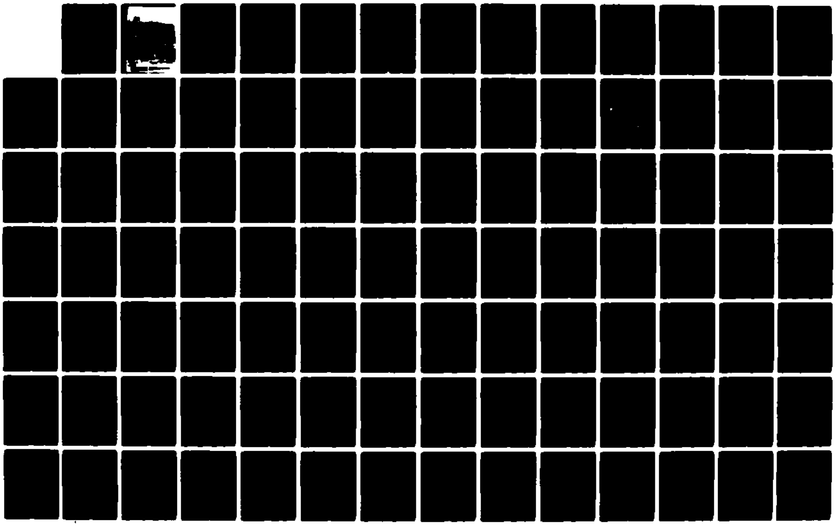
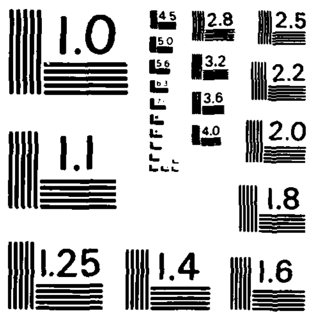
AD-A134 161 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX H BLOOMINGTON LA..(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83 1/5

UNCLASSIFIED MWA-83-P-APP-H-VOL-2 F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A134 161

DTIC FILE COPY

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
MWA-83-P

2. GOVT ACCESSION NO.
A134161

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY, [redacted] Appendix [redacted] H
VOLUME II

5. TYPE OF REPORT & PERIOD COVERED
Final

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Baltimore District
U.S. Army Corps of Engineers, ATTN: NABPL
P.O. Box 1715, Baltimore, Maryland 21203

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Baltimore District
U.S. Army Corps of Engineers, ATTN: NABPL
P.O. Box 1715, Baltimore, Maryland 21203

12. REPORT DATE
September 1983

13. NUMBER OF PAGES
~~3,000 pages, 1 plate~~

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
water resources planning; water demand; water supply; Potomac River; groundwater; reservoir; raw water interconnection; Low Flow Allocation Agreement; Bloomington Lake; Little Seneca Lake; wastewater reuse; Potomac Estuary Experimental Water Treatment Plant; PRISM/COE; water pricing; water conservation; demand reduction; Cooperative Operations on the Potomac; flowby;

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
In response to the Water Resources Development Act of 1974, the Baltimore District of the U.S. Army Corps of Engineers conducted a comprehensive water supply analysis of the Metropolitan Washington Area (MWA). Severe water supply shortages had been forecast for the MWA and the study was undertaken to identify and evaluate alternative methods of alleviating future deficits. Initiated in 1976, the study was conducted in two phases over a 7-year period. The first, or early action phase, examined the most immediate water supply problems and proposed solutions that could be implemented locally. The second or long

19. KEY WORDS (continued)

water shortage; reregulation; finished water interconnection; Occoquan Reservoir; Patuxent Reservoir; Potomac Estuary; Water Supply Coordination Agreement; Verona Lake

20. ABSTRACT (continued)

range phase included an analysis of the full spectrum of structural and nonstructural water supply alternatives. In addition to such traditional water supply alternatives as upstream reservoir storage, groundwater and conservation, the study also considered such innovative measures as wastewater reuse, raw and finished water interconnections between the major suppliers, the use of the upper Potomac Estuary, reregulation and water pricing. A key tool in the study was the development and use of a basin-specific model that was used to simulate the operation of all the MWA water supply systems and sources under various drought scenarios. As the study progressed, local interests used the technical findings of the Corps' study to make great strides toward a regional solution to their water supply problems. The Corps' study concluded that with the implementation of a series of regional cooperative management agreements, contracts, selected conservation measures, and the construction of one local storage project to be shared by all, severe water supply shortages could effectively be eliminated for the next 50 years. The Final Report of the study is comprised of eleven volumes which provide documentation of both the study process and the results of all the technical analyses conducted as part of the study.

METROPOLITAN WASHINGTON AREA
WATER SUPPLY STUDY

APPENDIX H

BLOOMINGTON LAKE REFORMULATION STUDY

VOL. II

ANNEXES H-III THROUGH H-X

Department of the Army
Baltimore District, Corps of Engineers
Baltimore, Maryland

September 1983

REPORT ORGANIZATION*

METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY

Appendix Letter	Appendix Title	Annex Number	Annex Title
	Main Report		
A	Background Information & Problem Identification		
B	Plan Formulation, Assessment, and Evaluation	B-I	Water Supply Coordination Agreement
		B-II	Little Seneca Lake Cost Sharing Agreement
		B-III	Savage Reservoir Operation and Maintenance Cost Sharing Agreement
C	Public Involvement	C-I	Metropolitan Washington Regional Water Supply Task Force
		C-II	Public Involvement Activities - Initial Study Phase
		C-III	Public Opinion Survey
		C-IV	Public Involvement Activities - Early Action Planning Phase
		C-V	Sample Water Forum Note
		C-VI	Public Involvement Activities - Long-Range Planning Phase
		C-VII	Citizens Task Force Resolutions
		C-VIII	Background Correspondence
		C-IX	Coordination with National Academy of Sciences - National Academy of Engineering
		C-X	Comments and Responses Concerning Draft Report
D	Supplies, Demands, and Deficits	D-I	Water Demand Growth Indicators by Service Areas
		D-II	Service Area Water Demand & Unit Use by Category (1976)
		D-III	Projected Baseline Water Demands (1980-2030)
		D-IV	Potomac River Low Flow Allocation Agreement
		D-V	Potomac River Environmental Flowby, Executive Summary
		D-VI	PRISM/COE Output, Long-Range Phase
E	Raw and Finished Water Interconnections and Reregulation	E-I	Special Investigation, Occoquan Interconnection Comparison
F	Structural Alternatives	F-I	Digital Simulation of Groundwater Flow in Part of Southern Maryland
G	Non-Structural Studies	G-I	Metropolitan Washington Water Supply Emergency Agreement
		G-II	The Role of Pricing in Water Supply Planning for the Metropolitan Washington Area
		G-III	Examination of Water Quality and Potability
H	Bloomington Lake Reformulation Study	H-I	Background Information
		H-II	Water Quality Investigations
		H-III	PRISM Development and Application
		H-IV	Flood Control Analysis
		H-V	US Geological Survey Flow Loss and Travel Time Studies
		H-VI	Environmental, Social, Cultural, and Recreational Resources
		H-VII	Design Details and Cost Estimates
		H-VIII	Drawdown Frequency and Yield Dependability Analyses
		H-IX	Bloomington Future Water Supply Storage Contract
		H-X	Novation Agreement
I	Outlying Service Areas		

*The Final Report for the Metropolitan Washington Area Water Supply Study consists of a Main Report, nine supporting appendices, and various annexes as outlined above. The Main Report provides an overall summary of the seven-year investigation as well as the findings, conclusions, and recommendations of the District Engineer. The appendices document the technical investigations and analyses which are summarized in the Main Report. The annexes provide detailed data or complete reports about individual topics contained in the respective appendices.

ANNEX H-III

PRISM DEVELOPMENT AND APPLICATION

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H-III - PRISM DEVELOPMENT AND APPLICATION

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H-III

PRISM DEVELOPMENT AND APPLICATION

The Metropolitan Washington Area's (MWA) water supply problems have been the subject of many studies, investigations, and reports. These past examinations have concentrated primarily on new projects to augment the flow in the Potomac River which furnishes the MWA with nearly two-thirds of its water supply needs. The remaining water supply needs of the major users (Washington Aqueduct Division, Fairfax County Water Authority, and Washington Suburban Sanitary Commission) are met by the existing Occoquan and Patuxent Reservoirs.

With the recent advances in operations research and the improved capability for computer simulation of complex systems, it became apparent in the late 1970's that a computer model of the MWA water supply system might be beneficial to all parties involved. Better management of existing sources might delay or negate the need for new structural projects in the headwaters of the Potomac River Basin. This general observation was reinforced with the publication of the Corps' August 1979 Progress Report which demonstrated the significant advantages to be gained by regional management of the varied water supply sources, particularly the then soon-to-be-completed Bloomington Lake project.

Such a computer simulation model for the MWA water supply system was developed, initially by a research team from Johns Hopkins University and later modified by the Corps of Engineers. The model, which was named the Potomac River Interactive Simulation Model (PRISM), was developed as a site-specific program for the major water supply utilities using the Potomac, Occoquan, and Patuxent sources.

PRISM was subsequently used as the basic analytical tool for the long-range phase of the MWA Water Supply Study because it offered several attractive features: (1) the potential to analyze many water supply management schemes, (2) the ability to examine the effects on water supply of storage reallocation within Bloomington Lake, (3) the capability to investigate different regulation schemes within Bloomington Lake's existing authorization, (4) the potential to consider various flowby levels and the impacts on water supply surpluses or shortages, and (5) the ability to simulate long, historic droughts and observe the effects of different management schemes on stream flows, remaining reservoir storages, and water shortages.

Because of PRISM's importance to both the Bloomington Lake Reformulation Study and the long-range phase of the overall MWA Water Supply Study, the purpose of Annex H-III is to fully describe the development and application of PRISM to the MWA water supply system.

PRISM/COE DEVELOPMENT

ORIGINAL MODEL DEVELOPMENT

In September 1977, a research team from the Department of Geography and Environmental Engineering at the Johns Hopkins University was awarded a matching funds grant from the Office of Water Research and Technology, U.S. Department of

Interior, and support from the Interstate Commission on the Potomac River Basin, the Commonwealth of Virginia, and the State of Maryland. The Hopkins project, entitled "Policy Analysis of Reservoir Operation in the Potomac River Basin," set out to develop and analyze potential operating policies for the reservoirs which serve the metropolitan Washington, D.C. area. Jared L. Cohon, Associate Professor, and Charles S. ReVelle, Professor of Geography and Environmental Engineering, were co-principal investigators for the project. A team of graduate research assistants, including Richard N. Palmer, James A. Smith, Jeffrey R. Wright, and Miriam Heller, provided major input to the study. Dr. Palmer, now Assistant Professor of Civil Engineering at the University of Washington, managed the entire project and developed the interactive simulation model. Dr. Palmer also worked with Baltimore District personnel to adapt the original model to the needs of the Bloomington Lake Reformulation Study.

The Hopkins University research, which was two years in length, resulted in the development of a series of optimization and simulation programs designed to model the water supply system which serves the MWA. These programs simulated the operation of the three water supply agencies that serve the region - the Fairfax County Water Authority (FCWA), the Washington Suburban Sanitary Commission (WSSC), and the Washington Aqueduct Division of the Army Corps of Engineers (Aqueduct). Five potential sources of water were included in the programs: Bloomington Lake, Savage River Reservoir, Occoquan Reservoir, Rocky Gorge and Triadelphia Reservoirs located on the Patuxent River, and the Potomac River near Little Falls, Maryland.

During the first year of study, linear programming models were developed to determine optimal management strategies for the reservoir system under a variety of operational objectives and constraints. Results from these studies indicated that significant gains in effective and efficient management could be obtained if the reservoirs were managed conjunctively. Because of the constraints and limitations imposed by the use of a linear program, however, several important features were not included in these linear programming models.

The most important feature absent from the linear programming formulations was the incorporation of the Low Flow Allocation Agreement (LFAA). The reader is referred to Annex H-I and Appendix D for detailed information about the LFAA. This Agreement, a result of many years of negotiations among the downstream users of the Potomac River, is a legally binding agreement that specifies the allocation of water to be made to the regional water supply agencies from the Potomac River during periods of drought. Most simply summarized, the LFAA bases the allocated withdrawals on a ratio of previous water use and available alternative sources. Although representing a first step in the regional management of water supply, the LFAA does not represent a comprehensive regional management plan. The LFAA specifies how water is to be allocated among the various jurisdictions during a drought; however, it does not give guidance to jurisdictions on how they might lessen the adverse impacts of water shortages during droughts. No rules are established on how the Bloomington and Savage Reservoirs might be operated in conjunction with the Occoquan and Patuxent Reservoirs to augment MWA water supply during a drought, nor is there any regional plan for voluntary or mandatory water use restriction incorporated in the LFAA.

Realizing the need for a hydrologic simulation model which would reflect the LFAA provisions and, at the same time, allow the user to "test" different operating strategies, the research team at JHU devoted its research during the second year to developing such a model. The result was a computer program, named "PRISM," which was designed to simulate potential reservoir operation and water management strategies during droughts. The program calculates the inflows, storages, and releases from Bloomington and Savage Reservoirs on a weekly basis and evaluates their impact on water availability to the MWA. The LFAA is incorporated into PRISM to determine potential allocations from the Potomac River to the Aqueduct, FCWA, and WSSC. Downstream reservoir regulation of the Occoquan and Patuxent reservoirs is simulated as well. Potential deficits in water availability for each service area are then calculated. The output from PRISM displays the state of the MWA water supply system (deficits, remaining reservoir storages, environmental flowby, etc.) on a simulated week-by-week basis. As its name implies, PRISM was also designed to be "interactive" whereby model users could interact directly with the model at the beginning of each weekly series of calculations. The findings of the two-year JHU research effort are presently documented in a three volume draft report, entitled "Policy Analysis of Reservoir Operation in the Potomac River Basin." Volume III of the report is devoted entirely to PRISM.

MODIFICATIONS TO PRISM

In November 1979, the Baltimore District Corps of Engineers contracted with Dr. Richard Palmer, primary author of PRISM, to modify the PRISM program for the purposes of the Bloomington Lake Reformulation Study. Working together, Dr. Palmer and Corps' personnel developed a modified version of PRISM, hereafter referred to as PRISM/COE to differentiate it from original PRISM program developed by JHU. The two models generally follow the same program logic and have some entirely identical sections; PRISM/COE, however, has some additional program capabilities.

PRISM/COE is only "interactive" in the sense that many parameters are designated by the user as initial input to the model. The interactive simulation features were eliminated from PRISM/COE largely due to the central memory limitations of the computer system on which PRISM/COE was placed. Also, the evaluation of water supply storage alternatives in Bloomington Lake did not require interactive simulation. The absence of interactive simulation has no effect on the validity of the PRISM/COE model.

The major programming difference between the two PRISM models is the treatment of the upstream reservoirs. PRISM/COE incorporates typical Corps of Engineers operating policies for multi-purpose reservoirs. PRISM/COE has the capability to track separate water quality and water supply storages in Bloomington Lake; inflows and outflows are credited to the appropriate storage based on an accounting system similar to the method used in other Corps multi-purpose projects. Additionally, PRISM/COE has the option of operating either or both of the Bloomington and Savage projects according to appropriate reservoir operating rule curves. This allows the reservoirs to be drawn down in winter to prepare for the spring flood season. In addition, PRISM/COE has the option of operating the two upstream reservoirs so as to enhance water quality in the North Branch Potomac River by making appropriate releases from the alkaline Savage River to dilute the normally acidic releases from Bloomington Lake (see later section and Table H-III-12).

The PRISM/COE model has three additional features for user convenience. The program allows input corrections to be made prior to the actual run. Also, several similar simulations can be run consecutively by only changing the dissimilar variables; and printout of the system data for each week is available in addition to the summary tables.

DATA BASE AND ASSUMPTIONS

The PRISM/COE relies on several data files and assumptions. One such data file contains 10 years of weekly streamflow data for the Potomac River at Little Falls, the North Branch Potomac River at Bloomington Lake, the Savage River at Savage Reservoir, Occoquan Creek at Occoquan Reservoir, and the Patuxtent River at Triadelphia Reservoir. These data are used to calculate inflows to the various reservoirs, except for the Little Falls data which are used to estimate the volume of water supply available from the Potomac's natural flow. Fifty years of historical flow data are available to the PRISM/COE user. Flow data for the period October 1929 to September 1979 were subdivided into five sets of decade flows for ease of computation.

A second data file contains weekly evaporation rates for the upstream reservoirs at Bloomington and Savage as well as slightly different weekly evaporation rates for the downstream reservoirs on the Patuxent and Occoquan. These values, along with an area-capacity curve for each reservoir, are used to calculate evaporation losses from lake surfaces. A third data file establishes the weekly winter drawdown levels for flood control purposes at both Bloomington Lake and Savage Reservoir. These rule curves dictate how the two upstream reservoirs will be operated during the winter to provide supplemental runoff control.

Within the PRISM/COE model, average annual water supply demands for the WAD, WSSC, and FCWA are calculated based on a given set of equations for each of these service areas. These water supply demands are the same values used in the MWA Water Supply Study. These demands were developed by the Corps of Engineers based on population projections developed by Council of Governments in cooperation with the MWA utilities. (For more details, see Appendix D, Supplies, Demands and Deficits). These same demands were also adopted by the Washington Metropolitan Regional Water Supply Task Force and used in its subsequent work. The interactive portion of the PRISM/COE model allows the user to specify both the year of investigation (later years have larger water supply demands) and a measure of water conservation (Baseline or Conservative Scenario 3 reduction level; see Appendix G for more details on how the Conservation Scenarios were developed). A weekly peaking factor is then applied to the average annual demands to reflect seasonal variations in demands. The weekly peaking factors are contained in the data files having separate factors for three different demand conditions (an average condition, the 1966 drought condition, or a hypothetical condition) for each of the three aforementioned service areas.

It should be noted, however, that the peaking factors given in the data file are in reality monthly peaking factors. Each of the peaking factor values has been repeated for all weeks of the corresponding month. For example, the same factor is used for all weeks within August. This is based on the assumption that in terms of storage requirements, average monthly demands would produce the same net effect on reservoir storage depletion as variable high and low demands within the month. It was further assumed that emergency conservation measures, as embodied in the Water Supply Emergency Plan, would help to reduce short-term demand peaks.

In addition to the data files and demand equations, there are several important assumptions which are implicit in PRISM/COE. At the time when the PRISM was first being developed and modified, it was assumed that the upstream reservoir releases would reach MWA undiminished in seven days. However, investigations made by USGS under a contract with Corps of Engineers indicated that 47 percent of the weekly releases from

Bloomington would reach the MWA in the first week and the remaining 53 percent would reach the MWA in the second week without significant losses. (Further details of these investigations are presented in Annex H-V - USGS Flow Loss and Travel Time Studies). In the PRISM/COE model, Bloomington and Savage releases for the current week are added to the natural flow at Little Falls for the current and following weeks according to the percentages determined by the USGS travel time study (47% and 53%, respectively).

A second assumption is that Savage storage and Bloomington water quality storage would be used to satisfy the flow target at Luke, Maryland. Thus, Bloomington water supply storage would be tapped only when releases for the Luke target would not provide sufficient flow to meet the MWA demands. A later section describes in more detail the combined operation of Bloomington Lake and Savage Reservoir to satisfy the flow target at Luke.

A third assumption was that WSSC and FCWA can furnish water to all of their respective service areas from their Potomac treatment plants. This assumption is important if either of the downstream reservoirs is dry and there is sufficient water in the Potomac River to satisfy the total water demand.

A fourth assumption is that streamflow at Little Falls can be predicted with reasonable accuracy using the previous three weeks of recorded flow data. This prediction is important because it triggers the Bloomington water supply release to meet the MWA's water demands.

Finally, the results of PRISM/COE reflect projected water demands occurring simultaneously with historic drought sequences. The results do not represent the worst possible situation because there is always the possibility, no matter what the probability, that future streamflow conditions will be more severe or more prolonged than any previously recorded.

PRISM/COE MODEL STRUCTURE

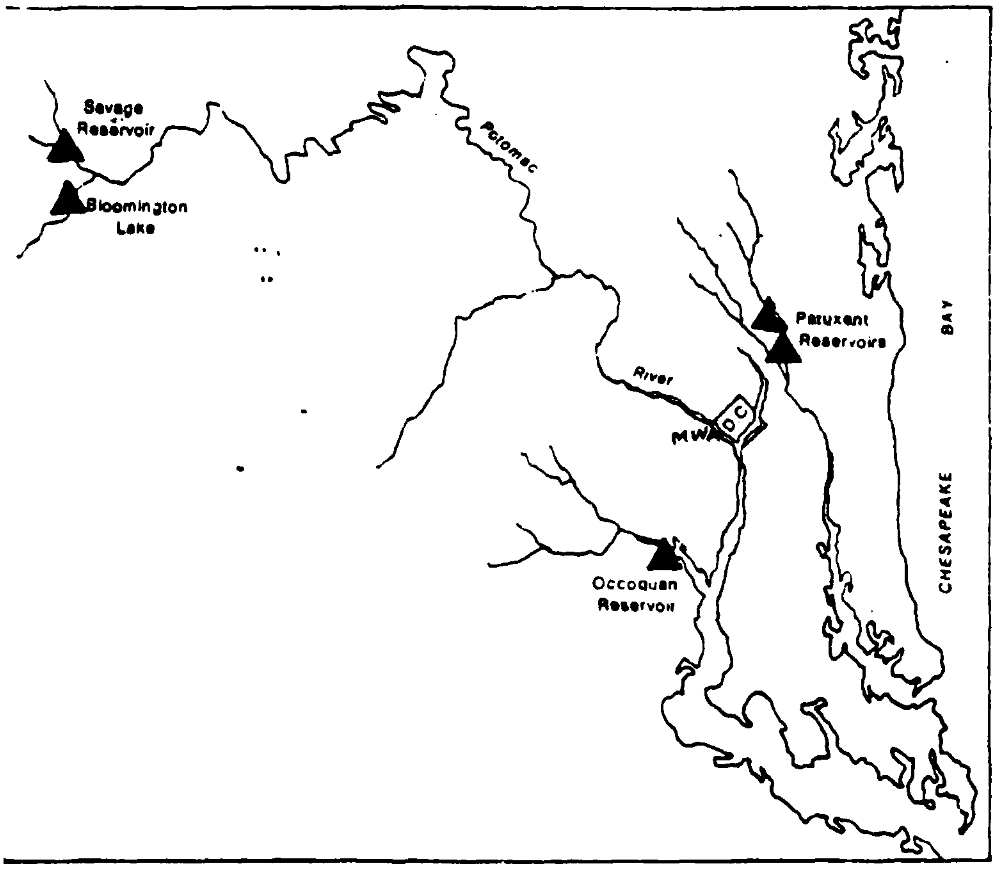
The PRISM/COE model describes the MWA water supply system for a specified upstream reservoir operating policy. Releases from Bloomington Lake and Savage River Reservoir augment the existing flow in the North Branch Potomac River near Luke, Maryland. This flow travels down the Potomac River and becomes available to the MWA Potomac users near Washington, D.C. Two MWA service areas, FCWA and WSSC, also have additional water supply sources on the Occoquan and Patuxent Rivers. These three sources, Potomac flow, Occoquan Reservoir, and the Patuxent Reservoirs, must meet nearly all of the water supply needs of the MWA. A schematic of this system is shown in Figure H-III-1.

For specified flow conditions, PRISM/COE simulates releases from the upstream reservoirs, allocations of Potomac flow, and releases from the offstream reservoirs. The model calculates the resulting storages, flows, and water supply deficits.

The simulation model basically serves as an accounting mechanism for the regional water supply system. For each reservoir, and for each time period (each week), the model uses a simple continuity equation to keep track of the reservoir's "account." This equation takes the following form:

Storage (t) = Storage (t-1) + Inflow (t) - Release (t) - Spill (t) - Evaporation (t)

FIGURE H-III-1
SCHEMATIC OF MWA REGIONAL WATER SUPPLY SYSTEM



The storage for each reservoir is restricted by the reservoir's capacity or the operating rule curve for the specific reservoir (upstream reservoirs only). With the PRISM/COE modifications, Bloomington Lake, for modelling purposes, consists of two reservoirs, a water supply reservoir and a water quality reservoir. The sum of their storages must be within the operating rule constraint.

In the continuity equation, release (t) refers to the quantity of water released from a reservoir to meet water demands or water release targets. For Bloomington and Savage, this release would flow into the North Branch Potomac River during week (t). For the Patuxent and Occoquan reservoirs, this release would be treated and pumped into the respective distribution system during week (t). Spill (t) is the water which the reservoir releases during week (t) to comply with storage limitations. For the downstream reservoirs only, spill can also refer to the flow which the reservoir releases to maintain a minimum flow downstream of the reservoir. This water would not be available as a water supply source for the MWA. Evaporation for each of the reservoirs is calculated from individual area-capacity curves and the maximum monthly evaporation rate observed during the decade of the 1960's. Evaporation (t) is a function of the lake surface area at the end of the previous week (t-1).

The simulation model also has accounts for the Potomac River at Luke, Maryland, and at Little Falls, Maryland. For Luke, the following equation expresses the calculation of flow:

Flow at Luke (t) = Bloomington Outflow (t) + Savage Outflow (t)

The reservoir outflow for week (t) is the sum of release (t) and spill (t) for the corresponding reservoir. The model assumes that no additional inflow occurs between the reservoirs and the river confluence at Luke.

For the Potomac River upstream of the MWA intakes, the flow is:

Flow at Intakes (t) = Potomac Flow (t) + Luke Flow (t) x Transit Value_1 + Luke Flow (t-1) x Transit Value_2 - Irrigation Withdrawal (t)

The Potomac Flow (t) is the actual flow in the Potomac River during week (t) less the recorded contribution of flow from the basin at Luke, Maryland. The Luke flows (t) and (t-1) represent the flows released from Bloomington and Savage Reservoirs during those weeks in accordance with the specified reservoir operating policy. According to flow analyses performed by the USGS, Luke flows in week (t) and week (t-1) will impact on the Potomac River flow upstream of the intakes during week (t). The USGS study indicated that 47% of the Luke flow reaches the MWA intakes within the initial week of release and the remaining 53% arrives during the following week (details of the USGS investigations and their results are presented in Annex H-V - <u>USGS Flow Loss and Travel Time Studies</u>). In the model, then, transit value, (47%) and transit value_2 (53%) correspond to the arrival percentage for releases in weeks (t) and (t-1), respectively. The USGS study also determined that there was no significant loss of flow between Luke, Maryland, and the MWA intakes. Consequently, the transit values sum to 100 percent. Irrigation withdrawal (t) refers to the volume of water taken from the river during the current week by consumptive users, such as irrigators, between the upstream reservoirs and the MWA intakes.

Downstream of the intakes, the flow into the Potomac estuary is defined by:

Estuary Flow (t) = Flow at Intakes (t) - WAD Withdrawal (t) - WSSC Withdrawal (t) - FCWA Withdrawal (t)
Estuary Flow $\geq$ Flowby Requirement

The five reservoir equations and three river equations form the foundation of the simulation model calculations. All of the model calculations must obey these continuity equations for the model to be valid hydrologically.

The PRISM/COE simulation is an iterative process as shown in the basic flow diagram on Figure H-III-2. In Step 1, the input files are read, the parameter values are set by the user, and the pertinent arrays and variables are initiated to appropriate values. The next step in the simulation determines the LFAA ratios for the model simulation.

Steps 3 through 10 are the main iteration. They represent the calculations of the weekly status of the regional system for week (t) in accordance with the given operating policy for the upstream reservoirs. The first step of the iteration determines the MWA demand for weeks (t) and (t+1). The sources of the demand equations are the Corps' water use projections through 2030. These have been segmented and linearized for each decade and service area. After the demand is known, the release targets are calculated.

The upstream target is a value set by the user at initiation of the simulation. The downstream target, if one is desired, is the difference between the demand on the Potomac supply and the predicted flow at Little Falls. The Potomac demand is the MWA supply demand plus the required estuary flowby less the planned use of offstream reservoirs. This can be written as:

Downstream Target (t):

Potomac Demand (t) = MWA Demand (t) + Estuary Flowby - (Occoquan Capacity + Patuxent Capacity) x Reliance Factor

Current Week Flow Need(t) = (Potomac Demand (t) - Predicted Potomac Flow (t) - Upstream Target - (Water Supply Releases (t-1) x Transit Value_2))/Transit Value_1

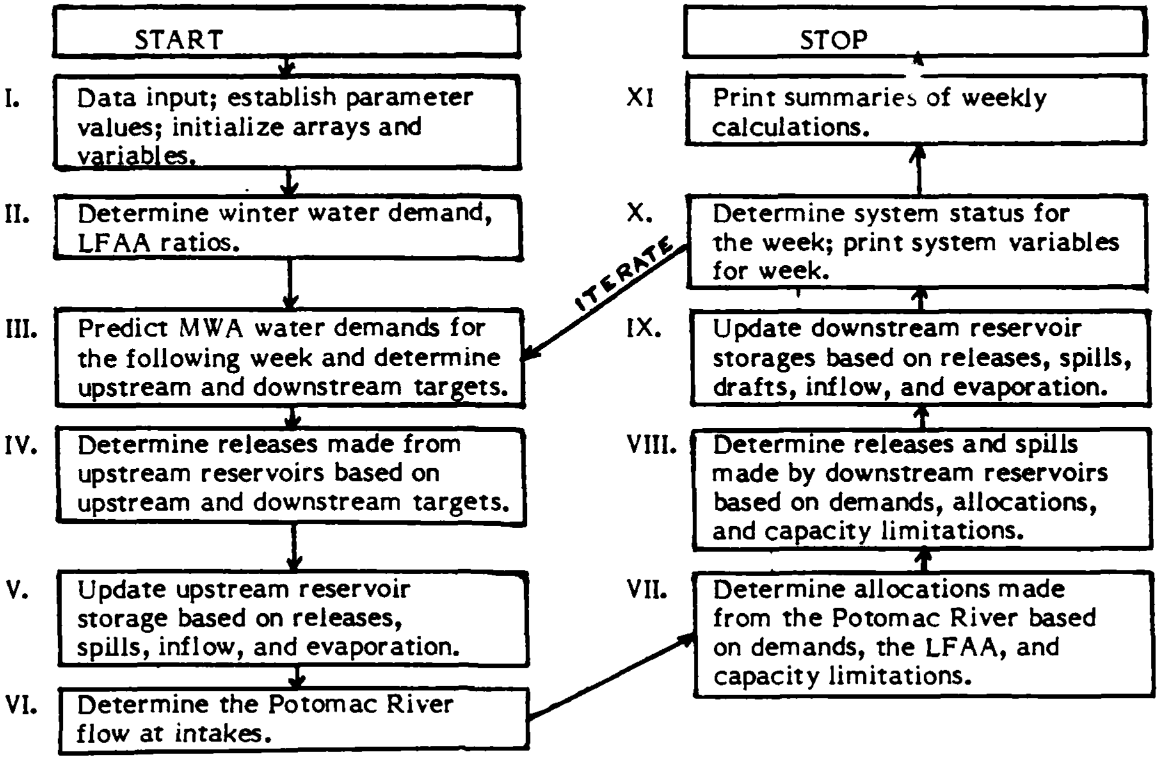
Following Week Flow Need (t) = Potomac Demand (t+1) - Predicted Potomac Flow (t+1) - Upstream Target - (Current Week Flow Need (t) x Transit Value_2)

Downstream Target (t) = Upstream Target + Current Week Flow Need (t) + Following Week Flow Need (t).

These targets are the basis for the upstream reservoir management decisions.

It should be noted here that the downstream target (t) is a combination of current and following week flow needs and the upstream target. This is due to the reason that all of the flow at Luke does not reach the MWA intakes during the same week.

FIGURE H-III-2
FLOW DIAGRAM OF PRISM/COE



The fourth step of the simulation uses the targets to determine the water quality releases from Savage and Bloomington and the water supply release from Bloomington. This step includes a complicated series of tests to ensure the efficient use of Bloomington and Savage River reservoir water. The water quality release calculation is based on the premise that Savage water has better quality than the acidic Bloomington water. Every Bloomington release would require a Savage release for dilution. The combination of these releases will meet the upstream target at Luke, Maryland, and will improve the in-stream water quality downstream of Luke, Maryland. (See Table H-III-12 for Bloomington-Savage release ratios). Each reservoir must also meet minimum flow standards downstream.

Any storage in Savage above the operating curve is released and can offset the Bloomington water quality release. The downstream target is then checked to see if a water supply release is needed. If the downstream target is greater than the releases and spills from the two upstream reservoirs, an additional release is needed to provide for downstream water supply needs. Thus, the water supply release is calculated. The total Bloomington storage as a result of the water supply and water quality releases is compared to the operating curve. If Bloomington is above the curve, the reservoir must release the extra storage. Adjustments are then made to reduce the Savage and the water supply releases if practical.

The determination of the water supply and water quality releases is complicated; however, the model has a set of operational priorities it follows throughout the calculation. In order, these priorities are:

(1) maintain the required minimum flow between each reservoir and Luke,

(2) meet the upstream target for flow at Luke,

(3) release water from water supply storage to meet MWA supply demands, and

(4) follow the established operating rule curve.

Once the releases are determined, the upstream reservoir continuity equations are used to calculate the system status of the upstream storages.

Step 6 in the simulation uses the river equation as discussed earlier to determine the Potomac flow upstream of the intakes. This flow, less the required estuary flow, is available for allocation to the MWA jurisdictions. The allocations are made in Step 7 according to the LFAA rules. The LFAA allocation can be expressed in the following form:

Allocation to Service Area (t) = (Service Area LFAA Ratio) x (Flow at Intakes (t) - Estuary Flowby + Total Offstream Capacity) - Service Area Offstream Capacity

The service area LFAA ratio is the ratio of the service area's demand to the total MWA demand, averaged over the prior five years of winter demand. The total offstream capacity refers to the maximum flow available from the Occoquan and Patuxent reservoirs. Similarly, the service area offstream capacity is the maximum flow available from the appropriate reservoir.

The allocations, thus computed, are checked and adjusted for non-positive values, for exceeding demands, and for exceeding Potomac withdrawal capacities. Any extra flow is reallocated to the other jurisdiction according to the ratio of the service area deficit to the total regional deficit.

The next step, Step 8, calculates the water supply releases from each of the two offstream reservoirs. The release is simply the service area demand minus the Potomac allocation, within the defined maximum and minimum values. The intent of this policy is to minimize WSSC and FCWA deficits. The maximum water supply release (draft) value is the constraint of the respective treatment plant's capacity, as defined by the model user. Step 8 also computes the flows (spills) which the offstream reservoirs release downstream. These values are based on minimum flow requirements or storage capacity limitations.

Using the reservoir continuity equations for the Occoquan and Patuxent reservoirs, the week's storage values are computed in Step 9. The last step of the major iteration makes final calculations of the system status, including service area deficits, the total regional deficit, the cumulative deficit for the specific drought, the Potomac flow into estuary, and the LFAA stage. A summary of the system status is then printed to the output file.

The iteration returns to Step 3 and proceeds with calculations for the next week. After calculations for all weeks of simulation are completed, the model prints summary tables of certain variable arrays (e.g., Bloomington storage, Savage storage, Luke flow, etc.) to the specified output file. This step, Step 11, completes the major program logic of the PRISM/COE model. Details for the eleven steps are explained in the following sections.

PRISM/COE MODEL COMPONENTS

PRISM/COE can be classified according to the five major programming components: (1) input and initial calculations, (2) upstream reservoir regulation, (3) Potomac flow allocation within the MWA, (4) downstream reservoir regulation, and (5) final calculations and output. These components are discussed in detail below. In the following discussions, where a time value, e.g. (t), is not specified for a variable in the equations, either the variable value is constant or the variable is an intermediate variable with an assumed time of (t).

INPUT AND INITIAL CALCULATIONS

The first component of the PRISM/COE Model includes Step I and II of Figure H-III-2. This component is diagrammed in Figure H-III-3.

The first component sets up the model for the major simulation calculations. The program begins by dimensioning the variable arrays and declaring the variable types. The next step is the input of the data files. These files are pulled from the model user's computer library. They contain the weekly flow data for the Potomac River at Little Falls, the weekly flows into the four reservoirs, the weekly demand factors for the three service areas, the weekly evaporation coefficients for upstream and downstream reservoirs, the Bloomington-Savage release ratios, and the operating rule curves for Savage and Bloomington. The data from these files is assigned to the appropriate arrays for further use.

The interactive input segment follows this step, involving a series of write and read statements. The computer writes to the terminal the description of the input variable; the user types the variable's value; the computer reads the value and assigns it to the variable. These inputs are the parameter values shown in Figure H-III-4 which define the regional reservoir management policy for the simulation. They include the reservoir storage capacities, the withdrawal capacities, the demand year, etc. They are listed in order in Table H-III-1 along with the appropriate variables.

The next segment of the input component is the section for input changes. The terminal prints out the parameter values and asks the user if changes are needed. If the change option is invoked, the computer asks for the parameter number and value, and reassigns the variable with the new parameter value. This section continues until the user declares that the input is accurate, via a specified computer response. The program then moves to the variable and array initialization segment.

First, the set of input variables with units of mgd are converted to mgw (million gallons per week) by multiplying by 7. This simplifies the model calculations. Next, the specified irrigation withdrawals from the Potomac River are subtracted from the natural Potomac flow at Little Falls. Then, the arrays and variables associated with calculations are zeroed out to avoid any computer malfunctions.

