On the East Branch, all natural storage was destroyed by the storm sewer system which encloses this branch through Hillside. A similar situation is to be found along the lower river where all tributaries in Elizabeth have been enclosed in storm sewers. Because of the small size of the drainage areas involved and because of the densely populated areas through which the tributaries flowed, this type of improvement has been the most economical. For the remaining unimproved tributaries the same type of improvement will undoubtedly be followed. Thus, complete improvement of all tributaries in Essex and Union Counties and of the main channel in Essex County, as shown on Plate 3, can be reasonably predicted.

TABLE 1

ELIZABETH RIVER TRIBUTARY CHARACTERISTICS
(Ultimate Conditions of Improvement)

Tributary	Distance from Mouth Miles	Drainage Area Sq.Mi.	Number Major Branches	Longest Branch Length Miles	Longest Branch Average Slope Ft./Mi.	K Mins.
West Drainage						
Valley Street S.S.	9.3	1.47	1	2.6	19	25
Allen Street S.S.	9.0	0.37	1	1.0	103	15
Lightning Brook	6.5	3.12	3	3.8	53	28
West Branch	5.6	2.98	1	4.4	13	73
Lehigh Valley Branch	5.1	0.85	1	2.1	33	19
Trotters Lane Branch	3.9	0.95	1	2.6	25	25
Westfield Avenue S.S.	3.3	1.23	2	2.3	30	25
Summer Street S.S.	1.5	0.58	1	1.3	35	20
East Drainage						
Elizabeth River S.S.	9.3	1.44	2	2.1	13	25
Lyons Avenue S.S.	8.2	1.09	1	2.3	45	19
North Creek	6.8	0.50	1	1.3	76	19
South Creek	6.7	0.57	1	1.9	53	19
East Branch	4.7	2.02	2	3.0	40	30
Parker Road S.S. *	3.8	0.51	1	1.5	20	20
Irvington Avenue S.S. *	3.6	0.29	1	1.0	23	15
Madison Avenue S.S.	2.5	0.11	1	0.5	25	12
Local Inflow Areas						
Valley Street S.S.	9.3					
Allen Street S.S.	9.0	0.10		0.3	7	11
Lyons Avenue S.S.	8.2	0.49		0.8	29	13
North Creek	6.8	0.54		1.4	39	10
South Creek	6.7	0.00		0.1	38	10
Lightning Brook	6.5	0.10		0.2	27	10
Route No. 29 Control	6.2	0.09		0.3	4	10
West Branch	5.6	0.50		0.6	19	10
Salem Road Control	5.4	0.10		0.2	5	10
Lehigh Valley Branch	5.1	0.06		0.3	14	10
East Branch	4.7	0.11		0.4	11	10
North Avenue	4.2	0.33		0.5	10	10
Ursino Dam Control	3.9	0.07		0.3	0	10
Trotters Lane S.S.	3.9	0.00		0.0	20	10
Parker Road S.S. *	3.8	0.02		0.1	10	11
Irvington Avenue S.S. *	3.6	0.02		0.2	10	12
Westfield Avenue S.S.	3.3	0.15		0.3	10	12
Madison Avenue S.S.	2.5	0.47		0.8	10	14
Summer Street S.S.	1.5	0.81		1.0	4	16
Central R.R. of N.J.	0.9	0.48		0.6	2	15
Arthur Kill (mouth)	0.0	0.38		0.9	2	15

Elizabeth River Channel (no major tributary branches)

* Proposed Storm Sewers

For design purposes, the Elizabeth River basin has been subdivided into 16 major tributary areas and 20 local inflow subareas. These subdivisions are defined by the drainage areas shown on Plate 3 and Table 1. Originally the City of Elizabeth was drained by combination sanitary and storm sewers discharging directly into the Elizabeth River. A program for separation of these systems to relieve flooding and to eliminate sewage discharge into the river has been initiated. The drainage divides shown on Plate 3 are based on plans for ultimate elimination of all combination sewers discharging into the Elizabeth River. The divides under present conditions are shown on Plate 2. On January 1, 1929 the drainage area tributary to the U. S. Geological Survey stream gage above Westfield Avenue was revised for diversion from 20.2 square miles to 18.0 square miles upon completion of the Orchard Street storm sewer system which discharged below the Westfield Avenue bridge, 200 feet downstream of the gage. On completion of the proposed Parker Road and Irvington Avenue storm sewers to relieve the existing Westfield Avenue combination sewer and Madison Avenue storm sewer, the drainage area tributary to this gage will be increased to 18.8 square miles.

Characteristics of the major subareas of the Elizabeth River basin shown in Plate 3 are presented in Table 1. All characteristics shown are based on ultimate conditions of improvement. Lag time, "K", of the areas is defined and discussed under Hydrology of this report.

The Elizabeth River and its tributaries drain parts of the eleven municipalities shown in Table 2. As indicated on Plate 1, South Orange and Maplewood in Essex County, and Kenilworth, Linden, and Roselle Park in Union County are located on tributaries at a distance from the main stream channel and therefor have no vital interest in the Elizabeth River flood problem. Of the total areas of the municipalities listed in Table 2, approximately 25 percent of the City of Newark and 20 percent of the City of Elizabeth are composed of undeveloped salt marsh lands.

TABLE 2

MUNICIPALITIES OF ELIZABETH RIVER BASIN

Municipality	Total Area	Area Within Basin	Distance from Mouth Miles From	To
Essex County				
East Orange	3.9	1.23	11.9	10.4
South Orange	2.5	0.27		
Newark	23.4	2.70	10.4	9.1
Irvington	3.4	3.00	9.1	7.6
Maplewood	2.8	1.13		
Union County				
Hillside	2.7	2.64	7.6	3.9
Union	8.7	5.88	7.6	3.9
Kenilworth	2.0	0.80		
Roselle Park	1.0	0.22		
Linden	11.3	0.18		
Elizabeth	9.7	4.85	3.9	0.0

Under present conditions, over 75 percent of the basin has reached a high degree of development. Good transportation facilities and the proximity to urban centers indicate that the semi-developed portions of the basin will continue to grow at a rapid rate and that, except for the West Branch, 100 percent development of the entire basin can reasonably be predicted for the near future.

The following population table for the political subdivisions within the basin is based on U. S. Census figures. These figures clearly show the development of the Elizabeth River basin from a rural to an urban area. In addition to the rapid increase in home construction in and about the Townships of Union and Hillside, the importance of this area industrially is evidenced by the postwar construction of numerous plants by large industries such as Westinghouse and the American Can Company.

TABLE 3

POPULATION OF ELIZABETH RIVER BASIN

	Population per Acre			
Municipality	1920	1930	1940	1950
Essex County				
East Orange	20	27	28	31
South Orange	5	8	9	19
Newark *	37	39	38	39
Irvington	12	26	25	27
Maplewood	3	12	13	14
Union County				
Hillside	3	10	11	13
Union	1	3	4	7
Kenilworth	1	2	2	4
Roselle Park	8	14	15	18
Linden **	19	23	22	23
Elizabeth *	19	23	22	23

* Areas in salt swamp not included in computation of population per acre.

** Assumed to be equal to Elizabeth for area affected.

Water Supply

The first use of the Elizabeth River as a source of public water supply began with the organization of the Elizabethtown Water Company in 1854. A pumping station was erected at Crane and Golden Streets on the west bank of the Elizabeth River in the City of Elizabeth. Water was drawn from an intake pond created by the construction of a small dam. The following year a small reservoir was built on Chilton Street for storage of the pumping station overflow.

As the City grew, the quantity and quality of the water became objectionable and in 1885 two storage reservoirs were constructed — one at Ursino on the main river having a capacity of 20 million gallons, and another downstream at Irvington Avenue adjacent to the river having a capacity of 21 million gallons.

To supplement this surface water, the Hummocks well field on the West Branch of the Elizabeth River was first used as a source of supply in 1898. Additional wells have been drilled and the present diversion from the field is approximately 3 million gallons per day. In 1903 a second well field was developed at Springfield in the Rahway River drainage basin as an additional source of ground water supply.

The Faitoute Reservoir on the West Branch and Salem Reservoir on the Elizabeth River upstream of the Ursino Reservoir were constructed in 1912 to increase the yield of the river to 3,000,000 gallons per day. In 1919 a filtration plant was built at the Ursino Reservoir.

As the area continued to develop the character of the water of the Elizabeth River became unsatisfactory, and in March, 1929 the river was abandoned as a source of public water supply.

During the last two decades the Irvington Avenue Reservoir has been filled and is now used as an athletic field; the Faitoute Dam has been breached and the Ursino and Salem Reservoirs have filled with silt. However, the Union County Park Commission has included replacement of the Faitoute Dam as part of their proposed park development on the West Branch, and the Salem and Ursino Reservoir sites were selected as logical locations for the construction of two of the three dry detention basins proposed for the Elizabeth River.

Water Power

Due to its size and the natural topographic characteristics of the drainage basin, the Elizabeth River was never developed as an important source of water power. While records indicate that at one time at least five water-powered mills were located along the banks of the Elizabeth River and its tributaries, only two small grist mills were still in operation as late as 1894 — one on the Elizabeth River in Essex County and one on the West Branch in Union County.

Navigation

At present all bridges crossing the tidal reach of the Elizabeth River below South Broad Street are of the lift or pivot type with the exception of the high-level Route 25 viaduct. However, the Corps of Engineers has maintained a navigable channel only as far upstream as the Central Railroad span, and river traffic above this point is extremely limited. When all riparian lands along both banks of the Elizabeth River from Mattano Park at Baltic Street to South Broad Street are acquired by the City of Elizabeth and the Union County Park

Commission for the development of the Elizabeth River Parkway, there will be no need to maintain river traffic in that reach. Construction of the proposed Trenton Avenue approach to the New Jersey Turnpike which will cross the Elizabeth River as a fixed low-level span, approximately 300 feet upstream of the existing Baltic Street bridge, will establish the upper limit of navigation at that point. As replacements are required, all bridges upstream of Baltic Street can therefor be reconstructed as fixed, low-level crossings.

Sanitary Services

The sanitary sewer system of the Elizabeth River drainage basin, known as the "Joint Meeting in the Matter of an Outlet Sewer for Certain Municipalities in Essex and Union Counties," was established in 1901. It drains the entire basin above the City of Elizabeth through separate sanitary sewers and, since 1942, portions of Elizabeth through combination sanitary and storm sewers. In addition, all sanitary drainage of the Rahway River basin above Springfield enters the Joint Meeting trunk line through a tunnel across the divide from above Burnett Avenue to below Vaux Hall Road in Union Township.

The main trunk sewer parallels the Elizabeth River in Essex County, crossing from the east to the west bank at Hill Road. It continues on the west side of the river across the proposed Route 29 and Salem Pond detention basins to the treatment plant and Arthur Kill outfall in the City of Elizabeth.

During the past decade, average daily flow from the area above Elizabeth has increased from approximately 25 to 30 million gallons, a rise indicative of the extent of development of the drainage basin. In addition, the City of Elizabeth is now contributing an average of approximately 10 million gallons per day to the system.

Under conditions of heavy rainfall, 6-hour peak flows in excess of 100 million gallons per day are not uncommon. However, except in local areas where sanitary sewers are of inadequate design, sewers generally are of sufficient capacity to carry this peak load. Only once has the entire system been overtaxed. In the month of July, 1938 the heaviest total amount of rainfall and the heaviest single day's precipitation fell since the operation of the treatment plant. Trunk lines were flowing at full capacity, and sewers never before known to flow full were found to be heavily surcharged at the height of the deluge. The peak flow was measured at 150 million gallons per day and the total daily flow for July 23, 1938 was 100 million gallons, four times the average daily flow.

This increase in flow during storm periods may be attributed to both surface and subsurface infiltration of flood waters. Surface waters enter the sewers through leakage at manholes, through illegal storm drain connections above the City of Elizabeth and, since 1942, through the combination sanitary and storm sewers of Elizabeth. Subsurface waters enter the system by underground leakage which increases with the external hydrostatic pressure on the sewers.

Recreation

At present, lands on the Elizabeth River basin which have been set aside for recreational purposes include a number of small municipal parks in Essex County and Elizabeth, and one golf course in Union Township; in addition to the Galloping Hill Golf Course in Kenilworth and Union, and Mattano Park in Elizabeth which are under the jurisdiction of the Union County Park Commission. Development by the Park Commission of the proposed dry flood detention basins between Ursino Dam and Union Avenue in Hillside and Union Townships, and the Elizabeth River Parkway from South Broad Street to Mattano Park in Elizabeth, as shown in Plate 1, will increase by approximately 280 acres those recreational areas now available to the public. In addition, it is proposed that 75 acres of land be developed for park purposes along the banks of the West Branch from Vaux Hall Road to Forest Avenue and from Morris Avenue to Chestnut Avenue.

DESIGN FLOOD

The degree of protection to be provided by a flood control project is determined by the size of its design flood. Complete protection against the maximum possible flood is seldom attainable because of practical and physical limitations. Moreover, except in rare instances where there is considerable hazard to life, or damage to certain highly congested key industrial areas would be excessive, can complete protection be justified for economic reasons, such as the ratio of benefits to cost and the financial ability to pay. On the other hand, partial protection against floods of lesser magnitude involves a calculated risk as to the amount of damage and probable frequency of such damage from floods which exceed the design capacity of the control works. Unless the extent of this calculated risk is fully appreciated by the area protected, and proper allowances are made for the limited degree of protection, partial flood control may be worse than no flood control.

On small streams such as the Elizabeth River, flood stages may be reached with little warning, but the duration of flooding as well as the volume of flood runoff are limited by the size of the drainage area. Storm sewer practice has long accepted the principle of economic limitation in the selection of design frequency, as hazard to life and extent of damage is usually not severe. For open channel improvement projects the risk is also limited as flood waters in excess of design are confined, in general, to the natural flood channel. However, covered reaches in the open channels and detention basin controls introduce unnatural hazards for which special allowances must be made in the selection of the design frequency.

In rapidly developing areas such as the Elizabeth River basin, the flood to be considered is not the flood of past records but the flood to be anticipated in the future when the development of the basin is complete and all improvements have been made.

The design flood against which partial protection is to be provided by the plan recommended herein was defined at the conference of July 26, 1939 with the County Engineers of Essex and Union Counties in accordance with these principles. Expressed in terms of the probable frequency of future floods to be expected when the drainage basin is fully developed and the plan, including the improvement of all tributaries as shown on Plate 3, has been completed, the design flood for the detention basins and the channel improvements on the main river downstream thereof is that flood which can be expected to be equaled or exceeded, on the average, once in 25 years. For the channel improvements on the main river above the detention basins and all major tributaries, the frequency of the design flood is once in 15 years. In both cases the frequency of the design flood is uniform along the main river, a condition not normally experienced in actual floods.

For floods in excess of the design flood, overflow of improved channels and flooding of lands adjacent to the detention basins must be expected. Such flooding is part of the calculated risk. The outlet control works for the detention basins, however, must provide for the safe passage of floods in excess of the design flood, since failure of these control works would release impounded flood waters upon the lower valley. In this design, due to the relative low height of the control works and to the improbability of complete failure because of the physical conditions at the sites of these works, the capacities of the emergency spillway provisions have been increased from 65 percent to 95 percent of the design flood.

Magnitude of the design flood and size of these "super floods" are given in cubic feet per second in Table 4.

Design Tide

On tidal estuaries, protection must be provided against combinations of flood runoff and tide levels. The magnitude of these combinations and the frequency of their recurrence are influenced by the probability of extreme high tides during flood periods. While simultaneous occurrence of high flood runoff and extreme high tide is possible, the probable frequency of such an event exceeds the limitations imposed on this design by the degree of protection to be provided.