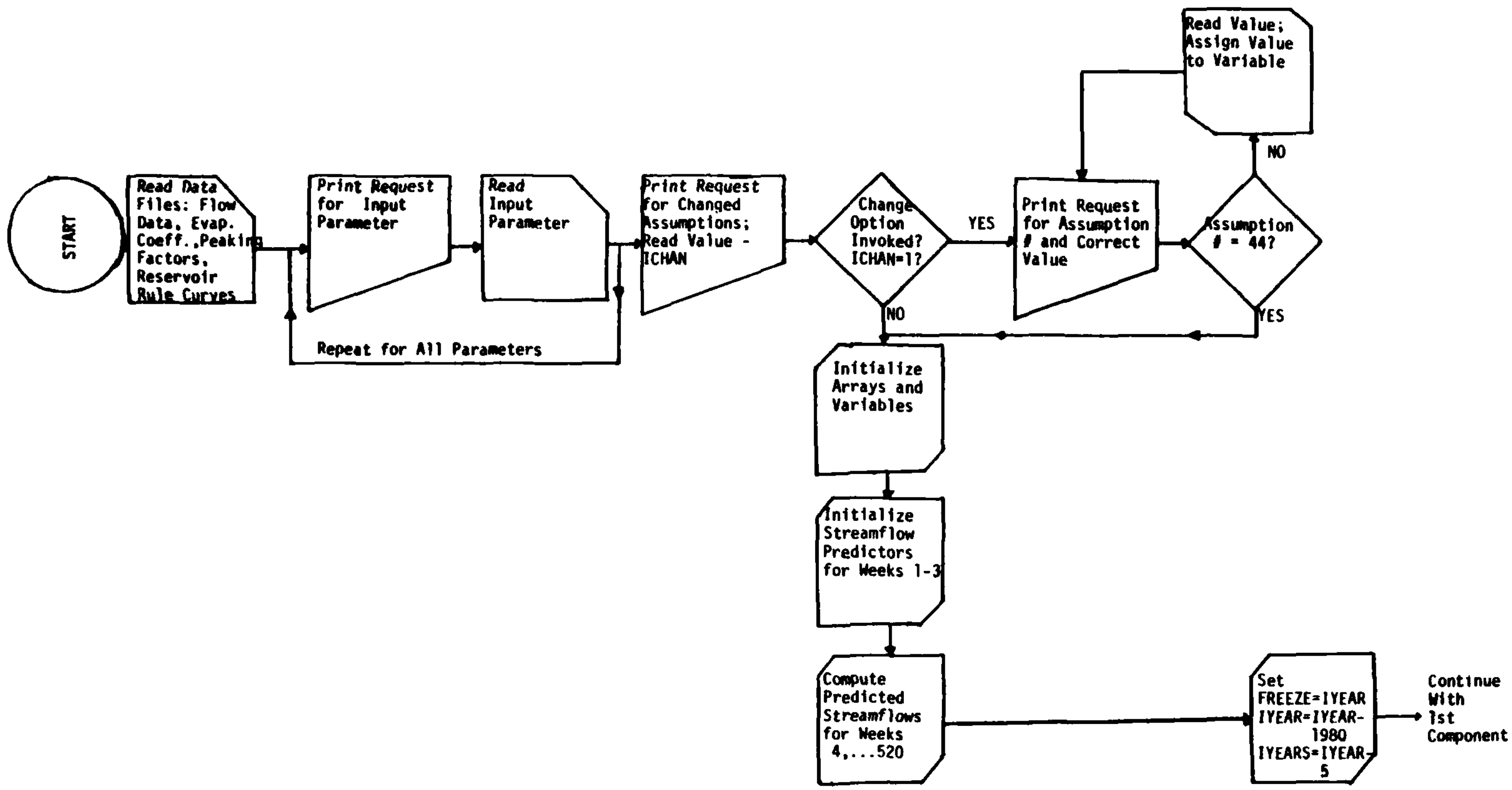


FIGURE H-III-3

FLOW DIAGRAM OF INPUT AND INITIAL CALCULATIONS (STEPS I AND II)

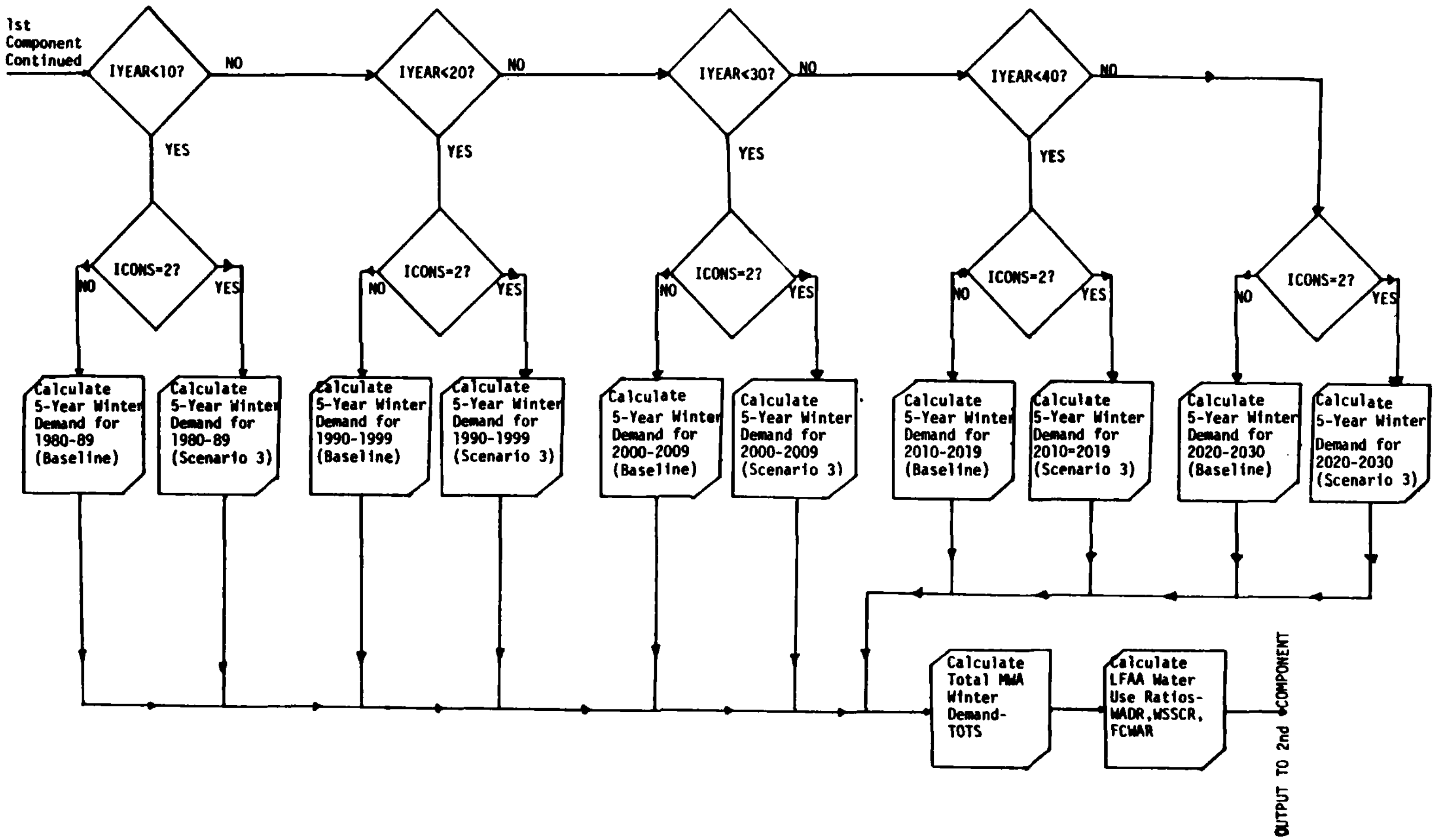


FIGURE H-III-3 (Continued)

FLOW DIAGRAM OF INPUT AND INITIAL CALCULATIONS (STEPS I AND II)

FIGURE H-III-4

INTERACTIVE PARAMETERS FOR PRISM/COE

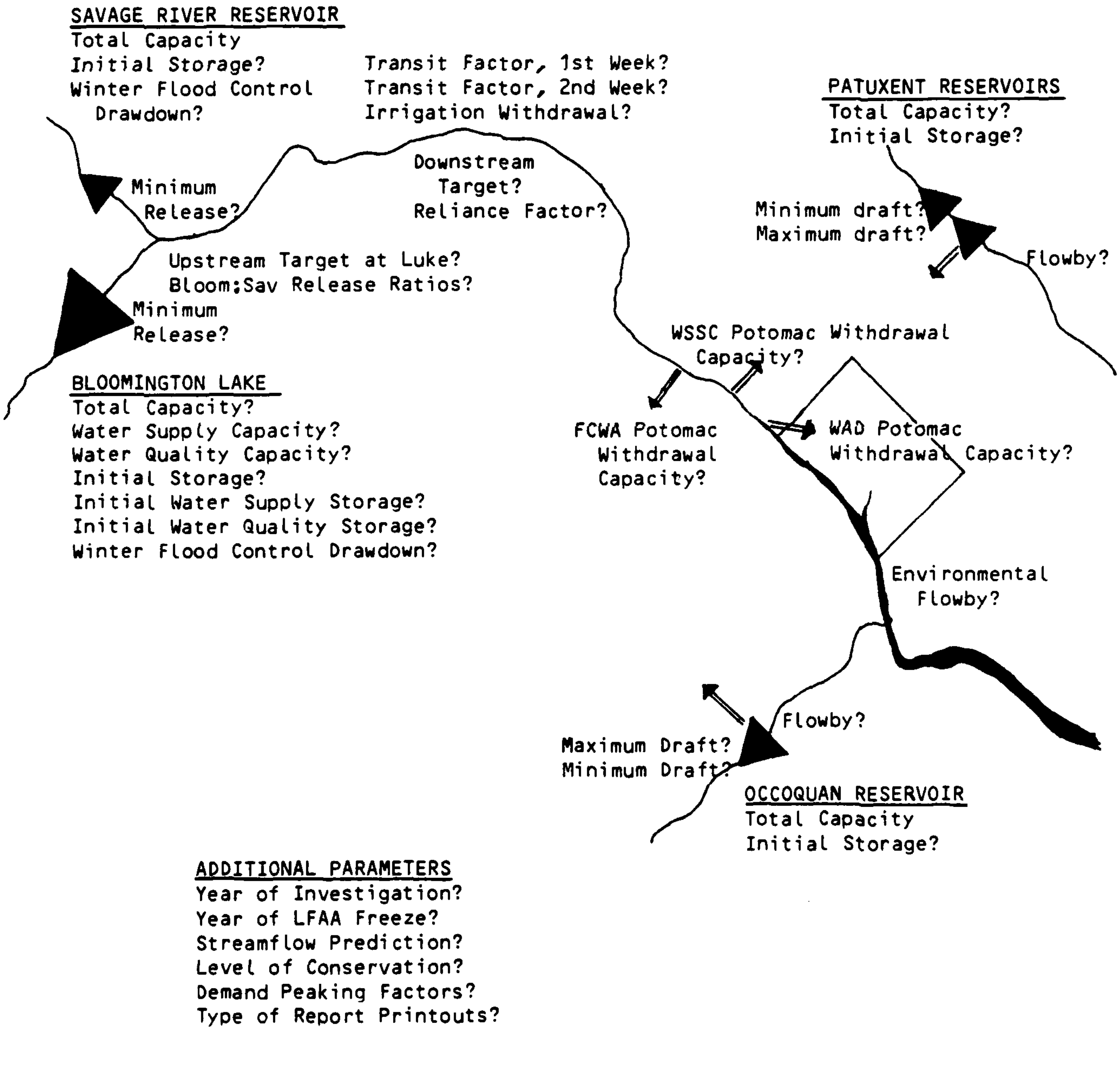


TABLE H-III-1

PRISM/COE INPUT PARAMETERS

	Parameter Description	Variable Name
1.	Capacity of Bloomington, mg	CAPB
2.	Capacity of Savage, mg	CAPS
3.	Capacity of Occoquan, mg	CAPO
4.	Capacity of Patuxent, mg	CAPP
5.	Potomac Withdrawal Capacity, FCWA, mgd	CWFCWA
6.	Potomac Withdrawal Capacity, WSSC, mgd	CWWSSC
7.	Potomac Withdrawal Capacity, WAD, mgd	CWWAD
8.	Environmental Flowby at Little Falls, mgd	ENFB
9.	Treatment Capacity of Occoquan, mgd	COCC
10.	Treatment Capacity of Patuxent, mgd	CPAT
11.	Upstream Consumptive Withdrawal, mgd	WIRG
12.	Minimum Release for Bloomington, mgd	RBMIN
13.	Minimum Release for Savage, mgd	RSMIN
14.	Environmental Flowby at Occoquan, mgd	SOMINI
15.	Environmental Flowby at Patuxent, mgd	SPMINI
16.	Bloomington Savage Flow-Dependent Ratios (0=No,1=Yes)	IBSANS
17.	Maximum Bloomington Savage Release Ratio	BSRAT
18.	Upstream Release Fraction, 1st Week	PER1
19.	Upstream Release Fraction, 2nd Week	PER2
20.	Year of Investigation	YEAR
21.	Downstream Factor, %	DSTF
22.	Upstream Target at Luke, mgd	TARGU
23.	Year of LFAA Freeze	IYEAR
24.	Minimum Draft from Occoquan, mgd	ROMIN1
25.	Minimum Draft from Patuxent, mgd	RPMIN1
26.	Initial Bloomington Storage, mg	SB(1)
27.	Initial Savage Storage, mg	SS(1)
28.	Initial Occoquan Storage, mg	SO(1)
29.	Initial Patuxent Storage, mg	SP(1)
30.	Streamflow Prediction (O=Model, 1=Perfect Foresight)	LD
31.	Type of Conservation (1=Baseline, 2=Scenario 3)	ICONS
32.	Weekly Demand Coefficients (1 = 8-Year Monthly Average 2 = 1966 Actual 3 = Hypothetical)	IDMD
33.	Initial Bloomington Water Supply Storage, mg	SBWS(1)
34.	Initial Bloomington Water Quality Storage, mg	SBWQ(1)
35.	Bloomington Water Supply Capacity, mg	CAPBWS
36.	Bloomington Water Quality Capacity, mg	CAPBWQ
37.	Separation of Bloomington Storage (0 = No, 1 = Yes)	IWSWQ
38.	Bloomington Winter Drawdown (0 = No, 1 = Yes)	IWTDRB
39.	Savage Winter Drawdown (0 = No, 1 = Yes)	IWTDRS
40.	Downstream Target (0 = No, 1 = Yes)	T
41.	Weekly Reports (0 = No, 1 = Yes)	IWEEKY
42.	Years of Weekly Reports	IWEEKR
43.	Summary Reports (0 = No, 1 = Yes)	SUMRPT

The streamflow prediction segment follows the variable initialization. The predictor calculations compute the predicted streamflows for Bloomington, Savage, and Little Falls, based on actual flow in the three preceding weeks. For weeks 1, 2, and 3, the predicted streamflow is set to the actual value of flow. For weeks 4 through 520, the streamflow prediction equations are:

$$FBPRE(t) = (FB(t-1))^{0.362}(FB(t-2))^{0.042}(FB(t-3))^{0.024}e^{2.894}$$

$$FSPRE(t) = (FS(t-1))^{0.475}(FS(t-2))^{-0.079}(FS(t-3))^{0.125}e^{1.577}$$

$$FPTPRE(t) = (FPOT(t-3))^{0.11}(FPOT(t-1))^{0.49}e^{3.35}$$

FB, FS, FPOT = actual weekly flow data for Bloomington, Savage, and the Potomac River at Little Falls

FBPRE, FSPRE, FPTPRE = predicted weekly flows for Bloomington, Savage and the Potomac River at Little Falls

These equations were the result of regression analyses performed by the Johns Hopkins University staff. In this segment, the model performs the calculations in a do-loop for all weeks and creates the predicted flow arrays FBPRE, FSPRE, and FPTPRE.

This last section of the initial component is the determination of the LFAA ratios for each jurisdiction. First, the program computes the total winter demand for each jurisdiction for the five preceding years. The variables WSSCS, WADS, and FCWAS are the total winter demand for each service area.

The demand equations were formed by linearizing the demand curve into five segments - one for each decade. The program utilizes a demand curve associated with the month of July (the maximum demand month) and then makes appropriate adjustments to calculate demands for the other 11 months of the year. Each segment has an equation with which it is associated. The program tests the demand year variable (I YEAR) for each decade, then it moves to the appropriate set of equations. Also, for each decade, baseline, and Conservation Scenario 3 demands are available. The computer tests the demand variable (ICONS) and chooses the final set of equations for further calculations.

For 2030 baseline demands, the LFAA ratio calculation uses the following equations:

$$WSSCS = \sum_{J}(2.49J + 218.8) \times .9133/1.154$$

$$WADS = \sum_{J}(0.71J + 257.3) \times .9185/1.167$$

$$FCWAS = \sum_{J}(2.03J + 82.5) \times .9133/1.154$$

for $J = (2030 - 1980)-5, \ldots\ldots, (2030 - 1980) - 1 = 45, \ldots\ldots, 49$

The ratios 0.9133/1.154 and 0.9185/1.167 represent the conversions of July demands to winter demand. Next, the program calculates the total regional winter demand (TOTS) and the water use ratios (WADR, WSSCR, FCWAR) for each service area, using these equations:

TOTS = WSSCS + WADS + FCWAS
WADR = WADS/TOTS
WSSCR = WSSCS/TOTS
FCWAR = FCWAS/TOTS

These ratios are the basis of the Potomac flow allocation in the third component. They are constant throughout the simulation.

UPSTREAM RESERVOIR REGULATION

The second component includes Step III through V of Figure H-III-2. A flow diagram of this component appears in Figure H-III-5.

The second component begins the main iteration (do-loop) in the computer program PRISM/COE. In the first step, the program calculates the water demand for each service area during all weeks of simulation, and sets them in appropriate demand arrays (FDWSSC, FDWAD, FDFCWA). The demand equations are the July demand segments used in the first component with modifications for weekly demands. For 2030 baseline demands, the appropriate demand equations are:

FDWSSC (t) = (2.49I + 218.8) x WWSSC (IDMD, t) x 7.
FDWAD (t) = (0.71I + 257.3) x WWAD (IDMD, t) x 7.
FDFCWA (t) = (2.03I + 82.5) x WFCWA (IDMD, t) x 7.

for I = 2030 - 1980 = 50

The weekly service area demands (FDWSSC, FDWAD, and FDFCWA) depend on the weekly demand factors (WWSSC, WWAD, and WFCWA). These factors are input from a data file in three 3 x 52 arrays, one for each jurisdiction. The IDMD variable refers to the type of weekly demand factor (8-year monthly average, 1966 actual, or hypothetical) which the model user chooses. There are 52 factors for each type, one for each week of the year. The service area demands are in units of million gallons per week (mgw).

Next, the upstream and downstream targets are set. The upstream target is simply the value specified in the user input interactive sequence. This value was assigned to the variable TARGU.

For the downstream target, the total water demands for the current week (TOTD) and the following week (TOTDP) are calculated first. It is assumed here that an accurate estimate of demand can be made one week in advance.

TOTD = FDWSSC (t) + FDFCWA (t) + FDWAD (t)
TOTDP = FDWSSC (t+1) + FDFCWA (t+1) + FDWAD (t+1)

Using these values, the downstream target (TGDFD) is calculated by the following series of calculations. First estimates of the expected demand on the Potomac for the current and following weeks are computed:

TTD = (TOTD - (COCC + CPAT) x DSTF + ENFB) x T
TTDP = (TOTDP - (COCC + CPAT) x DSTF + ENFB) x T

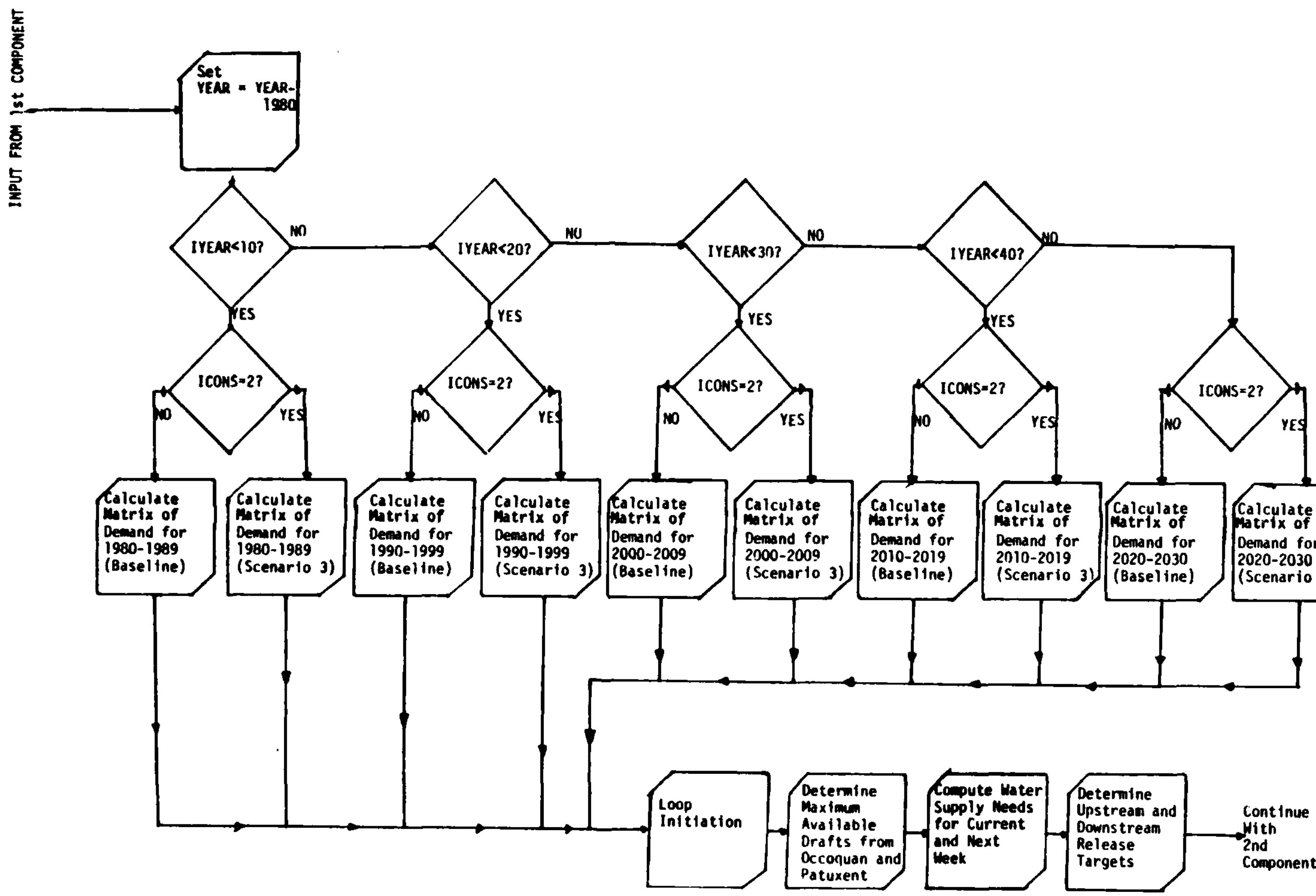


FIGURE H-III-5

FLOW DIAGRAM OF UPSTREAM RESERVOIR REGULATION

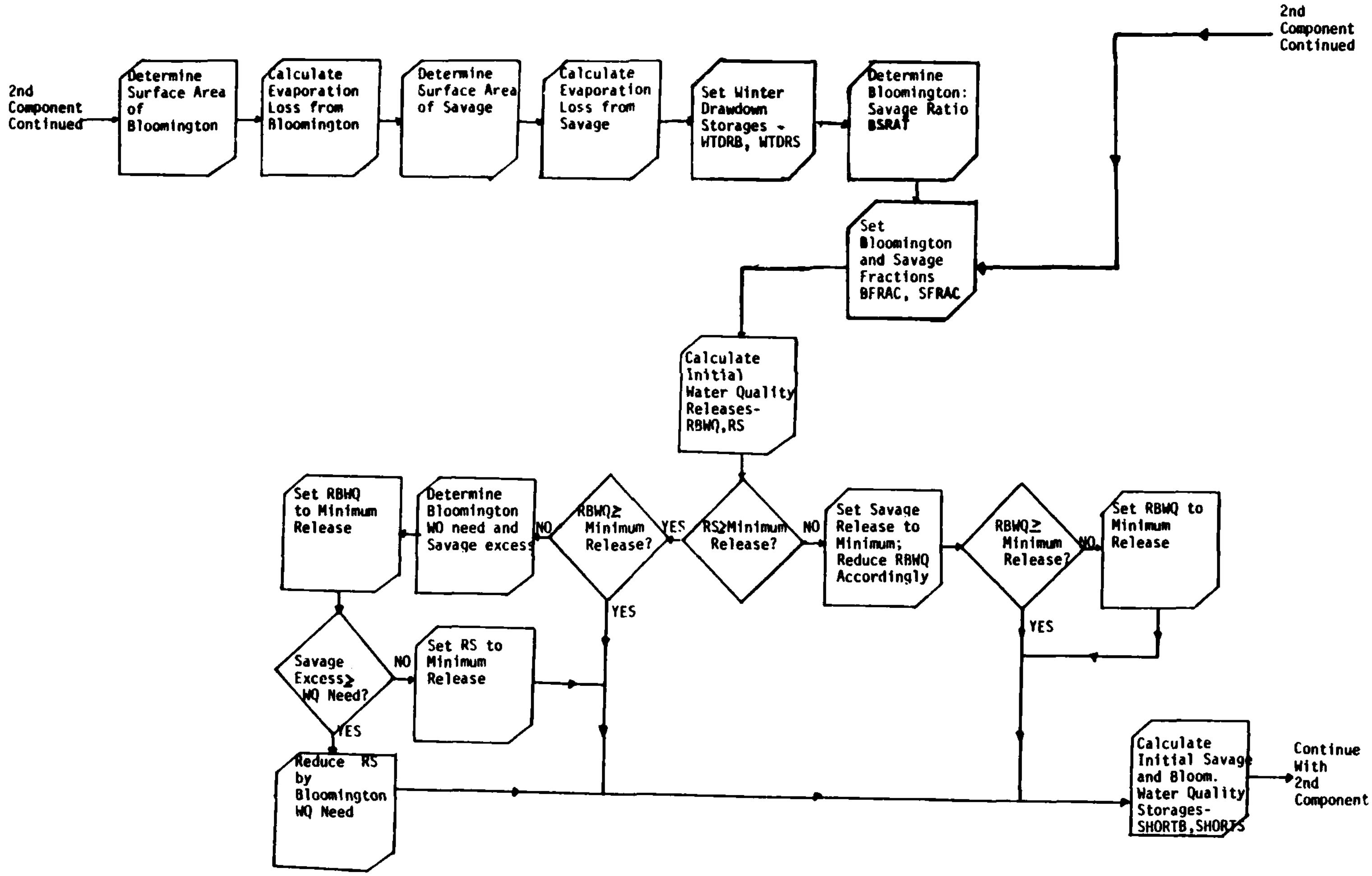


FIGURE H-III-5 (Continued)

FLOW DIAGRAM OF UPSTREAM RESERVOIR REGULATION (STEPS III, IV, AND V)

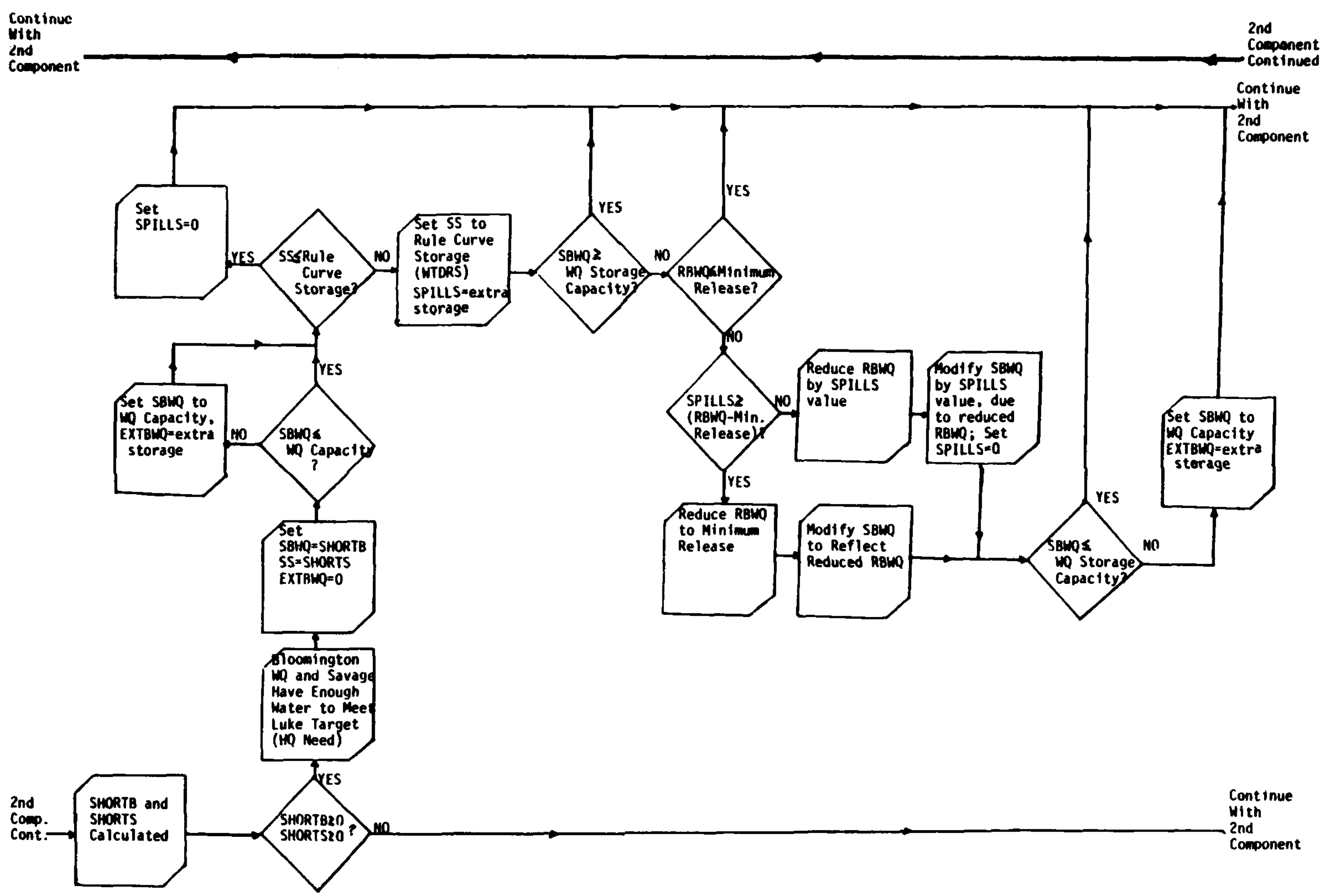


FIGURE H-III-5 (Continued)

FLOW DIAGRAM OF UPSTREAM RESERVOIR REGULATION (STEPS III, IV, AND V)

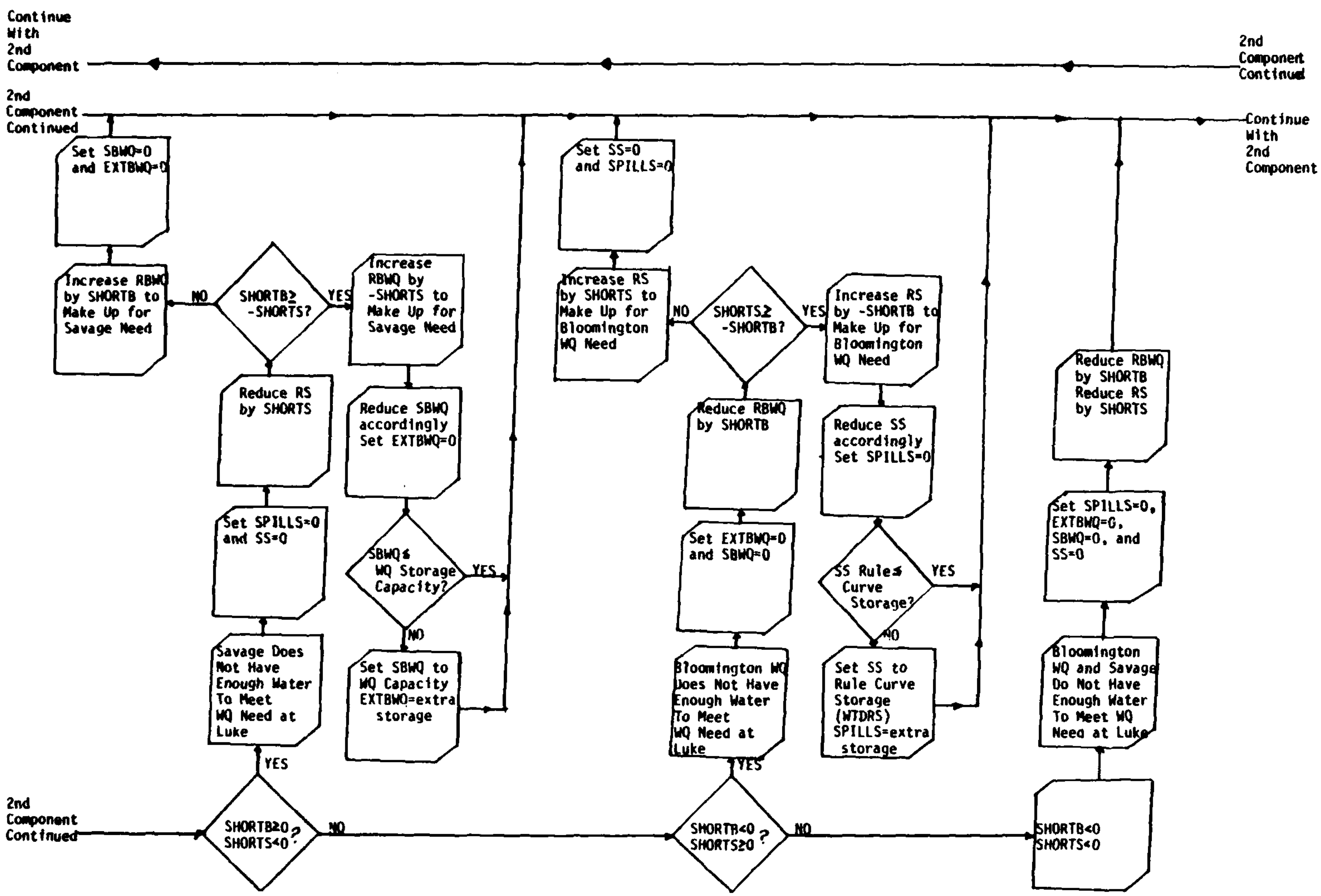


FIGURE H-III-5 (Continued)

FLOW DIAGRAM OF UPSTREAM RESERVOIR REGULATION (STEPS III, IV, AND V)

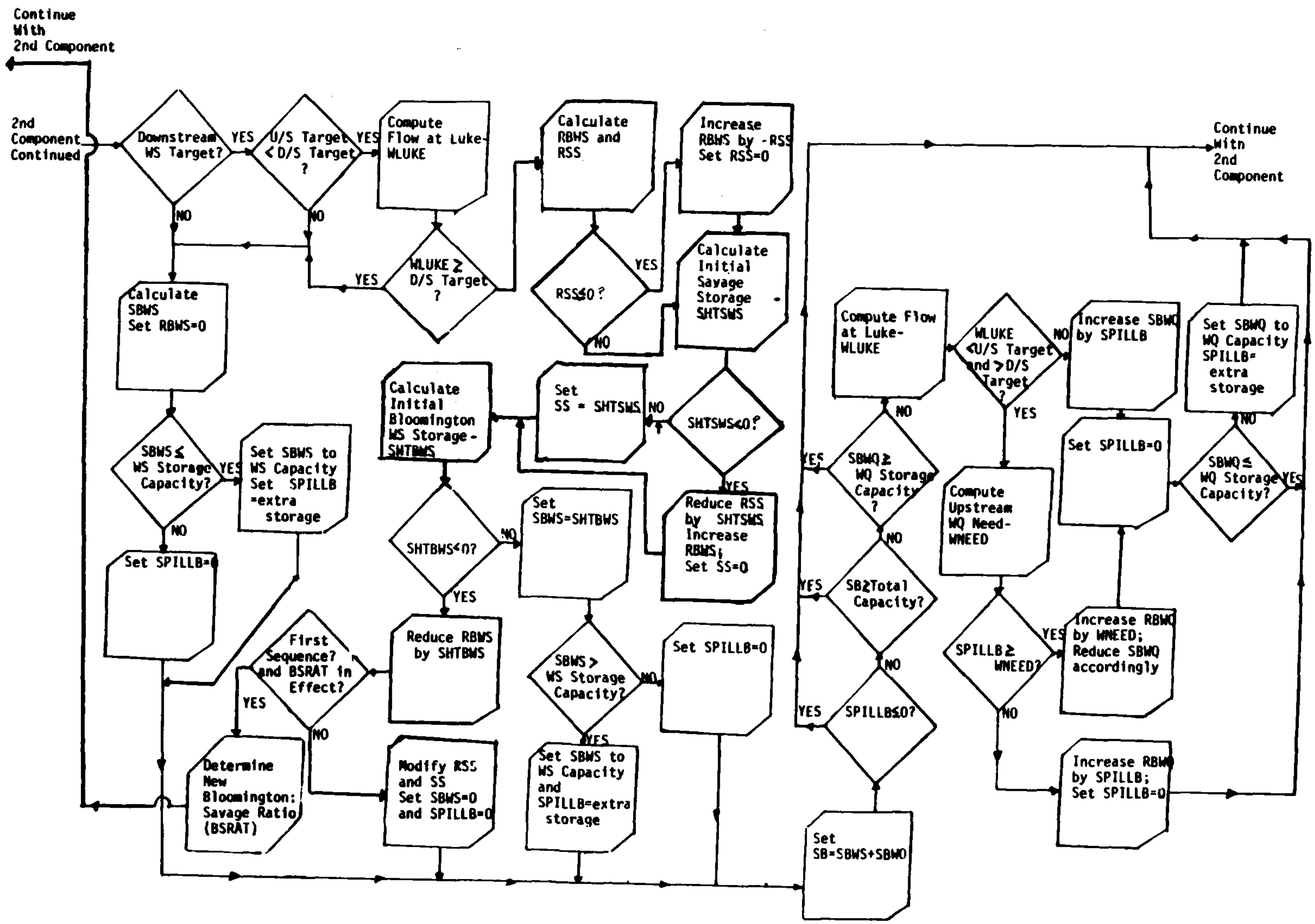


FIGURE H-III-5 (Continued)

FLOW DIAGRAM OF UPSTREAM RESERVOIR REGULATION (STEPS III, IV, AND V)

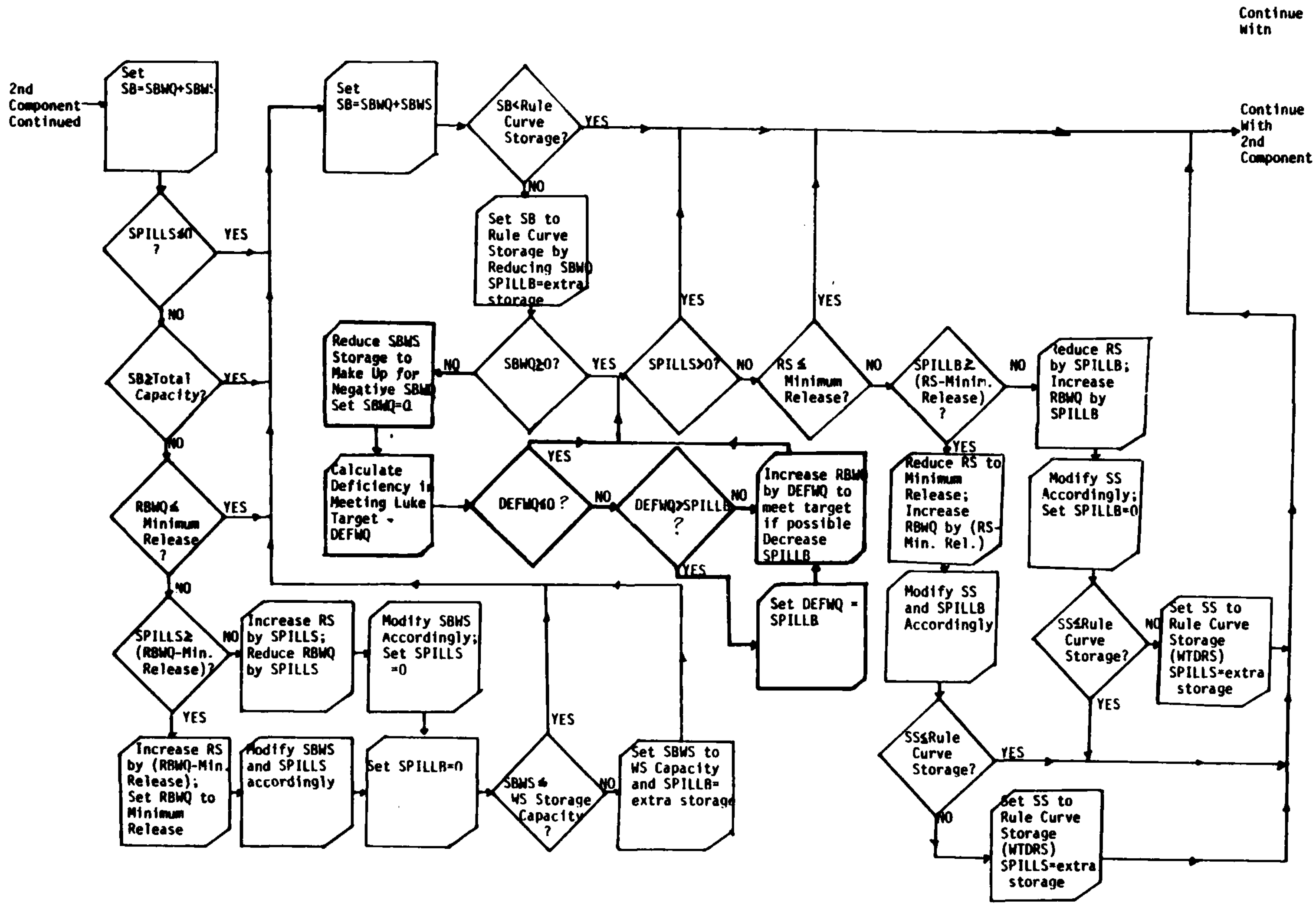


FIGURE H-III-5 (Continued)

FLOW DIAGRAM OF UPSTREAM RESERVOIR REGULATION (STEPS III, IV, AND V)

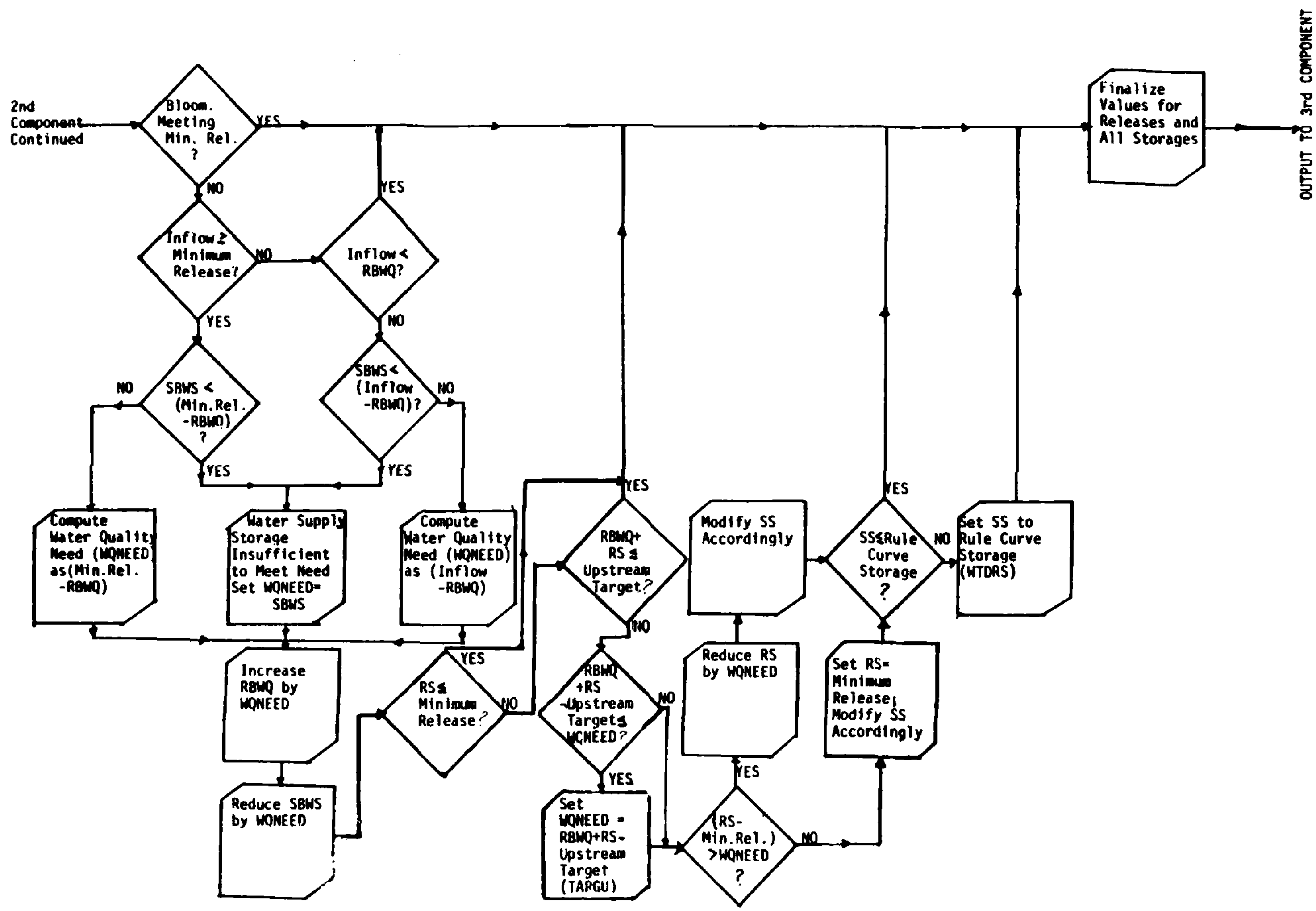


FIGURE H-III-5 (Continued)

FLOW DIAGRAM OF UPSTREAM RESERVOIR REGULATION (STEPS III, IV, AND V)

In the equations above, the current week's Potomac demand, TTD, equals the MWA water supply demand (TOTD) for the current week minus the reliance on the offstream reservoirs, (COCC + CPAT) x DSTF, plus the required estuary flow (ENFB). TTDP, the Potomac demand for the following week, is calculated as the MWA water supply demand in week (t+1) (TOTDP) minus the reliance on offstream reservoirs plus the required estuary flow. The reliance on offstream reservoirs value refers to how much of the Occoquan and Patuxent capacity the management policy plans to use. This is a percentage (DSTF) of their capacity, which is input by the user at simulation initiation. Should the storage level in either reservoir fall below a designated minimum (two times the draft capacity), the model assumes that no water may be drawn from that reservoir for that week (COCC/CPAT = 0). The variable T indicates whether the reservoir management policy includes water supply releases from Bloomington or not. For no water supply releases (T = 0), TTD = 0 and TTDP = 0. With water supply operations in effect (T = 1), the TTD and TTDP computations result in positive values generally.