For the lower Elizabeth River, hydrological studies indicate that the critical flood-producing storms are of the extra-tropical and hurricane types. For the former, prevalent during the summer months, high tides are usually normal since both the direction and duration of the storm limit its effect on tides. The hurricane storms, however, of late summer and fall are of several days duration and are normally accompanied by exceptionally high tides of prolonged duration. On the other hand, the duration of high runoff for critical floods on the lower Elizabeth River is less than half the normal tide cycle, thus reducing the probability of coincidence of flood peak with extremes of high tide.

Protection on the lower river will therefore be provided for two combinations of tide and flood runoff, both of which are consistent with the limitations imposed on the frequency of the design flood:

1. An extreme high tide of 25-year frequency at elevation +7.0 and no appreciable flood runoff.

2. A design flood of 25-year frequency with a high tide at elevation +4.0.

TABLE 4

DESIGN FLOOD - ELIZABETH RIVER

Point	Area Sq.Mi.	Design Flood Discharge-c.f.s. 15-year	25-year	Super Flood Peak Discharge c.f.s.
Valley Street-Elizabeth River S.S.	2.91	1800		
Above Allen Street S.S.	3.01	1820		
Below Allen Street S.S.	3.38	2100		
Above Lyons Avenue S.S.	3.87	2320		
Below Lyons Avenue S.S.	4.96	3210		
Below Union Avenue	5.50	3470	3680	
Route No. 29 Detention Basin				
Total Inflow	9.88		6440	
Suppressed Outflow *	9.88		5110	10,000
Salem Pond Detention Basin				
Total Inflow	13.42		6040	
Suppressed Outflow *	13.42		4660	7,700
Ursino Detention Basin				
North Avenue-Lehigh Valley R.R. Reach				
Total Inflow	16.83		5300	
Suppressed Outflow *	16.83		5210	8,700
Ursino Dam-North Avenue Reach				
Total Inflow	16.90		5210	
Suppressed Outflow *	16.90		5190	9,400
Below Trotters Lane S.S.	17.85		5300	
Below Parker Road S.S.	18.38		5390	
Below Irvington Avenue S.S.	18.69		5460	
Below Westfield Avenue S.S.	20.08		5790	
Above Summer Street S.S.	21.46		6030	
Below Summer Street S.S.	22.04		6150	
Above Central Railroad of N.J.	22.52		6210	
Mouth at Arthur Kill	22.90		6260	

* Suppressed outflow at Outlet Control Works

Methods of Estimating Size of Flood

Available Methods:

A. Existing Flood Records. This is the simplest and most accurate method as few assumptions subject to possible error are required in the application where adequate stream flow records are available. In the case of the Elizabeth River problem, however, this method is impractical as the drainage basin characteristics and channel regimen are subject to radical change.

B. Storm Rainfall Records. This method of determining flood runoff of desired frequency from rainfall of corresponding frequency presents a rather complex problem involving many factors which must be evaluated and are subject to errors of varying degree.

(a) The Rational Formula: ($Q = CIA$). This method is standard practice for designing storm sewer systems from rainfall records. For small drainage areas where channel and surface storage are not major factors, this method can be considered to give satisfactory results. For larger and more complex basins, such as the Elizabeth River, the Rational Method fails to meet the requirements of accuracy desired and to produce satisfactory hydrographs needed for routing floods through detention basins. The coefficient "C" is a composite of many variable factors which make satisfactory evaluation from hydrologic records most difficult.

(b) Unit Hydrograph-Retention Method. This method involves the application of the unit hydrograph and retention principles to storm rainfall. It is applicable to either actual or synthetic storms for any desired frequency. In this report, wherein the design flood has been defined in terms of frequency for fully developed and improved channel conditions, the method has had to be applied to synthetic storms and has been based on observed runoff factors derived from records at the Irvington stream gaging station. While this procedure is more complex than those discussed above, it was selected as the method most applicable to the Elizabeth River problem for the following reasons:

(1) The procedure is based, not on some empirical relation between storm rainfall and flood runoff, but on a rational approximation of the various natural phases involved in the storm rainfall-flood runoff phenomena which can be adjusted and refined to fit the available basic data.

(2) All hydrologic factors involved can be evaluated with reasonable accuracy from observed data and modified on that basis to meet design conditions.

(3) Method permits the most use of the observed records from the Irvington stream gaging station, which is considered representative of the future development and improvement of the entire Elizabeth River drainage area.

(4) The unit hydrograph represents the integrated effects of all the basin constants, such as drainage area, shape, stream pattern, channel capacities, and stream and land slopes, and provides satisfactory hydrographs for flood routing.

(5) Retention curves and indices take into account the intensity characteristics of storm rainfall and therefore are superior to coefficients that are volume ratios of runoff to rainfall.

(6) Method permits application in reverse of procedures used in analysis to synthesize storms and flood hydrographs, thereby reducing the error due to the incorrect evaluation of hydrologic factors.

(7) Method also permits satisfactory application of flood routing procedures to evaluate the effect of channel and detention basin storage.

RECOMMENDED PLAN

Available Methods

As applicable to the Elizabeth River problem, protection against floods can be provided by any of the following three methods, or combinations thereof:

1. Improvement or enlargement of stream channels to increase their capacities sufficiently to pass flood flows without causing damage.

2. Construction of storage or detention basins which temporarily hold back flood flows in excess of the capacity of the natural channel.

3. Removal of buildings and other improvements from low areas subject to flooding, thereby eliminating the necessity for protection.

The first of these methods is a man-made device which, without proper planning, may provide only temporary local protection and increase flood peak discharges beyond practical control limits. The second is nature's way of handling the problem but necessitates long-range planning. The third method, flood plain clearance, is often strenuously opposed locally but in many cases provides the most economical and equitable means of protection, particularly when the lands are utilized for needed recreational or other civic purposes. A most enlightening, comprehensive discussion of these questions is presented in the Progress Report of the Committee of the Hydraulics Division on Flood Control Methods, published in the Proceedings of February 1940 of the American Society of Civil Engineers.

For tidal reaches, the problem is further complicated. Protection against extreme high tides can be provided by either raising lowlands adjacent to the stream channel or by diking such lands and providing tide gates and emergency pumping stations to handle local drainage. Channel improvement in tidal reaches is also advisable to keep high water levels during flood runoff within the limits of extreme high tide.

Recommendations

The plan recommended by this Division for the control of floods on the Elizabeth River combines all three of the above methods. It is one of cooperation with nature, maintaining and increasing where possible the natural storage of the basin. The general plan, shown graphically in Plate 3, includes the following recommendations:

1. The construction of a series of three dry detention basins in the Townships of Union and Hillside with outlet control works located at Route No. 29, Salem Road, and Ursino Dam.

2. Channel improvement for the entire distance of 3.9 miles through the City of Elizabeth from Trotters Lane to Arthur Kill.

3. Reconstruction of 2730 feet of the Newark Flume located in the Town of Irvington below the outlet of the Elizabeth River and Valley Street storm sewers.

4. Modification of certain critical portions of the existing Irvington Flume at Clinton Avenue (780 feet), Lyons Avenue (350 feet), Chancellor Avenue (1400 feet), and possibly at Mill Road.

5. Extension of the Irvington Flume for a distance of 2020 feet in the Townships of Union and Hillside from Mill Road to the inlet of the Route No. 29 Detention Basin below Union Avenue.

Detention Basins

The proposed basins are of the so-called "dry detention basin" type. Under normal conditions these basins will be empty except for a few small permanent ponds located within their areas, and the lands will be available for recreational and other uses. During floods the basins will fill, the depth of water depending on the magnitude of the flood. Flood peaks, however, are of relatively short duration, and sustained flooding of major portions of the basins is not expected to exceed one day.

The general design of these basins has been made in conformity with grading plans submitted by the Union County Park Commission. Capacity-area curves presented on Plates 5, 6, and 7 are based on these grading plans, and were used in routing the design flood through the detention basins. A radical change in these curves by reduction of the storage capacity of the proposed detention basins will reduce the effectiveness of the basins in suppressing flood peaks and thus increase the size of flood on the lower Elizabeth River. All grading and park development plans of the detention basins will be completed by the Union County Park Commission.

To avoid the possibility of the proposed detention basins becoming unsightly nuisances, and to provide required additional recreational and park facilities, the plan recommends that all such lands be allocated to the Union County Park Commission for development and maintenance as part of its park system. In general, this park development of the detention basin sites will consist of regrading the existing ground surface to form a bowl-shaped basin through which the existing meandering stream will be relocated in well-defined low flow channels. In order to reduce maintenance, these low flow channels should be paved as shown by the typical cross-sections on Plate 9 and by the more detailed drawings of the detention basin control works. Examination of flood records indicates that the sizes recommended for these low flow channels are of adequate

capacity to limit flooding of parked lands to once or twice a year for one or two days duration. Where possible and desirable, small permanent shallow ponds may be constructed on or off the channel to provide facilities for ice skating and wading. The lower portions of the basins which are subject to frequent flooding will be planted in grass. Access paths will make this entire lawn area available for recreational purposes except during occasional flood periods. Baseball diamonds and other recreational facilities will be located in the higher portions of the basins which are not subject to frequent flooding. These upper portions of the basins, including lands between the design flood flow line and the taking line, will be planted in shrubbery with access paths for convenient entrances to the park areas. All buildings and other structures subject to damage from flooding will be located in the higher portions of the basin above or adjacent to the design flood flow line. Where adjoining private lands are low, the basin will be graded to form a protective dike inside of the taking lines and facilities will be provided for drainage of local flood runoff. In all detention basins, sanitary sewer manholes will be made water-tight.

Outlet controls are of the fixed-opening type which will discharge floods without operation of gates, While more efficient operation of the detention basin storage might be possible with gate control, the time of concentration of flood waters is considered of too short duration to rely on manual operation. In addition, the use of automatic gates is not considered advisable due to the possible failure of operating and control devices and to the high cost of such equipment. Size and shape of opening have therefore been designed to provide, for the storage available, the greatest suppression of the design flood discharges to be expected off the drainage basin above the control. All outlet controls are free from back-water submergence from points downstream. They are of the contracted-opening type which will pass the low flood flows with a minimum rise in water surface upstream of the control, thus conserving detention basin storage for the suppression of flood flows of such magnitude as to over-tax the downstream channels. In order to protect outlet control works from failure due to floods in excess of the design flood, emergency overflow spillways have been provided.

Inlet controls have been designed to reduce the high approach velocity and to confine the resulting hydraulic jump and its attendant turbulent flow to paved riprap reaches independent of the depth of the backwater from the basin or channel located downstream. The efficiency of these velocity reducing inlet controls is dependent upon their roughness and shape. The lengths of these control sections are minimum for design conditions. Should indications of scour of parked lands develop below the controls under actual flood conditions, the paved and riprap sections should be extended as required.

Major features of the detention basins are summarized in Table 5. The most effective storage for suppression of flood peaks is provided in the upper two basins -- 0.35 inch on the drainage area tributary to Route No. 29 Basin and 0.79 inch for the corresponding area above Salem Pond Basin. While the storage provided in the Ursino Basin does not increase appreciably the total cumulative storage, that storage will be beneficial in suppressing the flood peaks off the East Branch and for storms centered on the lower basin below one or both of the upper detention basins.

Route No. 29 Detention Basin

This basin, with outlet control works located immediately upstream of the Route No. 29 bridge in Union and Hillside Townships, is the first, or uppermost, of the series of three detention basins proposed for the Elizabeth River. Pertinent data, capacity-area curves for present and proposed future conditions, and continuous profile of the detention basin reach which includes cross-sections of the major control works are presented in Table 5 and Plates 5 and 9. In addition, Drawing I, showing details of the principal hydraulic features of the inlet and outlet control works and of the detention basin between Route No. 29 and Union Avenue, has been included as a supplement to this report.

The outlet control is a 35-foot wide rectangular contracted opening, located 75 feet upstream of the existing 59-foot span bridge on Route No. 29. It is designed to maintain a high water flow line 100 feet upstream of the control at elevation 52.36 for the design flood of 5110 cubic feet per second. A rating curve for this control section is shown in Plate 4. The curved approach walls, paved transition reach between the control section and the bridge, and paved invert through the bridge are designed to assure efficient operation of the control and stable supercritical flow through the bridge. The outlet transition below Route 29 into the proposed Salem Pond Detention Basin is designed to reduce the high discharge velocity before it reaches park lands and to contain the hydraulic jump to the paved apron below the outlet of the bridge for all stages of backwater from the lower basin.

In order to safeguard the control works, and to prevent flooding of Route No. 29 and the adjacent built-up sections of Hillside, the control section and approach wing walls have been carried vertically to elevation 60.0 to provide for a flood peak discharge of 10,000 cubic feet per second, the estimated "just full" capacity of the Route No. 29 bridge under present conditions. The grading should provide for dikes at elevation 60.0, or higher, to connect the wing walls to natural ground. Should this design prove to be objectionable aesthetically, or from the standpoint of safety, a sloping or other type section may be substituted for the vertical walls one foot above the design flood high water. Such a design, however, would probably require core wall construction and protective riprapping of the side slopes to safeguard the control and bridge for floods in excess of the design flood.

Inlet controls on North and South Creeks are combined in the inlet control works on the Elizabeth River below Union Avenue. It is recommended that in connection with the construction of Route 4 Parkway and the resultant relocation of Glenwood Avenue, North Creek be relocated and enclosed in a 72-inch storm sewer to conform to the American Can Company storm sewer in which the upper reach of this stream has been enclosed. It is similarly recommended that South Creek also be relocated below Glenwood Avenue in a 10-foot wide walled and paved flume through park lands to the river.

The type of design of the inlet control works on the Elizabeth River is required to protect park lands from severe erosion. The works are designed to check high approach velocities by spreading flood waters over a heavy riprap, rough paved apron and to deflect such waters into the broad portion of the basin for all discharges and stages of backwater. The control works are to be connected to the Union Avenue bridge by the extension of the 35-foot wide walled and paved channel recommended for the improvement of the river above that point.

The inlet control works on Lightning Brook below Union Avenue is designed on the same basis. No design is provided for the approach channel above Union Avenue since that channel is considered part of the Lightning Brook Improvement and beyond the scope of this report. The design, however, does provide for supercritical flow through the Union Avenue bridge, which must be maintained if flooding of Union Avenue is to be avoided.

The low flow channel on Lightning Brook involves a sanitary trunk sewer crossing of the Joint Meeting consisting of two lines, one a 42-inch diameter pipe above the stream bed and the other a 3-foot high by 6.5-foot wide concrete sewer under the improved grade. It is recommended that the upper sewer, which is not in use at present, be removed to eliminate a possible control and erosion of parked lands.

The proposed location of the Route No. 4 Parkway through the basin, together with tentative road grade elevations, are indicated on Drawing I and the continuous profile, Plate 9. The storage lost by this location has been compensated for by slightly increasing the design flood high water elevation. For design purposes the crossing has been assumed to be a single-span, flat arch bridge with a normal span of 100 feet to avoid any further increase in top of dike elevation along Union Avenue. An acceptable alternate design would be a two-span bridge with each span not less than 60 feet normal.

To protect private lands south of Union Avenue from flooding under design flood conditions, diking to elevation 55.0 will be required from the inlet control works below Union Avenue for a distance of approximately 600 feet along the north side of the basin. Provisions must also be made for handling local flood drainage off lands back of this dike unless such lands can be raised by fill.