Using these Potomac demand estimates, the water supply needs are derived from the known and predicted supply and demand conditions. The supply conditions include any water supply releases from the previous week (RWSB and RSS), the predicted Potomac River flow (FPTPRE), and the minimum target flow at Luke. Needs for both the current and the following weeks (WSREL and WSRELP, respectively) are calculated by these equations:

Current Week: $$\text{WSREL} = (\text{TTD} - \text{FPTPRE}(t) - \text{TARGU} - (\text{RWSB}(t-1) + \text{RSS}(t-1)) \times \text{PER2})/\text{PER1}$$

Following Week: $$\text{WSRELP} = \text{TTDP} - \text{FPTPRE}(t+1) - (\text{TARGU} - \text{WSREL}) \times \text{PER2}$$

In these equations, the upstream releases of the previous week are multiplied by PER2 to reflect the effects of flow travel between Luke and Little Falls. Similarly, the demand minus supply value for the current week is divided by PER1 to insure the arrival of the needed amount that week. In the calculation for the following week's need, this precaution was not necessary and tended to waste water. In the event a negative value of WSREL or WSRELP is calculated, the program assigns 0 to that variable for the succeeding calculations.

The downstream target (TGDFD) is then expressed as:

$$\text{TGDFD} = \text{TARGU} + \text{WSREL} + \text{WSRELP}$$

This target flow is the total amount of upstream releases required by the MWA users in week (t). This can be satisfied by water quality releases from Savage and Bloomington, and Bloomington water supply releases, if needed. This downstream target is very dependent on the predicted Potomac River flow (FPTPRE); therefore, good streamflow predictors and the flexibility of offstream reservoir reliance are integral to proper reservoir management policies.

The next step in the upstream reservoir component is the evaporation calculations. Evaporation from both Bloomington and Savage Reservoirs are based on the surface area of each at the end of the previous week and the 1966 pan evaporation rate (EVAPU). The surface area is determined by segmenting and linearizing the curve for surface area vs. storage of each reservoir. The following equations for area and evaporation are used:

Bloomington: for $0 \leq SB(t-1) \leq 6516.576$ $AREA = 0.0537092 \times SB(t-1)$

$6516.576 < SB(t-1) \leq 13033.152$ $AREA = 0.383637 \times SB(t-1) + 100.0$

$13033.152 < SB(t-1) \leq CAPB$ $AREA = 0.0189016 \times SB(t-1) + 353.653$

$$EVAPB = EVAPU(t) \times AREA \times 0.3258288 \times 12./52.$$

Savage: for $0 \leq SS(t-1) \leq 1303.3152$ $AREA = 0.09053 \times SS(t-1)$

$1303.3152 < SS(t-1) \leq CAPS$ $AREA = 0.051963 \times SS(t-1) + 50.276$

$$EVAPS = EVAPU(t) \times AREA \times 0.3258288 \times 12./52.$$

The AREA values have units of acres; the evaporation rate (EVAPU) is from a data file array and has units of feet per month. The constant (0.3258288 x 12./52.) is the conversion factor for acre-feet/month to mgw, the units of EVAPB and EVAPS.

The premises of the separate storage accounting system are that the reservoir inflow is apportioned according to the ratio of storage capacity to reservoir capacity, that the releases are attributed to the storage of its purpose, and that evaporation losses are based on the ratio of the account storage to the total Bloomington storage for the previous week. For upstream reservoir management, the model assumes that Savage storage and Bloomington water quality storage share the responsibility of maintaining flow at Luke. Consequently, the model tries to keep the two storages in the same proportion (percent full) if possible and still maintain minimum releases and adequate water quality downstream of the reservoirs.

The upstream calculation begins by fixing the operating rule storages for the week (WTDRB and WTDRS). The operating rule storages are checked for invalid values and reset, if necessary (storages must be greater than zero and less than or equal to the reservoir capacity). If no winter drawdown is desired for the reservoir, the operating rule storage is set to the reservoir capacity (CAPB or CAPS).

Next, the program determines an initial estimate of the desired ratio of Bloomington flow to Savage flow. This is achieved by a series of checks based on the total amount of release required from the upstream reservoirs (TGDFD, which is equal to or greater than TARGU) and the week of simulation. This ratio is assigned to the variable BSRAT. From this ratio, the respective fractions for Bloomington and Savage (BFRAC and SFRAC) are determined by the following equations:

$$BFRAC = \frac{BSRAT}{1 + BSRAT}$$

$$SFRAC = \frac{1}{1 + BSRAT}$$

These fractions are used to calculate how much of the targeted flows come from each reservoir. For the upstream target, the Bloomington and Savage water quality releases (RBWQ and RS) are then initially computed as:

$$RBWQ = BFRAC \times TARGU$$
$$RS = SFRAC \times TARGU$$

If the Bloomington-Savage ratio option was not invoked, then the program computes an initial value for the Bloomington water quality release and the Savage release according to the proportional storage rule.

$$RBWQ = \frac{CAPS}{(CAPBWQ + CAPS)} \quad x \quad (SBWQ(t-1)+(FB(t) \times \frac{CAPBWQ)}{CAPB} - EVAPB \times \frac{SBWQ(t-1)}{SB(t-1)})$$

$$- \frac{CAPBWQ}{(CAPBWQ + CAPS)} \quad x \quad (SS(t-1) + FS(t)-EVAPS-TARGU)$$

$$RS = TARGU-RBWQ$$

where SS = storage in Savage (mg)
SBWQ = water quality storage in Bloomington (mg)
SB = total storage in Bloomington (mg)
FB, FS = inflow into Bloomington, Savage (mgw)
EVAPB, EVAPS = evaporation from Bloomington, Savage (mgw)
CAPBWQ = Bloomington water quality storage capacity (mg)
CAPS = total Bloomington storage capacity (mg)
TARGU = upstream flow target at Luke (mgw)

The model then tests these values to see if they meet the minimum downstream flow standards (RBMIN and RSMIN). If not, the releases are adjusted. An increase in Savage release means Bloomington could release less and vice versa. The model checks these values carefully and assures that the minimum flow standards and upstream target are maintained if water is available.

Next, the program calculates the storages (SHORTB and SHORTS) which would result for the calculated water quality releases.

$$SHORTB = SBWQ(t-1) + FB(t) \times \frac{CAPBWQ}{CAPB} - EVAPB \times \frac{SBWQ(t-1)}{SB(t-1)} - RBWQ$$

$$SHORTS = SS(t-1) + FS(t) - EVAPS - RS$$

These intermediate storage values are tested for negativity. If enough water exists in both projects to supply the water quality releases, then SHORTB and SHORTS are assigned to SBWQ(t) and SS(t). Capacity tests are then performed. If SBWQ(t) exceeds CAPBWQ, the extra water is assigned to EXTBWQ, and SBWQ(t) is set to CAPBWQ. If Savage storage exceeds the operating rule storage (WTDRS), the extra water is assigned to SPILLS and SS(t) set to WTDRS. The model then checks to see if the Savage spill can offset the Bloomington water quality release. If so, the Bloomington water quality release is reduced and storage increased proportionally. Checks for minimum downstream flow and excess storage are performed. The results are water quality releases that meet the minimum flow standards and that efficiently and fairly use the available water quality storage to meet the Luke target.

If either or both SHORTB and SHORTS are negative the program performs similar checks. For example, a negative SHORTS and positive SHORTB indicates that there is enough water in Bloomington to meet the water quality releases but a shortage in Savage. Therefore, Savage releases all that it can (RS + SHORTS) and has no storage remaining (SS(t) = 0). If Bloomington has enough storage to offset Savage's deficit

(SHORTB ≥(SHORTS), then it releases its original allotment plus Savage's deficit (RBWQ - SHORTS; remember, SHORTS is negative). The Bloomington water quality storage is reduced accordingly.

In the next segment, the program computes the Bloomington water supply release. If there is no downstream water supply operations (T=0), if the upstream target equals or exceeds the downstream target, or if the flow at Luke exceeds the downstream target (TGDFD), the program sets the water supply release (RBWS) to zero and computes the new water supply storage (SBWS) according to the following formula:

$$SBWS\ (t) = SBWS\ (t-1) + \left(FB(t) \times \frac{CAPBWS}{CAPB}\right) - EVAPB \times \frac{SBWS(t-1)}{SB(t-1)} + EXTBWQ$$

where CAPBWS = Bloomington water supply storage capacity (mg)
EXTBWQ = Spill from water quality storage (mgw)

If SBWS (t) exceeds its capacity, SBWS (t) is set to CAPBWS and SPILLB equals the extra storage.

For the case where the downstream target TGDFD exceeds the water available at Luke from the water quality releases and spills (WLUKE), the reservoir will make a water supply release to make up the difference. This release (RBWS) is calculated by:

$$RBWS = \frac{(TGDFD - WLUKE) \times BSRAT - RBWQ + RS \times BSRAT + SPILLS \times BSRAT}{BSRAT + 1}$$

This equation essentially assigns RBWS, the Bloomington fraction of the additional flow required above the available Luke flow (TGDFD-WLUKE). Since Savage would release some flow to dilute this water supply release, the model assumes an additional Savage release (RSS) which equals the Savage fraction of the needed flow. This release is calculated by the following equation:

$$RSS = \frac{(TGDFD - WLUKE - BSRAT \times RS - SPILLS \times BSRAT + RBWQ)}{BSRAT + 1}$$

If no Savage dilution is required, BSRAT is a very large number (9999); consequently, RSS would be zeroed out in the equation and RBWS would be assigned the full amount of the water supply release.

The intermediate variable for the Bloomington water supply storage (SHTBWS) is then calculated:

$$SHTBWS = SBWS\ (t-1) + FB\ (t) \times \frac{CAPBWS}{CAPB} - EVAPB\ \times \frac{SBWS(t-1)}{SB(t-1)} - RBWS + EXTBWQ$$

The program then proceeds with the checks for negativity and capacity, similar to the water quality checks.

Next, the program determines whether any water supply spill can be used to increase the water quality release to meet the upstream flow target at Luke. If needed, the water quality release is increased. Tests and adjustments for negative storages and storage capacity exceedance follow, to ensure sensible operation of the reservoirs. Similarly, the program adjusts the Bloomington water quality release and storage for any spill from Savage.

Following these analyses, the model turns its attention to the Bloomington operating rule curve. The program compares the total Bloomington storage (SBWQ + SBWS) to the rule curve storage (WTDRB). If the Bloomington storage is less than WTDRB, then the program accepts the SBWQ and SBWS values. If Bloomington has storage above WTDRB, the extra is subtracted from the water quality storage. If the water quality storage empties in the process, the water supply storage releases the remainder necessary to meet the operating rule. The resulting increase in Bloomington releases due to the winter drawdown provides the opportunity for a reduction in Savage release. The program tests for this potential and adjusts the Savage release (within the bounds of the dilution ratios) and storage accordingly.

The final test of the upstream reservoir component guarantees that the sum of Bloomington's releases meet the minimum flow requirement downstream of the dam (RBMIN). The situation of not conforming to this flow requirement only occurs if Bloomington storage is nearly empty. For this situation, the Corps' usual practice is that reservoirs will release the minimum flow or the reservoir inflow, whichever is less regardless of the state of the water quality storage. To meet this policy, the program first makes the test for flow standard conformity:

$$(SPILLB + RBWQ + RBWS) \geq RBMIN$$

If the answer is negative, then the program tests for inflow conditions with the if statement ($FB \geq RBMIN$). The lesser of the two is the amount that must be released from Bloomington storage (if water is available). Bloomington water supply storage provides the additional needed release, from its allotment of reservoir inflow. The water supply storage is reduced accordingly. The Savage storage and release are then checked and adjusted, similar to previous steps.

The last step of the upstream reservoir management component is the assignment of the calculated values to the variable arrays for permanent storage. Total releases and storage for Bloomington and Savage are computed. For computational purposes, all zero values of Bloomington and Savage storage (SB, SBWQ, SBWS, and SS) are set to 0.001, since these variables are the denominators in several equations.

POTOMAC FLOW ALLOCATION

The third component of the simulation model encompasses Steps VI & VII of Figure H-III-2.

This component is diagrammed in Figure H-III-6 and primarily deals with the allocation of Potomac River flow available to the MWA region.

The first step of this component compares the Occoquan and Patuxent storages going into week (t) (that is, SO(t-1) and SP(t-1)) with their respective minimum water supply drafts. If the storages are below those values, the minimum variable is set to the available storage.

The next step is the calculation of the water supply demand for each service area for week (t) less the minimum offstream draft (RPMIN or ROMIN). These calculations draw from ones earlier in the program.

DWSSC(t) = FDWSSC(t) - RPMIN
DWAD(t) = FDWAD(t)
DFCWA(t) = FDFCWA(t) - ROMIN

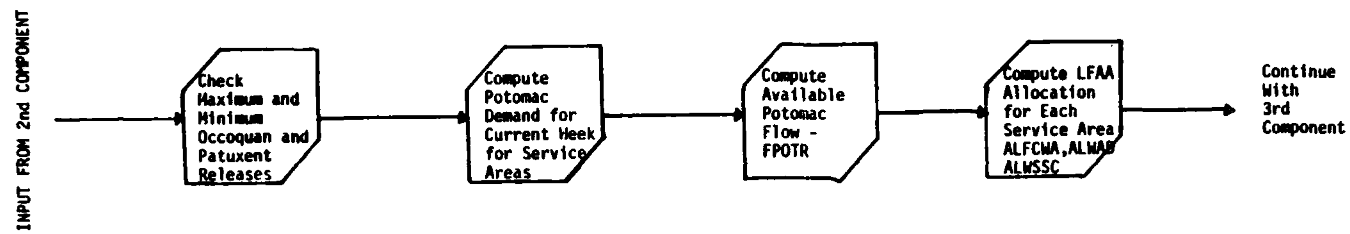


FIGURE H-III-6

FLOW DIAGRAM OF POTOMAC FLOW ALLOCATION (STEPS VI AND VII)

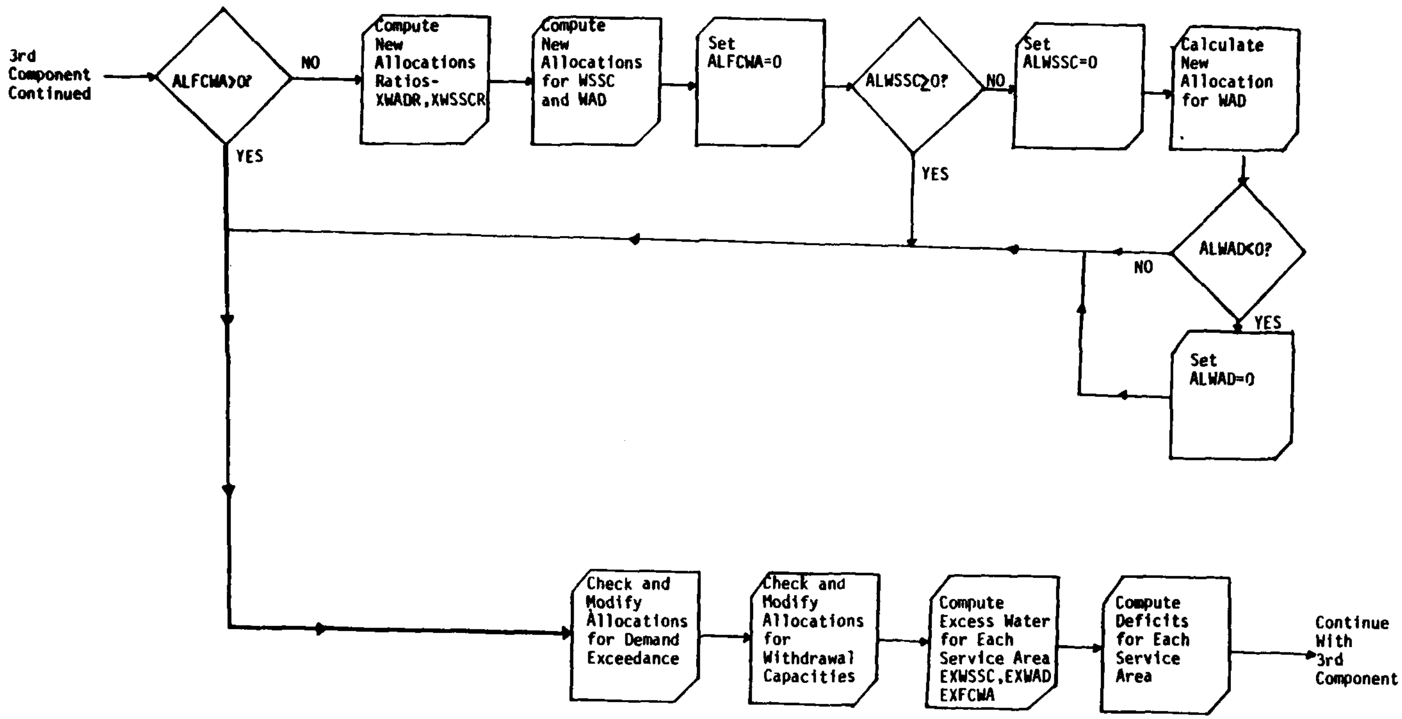


FIGURE H-III-6 (Continued)

FLOW DIAGRAM OF POTOMAC FLOW ALLOCATION (STEPS VI AND VII)

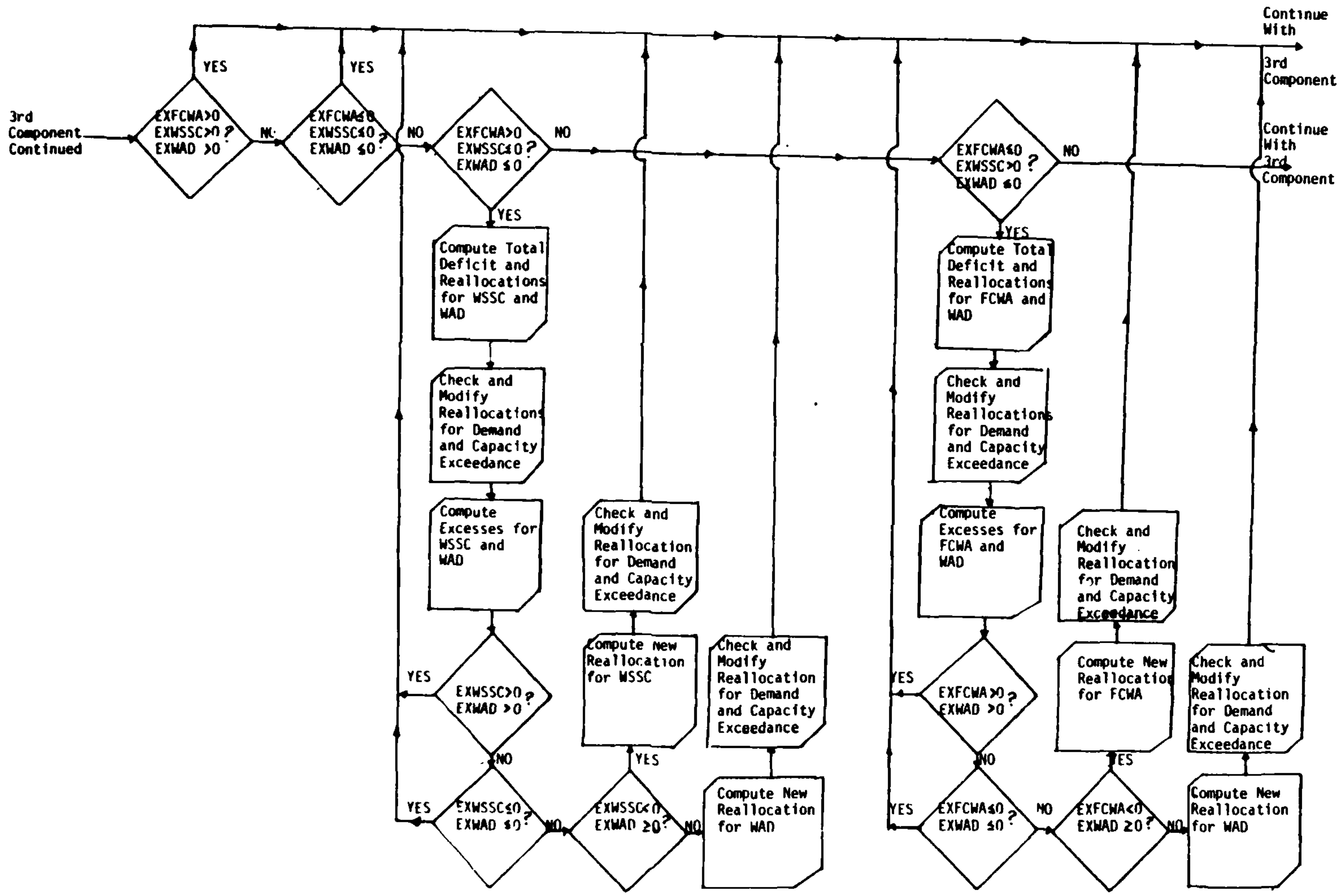


FIGURE H-III-6 (Continued)

FLOW DIAGRAM OF POTOMAC FLOW ALLOCATION
(STEPS VI AND VII)

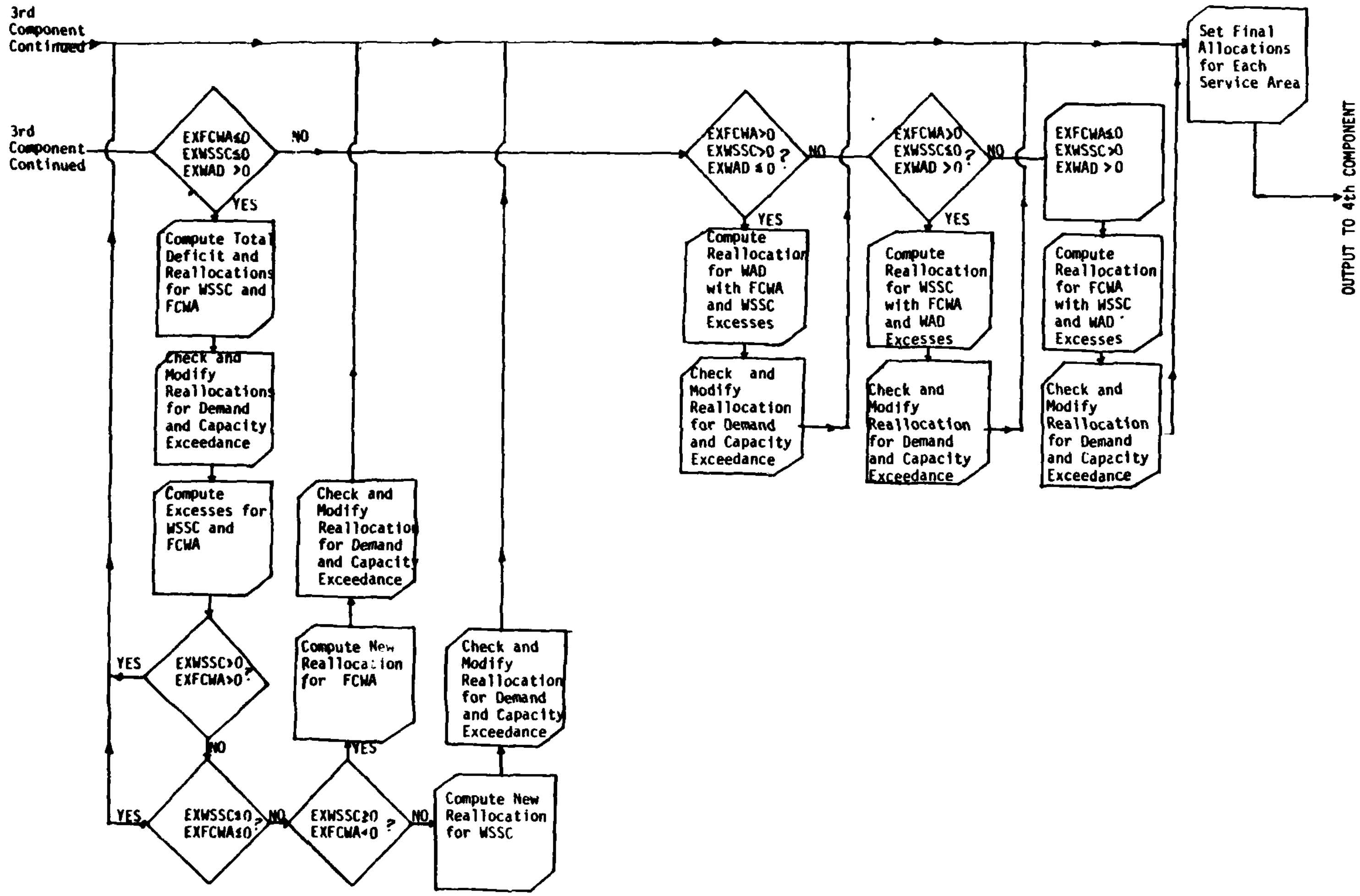


FIGURE H-III-6 (Continued)

FLOW DIAGRAM OF POTOMAC FLOW ALLOCATION (STEPS VI AND VII)

The next step is the basic application of the LFAA. This step computes the service area allocations (ALWAD, ALWSSC and ALFCWA) according to the formula stipulated in the LFAA. The equations are:

FPOTR = FPOT(t) + PER1 x FL(t) + PER2 x FL(t-1)
ALWAD(t) = WADR x (FPOTR - ENFB + CPAT + COCC)
ALWSSC(t) = WSSCR x (FPOTR - ENFB + CPAT + COCC) - CPAT
ALFCWA(t) = FCWAR x (FPOTR - ENFB + CPAT + COCC) - COCC

for WADR, WSSCR, FCWAR = the jurisdictional LFAA ratios
FPOTR = augmented flow in Potomac River above MWA intakes
PER1 = upstream release fraction for current week
PER2 = upstream release fraction for second week
FPOT = natural flow in Potomac River at Little Falls
ENFB = required level of flow into the Potomac estuary
CPAT, COCC = offstream reservoir draft capacities (Patuxent and Occoquan)
FL = flow at Luke provided by upstream reservoirs

If any of the allocations are negative, the remaining jurisdictions share the available water. Fairfax County has the lowest demand level (therefore the lowest LFAA ratio) and the highest offstream water supply capacity. Consequently, FCWA will be the first service area to incur a negative allocation if it happens. Similarly, WSSC is the second candidate for negative allocation. Therefore, the program first tests FCWA's allocation for negativity. If ALFCWA is positive, all allocations are positive and no adjustments are made. However, if ALFCWA is negative, the allocations are recalculated using new LFAA ratios. The new ratios are:

XWADR = WADS/XTOTS
XWSSCR = WSSCS/XTOTS

for WSSCS, WADS = service area winter demands
XTOTS = WSSCS + WADS

The formula for allocations are reapplied, and ALFCWA is set to zero. Further, if the allocation to WSSC is also computed to be non-positive, its allocation is set to zero and WAD is allocated all of the available Potomac flow.

Proceeding to the next step, the model compares the service area Potomac allocations to the corresponding water supply demands and Potomac withdrawal capacities. The minimum of the three becomes the service area's allocation since the allocation should not exceed the LFAA, the demand, nor the intake capacity. The program then computes the excess water resulting from the demand or withdrawal limitations. Continuing, the deficits for each jursidiction with the current allocation are computed.

If one or more jurisdictions have excesses which can be redistributed to the jurisdiction(s) needing water, then a reallocation of Potomac flow is carried out. If excesses do not exist, no re-allocation is possible. Reallocations are based on each jurisdiction's deficit in relationship to the total deficit.

For example, if FCWA has an excess allocation of EXFCWA, WSSC and WAD are given their previous allocations plus a fraction of EXFCWA. The new allocations would be:

ALWSSC(t) = ALWSSC(t) + (BB/TOTDF) x EXFCWA
ALWAD(t) = ALWAD(t) + (CC/TOTDF) x EXFCWA

for BB = WSSC deficit
CC = WAD deficit
TOTDF = total regional deficit (BB + CC)

The excesses and deficit are recomputed. If one service area now has an excess and the other has a deficit, the remaining excess is reallocated to the "short" service area.

This type of reallocation occurs for all possible combinations of excesses and deficits within the three jurisdictions. Thus, the allocations are set and assigned to each service area. The program continues with the offstream reservoir calculations.

DOWNSTREAM RESERVOIR REGULATION

Steps VIII and IX of Figure H-III-2 comprise the downstream reservoir component of the PRISM/COE program. A flow diagram of this component, the fourth, is presented in Figure H-III-7.

This segment begins with an initial calculation of the service area needs (RWSSC and RFCWA) with the following equations:

RWSSC = ALWSSC(t) - DWSSC(t)
RFCWA = ALFCWA(t) - DFCWA(t)
IF (RWSSC. LE. 0.0) RP(t) = -RWSSC
IF (RFCWA. LE. 0.0) RO(t) = -RFCWA

The need is simply the service area's allocation minus the demand which can be supplied by the Potomac (total demand minus minimum offstream draft). The total releases from the offstream reservoirs are then the needs plus the minimum drafts. In equation form, these are:

RP(t) = RP(t) + RPMIN
RO(t) = RO(t) + ROMIN

The releases are then compared to the maximum drafts and previous week's storages. The model assures that the reservoir water supply release is within the draft capacity, that reservoir storages do not become negative, and that the minimum environmental release to downstream areas is made.

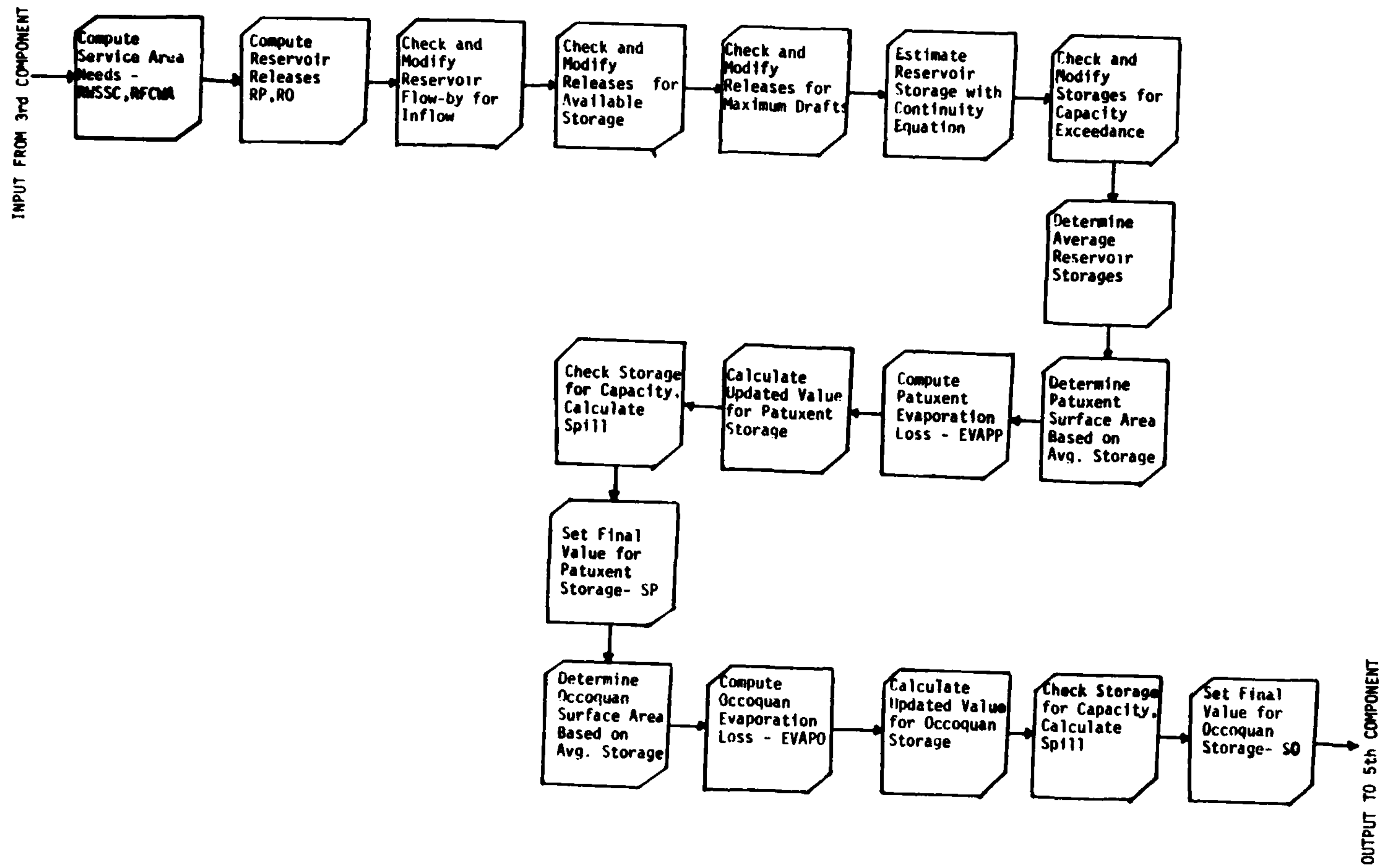


FIGURE H-III-7

FLOW DIAGRAM OF DOWNSTREAM RESERVOIR REGULATION (STEPS VIII AND IX)

The program then estimates the downstream reservoir storages for week (t) and determines the surface areas and evaporation losses as a function of the storage. The following calculations are used:

Patuxent:	for	$0 \leq SP(t) \leq 3258.288$	$AREA = 0.21637 \times SP(t)$
		$3258.288 < SP(t) \leq CAPP$	$AREA = 0.103582 \times SP(t) + 367.5$

$$EVAPP = EVAPD(t) \times AREA \times 0.3258288 \times 12./52$$

Occoquan:	for	$0 \leq SO(t) \leq 1303.0152$	$AREA = 0.29923 \times SO(t)$
		$1303.0152 < SO(t) \leq 5864.9184$	$AREA = 0.175379 \times SO(t) + 161.429$
		$5864.9184 < SO(t) \leq CAPO$	$AREA = 0.1304066 \times SO(t) + 425.0$

$$EVAPO = EVAPD(t)\ AREA \times 0.3258288 \times 12./52.$$

The AREA values have units of acres; the evaporation rate (EVAPD) is from a data file array and has units of feet per month. The constant (0.3258288 x 12/52) is the conversion factor for acre-feet/month to mgw, the units of EVAPP and EVAPO.

The final values of storage and spill of the downstream reservoir are then determined utilizing the reservoir continuity equation. The following equations are employed:

$$SP(t) = SP(t-1) + FP(t) - RP(t) - WP(t) - EVAPP$$
$$SO(t) = SO(t-1) + FO(t) - RO(t) - WO(t) - EVAPO$$

for FP, FO = reservoir inflow (mgw)
RP, RO = water supply release (draft) (mgw)
WP, WO = reservoir spill to meet downstream flowby and/or storage above capacity (mgw)
EVAPP, EVAPO = evaporation loss (mgw)

The downstream reservoir calculations are now complete.

FINAL CALCULATIONS AND OUTPUT

The last component of the PRISM/COE model is the final calculations and output segment. This segment, represented by Steps X and XI in Figure H-III-2, is diagrammed in detail in Figure H-III-8. This component makes some final calculations for the system status and prints the output file.

First, the final deficit (DTWSSC, DTFCWA, DTWAD) for each service area is computed for the current week using these equations:

$$DTWSSC(t) = FDWSSC(t) - RP(t) - ALWSSC(t)$$
$$DTFCWA(t) = FDFCWA(t) - RO(t) - ALFCWA(t)$$
$$DTWAD(t) = FDWAD(t) - ALWAD(t)$$

for FDWSSC, FDFCWA, FDWAD = service area total demand
RP, RO = offstream reservoir water supply release
ALWSSC, ALFCWA, ALWAD = Potomac flow allocation to service area

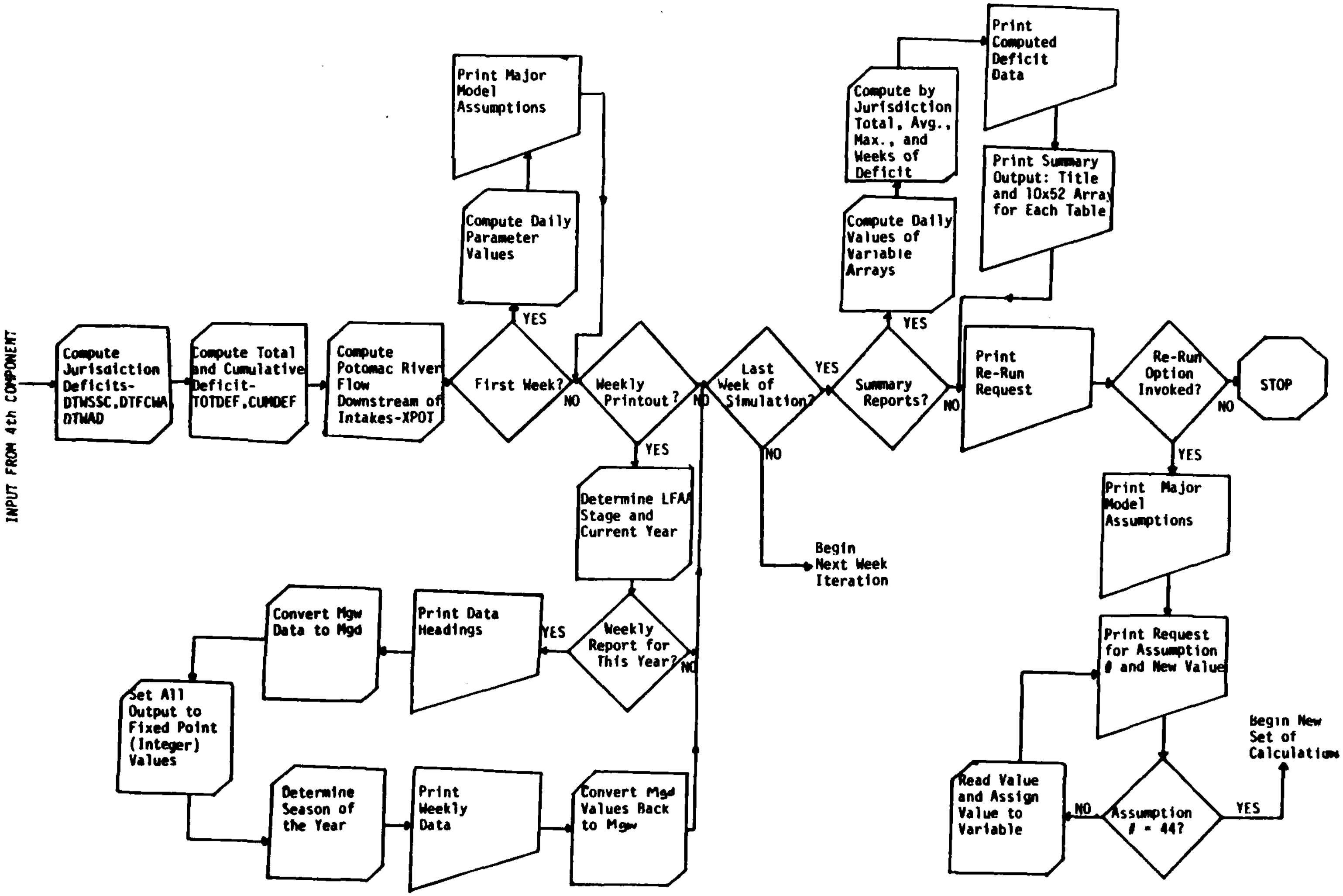


FIGURE H-III-8

FLOW DIAGRAM OF FINAL CALCULATIONS AND OUTPUT (STEPS X AND XI)

The total regional and cumulative deficits are next determined:

TOTDEF(t) = DTWSSC(t) + DTFCWA(t) + DTWAD(t)
CUMDEF(t) = CUMDEF(t-1) + TOTDEF(t)

The flow remaining in the Potomac River after water supply withdrawals (XPOT) is next computed. This amount includes environmental flowby, and represents the amount of water which reaches the Potomac estuary. The calculation uses the following equation:

XPOT(t) = FPOTR - ALWSSC(t) - ALFCWA(t) - ALWAD(t)

for FPOTR = augmented flow in the Potomac River above MWA intakes
ALWSSC, ALFCWA, ALWAD = Potomac flow allocations to service area

The remaining program elements define the output file. First, the program contains a routine to produce weekly status reports. The status report contains a list of the input parameters and data associated with weekly calculations. The elements listed in Table H-III-2 are printed for the user's verification of model calculation. The program converts many of the variables from mgw to mgd for easier comprehension. The program calculates the LFAA stage according to the following formula:

FTF = FPOTR - ENFB
TOTDPR = FDWAD(t) + FDWSSC(t) + FDFCWA(t) - RO(t) - RP(t)

TOTDPR $<$ 0.5 FTF	No Stage
0.5 FTF $\leq$ TOTDPR $<$ 0.8FTF	stage = ALERT
0.8 FTF $\leq$ TOTDPR $<$ FTF	stage = RESTRICTION
FTF $\leq$ TOTDPR	Stage = EMERGENCY

for FTF = Potomac flow available for water supply distribution
TOTDPR = total MWA demand to be supplied by Potomac flow

For the weekly printout, all variables are converted to integer form, and have upper limits (i.e., 9999) for printing purposes, due to space limitations. The completion of the weekly printout segment also signals the end of the main iteration. Calculations within this loop would be repeated for all weeks of simulation.

At the completion of the simulation calculations, the program assigns a number of the variable arrays to the output file for summary table printout. The variable arrays thus designated are listed in Table H-III-3 in order of appearance in the output file. The program also makes minor summary calculations for the output file, including computation of the total deficit, number of weeks of deficit, the average deficit, and the maximum deficit, by service area.

The output file for this simulation is now completed. The last section of the PRISM/COE model contains the re-run provision. The section prints the major parameters to the input terminal and asks the user for changes for the next simulation. The changed values are assigned to the appropriate array and the program proceeds with the new simulation.

TABLE H-III-2

WEEKLY PRINTOUT DATA

	Bloomington	Savage	Occoquan	Patuxent
1. Run Number				
2. Year Number				
3. Week Number				
4. Season of the Year				
5. Predicted Reservoir Inflow, mgd	X	X		
6. Reservoir Inflow, mgd	X	X	X	X
7. Actual-Predicted Reservoir Inflow, mgd	X	X		
8. Water Quality Release, mgd	X	X	X	X
9. Water Supply Release, mgd	X	X	X	X
10. Release from Storage, mgd	X	X	X	X
11. Total Release, mgd	X	X	X	X
12. Evaporation Loss, mgd	X	X	X	X
13. Storage at End of Week, mg	X	X	X	X
14. Rule Curve Storage, mg	X	X		
15. Water Quality Storage, mg	X			
16. Water Supply Storage, mg	X			
17. Upstream Target, mgd				
18. Bloomington: Savage Target Release Ratio				
19. Flow at Luke, mgd				
20. Current Week's Water Supply Release Arriving This Week, mgd				
21. Previous Week's Water Supply Release Arriving This Week, mgd				
22. Model Flow at Intake, mgd				
23. Predicted Flow at Intake, mgd				
24. Actual Flow at Intake, mgd				
25. Actual-Predicted Flow at Intake, mgd				
26. LFAA Stage				
	WAD	**FCWA**	**WSSC**	**Total**
27. LFAA Ratio	X	X	X	
28. Demand, mgd	X	X	X	X
29. Preliminary Allocation, mgd	X	X	X	X
30. Final Allocation, mgd	X	X	X	X
31. Deficit, mgd	X	X	X	X
32. Flow to Estuary, mgd				

TABLE H-III-3

SUMMARY PRINTOUT TABLES

	Table	Units
1.	Storage in Bloomington Reservoir	mg
2.	Water Supply Storage in Bloomington Reservoir	mg
3.	Water Quality Storage in Bloomington Reservoir	mg
4.	Storage in Savage Reservoir	mg
5.	Storage in Patuxent Reservoir	mg
6.	Storage in Occoquan Reservoir	mg
7.	Water Supply Release from Bloomington Reservoir	mgd
8.	Water Quality Release from Bloomington Reservoir	mgd
9.	Savage Release to Dilute Bloomington Water Supply Releases	mgd
10.	Allocation to WSSC	mgd
11.	Allocation to FCWA	mgd
12.	Allocation to WAD	mgd
13.	Deficit of WSSC	mgd
14.	Deficit of FCWA	mgd
15.	Deficit of WAD	mgd
16.	Deficit of MWA Region	mgd
17.	Cumulative Deficit of MWA Region	mgd
18.	Total Release from Bloomington Reservoir	mgd
19.	Total Release from Savage Reservoir	mgd
20.	Release from Patuxent Reservoir	mgd
21.	Release from Occoquan Reservoir	mgd
22.	Demand of WSSC	mgd
23.	Demand of FCWA	mgd
24.	Demand of WAD	mgd
25.	Flow in Potomac after Withdrawals Including Environmental Flowby	mgd
26.	Total Flow at Luke, Maryland	mgd

The PRISM/COE model is summarized in the flow diagram in Figure H-III-9.

MODEL PROGRAMMING

USER ACCESS

PRISM/COE is currently maintained on the EKS1 system of the Boeing Computer Services under the Baltimore District's user number. User access to the model begins with the normal connection and log-in procedures for Boeing's Mainstream EKS1 system. Once successfully logged in, the user will be in the NULL subsystem. To execute PRISM/COE, the batch subsystem must be used. Batch mode is achieved by the BAT command.

The user is now ready to execute PRISM/COE. The command CALL, PROC# (OUT = filename, PLOT = filename) initiates the PRISM/COE run. PROC# is a procedure file which contains the required execution commands. The PROC# statements retrieve the necessary data files and program input, execute the FORTRAN program, return an output file, and create a listing of the actual execution (DAYFILE). The parenthetical expression (OUT = filename, PLOT = filename) is required for PRISM/COE execution, and

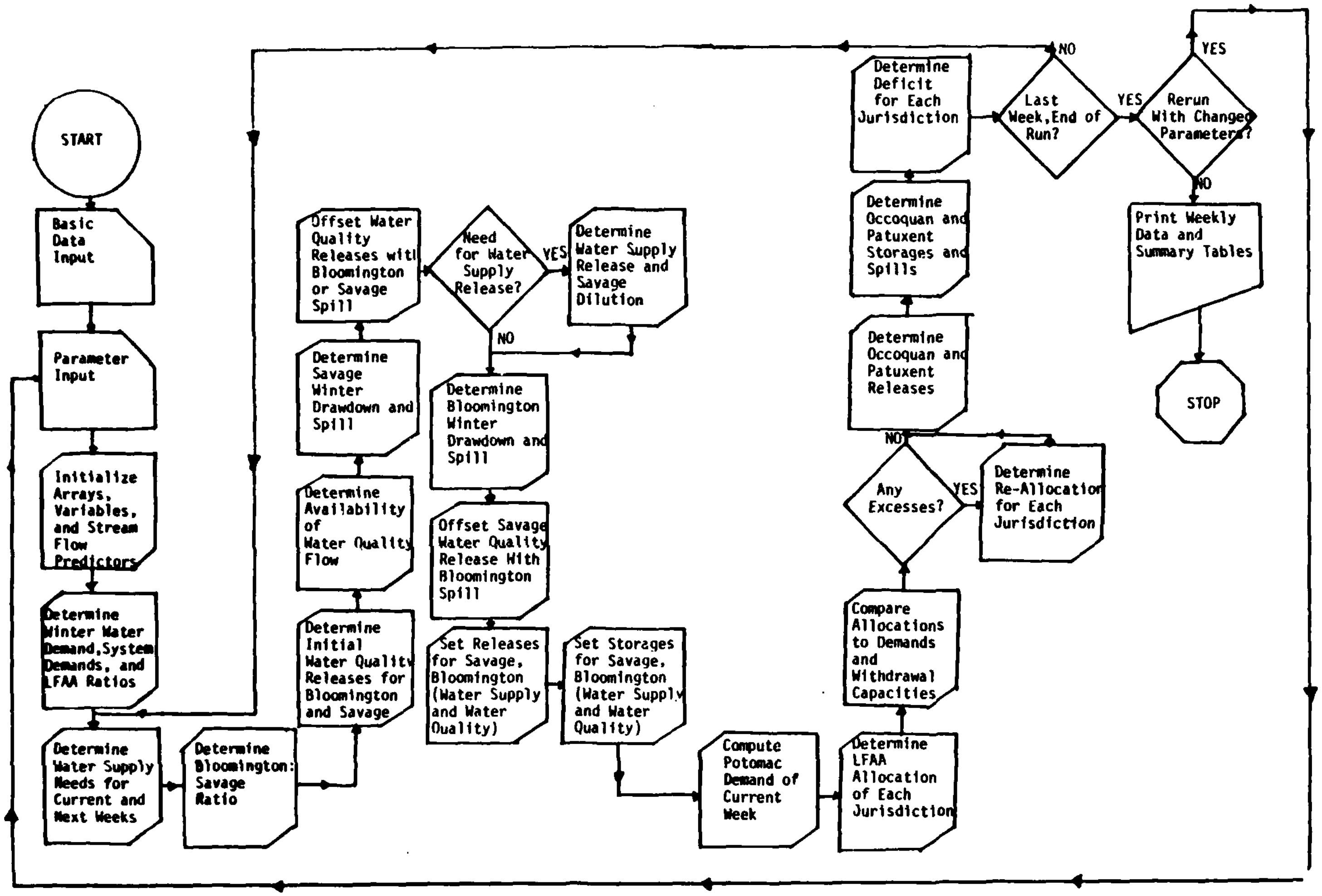


FIGURE H-III-9

SUMMARY FLOW DIAGRAM OF PRISM/COE

is the assignment of the output filenames. In this manner, the filename (a string of characters up to 7 characters in length) can be changed for each PRISM/COE run; thus a series of output files can be created without destroying previous files. A listing of the PROC# procedure file is given in Table H-III-4. Separate procedure files for each of the flow data sets have been created. The procedure file for the first decade of flows is named PROC1. The other procedure files are designated similarly.

After the CALL, PROC# (OUT = filename, PLOT = filename) command has been entered, PRISM/COE begins execution. The program prints out "WELCOME TO PRISM/COE," then requests a series of input. The computer prints the type of information required and then indicates that input is desired by printing I>. The user then enters the value and a carriage return (CR). The process is followed for the 43 data inputs. An explanation of each data input is given in the next section.

After the input series is completed, the program prints a listing of the input parameters and asks if the user would like to make any changes. This allows the user to examine the input for any typographical errors and to make the appropriate corrections before the heart of the program is run. The format for the corrections is similar to the original input. The number associated with the input is entered; an input prompt (I>) is returned; and the data value is then entered. Once the changes are complete, the main program is run and the output file is created. Within seconds, the satisfactory completion of the program run is signalled by the printed computer request for a re-run.

The re-run capability of the program permits the user to make additional PRISM/COE runs with ease. If a re-run is desired, the program lists the 43 major model assumptions and asks for changes. The changes are entered in identical fashion as the correction program segment. The model then runs with the new input values, and again the re-run request appears at the end of the program run. The second and all subsequent sets of output are attached to the end of the first output file, creating one large output file. With these procedures, many runs can be executed consecutively with little effort.

When the last run is complete and re-run is not selected, the program ends the execution. This is signalled by the statement, RETURN, TAPE6, and a batch prompt (C>). All that remains of the run is to inspect the simulation results. This is done simply by printing the outpile file that was designated in the initiating execution statement, CALL, PROC# (OUT=filename, PLOT=filename).

The output file lists the major model assumptions for the specific simulation, weekly data printout, and summary tables. The major model assumptions are the input values which the user has specified. These parameters are detailed in the next section. The weekly data printout can be specified in the input for any of the years of simulation. The printout consists of program-specified system data, describing the upstream and downstream reservoirs, the Potomac flow, and the three jursidictions' water supply demands. The weekly output was designed as a diagnostic tool for programming errors.

Following the weekly output, a short description of the deficit conditions and the summary tables are listed. The deficit summary shows the total water supply deficit, the number of weeks of deficit, the average deficit, and the maximum deficit for each MWA service area. The 26 summary tables are internally programmed within the model. The tables present the weekly data value for ten years of simulation (a total of 520 values) for some variables including reservoir storages, reservoir releases, Potomac River flows, and service area demands, allocations, and deficits. A complete listing of the summary tables was given in Table H-III-3.

TABLE H-III-4

PROC# - SAMPLE PROCEDURE FILE FOR PRISM/COE

```
ASSIGN, TT, TAPE 6.

RETURN PRISMP, FLOW #, DATA2, DATA3, DATA4, DATA5, DATA6.
GET, PRISMP, FLOW#, DATA2, DATA3, DATA4, DATA5, DATA6.
RETURN, OUT.
RETURN, PLOT.
CC, FF.
GET, INPUT = IN/NA.
PRISMP, PL=77777, INPUT, FLOW#, DATA2, DATA3, DATA4, DATA5, DATA6, OUT, PLOT.
REPLACE, OUT.
REPLACE, PLOT.
EXIT, U.
DAYFILE, NELSON.
REPLACE, NELSON.
RETURN, TAPE6.
```

PROGRAM INPUT

For each PRISM/COE run, the user selects values for the major assumptions. These values are input at the initiation of the PRISM/COE run, following the WELCOME TO PRISM/COE statement. These values define certain key variables within the program. All input data must follow an input prompt (I). After data input, a carriage return (CR) formally completes the input action.

The first input is the response to the statement, PRISM RUN NO. The data input is assigned to the variable NUMB. This number value appears in major headings throughout the output file for the specific run. The remaining input parameters appear in numerical order in the input listing. They are listed below, with detailed descriptions:

1. CAPACITY OF BLOOMINGTON, MG - This value is the maximum volume of conservation storage in Bloomington Lake, in million gallons. It is the sum of the reservoir's water quality and water supply storage capacities. The input is assigned to the variable CAPB.

2. CAPACITY OF SAVAGE, MG - This value is the maximum volume of usable conservation storage in Savage River Reservoir, in million gallons. The input is assigned to the variable CAPS.

3. CAPACITY OF OCCOQUAN, MG - This input represents the conservation storage capacity of the Occoquan Reservoir, in million gallons. CAPO is assigned the input value.

4. CAPACITY OF PATUXENT, MG - The input represents the total conservation storage capacity of the Patuxent River reservoirs, in million gallons. It is the sum of the conservation volumes in Rocky Gorge and Triadelphia Reservoirs. CAPP is assigned the input value.

5. POTOMAC WITHDRAWAL CAPACITY, FCWA, MGD - This value is the maximum rate of withdrawal by Fairfax County's Potomac intake in million gallons per day. The rate reflects the maximum amount of Potomac flow which can be withdrawn, treated, and distributed by the Fairfax County Water Authority. The input value is assigned to the program variable CWFCWA.

6. POTOMAC WITHDRAWAL CAPCITY, WSSC, MGD - This value is the maximum rate of withdrawal by WSSC's intake on the Potomac River, in million gallons per day. The rate reflects the maximum Potomac flow which can be withdrawn, treated, and distributed by the Washington Suburban Sanitary Commission. CWWSSC is assigned the input value.

7. POTOMAC WITHDRAWAL CAPACITY, WAD, MGD - This value is the maximum rate of withdrawal by the Aqueduct's intakes on the Potomac River, in million gallons per day. The rate reflects the maximum Potomac flow which can be withdrawn, treated, and distributed by the Aqueduct. The input value is assigned to the variable CWWAD.

8. ENVIRONMENTAL FLOWBY AT LITTLE FALLS, MGD - This input represents the minimum desired level of Potomac River flow into the estuary in million gallons per day. This flow is the quantity of water desired in the river at Little Falls, Maryland, after all withdrawals are completed. ENFB is assigned the input value.

9. TREATMENT CAPACITY AT OCCOQUAN, MGD - This value is the maximum quantity of water which can be withdrawn from the Occoquan Reservoir, treated, and then distributed (in million gallons per day). The water treatment plant capacity is normally the determining factor for this value. The input is assigned to the variable COCC.

10. TREATMENT CAPACITY AT PATUXENT, MGD - This value is the maximum quantity of water which can be withdrawn from the Patuxent reservoir system for water supply use, in million gallons per day. The water treatment plant capacity is normally the determining factor for this value. CPAT is assigned this input value.

11. UPSTREAM CONSUMPTIVE WITHDRAWAL, MGD - This value represents the flow withdrawals for irrigation or other purposes downstream of Luke, Maryland, and upstream of Little Falls, which are not returned to the Potomac River (in million gallons per day). This value is assigned to the variable WIRG. Within the PRISM/COE program, the Potomac flows are modified to reflect this flow loss, by subtracting WIRG from FPOT.

12. MINIMUM RELEASE FOR BLOOMINGTON, MGD - This input represents the minimum flow required immediately downstream of Bloomington Lake to maintain aquatic life, in million gallons per day. This flow is an important element in the upstream reservoir operation, because downstream flow maintenance is the first goal of the Bloomington operation. RBMIN is assigned the input value.

13. MINIMUM RELEASE FOR SAVAGE, MGD - This input represents the minimum flow required immediately downstream of Savage River Reservoir to maintain aquatic life, in million gallons per day. The model tries to achieve this goal at all times. RSMIN is assigned the input value.

14. ENVIRONMENTAL FLOWBY AT OCCOQUAN, MGD - This value is the required minimum flow downstream of the Occoquan Reservoir, in million gallons per day. The input is assigned to the variable SOMIN1.

15. ENVIRONMENTAL FLOWBY AT PATUXENT, MGD - This value is the required minimum flow downstream of Rocky Gorge Reservoir on the Patuxent River, in million gallons per day. The input is assigned to the variable SPMIN1.

16. ARE BLOOMINGTON:SAVAGE RATIOS FLOW-DEPENDENT (1 = YES, 0 = NO) - This input allows the user to regulate the upstream reservoir with the flow-dependent, time-dependent release ratios. If flow-dependent ratios are selected (input=1), question #17 is skipped and the program continues with #18. IBSANS is assigned the input value.

17. MAXIMUM DESIRED RATIO OF BLOOMINGTON TO SAVAGE RELEASE (IF NO DILUTION IS REQUIRED, ENTER 100) - This value represents the maximum ratio between Bloomington and Savage releases that is desired to maintain adequate water quality in the North Branch Potomac River. The input value is assigned to the variable BSRAT. If 100 is entered, the model does not use Savage as dilution storage, and Luke target releases are then calculated such that Bloomington water quality storage and Savage storage remain about equal on a percentage full basis.

18. AMOUNT OF BLOOMINGTON WATER SUPPLY RELEASE REACHING THE MWA INTAKES IN FIRST WEEK, % - This input reflects the travel time between the upstream reservoirs and the MWA intakes near Great Falls, Maryland. The value represents the percentage of upstream reservoir releases which will arrive at the downstream intakes within the week of release. PER1 is assigned the input value.

19. AMOUNT OF BLOOMINGTON WATER SUPPLY RELEASE REACHING THE MWA INTAKES IN SECOND WEEK, % - This value represents the percentage of upstream reservoir releases which will arrive at the downstream intakes in the week following release. The input value is assigned to the variable PER2.

20. YEAR OF INVESTIGATION - This value is the demand year which the simulation models. This value, simply designated as YEAR in the model, determines what demands are placed on the MWA water supply system. Within the model programming, the demands for the three Washington area jurisdictions have been calibrated for the years 1980-2030, according to regional projections.

21. DOWNSTREAM FACTOR, % - This value represents how much the water supply system plans to rely on downstream reservoirs. In determining water supply releases from Bloomington Lake, the model assumes a certain percentage (the input value) of the downstream reservoir water supply capacity is used. The percentage is input in decimal form ranging from 0.0 to 1.0, and is assigned to the program variable DSTF. High values of DSTF yield a system heavily dependent on the Occoquan and Patuxent reservoirs. Low values of DSTF produce a system which significantly relies on Bloomington water supply releases to meet MWA demands.

22. UPSTREAM TARGET AT LUKE, MGD - This input is the minimum flow desired in the Potomac River as it passes Luke, Maryland, in million gallons per day. The Luke flow target is met by releases and spills from Savage and Bloomington water quality storage. Water supply storage is not utilized to meet the Luke flow target. The target value is assigned the program variable TARGU.

23. YEAR OF LFAA FREEZE - This value represents the year in which the LFAA is considered frozen. This value, assigned to the variable I YEAR, determines which five years of winter demand data are used for the jurisdiction allocation ratios. Normally, the LFAA freeze year is assumed to be identical to the model simulation demand year (and input as such). The winter demand curves are calibrated for the years 1980-2030 inclusive.

24. MINIMUM DRAFT FROM OCCOQUAN, MGD - This input represents the minimum flow which has to be withdrawn from the Occoquan Reservoir, treated, and then distributed (in million gallons per day). This minimum flow is normally required to maintain the treatment plant and distribution system in good working order. The input value is assigned to the variable ROMIN1.

25. MINIMUM DRAFT FROM PATUXENT, MGD - This input represents the minimum flow which has to be withdrawn from the Patuxent reservoir system, treated, and then distributed (in million gallons per day). This minimum flow is normally required to maintain the treatment plant and distribution system in good working order. RPMIN1 is assigned this input.

26. INITIAL STORAGE, BLOOMINGTON, MG - This input is the designated conservation storage for Bloomington Lake during the first week of simulation, in million gallons. This value is assigned to SB(1).

27. INITIAL STORAGE, SAVAGE, MG - This input is the designated conservation storage for Savage River Reservoir during the first week of simulation, in million gallons. This value is assigned to SS(1).

28. INITIAL STORAGE, OCCOQUAN, MG - This input is the designated conservation storage for Occoquan Reservoir during the first week of simulation, in million gallons. This value is assigned to SO(1).

29. INITIAL STORAGE, PATUXENT, MG - This input is the total designated conservation storage for Rocky Gorge and Triadelphia Reservoirs during the first week of simulation, in million gallons. This value is assigned to SP(1).

30. ARE STREAMFLOWS PREDICTED BY MODEL OR PERFECT FORESIGHT (0 = MODEL, 1 = PERFECT FORESIGHT) - This value indicates which Potomac River flow data is used to determine water supply releases for MWA needs. If model prediction (0) is chosen, then the model utilizes a set of prediction equations to determine the expected flow in the Potomac River. If perfect foresight (1) is selected, the model assumes that the expected Potomac River flow is the actual recorded flow. This input (0 or 1) is assigned to the variable LD.

31. TYPE OF CONSERVATION (1 = BASELINE, 2 = SCENARIO 3) - This value indicates which set of demand curves will be followed during the simulation. The baseline scenario (input = 1) represents the most probable water demand situation for the time frame 1980-2030 without further actions by the local utilities. It includes the anticipated water use reduction due to actions regulated prior to 1980. Scenario 3 demands (input = 2) assume that both residential and non-residential conservation practices are effective to the extent that water use is reduced approximately 11 percent. ICONS is assigned this input value.

32. WEEKLY DEMAND COEFFICIENTS (1 = 8 YEAR MONTHLY DISTRIBUTION, 2 = 1966 ACTUAL, 3 = HYPOTHETICAL) - This input allows the user to select the set of demand coefficients for the program. The weekly demand coefficients and the average annual demand from the demand curves are multiplied together to produce a weekly demand value which reflects seasonal changes in water use. The first coefficient set was derived from eight years of monthly use data for the MWA jurisdictions between 1968 and 1976. The second set was obtained from actual weekly records from 1966. As expected, the second set shows a greater range of demands. The third coefficient option permits a hypothetical set of demand coefficients to be employed. At this time, that hypothetical set has coefficient values of zero. The input value for demand coefficients is assigned to the program variable IDMD.

33. INITIAL WATER SUPPLY STORAGE, BLOOMINGTON, MG - This input designates the water supply storage in Bloomington Lake during the first week of simulation, in million gallons. This value is assigned to SBWS(1).

34. INITIAL WATER QUALITY STORAGE, BLOOMINGTON, MG - This input designates the water quality storage in Bloomington Lake during the first week of simulation, in million gallons. This value is assigned to SBWQ(1).

35. WATER SUPPLY CAPACITY BLOOMINGTON, MG - This value is the maximum volume of water supply storage in Bloomington Lake, in million gallons. This input is assigned to the variable CAPBWS.

36. WATER QUALITY CAPACITY BLOOMINGTON, MG - This value is the maximum volume of water quality storage in Bloomington Lake, in million gallons. The input is assigned to the variable CAPBWQ.

37. DO YOU WANT SEPARATE WATER SUPPLY AND WATER QUALITY STORAGES IN BLOOMINGTON (1 = YES, 0 = NO) - This input indicates which upstream reservoir program component is utilized. If separate storages are desired (input = 1), then the model uses the water supply/water quality accounting system where Savage and Bloomington water quality storage are kept proportionally full, and Bloomington water supply storage is used to meet MWA needs. For input = 0, the Bloomington storage is undivided. This input value is assigned to the variable IWSWQ.

38. DO YOU WANT WINTER DRAWDOWN FOR BLOOMINGTON (0 = NO, 1 = YES) - This input allows the user to select the operating policy for Bloomington Lake. If winter drawdown is chosen (input = 1), the model operates the reservoir according to the rule curve located in the data files, to the extent that water quality and water supply releases allow. If no drawdown is desired (input = 0), the operating goal is to maintain conservation storage capacity. IWTDRB is assigned the input value.

39. DO YOU WANT WINTER DRAWDOWN FOR SAVAGE (0 = NO, 1 = YES) - This input allows the user to select the operating policy for Savage River Reservoir. If winter drawdown is chosen (input = 1), the model operates the reservoir according to the rule curve located in the data files. If no drawdown is desired (input = 0), the reservoir's operating goal is to maintain conservation storage capacity. IWTDRS is assigned the input value.

40. DO YOU WANT A DOWNSTREAM TARGET (1 = YES, 0 = NO) - This input indicates whether the model should operate with a downstream water supply target in

addition to the upstream flow maintenance targets. If a downstream target is desired (input = 1), the model releases water supply storage to avoid water supply deficits. The amount of water supply release depends on the jurisdictional demands, the predicted Potomac flow, the instream and consumptive losses, and the downstream target factor (input 21). Operating without a target (input = 0) means the model is oblivious to MWA demands and only attempts to maintain the streamflow at Luke. This input is assigned to T.

41. DO YOU WANT WEEKLY REPORT (1 = YES, 0 = NO) - This input allows the user to select the weekly data printout as an output option. IWEEKY is assigned the input value.

42. ENTER YEARS THAT YOU WANT WEEKLY REPORTS (1 = YES, 0 = NO); EXAMPLE 1,1,1,0,0,0,0,0,0,1; YOU MUST ENTER 10 NUMBERS SEPARATED BY COMMAS - This series of input indicates the years for which weekly printout is requested. These values are assigned to the array IWEEKR.

43. DO YOU WANT SUMMARY REPORTS (1 = YES, 0 = NO) - This input allows the user to select the summary tables as an output option. SUMRPT is assigned the input value.

After all variables are input, the program lists the model assumptions and asks "DO YOU WANT TO CHANGE ANY OF THE MODEL ASSUMPTIONS (0 = NO, 1 = YES)." A negative response sends the program to the beginning of the program calculations. After a positive response, the computer replies by commanding "ENTER THE IDENTIFICATION NUMBER OF ASSUMPTION TO BE CHANGED; ENTER 44 WHEN YOU ARE FINISHED CHANGES." with an input prompt (I>). This input is a number between 1 and 43 which corresponds to the incorrect assumption. After the value is input, the computer prints "ENTER NEW ASSUMPTION IN SAME FORMAT PREVIOUSLY REQUESTED." The user now inputs the correct model assumption, and the computer asks for another model assumption reference number. The process continues in this manner until the user is satisfied with the input parameters. At that time, the user types in "44" as the assumption number and the program calculations commence.

Once the run calculations are completed (it takes only a few seconds), the computer requests one additional segment of input. The computer prints "DO YOU WISH TO RERUN WITH CHANGED ASSUMPTIONS (1 = YES, 0 = NO)." A negative input (0) immediately returns the user to the terminal and the statement, RETURN, TAPE6., and and a batch mode prompt (C>) appears. A positive answer commands the computer to list the major model assumptions and print "ENTER IDENTIFICATION NUMBER PRECEEDING MODEL ASSUMPTION, ENTER 44 WHEN YOU ARE FINISHED CHANGES." The change process continues in similar fashion to the earlier change process. When the user has completed all of the modifications to the model assumptions (signalled by inputting "44"), the program returns to the initiation of calculations, and so on.

INPUT SAMPLE

Table H-III-5 on the following few pages list the actual input to a PRISM/COE run as it appeared at the computer terminal. Note at the end, there is an example of an assumption error and change and a second run using the program's rerun capability. These two sections following the 43 initial input parameters.

CALL,PROC1(OUT=O200,PLOT=P200)

execution statement

TABLE H-III-5

SAMPLE INPUT TO PRISM/COE

```
WELCOME TO PRISM/COE

PRISM RUN NO.
I>1
1. CAPACITY OF BLOOMINGTON,MG
I>30000
2. CAPACITY OF SAVAGE,MG
I>5900
3. CAPACITY OF OCCOQUAN,MG
I>10300
4. CAPACITY OF PATUXENT,MG
I>10100
5. POTOMAC WITHDRAWAL CAPACITY,FCWA,MGD
I>200
6. POTOMAC WITHDRAWAL CAPACITY,WSSC,MGD
I>400
7. POTOMAC WITHDRAWAL CAPACITY,WAD,MGD
I>650
8. ENVIRONMENTAL FLOWBY AT LITTLE FALLS,MGD
I>500
9. TREATMENT CAPACITY AT OCCOQUAN,MGD
I>95
10. TREATMENT CAPACITY AT PATUXENT,MGD
I>55
11. UPSTREAM CONSUMPTIVE WITHDRAWAL,MGD
I>0
12. MINIMUM RELEASE FOR BLOOMINGTON,MGD
I>32
13. MINIMUM RELEASE FOR SAVAGE,MGD
I>13
14. ENVIRONMENTAL FLOWBY AT OCCOQUAN,MGD
```

parameter input

TABLE H-III-5 (CONT'D)

SAMPLE INPUT TO PRISM/COE

I>0
15. ENVIRONMENTAL FLOWBY AT PATUXENT,MGD

I>10
16. ARE BLOOMINGTON:SAVAGE RATIOS FLOW-DEPENDENT?
(1=YES,0=NO)

I>1
18. AMOUNT OF BLOOMINGTON WATER SUPPLY RELEASE
REACHING THE MWA INTAKES IN FIRST WEEK,%

I>0.47
19. AMOUNT OF BLOOMINGTON WATER SUPPLY RELEASE
REACHING THE MWA INTAKES IN SECOND WEEK,%

I>0.53
20. YEAR OF INVESTIGATION

I>2030
21. DOWNSTREAM FACTOR, %

I>0.6
22. UPSTREAM TARGET AT LUKE,MGD

I>78
23. YEAR OF LFAA FREEZE

I>2030
24. MINIMUM DRAFT FROM OCCOQUAN,MGD

I>30
25. MINIMUM DRAFT FROM PATUXENT,MGD

I>20
26. INITIAL STORAGE,BLOOMINGTON,MG

I>29500
27. INITIAL STORAGE,SAVAGE,MG

I>5900
28. INITIAL STORAGE,OCCOQUAN,MG

I>10300
29. INITIAL STORAGE,PATUXENT,MG

I>10100
30. ARE STREAM FLOWS PREDICTED BY MODEL OR PERFECT FORESIGHT
(0=MODEL,1=PERFECT FORESIGHT)

I>0
31. TYPE OF CONSERVATION
(1=BASELINE, 2=SCENARIO 3)

parameter input

```
I>2
32.  WEEKLY DEMAND COEFFICIENTS
(1=8 YEAR MONTHLY DISTRIBUTION, 2=1966 ACTUAL, 3=HYPOTHETICAL)

I>1
33.  INITIAL WATER SUPPLY STORAGE, BLOOMINGTON, MG

I>13370
34.  INITIAL WATER QUALITY STORAGE, BLOOMINGTON, MG

I>16630
35.  WATER SUPPLY CAPACITY BLOOMINGTON, MG

I>13370
36.  WATER QUALITY CAPACITY BLOOMINGTON, MG

I>16630
37.  DO YOU WANT SEPARATE WATER SUPPLY AND WATER QUALITYSTORAGES IN BLOOMINGTON
(1=YES, 0=NO)

I>1
38.  DO YOU WANT WINTER DRAWDOWN FOR BLOOMINGTON
(0=NO,1=YES)

I>1
39.  DO YOU WANT WINTER DRAWDOWN FOR SAVAGE
(0=NO,1=YES)

I>1
40. DO YOU WANT A DOWNSTREAM TARGET, 1=YES, 0=NO

I>1
41. DO YOU WANT WEEKLY REPORTS, 1=YES, 0=NO

I>0
43. DO YOU WANT SUMMARY REPORTS, 1=YES, 0=NO

I>1
```

TABLE H-III-5 (CONT'D)

SAMPLE INPUT TO PRISM/COE

parameter input

MAJOR MODEL ASSUMPTIONS
PRISM RUN NO. 1

TABLE H-III-5 (CONT'D)
SAMPLE INPUT TO PRISM/COE

1. CAPACITY OF BLOOMINGTON = 30000.0 MG
2. CAPACITY OF SAVAGE RIVER = 5900.0 MG
3. CAPACITY OF OCCOQUAN = 10300.0 MG
4. CAPACITY OF PATUXENT = 10100.0 MG
5. POTOMAC WITHDRAWAL CAPACITY FOR FCWA = 200.0 MGD
6. POTOMAC WITHDRAWAL CAPACITY FOR WSSC = 400.0 MGD
7. POTOMAC WITHDRAWAL CAPACITY FOR WAD = 650.0 MGD
8. ENVIRONMENTAL FLOWBY AT LITTLE FALLS = 500.0 MGD
9. TREATMENT CAPACITY AT OCCOQUAN = 95.0 MGD
10. TREATMENT CAPACITY AT PATUXENT = 55.0 MGD
11. WITHDRAWAL FOR IRRIGATION = 0.0 MGD
12. MIN RELEASE FOR BLOOMINGTON = 32.0 MGD
13. MIN RELEASE FOR SAVAGE RIVER = 13.0 MGD
14. ENVIRONMENTAL FLOWBY FOR OCCOQUAN = 0.0 MGD
15. ENVIRONMENTAL FLOWBY FOR PATUXENT = 10.0 MGD
16. B:S FLOW-DEPENDENT RATIOS (1=YES,0=NO)= 1
17. BLOOMINGTON:SAVAGE RELEASE RATIO= 0.00 : 1
18. WATER SUPPLY RELEASE FRACTION, 1ST WEEK= .47
19. WATER SUPPLY RELEASE FRACTION, 2ND WEEK= .53
20. YEAR OF INVESTIGATION = 2030
21. DOWNSTREAM TARGET FACTOR .600
22. UPSTREAM TARGET AT LUKE, MD. = 78.0 MGD
23. YEAR OF LFAA FREEZE= 2030
24. MINIMUM DRAFT FROM OCCOQUAN= 30.0 MGD
25. MINIMUM DRAFT FROM PATUXENT= 20.0 MGD
26. INITIAL STORAGE BLOOMINGTON= 29500.0 MG
27. INITIAL STORAGE SAVAGE= 5900.0 MG
28. INITIAL STORAGE OCCOQUAN= 10300.0 MG
29. INITIAL STORAGE PATUXENT= 10100.0 MG
30. ARE STREAMFLOWS PREDICTED(0=MODEL,1=PERFECT FORESIGHT)= 0
31. TYPE OF CONSERVATION= 2
 (1=BASELINE,2=SCENARIO 3)
32. WEEKLY DEMAND COEFFICIENTS= 1
 (1=8-YEAR MONTHLY DISTRIBUTION)
 (2=1966 ACTUAL)
 (3=HYPOTHETICAL)

33. INITIAL WATER SUPPLY STORAGE, BLOOMINGTON = 13370.0 MG
34. INITIAL WATER QUALITY STORAGE BLOOMINGTON = 16630.0 MG
35. WATER SUPPLY CAPACITY, BLOOMINGTON = 13370.0 MG
36. WATER QUALITY CAPACITY, BLOOMINGTON = 16630.0 MG
37. SEPARATE WATER SUPPLY AND WATER QUALITY
 STORAGES IN BLOOMINGTON(0=NO,1=YES)= 1
38. WINTER DRAWDOWN FOR BLOOMINGTON(0=NO,1=YES)= 1
39. WINTER DRAWDOWN FOR SAVAGE(0=NO,1=YES)= 1
40. DOWNSTREAM TARGET(0=NO,1=YES=) 1
41. WEEKLY REPORTS(0=NO,1=YES)= 0
42. YEARS OF WEEKLY REPORTS(0=NO,1=YES)=0,0,0,0,0,0,0,0,0,0

parameter list
for
assumption change
option

TABLE H-III-5 (CONT'D)
SAMPLE INPUT TO PRISM/COE

```
43. SUMMARY REPORTS(0=NO,1=YES)= 1
```

parameter list

```
DO YOU WANT TO CHANGE ANY OF THE MODEL ASSUMPTIONS?
(0=NO,1=YES)

I>1
ENTER THE IDENTIFICATION NUMBER OF ASSUMPTION TO BE   CHANGED
ENTER 44 WHEN YOU ARE FINISHED CHANGES

I>8
ENTER NEW ASSUMPTION IN SAME FORMAT PREVIOUSLY REQUESTED

I>200
ENTER THE IDENTIFICATION NUMBER OF ASSUMPTION TO BE   CHANGED
ENTER 44 WHEN YOU ARE FINISHED CHANGES

I>26
ENTER NEW ASSUMPTION IN SAME FORMAT PREVIOUSLY REQUESTED

I>30000
ENTER THE IDENTIFICATION NUMBER OF ASSUMPTION TO BE   CHANGED
ENTER 44 WHEN YOU ARE FINISHED CHANGES

I>44
```

assumption change option

```
DO YOU WISH TO RERUN WITH CHANGED ASSUMPTIONS?(1=YES,0=NO)

I>1
```

rerun option request

TABLE H-III-5 (CONT'D)

SAMPLE INPUT TO PRISM/C

MAJOR MODEL ASSUMPTIONS
PRISM RUN NO. 1

1. CAPACITY OF BLOOMINGTON = 30000.0 MG
2. CAPACITY OF SAVAGE RIVER = 5900.0 MG
3. CAPACITY OF OCCOQUAN = 10300.0 MG
4. CAPACITY OF PATUXENT = 10100.0 MG
5. POTOMAC WITHDRAWAL CAPACITY FOR FCWA = 200.0 MGD
6. POTOMAC WITHDRAWAL CAPACITY FOR WSSC = 400.0 MGD
7. POTOMAC WITHDRAWAL CAPACITY FOR WAD = 650.0 MGD
8. ENVIRONMENTAL FLOWBY AT LITTLE FALLS = 200.0 MGD
9. TREATMENT CAPACITY AT OCCOQUAN = 95.0 MGD
10. TREATMENT CAPACITY AT PATUXENT = 55.0 MGD
11. WITHDRAWAL FOR IRRIGATION = 0.0 MGD
12. MIN RELEASE FOR BLOOMINGTON = 32.0 MGD
13. MIN RELEASE FOR SAVAGE RIVER = 13.0 MGD
14. ENVIRONMENTAL FLOWBY FOR OCCOQUAN = 0.0 MGD
15. ENVIRONMENTAL FLOWBY FOR PATUXENT = 10.0 MGD
16. B:S FLOW-DEPENDENT RATIOS (1=YES,0=NO)= 1
17. BLOOMINGTON:SAVAGE RELEASE RATIO= 6.67 : 1
18. WATER SUPPLY RELEASE FRACTION, 1ST WEEK= .47
19. WATER SUPPLY RELEASE FRACTION, 2ND WEEK= .53
20. YEAR OF INVESTIGATION = 2030
21. DOWNSTREAM TARGET FACTOR .600
22. UPSTREAM TARGET AT LUKE, MD. = 78.0 MGD
23. YEAR OF LFAA FREEZE= 2030
24. MINIMUM DRAFT FROM OCCOQUAN= 30.0 MGD
25. MINIMUM DRAFT FROM PATUXENT= 20.0 MGD
26. INITIAL STORAGE BLOOMINGTON= 29500.0 MG
27. INITIAL STORAGE SAVAGE= 3900.0 MG
28. INITIAL STORAGE OCCOQUAN= 10300.0 MG
29. INITIAL STORAGE PATUXENT= 10100.0 MG
30. ARE STREAMFLOWS PREDICTED(0=MODEL,1=PERFECT FORESIGHT)= 0
31. TYPE OF CONSERVATION= 2
(1=BASELINE,2=SCENARIO 3)
32. WEEKLY DEMAND COEFFICIENTS= 1
(1=8-YEAR MONTHLY DISTRIBUTION)
(2=1966 ACTUAL)
(3=HYPOTHETICAL)

33. INITIAL WATER SUPPLY STORAGE, BLOOMINGTON = 13370.0 MG
34. INITIAL WATER QUALITY STORAGE BLOOMINGTON = 16630.0 MG
35. WATER SUPPLY CAPACITY, BLOOMINGTON = 13370.0 MG
36. WATER QUALITY CAPACITY, BLOOMINGTON = 16630.0 MG
37. SEPARATE WATER SUPPLY AND WATER QUALITY STORAGES IN BLOOMINGTON(0=NO,1=YES)= 1
38. WINTER DRAWDOWN FOR BLOOMINGTON(0=NO,1=YES)= 1
39. WINTER DRAWDOWN FOR SAVAGE(0=NO,1=YES)= 1
40. DOWNSTREAM TARGET(0=NO,1=YES=) 1
41. WEEKLY REPORTS(0=NO,1=YES)= 0
42. YEARS OF WEEKLY REPORTS(0=NO,1=YES)=0,0,0,0,0,0,0,0,0,0

parameter list for rerun option

43. SUMMARY REPORTS(0=NO,1=YES)= 1

parameter list

ENTER IDENTIFICATION NUMBER PRECEEDING MODEL ASSUMP TION,
ENTER 44 WHEN YOU ARE FINISHED CHANGES .