Salem Pond Detention Basin

This basin, with outlet control works located at Salem Road in Hillside and Union Townships, extends upstream to Route No. 29. Pertinent data, capacity-area curves for present and proposed future conditions, and continuous profile of the detention basin reach which includes a cross-section of the major control works are presented in Table 5 and Plates 6 and 9. In addition, Drawing II, showing details of the principal hydraulic features of the inlet and outlet control works of this basin, has been included as a supplement to this report.

The outlet control, located in the upstream face of the Salem Road bridge, is designed to maintain a high water flow line immediately upstream of the control at elevation 42.71 for the design flood of 4660 cubic feet per second. It consists of two semicircular arch contracted openings, each 17 feet in diameter, created by the construction of a concrete curtain wall in the inlet of the existing twin-span, 25-foot rectangular bridge openings with stream bed paved through the bridge to the invert grades shown on Plate 9. A rating curve for this control section is shown on Plate 4.

In order to confine the design flood and prevent overtopping of the present road surface at elevation 39.5, the upstream railing of the existing bridge is to be reconstructed as a solid concrete parapet wall and extended to create a dam 300 feet in length with spillway crest at elevation 43.0. Concrete wing walls and short earth dikes are to be provided to elevation 45.0 to connect this parapet to natural high ground. For floods in excess of the design flood, the parapet wall and Salem Road become an emergency overflow spillway, 300 feet long, increasing the outlet capacity to 7700 cubic feet per second for high water at top of wing walls and dikes. Free passage of flood waters across Salem Road should be provided by installing an open pipe railing on the downstream side of the bridge.

This design converts Salem Road bridge into a safe and efficient control with the minimum of new construction and costs. The design utilizes the depressed profile of the Salem Road crossing. Flooding of Salem Road will be experienced at rather infrequent intervals, but such flooding is not considered objectionable or dangerous if the recommendations for the design of the outlet transition channel are adopted.

This outlet transition discharges into a short reach of natural channel connecting this basin to the Ursino Detention Basin at the Lehigh Valley Railroad bridge. It is designed to reduce the high discharge velocity of the control through the bridge and to confine the attendant hydraulic jump to the paved apron for all stages of flow. For floods which overflow Salem Road, the downstream road embankment and channel side slopes of the transition are to be protected by paving, riprap, or other satisfactory material, and graded so as to channelize overflow waters into the main channel. Protection should extend to elevation 42.0 at the downstream end of the transition and be warped to meet the downstream curb or sidewalk elevations along Salem Road below elevation 46. The extent of this protection, as shown on Drawing II, is the estimated minimum required. Experience, however, may indicate that extensions are advisable to reduce erosion.

It is recommended that the existing Salem Pond Dam immediately upstream of Salem Road be removed, and that a permanent pond for recreational purposes be provided in the flood plain east of the low flow channel. This recommendation conforms to the plans of the Union County Park Commission and provides for better utilization of the storage on the lower reach of the basin to be made available by the relatively deep cut shown on the continuous profile, Plate 9.

In order to reduce the possibility of turbulent flow and resultant scour of parked lands on the West Branch below Vaux Hall Road, the bridge transition section, low flow channel, and flood plain from Vaux Hall Road to the Elizabeth River have been designed to maintain stable subcritical flow by varying the size and shape of the channel cross-section. Deepening of the invert of the Vaux Hall Road bridge from elevation 42.5 to elevation 34.0 is proposed to reduce the stream bed slope of the downstream channel. This recommendation conforms to the design adopted for carrying the Joint Meeting Supplementary Sanitary Trunk Sewer crossing through the waterway opening of the Vaux Hall Road bridge when that bridge was extended downstream in 1939. Details of the replacement of the existing Faitoute Dam and of the original upstream portion of the Vaux Hall Road bridge, protection of the Joint Meeting Sanitary Trunk Sewer crossing located in that dam, and the design of the West Branch approach channel above Vaux Hall Road are considered part of the West Branch Improvement and beyond the scope of this report.

In order to protect private lowlands outside of the park limits from flooding under design flood conditions, diking to elevation 45.0 will be required from Route No. 29 for a distance of approximately 1800 feet along the north taking line in Hillside Township adjacent to Harvard Avenue. Provisions must also be made for handling local flood drainage off lowlands back of this dike.

Ursino Detention Basin

This basin, the last of the detention system, combines the Ursino Lake and North Avenue Detention Basins recommended as two basins in Report No. 1 of the Joint Engineering Committee. For descriptive purposes it may be divided into three reaches; namely, Ursino Dam-North Avenue, North Avenue-Lehigh Valley Railroad, and Lehigh Valley Railroad-Salem Road. Pertinent data, capacity-area curves for present and proposed future conditions, and continuous profile of the detention basin reach which includes cross-sections of the major control works, are presented in Table 5 and Plates 7 and 9. In addition, Drawings III and IV, showing details of the principal hydraulic features of the inlet and outlet control works of this basin have been included as a supplement to this report.

The primary outlet control, located at the existing Ursino Dam, is designed to maintain a high water flow line upstream of the dam at elevation 23.80 for the design flood of 5190 cubic feet per second. The alterations to the existing dam required to provide this control consist of lowering the crest of the center portion of the 105-foot broad-crested spillway from elevation 22.4 and constructing an ogee spillway section, 50 feet in length, with crest at elevation 16.0. In addition, the existing earth dike extending along the west bank from the dam to North Avenue is to be widened, strengthened and raised to a minimum top elevation 27.0.

TABLE 5
DETENTION BASIN DATA

	Route No. 29 Detention Basin	Salem Pond Detention Basin	Ursino Detention Basin	
			North Avenue	Ursino Lake
Drainage Area above Control-Sq.Mi.	9.88	13.42	16.83	16.90
Detention Basin:				
Design Flood High Water				
Outlet Control	El. 52.36	El. 42.71	El. 25.16	El. 23.80
Inlet Control	El. 53.19	El. 43.66	El. 28.62	El. 23.95
Area of Maximum Flooding - Acres	39	53	24	10
Area within Taking Line - Acres	71	73	63	14
Maximum Available Storage- M.C.F.	8	17	4	3
Total Accumulated Storage- Inches	0.35	0.79	0.74	0.81
Outlet Control Works - Location	75'above R.29 Bridge	Inlet Salem Rd.Bridge	Inlet North Ave.Bridge	Ursino Dam
Type of Control	Contracted opening in approach channel	Contracted opening in twin arches	Contracted opening in bridge	Notch in 105' Spillway
Width of opening - Feet	35.0	2 - 17.0 diameter	2-45x8(or equivalent)	50.0
Invert of Control	El. 38.54	El. 26.0	El. 12.0	El. 16.0
Top of Control Dam	El. 60.0	El. 45.0	El. 30.0	El. 27.0
Design Flood Discharge:				
Inflow - Cubic Feet per Second	6440	6190	5300	
Outflow- Cubic Feet per Second	5110	4660		5190
Earth Dikes - Location	Below inlet control adj.to Union Avenue	Above outlet control & along Harvard Ave.	Outlet of East Branch	Along w.bank above dam
Length - Feet	600±	1800±	200±	1300±
Top of Dike	El. 55.0	El. 45.0	El. 30.0	El. 27.0
Average Height - Feet	3	3	2	7
Super Flood Protection:				
Type of Overflow Control	Contracted opening in approach channel	Bridge parapet	Bridge openings	Exist.Spillway & Flood Gate
Peak Discharge - Cubic Ft. per Sec.	10,000	7,700	8,700	9,400
Emergency Spillway Crest	El. 60.0	El. 43.0	El. 30.0	El. 22.6
Flood High Water	El. 60.0	El. 45.0	El. 30.0	El. 27.0

For flood heights above elevation 22.4, additional spillway capacity will be provided by the remaining 55 feet of the existing dam crest. Total capacity of the control for high water at top of dike elevation is estimated at 9400 cubic feet per second for free discharge, not submerged by backwater from the lower channel. A rating curve for this control is shown on Plate 4. The existing 15-foot gate at the east end of the dam is manually operated and, therefore, is not considered effective for flood control purposes. While its capacity has been neglected in the design of the control works, it is recommended that the structure be repaired for lowering the water level in Ursino Lake and for emergency use. In that event, a separate outlet channel, 10 feet in width, should be provided from the gate to below Trotters Lane bridge.

Complete reconstruction of the existing two-span Trotters Lane bridge is required to eliminate the center pier and to raise the under-clearance of the bridge deck to a minimum elevation 21.0. The recommended new design is a three-span structure with a center span 50 feet wide, for the passage of the flood discharge from the Ursino Dam spillways, and two side spans each 10 feet wide. The east side span is for the discharge of the Ursino Lake gate and is to be connected to that gate by a walled and paved flume 160 feet long. The west side span is for the outlet discharge of the Trotters Lane Branch, which was enclosed many years ago below Morris Avenue in a 42-inch by 48-inch elliptical storm sewer to relocate the outlet below Ursino Lake. While the capacity of this storm sewer will probably be inadequate for the ultimate flood runoff to be expected off this branch, the design of its reconstruction is considered part of the Trotters Lane Branch Improvement and beyond the scope of this report.

For the design flood or smaller, the design provides for connecting the 50-foot span to the ogee spillway section by a smooth paved flume of the same width with low walls at elevation 15.5. For the larger floods, the discharge over the overall spillway is to be channelized into this design flood channel by smooth paved aprons constructed on top of the low walls with side training walls extending from the existing spillway wing walls to the 50-foot bridge span. Downstream, the overall bridge span is to be connected to the 50-foot wide improved channel recommended for that reach of the lower river by a 30-foot long transition to provide for the junction of the two 10-foot wide side channels.

The basic principles of the hydraulic design of this control and its outlet transitions are to maintain free-fall discharge over the new ogee spillway section, free from any backwater submergence, and to shift the hydraulic jump, if possible, to the improved channel downstream of the Trotters Lane bridge. The transitions, therefore, have been designed to streamline the flow pattern so as to eliminate disturbances and the attendant energy losses. The recommended design is shown on Drawing III. Certain details will probably have to be modified when a more detailed survey of this site is made. The length of transition, however, between Ursino Dam and Trotters Lane bridge should not be reduced below 120 feet.

Numerous designs were investigated to reduce the overall cost of this control, and especially to avoid raising Trotters Lane bridge. The recommended design provides the best hydraulic solution of this problem, but backwater computations do not give sufficient assurance that the supercritical flow in the approach channel can be maintained to shoot flood waters under the Trotters Lane bridge for design flood conditions on the lower river, especially during high tides. For design conditions, the flow in the improved channel downstream of Trotters Lane will be subcritical and is affected directly by tide levels at the mouth. A hydraulic jump is therefore created at some point below Ursino Dam. For an underclearance at the present elevation, the location of this jump within the bridge opening would submerge the bridge underclearance, cause flooding of Trotters Lane and reduce appreciably the discharge capacity of Ursino Dam.

Raising the underclearance of Trotters Lane bridge as recommended will necessitate raising the roadway from elevation 19.6 to 24.0. No difficulty is presented on the west approach which has a steep grade. The east approach, however, is level and will have to be raised. The present road grade of this approach is also too low to provide satisfactory freeboard for the design flood flow line in the improved channel below Trotters Lane.

If desired, modification of the ogee section of the Ursino Dam spillway can be considered to reduce cost of alteration provided a smooth overflow nappe is maintained and the spillway length is adjusted to satisfy the design requirements. The spillway crest was lowered for four reasons. It increased the storage available for flood waters; it conformed to the desire of the Union County Park Commission for a shallower amusement lake; it reduced the flood backwater on North Avenue which is frequently overtopped under present conditions; and last and most important, it increased the freeboard and safety of the earth dike which confines Ursino Lake along the west bank between the dam and North Avenue. The failure of this dike would release flood waters on a congested section of Elizabeth east of Morris Avenue.

A secondary control in the Ursino Detention Basin is located at North Avenue which raises the high water flow line 1.2 feet to elevation 25.16 immediately upstream of the bridge, for the design flood of 5200 cubic feet per second. This flow line, approximately five feet lower than the present 25-year high water, will be maintained by increasing the present size of the bridge which has proved to be inadequate and is difficult to maintain free of debris. The existing twin 22-foot diameter arch spans will be maintained with stream bed deepened to elevation 12.0. A new bridge with a rectangular opening 50-foot wide by 8-foot high, or the equivalent in capacity, will be constructed in the middle of the crossing between the existing twin arch bridge and the old 10-foot span arch which is now practically buried in the lake bottom near the east end of the crossing. The vertical opening of the new span is limited to 8 feet by an 18-inch diameter sanitary sewer located in the road embankment of this crossing. This design is preferable to the reconstruction of the existing bridge since it is more economical, provides for a better distribution of flow, and should reduce maintenance. A park underpass at North Avenue is desirable but the available headroom is limited by the sanitary sewer crossing.

While the modifications of Ursino Dam and the North Avenue bridge as discussed above reduce the frequency of flooding of the North Avenue crossing, it is recommended that protection from overflow of North Avenue with the resultant inundation of Morris Avenue and the adjacent built-up sections of Elizabeth be provided for the maximum capacity of the Ursino Dam spillway. By raising the present North Avenue roadway from a low point elevation 25.3 to elevation 27.0 to conform to the top of the Ursino Lake dike, and by providing a solid parapet wall similar to that proposed for Salem Road to elevation 30.0 for a distance of approximately 500 feet along the upstream face of North Avenue, the capacity of the North Avenue bridge openings will be increased to 8700 cubic feet per second with flood high water at the top of the North Avenue parapet wall and Ursino Lake dike. Both ends of the parapet wall should be carried to natural high ground by short dikes at elevation 30.0 or higher. A rating curve for the North Avenue bridge is shown on Plate 4.

By lowering the design high water above the North Avenue bridge to elevation 25, the flood storage available in the North Avenue-Lehigh Valley Railroad reach will be reduced from approximately eleven million cubic feet under present conditions to four million cubic feet. A similar but smaller loss is created for the same reason in Ursino Dam-North Avenue reach. However, the Ursino Basin is the least effective of the proposed detention basin system in reducing peak discharges, and it is estimated that the loss of this storage will not increase the design flood peak through the City of Elizabeth more than four percent. Moreover, this loss is more than compensated for by the increased protection to the Ursino Lake dike, the relief from frequent flooding of the North Avenue crossing, and the reduced flood backwater on the East Branch storm sewer system.

The flood problem on the East Branch is considered part of the improvement of that stream and beyond the scope of this report. The outlet capacity of the comprehensive storm sewer system which encloses all of this branch, however, was investigated to determine the maximum high water which could be adopted for this detention basin and the proper design for the inlet control works. Much of the flooding which has been experienced on this branch is due to the limited capacity of the 16-foot wide by 6-foot high outlet section, for which the "just full" capacity is estimated at 900 cubic feet per second. This problem, however, is seriously aggravated by the flood heights now experienced on the main river which reduce the flat slope available on the lower reaches of the East Branch and place that storm sewer system under head for approximately a mile upstream. The adoption of the observed maximum high water elevation 28.0 for the design high water above North Avenue as originally contemplated would have made the solution of this East Branch problem exceedingly difficult, if not practically impossible. The design flood high water was therefore established at elevation 25 upstream of North Avenue so as to create no backwater on the East Branch outlet sewer either under present or future improved conditions. The control will be the outlet cross-section under both conditions and the total natural slope will be available for the future enlargement of the East Branch storm sewer when required.

The inlet control on the East Branch was designed to meet these conditions. The existing storm sewer will be extended for a distance of approximately 500 feet through private lands below Conant Avenue to the detention basin limits by an open walled and paved channel, 25 feet in width, with top of walls at elevation 30.0 or higher. A short, flaring, paved outlet transition section with wing walls will be provided to reduce discharge velocities and scour of park lands. Wing walls will be connected to natural high ground by short earth dikes to protect private lowlands adjacent to the inlet control. Such lands should be raised by fill to elevation 30.0 or higher before the sites are developed.

For the Lehigh Valley Railroad-Salem Road reach of the Ursino Detention Basin, a uniform trapezoidal earth channel with very flat side slopes, as shown on Plate 9, was tentatively selected for design purposes. Inasmuch as the effect of this channel storage in reducing peak discharges is considered negligible, other sections may be substituted for this reach which best meet the grading requirements of the Union County Park Commission and do not increase backwater on the Salem Pond Detention Basin outlet control works below Salem Road. The design for the inlet channel on the Lehigh Valley Branch is discussed under Bridges. Details of this control can be modified to meet grading requirements for this reach.

It may appear from the preceding description and from examination of Table 5 that the cost of this basin is not justified by the degree of flood peak suppression to be derived therefrom. Much of the cost would be required if the basin was eliminated entirely. For the design conditions, the flood-producing storm was centered uniformly on the drainage basin tributary to this control. Actual storms, however, are distributed unevenly. For certain distributions, the value of this basin will be greater. The reach also has attractive recreational features. For these reasons, Ursino Basin has been retained in the detention basin system and its development is recommended.

Channel Improvements - Lower River

Extensive and expensive channel improvements through the City of Elizabeth will ultimately be required from the City Line at Trotters Lane for a distance of 3.9 miles to Arthur Kill. Details of the plan, including typical cross-sections of the improved rectangular walled channels, are shown on the continuous profile of the lower reach of the Elizabeth River, Plate 10. Also shown thereon are the recommended improved stream bed grade, design flood high water flow line, and observed high water profiles for four major floods of record.

Boring data obtained from the Corps of Engineers, New York District Office, indicate that the recommended improved grade for the tidal reach can be obtained by dredging without rock excavation. For the reach above South Broad Street, ledge rock is close to the present stream bed grade and no appreciable deepening is practical.

The improvement has been designed to provide protection against the combination of either a moderate high tide at elevation +4.0 and the 25-year design flood suppressed by detention basin storage, or an extreme high tide at elevation +7.0 and no appreciable flood runoff.

The capacity of the recommended improvement is approximately double that of the existing unimproved channel, and has been designed to provide a high water flow line satisfactory for the discharge of side drainage and storm sewers. Flow will be stable subcritical throughout the lower reach of the river with average velocities of 5 and 9 feet per second for the tidal and upper reaches, respectively. Paving of the channel invert will not be required except for a distance of approximately 600 feet from above Crane Street through the Mulford Coal Yard to below West Grand Street where a constricted section 40 feet wide was adopted to avoid reconstruction of the Central Railroad bridge. Widths of the improved channel conform, for the most part, to the overall top widths of the existing channel and do not involve any major reconstruction or alteration of private structures.

Above head of tide in the City of Elizabeth, rectangular walled channels 50 and 55 feet in width are required for the reaches from Trotters Lane to Irvington Avenue and from Irvington Avenue to Westfield Avenue, respectively. For the reach from Westfield Avenue to below South Broad Street, a channel 60 feet in width is recommended except for the 600 feet of paved channel discussed above. Masonry or concrete walls are considered practical and advisable for this reach where low flows are shallow and ledge rock is close to the improved stream bed grade. Minimum freeboard to top of wall or below underclearance of bridges is one foot. Design flood peak discharges vary from 5300 and 5390 cubic feet per second at Trotters Lane and at Irvington Avenue, 5460 and 5790 cubic feet per second above and below the Westfield Avenue storm sewer, to 5890 cubic feet per second below South Broad Street.

In the tidal reach of the Elizabeth River below South Broad Street, a rectangular section 80 feet in width with walls of timber or steel sheet piling is recommended. Because of the depth to rock, this type of construction is considered practicable and advisable. For the navigable reach below Trenton Avenue, the recommended sheeting is timber, conforming to standard pierhead construction which probably will be adopted for the development of docks along that reach of the channel. For the balance of the tidal reach through Mattano Park and the proposed Elizabeth River Parkway, steel sheet piling is recommended to reduce cost of subaqueous construction and width of required channel. In the upper reaches where rock is close to the improved stream bed grade and the depth below mean low water is shallower, masonry or concrete walls are submitted as an alternative design. For the entire tidal reach walls are to be carried to a minimum elevation +3.0, one foot above the probable extreme high tide, and higher where required to maintain a minimum freeboard of one foot above the design flood high water flow line. Design flood peak discharges vary from 5890 cubic feet per second below South Broad Street to 6260 cubic feet per second at Arthur Kill.

Modification of the rectangular channel section can be considered through park lands should the high vertical walls prove to be objectionable aesthetically or from the standpoint of safety. Satisfactory treatment of this reach to conform to desirable park landscape practices is complicated by the depth of the improved channel, the relative narrow width of the parkway, and the natural tide fluctuation. An earth trapezoidal channel section, with or without dikes, would reduce cost of channel improvement and better conform to the landscape treatment of adjacent park lands. Hydraulically, such a channel can be considered provided suitable transitions are constructed at the various bridges. The trapezoidal channel section, however, was not included as an alternate design for three reasons. First, the greatly increased top width would seriously encroach on lands available for the parkway, and at many points would reduce such lands to unsatisfactory widths. Second, maintenance of the flood channel would be extremely difficult due to the effect of tidal fluctuations. And last, but not least, the appearance of the banks would be detrimental to park development as planting and landscaping cannot be undertaken between mean low water elevation -2.3 and elevation +4.0± because of frequent exposures to oily, salty, or brackish water. While mean high tide is at elevation +2.4, records indicate that high tides at elevation +3.4 occur, on the average, twice per month and that tides as high as elevation +5.0 are not exceptional. This condition could be eliminated and maintenance reduced by the construction of a tide gate such as the Union County Park Commission has proposed in Mattano Park. While such a tide gate would create many attractive features along the Parkway and in Mattano Park, its cost would be great since sensitive controls and very rapid gate operation would be required because of the limited storage available in the approach channel. Combinations of the rectangular and trapezoidal channels with top of sheeting cutoff at mean high water or some corresponding point were also considered but discarded because of no material saving in cost and of the greater top width required. Further study of this reach by interested local agencies is desirable.

Upper River

Upstream of the detention basin system, for a distance of 2.5 miles, from below Union Avenue in Union and Hillside to the outlet of the Valley Street and Elizabeth River storm sewer systems downstream of Valley Street in Irvington, less channel improvement is required. Much of this work has been completed by the Town of Irvington and is of adequate capacity to provide protection against the design flood of 15-year frequency. Moreover, the area tributary to the upper reach of the river in Essex County is practically fully developed and storm-sewered, and little increase in present flood discharges will be experienced under future conditions. A profile of this reach showing the design flood high water flow line, recommended modifications and extensions of existing walled and paved channels, and typical cross-sections of these channels is presented on Plate 8.

The most extensive work required is the reconstruction of the Newark Flume in Irvington, which extends downstream for a distance of 2730 feet below the outlet of the storm sewer systems at Valley Street. The existing paved channel with sloping concrete walls and a bottom width of 16 feet has inadequate capacity, as has been evidenced by frequent overflow of banks. A rectangular walled and paved section 27.0 feet in width upstream of the outlet of the Allen Street storm sewer and 31.0 feet below that point is recommended to confine the design flood which varies from 1800 to 2100 cubic feet per second.

Except for modification of certain critical sections, the Irvington improved channel extending for a distance of 1.6 miles from the outlet of the Newark Flume to Mill Road at the Essex-Union County Line has adequate capacity for the 15-year design flood. The most critical of these points is the twin 9-foot diameter pipe culvert at Chancellor Avenue, which creates a flood backwater under present conditions extending to above Lyons Avenue. Reconstruction of this culvert and possibly of the existing two-span bridge at Mill Road to provide single-span openings conforming to the width of improved channel is included in plans for the extension of Route 4 Parkway through Irvington. The Chancellor Avenue reconstruction involves the relocation of 1400 feet of existing improved channel and will provide for deepening of the improved grade. The reconstruction of the Mill Road bridge will reduce disturbances in the high velocity flow by easing the curvature at that point and eliminating the center pier.

While hydraulic jumps will occur upstream and downstream of Lyons Avenue, flow in the Irvington Flume, in general, will be supercritical. However, in order to maintain this flow and prevent serious flooding at Lyons Avenue under design flood conditions, it is recommended that the existing channel 50 feet downstream of the Lyons Avenue bridge be widened from 26.2 to 32.0 feet and the channel downstream be rebuilt as required to provide a uniform transition section between the bridge and the existing 28.6-foot channel 350 feet downstream. In the vicinity of Clinton Avenue it is recommended that the width of the channel be increased from a minimum of 15.5 feet to 21.0 feet for a distance of 780 feet, to maintain supercritical flow and eliminate a hydraulic jump which would cause flooding at that point under design flood conditions. No changes in existing paved inverts are required. Channel walls should be raised as required to provide a freeboard of one foot on straight reaches, and for the supercritical reach below the Newark Flume as required to confine waves at and downstream of curves. In addition to these modifications of existing improved channels in Irvington, extension of that improvement is recommended through Union and Hillside by the construction of a walled and paved flume, 35 feet in width, from the Mill Road bridge to the inlet of the Route No. 29 Detention Basin below Union Avenue.

Bridges

Existing and proposed bridges are summarized in Table 6 and shown in profile on Plates 8, 9, and 10. In all, a total of 44 existing bridges, including six footbridges, span the Elizabeth River, and four new crossings are proposed. Of this number it is recommended that 18 be reconstructed, three removed, one relocated, and two modified. Of these, two are State Highway crossings at Westfield and North Avenues, two are private bridges in Elizabeth, and two are footbridges in Irvington.

Twelve of the 24 bridges located in the City of Elizabeth will ultimately need to be rebuilt to provide spans conforming to the required improved channel section. Of these, eight are brownstone multiple arches which create obstructions to flood flows and two are movable bridges at South and Bridge Streets which have inadequate capacity under present conditions. For four of the 12 bridges, reconstruction will probably involve raising street grades. All bridges will be reconstructed as single-span structures, except at Bridge Street, West Jersey Street, and Trotters Lane. The Trotters Lane Bridge is to be a special three-span design which has been described with the outlet control works for the Ursino Detention Basin. The channel alignment at the Baltic Street Bridge is poor, and it is recommended that this span be removed upon completion of the proposed Trenton Avenue Bridge to be constructed 140 feet upstream on an access road to the New Jersey Turnpike. It is further recommended that the South Street Bridge be relocated at John Street to provide higher approaches and to raise the bridge underclearance. The crossings at Murray Street and at Crane Street should be removed to reduce cost of bridge reconstruction.

Three of the total number of bridges crossing the river in Elizabeth are main line railroad spans. The lower Central Railroad of New Jersey structure downstream of the proposed New Jersey Turnpike bridge conforms to the recommended plan. The capacity of the twin-arch Pennsylvania Railroad span upstream of Rahway Avenue is inadequate for the design flood, and it is recommended that this structure be rebuilt to conform to the recommended plan when realignment of the railroad is made through Elizabeth to improve its curvature. No changes are proposed in the upper crossing of the Central Railroad of New Jersey. The improved channel has been designed to conform to this structure and to provide adequate capacity by paving the restricted channel for a distance of approximately 600 feet from above Crane Street to below West Grand Street. Reconstruction of this bridge to eliminate a constriction in the channel at this point would be considerably more costly than the recommended paving of the channel invert.

For practical purposes, head of navigation will be established at Trenton Avenue by the construction of the low-level fixed bridge approved for the New Jersey Turnpike Authority by the Navigation Council, Division of Planning and Development, New Jersey State Department of Conservation and Economic Development, and the Corps of Engineers. Reconstruction of existing movable bridges upstream of that point can therefore be considered, subject to the approval of the above agencies.

Five bridges cross the Elizabeth River in the Townships of Union and Hillside. The State Highway Route 29 span has been incorporated in the design of the outlet control works for the Route No. 29 Detention Basin and is described under that subject. The bridge at Salem Road has been modified to provide the outlet control for the Salem Pond Detention Basin. Details are given in the description of that basin. In order to alleviate flooding of North Avenue, and to reduce flood backwater on the East Branch tributary, the additional waterway opening described for the North Avenue control of the Ursino Detention Basin must be provided at that crossing. The Lehigh Valley Railroad span between North Avenue and Salem Road conforms to the recommended plan. The proposed Route No. 4 Parkway will cross the Elizabeth River in the Route No. 29 Detention Basin and is described under that basin.

At Union Avenue the existing two-span bridge on the main river may have to be either modified or rebuilt to provide a single 35-foot span conforming to the improved channel. The center pier and low underclearance of the existing bridge introduce objectionable obstructions to the supercritical approach flow which may cause the roadway to be overtopped. In an attempt to eliminate this obstruction and maintain supercritical flow with adequate freeboard below the present underclearance, an inlet drop has been introduced in the invert grade through the bridge. In the event that this design fails to pass flood flows satisfactorily, the bridge can be modified by removal of the center pier and reconstruction of the deck to provide the required single span with no appreciable change in roadway grade.

In addition to the bridges crossing the Elizabeth River, five spans over tributaries have been investigated in connection with the design of the detention basins. Hydraulic details are shown on Drawings I to IV, inclusive.

The existing bridge at Glenwood Avenue in Hillside below the present junction of the North and South Creek tributaries at the inlet to the Route No. 29 Detention Basin will be abandoned upon construction of Route No. 4 Parkway and relocation of Glenwood Avenue. Recommendations for its reconstruction as separate crossings on North and South Creeks are given in the description of the Route No. 29 Detention Basin.

The Union Avenue Bridge on the Lightning Brook tributary in Union conforms to the tentative design for the improvement of that stream and the design recommended herein for the inlet control works on Lightning Brook in the Route No. 29 Detention Basin. Details are given in the description of that basin.

The Vaux Hall Road Bridge on the West Branch tributary in Union must be modified to conform with the design recommended for the inlet channel on the West Branch in the Salem Pond Detention Basin. This bridge consists of two structures -- the original 10.7-foot span bridge, 18 feet long, and an 18.0-foot span downstream extension, 37.4 feet long, which was designed and constructed to provide for a future two-level waterway opening around the 11-foot wide by 3-foot high Joint Meeting Supplementary Sanitary Trunk Sewer crossing located in that reach. The existing outlet cutoff wall and paving in the upper level on top of the sanitary sewer crossing will have to be removed so that the invert can be lowered from

elevation 42.5 to 34.0 to meet inflow conditions established in the description of the Salem Pond Detention Basin. No change will be required in the sanitary sewer crossing but reconstruction of the original bridge section to conform to the extension will be required when the improvement of the West Branch is undertaken.

The Morris Avenue Bridge on the Lehigh Valley tributary in Union is inadequate. The capacity of this structure will have to be increased and the invert lowered approximately 1.5 feet to conform to the proposed inlet channel on this tributary in the Ursino Detention Basin on the Elizabeth River.