I>8

TABLE H-III-5 (CONT'D)

SAMPLE INPUT TO PRISM/COE

ENTER NEW VALUE OF MODEL ASSUMPTION

rerun option

I>225

ENTER IDENTIFICATION NUMBER PRECEEDING MODEL ASSUMP TION,
ENTER 44 WHEN YOU ARE FINISHED CHANGES

I>44

DO YOU WISH TO RERUN WITH CHANGED ASSUMPTIONS?(1=YES,0=NO)

I>0
C>

PROGRAM OUTPUT

The PRISM/COE output as mentioned earlier comes in two forms, weekly data printout and summary tables. The weekly printout serves as a convenient tool for viewing the logic of the internal program calculations and diagnosing program errors. The summary tables enable the user to gage long-term trends in the simulation elements, i.e., reservoir storages and releases.

The program output is listed by accessing the primary file designated in the PROC# command. This is done by entering the command OLD, filename after a batch mode prompt (C>), and then a PRIMARY, filename command. The user should designate ASCII format by its command (C>ASCII). This keeps the output tables in a convenient page format. The user then asks the computer to print the primary file using the LIST command. The output file begins with a tabulation of the major input parameters under the heading, MAJOR MODEL ASSUMPTIONS. This table is followed by the weekly printout, summary tables, or both.

Weekly Printout

The weekly printout contains much information for each week of every year requested. This output contains data similar to that shown in Table H-III-2.

Summary Tables

The second type of output consists of a concise deficit summary followed by twenty-six tables of 520 values each. The deficit summary describes the total deficit, the number of weeks of deficit, the average deficit, and the maximum deficit for each service area (WAD, WSSC, and FCWA). An array for the number of weeks of water use restrictions and LFAA is also printed. This array is a carryover from the PRISM/JHU model and is not an effective tool for run analysis. Following this data, the summary tables are listed in 52 X 10 arrays (52 lines of 10 columns each). The summary table includes data as presented in Table H-III-3.

Output Sample

The following pages in Table H-III-6 show a partial sample of the actual output from a PRISM/COE run as it was taken from the computer terminal. This sample shows remaining reservoir storage; complete printout are available for review in the Baltimore District office.

PROGRAM DATA FILES

The river flow data, evaporation loss rates, demand peaking factors, Bloomington: Savage release ratios, and operating rule curves are stored in data files in the user's library. These files are named FLOW#, DATA2, DATA3, DATA4, DATA5, and DATA6. The PRISM/COE program accesses these files immediately before the user input section and stores them in the appropriate arrays. A complete explanation and listing of each data file is given below.

FLOW# contains ten years of weekly flow data for the Potomac River at Little Falls, North Branch Potomac River at Bloomington Lake, Savage River at the Reservoir, Occoquan Creek at the Reservoir, and Patuxent River at Rocky Gorge Reservoir (in million gallons per week). Existing U.S.G.S. stream gage flows were modified according

TABLE H-III-6

SAMPLE OUTPUT FROM PRISM/COE

WATER SUPPLY RELEASE FROM BLOOMINGTON RESERVOIR, MGD

	1	2	3	4	5	6	7	8	9	10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	38.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	38.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	60.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	78.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	90.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	31.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NOTE: FULL SAMPLE OUTPUT FROM PRISM/COE IS PROVIDED IN ANNEX D-VI

TABLE H-III-6 (CONT'D)

SAMPLE OUTPUT FROM PRISM/COE

WATER QUALITY RELEASE FROM BLOOMINGTON RESERVOIR, F3D

	1	2	3	4	5	6	7	8	9	10
1	65.00	34.70	32.00	32.00	32.00	65.00	32.00	32.00	65.00	65.00
2	65.00	34.73	32.00	32.00	32.00	32.00	32.00	32.00	65.00	65.00
3	32.00	34.37	32.00	32.00	32.00	32.00	32.00	32.00	32.00	65.00
4	32.00	33.67	32.00	32.00	32.00	32.00	32.00	32.00	65.00	65.00
5	32.00	47.80	65.00	32.00	65.00	65.00	32.00	65.00	65.00	65.00
6	32.00	47.27	65.00	32.00	65.00	32.00	65.00	32.00	32.00	65.00
7	32.00	62.87	65.00	32.00	65.00	32.00	32.00	32.00	32.00	65.00
8	32.00	65.00	65.00	32.00	32.00	32.00	32.00	65.00	32.00	65.00
9	32.00	65.00	65.00	32.00	65.00	32.00	32.00	65.00	32.00	65.00
10	32.00	65.00	65.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
11	32.00	65.00	32.00	65.00	32.00	32.00	32.00	32.00	32.00	32.00
12	32.00	65.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
13	32.00	65.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	65.00
14	32.00	65.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
15	32.00	65.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
16	32.00	65.00	32.00	32.00	32.00	32.00	32.00	32.00	65.00	65.00
17	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
18	41.20	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
19	32.00	32.00	32.00	32.00	37.41	32.00	36.37	32.00	32.00	32.00
20	32.00	32.00	32.00	32.00	42.97	32.00	32.00	32.00	32.00	32.00
21	32.00	32.00	32.00	32.00	50.40	32.00	32.00	32.00	32.00	32.00
22	32.00	32.00	37.16	32.00	32.27	32.00	32.00	32.00	32.00	32.00
23	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
24	32.00	32.00	32.00	65.00	32.00	32.00	65.00	32.00	32.00	32.00
25	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	32.00	65.00
26	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
27	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
28	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
29	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
30	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
31	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
32	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
33	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
34	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
35	65.00	65.00	65.00	65.00	65.00	65.00	61.95	65.00	65.00	64.92
36	65.00	65.00	65.00	65.00	64.87	65.00	63.53	65.00	65.00	65.00
37	65.00	65.00	65.00	65.00	62.63	65.00	32.00	65.00	65.00	65.00
38	63.14	65.00	65.00	63.50	32.00	65.00	55.66	65.00	65.00	65.00
39	65.00	65.00	65.00	65.00	59.84	65.00	65.00	65.00	65.00	65.00
40	65.00	36.94	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
41	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
42	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
43	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
44	65.00	65.00	65.00	65.00	65.00	65.00	39.77	65.00	65.00	65.00
45	65.00	65.00	65.00	65.00	65.00	65.00	32.00	65.00	65.00	65.00
46	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
47	65.00	65.00	65.00	65.00	32.00	53.75	37.88	53.53	47.55	65.00
48	65.00	42.19	40.50	65.00	44.60	53.97	40.25	65.00	[illegible]	44.49
49	65.00	32.00	35.22	65.00	32.21	65.00	[illegible]	65.00	[illegible]	32.00
50	65.00	32.5?	35.39	65.00	[illegible]	65.00	32.93	[illegible]	[illegible]	[illegible]

TABLE H-III-6 (CONT'D)

SAMPLE OUTPUT FROM PRISM/COE

SAVAGE RELEASE TO DILUTE BLOOMINGTON   WATER SUPPLY RELEASES, MGD

	1	2	3	4	5	6	7	8	9	10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	9.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	12.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	3.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					

TABLE H-III-6 (CONT'D)

SAMPLE OUTPUT FROM PRISM/COE

ALLOCATION TO WSSC, MGD

	1	2	3	4	5	6	7	8	9	10
1	230.50	216.97	230.50	230.50	230.50	230.50	230.50	230.50	230.50	230.50
2	230.50	215.13	230.50	230.50	230.50	230.50	230.50	230.50	230.50	230.50
3	230.50	226.56	230.50	230.50	230.50	230.50	230.50	230.50	230.50	230.50
4	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86
5	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86
6	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86
7	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86	212.86
8	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61
9	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61
10	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61
11	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61
12	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61	208.61
13	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05
14	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05
15	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05
16	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05
17	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05	204.05
18	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35
19	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35
20	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35
21	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35
22	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35	204.35
23	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66
24	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66
25	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66
26	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66
27	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66	204.66
28	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99
29	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99
30	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99
31	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99	214.99
32	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96
33	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96
34	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96
35	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96	242.96
36	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62
37	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62
38	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62
39	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62	270.62
40	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00
41	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00
42	283.46	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00
43	271.06	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00	284.00
44	257.97	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32
45	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32
46	242.96	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32
47	255.90	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32	270.32
48	[illegible]	270.02	270.02	270.02	270.02	270.02	270.02	270.02	270.02	[illegible]
49	[illegible]	270.02	270.02	270.02	270.02	270.02	270.02	270.02	270.02	270.02
50	270.02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	270.02	[illegible]	[illegible]	[illegible]

TABLE H-III-6 (CONT'D)

SAMPLE OUTPUT FROM PRISM/COE

DEFICIT OF WSSC, MGD

	1	2	3	4	5	6	7	8	9	10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE H-III-6 (CONT'D)

SAMPLE OUTPUT FROM PRISM/COE

DEFICIT OF MWA REGION, MGD

	1	2	3	4	5	6	7	8	9	10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	4.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	6.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

to standard hydrologic methods to obtain the flow data for these specific points. For programming purposes, the Potomac flows at Little Falls do not include contributions from the North Branch Potomac (Bloomington's inflow) or Savage River. The Potomac River flow data at Little Falls is assumed to be immediately upstream of all MWA intakes. The flow data reflects this assumption by including any historical water supply withdrawals in the Little Falls flows.

The PRISM/COE model has the option of using five sets of flow data. Each set contains a decade, starting with October 1929 and ending with September 1979. The user changes the flow decade by specifying the flow file in the execution program (FLOW1 for the first decade, FLOW2 for the second decade, etc).

The flow data in FLOW# is arranged chronologically for each reservoir. The file is arranged in six columns. Each year of data is contained in eight full rows and one partial row of four values. The first 90 rows in FLOW# represent the Potomac flows at Little Falls and are assigned to the array FPOT. The second 90 rows in FLOW# represent the inflows to Bloomington Lake from the North Branch Potomac River. They are assigned to the array FB. The third set of 90 rows form the inflows to Savage River Reservoir and is assigned to the array FS. The fourth and fifth sets of 90 rows contain the Occoquan and Patuxent flow data, respectively. FO and FP are the assigned arrays for this data. The following pages list the actual contents of FLOW#1, the flow data for the first decade, October 1929 to September 1939, (Table H-III-7).

DATA2 contains the demand peaking factors for the WSSC water user jurisdiction. The file contains 13 columns and 12 rows of values. The first four rows represent the 8-year monthly average coefficients. Rows 5 through 8 comprise the actual 1966 weekly peaking factors. The last four rows are reserved for the hypothetical demand coefficients.

The program reads the data file row by row, starting with column 1 and ending with column 13. The program assigns these values to the 2-dimensional array WWSSC (3,52). The contents of DATA2 are listed in Table H-III-8.

DATA3 contains the demand peaking factors for the FCWA water use jurisdiction. The file contains 13 columns and 12 rows of values. The first four rows represent the 8-year monthly average coefficients. Rows 5 through 8 comprise the actual 1966 weekly peaking factors. The last four rows are reserved for the hypothetical demand coefficients.

The program reads the data file row by row, starting with column 1 and ending with column 13. The program assigns these values to the 2-dimensional array WFCWA (3,52). Table H-III-9 lists the DATA3 file.

The demand peaking factors for the Aqueduct's service area are filed in DATA4. The file contains 13 columns and 12 rows of values. The first four rows represent the 8-year monthly average coefficients. Rows 5 through 8 comprise the actual 1966 weekly peaking factors. The last four rows are reserved for the hypothetical demand coefficients.

The program reads the data file row by row, starting with column 1 and ending with column 13. The program assigns these values to the 2-dimensional array WWAD (3,52). Table H-III-10 lists the DATA4 file.

TABLE H-III-7

FLOW # INPUT FILE.

First Flow Year

1930					
106833.39	21447.40	10517.97	187300.30	38731.07	60444.10
30596.91	137013.64	35342.08	28608.17	32145.57	37671.09
39874.41	65180.43	34842.51	28775.37	22326.39	21028.24
74302.83	43525.45	33645.65	37696.32	65596.91	74472.00
45809.31	32981.65	29881.26	55174.32	32081.02	32817.31
23181.26	17951.11	14637.07	14035.97	9829.84	8291.91
14655.86	11772.90	9616.70	7511.56	5782.66	4717.58
4458.92	3830.05	4324.13	3654.43	3397.26	3985.79
4018.77	4790.48	4023.69	4130.33		
3535.22	3549.51	3745.74	3700.51	3746.92	4077.28
4406.73	4373.72	4815.87	4683.63	5745.56	6234.28
12473.14	10702.93	17204.48	10734.44	8676.20	11531.30
6476.38	15601.98	15514.95	12578.06	23508.16	18226.99
16969.61	51009.82	113253.97	81262.47	27997.58	56277.91
34489.91	54861.15	92764.45	100302.81	46829.20	34140.34
18588.76	32490.79	18964.25	16580.96	36291.61	33195.78
33561.98	14195.40	17269.47	10986.40	18956.93	31546.62
15072.77	7683.35	7123.17	10102.97		
7394.25	5615.03	5143.47	4523.96	4943.43	4450.34
4455.18	4619.57	4814.44	5323.55	17184.77	9425.95
7962.46	20299.97	40639.00	20531.83	16724.48	28683.15
136302.11	26568.03	19900.26	15056.84	39545.30	41620.25
80137.22	128307.75	173383.76	72845.61	59679.95	31039.42
58978.76	65846.51	358878.42	51371.14	31665.61	18478.63
13917.43	20451.45	14517.54	13874.79	23783.05	10165.25
7799.23	6819.15	6340.36	4833.86	5381.89	4741.79
7414.49	5181.35	4014.55	3952.80		
7883.45	8192.80	63990.93	30142.62	30948.77	98736.76
91351.91	112376.50	38003.03	25985.61	19856.98	17788.84
63319.01	66237.66	36802.76	79094.04	78319.98	132707.20
61005.70	48332.57	60604.41	55802.44	39661.33	118633.57
203351.91	86248.07	63774.89	123351.66	264351.89	221955.40
63239.61	146502.84	149138.52	62177.70	52520.36	35456.97
28169.57	19498.07	15064.15	32093.51	20083.47	15796.15
13174.81	31872.79	18478.45	16109.42	73515.90	88125.70
31329.43	18949.74	60740.59	23152.09		
19841.66	13563.15	14358.58	12311.44	10194.51	11050.82
10698.26	10728.13	10635.08	9848.83	8964.08	27723.95
16013.32	32675.42	91928.80	20360.82	18416.10	14515.11
14162.35	11656.89	12060.00	13542.79	74363.73	38946.92
31271.56	65563.58	78586.56	56710.90	51041.61	36239.25
24990.55	25564.56	20837.76	22340.44	18376.63	14107.72
10652.38	22176.70	13856.71	7809.99	7949.07	6690.96
6383.85	11080.83	6947.73	21106.39	24827.00	10138.79
6343.86	10957.69	78022.83	19618.96		
47902.43	21674.35	12750.66	9385.33	8860.26	12887.85
10177.60	9249.37	137749.36	155916.19	31951.86	26334.59
37523.67	34509.35	38031.25	33903.39	165655.67	53740.07
63959.52	156830.50	145594.14	78672.77	61618.09	110270.91
73988.48	65547.36	81195.74	220877.71	120193.54	52009.86
44490.07	96735.92	51341.36	37272.48	28674.61	72838.11

Potomac River (at Little Falls) Streamflows

FLOW # INPUT FILE

25552.77	20887.08	16535.57	17837.90	22151.55	17467.59
16395.61	14271.36	20980.54	36845.20	20373.15	16065.23
92892.27	47529.70	18469.05	12981.09		
9843.47	8941.24	8160.21	7814.50	15787.18	10378.46
47968.55	43371.46	26262.80	23365.21	38575.74	65195.81
21932.34	89977.71	159389.04	102929.36	70314.94	34827.53
38076.69	65037.97	120858.07	302320.61	154584.22	244604.31
848467.99	181249.93	95165.83	195063.89	89637.74	49053.52
37615.94	33494.09	29151.93	25477.80	19296.67	17023.54
26927.37	22757.29	14683.25	14076.57	16982.61	14221.87
11610.01	18066.11	9477.35	10535.59	9330.09	15945.10
10343.31	8112.76	9542.32	6309.56		
9223.83	9032.26	61351.54	20387.68	11818.40	20777.95
12067.19	9881.17	8762.21	26638.68	64483.88	64190.30
57089.42	108875.63	129755.90	94531.80	308316.36	97569.28
88636.29	105674.10	159677.58	109524.91	54593.33	41051.51
77999.58	54950.68	34043.92	44797.18	35782.55	467801.69
221396.11	79123.17	50328.72	40326.58	36564.46	28025.94
33459.21	31382.39	26615.41	21191.09	16698.26	31183.04
16554.72	12119.87	11018.22	12965.74	15847.28	130646.37
41680.21	39137.82	17789.28	12677.87		
20165.42	34729.29	63123.62	151227.88	345030.47	49216.92
82516.25	44991.63	41905.60	37147.27	24769.25	50677.57
27528.63	31383.24	31092.31	24914.81	37150.30	54225.08
31250.05	41291.81	42327.69	37757.48	32909.90	49689.42
87845.70	40951.77	46246.18	41741.46	35904.71	34847.06
23664.15	21498.81	22484.00	90894.07	52932.04	30762.83
19140.91	21256.11	28526.00	16649.01	11116.08	11240.70
58670.09	31971.75	35526.95	26450.80	14214.58	8783.26
8694.49	7876.74	11418.47	11031.18		
7703.56	6825.76	6472.30	7568.20	7580.45	10691.38
8927.98	10211.89	11181.80	28557.69	93985.43	26419.19
19838.11	20699.02	30477.87	21993.54	32769.28	147570.62
268682.85	137454.34	87218.37	177897.33	112945.52	93866.24
59584.17	39788.92	49132.38	47690.55	165575.89	72487.52
62015.37	38112.41	28771.55	31659.57	26160.80	30196.61
15721.88	24130.95	28590.55	33480.97	20711.52	11751.83
51961.28	74379.55	24893.54	13241.05	19540.26	12360.00
11591.44	9418.39	6987.79	6127.92		
2154.85	2154.85	2154.85	2154.85	2631.83	2045.33
3484.04	4069.75	1235.88	1957.18	4078.98	2465.92
2239.74	3014.70	2165.22	1283.84	499.02	580.67
2146.42	2145.77	2271.50	3564.40	3163.89	4171.00
4522.26	1948.11	2819.77	3757.53	2102.35	1885.25
1392.07	1088.76	839.26	727.14	406.34	247.57
1915.71	405.70	647.42	239.78	209.33	255.34
388.20	186.00	203.50	267.01	188.59	164.61
151.00	204.14	208.68	146.30		
139.34	106.28	91.38	90.73	97.21	109.52
58.98	83.60	97.86	573.54	515.87	97.86
355.79	309.13	506.14	272.20	2079.02	2277.34
2427.03	2502.86	2845.04	2299.37	1611.76	1480.20
2172.35	5572.78	6840.42	5892.92	2184.65	4955.82

Potomac River (at Little Falls) Streamflow

Bloomington Lake Inflows

TABLE H-III-7 (CONT'D)

FLOW # INPUT FILE

3115.29	4108.78	5624.62	8554.58	3450.99	2373.89
1535.93	756.95	464.02	294.23	1145.79	380.42
260.52	178.22	230.07	196.37	1131.53	824.35
477.63	184.05	769.26	2264.29		
638.13	397.04	543.26	300.22	414.59	332.71
517.91	356.11	647.23	725.86	6754.96	2035.26
1649.91	2416.07	4156.95	1561.53	2372.52	4153.05
10865.12	2495.34	1667.46	1147.60	2619.46	1481.61
8200.83	6322.83	10497.97	2938.52	2523.28	1433.52
2080.75	4205.03	12440.96	1837.07	803.18	491.27
820.73	935.75	1559.59	1276.26	3023.00	484.77
326.22	244.99	389.25	371.71	848.02	484.77
302.17	193.00	83.57	132.12		
323.39	235.90	2071.89	740.75	748.52	2036.25
1325.32	2787.37	883.33	609.18	621.50	813.34
2964.93	2034.30	1681.75	1335.03	2191.78	3005.12
3636.99	3653.20	3079.00	4231.27	2495.73	10649.14
11671.80	4296.73	5097.10	5237.09	9772.95	6237.71
2848.28	8711.09	8768.43	2379.73	1659.72	1395.95
670.76	329.22	365.51	913.14	231.36	243.67
544.38	390.14	1314.95	922.21	4824.90	1487.98
3062.15	1095.25	2298.07	750.79		
423.84	257.93	439.39	624.10	364.87	1012.29
1414.75	1948.11	1204.77	1412.15	1154.87	6202.07
1817.85	5299.95	8238.30	2047.91	2387.50	2058.28
1023.96	1114.68	745.28	1594.26	7986.21	2940.32
2440.64	4220.90	4589.01	3749.11	3223.52	1641.58
1077.10	733.62	771.86	647.42	536.61	314.97
467.26	769.91	263.12	139.34	696.68	253.39
307.18	694.74	406.34	2049.86	600.76	287.74
189.88	256.64	1621.48	671.97		
1050.53	554.10	380.42	404.40	664.27	1139.32
777.68	1814.61	3506.08	2254.00	1100.43	1127.00
3592.92	2066.07	3670.04	3916.96	9934.32	2005.79
2202.15	5568.25	3387.48	3803.54	2879.49	6727.00
3101.03	2841.80	3187.87	8614.85	5622.03	2172.99
2791.90	6491.11	2983.09	3067.34	1265.04	1472.42
1349.29	2608.50	1303.27	1014.24	1556.67	578.73
751.76	1303.92	1944.27	651.32	399.86	400.51
5800.25	1467.24	761.49	499.59		
348.30	369.10	289.83	507.51	693.37	588.74
2052.15	1447.16	1022.83	1442.62	3663.73	2577.22
1007.24	3068.49	6754.96	5110.89	2666.25	1384.13
1195.68	1780.53	2274.40	13074.54	6868.68	9916.37
21691.25	13990.80	6372.83	8395.77	3620.84	1878.00
1198.28	850.62	1084.57	890.91	462.67	338.57
654.38	263.83	144.21	568.60	262.53	175.46
448.38	784.99	659.58	187.80	242.38	228.09
277.48	144.76	167.01	159.72		
234.60	169.15	2853.47	1114.68	434.86	1753.04
739.46	576.78	418.65	3156.12	2281.87	1421.23
3526.87	4925.36	7878.73	6234.47	16791.60	3953.90
6810.61	3938.99	3629.22	2336.30	2310.04	2065.41

Bloomington Lake Inflows

TABLE H-III-7 (CONT'D)

FLOW # INPUT FILE

8003.07	4390.70	2055.68	1719.99	1804.88	12910.92
4247.47	2362.88	2182.07	1602.68	3882.61	1173.66
1442.61	1718.04	1004.51	536.61	378.48	453.00
228.77	229.41	200.90	211.92	1020.07	3355.72
1092.65	440.78	278.02	235.90		
1662.96	1858.67	1953.29	14550.55	9481.32	2016.80
1767.95	957.21	1630.55	992.85	1169.77	6635.62
2504.80	2170.40	1298.09	768.62	2521.01	1840.53
2226.13	3809.38	2633.13	1940.98	3920.85	5153.48
3729.66	7556.00	3360.26	2941.61	2550.17	2497.03
1473.08	1206.07	5972.00	9896.08	2777.64	1828.22
1287.08	2669.41	983.77	458.84	359.68	850.92
4701.12	1566.39	1116.63	556.04	314.32	185.35
209.33	379.12	448.47	230.79		
189.24	174.34	165.26	189.24	211.92	305.89
272.84	901.47	521.05	1642.72	2091.34	787.41
755.65	1578.05	1390.76	939.05	2394.63	7358.88
10330.29	9403.55	4178.77	6646.64	4990.16	5130.79
2517.12	1974.03	2770.51	2979.84	10324.47	3165.84
2594.89	1352.53	1200.88	798.42	483.47	1637.68
779.63	3080.29	3926.68	3293.51	1481.50	981.84
3355.08	2587.76	904.71	688.90	587.15	307.84
373.93	401.15	258.58	331.73		
2049.21	278.02	182.11	1211.90	806.21	819.16
990.90	1458.16	425.13	556.69	1803.59	940.35
776.40	1238.47	617.62	365.52	226.82	258.58
876.85	695.38	681.77	1143.20	994.14	1443.91
817.87	426.43	542.44	1262.45	535.96	903.42
492.54	311.08	213.87	164.62	104.99	71.93
338.95	115.35	90.73	62.47	37.33	30.85
17.31	9.01	8.36	35.97	26.31	19.57
10.63	13.80	23.26	10.37		
8.36	7.45	9.20	13.48	14.07	17.31
18.21	17.76	12.90	72.91	73.30	15.88
57.16	100.45	117.95	82.31	538.55	565.12
639.00	1036.92	666.87	935.81	611.13	438.10
706.40	2492.49	2734.87	2020.04	483.46	1522.33
795.19	1395.31	2683.67	2288.35	707.69	366.81
185.35	106.93	91.37	310.43	204.14	95.26
49.32	37.46	51.07	22.75	138.75	132.21
65.98	25.01	48.41	255.75		
87.73	41.59	57.19	30.54	36.71	28.59
36.40	29.89	52.31	55.23	1450.42	387.95
250.84	608.89	1191.78	371.70	785.64	1332.80
2870.29	694.67	420.44	287.22	716.76	523.76
2473.89	2004.71	4394.78	820.74	787.59	393.14
339.86	1555.69	4675.51	604.34	227.44	135.81
115.02	117.62	113.73	106.57	116.97	79.27
69.86	67.25	43.47	20.86	43.99	11.64
7.34	5.26	5.46	7.43		
51.98	76.89	359.75	156.84	276.73	876.85
489.95	1443.91	283.86	158.13	121.19	204.79
1435.48	796.48	562.53	529.47	1281.89	1425.76

Bloomington Lake Inflows

Savage River Reservoir Inflows

TABLE H-III-7 (CONT'D)

FLOW # INPUT FILE

1084.88	754.36	913.78	1405.02	751.12	5359.57
4139.90	1231.99	1742.02	2090.69	4161.93	1721.93
781.57	4232.57	2186.60	709.64	408.93	370.05
197.66	112.77	84.90	120.54	47.31	85.87
141.92	64.80	68.37	44.40	146.66	105.64
227.47	112.77	179.52	69.75		
55.74	40.37	48.35	39.47	33.82	87.75
117.95	223.58	115.35	140.64	162.02	1767.95
454.30	2139.30	3717.34	471.15	377.82	536.60
785.15	246.26	194.42	321.44	1784.14	690.20
594.29	1585.19	2316.87	1016.18	1042.75	505.49
276.08	205.44	264.42	265.71	224.88	103.04
118.59	780.93	138.69	55.15	73.49	42.90
46.34	61.31	66.95	397.26	141.27	40.96
21.38	39.59	262.47	286.93		
394.03	123.78	68.69	69.34	111.47	223.58
156.19	484.11	1090.70	703.81	286.45	239.79
1197.64	658.44	1726.47	994.79	2823.66	608.54
578.08	2609.79	1270.87	1455.57	1546.31	1857.38
958.51	734.26	754.36	3050.48	1230.69	507.44
1925.43	2963.64	773.15	612.43	312.37	226.18
169.79	342.84	307.84	173.03	333.76	86.20
111.47	773.80	1033.68	320.14	110.18	123.13
2242.34	399.86	176.92	95.84		
77.33	100.08	68.88	66.93	127.36	94.22
574.45	421.09	245.64	201.45	1087.81	960.45
402.39	778.49	2079.45	1573.85	901.31	454.88
292.42	529.60	740.80	5537.19	2998.96	5541.08
11462.97	3671.53	1916.99	2325.74	926.66	497.77
433.44	409.40	504.26	264.48	152.71	112.42
499.71	167.66	70.84	87.73	37.30	14.36
181.24	397.04	338.56	92.27	98.12	72.78
49.07	22.42	22.29	18.70		
36.81	41.29	780.09	154.24	116.65	912.48
222.29	154.24	103.04	905.36	1087.47	556.69
1713.51	2106.24	4248.77	2471.76	4986.92	1128.95
1555.37	1150.33	1265.04	734.91	624.75	506.14
2482.77	1198.93	522.35	569.01	733.62	7118.44
1552.78	764.73	552.15	397.26	1226.80	329.87
333.11	214.52	157.48	128.97	95.26	90.73
41.09	50.23	26.84	15.62	268.24	1444.56
714.82	289.04	101.10	56.14		
405.44	431.62	439.40	4377.09	3060.85	451.05
496.70	311.73	385.60	351.90	236.55	2292.24
554.10	744.64	416.71	266.36	645.48	628.63
543.74	1731.00	804.91	506.14	793.89	1928.67
1268.29	673.35	885.91	1082.93	863.88	589.75
321.44	255.34	1887.84	3108.81	603.35	284.51
181.46	180.81	110.18	64.15	137.26	99.80
792.59	280.62	146.46	75.82	46.86	29.55
42.32	91.70	71.29	34.81		
21.52	18.34	23.40	25.08	23.01	39.47
32.14	101.75	75.82	366.16	310.43	127.67

Savage River Reservoir Inflows

FLOW # INPUT FILE

71.93	336.35	454.95	208.03	531.42	2386.21	Savage River Reservoir Inflows
3182.04	3007.07	1299.38	2106.24	1686.93	1843.77	
845.74	757.59	1524.27	1306.52	4386.16	861.93	
950.73	471.15	381.07	261.82	195.71	405.69	
164.62	296.81	1027.85	1077.75	225.53	156.84	
531.42	255.34	124.43	84.25	71.93	43.10	
117.95	41.87	35.84	50.58			
1994.42	308.72	725.64	20336.48	1786.49	1502.74	Occoquan Reservoir Inflows
1314.78	2164.67	1293.45	1271.20	1002.43	994.71	
1948.57	2055.71	1318.87	1351.10	1283.46	1643.48	
8417.61	2033.01	1608.07	1106.85	6200.28	2688.59	
1343.84	1021.95	2396.67	2139.70	1215.36	771.35	
538.44	446.74	510.30	621.98	283.30	231.54	
260.14	330.97	136.65	241.07	63.56	54.48	
44.49	46.76	41.31	39.95	39.95	40.41	
91.25	64.01	59.02	47.22			
38.59	37.23	36.77	39.04	48.12	54.48	
57.20	60.84	59.02	54.03	61.29	43.13	
129.84	474.43	405.88	99.43	76.73	95.34	
88.98	182.96	198.85	150.73	412.69	255.15	
246.07	578.40	1566.30	790.87	266.04	391.80	
175.24	1256.67	1849.14	1117.75	776.34	553.88	
361.84	173.88	143.46	639.69	318.25	773.16	
267.86	134.38	1061.00	296.01	733.21	995.62	
408.60	138.02	97.61	337.32			
87.62	76.27	83.99	57.66	120.76	62.65	
59.93	94.43	78.09	71.28	158.45	94.43	
85.81	1175.86	3415.44	889.84	444.01	512.11	
6004.60	839.45	435.84	366.83	4844.63	1969.00	
1743.81	4805.59	2153.32	4624.44	1457.79	982.00	
1679.35	2655.45	20904.88	1835.98	878.49	458.09	
464.90	1246.68	495.31	383.63	1085.51	318.71	
184.32	226.55	365.47	102.60	77.63	50.85	
106.69	97.16	59.02	44.95			
437.66	195.22	4211.30	1262.12	3992.02	21660.34	
3877.61	5526.54	1497.29	989.72	1082.34	787.24	
9970.29	3507.15	2170.57	1499.11	7610.40	8442.13	
2993.68	3553.91	5185.59	2563.28	2345.34	1946.30	
6806.82	2351.27	2640.01	7080.58	44295.42	7245.39	
3835.85	3404.55	4939.97	1402.86	3945.26	908.91	
824.01	449.01	927.98	814.48	632.42	866.23	
1260.76	570.22	521.65	486.23	4663.03	1560.85	
1446.44	561.60	1565.39	435.84			
552.97	331.87	478.97	445.37	335.96	405.42	
303.73	309.63	222.01	251.97	205.21	446.28	
451.28	647.86	1104.58	392.71	579.76	352.30	
304.18	192.04	441.74	1241.24	7347.08	1656.19	
1258.03	7345.72	2603.24	1130.91	2666.34	1071.44	
1004.25	787.69	814.48	778.61	956.12	528.46	
919.35	2975.06	496.68	687.36	334.14	136.20	
294.65	254.06	485.78	1060.54	399.97	416.32	
370.92	2645.46	7800.17	1444.17			
1435.09	1012.42	560.69	445.37	440.83	771.35	

TABLE H-III-7 (CONT'D)

FLOW # INPUT FILE

420.86	852.16	19061.64	7673.96	2143.33	2857.93
1692.06	1529.98	2006.23	1687.06	17431.33	3217.95
4537.73	12915.85	6248.40	4886.40	2803.90	7499.17
2924.67	2325.39	4988.55	19135.19	4452.38	2414.37
1670.72	2072.96	1293.90	1101.86	2656.35	1246.68
929.34	501.67	354.12	861.24	1466.87	477.61
501.22	272.40	648.31	375.46	505.30	271.49
7273.08	1533.16	639.69	455.82		
369.10	359.57	308.72	295.55	1658.92	632.42
4298.93	2134.25	1785.13	1084.61	3849.47	2230.05
1348.38	17110.35	11809.45	9173.52	4160.46	2724.00
3449.04	21760.67	6457.70	13294.94	4011.09	15935.85
44000.77	7608.59	4316.63	5706.33	2879.27	1719.30
1435.09	1109.12	771.80	717.32	438.11	496.22
708.24	325.52	270.13	467.62	604.27	241.07
506.66	330.51	572.95	192.04	116.22	162.99
103.06	183.42	150.73	75.82		
311.44	129.39	2861.56	403.61	259.69	385.90
266.04	219.28	187.96	1744.27	3680.58	7365.70
2172.84	4104.61	5769.89	11796.74	18987.64	8565.62
7108.73	5874.76	15577.19	6334.66	3214.77	2726.27
3160.29	1969.91	3908.03	3670.59	2055.71	100287.69
10545.51	2904.69	2593.70	2410.29	1913.61	2755.78
3102.64	3600.67	1151.80	1563.58	802.22	899.37
518.47	742.74	366.83	548.89	3862.63	8732.24
1840.06	1106.40	655.12	719.14		
1383.79	963.39	9651.13	11761.32	3476.73	1603.07
6536.69	1597.17	3913.93	1841.42	1028.31	1219.44
1050.56	1387.88	3208.42	1321.59	4508.67	1907.25
1516.36	1373.80	6149.88	2824.79	1678.89	2527.42
3573.49	1534.07	1414.21	2864.74	1280.28	1037.84
573.86	485.33	533.45	1030.13	1331.58	454.91
274.67	452.18	1890.91	616.53	306.45	662.84
2060.25	1940.40	2283.62	689.17	630.61	239.26
240.62	206.12	207.02	278.76		
226.09	227.45	179.33	160.26	221.10	183.42
281.48	781.79	861.24	3933.00	5243.69	968.84
3021.82	1219.90	1031.03	970.20	2539.68	15100.49
9263.42	8700.00	2404.84	9376.46	3547.56	4908.19
1829.17	1344.29	1438.73	1297.08	6284.72	2575.54
2161.04	947.04	646.50	444.01	495.31	495.31
617.44	559.78	1412.85	1280.28	393.16	319.16
4792.42	3751.40	454.91	324.61	3060.41	328.70
625.61	298.28	221.10	182.51		
934.16	230.51	211.63	804.08	557.40	436.08
430.68	455.62	309.36	328.91	373.39	361.94
409.79	460.34	355.87	377.44	283.08	303.30
1051.43	924.05	603.90	488.65	1168.04	669.95
496.06	507.52	1178.15	764.31	619.40	474.49
412.49	345.09	346.43	316.78	246.68	221.74
212.31	249.38	168.50	148.95	100.43	82.90
81.55	49.88	36.94	48.26	53.25	57.96
39.70	47.92	57.36	33.08		

Occoquan Reservoir Inflows

Patuxent Reservoirs Inflows

FLOW # INPUT FILE

30.13	38.01	47.99	74.81	83.58	85.60
104.47	99.08	82.23	116.60	105.82	84.92
401.03	313.41	136.82	409.79	160.41	142.89
172.54	167.15	210.29	237.25	252.07	201.52
272.29	475.84	499.43	438.77	219.05	266.23
195.46	250.05	320.15	442.14	239.27	283.08
250.05	289.82	327.56	338.35	134.80	1494.93
94.36	94.36	640.30	235.90	363.28	409.12
119.97	92.34	82.90	84.92		
52.71	39.87	74.34	56.77	176.39	82.45
92.59	104.08	131.79	121.65	232.48	155.44
157.47	466.99	727.86	309.53	251.41	291.28
804.23	327.10	312.23	243.97	484.56	339.94
446.72	1166.47	627.16	814.36	479.16	386.57
450.10	421.04	1385.43	413.60	332.50	233.83
316.96	704.21	450.77	233.16	193.28	148.68
120.30	72.31	276.41	96.64	102.72	48.52
114.08	42.17	31.83	132.30		
674.67	140.87	924.05	314.76	1155.23	1121.53
512.91	971.90	422.60	368.00	367.33	374.07
1121.53	574.24	606.60	467.75	931.46	703.65
742.74	634.23	1056.15	638.27	701.63	812.84
1392.48	905.85	1056.83	1235.44	2047.60	1078.40
1089.18	1353.39	1004.93	797.34	1166.01	990.78
620.08	532.46	725.89	2081.98	876.20	430.68
396.98	361.26	372.84	300.60	5948.70	674.00
506.85	688.82	568.18	409.87		
448.21	384.18	485.28	390.92	380.81	446.86
369.35	372.05	344.41	349.80	322.84	547.29
365.31	771.05	692.19	455.62	552.00	364.63
343.74	360.59	554.03	1115.46	1724.76	692.19
521.00	1213.87	892.37	624.79	1097.27	651.08
987.41	669.28	607.94	756.90	555.37	395.64
535.15	634.23	372.05	310.04	222.42	190.74
161.09	178.61	136.82	330.26	188.72	310.04
699.61	538.52	2027.38	1200.14		
731.96	462.36	398.33	384.18	384.85	413.16
354.52	442.82	1522.56	748.81	485.95	778.47
591.77	605.92	712.41	574.92	1248.24	740.05
727.24	1596.02	1325.75	1174.78	866.09	1647.92
926.07	838.45	922.70	2290.92	972.58	796.66
1126.25	1871.02	812.84	694.22	585.03	808.12
561.44	486.63	408.44	396.31	561.44	661.19
405.07	258.81	252.75	305.32	241.29	177.94
1649.27	566.83	317.45	283.08		
275.73	287.22	260.19	281.82	740.70	385.89
1078.61	602.16	635.95	497.40	629.86	493.35
412.25	2472.15	1790.93	1187.42	777.87	564.31
596.07	2504.59	1737.43	3913.68	969.13	2074.10
1852.43	1307.04	1071.18	1309.74	910.33	744.08
738.67	609.59	621.08	598.10	416.31	529.17
542.68	336.56	320.34	471.05	262.89	208.15
338.59	323.04	237.21	212.21	519.03	1043.47

Patuxent
Reservoirs
Inflows

FLOW # INPUT FILE

282.49	208.83	180.44	167.68		
279.03	235.90	318.13	228.48	222.42	267.58
235.22	221.07	244.66	1041.32	545.94	926.07
456.97	759.59	801.38	1294.75	1544.80	1111.42
1093.90	907.87	1697.80	926.07	770.38	793.97
1033.91	807.45	807.45	684.78	648.38	3552.64
1266.44	1058.85	938.88	714.44	774.42	684.11
542.57	1683.64	665.91	550.66	390.24	659.17
402.38	394.29	349.13	1266.44	1416.07	1962.00
605.25	407.09	333.63	312.57		
403.05	367.33	1076.37	3342.35	977.30	665.91
2636.68	759.59	924.72	746.11	595.81	707.02
626.14	622.77	725.89	558.74	808.80	624.79
595.14	616.71	1217.91	762.96	653.10	798.69
754.88	710.39	647.04	683.43	676.02	533.81
463.71	407.09	473.15	721.18	581.66	394.85
343.74	288.47	408.44	237.92	201.52	445.51
714.44	433.38	337.67	338.35	215.00	280.38
326.89	229.16	487.97	274.82		
250.05	225.79	231.85	260.16	261.51	370.82
258.81	330.93	347.78	847.21	520.32	375.42
439.45	364.63	347.11	343.06	370.70	2428.41
1298.79	1387.76	802.73	1418.76	988.75	1077.72
736.68	829.02	806.10	695.56	1144.45	1204.43
817.56	630.86	593.12	468.43	408.44	381.48
547.96	494.04	378.11	337.00	311.39	252.75
242.64	221.74	153.67	133.45	328.24	137.50
176.59	138.84	104.47	108.51		

Patuxent
Reservoirs
Inflows

TABLE H-III-8
DATA2 INPUT FILE

WSSC

.824	.824	.824	.766	.766	.766	.766	.752	.752	.752	.752	.752	.737	8-Year Monthly Average Coefficients
.737	.737	.737	.737	.738	.738	.738	.738	.738	.739	.739	.739	.739	
.739	.773	.773	.773	.773	.865	.865	.865	.865	.956	.956	.956	.956	
1.0	1.0	1.0	1.0	.955	.955	.955	.955	.954	.954	.954	.954	.824	
0.704	0.698	0.725	0.718	0.742	0.734	0.715	0.723	0.703	0.727	0.706	0.712	0.697	1966 Actual Demand Coefficients
0.701	0.711	0.708	0.695	0.691	0.735	0.738	0.713	0.670	0.670	0.715	0.734	0.776	
0.729	0.724	0.753	0.701	0.723	0.793	0.808	0.862	0.762	0.975	0.896	0.975	1.295	
1.231	1.195	1.154	1.356	1.138	1.068	0.881	1.115	1.255	1.192	1.017	0.822	0.813	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Hypothetical Coefficients
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

TABLE H-III-9
DATA3 INPUT FILE

FCWA

.803	.803	.803	.758	.758	.758	.758	.748	.748	.748	.748	.748	.710	8-Year Monthly Average Coefficients
.710	.710	.710	.710	.710	.710	.710	.710	.710	.713	.713	.713	.713	
.713	.773	.773	.773	.773	.848	.848	.848	.848	.922	.922	.922	.922	
1.0	1.0	1.0	1.0	.945	.945	.945	.945	.898	.898	.898	.898	.803	
0.704	0.698	0.725	0.718	0.742	0.734	0.715	0.723	0.703	0.727	0.706	0.712	0.697	1966 Actual Demand Coefficients
0.701	0.711	0.708	0.695	0.691	0.735	0.738	0.713	0.670	0.670	0.715	0.734	0.776	
0.729	0.724	0.753	0.701	0.723	0.793	0.808	0.862	0.762	0.975	0.896	0.975	1.295	
1.231	1.195	1.154	1.356	1.138	1.068	0.881	1.115	1.255	1.192	1.017	0.822	0.813	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Hypothetical Coefficients
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

TABLE H-III-10
DATA4 INPUT FILE

Aqueduct (WAD)

.845	.845	.845	.795	.795	.795	.795	.775	.775	.775	.775	.775	.769	8-Year Monthly Average Coefficients
.769	.769	.769	.769	.769	.765	.765	.765	.765	.747	.747	.747	.747	
.747	.781	.781	.781	.781	.820	.820	.820	.820	.919	.919	.919	.919	
1.0	1.0	1.0	1.0	.988	.988	.988	.988	.924	.924	.924	.924	.845	
0.824	0.804	0.814	0.786	0.771	0.766	0.756	0.754	0.737	0.755	0.750	0.739	0.707	1966 Actual Demand Coefficients
0.727	0.741	0.732	0.724	0.754	0.770	0.755	0.734	0.741	0.738	0.745	0.751	0.737	
0.746	0.757	0.781	0.768	0.770	0.790	0.821	0.866	0.797	0.938	0.924	0.961	1.156	
1.089	1.119	1.096	1.176	1.064	1.027	0.958	1.083	1.122	1.046	0.918	0.802	0.776	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Hypothetical Coefficients
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

DATA5 holds the upstream evaporation factors and the upstream reservoir operating curves. The first 52 values, arranged in one column, comprise the evaporation loss factors for Savage and Bloomington. The reservoir evaporation rates are based on historical records from the 1960's. The data matches the observed maximum monthly pan evaporation rates for the corresponding reservoir. The rates are in units of feet per month. These rates are assigned to the array EVAPU.

The last eight rows of 13 columns of DATA5 form the rule curve values for Bloomington and Savage, in order from week 1 to week 52. Bloomington's values (rows 53-56) represent the differences in storage between the capacity and the desired level. This formulation accommodates changes in capacity. For example in week 13, the drawdown value is 13,700 mg for Bloomington. If Bloomington's capacity is 30,000 mg, then the desired storage for that week is (30000-13700) or 16,300 mg. Similarly, Bloomington with a capacity of 38,700 mg would operate for a 25,000 mg in storage (38700-13700) in week 13. These values were taken from the current Baltimore District operating rule curve. The Bloomington rule values are assigned to the array WINDRB.

The last set of rows (row 57-60) hold the actual fall and winter storage values for Savage River Reservoir. These values were derived from the present reservoir operating curve. The array WINDRS is assigned the Savage rule values. The complete contents of DATA5 are listed in Table H-III-11.

DATA6 holds the downstream evaporation factors. The 52 values, arranged in one column, comprise the evaporation loss coefficients for the Occoquan and Patuxent reservoirs. The reservoir evaporation rates are based on historical records from the 1960's drought. The data matches the observed maximum monthly pan evaporation rates for the corresponding reservoir. The rates are in units of feet per month. They are assigned to the array EVAPD.

DATA6 also contains the Bloomington/Savage release ratios for proper balancing of water quality downstream of Luke, as described earlier. The contents of the DATA6 data file are found in Table H-III-12.

FORTRAN PROGRAMMING

The PRISM/COE program is written in the standard ANSI FORTRAN computer language. The source program for the PRISM/COE model is contained in the library file RPSPLOT under the Baltimore District's user number in the BCS computer system. That is, RPSPLOT is the set of FORTRAN statements which is normally associated with a computer program.

To execute the PRISM/COE computer program, the source file RPSPLOT must be successfully compiled. This is achieved by using the following commands in the batch mode:

```
C > GET, source file
C > REWIND, source file
C > REWIND, source listing file
C > REWIND, object file
C > FTN, I = source file, L = source listing file, B = object file
C > REPLACE, object file
C > REPLACE, source listing file
```

TABLE H-III-11

DATA 5 INPUT FILE

Upstream Evaporation Coefficients
.262
.240
.212
.192
.172
.150
.131
.119
.103
.089
.072
.071
.082
.095
.105
.117
.126
.130
.138
.142
.161
.179
.194
.211
.238
.261
.289
.313
.339
.361
.385
.409
.431
.427
.419
.415
.409
.421
.431
.442
.430
.411
.395
.376
.367
.352
.341
.378
.312
.289
.276
.406

Bloomington Rule Curve	500	1400	2400	3300	4400	5500	6600	7700	8800	10000	11200	12400	13700
	14500	14500	14500	14500	13800	11300	8700	6600	4800	3500	2300	1500	800
	300	100	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Savage Rule Curve	3900	3600	3300	3000	2800	2600	2400	2300	2100	1900	1700	1500	1300
	1300	1200	1200	1100	1100	1100	1100	1100	1100	1100	1100	1800	2600
	3700	4900	5500	5700	5800	5900	5900	5900	5900	5900	5900	5900	5900
	5900	5900	5900	5900	5900	5900	5900	5700	5500	5200	4900	4400	4200

TABLE H-III-12

DATA 6 INPUT FILE

Downstream Evaporation Coefficients

.318
.280
.255
.260
.265
.270
.275
.257
.236
.211
.199
.173
.160
.148
.133
.127
.120
.115
.119
.109
.118
.125
.135
.148
.170
.190
.212
.235
.275
.320
.358
.401
.425
.427
.429
.431
.435
.470
.498
.528
.558
.557
.548
.539
.530
.515
.490
.460
.435
.407
.375
.350

Bloomington: Savage Flow Ratios

0.0	111.5	6.67
111.5	227.1	5.71
227.1	348.2	5.00
348.2	524.2	4.00
524.2	839.4	3.33
839.4	1307.9	2.86
1307.9	1400.0	2.50
1400.0	1400.0	2.50
1500.0	1600.0	2.50
1600.0	99999.0	2.50
0.0	0.0	5.00
0.0	0.0	100.00
0.0	0.0	6.67
0.0	0.0	5.00

These commands are specific to the FORTRAN compiler. The source file is the input (RPSPLOT) for compilation. The source listing file is a listing of the source program, together with any error messages. This is a convenient tool for error diagnostics. The object file is the useful output of a successful FORTRAN compilation. It is the binary representation of the source program with the required machine instructions for the computer. The listing of this object file results in a long incomprehensible (to the non-systems programmer) string of characters. However, the object file is the required input to the processing file for program execution. The object file for the source program RPSPLOT is found in the user library as PRISMP. Note that PRISMP was the input to the PROC# execution file.

SOURCE LISTING

The PRISM/COE FORTRAN program (RPSPLOT) is forty-eight pages long and is not reproduced here; it is available for review in the Baltimore District.

MODEL APPLICATION

PURPOSE

Because PRISM/COE is a basin-specific hydrologic simulation model, it does not optimize the operation of the water supply system. Instead, it reports the consequences of a prescribed set of operating conditions, given certain physical restrictions. Thus, the model user must apply the model in a more or less "trial and error" fashion to screen the many possible operating possibilities. Identification of very good, if not optimal, operating strategies is possible by repeated model runs with slightly different assumptions.

The purpose in applying the PRISM/COE model, then, was to identify the consequences of different operating strategies within the water supply system and select the "best" strategies for further consideration. It is important to note that the PRISM/COE model was a key evaluation tool not only for the Bloomington Lake Reformulation Study, but for the overall MWA Water Supply Study as well. The model greatly reduced the time and effort required to evaluate many different operating strategies, and provided valuable insights as to ways for improving the regional management of the MWA's existing water supply system. The following sections discuss in more detail the various applications of PRISM/COE and the results of these applications.

APPROACH TO MODEL APPLICATION

PHASED DEVELOPMENT

Due to the dynamic nature of model development and the large number of variables under initial consideration, the PRISM/COE model was applied in three distinct phases to facilitate decisions as the study progressed. Each phase refined the model by expanding its simulation capabilities, adding new information, and/or upgrading information from the previous phase. Model development and application was actually an iterative process with the results from the applications in one phase indicating that cetain modifications be made in the following phase.

As results from other on-going technical investigations became available, they were also incorporated into the model. Thus, the model gradually became more complete and directly applicable to system regulation for water supply in the Potomac River Basin. The three-phase sequence of PRISM/COE model development and application is shown schematically on Figure H-III-10 and discussed brifely in the following paragraphs. Later sections more fully explain the objectives, assumptions, and results of each phase.

Starting with tne Johns Hopkin's original version of PRISM, the Corps modified the program during the Phase I work, primarily to enable a more detailed investigation of Bloomington Lake storage reallocation. The existing conservation storage (92,000 acre-feet) in Bloomington Lake was subdivided into water quality storage (51,000 acre-feet) and water supply storage (41,000 acre-feet) to enable PRISM/COE to keep track of separate volumes of storage within the lake. The ability to simulate the winter drawdown in both Bloomington and Savage for seasonal flood control was also added to PRISM/COE in Phase I. Other important model additions and modifications in Phase I included: expansion of the number of input variables specified by the user, an expansion of the output tables for user convenience, a provision to keep the storage in the two upstream reservoirs at approximately equal percentages of full capacity during drawdown situations, an option to use Conservation Scenario 3 demands, and an option to use weekly demand coefficients instead of monthly demand coefficients.

During Phase II, the preliminary results of two associated technical investigations became available and were incorporated into PRISM/COE. First, water quality analyses indicated that a ratio of no more than 4 to 1 of Bloomington to Savage releases should be maintained to minimize low pH problems in the North Branch Potomac River near Luke, Maryland. And second, studies by the United States Geological Survey estimated that 47 percent of the flow released from the upstream reservoirs would reach the MWA in the same week, with the remaining 53 percent arriving in the following week.

Moving into Phase III, some additional changes were made to PRISM/COE to make it more applicable to the MWA regional water supply system. Water quality investigations subsequent to Phase II further refined the Bloomington/Savage release ratios to provide seasonally varying and flow-dependent values; these values and the capability to apply them in different situations were added to the model in Phase III. Also, the model was slightly modified to allow the user to select for simulation any 10 years out of 50 possible years of flow record (the model previously contained only the 10 worst years of record in its data base). Additionally, the water supply release calculation was slightly refined to enable more efficient releases from the upstream reservoirs.

MODEL VARIABLES

As listed earlier in Table H-III-1, PRISM/COE eventually offered 43 variables which the user could specify prior to initiating each run. This capability allowed the user to investigate different operating strategies as well as test the sensitivity of a given strategy to changes in a particular variable while others were held constant. Table H-III-13 lists the important variables under investigation and the phase in which significant efforts were made to test the sensitivity of the simulations to that particular variable. Table H-III-14, on the other hand, lists those variables which were not the

FIGURE H-III-10
MODEL DEVELOPMENT PHASES

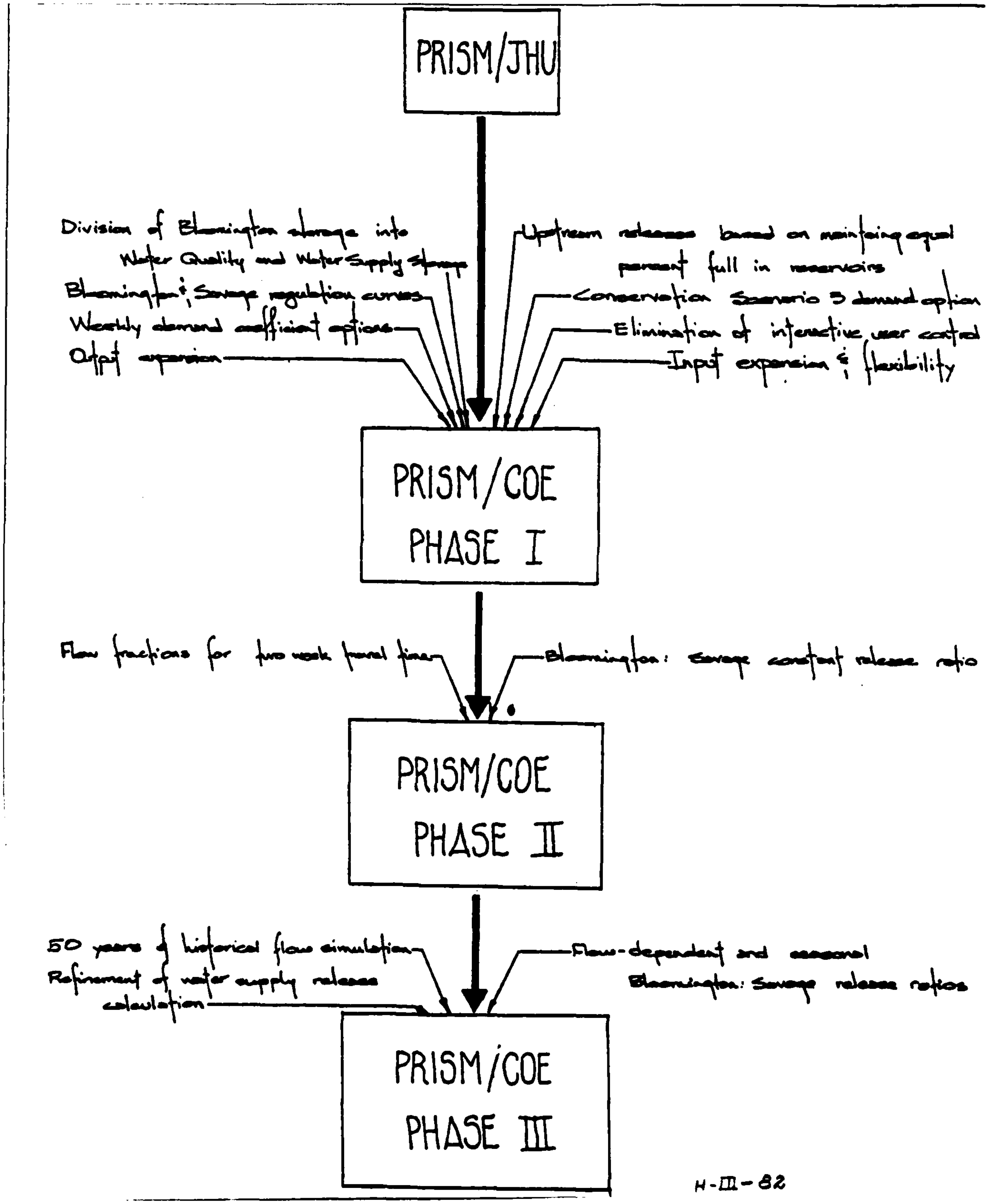


TABLE H-III-13

STUDY VARIABLES

Variable	Phase I	Phase II	Phase II
Year of Water Demand	X		
LFAA Freeze Year	X		
Upstream Flow Target	X		
Downstream Water Supply Target	X		
Downstream Target Factor	X	X	
Bloomington Storage Capacity	X		X
Bloomington Water Supply Storage	X		X
Bloomington Water Quality Storage	X		X
Level of Conservation		X	
Seasonal Pool for Bloomington			X
Potomac Estuary Flowby	X	X	X

primary focus of investigation and which were held constant throughout each phase. The following sections describe the assumptions, variables, applications, and results of the three-phased approach using PRISM/COE to evaluate the various operating schemes for regional water supply management.

PHASE I

OBJECTIVES

In the first phase of analysis, the application of PRISM/COE model centered on establishing base conditions and examining the effects of additional water storage with increased flowby levels. Certain modelling objectives were established and a logical series of test runs were made to meet these objectives. These modelling objectives were to: (1) determine how effective the operational strategy proposed in the project authorization document would be in satisfying MWA water supply demands; (2) determine the effect of flow targets at Luke, Maryland on reservoir stages and MWA deficits; (3) investigate the balance between releases from the upstream reservoirs (Bloomington and Savage) and withdrawals from the downstream reservoirs (downstream target factor); (4) investigate the effects of different water supply and water quality storage volumes in the existing Bloomington Lake Project; (5) determine the effects of different water supply and flood control storage volumes in the Bloomington Lake Project; and (6) determine effects of different environmental flowby volumes on the entire water supply system serving the MWA.

TABLE H-III-14

CONSTANT VARIABLES

Variable	Phase I	Phase II	Phase III
Savage Storage Capacity	6,500 MG	6,500 MG	5,900 MG
Occoquan Storage Capacity	10,200 MG	10,300 MG	10,300 MG
Patuxent Storage Capacity	10,100 MG	10,100 MG	10,100 MG
FCWA Potomac Capacity	200 MGD	200 MGD	200 MGD
WSSC Potomac Capacity	400 MGD	400 MGD	400 MGD
WAD Potomac Capacity	650 MGD	650 MGD	650 MGD
Occoquan Treatment Capacity	95 MGD	95 MGD	95 MGD
Patuxent Treatment Capacity	55 MGD	55 MGD	55 MGD
Consumptive Withdrawal	0 MGD	0 MGD	0 MGD
Minimum Bloomington Release	10 MGD	32 MGD	32 MGD
Minimum Savage Release	6 MGD	6 MGD	15 MGD
Occoquan Flowby	0 MGD	0 MGD	0 MGD
Patuxent Flowby	10 MGD	10 MGD	10 MGD
Seasonal Losses	None	None	None
Minimum Occoquan Draft	50 MGD	50 MGD	50 MGD
Minimun Patuxent Draft	20 MGD	20 MGD	20 MGD
Streamflow Prediction	Model	Model	Model
Demand Coeıficients	Average Monthly	Average Monthly	Average Monthly
Separate Bloomington Storages	Yes	Yes	Yes
Seasonal Pool for Savage	Yes	Yes	Yes
Bloomington/Savage Release Ratios	None	4:1	Variable
Travel Time Release Fractions	None	0.47/0.53	0.47/0.53

It should be noted here that the development of the PRISM/COE model was in the initial stage during Phase I, as shown in Figure H-III-10. Results of the related technical investigations were not yet available, and the interrelationships of many of the model variables were unknown. Thus, the Phase I investigations were made to explore the interrelationship of the various model elements and to determine which of these elements were most important to study accomplishment.

APPLICATION

Within the context of the six broad objectives and exploratory efforts for Phase I, 46 model runs were identified. Table H-III-15 lists these 46 runs which were evaluated in the Phase I analyses.

The basic rationale for the Phase I testing program was to isolate one objective at a time for detailed consideration, and then identify those variables which would directly affect how the objective was achieved. This was done by holding most of the variables at constant values and allowing one or two critical variables to change from run to run.

The first three runs investigated the capability of the MWA water supply system for the years 1990, 2010, and 2030, assuming no storage in Bloomington Lake. The upstream target was set at 60 mgd (93 cfs) which represented the then-existing target at Luke, Maryland. The results of these runs established a "without" condition to test the effectiveness of Bloomington Lake in meeting water supply needs.

Runs 4 through 12 assumed that Bloomington Lake was part of the regional system. For the years 1990, 2010, and 2030, the basic assumptions of this series of runs were a Luke flow target of 197 mgd (305 cfs) (the authorization document determined 197 mgd to be the safe yield of the Bloomington - Savage reservoir system), no downstream water supply target (essentially devoting all of Bloomington's conservation storage to water quality storage,) and flowbys of 100, 200, and 400 mgd. The results of these runs indicated the relative ineffectiveness of the Bloomington Lake project in satisfying different flowby levels if operated according to the authorization document. In addition, the model output indicated that shortages would occur if Bloomington was operated strictly for an upstream target with no regard for the size or timing of MWA water demands.

The third series of runs (13 through 20) determined the safe yield of the Bloomington Lake project and Savage River Reservoir, as represented by the flow at Luke, Maryland, using only the water quality storage in Bloomington Lake. Several allocations of Bloomington's total storage of 30,000 MG among water supply and water quality were assumed, and a maximum safe yield of the water quality storage (together with Savage) was determined. This yield number provided a rough relationship between the available storage in Bloomington Lake and the upstream flow target at Luke, Maryland.

Runs 21 through 29 examined the feasibility of conjunctive use as represented by the downstream target factor. The downstream target factor was defined as the percentage of reliance on the downstream reservoirs (Occoquan and Patuxent reservoirs). The use of a downstream target factor permitted the release of water from Bloomington's water supply storage when there was a need in the MWA. Bloomington storage would then satisfy both an upstream target (flow at Luke, Maryland) for water quality and a

TABLE H-III-15

LIST OF PRISM/COE RUNS FOR PHASE I

Run No.	Bloomington Capacity/ Bloomington Initial Storage (mg)3/	Bloomington Water Supply Capacity/ Initial Water Supply Storage (mg)3/	Bloomington Water Quality Storage/ Initial Water Quality Storage (mgd)3/	Upstream Target at Luke Maryland (mgd)	Downstream Target Factor	Environmental Flowby2/ (mgd)	Year of Investigation
1	2 1/	1 1/	1 1/	60	NONE	100	2030
2	2 1/	1 1/	1 1/	60	NONE	100	2010
3	2 1/	1 1/	1 1/	60	NONE	100	1990
4	30,000	1 1/	29,999	197	NONE	100	2030
5	30,000	1 1/	29,999	197	NONE	100	2010
6	30,000	1 1/	29,999	197	NONE	100	1990
7	30,000	1 1/	29,999	197	NONE	200	2030
8	30,000	1 1/	29,999	197	NONE	200	2010
9	30,000	1 1/	29,999	197	NONE	200	1990
10	30,000	1 1/	29,999	197	NONE	400	2030
11	30,000	1 1/	29,999	197	NONE	400	2010
12	30,000	1 1/	29,999	197	NONE	400	1990
13	30,000	29,999	1	80	NONE	100	2030
14	30,000	22,500	7,500	105	NONE	100	2030
15	30,000	13,370	16,630	135	NONE	100	2030
16	30,000	7,500	22,500	159	NONE	100	2030
17	30,000	1	29,999	190	NONE	100	2030
18	30,000	22,500	7,500	96	NONE	100	2030
19	30,000	13,370	16,630	135	NONE	100	2010
20	30,000	13,370	16,630	135	NONE	100	1990
21	30,000	13,370	16,630	135	0.0	100	2030
22	30,000	13,370	16,630	135	0.3	100	2030
23	30,000	13,370	16,630	135	0.4	100	2030
24	30,000	13,370	16,630	135	0.5	100	2030
25	30,000	13,370	16,630	135	0.6	100	2030
26	30,000	13,370	16,630	135	0.7	100	2030
27	30,000	13,370	16,630	135	1.0	100	2030
28	30,000	13,370	16,630	135	0.6	100	2010

TABLE H-III-15 (Cont'd)

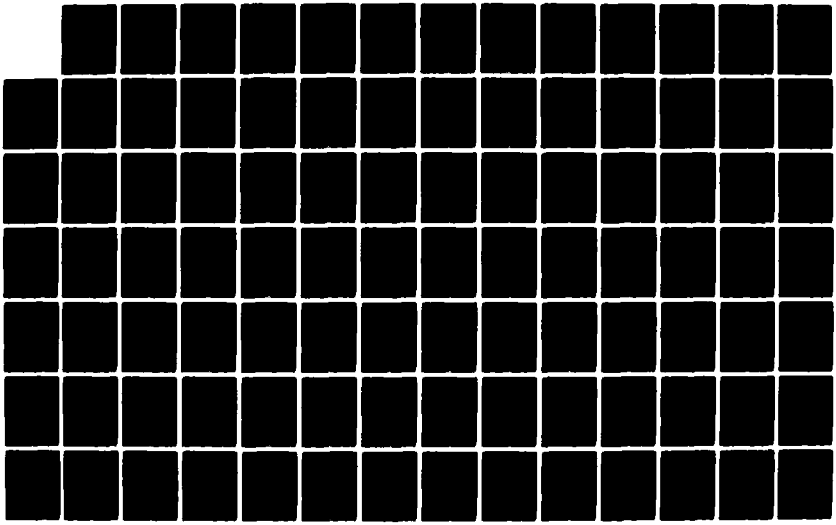
LIST OF PRISM/COE RUNS FOR PHASE I

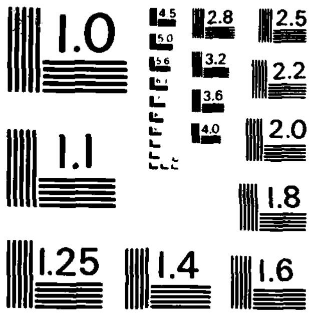
Run No.	Bloomington Capacity/ Bloomington Initial Storage[3] (mg)[1]	Bloomington Water Supply Capacity/ Initial Water Supply Storage (mg)[1][3]	Bloomington Water Quality Storage/ Initial Water Quality Storage (mgd)[1][3]	Upstream Target at Luke Maryland (mgd)	Downstream Target Factor	Environmental Flowby[3] (mgd)	Year of Investigation
29	30,000	13,370	16,630	135	0.6	100	1990
30	30,000	29,999	1	80	0.6	100	2030
31	30,000	22,500	7,500	105	0.6	100	2030
32	30,000	7,500	22,500	159	0.6	100	2030
33	30,000	13,370	16,630	135	0	200	2030
34	30,000	13,370	16,630	135	0	400	2030
35	30,000	13,370	16,630	135	0.6	200	2030
36	30,000	13,370	16,630	135	0.6	400	2030
37	30,000	29,999	1	60	0.6	100	2030
38	30,000	29,999	1	60	0.6	200	2030
39	30,000	29,999	1	60	0.6	400	2030
40	30,000	13,370	16,630	60	0.6	100	2030
41	30,000	13,370	16,630	60	0.6	200	2030
42	30,000	13,370	16,630	60	0.6	400	2030
43	32,800	16,170	16,630	135	0.6	200	2030
44	32,800	16,170	16,630	135	0.6	400	2030
45	38,700	22,070	16,630	135	0.6	200	2030
46	38,700	22,070	16,630	135	0.6	400	2030

1/ Minimum storage required to avoid non-zero storage volume; this problem was corrected in later versions of the model.
2/ At Little Falls.
3/ Initial storage was assumed equal to storage capacity.

AD-A134 161 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX H BLOOMINGTON LA..(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83 2/5

UNCLASSIFIED MWA-83-P-APP-H-VOL-2 F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

downstream target for water supply. Seven different downstream factors (0.0, 0.3, 0.4, 0.5, 0.6, 0.7, and 1.0) were investigated during these runs. For every run an upstream target of 135 mgd, water supply storage of 13,370 mg, water quality storage of 16,630 mg, and an environmental flowby of 100 mgd was assumed. The results of these runs indicated that a trade-off between higher and lower downstream target factors would be needed to allow all reservoirs to maintain an adequate level while still meeting the MWA demands. Higher downstream target factors tended to deplete downstream reservoirs too quickly and lower downstream target factor tended to exhaust upstream water supply storage too rapidly.

Runs 30 through 32 investigated various possibilities for storage reallocation within Bloomington's existing conservation storage of 30,000 mg. Three levels of water supply storages 29,999 mg, 22,500 mg and 7,500 mg with corresponding water quality storages of 1 mg, 7,500 mg and 22,500 mg were used for these investigations. For each of these runs, a downstream target factor of 0.6 and a flowby of 100 mgd were used.

Runs 33 through 42 considered the impact of various flowby levels on different operating strategies. Flowby levels of 100, 200, and 400 mgd were used with different upstream targets (60 and 135 mgd) and different downstream target factors. The purpose of these runs was to examine the effect of keeping as much water quality storage as possible in Bloomington Lake to act as a buffer for potential acid inflows.

Runs 43 through 46 investigated the feasibility of reallocating part of Bloomington Lake's flood control storage to water supply storage for additional downstream releases. Two levels of conservation storage (32,800 mg and 38,700 mg) were investigated. In both cases, water quality storage was kept at 16,630 mg. An upstream target of 135 mgd, a downstream target factor of 0.6, flowbys of 200 mgd and 400 mgd, and MWA water demands for the year 2030 were used for these runs.

RESULTS

The Phase I model runs furnished general information regarding the relationships among the model variables as well as their interdependence. This information was very helpful in setting the course for the next phase, both by identifying those parameters requiring additional analysis and by identifying those parameters not critical to the examination.

The following observations were made concerning the results of Phase I model runs.

- Higher levels of required flowby would result in significantly larger water supply shortages, given any particular year. Similarly, higher flowby levels would cause shortages earlier in the planning period than lower flowby levels.

- The safe yield of the entire conservation storage in Bloomington Lake plus Savage River Reservoir and the natural flow in the North Branch Potomac River was cited as 197 mgd in Bloomington Lake's authorization report. This value was confirmed by the PRISM/COE analysis. However, reservoir regulation to meet a daily flow target at Luke of 197 mgd would result in a very inefficient use of Bloomington's water supply storage for meeting downstream needs.

- The 51,000 acre-feet of Bloomington Lake water quality storage, together with the North Branch Potomac River natural flow and releases from Savage River Reservoir, were estimated to provide a safe yield of 135 mgd at Luke. Higher flow targets at Luke would require additional water quality storage, resulting in less storage available for water supply.

- The 41,000 acre-feet of Bloomington Lake water supply storage could be used to effectively satisfy downstream water supply needs, given an appropriate downstream target factor, an upstream flow target within the capability of the existing water quality storage, and a 100 mgd flowby level.

- Water supply shortages would likely not occur in the MWA before 2030, given an efficient regional management strategy for all of the reservoirs serving the MWA, implementation of Little Seneca Lake, 100 mgd flowby, and a recurrence of the worst drought of record (1930-1931).

In addition to the above general indications, the Phase I model runs showed that model results were most sensitive to variables such as the upstream flow target, the downstream target factor, and flowby. These important variables had substantial impact on the system operations, and further investigations were warranted to determine how system operation could be optimized with regard to these variables.

PHASE II

OBJECTIVES

The objectives of Phase II were two-fold: (1) to optimize the model variables which had the greatest impact on operation of the system; and (2) to modify PRISM/COE to incorporate the results of certain completed technical investigations.

MODIFICATIONS

During Phase II, the results of two companion technical investigations became available as shown on Figure H-III-10.

First, preliminary water quality investigations developed a minimum flow value which was to be maintained at Luke during low flow periods in order to provide an acceptable level of water quality further downstream. As part of this work, a ratio of Bloomington to Savage releases, estimated as 4 to 1, was developed to help dilute probable acidic Bloomington water with normally alkaline Savage water. The minimum flow value at Luke (labelled as the upstream flow target), taking into account the 4 to 1 release ratio, was tentatively established as 71 mgd (110 cfs).

Second, estimates of flow travel time between Bloomington and the MWA were incorporated into PRISM/COE. For the Phase I model runs, it was assumed that the Bloomington and Savage releases would reach the MWA intakes undiminished between 7 and 14 days after release. Detailed investigations made by the United States Geological Survey (USGS) under contract to the Corps of Engineers, however, indicated that 47 percent of the releases would reach the MWA within the same week and the remaining 53 percent would reach the MWA during the following week without any significant losses. (See Annex H-V for detailed information). Given the observations from Phase I, the objectives for Phase II, and the tentative results of the two related technical studies, PRISM/COE was modified to include the following items in Phase II:

- An upstream target of 71 mgd (110 cfs).

- A constant Bloomington to Savage release ratio of 4 to 1.

- The results of the flow travel time studies with 47 percent of the upstream release arriving in the same week, and 53 percent arriving in the following week.

APPLICATION

Once the upstream flow target, release ratios, and travel times were established, the efforts in Phase II were concentrated primarily on investigations of the downstream target factor, the flowby level, and the demand level (Baseline or Conservation Scenario 3 demands). Fourteen model runs were made as listed on Table H-III-16.

TABLE H-III-16

LIST OF PRISM/COE RUNS FOR PHASE II

Run No.	Bloomington Lake Storage (mg)	Water Supply Storage (mg)	Water Quality Storage (mg)	Upstream Target at Luke (mgd)	Downstream Water Supply Target Factor	Flowby (mgd)	Demand Year	Conservation Scenario	Bloomington to Savage Ratio
1	30,000	0	30,000	197	--	100	2030	Baseline	--
2	30,000	13,370	16,730	71	0.2	100	2030	Baseline	4:1
3	30,000	13,370	16,730	71	0.6	100	2030	Baseline	4:1
4	30,000	13,370	16,730	71	1.0	100	2030	Baseline	4:1
5	30,000	13,370	16,730	71	0.2	100	2030	Scenario 3	4:1
6	30,000	13,370	16,730	71	0.6	100	2030	Scenario 3	4:1
7	30,000	13,370	16,730	71	1.0	100	2030	Scenario 3	4:1
8	30,000	13,370	16,730	71	0.0	300	1980	Scenario 3	4:1
9	30,000	13,370	16,730	71	0.2	300	2030	Scenario 3	4:1
10	30,000	13,370	16,730	71	0.6	300	2030	Scenario 3	4:1
11	30,000	13,370	16,730	71	1.0	300	2030	Scenario 3	4:1
12	30,000	13,370	16,730	71	0.2	500	2030	Scenario 3	4:1
13	30,000	13,370	16,730	71	0.6	500	2030	Secnario 3	4:1
14	30,000	13,370	16,730	71	1.0	500	2030	Scenario 3	4:1

Three values for the downstream target factor were considered in order to provide a broad range of impacts on the operation of the MWA water supply system. Three levels of flowby were also considered to assess the sensitivity of reservoir storage and water shortages to different flowby values. With the exception of the first run, all runs considered Bloomington Lake's conservation storage (92,000 acre-feet, 30,000 mg) to be divided between water quality storage (51,000 acre-feet, 16,630 mg) and water supply storage (41,000 acre-feet, 13,370 mg). No flood control reallocation was considered in Phase II. Run 1 was made to examine the impacts of operating Bloomington to satisfy the upstream flow target cited as the safe yield in the authorization document, without regard to water supply and water quality storage suballocations.

A majority of the efforts during Phase II concentrated on identifying the downstream target factor which would provide the best trade-off between the use of Bloomington Lake storage and storage in the downstream reservoirs. This was done in Phase II so that the range of options could be narrowed before entering Phase III when storage reallocation within Bloomington Lake was to be the primary element under examination.

RESULTS

From the results of Phase II model runs, it was clear that some significant trade-offs were necessary to establish an appropriate downstream target factor which provided adequate water for the MWA needs without endangering the water quality in the North Branch Potomac River. Table H-III-17 provides a comparison of storage remaining in the different reservoirs under different downstream target factors. Storages in the downstream reservoirs would be depleted more quickly if a higher downstream target factor was adopted. On the contrary, Bloomington storage would be reduced more quickly if a lower value of the downstream target factor was adopted.

TABLE H-III-17

COMPARISON OF STORAGE REMAINING (MG)
WITH DIFFERENT DOWNSTREAM TARGET FACTORS

	DOWNSTREAM TARGET FACTOR		
	0.2	0.6	1.0
1930 Drought			
Bloomington (Water Supply)	6,337	11,607.	13,370
Downstream Reservoirs	9,770	6,391	4,702
1966 Drought			
Bloomington (Water Supply)	5,915	10,431	12,985
Downstream Reservoirs	15,591	13,054	12,180

Simulation constants: 2030 Demands, Conservation Scenario 3, Bloomington: Savage ratio 4:1, Upstream target flow 71 mgd (110 cfs), Bloomington Conservation Storage 92,000 acre-feet (30,000 mg), and flowby 100 mgd.

Because the value of the downstream target factor could also affect the fishery and aquatic resources in the various reservoirs (more or less drawdown), the U.S. Fish and Wildlife Service (USFWS) was requested to evaluate the potential consequences of selecting different downstream target factors. Based on their work, the USFWS concluded that heavy dependence on the downstream reservoirs would cause drawdowns to low levels during droughts, which would result in significant adverse impacts to fishery resources. On the other hand, trying to save water in the downstream reservoirs by relying more heavily on the upstream reservoirs would also cause adverse impacts. Since there are expected to be minimal fishery resources in Bloomington Lake, a drawdown would have little biological impacts there. However, large releases and subsequent drawdowns would likely affect the degree to which the impoundment could maintain its ability to moderate the water quality of the North Branch. Also since releases from Bloomington Lake are made concurrently with releases from Savage Reservoir for water quality reasons, high dependence on Bloomington for water supply releases would result in a drawdown of Savage Reservoir which would be detrimental to the fine fishery resources there. Therefore, it appeared that the best downstream target factor from a fish and wildlife perspective would be one which produces a balanced use of the upstream and downstream reservoirs in order to minimize the possibility of severe drawdowns in any one of them.

From the output of the 14 Phase II runs and the information provided by the USFWS, the following observations were made:

- From an environmental viewpoint, the downstream target factor should be one which balances the use of upstream and downstream reservoirs;

- Higher values of the downstream target factor and the subsequent lesser reliance on Bloomington Lake storage would produce better water quality conditions in the North Branch Potomac River below Luke, Maryland.

- In terms of water supply, maximum system flexibility would be achieved with a downstream target factor in the mid-range. Higher values of the downstream target factor would save water in Bloomington Lake for long term droughts. This would cause downstream reservoirs to use their storages more quickly, and losing the ability to respond adequately to large short-term flucuations in either supply or demand. On the other hand, low downstream target factors could require more reliance on Bloomington Lake storage with possible water wastage due to inaccurate flow predictions for the Potomac River, while saving water in downstream reservoirs.