Of the 15 bridges crossing the Elizabeth River in Irvington, it is recommended that three major bridges and two footbridges be rebuilt. The reconstruction of the Chancellor Avenue culvert and perhaps of the County Line Bridge at Mill Road will be incorporated in the design of the river crossings on the proposed Route No. 4 Parkway at these locations. At Mill Road the center pier and low underclearance of the existing two-span bridge introduce objectionable obstructions to the supercritical approach flow. Reconstruction as a single 35-foot span with underclearance at present elevation is considered advisable. However, in the event that this structure is not rebuilt in connection with Route No. 4 Parkway, reconstruction may be deferred until the downstream channel has been improved so as to relieve flood backwater which may be primarily responsible for flooding of roadway. The Clinton Avenue Bridge should also be rebuilt when the Irvington Flume is modified to eliminate a constriction which studies indicate will create flooding at that point under design flood conditions. The Madison Avenue Bridge apparently conforms to the improved channel design recommended for reconstruction of the Newark Flume.

Six of the 15 bridges in Irvington are footbridges. Of these, only the two timber bridges across the Newark Flume need be rebuilt.

Utility Crossings

All utility crossings of record are shown on the continuous profiles of the Elizabeth River, Plates 8, 9, and 10. As summarized in Table 7, 13 of these crossings on the main river channel and one on Lightning Brook tributary in the Route No. 29 Detention Basin must be either removed or relocated as they are above the proposed improved channel grades and would obstruct flood flows at their present elevations. The 8-inch Schering Corporation sanitary sewer crossing may be left to serve as a low dam in the parked channel if so desired.

TABLE 6
ELIZABETH RIVER DESIGN

SUMMARY OF BRIDGES
(including dams)

	Existing Bridges				Required New Bridge		
	Type	No. of Spans	Net Span Normal - Feet	Gross Span Normal - Feet	Type	Net Span Normal - Feet	Remarks
City of Elizabeth							
South Front Street	Drawbridge	1	78.0	82.0	Adequate		
South First Street	Drawbridge	1	60.0	76.0	Adequate		
Central Railroad	Drawbridge	3	2-30 & 1-60	142.0	Adequate		
Turnpike					Viaduct	75.0	New Bridge
Baltic Street	Drawbridge	2	1-25 & 1-61	97.0	Adequate		To be removed
Trenton Avenue					Girder	80.0	New Bridge
Summer Street	Drawbridge	1	60.0	60.0	Adequate		
John Street					Girder	75.0	New Bridge
South Street	Turnbridge	2	1-48 & 1-15	93.0			To be relocated at John Street
Route No. 25	Viaduct	1	65.0	65.0	Adequate		
Route No. 25	Viaduct	1	65.0	65.0	Adequate		
Bridge Street	Turnbridge	2	1-33 & 1-11	48.0	Girder	2-38.0	To be rebuilt and raised
Route No. 25	Viaduct	1	60.0	60.0	Adequate		

TABLE 6 (continued)

City of Elizabeth-Continued	Existing Bridges Type	No. of Spans	Net Span Normal - Feet	Gross Span Normal - Feet	Required New Bridge Type	Net Span Normal - Feet	Remarks
Broad Street	Arch	3	3-17.6	58.8	Girder	60.0	To be rebuilt
Rahway Avenue	Arch	2	2-22.1	55.4	Girder	60.0	To be rebuilt
Pennsylvania Railroad	Arch	2	2-22.8	52.6	Girder	60.0	To be rebuilt
Murray Street	Arch	2	2-20.7	44.5			To be removed
West Jersey Street	Girder	1	46.3	46.3	Girder	2-28.5	To be rebuilt
West Grand Street	Arch	2	2-22.5	48.0	Girder	40.0	To be rebuilt
Mulford Coal Yard	Beam	1	34.9	34.9	Girder	40.0	To be rebuilt
Railroad Siding	Trestle	2	1-11.5 & 1-19	35.0	Girder	40.0	To be rebuilt
Central Railroad of N.J.	Arch	1	40.0	40.0	Adequate		
Crane Street	Arch	2	2-21.5	46.0			To be removed
Westfield Avenue	Arch	4	4-20±	90.1	Girder	55.0	To be rebuilt
U.S.G.S. Gaging Weir	Dam	1	48.0	56.5	Dam	55.0	To be relocated
Morris Avenue	Arch	2	2-21.0	45.6	Girder	55.0	To be rebuilt and raised
Irvington Avenue	Flat Arch	1	45.5	45.5	Girder	50.0	To be rebuilt and raised
Dams	Rock	2	30.±	30.±			To be removed
Trotters Lane	Girder	2	2-30.3	64.6	Girder	1-50 & 2-10	To be rebuilt and raised

TABLE 6 (continued)

	Existing Bridges				Required New Bridge		
	Type	No. of Spans	Net Span Normal - Feet	Gross Span Normal - Feet	Type	Net Span Normal - Feet	Remarks
Townships of Union and Hillside							
Ursino Dam	Dam	1	105' broad crested		Dam	1-50' Ogee 1-55' broad crested	Detention basin control
North Avenue	Arch	2	2-22.0	50.0	Arch Girder	2-22.0 1-50.0	Detention basin control
Lehigh Valley Railroad	Girder	1	69.0	69.0	Adequate		
Salem Road	Concrete	2	1-25.0 1-25.35	53.5	Arch	2-17.0	Detention basin control
Salem Pond Dam	Dam	1	80.0	80.0			To be removed
Route No. 29	Concrete	1	59.34	59.34	Adequate		Detention basin control
Route No. 4					Girder	100	New Bridge
Union Avenue	Concrete	2	2-16	35.0	Girder	35.0	May be rebuilt
Town of Irvington							
Mill Road	Concrete	2	2-16.0	35.0	Girder	35.0	May be rebuilt and raised
Footbridge (Park)	Flat Arch	1	27.0	27.0	Adequate		
Footbridge (Park)	Flat Arch	1	25.9	25.9	Adequate		
Chancellor Avenue	Pipe Culvert	2	2-9.0		Girder	30.0	To be rebuilt

TABLE 6 (continued)

Town of Irvington - continued	Existing Bridges				Required New Bridge		
	Type	No. of Spans	Net Span Normal - Feet	Gross Span Normal - Feet	Type	Net Span Normal - Feet	Remarks
Yale Avenue	Concrete	1	26.0	26.0	Adequate		
Lyons Avenue	Concrete	1	22.0	22.0	Adequate		
Nye Avenue	Concrete	1	22.9	22.9	Adequate		
Springfield Avenue	Beam	1	19.7	19.7	Adequate		
Footbridge (Playground)	Girder	1	22.5	22.5	Adequate		
Clinton Avenue	Concrete	1	15.5	15.5	Girder	21.0	To be rebuilt
Footbridge (Stadium)	Timber	1	16.5	16.5	Adequate		
Footbridge (Rich Street)	Timber	1	27.0±	27.0±	Girder	31.0	To be rebuilt
Madison Avenue	Girder	1	31.0	31.0	Adequate		
Footbridge (Allen Street)	Timber	1	16.0	16.0	Girder	27.0	To be rebuilt
U.S.G.S. Gaging Weir	Dam	1	16.0	16.0	Dam	27.0	To be relocated
Valley Street	Concrete	2	1-10.5 & 1-12.5	27.5	Adequate		

TABLE 7

Utility Crossings to be Removed or Relocated

Location	Owner	Description
Elizabeth River		
City of Elizabeth		
Front Street	N.J. Bell Telephone Co.	3" Telephone Cable
Front Street	Union County	Electric Cable
South First Street	Union County	Electric Cable
South First Street		Cable (concrete casing)
Central Railroad	Central Railroad	Signal Cables
Central Railroad	Western Union	Telegraph Cables
Baltic Street	Union County	Electric Cable
Summer Street	Union County	Electric Cable
Townships of Union and Hillside		
Below Lehigh Valley Railroad	Schering Corporation	8" Sanitary Sewer
Below Salem Road	Elizabethtown Water Company	12" Water Main
Below Salem Road		6" Sanitary Sewer
Above Route No. 29	Joint Meeting	16" Sanitary Sewer
Below Union Avenue	Elizabethtown Water Company	6" Water Main
Lightning Brook Tributary		
Below Union Avenue	Joint Meeting	42" Sanitary Sewer (abandoned)

Dams

The six existing dams across the Elizabeth River are included in the summary of bridges, Table 6, and are shown on the continuous profiles on Plates 8, 9, and 10. Two are control weirs for U. S. Geological Survey stream gaging stations located downstream of Valley Street in Irvington and upstream of Westfield Avenue in Elizabeth. Both must be rebuilt when channel improvement of these reaches is undertaken. It is recommended that the Irvington Station be relocated and incorporated in the new Chancellor Avenue bridge when that structure is built in order to record total inflow off the Elizabeth River into the detention basin system. However, before being discontinued, the present station should be maintained for a short period to obtain correlation between flood records and to check flood routing computations on the intervening reach of the improved flume. Relocation of the Elizabeth Station at Ursino Dam is also recommended when that dam is modified to provide the recommended control. Such relocation will eliminate flood backwater now experienced at the present station for the larger floods and provide records of the suppression obtained from the recommended series of detention basins. If possible, gaging stations should be incorporated in the outlet control works of the Route No. 29 and Salem Pond Detention Basins to record the outlet flood hydrograph at those points.

Two low rock dams below Trotters Lane in Elizabeth are obstructions to flow and should be removed. Two dams are located in the Townships of Union and Hillside -- the Salem Pond Dam above Salem Road and Ursino Dam upstream of Trotters Lane. It is proposed that the former be removed and the latter modified, as shown in cross-section in Plate 9, to provide the outlet control for the Ursino Detention Basin. In addition to these dams across the main Elizabeth River channel, it is recommended that the Faitoute Dam on the West Branch tributary be rebuilt to conform to the proposed modification of the Vaux Hall Road bridge and West Branch approach channel to the Salem Pond Detention Basin.

COST ESTIMATES

Estimates of cost of the Elizabeth River project are not included as a part of this report. While the State, as a participant in the cooperative program, has prepared the details of the hydraulic features of the flood control improvements presented herein and will review structural plans prior to construction to assure their conformity to the recommended plan and their safe operation, preparation of construction drawings and estimates of costs are referred to the interested counties and municipalities. In addition to the plates and tables submitted under the Recommended Plan, Drawings I to IV, inclusive, showing details of the detention basin control works are available to assist in the preparation of these estimates.

REAL ESTATE ACQUISITION

The acquisition of real estate required for the development of the recommended plan can be divided into two classes:

(1) Lands required for the detention basin areas.
(2) Lands required for the channel improvements.

The first of these lands is to be acquired by joint effort of all interested agencies and transferred to the Union County Park Commission for development into parks in accordance with the plan submitted herein. The second class is the sole responsibility of the municipality in which the improved channels are located.

Actual acquisition of lands required for channel improvements is not considered necessary. Under the provisions of Chapter 229, Laws of 1938, Amending Title 40, Chapter 56-1, Revised Statutes, the lands required can be defined by the establishment of encroachment lines conforming to the width of channel required for the safe passage of flood flows. For such lands, past practice has provided that no payment be made on the theory that under the common law the riparian property owner is responsible for providing a channel of adequate capacity through his lands and that where walls are constructed or the stream is enclosed and improved through private property and no direct assessment for the cost of such improvement is made against the riparian property owners, those owners benefit to the value of the lands required for such improvements. Establishment of such encroachment lines is a matter of highest priority and should be undertaken at once in order to prevent encroachments by buildings, fills, and other private construction on the required right of way. When established, the encroachment line should be properly monumented and adequately designated on maps filed with the building inspector and other officials interested in construction. The cost involved is not great. With the right of way protected, the actual construction of the improved channels can be deferred until such time as and when required by flood damages.

While the progress in the acquisition of lands for detention basins has been most gratifying, highest priority should still be given this phase of the plan. In accordance with the recommendations of Special Report 1 of the Joint Engineering Committee, "Control of Floods on the Elizabeth River, Section No. 1, Salem Road-County Line (Mill Road), Union County," 90 percent of the lands required for the Route No. 29 and Salem Pond Detention Basins has been acquired and turned over to the Union County Park Commission. This program should be extended at once to the area below Salem Road to insure the Ursino Detention Basin. The various methods by which lands can be acquired and have been acquired along the Rahway River by the Union County Park Commission for its Rahway River parkway were summarized in Special Report 1. These methods will be repeated in order that the report may be complete in all phases of the work involved in carrying out the recommended plan.

"Methods which have proven successful along the Rahway River are as follows:

1. Donations by municipalities of public lands which had not been specifically acquired for parking of the river.

2. Specific purchase by municipalities of lands required for parking of the river and donation of same to the Park Commission.

3. Cooperation of municipalities with the Park Commission in cases which involved tax and assessment distressed properties by adjustment of taxes and assessments where private owners were willing to deed to the Commission the portion of the property needed for park purposes.

4. Donations by private owners with foresight sufficient to realize that the improvement and parking of the lowlands along the river would increase the value of the balance of their properties.

5. Free sale on very favorable terms by private property owners to the Park Commission of the rear portions of their properties adjoining the river.

6. Direct purchase by Park Commission.

7. Condemnation by Park Commission."

DAMAGES

The special features of the Elizabeth River flood problem have been discussed in the Introduction. Flood damages in the basin may be classified as follows:

1. Past damages which have been eliminated or greatly alleviated by relief work programs similar to the procedure of step construction recommended herein.

2. Past damages for which protection is to be provided against their recurrence.

3. Future damages, which would occur if the natural flood storage of the basin were to be destroyed, to be eliminated by the recommended plan.

4. Future damages, due to increased flood runoff to be experienced by the continued development of the basin, which can be alleviated only by the channel improvement measures of the recommended plan.

No estimate of damages in terms of dollars and cents is presented in this report. This estimate can best be made by local officials who must also evaluate benefits and determine equitable allocations of cost. General data on the extent and frequency of damages are presented for assistance in the preparation of such estimates.

Irvington

Much of the flood damage in this reach has been either eliminated or greatly reduced by the channel improvements constructed as work-relief projects between 1933 and 1939. Prior to completion of these improvements, serious flooding was frequently experienced at most points along the river. Stream flow and other records indicate that flooding occurred at Nye Avenue, Lyons Avenue, Springfield Avenue, Mill Road, and along the Newark Flume reach four or five times a year. Damage for the July 23, 1938 flood would have been considerably greater had not the channel improvement been partially completed at that time, particularly at Springfield and Nye Avenues where satisfactory relief was obtained.

In 1930, the flood problem in Irvington was brought forcibly to the attention of interested parties by a severe flood of unknown magnitude that occurred on July 22 of that year. As a result of the damages and inconveniences suffered during this flood, the Irvington stream gaging station was installed to provide data for study, and the Town of Irvington undertook one of the first channel improvement projects in the State. Bridges at Nye and Lyons Avenues were rebuilt by Essex County. Extensive flood studies were made by the Town, the County, and this Division by the Rational Method, based on observed data at the Irvington gaging station. Unfortunately, this method failed to disclose the high degree of storm sewer suppression involved in those records, with the result that the design flood adopted in this report has had to be increased above the design capacity of parts of the Irvington improvement.

No great increase in flood damage is anticipated in this area which is now fully developed and storm sewered. Present flood damage is confined to the following reaches:

Newark Flume - This reach constitutes the area of maximum flooding. Capacity of the existing concrete flume is approximately two-thirds that which should be provided. For the maximum floods of recent years, July 23, 1938 and September 14, 1945, which frequency studies indicate may be expected to be equaled or exceeded, on the average, once in 15 years, observed high waters at the Irvington gaging station rose five feet over the top of the walls. For the 17-year period, 1931-38 and 1940-49, stream flow and other records indicate that flooding has been experienced approximately 25 times in varying degrees along this reach, with a maximum of six times in 1936. However, as building, in general, has been restricted in the flood area and protective measures have been taken by those property owners subject to frequent high water, damage for the most part has been confined to the flooding of garages and cellars and to the inconveniences arising from frequent flooding.