- The selected downstream target factor should allow some margin of error for imperfect prediction of streamflow so that the system has enough remaining flexibility to compensate for such prediction errors.

Considering all of these concerns, observations, and results, it was concluded that a downstream target factor of 0.6 would be reasonable. This value of 0.6 would assume a 60 percent reliance on the downstream reservoirs for the water supply release determination. Based on this decision, the remaining PRISM/COE runs in Phase III used this value (0.6) for the downstream target factor.

From the results of the Phase II analysis, it was also evident that the value selected for flowby was perhaps the most important variable in estimating the water supply system's potential to meet the MWA demands. Continued efforts were therefore planned for Phase III to determine the sensitivity of MWA water shortages to various flowby levels.

PHASE III

The third and final phase of model development and application was geared primarily to evaluating the potential for flood control storage reallocation and to estimating the sensitivity of model results to different flowby levels. This phase took advantage of the decisions, refinements, and modifications made in the previous phases. The results from Phase III were then used in the formulation and evaluation of the long-range components for the overall MWA Water Supply Study.

OBJECTIVES

The objectives of the Phase III analysis were established as the following: (1) to incorporate the results of the completed technical studies regarding proper values for certain model variables; (2) to determine the desirability, from a water supply viewpoint, of reallocating some of Bloomington Lake's flood control storage to water supply storage; and (3) to evaluate the sensitivity of projected MWA shortages to various flowby levels, given different volumes of water supply storage in Bloomington Lake.

MODIFICATIONS

In light of the selection of 0.6 as the downstream target factor and the results of the USGS flow loss and travel time studies, the water quality analyses were reviewed to determine if any adjustments should be made. These reevaluations indicated that the minimum upstream flow target should be revised from 110 cfs (71 mgd) to 120 cfs (78 mgd) to achieve slightly better water quality in the North Branch Potomac River. In addition, the Bloomington/Savage release ratio was modified to make it a flow-dependent variable rather than a constant ratio (4:1), as was used for Phase II model runs. The flow-dependent ratios were listed in Table H-III-12.

Because of the reservoir simulation capability of PRISM/COE, it was decided to use the model to perform the drawdown frequency analysis as documented in Annex H-VIII. To accomplish this purpose, it was necessary to expand the data base in PRISM/COE to include the entire period of record (1929-1979) to make sure that all of the drought years were covered sequentially. Previously, Phases I and II had considered only the ten worst years of record linked together in April of each year.

With the above-mentioned modifications, new information, and revised data, PRISM/COE was revised to reflect the following changes:

- An upstream target factor of 78 mgd (120 cfs).
- Flow-dependent Bloomington/Savage release ratios as shown in Table H-III-12.
- 50 years of flow record (October 1929 to September 1979).

APPLICATION AND RESULTS

Thirteen model runs were identified for PHASE III analysis, as shown in Table H-III-18. Three levels of flowby (100, 300, and 500 mgd) were considered in order to provide an estimate of the sensitivity of MWA deficits to this parameter. Based on the results of the flood control analyses (described in Annex H-IV), two pools higher than the existing conservation pool at elevation 1466 feet msl (36,200 acre-feet of flood control storage) were considered for storage reallocation. These two pool levels at 1475 and 1484 feet msl would reallocate 25 percent (9050 acre-feet) and 50 percent (18,100 acre-feet), respectively of the existing flood control storage. The reduction in flood control benefits

TABLE H-III-18

LIST OF PRISM/COE RUNS FOR PHASE III

Run No.	Bloomington Lake Elevation (feet msl)	Bloomington Lake Storage (mg)	Water Supply Storage (mg)	Water Quality Storage (mg)	Upstream Target at Luke, MD (mgd)	Downstream Target Factor	Flood Control Operation	Environmental Flowby (mgd)
1	1466	30,000	13,370	16,630	78	0.6	Seasonal	100
2	1466	30,000	13,370	16,630	78	0.6	Seasonal	300
3	1466	30,000	13,370	16,630	78	0.6	Seasonal	500
4	1466	30,000	13,370	16,630	78	0.6	Year-round	100
5	1466	30,000	13,370	16,630	78	0.6	Year-round	300
6	1466	30,000	13,370	16,630	78	0.6	Year-round	500
7	1466	30,000	15,000	15,000	78	0.6	Year-round	300
8	1466	30,000	15,000	15,000	78	0.6	Year-round	500
9	1475	32,900	17,900	15,000	78	0.6	Year-round	300
10	1475	32,900	17,900	15,000	78	0.6	Year-round	500
11	1484	35,900	20,900	15,000	78	0.6	Year-round	300
12	1484	35,900	20,900	15,000	78	0.6	Year-round	500
13	1466	30,000	0	30,000	197	N.A.	Seasonal	100

Assumptions:
- 2030 demands, Scenario 3 Conservation.
- Flow-dependent ratios for the Bloomington and Savage releases for water quality.
- Simulation for 50 years of flow record.

for the 1475 and 1484 pools were estimated as 3 percent and 7 percent, respectively, based on calculations provided in Annex H-IV. A third higher pool elevation of 1492 feet msl was not considered in the PRISM/COE analysis as it would reduce the flood control storage by 75 percent (27,150 acre-feet) with an associated reduction in flood control benefits of 31 percent.

The Bloomington Lake authorization document assumed a winter drawdown of 44,400 acre-feet in the lake to provide additional flood runoff control during the winter and early spring. During the Phase III analyses, the hydrologic effects of both a year-round permanent pool and seasonal pool were investigated.

Further investigations also indicated that the water quality conditions in the North Branch Potomac River and in Bloomington Lake could be maintained with only 46,000 acre-feet (15,000 mg) of water quality storage instead of the presently allocated 51,000 acre-feet. The remaining 5000 acre-feet could possibly be reallocated to other purposes. In the end, it was decided, however, not to change the water quality storage from 51,000 acre-feet (16,630 mg) to 46,000 acre feet (15,000 mg) because there may be some rare instances when it would not be possible to meet the MWA flowby target of 100 mgd using only water quality storage in Bloomington Lake. For those extreme cases, the flow at Luke, Maryland, could be increased from 78 mgd to 100 mgd using the extra 5,000 acre-feet of water quality storage in order to provide a flowby of 100 mgd at the MWA.

It should be noted that PRISM/COE did not include the proposed Little Seneca Lake project as part of the MWA water supply system. At the time PRISM/COE was being developed, it was not at all certain whether Little Seneca Lake would be constructed. By the time the Phase III analysis was being conducted, however, it had become apparent that the new reservoir project would be added to the system. Hence, the results of the Phase III model runs, without Little Seneca Lake, were carried further by hand calculations to account for the projected effects of the new project as part of the regional system.

Runs 1, 2, and 3

As shown on Table H-III-18, the first three runs investigated the effects of different flowby levels (Run 1 - 100 mgd, Run 2 - 300 mgd, and Run 3 - 500 mgd) on satisfying the MWA water supply demands for the year 2030, if Bloomington Lake was operated with its authorized conservation pool at elevation 1466 feet msl and a seasonal drawdown for flood control. The existing conservation storage of 92,000 acre-feet (30,000 mg) was assumed to be suballocated to water supply storage (41,000 acre-feet, 13,370 mg) and water quality storage (51,000 acre-feet, 16,630 mg). Table H-III-19 shows the results of the first three runs for the 1930-1931 drought - the worst long-term drought on record and Figures H-III-11 through H-III-13 show the regional deficits and Potomac flow hydrographs for these simulations. Shown on Table H-III-19 are the following: the maximum weekly deficit (mgd) during the drought; the total cumulative deficit (mg) incurred throughout the drought; the volume of storage (mg) remaining in the MWA system's reservoirs following the severest part of the drought, along with a percentage figure showing how much of the system's full water storage capability remained; and the number of weeks at the minimum flowby level.

In terms of cumulative regional deficit, a flowby of 100 mgd (Run 1) would cause no regional shortages, and approximately 67 percent of the system's storage capacity would remain. Flowby would be at the minimum level of 100 mgd for 13 weeks. For a flowby of 300 mgd (Run 2), a small regional shortage of about 2100 mg would be incurred, but only 16 percent of the reservoir storage would remain indicating that the higher flowby target would mean more severe drawdowns in all the reservoirs. On the other hand a flowby target of 500 mgd (Run 3) would cause a regional shortage of almost 32,000 mg. Furthermore, all of the reservoirs would be nearly empty, with only 13 percent of the system's total storage capacity remaining. Flowby would be at the minimum level of 500 mgd for 21 weeks. Figures H-III-11 through H-III-13 show the magnitude of the cumulative regional deficit for Runs 1, 2, and 3 respectively. These figures indicate the Potomac River flow conditions and MWA deficits during the 1930-31 simulated time period.

Regulation of Bloomington Lake to satisfy large flowby requirements would have certain water quality effects in the North Branch Potomac River Basin as well. The higher the flowby level, the lower the water temperature and conductivity of Bloomington Lake releases as the reservoir is drafted more heavily. Higher flowby levels would also cause a drop in the pH just downstream of the lake, and most likely within the lake as well because of a reduction in its buffering capability. Downstream from Luke, the pH would be slightly higher with higher flowby levels because additional alkaline water would be released from Savage (see discussion of flow-dependent release ratios for Bloomington and Savage in an earlier section). The pH would also be elevated at Luke for any flow level because of the effects of the discharge from the Upper Potomac River Commission's

TABLE H-III-19

PRISM/COE PHASE III
RESULTS OF RUNS #1, 2 AND 3

PARAMETER	PROJECT CAPACITY (MG)	RUNS/FLOWBY #1 100 MGD	#2 300 MGD	#3 500 MGD
MAXIMUM DEFICIT, MGD				
WSSC		0	69	193
FCWA		0	28	74
WAD		0	2	137
TOTAL REGION		0	99	362
CUMULATIVE DEFICIT, MG				
WSSC		0	1,423	16,729
FCWA		0	654	5,454
WAD		0	12	9,769
TOTAL		0	2,089	31,952
AVAILABLE STORAGE REMAINING, MG				
WATER SUPPLY				
BLOOMINGTON	13,370	11,822	0	0
OCCOQUAN	10,300	2,336	0	0
PATUXENT	10,100	4,220	2,499	1,338
LITTLE SENECA	4,020	3,797	0	0
TOTAL REMAINING	37,790	22,175	2,499	1,338
PERCENT OF CAPACITY REMAINING		58.7	6.6	3.5
NON-WATER SUPPLY				
BLOOMINGTON	16,630	13,275*	6,852	6,778
SAVAGE	5,900	4,801*	544	0
TOTAL REMAINING	22,530	18,076	7,396	6,778
PERCENT OF CAPACITY REMAINING		80.2	32.8	30.1
TOTAL STORAGE REMAINING	60,320	40,251	9,895	8,116
PERCENT OF TOTAL CAPACITY REMAINING		66.7	16.4	13.5
WEEKS AT MINIMUM FLOWBY LEVEL		13	18	21

*Before Seasonal Drawdown

Assumptions:
- 2030 damands, Scenario 3 Conservation.
- Flow-dependent ratios for Bloomington and Savage releases for water quality.
- Simulation of 50 years of flow record.
- Downstream target factor of 0.6.
- Conservation pool at 1466 seasonal.
- Conservation storage split WS 13370/WQ 16630.

FIGURE H-III-11
Simulated Potomac River Hydrograph
Run #1

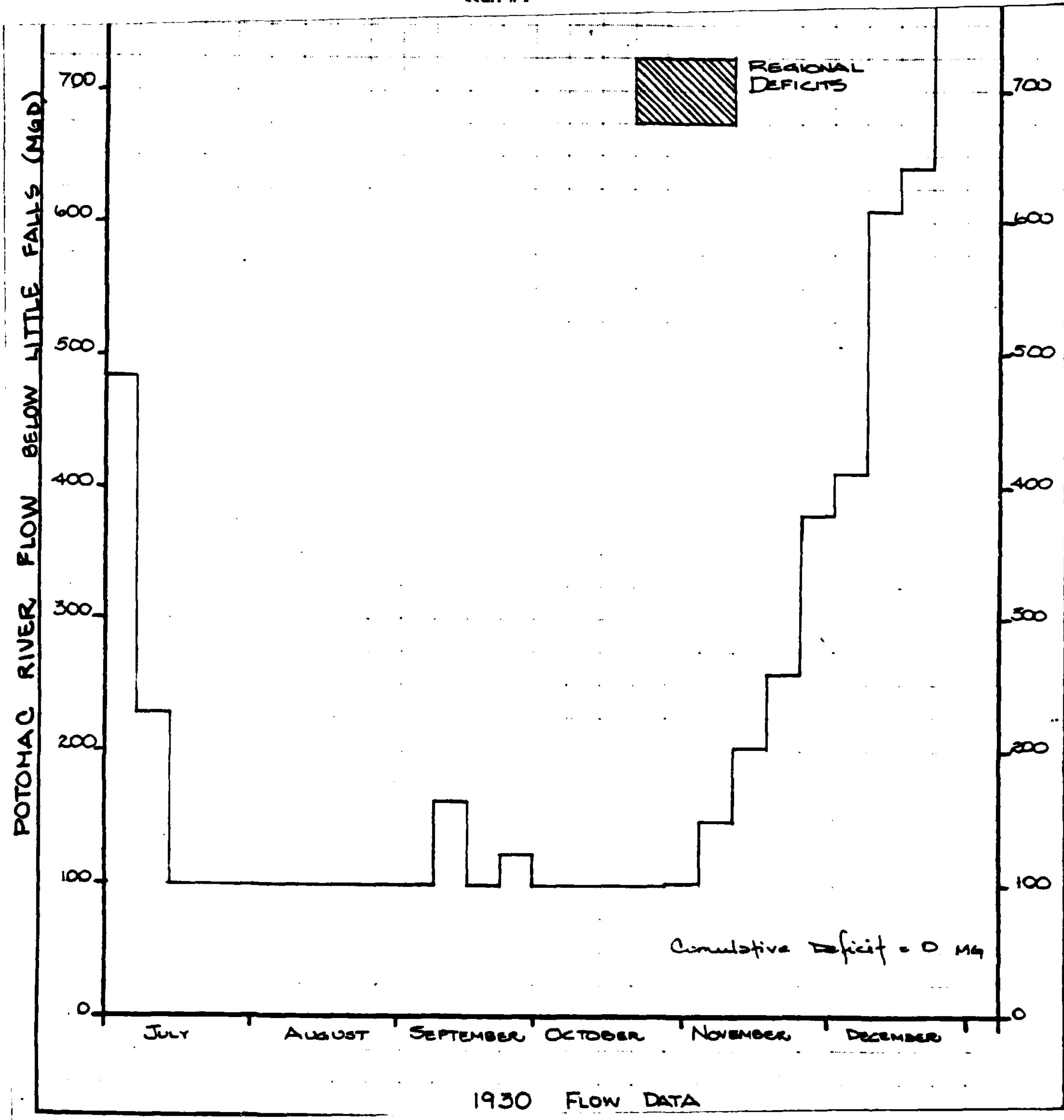


FIGURE H-III-12
Simulated Potomac River Hydrograph
Run #2

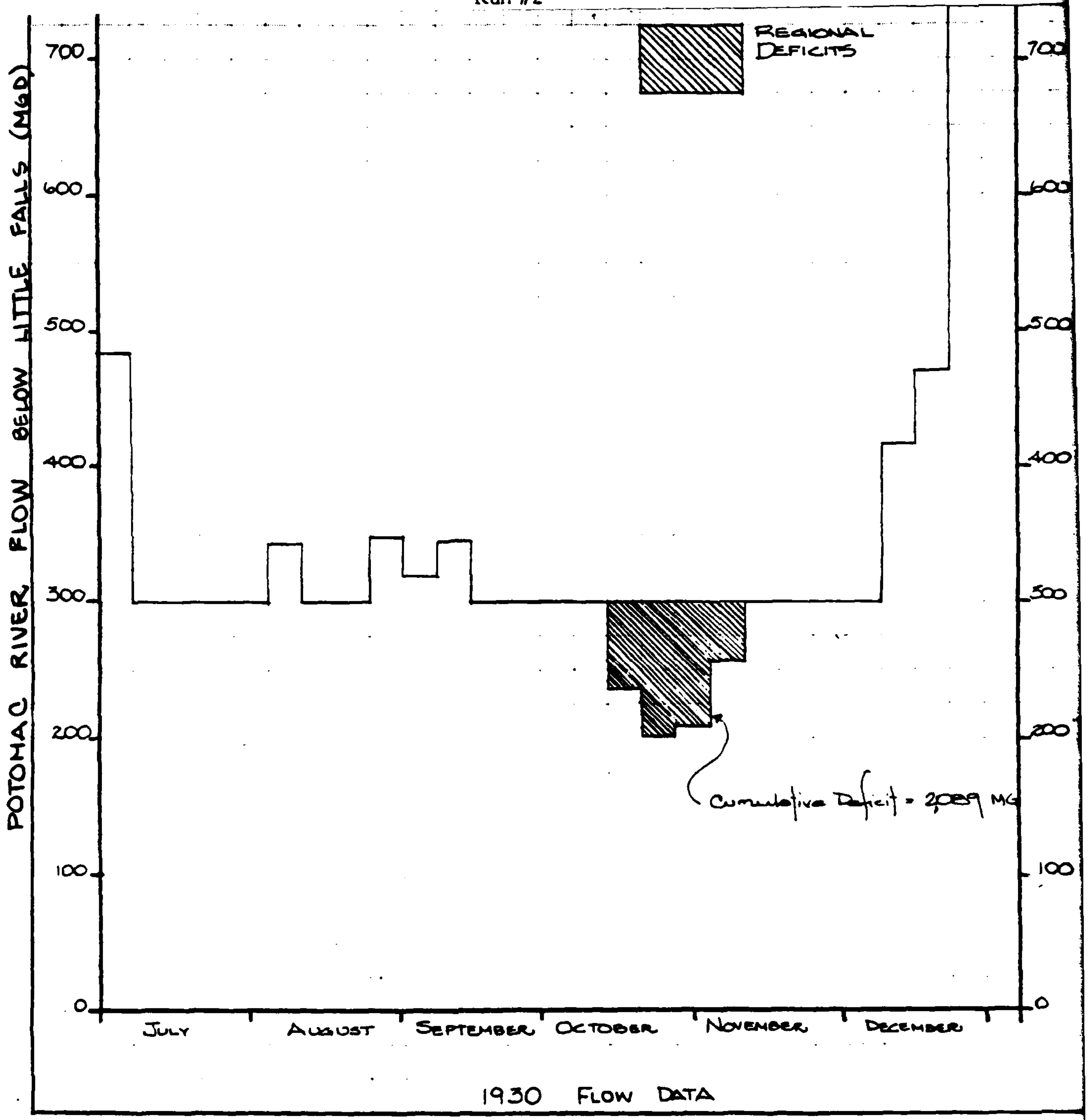
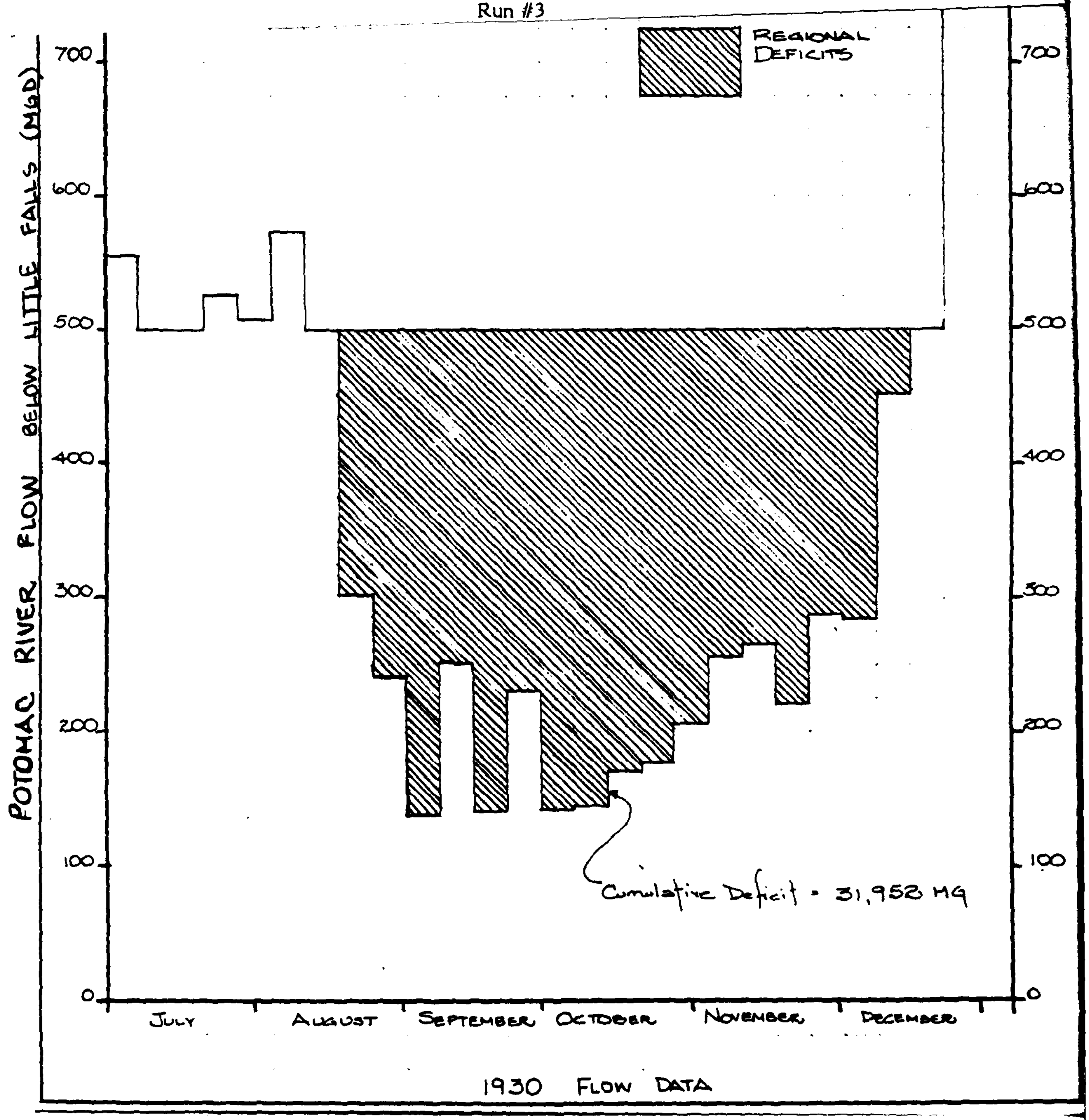


FIGURE H-III-13
Simulated Potomc River Hydrograph
Run #3



sewage treatment plant. Detailed data concerning the effects of different Bloomington Lake regulation schemes on water quality in the North Branch are contained in Annex H-II - Water Quality Investigations.

Runs 4, 5, and 6

Runs 4, 5, and 6 were identical to Runs 1, 2, and 3, respectively, except that a year-round pool was assumed in Bloomington Lake instead of a seasonal drawdown for additional flood control. The results of Runs 4, 5, and 6 are tabulated in Table H-III-20 in a format identical to Table H-III-19.

From the information contained in Table H-III-20, it was evident that the provision of a year-round pool in Bloomington Lake had no benefical or adverse affect on the magnitude of deficits in the MWA. The data in both tables are identical. Therefore Figures H-III-11 through 13 for Runs 1, 2, and 3 also apply to Runs 4, 5, and 6 respectively, with the year-round pool at elevation 1466 feet msl.

Reregulating Bloomington Lake to maintain a permanent year-round pool would result in some changes to projected water quality conditions downstream of the reservoir during certain times of the year. With a year-round pool, large spring-time releases would occur with potential for low pH, requiring dilution by Savage releases. (Normally, these spring inflows would be stored as Bloomington Lake is brought back up to its summer elevation). The Savage River Reservoir, however, would be unable to furnish the required volume of releases as its regulation also calls for a winter drawdown, and it would be "saving" its spring inflows to return the conservation pool to normal summer levels. This potential for low pH in the early spring with a year-round Bloomington pool could possibly be avoided if Savage Reservoir was also regulated to provide a permanent year-round pool. Water quality conditions throughout the remainder of the year would be similiar to those projected for Runs 1, 2, and 3.

Runs 7 and 8

Runs 7 and 8 assumed a different storage reallocation between water quality (46,000 acre-feet, 15,000 mg) and water supply (46,000 acre-feet, 15,000 mg) than is presently provided. Two levels of flowby (300 mgd for Run 7 and 500 mgd for Run 8) were tested as it was evident from earlier runs that the system was capable of maintaining 100 mgd flowby with no deficits. The results of Runs 7 and 8 are shown in Table H-III-21 in a format similiar to the earlier tables. Figures H-III-14 and H-III-15 show the regional deficits and Potomac flow hydrographs for these simulations.

Even with the extra water supply storage, cumulative regional deficits would not be significantly reduced from the comparable data in Runs 2 or 3. With a 500 mgd flowby target, the regional deficit would still approach 30,000 mg and almost 90 percent of the system's reservoir storage would be used. For the 500 mgd scenario, there could be some adverse effects on downstream water quality because sufficient Savage storage would not be available to adequately dilute the releases from Bloomington Lake.

Runs 9 and 10

Runs 9 and 10 considered the potential effects on water supply availability of reallocating 25 percent of Bloomington Lake's flood control storage and maintaining a permanent year-round pool at elevation 1475 feet msl. Water supply storage would be increased to 17,260 mg, and water quality storage would be set at 15,640 mg. (The effects of such reallocation on the project's flood control capability is examined in Annex

TABLE H-III-20

PRISM/COE PHASE III
RESULTS OF RUNS #4, 5, AND 6

PARAMETER	PROJECT CAPACITY (MG)	RUNS/FLOWBY #4 100 MGD	#5 300 MGD	#6 500 MGD
MAXIMUM DEFICIT, MGD				
WSSC		0	69	193
FCWA		0	28	74
WAD		0	2	137
TOTAL REGION		0	99	362
CUMULATIVE DEFICIT, MG				
WSSC		0	1,423	16,729
FCWA		0	654	5,454
WAD		0	12	9,769
TOTAL		0	2,089	31,952
AVAILABLE STORAGE REMAINING, MG				
WATER SUSPPLY				
BLOOMINGTON	13,370	11,822	0	0
OCCOQUAN	10,300	2,336	0	0
PATUXENT	10,100	4,220	2,499	1,338
LITTLE SENECA	4,020	3,797	0	0
TOTAL REMAINING	37,790	22,175	2,499	1,338
PERCENT OF CAPACITY REMAINING		58.7	6.6	3.5
NON-WATER SUPPLY				
BLOOMINGTON	16,630	13,275	6,852	6,778
SAVAGE	5,900	4,801	544	0
TOTAL REMAINING	22,530	18,076	7,396	6,778
PERCENT OF CAPACITY REMAINING		80.2	32.8	30.1
TOTAL STORAGE REMAINING	60,320	40,251	9,895	8,116
PERCENT OF TOTAL CAPACITY REMAINING		66.7	16.4	13.5
WEEKS OF MINIMUM FLOWBY LEVEL		13	18	21

ASSUMPTIONS:
- 2030 Demands, Scenario 3 Conservation.
- Flow dependent ratios for Bloomington and Savage releases for water quality.
- Simulation of 50 years of flow record.
- Downstream target factor of 0.6.
- Conservation pool at 1466 year-round.
- Conservation storage split WS 13370/WQ 16630.

TABLE H-III-21

PRISM/COE PHASE III
RESULTS OF RUNS #7 AND 8

PARAMETER	PROJECT CAPACITY (MG)	RUNS/FLOWBY #7 300 MGD	RUNS/FLOWBY #8 500 MGD
MAXIMUM DEFICIT, MGD			
WSSC		44	92
FCWA		23	74
WAD		0	136
TOTAL REGION		67	360
CUMULATIVE DEFICIT, MG			
WSSC		525	15,736
FCWA		248	5,206
WAD		0	9,090
TOTAL		773	30,032
AVAILABLE STORAGE REMAINING, MG			
WATER SUPPLY			
BLOOMINGTON	15,000	0	0
OCCOQUAN	10,300	0	0
PATUXENT	10,100	2,707	1,333
LITTLE SENECA	4,020	0	0
TOTAL REMAINING	39,420	2,707	1,333
PERCENT OF CAPACITY REMAINING		6.9	3.4
NON-WATER SUPPLY			
BLOOMINGTON	15,000	4,923	4,588
SAVAGE	5,900	165	0
TOTAL REMAINING	20,900	5,088	4,588
PERCENT OF CAPACITY REMAINING		24.3	22.0
TOTAL STORAGE REMAINING	60,320	7,795	5,921
PERCENT OF TOTAL CAPACITY REMAINING		12.9	9.8
WEEKS AT MINIMUM FLOWBY LEVEL		18	21

Assumptions:
- 2030 Demands, Scenario 3 Conservation.
- Flow-dependent ratios for Bloomington and Savage releases for water quality.
- Simulation of 50 years of flow record.
- Downstream target factor of 0.6.
- Conservation pool at 1466 Year-round.
- Conservation storage split WS 15000/WQ 15000.

FIGURE H-III-14

Simulated Potomac River Hydrograph
Run #7

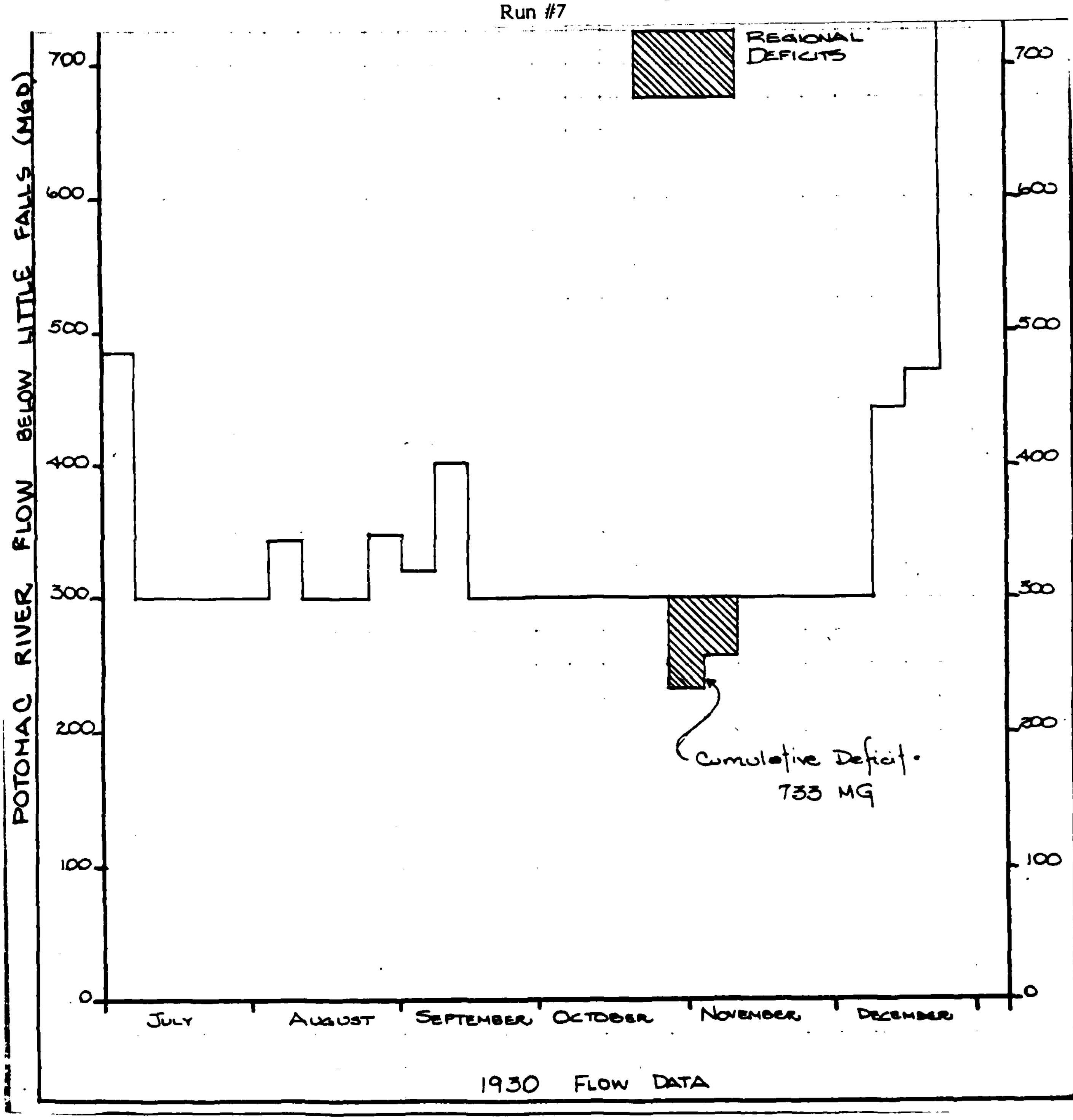
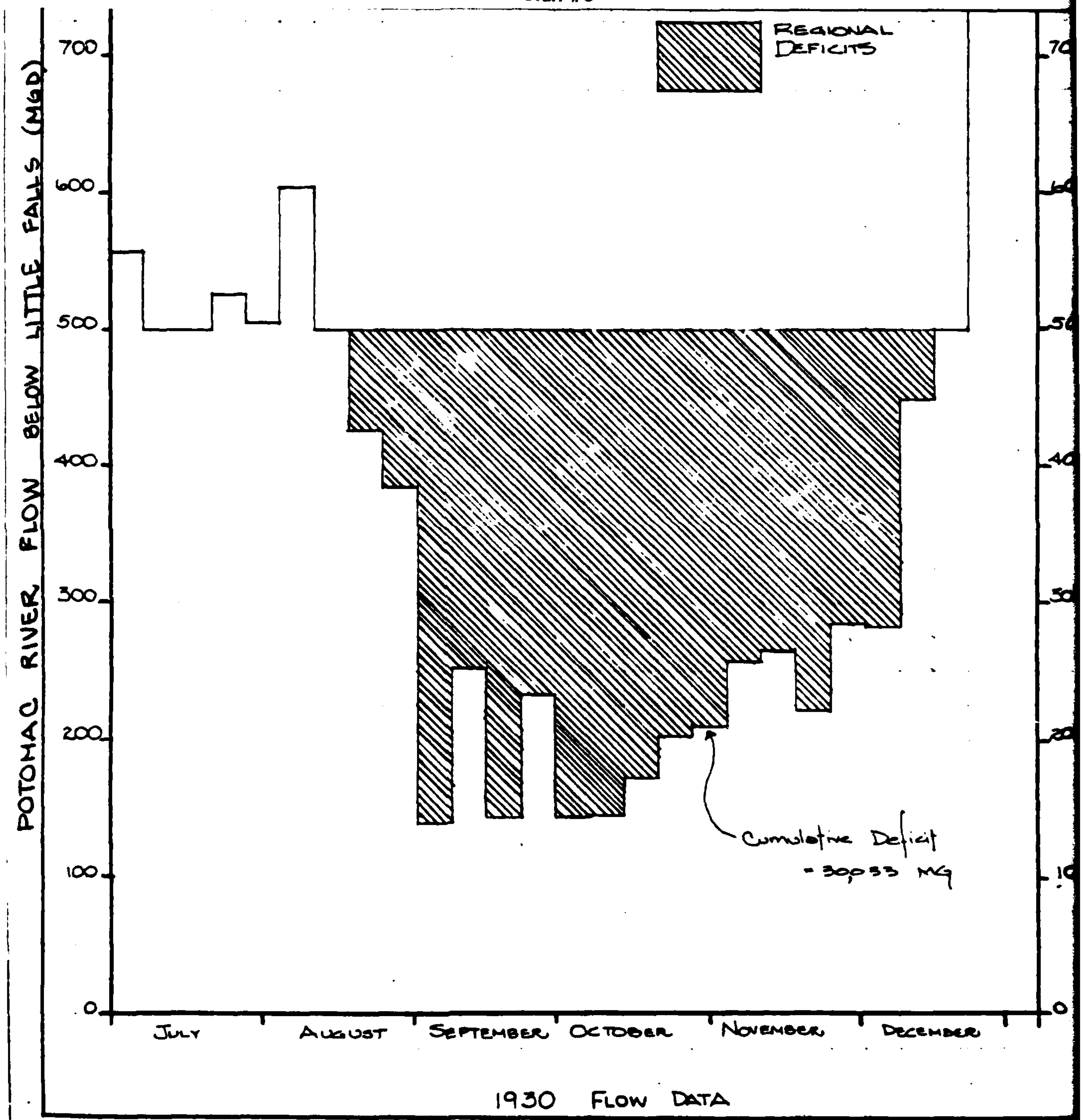


FIGURE H-III-15

Simulated Potomac River Hydrograph
Run #8



H-IV - Flood Control Analysis.) Run 9 evaluated the effects of maintaining a 300 mgd flowby target and Run 10 analyzed the effects of maintaining a 500 mgd flowby target. A 100 mgd flowby target was not investigated because there would be no shortages under the existing condition and hence no storage reallocation would be needed. Cumulative regional deficits for Runs 9 and 10 are tabulated in Table H-III-22 and shown graphically in Figures H-III-16 and H-III-17.

Information obtained from Run 9 indicated that deficits for a 300 mgd flowby target could be eliminated with the reallocated flood control storage in Bloomington Lake, but only 15 percent of the system's reservoir storage would remain. With a 500 mgd flowby target, a large cumulative regional deficit would still occur, reaching as high as 28,000 mg and using nearly 90 percent of the system's available reservoir storage. Water quality impacts in the North Branch Potomac River would be slight with the higher pools, the system would have less control over floods in the North Branch Potomac River; consequently, highly acid flows could pass through the reservoir uncontrolled more frequently. As with Run 8, the 500 mgd scenario could have some adverse impacts.

Runs 11 and 12

Similar to Runs 9 and 10, Runs 11 and 12 were based on reallocating 50 percent of the flood control storage to water supply storage. The conservation pool would be maintained at elevation 1484 feet msl year-round. The water supply storage would be increased to 20,900 mg and water quality was assumed as 15,000 mg. Two levels of flowby, 300 mgd and 500 mgd, were used. The results of these runs are given in Table H-III-23, and shown graphically in Figures H-III-18 and H-III-19.

From the results of Runs 11 and 12, it was evident that even with the transfer of 50 percent of the flood control storage to water supply storage in the Bloomington Lake it would not be possible to meet the regional water supply demands and a 500 mgd flowby target. With a 500 mgd flowby, the region would have a cumulative deficit of about 25,000 mg. Additionally, more than 90 percent of the regional storage capacity would be used to maintain a flowby level of 500 mgd.

If Bloomington Lake was operated as represented by Run 12, the water quality in the North Branch Potomac River would be severly impacted. The Bloomington-Savage release ratios could not be maintained, and subsequently the necessity for water supply releases would allow the acidic water from Bloomington to flow in the North Branch below Luke, Maryland. Consequently, it may lower the pH significantly. Additionally, the higher pool would provide less control of potential acid slugs.

Run 13

Run 13 was made to compare the results of the other runs with the conditions assumed for the authorization document. The full 92,000 acre-feet of conservation storage was committed to maintain a continuous flow of 305 cfs (197 mgd) at Luke, Maryland, in conjunction with Savage Reservoir and natural flow in the North Branch Potomac River. A seasonal pool was assumed for Bloomington Lake and a flowby of 100 mgd was assumed. No storage reallocation was considered. The results of Run 13 are shown in Table H-III-24.

TABLE H-III-22

PRISM/COE PHASE III
RESULTS OF RUNS #9 AND 10

PARAMETER	PROJECT CAPACITY (MG)	RUNS/FLOWBY #9 300 MGD	#10 500 MGD
MAXIMUM DEFICIT, MGD			
WSSC		0	190
FCWA		0	70
WAD		0	136
TOTAL REGION		0	355
CUMULATIVE DEFICIT, MG			
WSSC		0	4,816
FCWA		0	4,611
WAD		0	8,520
TOTAL		0	27,947
AVAILABLE STORAGE REMAINING, MG			
WATER SUPPLY			
BLOOMINGTON	17,900	0	0
OCCOQUAN	10,300	150	0
PATUXENT	10,100	2,934	1,570
LITTLE SENECA	4,020	1,230	0
TOTAL REMAINING	42,320	4,314	1,570
PERCENT OF CAPACITY REMAINING		10.4	3.8
NON-WATER SUPPLY			
BLOOMINGTON	15,000	5,282	4,910
SAVAGE	5,900	0	0
TOTAL REMAINING	20,900	5,282	4,910
PERCENT OF CAPACITY REMAINING		24.5	22.8
TOTAL STORAGE REMAINING	63,220	9,596	6,480
PERCENT OF TOTAL CAPACITY REMAINING		15.2	10.2
WEEKS AT MINIMUM FLOWBY LEVEL		18	20

Assumptions:
- 2030 Demands, Scenario 3 Conservation.
- Flow-dependent ratios for Bloomington and Savage releases for water quality.
- Simulation of 50 years of flow record.
- Downstream target factor of 0.6.
- Conservation pool at 1475 Year-round.
- Conservation storage split WS 17260/WQ 15640.