Chancellor Avenue-Yale Avenue - Backwater flooding extending to Yale Avenue and for some distance upstream thereof is created by the twin pipe culvert at Chancellor Avenue. The depth and extent of flooding for the July 23, 1938 flood are shown on the continuous profile, Plate 8. While flooding in this reach is severe and frequent, damage has been negligible due to the high banks and type of development of adjacent lands. For the larger floods, however, the inadequate capacity of the Chancellor Avenue culverts may seriously affect height of flood waters above Lyons Avenue.

Mill Road - The frequency and magnitude of flooding at this point has been increased by the upstream channel improvements. While the relatively low underclearance of the bridge and center pier losses undoubtedly contribute to the extent of flooding, the condition is due primarily to flood backwater from the unimproved and constricted channel downstream of Mill Road. During the flood of July 23, 1938 three concrete block garages on the east bank collapsed, and approximately four times a year two cellars are flooded and traffic is interrupted when flood waters overflow Mill Road.

Clinton Avenue and Lyons Avenue - Flooding in the vicinity of Clinton Avenue and at Lyons Avenue has been greatly alleviated by the Irvington Flume improvement. However, flood backwater computations have indicated that critical sections in the Irvington Flume exist downstream of Lyons Avenue and at the Clinton Avenue bridge and channel upstream and downstream thereof. While the capacity of these reaches proved adequate for the passage of both the July 23, 1938 and September 14, 1945 floods, a slight increase in discharge would undoubtedly have caused serious flooding at these bridges.

Union and Hillside

Much of the flood damages experienced in these Townships have been located on tributaries -- Lightning Brook, North and South Creeks, and the East and West Branches. Such flood damage will not be alleviated by the plan recommended herein, although the backwater effect on the East Branch will be reduced. Great increase in flood damage must be anticipated on many of these tributaries as these areas continue to develop. Additional studies which are beyond the scope of this report will be required to remedy these conditions.

On the main river, however, the extent of future damages will be limited by the acquisition of lowlands for the detention basins recommended herein. Under present conditions flood damage has been experienced at the points which are described in detail below. The observed flood high water for two floods, the July 23, 1938 and May 31, 1940, with estimated frequencies of once in 12 years and 6 years, respectively, under present conditions, are shown on the continuous profile, Plate 9.

Union Avenue - Frequent flooding has been experienced at this point with resultant damages to a dairy and one residence on the west bank, and a florist business on the east bank. Until measures are undertaken to realign the approach channel to the Union Avenue bridge and improve the stream channel by continuation of the Irvington Flume from Mill Road to the inlet of the Route No. 29 Detention Basin, increased flood damage may be expected. Probable modification of the bridge to meet design requirements of the plan is presented on page 63. Observed flood high water records indicate that for the period of record, 1924 to 1949, the roadway at Union Avenue has been overtopped at least 18 times, and flooding to some degree is now experienced at this point, on the average, four or five times a year.

Baldwin Place - Flooding of lowlands at the foot of Baldwin Place is a source of constant irritation. However, these lands have been acquired by the Union County Park Commission as part of the Route No. 29 Detention Basin and all structures, including eight residences, are to be demolished or moved to higher ground. Observed high water records indicate that cellars of these homes are now flooded five or six times a year. While adjacent property along Union Avenue outside of the proposed detention basin limits is now subject to occasional flooding, satisfactory protection will be provided by construction of the recommended dikes.

Harvard Avenue - Prior to the construction of the dikes and storm sewer extension in 1943 as part of the recommended plan, serious flooding was experienced along Harvard Avenue and on lowlands at the foot of Cornell Place and John, Spring, and Gardner Streets from backwater on the main river in the Salem Pond Detention Basin site. Flooding was frequent, and high water several feet deep in the vicinity of the intersection of Harvard Avenue and Cornell Place was not unusual. While the diking is adequate, satisfactory drainage of accumulated flood runoff behind the dike has not been provided.

Salem Road - Flood damage to property has been negligible at this crossing. During both major floods of recent years, July 23, 1938 and September 14, 1944, the roadway was not overtopped.

Conant Street - While flooding on the East Branch above Conant Street is frequent and severe, flooding at Conant Street due to backwater from North Avenue has been negligible. However, the frequency of such flooding is of interest in the appraisal of the flood problem on the East Branch. Observed flood high water records indicate that Conant Street has been overtopped approximately seven times since the major flood of record of July 23, 1938. Frequency of such flooding, which in addition to causing traffic interruptions at Conant Street increases the flood problem on the East Branch storm sewer system by backwater, will be greatly reduced by the recommended plan for the Ursino Detention Basin.

North Avenue - The frequency and magnitude of flooding at this point has been increased considerably in recent years by the accumulation of silt and debris in the approach channel and openings of the North Avenue bridge and in Ursino Lake. While flood damage has been limited primarily to the interruption of traffic, flooding of North Avenue constitutes a serious flood hazard to the Morris Avenue residential section of Elizabeth.

Ursino Dam - In 1928, following the then major flood of September 1, 1927, a 15-foot sluice gate was installed by the Elizabethtown Water Company Consolidated in its Ursino Dam to permit regulation of flood high water. Until 1929, when this reservoir was abandoned as a source of water supply, flood heights at this point and flood discharges at the Elizabeth gaging station were regulated by 24-hour operation of this gate. Since then the gate has been operated with less regularity and Ursino Lake itself has been given less maintenance.

While no appreciable flood damage has been experienced, the dikes on the west bank above Ursino Dam were damaged by the relatively minor flood of November 5, 1950, and until such time as the crest of Ursino Dam is lowered, the accumulation of silt is removed from the lake bed to provide additional storage, and the dikes are strengthened and raised, the possibility of serious damage to property along Morris Avenue will exist.

Elizabeth

The major flood problem on the lower river is the threat of loss of flood storage in Union and Hillside. Under present conditions the flood damage to property for the period of record, 1921 to date, has been limited to relatively small areas. However, the two maximum observed floods during this period, July 23, 1938 and September 14, 1944, are not of exceptional magnitude. Based on the assumption that the entire period of record is representative of present conditions, these floods have a frequency of recurrence of once in 12 years. However, as development of the basin, and particularly the improvement of the channel in Irvington, has increased the flood runoff from the Elizabeth River basin, the actual frequency of the July, 1938 and September, 1944 floods is considerably less than 12 years under present conditions. The present flood problem, therefore, is more critical than is indicated by past records, and large increases in flood damages must be anticipated if no relief is provided. Another special and important feature of the Elizabeth River problem is the adverse effect of present flood high water on street storm sewers which prevents satisfactory drainage of low sections of the City. In addition, high tides are a major factor which complicate protection of this area.

Observed high water profiles for four major floods on the lower river are given on Plate 10. Damages experienced during these floods are as follows:

July 28, 1897 - This flood of unknown magnitude and frequency was the most disastrous flood experienced on the Elizabeth River. High ground saturation at the beginning of the storm, excessive storm rainfall, and exceptionally high tide all constributed to the occurrence of the extremely high flood water experienced in most parts of the City. While the magnitude and frequency of this storm far exceed the limits of partial protection to be provided for control of floods on the Elizabeth River, the size of that flood as experienced under 1897 conditions is probably equaled or exceeded by the size of the design flood adopted for the recommended plan. The following description of flood damage, therefore, may be considered a basis for estimating the merits and benefits of the recommended channel improvements through Elizabeth.

Flood waters reached depths up to 17 feet above normal water. While considerable loss was experienced by high tide along the Sound, the greatest damage was suffered in the upper portion of the City. All storm sewers were overtaxed, traffic was practically at a standstill for several hours, and both the electric plant and water supply pumping station were forced to shut down. Greatest damage to buildings and stock was experienced in the Broad Street business section where flood waters reached depths up to 7 feet in many stores. Tracks of the Pennsylvania Railroad north of Broad Street were washed out, the Central Railroad underpasses were flooded to depths up to 10 feet. Cellars were flooded along First Street and in the vicinity of Fifth and Franklin Streets. Lowlands below Elizabeth Avenue on the east side of the river were inundated and isolated from the rest of the City. Water was five feet deep in Golden Street. Catherine Street was flooded from Lafayette Street to Emma Street, and Grand Street from 200 feet west of Catherine Street to Reid Street. Reid Street was flooded three feet deep, and Elizabeth

Avenue was severely damaged by washouts. Severe damage was suffered at Bridge Street where flood waters rose several feet over the top of the railing. Houses were damaged in the vicinity of Washington Avenue. At West Jersey Street the bridge was overtopped and lower floors of houses along the river were flooded, and at Price Street flood waters rose to the second stories of residences. Lumber from the Mulford Coal Yard washed away and caused severe flooding by forming a dam at West Grand Street bridge. At Crane Street the first floors of houses were flooded, and at Westfield Avenue flood waters overtopped the bridge and destroyed the Harris Mill. Considerable damage to gardens and property was experienced along the river from Morris Avenue to Prince Street; the Morris Avenue bridge was overtopped and badly damaged; and on the east side of the river in this vicinity buildings were swept from their foundations. The Irvington Avenue bridge was damaged and many basements were flooded on Sayre and Orchard Streets. Many families had to be evacuated and were left homeless in the wake of the high waters, and at least one death was attributed to the flood.

In the past 54 years since this flood, the character of the drainage basin above Elizabeth has changed tremendously, and each step in the progress of development has increased the flood potentialities of the lower river. If the storm of 1897 were to occur under present conditions, the extent and magnitude of flooding would be far greater, and damages, measured in thousands of dollars by standards of 1897, would undoubtedly be measured in millions under present-day values. While completion of the recommended plan for flood control would greatly reduce flood damages if this storm were to occur under future conditions, extensive damage would, nevertheless, be experienced in the City of Elizabeth.

October 9, 1903 - This flood approached in severity the great flood of July 28, 1897. While rainfall was not as heavy, high tide was estimated to be at least six inches higher than the extremely high tide which contributed to the damage suffered in the flood of 1897. Bridges were overtopped at Morris Avenue, and at Sayre, Crane, West Jersey, Bridge, and Summer Streets. The greatest flooding was experienced in the vicinity of West Jersey and Price Streets, where flood waters reached depths of five feet, and at Union Street, Harrison, and Crane Streets. Once again the City was plunged into darkness when flood waters reached the fire boxes of the electric plant, an estimated 75 to 100 families were left homeless, and a child was drowned in a flooded cellar a day after the storm.

July 23, 1938 - This flood may be considered to represent the maximum flood which can occur under present conditions without causing widespread and serious damage in the City of Elizabeth. Traffic was interrupted and cellars were flooded in many parts of the City as flood waters overtopped bridges, overflowed the stream banks, and surcharged storm sewers. The Trotters Lane bridge was overtopped by 2.5 feet of water, and at Morris Avenue, between Westfield Avenue and Sayre Street, business houses were inundated and suffered considerable stock loss. At Westfield Avenue and Harrison Street a garage and trucks were flooded; Crane Street was overtopped; and the Elizabethtown Water Company garage on Golden Street was inundated. Lumber and other materials stored in the Mulford Coal Yard were damaged, and flooding was experienced on Union Avenue between West Grand and West Jersey Streets and above Bridge Street.

May 31, 1940 - While the peak discharge of this flood was 400 cubic feet per second less than that experienced in July, 1938, flood high water below West Grand Street was greater due to higher tide backwater. However, damage was somewhat less during this flood, as much of the extensive damage suffered in the flood of July, 1938 occurred in the upper portion of the City above West Grand Street. During the period of stream gaging record four additional floods occurred on August 9, 1942, October 27, 1943, September 14, 1944, and November 8, 1947 which had frequencies equal to or exceeding that of the May 31, 1940 flood and damages approaching that experienced during the flood of July 23, 1938.

BENEFITS

No attempt has been made to evaluate, in terms of dollars and cents, present or future damages and benefits, nor the allocation of costs. However, it is considered that the size of flood for which protection is to be provided, the methods recommended for alleviating flooding, and the long-range construction program presented in this report offer the most economical solution to the flood problem on the Elizabeth River. Merits of the recommended plan are discussed in the Introduction. All county, municipal and other agencies must now determine, by a detailed analysis of damages and benefits, whether they are willing to suffer the damages and inconveniences of present and future flooding or expend the funds, as required, for the recommended control and improvement works. Moreover, as many interests must share the cost as well as reap the benefits of the proposed project, a careful analysis must be made to assure a fair distribution of the expense of the program.

Two fundamental principles govern the proper planning of such a public works program:

1. Benefits derived must equal or exceed the cost of the project.

2. The cost must be imposed on the area or interests benefited, in proportion to the benefits conferred.

In evaluating damages and benefits to be derived from a program of flood control, consideration must be given not only to present conditions but also to the future. While flood control benefits accrue throughout the life of the control works, the generation which builds the project usually bears the major burden of the cost and receives only a small percentage of the total benefits. However, the recommended plan for flood control of the Elizabeth River is rather unique in that it provides a program of step construction which includes not only measures for the immediate alleviation of the relatively minor damages and inconveniences of present flooding but, in addition, provides for safeguarding the drainage basin from future abuses, and permits the more expensive work to be deferred until such time as future flood runoff warrants such expenditures.

Flood control benefits are many. While some can be accurately determined or closely estimated, others, none the less real and usually comprising a major portion of the total, are of such an indirect or intangible nature that they cannot be readily evaluated in terms of dollars and cents. It is these indirect and intangible benefits which justify the assessment of the community at large, both county and municipal, for a considerable portion of the cost of flood control works.

General flood control benefits are as follows:

Release from Damages

Flood damages include not only direct physical destruction of property within the flooded area but, in addition, indirect damages to the general public both within and without the area subject to flooding. Indirect damages consist of such items as the general interruption of the business and social life of a community, interruption of transportation, loss of business, loss of profits, loss of wages, and cost of relief work and prevention of epidemics.

A serious aspect of many floods is the loss of life. There can be no doubt that protection to life is an important benefit from flood-relief measures and that it should be evaluated when costs and benefits are balanced.

Release from Real Estate Depreciation

Lands in and adjacent to areas subject to flooding are in a constant state of depreciation and drop sharply in value immediately after a damaging flood. By removing the flood menace, the lands thus become more attractive for development and return to their natural value. Benefits of this nature apply only to land that is habitable or usable under normal conditions and affected only by flood waters.

Reclamation of Swamp Land

Lowlands in flood plains which are unfit for development are made usable and increase in value when the meandering streams are confined in channels and the swamplands are drained, graded, or filled. By developing much of the waste lands of the Elizabeth River flood plain as detention basin sites to be incorporated in the Union County Park System for maintenance as public park lands, the community as a whole will benefit from the much needed recreational facilities provided.

Increase in Upland Values

Lands above the area of actual flooding are retarded in their development by their proximity to waste swamp areas or lands depreciated by actual flooding. Thus, by eliminating the unattractive areas subject to flooding, material increase in upland values will be experienced, especially if the reclamation and improvement of the flood areas are coupled with park development.

Intangible Benefits

Aside from those benefits mentioned above, certain intangible benefits accrue from a program of flood control which defy evaluation in terms of dollars and cents but none the less increase the happiness and well being of the community as a whole. The reduction of the mosquito nuisance, the improvement of the unsightly and unsanitary condition of the stream, and the general tendency to improve the healthfulness of the community are among the more important.

CONSTRUCTION PROGRAM

The flood control plan submitted herein requires no immediate large outlay of funds. Construction of the complete plan at the present time is not essential and is not recommended. A satisfactory solution of the Elizabeth River flood problem can be provided by a program of step construction of improvements made in accordance with the plan as and when required to alleviate flood damage. This procedure, however, requires long-range planning and the adoption of a comprehensive construction program to coordinate the efforts of the various affected agencies and to insure the maximum benefit from all monies expended for any reason whatsoever on river structures and improvements. For instance, the reconstruction of a bridge for any reason should be accompanied by sufficient improvement of adjacent channels to develop the maximum benefit of the bridge reconstruction. Similarly, channel improvements should include reconstruction of bridges of inadequate capacities.

Complete construction of the improved channel, however, need not be undertaken at one time. Such construction can be undertaken as separate partial improvement projects extended over a period of years -- first by increasing the capacity of the channel by widening and deepening, then by construction of walls, and eventually by paving the bottom -- all in accordance with the recommended plan. Each step of such a program should provide adequate temporary flood control relief until such time as the increase in flood runoff warrants additional construction.

In order to assist in the formation of a comprehensive improvement program, the following recommendations are submitted on the priority to be given the construction of the major features of the plan.

In Union County, the development of the detention basins will provide the most benefit for the least cost. Suppression of flood flows by the storage in these basins will defer for many years the need for most of the expensive improvement recommended for the lower river. The first priority should be given to the Salem Pond Detention Basin which provides the greatest amount of flood storage and entails the least cost for control works. Consideration should be given next to the Route No. 29 Detention Basin. While the control works are rather expensive, its development should not be deferred too long. This basin takes the shock of the flood runoff from the walled and paved flume of the upper drainage basin, and the suppression provided by the storage of the basin is needed to protect the outlet control works of the Salem Pond Basin. Construction of the inlet control works on the main river below Union Avenue can probably be deferred until the channel is improved above that point. However, the recommended relocation of North and South Creeks at the inlet of the Route No. 29 Detention Basin should be incorporated in the plans for the proposed Route No. 4. Eventually, development of the Ursino Detention Basin should be undertaken in order to derive the maximum degree of flood suppression from the detention basin system. Reconstruction of the Trotters Lane bridge should be undertaken when the Ursino Dam

spillway is modified. Special priority should be given to the enlargement of the North Avenue crossing to alleviate the present flooding at that point, the potential flood hazard to the Morris Avenue section of Elizabeth, and the backwater flooding now experienced on the East Branch tributary. Raising the North Avenue roadway and increasing the height of the Ursino Lake dikes should be undertaken as soon as possible to provide additional flood protection in this area. In addition, modification of the Ursino Dam and construction of the recommended parapet wall along North Avenue should not be deferred too long.

On the lower river, the construction schedule for the most part will be influenced by the location of future flood damages. Upon completion of the detention basins, immediate relief may be expected, provided construction is not delayed too long. However, as flood runoff continues to increase, channel capacities will again be overtaxed, and more and more local improvements will be required to relieve flooding. In establishing a construction schedule for the lower river, these future conditions should be anticipated as far as possible. In addition, the cost of the comprehensive improvements, including the reconstruction of bridges, should be distributed over a sufficient period of time to maintain annual costs within the financial ability of the interested agencies. Where possible, the program should be coordinated with other civic improvements, such as the reconstruction of bridges to relieve traffic congestion and the development of automobile parking areas and parked lands for recreation. Under present conditions, the most relief for the least cost can be obtained by deepening and enlarging the channel from below South Broad Street to the head of navigation at Mattano Park so as to relieve flood backwater on the river above South Broad Street and on the street storm sewer system. The recommended removal of inadequate bridges at Murray and Crane Streets involves little cost and should not be delayed. Upon completion of the Trenton Avenue approach to the New Jersey Turnpike, the poorly aligned bridge, including abutments, at Baltic Street should be removed. Another improvement which may be justified under present conditions is the construction of the recommended walled and paved flume in the vicinity of the Central Railroad of New Jersey bridge to reduce flood levels as far upstream as Trotters Lane.

For the upper river above the detention basins, no appreciable increase in future runoff is to be expected. Thus, the construction program can be based on past records of actual flood damage rather than estimates of probable damages to be experienced by increased runoff of the future. Moreover, the flood problem in Irvington has been simplified and the cost of a flood control construction program greatly reduced by past improvements which have satisfactorily alleviated or greatly reduced flood damages in this reach of the river. Reconstruction of the bridge and channel at Chancellor Avenue, and possibly the Mill Road crossing, should be incorporated in the plans for the extension of Route No. 4 through Irvington. Reconstruction of the Newark Flume, the most expensive improvement recommended, the channel below Lyons Avenue, the Clinton Avenue bridge, and the channel upstream and downstream thereof may best be undertaken by a program of step construction with cost of improvement distributed over a number of years. Extension of the Irvington Flume from Mill Road to below Union Avenue and modification of the Union Avenue bridge should be undertaken prior to or shortly after completion of the outlet control works of the Route No. 29 Detention Basin so as not to unduly delay the construction of the inlet control works of that basin.

ACKNOWLEDGMENTS

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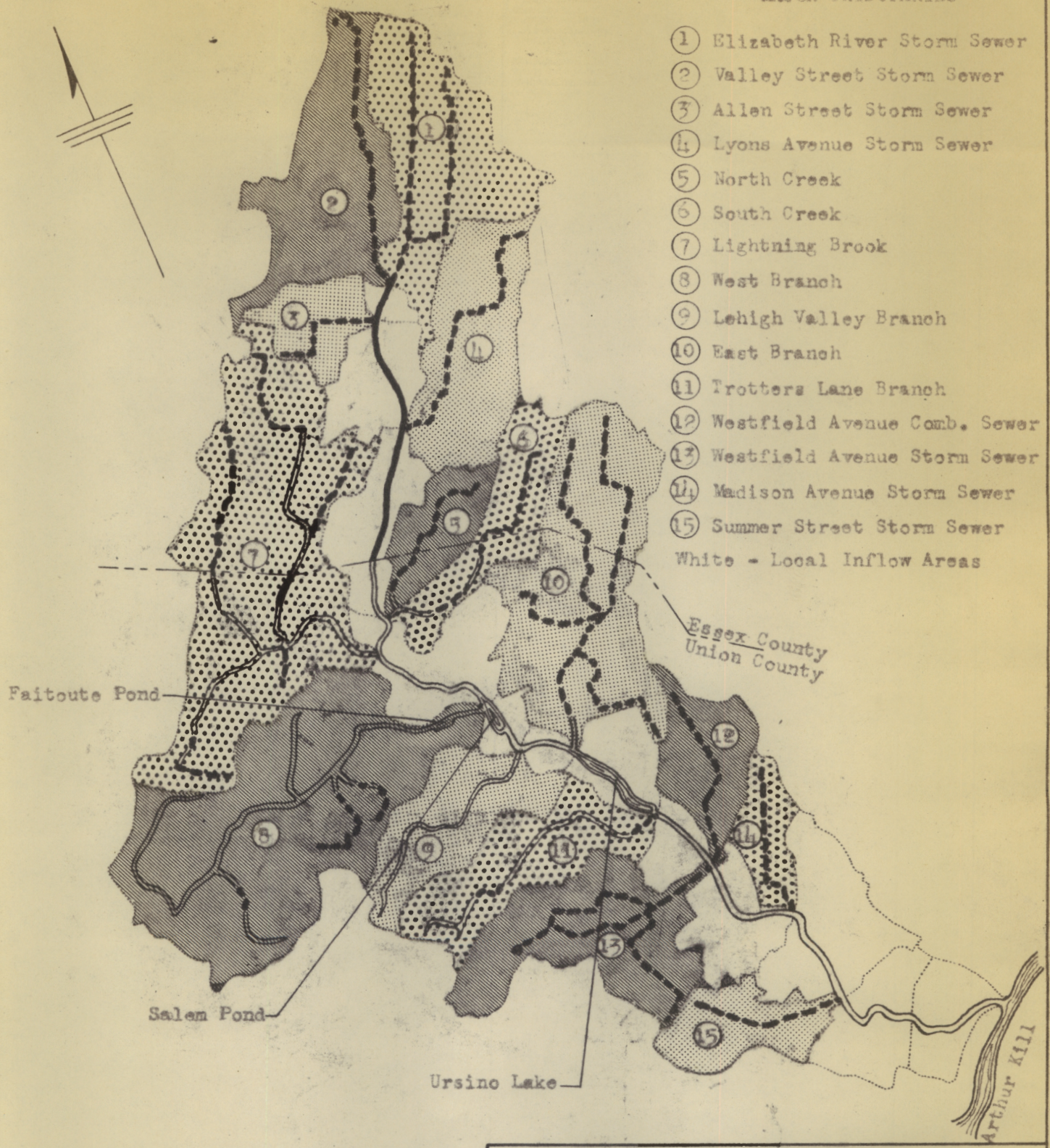
The preparation of this report, the hydrologic analysis of records, and the design of the recommended plan have been made by Robert E. Cyphers, Jr., Principal Hydraulic Engineer, under the general direction of George R. Shanklin, Assistant Chief Engineer. Invaluable assistance was given by Anthony M. Lunetta, Assistant Hydraulic Engineer, in the hydraulic determinations of the plan and the preparation of the report.



LEGEND

Improved Channel-Storm Sewer

Improved Channel-Open Walled Flume

Unimproved Channel

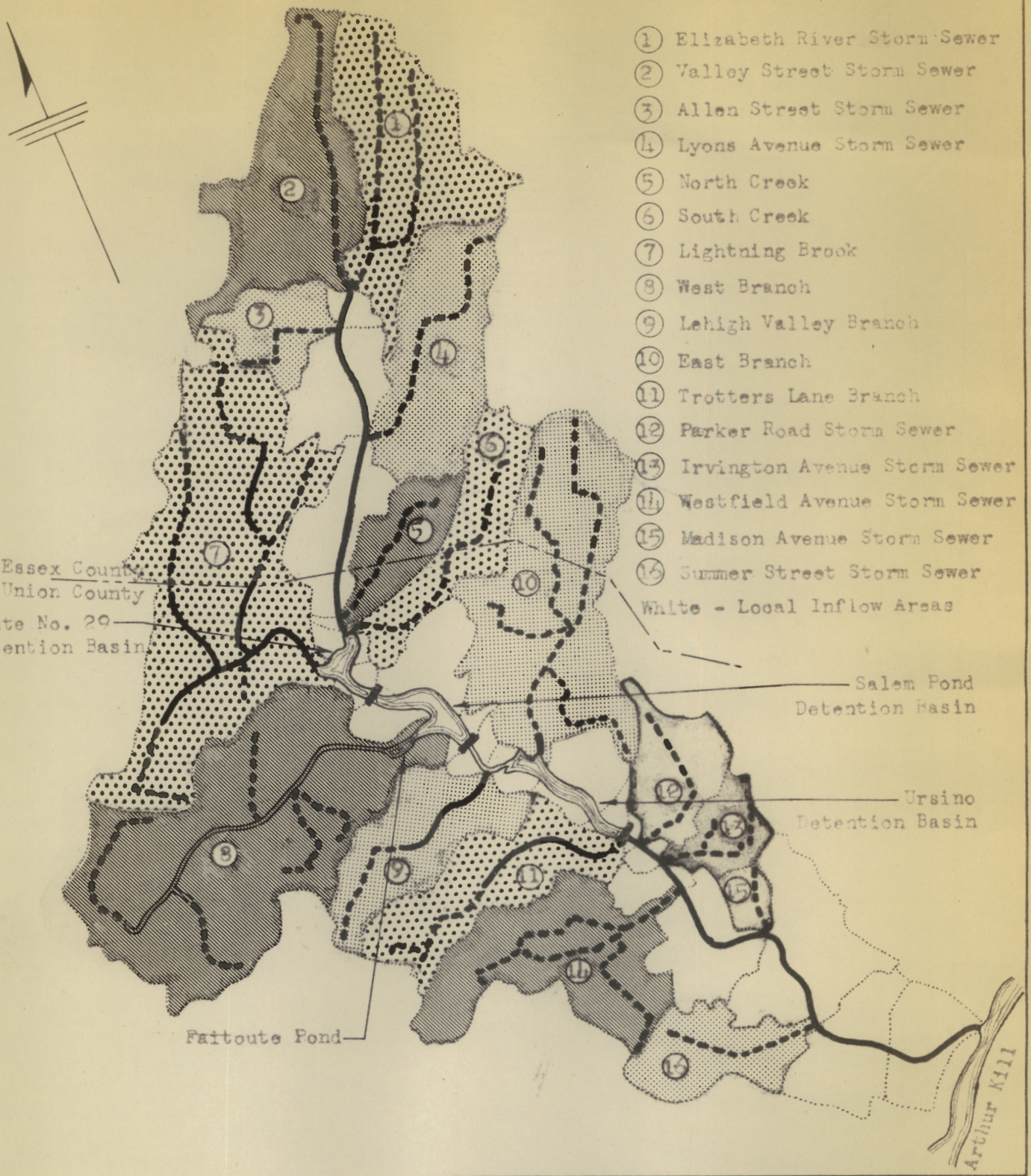
State of New Jersey
Department of Conservation and
Economic Development
Division of Water Policy and Supply

ELIZABETH RIVER FLOOD CONTROL

PRESENT STATUS OF CHANNEL IMPROVEMENT
ELIZABETH RIVER BASIN

Scale: 1000 500 0 1000 YARDS

April, 1951



LEGEND

Improved Channel-Storm Sewer

Improved Channel-Open Walled Flume

Improved Channel-Earth Trapazoidal

Outlet Control Works of Detention Basins

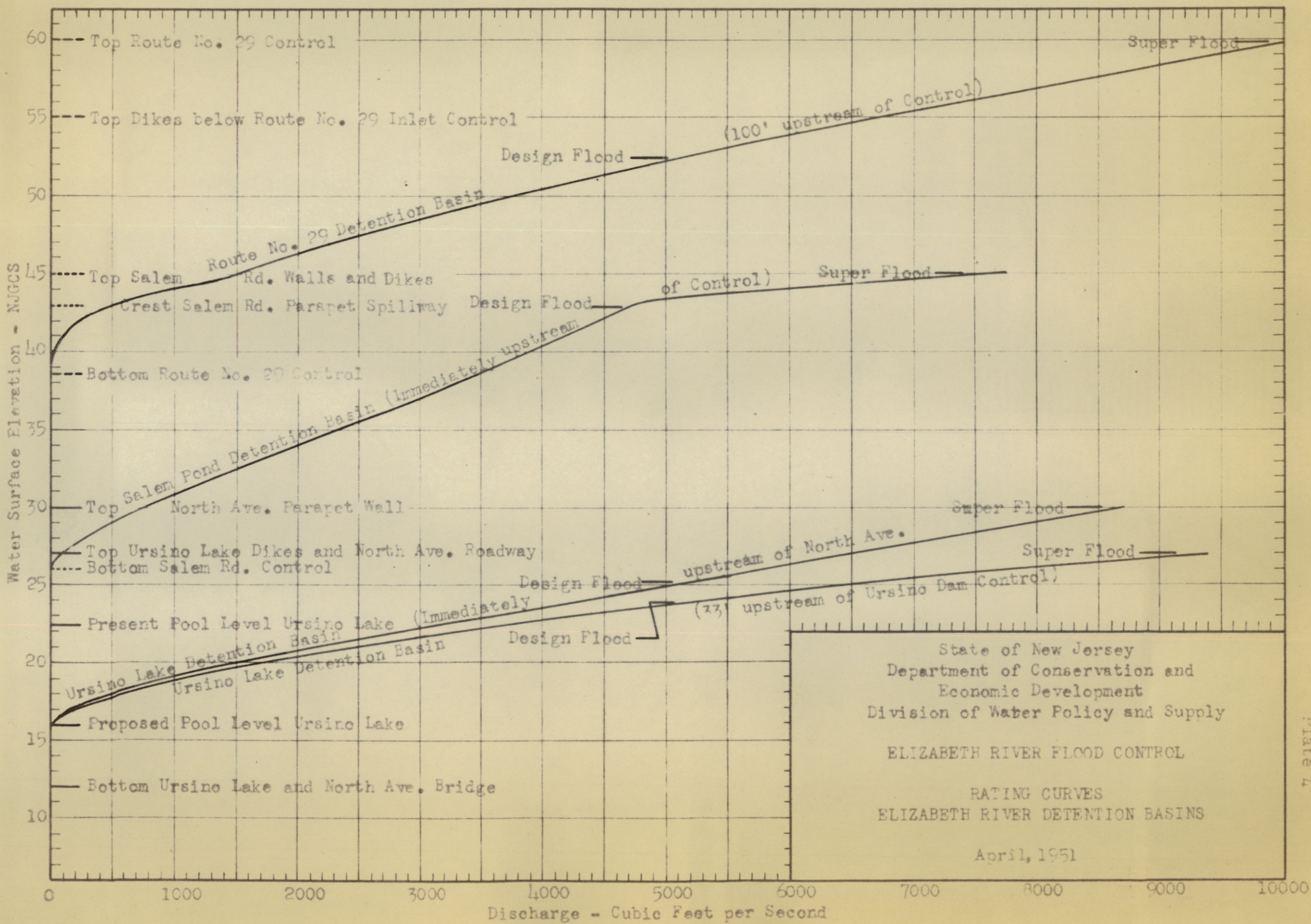
State of New Jersey
Department of Conservation and
Economic Development
Division of Water Policy and Supply

ELIZABETH RIVER FLOOD CONTROL

RECOMMENDED PLAN
ELIZABETH RIVER BASIN

Scale: 1000 500 0 1000 YARDS

April, 1951



State of New Jersey
Department of Conservation and
Economic Development
Division of Water Policy and Supply

ELIZABETH RIVER FLOOD CONTROL

RATING CURVES
ELIZABETH RIVER DETENTION BASINS

April, 1951

Plate 7

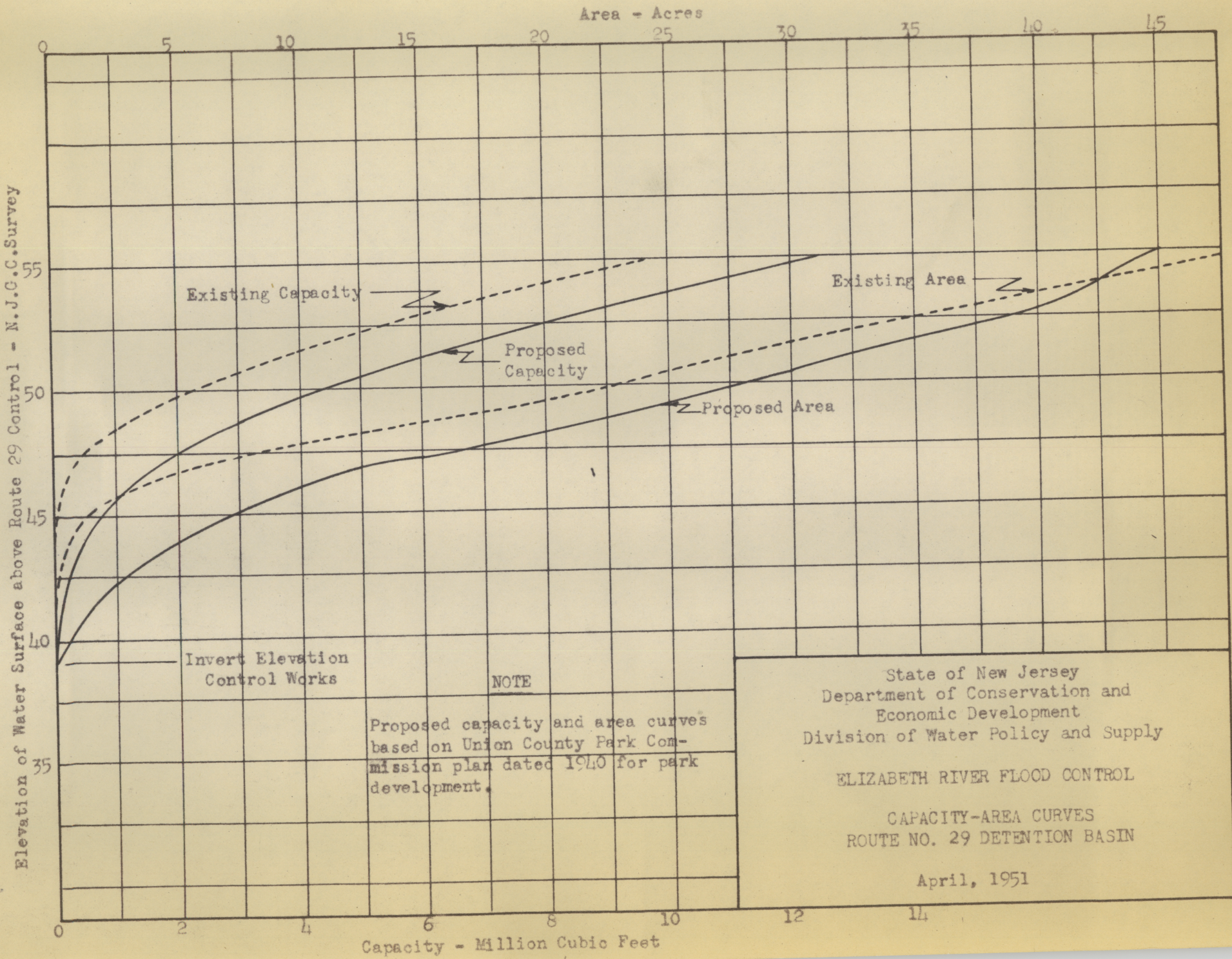
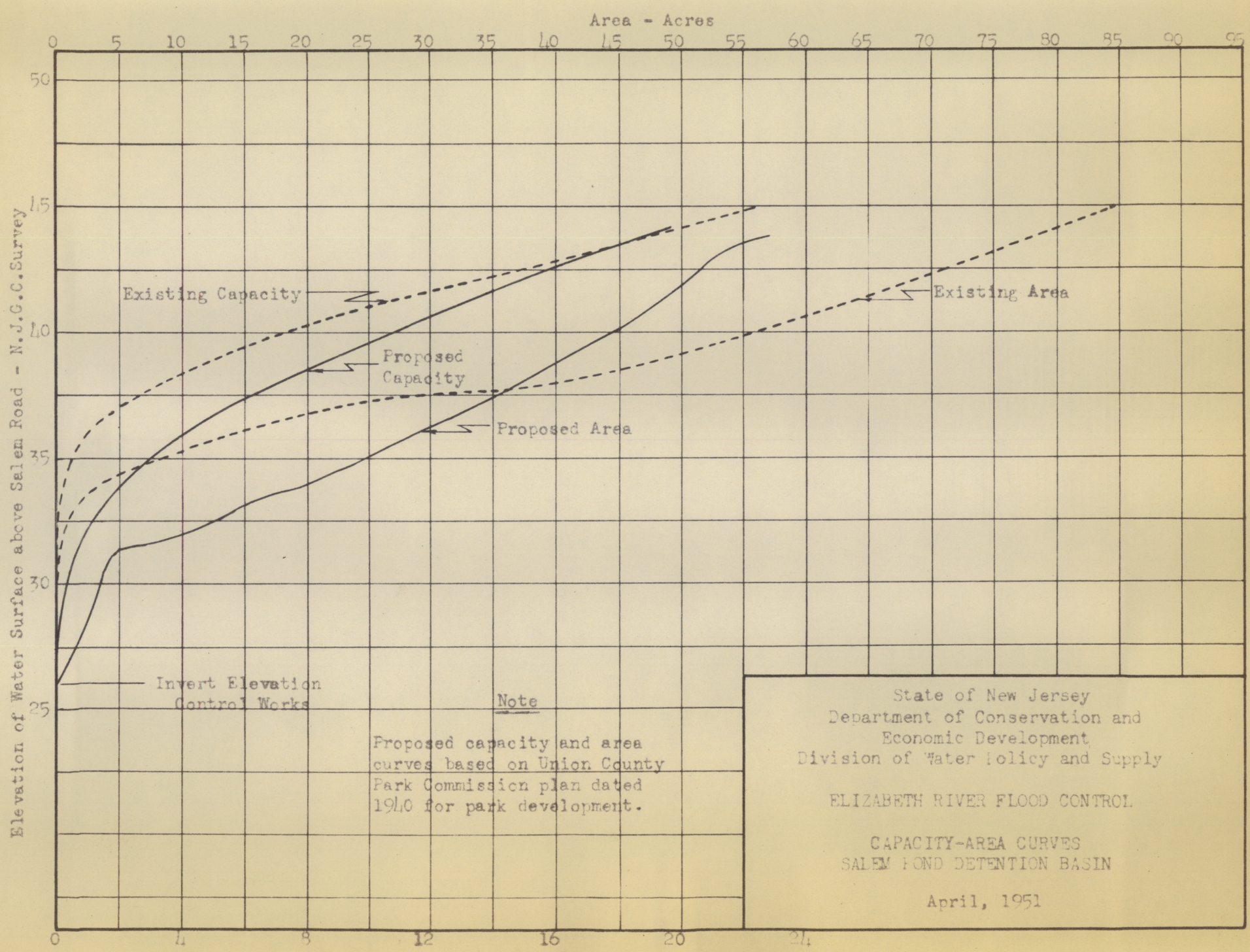

Area - Acres
0
5
10
15
20
25
30
35
40
45
Elevation of Water Surface above Route 29 Control - N.J.C.C.Survey
55
50
45
40
35
Existing Capacity
Proposed Capacity
Existing Area
Proposed Area
Invert Elevation Control Works
NOTE
Proposed capacity and area curves based on Union County Park Commission plan dated 1940 for park development.
State of New Jersey
Department of Conservation and Economic Development
Division of Water Policy and Supply
ELIZABETH RIVER FLOOD CONTROL
CAPACITY-AREA CURVES
ROUTE NO. 29 DETENTION BASIN
April, 1951
0
2
4
6
8
10
12
14
Capacity - Million Cubic Feet

Plate 5


Area - Acres
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
50
45
40
35
30
25
Elevation of Water Surface above Salem Road - N.J.G.C.Survey
Existing Capacity
Proposed Capacity
Proposed Area
Existing Area
Invert Elevation Control Works
Note
Proposed capacity and area curves based on Union County Park Commission plan dated 1940 for park development.
0 4 8 12 16 20 24
Capacity - Million Cubic Feet
State of New Jersey
Department of Conservation and Economic Development
Division of Water Policy and Supply
ELIZABETH RIVER FLOOD CONTROL
CAPACITY-AREA CURVES
SALEM POND DETENTION BASIN
April, 1951
Plate 6

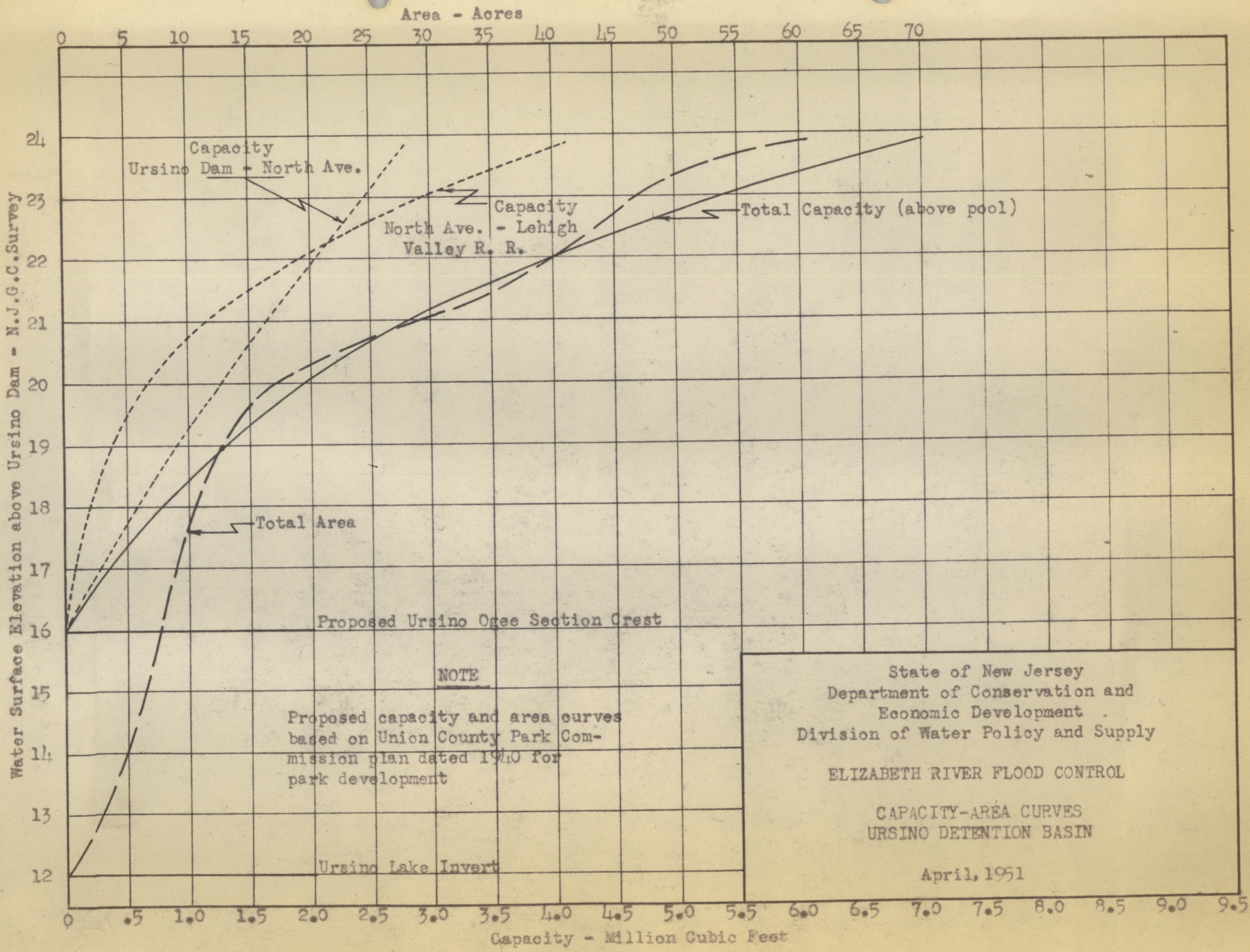

Area - Acres
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Water Surface Elevation above Ursino Dam - N.J.G.C.Survey
24 23 22 21 20 19 18 17 16 15 14 13 12
Capacity
Ursino Dam - North Ave.
Capacity
North Ave. - Lehigh
Valley R. R.
Total Capacity (above pool)
Total Area
Proposed Ursino Ogee Section Crest
NOTE
Proposed capacity and area curves based on Union County Park Commission plan dated 1940 for park development
Ursino Lake Invert
0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5
Capacity - Million Cubic Feet
State of New Jersey
Department of Conservation and
Economic Development
Division of Water Policy and Supply
ELIZABETH RIVER FLOOD CONTROL
CAPACITY-AREA CURVES
URSINO DETENTION BASIN
April, 1951

Plate 7