FIGURE H-III-16
Simulated Potomac River Hydrographs
Run #9

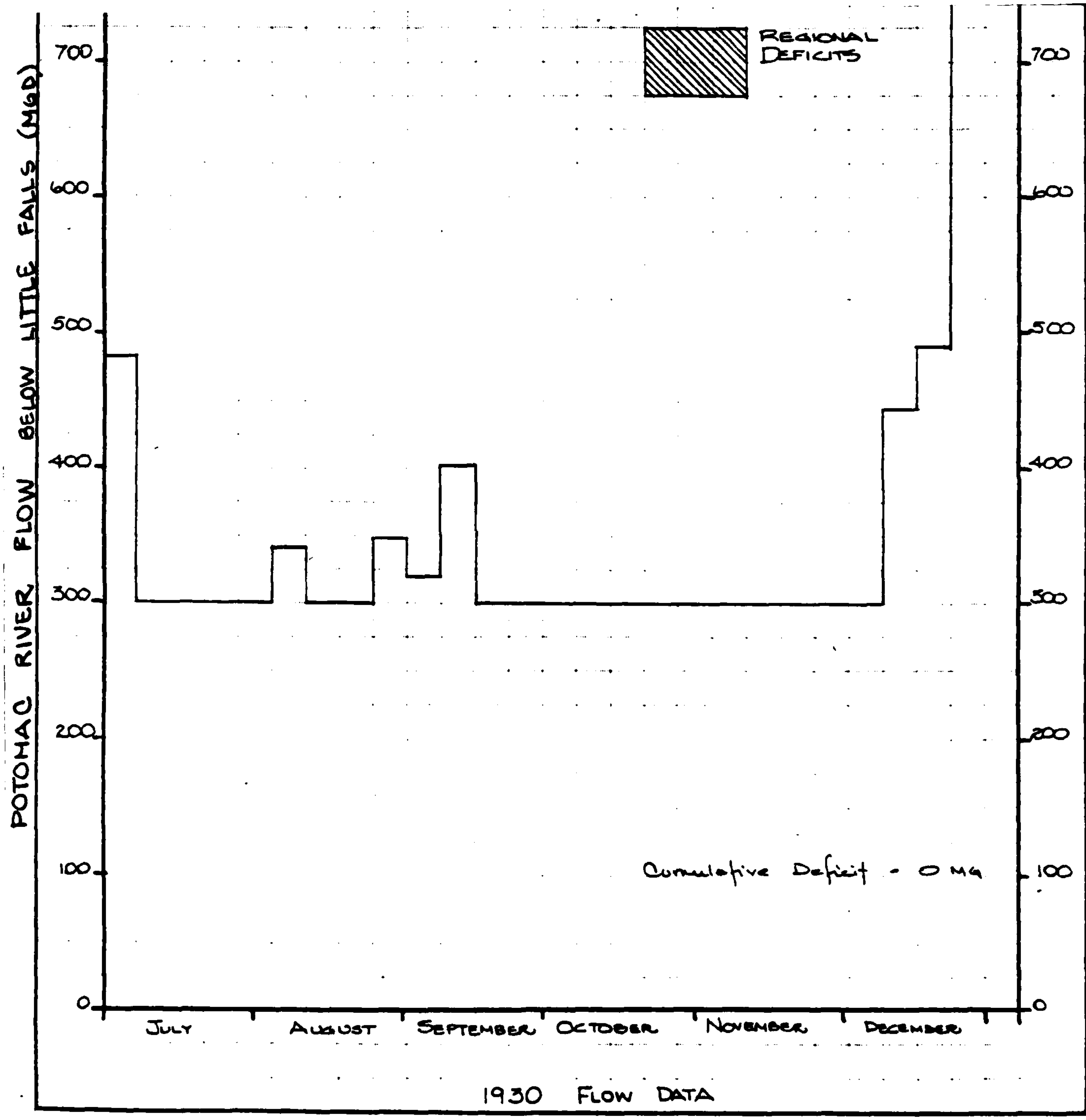


FIGURE H-III-17

Simulated Potomac River Hydrograph
Run #10

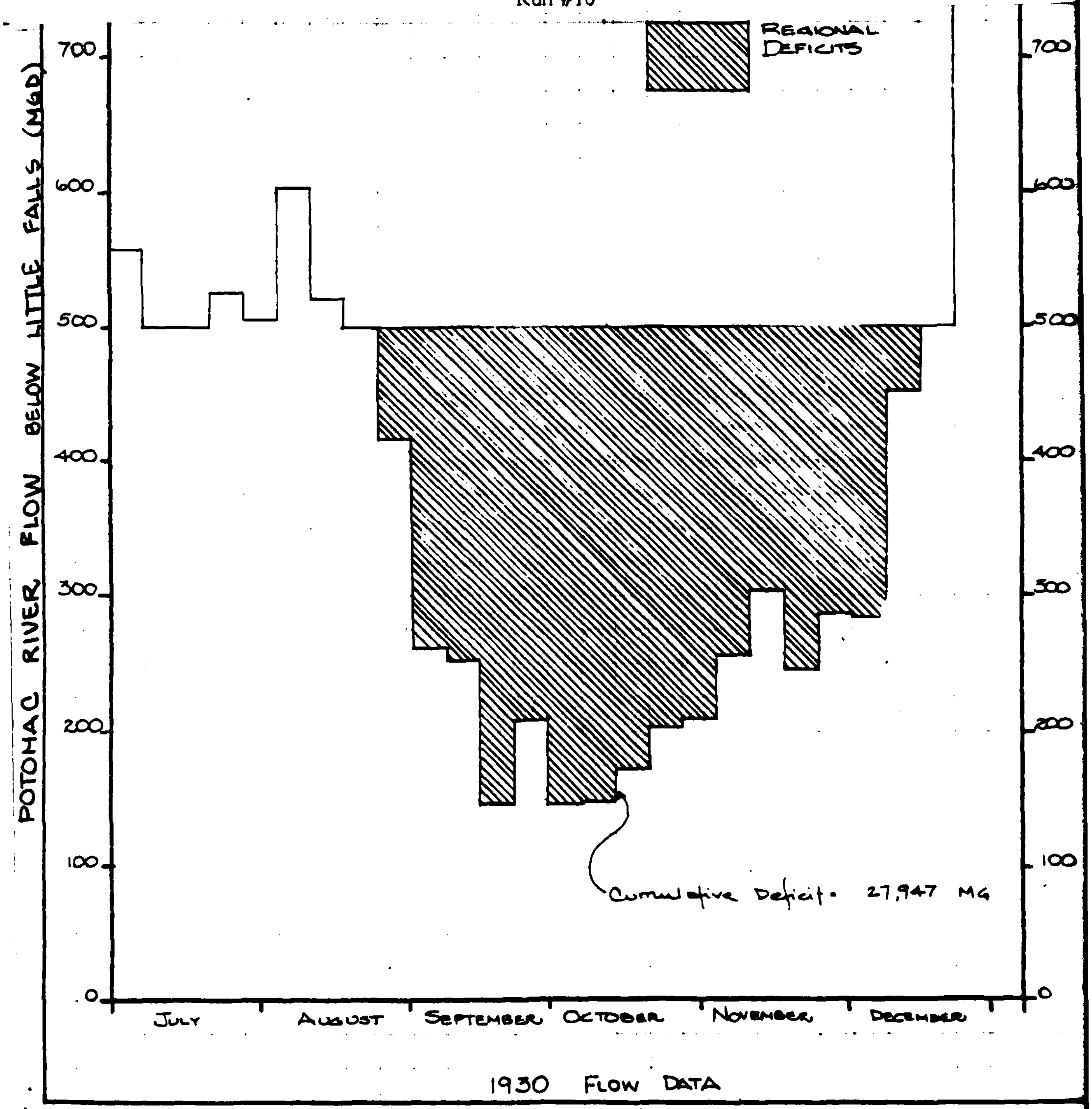


TABLE H-III-23

PRISM/COE PHASE III
RESULTS OF RUNS 11 AND 12

PARAMETER	PROJECT CAPACITY (MG)	RUNS/FLOWBY #11 300 MGD	#12 500 MGD
MAXIMUM DEFICIT, MGD			
WSSC		0	189
FCWA		0	51
WAD		0	135
TOTAL REGION		0	354
CUMULATIVE DEFICIT, MG			
WSSC		0	13,045
FCWA		0	3,917
WAD		0	7,688
TOTAL		0	24,650
AVAILABLE STORAGE REMAINING, MG			
WATER SUPPLY			
BLOOMINGTON	20,900	0	0
OCCOQUAN	10,300	823	0
PATUXENT	10,100	3,386	1,730
LITTLE SENECA	4,020	3,432	0
TOTAL REMAINING	45,320	7,641	1,730
PERCENT OF CAPACITY REMAINING		17.1	3.9
NON-WATER SUPPLY			
BLOOMINGTON	15,000	4,738	3,348
SAVAGE	5,900	0	0
TOTAL REMAINING	20,900	4,738	4,348
PERCENT OF CAPACITY REMAINING		22.0	20.2
TOTAL STORAGE REMAINING	66,220	12,379	6,078
PERCENT OF TOTAL CAPACITY REMAINING		18.7	9.2
WEEKS OF MINIMUM FLOWBY LEVEL		17	20

Assumptions:
- 2030 Demands, Scenario 3 Conservation.
- Flow-dependent ratios for Bloomington to Savage Release for water quality.
- Simulation of 50 years of flow record.
- Downstream target factor of 0.6.
- Conservation pool at 1484 year-round.
- Conservation storage split WS 20,900/WQ 15,000.

FIGURE H-III-18

Simulated Potomac River Hydrograph
Run #11

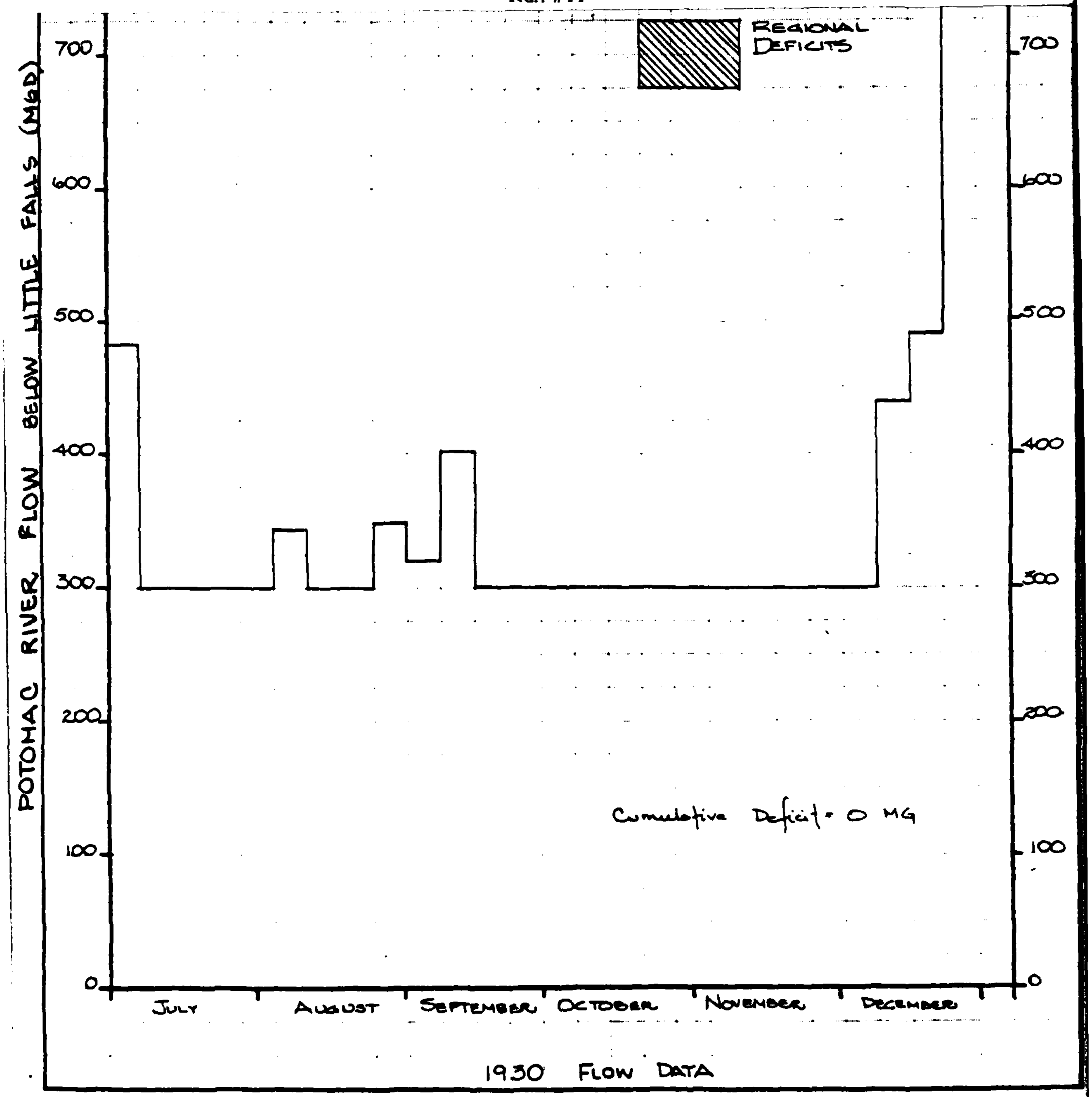


FIGURE H-III-19

Simulated Potomac River Hydrograph
Run #12

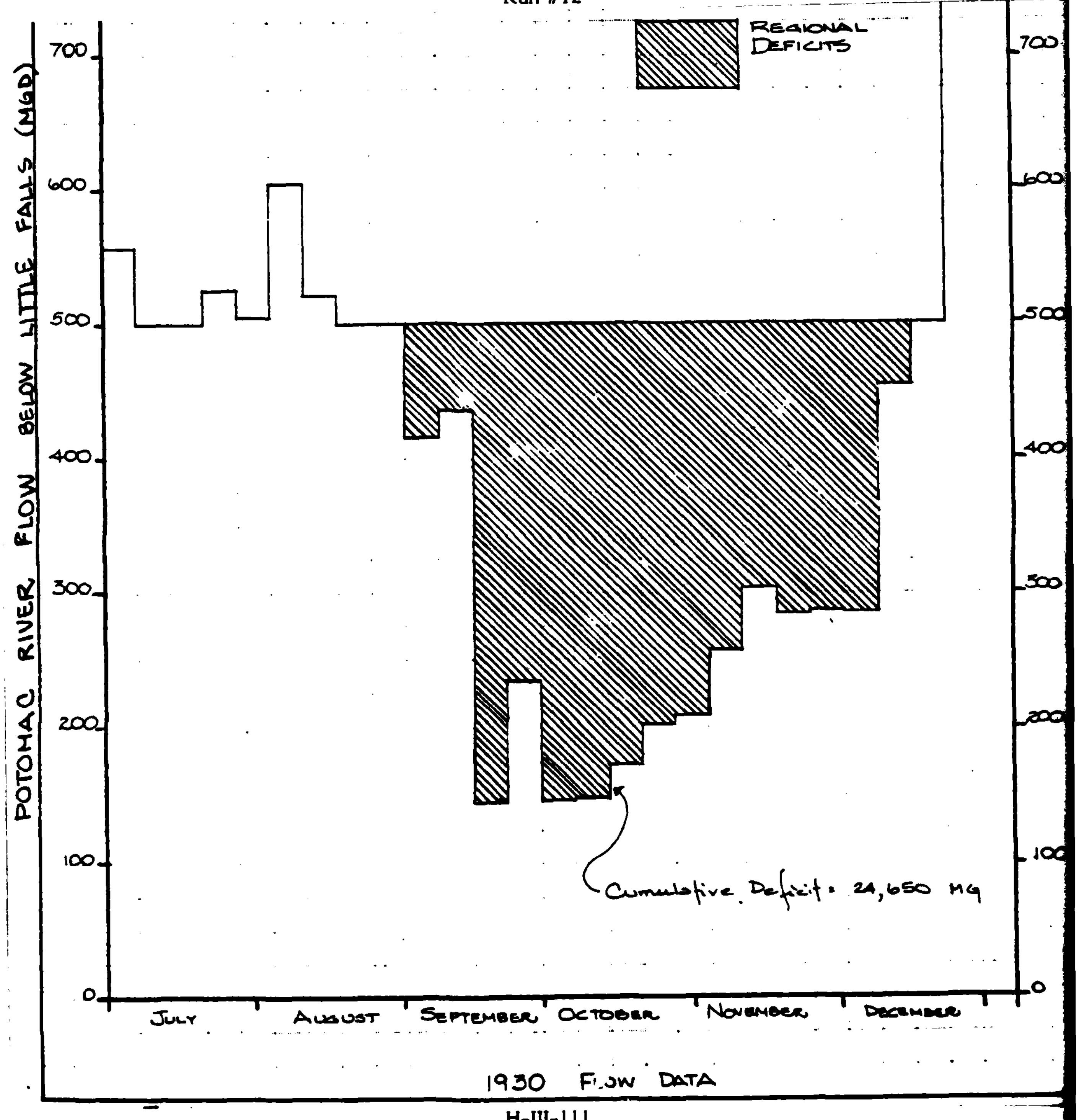


TABLE H-III-24

PRISM/COE PHASE III
RESULTS OF RUNS #13

PARAMETER	PROJECT CAPACITY (MG)	RUNS/FLOWBY #13 100 MGD
MAXIMUM DEFICIT, MGD		
WSSC		0
FCWA		0
WAD		0
TOTAL REGION		0
CUMULATIVE DEFICIT, MG		
WSSC		0
FCWA		0
WAD		0
TOTAL		0
AVAILABLE STORAGE REMAINING, MG		
WATER SUPPLY		
BLOOMINGTON		0
OCCOQUAN	10,300	4,547
PATUXENT	10,100	5,041
LITTLE SENECA	4,020	3,871
TOTAL REMAINING	24,420	14,109
PERCENT OF CAPACITY REMAINING		57.8
NON-WATER SUPPLY		
BLOOMINGTON		0
SAVAGE		0
TOTAL REMAINING		0
PERCENT OF CAPACITY REMAINING		
TOTAL STORAGE REMAINING		14,109
PERCENT OF TOTAL CAPACITY REMAINING		23.4
WEEKS AT MINIMUM FLOWBY LEVEL		3

Assumptions:
- 2030 Demands, Scenario 3 Conservation.
- Flow-dependent ratios for Bloomington and Savage releases for water quality.
- Simulation of 50 years of flow record.
- Downstream target factor of 0.6.
- Conservation pool at 1466 seasonal.
- Flow at Luke, Maryland 305 cfs (197 mgd).

The results of Run 13 clearly indicated that a flow target of 305 cfs (197 mgd) could be maintained at Luke for the low flow periods, thus confirming the yield estimate of the project authorization document. However, Bloomington Lake would be emptied quickly and would not be able to maintain a desirable minimum storage of 10,000 acre-feet for water quality purposes within the reservoir. Bloomington's contributions for meeting MWA water supply needs, although incidental, would be significant. By providing a continuous flow of 197 mgd, this reservoir regulation scheme allowed the downstream reservoirs to conserve more of their water supply storage (about 14,000 mg of downstream storage remaining) than with the existing reservoir management scheme as simulated in Run 1 (about 10,000 mg of downstream storage remaining). However, from a total regional point of view, the constant 197 mgd release scheme was quite inefficient, consuming more than 75 percent of the system's total storage capacity. In Run 1, which had the identical demand conditions, only one-third of the system storage was used to meet the MWA needs. Thus, the system, as a whole, would be less prepared to deal with more severe droughts under the constant 197 mgd release plan.

Water quality in the North Branch Potomac River would be adversely impacted as Savage Reservoir would not be able to maintain the desired release ratios.

EVALUATION OF PRISM/COE APPLICATIONS

The numerous PRISM/COE simulations performed in Phases I, II, and III accomplished several tasks. First, with the results of the PRISM/COE runs and several interrelated technical investigations, a base condition for the MWA Water Supply Study was formulated and tested for water supply capability. Secondly, the impacts of higher levels of flowby on the MWA regional water supply system were defined by the model simulations for various potential water supply conditions. Additionally, the PRISM/COE application enabled a detailed look at the water supply potential of reallocating Bloomington Lake's flood control and water quality storage. Several conclusions were derived from these investigations. These findings are detailed in the following sections.

ESTABLISHMENT OF THE BASE CONDITION

The PRISM/COE modelling provided several opportunities to test the effects of upstream management policies on the downstream (MWA) supply system. Based on these tests and concurrent water quality and fish and wildlife investigations, several upstream supply parameters were set. These supply conditions were then the basis for the overall MWA Water Supply Study analyses and the determination of the feasibility of Bloomington storage reallocation.

The Bloomington Lake project authorization document outlined an operational strategy which assumed a continuous target flow of 305 cfs (197 mgd) from the combined Bloomington-Savage system. The PRISM/COE applications confirmed that the upstream system could provide this amount throughout the 50 years of historical flow. However, the PRISM/COE modelling indicated that this type of reservoir regulation would completely deplete the entire Bloomington storage during severe low flow periods, and would also result in an inefficient use of the system storage from a water supply viewpoint. Therefore, other reservoir management strategies were investigated.

These investigations first concentrated on a minimum target flow for the upstream system. Water quality investigations, using results of the early PRISM/COE applications, determined that a minimum flow of 120 cfs (78 mgd) at Luke, Maryland, would be adequate to maintain acceptable water quality throughout the range of expected flow conditions in the North Branch Potomac River. The water quality basis for this selection is discussed in detail in Annex H-II of this appendix. The PRISM/COE simulations verified that the Bloomington water quality storage as allocated (51,000 acre-feet, 16,630 mg), the Savage Reservoir storage and the natural flow in the North Branch could easily provide this flow within the storage limits. Therefore, this target was specified for the base condition.

In addition, the extent of the pH problems in the North Branch warranted detailed consideration, so that Bloomington releases could be properly diluted by Savage Reservoir releases. To this end, PRISM/COE results were input to the water quality modelling, and a flow-dependent, seasonally varying dilution scheme devised to minimize the pH problems (this is further described in Annex H-II). This scheme was represented by a set of Bloomington-Savage release ratios, which were then included in the final PRISM/COE applications and the overall MWA supply base.

For the last piece in the upstream reservoir management strategy, regional management of the upstream and downstream reservoirs was examined in detail. The PRISM/COE modelling efforts revealed that much efficiency in the supply system could be gained by intelligent manipulation of the major reservoirs. This reservoir manipulation had several aspects - water quality, environmental, recreation, and water supply. These concerns were evaluated; subsequently, trade-offs between the major concerns were achieved to arrive at a reasonable management scheme. This eventual scheme was represented by the selection of 0.6 as a downstream target factor with conjunctive reservoir operations, with Bloomington water supply storage as allocated (41,000 acre-feet, 13,370 mg) to supplement the downstream MWA supply system as needed.

These three elements, the 120 cfs upstream target, dilution of Bloomington releases by Savage releases, and conjunctive reservoir operations, formed the upstream reservoir management strategy along with the regulation practices detailed in the Project Regulation Manual for minimum flow immediately downstream of the reservoirs (50 cfs for Bloomington and 20 cfs for Savage) and seasonal flood control operation. This management strategy that evolved from the PRISM/COE modelling and other technical efforts, was combined with the designated downstream supply and demand conditions (i.e. demands Conservation, Scenario 3 Little Seneca Lake, the existing reservoir capacities, 2030 monthly average demands, and 100 mgd flowby), to form the MWA study base. This base condition was simulated for the 50 years of historical flow record between October 1929 and September 1979. The simulation results indicated that existing MWA supply system with the additional storage in Little Seneca Lake would provide sufficient supply for the region's needs through the year 2030.

FLOWBY SENSITIVITY ANALYSIS

Since several environmental agencies had expressed concern about the assumed level of flowby (100 mgd), the sensitivity of the supply and demand balance of the MWA system to higher levels of flowby was evaluated using the PRISM/COE model. As noted above, the MWA system did not experience any deficits with the designated flowby level of 100 mgd. In addition, most of the system's storage (67 percent) was still available for use.

According to the PRISM/COE model, a policy of maintaining 300 mgd flowby caused water supply deficits in the MWA unless other sources of supply were developed, or Bloomington storage was reallocated. For 300 mgd flowby, the cumulative regional deficit was estimated to be about 2,100 mg for the 1930-31 drought. The maximum regional deficit was estimated to approach 100 mgd, and the system storage dipped to 16 percent of its capacity during this same drought sequence. In the other 49 years of simulated flow, the MWA did not experience any deficits under the 300 mgd scenario.

The water quality consequences of the 300 mgd flowby policy were insignificant. During the water supply release period, the pH in the North Branch Potomac River would increase slightly. This was due to the lower ratio of Bloomington flow to Savage flow at higher levels of flow, as set up by the reservoir management policy. The instream temperature would slightly decrease as would conductivity during the water supply release periods. These changes would only be noted during the infrequent drought events when water supply releases are required.

Simulations for the 500 mgd flowby scenario concluded that this would have a profound impact on the MWA water supply situation. Given a recurrence of the 1930-31 drought, the regional deficit amounted to 32,000 mg at the end of the drought, with a maximum weekly-deficit of greater than 350 mgd. Additionally, the regional storage had only 13 percent of its capacity remaining, and the Bloomington water supply, Savage, and Occoquan storages were completely depleted.

The 500 mgd flowby policy would affect the North Branch's water quality significantly during a rare low flow occurrence. The release of large volumes of Bloomington Lake storage would require proportional releases of Savage storage. During the extended drought period of 1930-31, the PRISM/COE simulations showed that Savage River Reservoir would exhaust its storge completely and would not be able to maintain the desired Bloomington-Savage release ratio. Without sufficient neutralization of the Bloominton releases, the pH in the North Branch would drop quickly once control of the system was lost. Prior to the emptying of Savage, the pH of the North Branch would be slightly increased due to the larger releases of flow, similar to to the 300-mgd scenario. Temperatures and conductivity would decrease slightly during the release period.

STORAGE REALLOCATION EFFECTS

The PRISM/COE modelling examined two levels of flood control storage reallocation and one level of water quality storage reallocation. For flood control storage reallocation, two pools, 1475 feet msl and 1484 feet msl, were considered. Reallocation of 5,000 acre-feet (1,630 mg) of water quality storage within the 1466 pool was also evaluated.

Water quality investigations determined that only 46,000 acre-feet (15,000 mg) would be needed to provide acceptable water quality in the North Branch Potomac River with a 1466 pool, therefore 5,000 acre-feet could be utilized for environmental flowby or water supply storage. PRISM/COE simulations with the reallocation of this water quality storage and the 300-mgd flowby policy indicated that the cumulative regional deficit in the 1930-31 drought sequence would be reduced from 2,100 mg to less than 800 mg. The maximum weekly deficit would decrease about 20 mgd to 67 mgd. For the 500 mgd flowby scenario, the reallocation of water quality storage would hardly affect the sizeable regional deficit for the 1930-31 drought. A deficit of 30,000 mg would remain. The reallocation of water quality storage would not require any modifications to the current project. Water quality impacts would not be significant.

Reallocation of 25 percent of the existing flood control (the 1475 pool) would be sufficient to eliminate the expected water supply deficit in the MWA in 2030 for the 300-mgd flowby scenario. For the 500-mgd scenario, 28,000 mg of deficit would still remain under the 1930-31 drought conditions. Reallocation of this storage would require modifications to the existing project facilities at an estimated cost of $1,540,000 (see Annex H-VII, Design Details and Cost Estimates for back-up data). In addition, it would slightly lower the degree of flood protection provided by the project by reducing the flood control benefits by 3 percent. The higher pool would have a slight impact on downstream water quality by providing less control of potential acid slugs.

Reallocation to the 1484 pool would reduce the existing flood control storage by 50 percent (18,100 acre-feet). The additional water supply storage would reduce the cumulative deficit with 500 mgd flowby to 24,600 mg, according to the PRISM/COE simulation. The maximum weekly deficit would still be above 350 mgd. To achieve this deficit reduction, modifications to the project at a cost of $2,447,000 would be necessary. The flood control benefits provided by the project would be reduced by 7 percent (see Annex H-IV for details). As for the 1475 pool, the 1484 pool would have a slight impact on downstream water quality.

ANNEX H-IV

FLOOD CONTROL ANALYSIS

BLOOMINGTON LAKE REFORMULATION STUDY
ANNEX H-IV - FLOOD CONTROL ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF PLATES

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H-IV

FLOOD CONTROL ANALYSIS

The purpose of Annex H-IV, Flood Control Analysis, is to investigate the hydrologic and economic feasibility of reallocating some flood control storage to water supply storage within the existing Bloomington Lake Project. The first part of this Annex describes the hydrology and hydraulic examinations including development of the Standard Project Flood (SPF), Probable Maximum Flood (PMF), flow-frequency curves for different gaging stations assuming higher permanent pool elevations, and the impacts of higher pool elevations on Kitzmiller, Maryland, a small community located upstream of Bloomington Lake. The second part of the Annex presents the results of the flood damage calculations. This section describes the efforts made in updating the original flood damage data which were collected in 1960 and used for the authorizing document as well as the collection of new flood damage data. Using the hydrologic data and the flood damage data, the degree of reduction in average annual flood control benefits for several project operation scenarios is then presented.

HYDROLOGIC AND HYDRAULIC EXAMINATIONS

INTRODUCTION

The recently completed Bloomington Lake Project was authorized by the Flood Control Act of 1962 (Public Law 874) for the purposes of flood control, water supply, water quality control, and recreation. The summer and winter pool elevations for Bloomington Lake are 1466 feet msl and 1410 feet msl, respectively, furnishing an additional 44,500 acre-feet of flood control storage during winter and early spring months. At elevation 1466 feet msl, the project storage provides 92,000 acre-feet of storage which includes 41,000 acre-feet for water supply and 51,000 acre-feet for water quality control. In addition, the project provides 36,200 acre-feet of storage capacity for flood control in the summer at maximum conservation pool.

One of the objectives of the Bloomington Lake Reformulation Study was to determine the feasibility of reallocating a portion of this available flood control storage (36,200 acre-feet) to water supply storage. The purpose of this section is to examine the effects of higher lake elevations on the flood control purpose of the Bloomington Lake Project.

For the hydrology and hydraulic analysis, ten different plans were developed, each assuming differing storage allocations and starting pool conditions. These plans are listed in Table H-IV-1. Elevation 1468 feet msl was selected, as it is the crest elevation of the gated spillway. The other elevations of 1475, 1484, and 1492 feet msl represent the reallocation of 25 percent, 50 percent, and 75 percent, respectively, of the available flood control storage and would place water against the existing tainter gates. The corresponding winter pool elevations for Plans 2 through 5 were selected to maintain approximately the same storage differential between summer and winter pools as in the existing plan (44,500 acre-feet). Plans 6 through 10 assumed a constant pool level throughout the year with no winter drawdown. Plate H-IV-1 shows the Rule Curve for

TABLE H-IV-1
FLOOD CONTROL PLANS

Plan Number	DESCRIPTION	WATER SUPPLY AND WATER QUALITY STORAGE (acre-feet) At Summer Pool	AVAILABLE FLOOD CONTROL STORAGE (acre-feet) Summer	Winter
1	Existing Plan, Summer Pool -1466, Winter Pool - 1410	92,000	36,200	80,700
2	Summer Pool - 1468, Winter Pool - 1413	93,900	34,300	78,800
3	Summer Pool - 1475, Winter Pool - 1423	100,800	27,400	71,900
4	Summer Pool - 1484, Winter Pool - 1436	110,200	18,000	62,500
5	Summer Pool - 1492, Winter Pool - 1447	119,000	9,200	53,700
6	1466 - All Year	92,000	36,200	36,200
7	1468 - All Year	93,900	34,300	34,300
8	1475 - All Year	100,800	27,400	27,400
9	1484 - All year	110,200	18,000	18,000
10	1492 - All Year	119,000	9,200	9,200

Plans 1 through 5. Because of the large number of figures in Annex H-IV, both the figures and the plates have been placed at the end of the Annex.

HYDROLOGIC MODEL

A hydrologic model using the HEC-1 computer program of the Corps of Engineers, Hydrologic Engineering Center, Davis, California, was adapted to simulate the rainfall-runoff characteristics of the North Branch Potomac River Basin from its headwaters to the USGS gaging station, North Branch Potomac River at Cumberland, Maryland (drainage area = 875 square miles). The river basin above Cumberland was divided into 13 sub-areas ranging in size from 32 square miles to 146 square miles (Plate H-IV-2). The hydrologic model determines runoff hydrographs for each sub-area, and routes and combines them in a logical, upstream to downstream sequence to develop hydrographs at key locations. The sub-area descriptions are given in Table H-IV-2, and Table H-IV-3 lists the USGS stream gages along with the period of record at each gage.

UNIT HYDROGRAPHS

One-hour unit hydrographs were developed using the HEC - 1 computer program's loss rate and unit hydrograph optimization routine for the following locations:

Sub-Area 1, North Branch Potomac River at Steyer, Maryland
Sub-Area 5, Savage River near Barton, Maryland
Sub-Area 8, Georges Creek at Franklin, Maryland
Sub-Area 9, New Creek at Keyser, West Virginia
Sub-Area 11, Wills Creek at Hyndman, Pennsylvania

Several unit hydrographs were computed from observed rainfall and runoff for each of the sub-areas. Representative values of Snyder's coefficients, t_p and C_p, were selected for each sub-area. These were adjusted, as necessary, to obtain the best reconstituted flood hydrographs. The unit hydrograph derivations for the sub-areas are shown on Figures H-IV-1 to H-IV-21.

Unit hydrographs for the remaining sub-areas were developed in accordance with EM 1110-2-1405, Flood-Hydrograph Analyses and Computations and Civil Works Investigations, Project 152, Unit Hydrographs, Part 1 - Principles and Determinations. Snyder's coefficients C_p and C_t were determined from the unit hydrographs previously derived. After determining the sub-area parameters L and L_{ca}, values of t_p could be calculated for each area. See Table H-IV-4 for sub-area unit hydrograph data.

HISTORICAL FLOOD RECONSTITUTION

THE HEC-1 hydrologic model for the North Branch Potomac River Basin above Cumberland, Maryland, was verified by reproducing three historical flood events: 15-17 October 1954, 17-19 August 1955, and 2-4 July 1978. These floods are the three largest floods of record at the Kitzmiller gage. The observed and reconstituted flood hydrographs at Kitzmiller, Luke, Pinto, and Cumberland are shown on Figures H-IV-22 to H-IV-33. Figure H-IV-34 shows the HEC - 1 model in flow chart form with the Muskingum k and x values.

TABLE H-IV-2

SUB-AREA DESCRIPTIONS*

Sub-Area 1 - North Branch Potomac River above the USGS stream gage at Steyer, Maryland (D.A. = 73 sq. mi).

Sub-Area 2 - Stony River above the USGS stream gage near Mt. Storm, West Virginia (D.A. = 48.8 sq. mi.).

Sub-Area 3 - North Branch Potomac River above the USGS stream gage at Kitzmiller, Maryland and below sub-areas 1 and 2 (D.A. = 103 sq. mi.).

Sub-Area 4 - North Branch Potomac River above the Bloomington damsite and below sub-area 3 (D.A. = 38 sq. mi.).

Sub-Area 5 - Savage River above the USGS stream gage on Savage River near Barton, Maryland (D.A. = 49.1 sq. mi.).

Sub-Area 6 - Savage River above the USGS stream gage below Savage River Dam and below sub-area 5 (D.A. = 56 sq. mi.).

Sub-Area 7 - North Branch Potomac River above USGS stream gage at Luke, Maryland and below sub-areas 4 and 6 (D.A. = 36 sq. mi.).

Sub-Area 8 - Georges Creek above the USGS stream gage at Franklin, Maryland (D.A. = 72.4 sq. mi.).

Sub-Area 9 - New Creek above the discontinued stream gaging station at Keyser, West Virginia (D.A. = 45.7 sq. mi.).

Sub-Area 10 - North Branch Potomac River above the USGS stream gage at Pinto, Maryland and below sub-areas 7, 8, and 9 (D.A. - 73.9 sq. mi.).

Sub-Area 11 - Wills Creek above the discontinued stream gaging station at Hyndman, Pennsylvania (D.A. = 146 sq. mi.).

Sub-Area 12 - Wills Creek above the USGS stream gage on Wills Creek at Cumberland, Maryland and below sub-area 11 (D.A. = 101 sq. mi.).

Sub-Area 13 - North Branch Potomac River above the USGS stream gage at Cumberland Maryland and below sub-areas 10 and 12 (D.A. = 32 sq. mi.).

*Table H-IV-3 lists the stream gages that provide data for this study. See Plate H-IV-2 for the location of sub-areas, stream gages, and precipitation gages.

TABLE H-IV-3

USGS STREAM GAGES

USGS GAGE NUMBER	LOCATION	PERIOD OF RECORD
01595000	North Branch Potomac River at Steyer, MD	1956 - present
01595200	Stony River near Mt. Storm, WV	1961 - present
01595500	North Branch Potomac River at Kitzmiller, MD	1949 - present
01595800	North Branch Potomac River at Barnum, MD	1966 - present
-	North Branch Potomac River at Bloomington, MD	1924 - 1927 1929 - 1950
01596500	Savage River near Barton, MD	1948 - present
01597500	Savage River below Savage River Dam	1948 - present
01598500	North Branch Potomac River at Luke, MD	1949 - present
01599000	Georges Creek at Franklin, MD	1929 - present
01599500	New Creek at Keyser, WV (discontinued)	1947 - 1963
01600000	North Branch Potomac River at Pinto, MD	1938 - present
01601000	Wills Creek at Hyndman, PA (discontinued)	1951 - 1967
01601500	Wills Creek at Cumberland, MD	1929 - present
01603000	North Branch Potomac River near Cumberland, MD	1929 - present

TABLE H-IV-4
UNIT HYDROGRAPH DATA

Sub-Area	1	2	3	4	5	6	7	8	9	10	11	12	13
D.A.	73	48.8	103	38	49.1	56	36	72.4	45.7	73.9	146	101	32
$(LL_{ca})^{.3}$	3.78	4.67	4.73	3.10	3.90	4.79	2.80	4.20	4.00	5.25	4.27	3.41	3.32
C_p	.55	.55	.50	.50	.65	.65	.50	.37	.65	.50	.37	.37	.50
C_t	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
t_p	6.00	5.82	5.9	3.95	5.20	5.97	3.58	5.33	5.00	6.50	5.30	4.31	4.20
Hour	0	0	0	0	0	0	0	0	0	0	0	0	0
1	259	186	344	336	306	253	411	222	319	192	453	528	236
2	955	696	1275	1225	1107	924	1496	833	1153	715	1693	1965	864
3	1909	1392	2566	2306	2158	1822	2660	1687	2242	1445	3431	3795	1661
4	2946	2126	3948	3055	3178	2773	3134	2529	3245	2267	5137	5201	2279
5	3812	2702	5062	3070	3851	3538	2835	3104	3828	3005	6297	5511	2422
6	4308	2987	5657	2608	4003	3930	2317	3234	3803	3501	6549	5056	2159
7	4329	2892	5560	2139	3553	3871	1894	3027	3229	3690	6122	4525	1805
8	3912	2544	4990	1755	2831	3383	1548	2766	2529	3503	5591	4050	1509
9	3376	2194	4397	1440	2238	2781	1265	2528	1980	3132	5107	3624	1262
10	2914	1892	3875	1181	1769	2286	1034	2309	1551	2797	4664	3244	1055
11	2515	1632	3415	969	1398	1879	845	2110	1214	2499	4259	2903	883
12	2171	1407	3009	795	1106	1545	691	1928	951	2232	3890	2598	738
13	1873	1214	2652	652	874	1270	565	1762	745	1994	3553	2325	617
14	1617	1047	2337	535	691	1044	461	1610	583	1781	3245	2081	516
15	1395	903	2060	439	546	858	377	1471	457	1591	2963	1863	431
16	1204	779	1815	360	432	705	308	1344	358	1421	2707	1667	361
17	1039	672	1600	295	341	580	252	1228	280	1270	2472	1492	302
18	897	579	1410	242	270	477	206	1122	219	1134	2258	1335	252
19	774	500	1242	199	213	392	168	1025	172	1013	2062	1195	211
20	668	431	1095	163	169	322	138	937	134	905	1883	1070	176
21	577	372	965	134	133	265	112	856	105	809	1720	957	147
22	498	320	850	110	105	218	92	782	82	722	1571	857	123
23	430	276	749	90	83	179	75	715	65	645	1434	767	103
24	371	238	660	74	66	147	61	653	51	576	1310	686	86
25	320	206	582	71	52	121	50	597	40	515	1197	614	72
26	276	177	513	50	41	99	41	545		460	1093	550	60
27	238	153	452	41		82	34	498		411	998	492	50
28	206	132	398	33		67	27	455		367	912	440	42
29	178	114	351	27		55	22	416		328	832	394	35
30	153	98	309	23		45		380		293	760	353	29

STANDARD PROJECT FLOODS (SPF)

Two SPF's were developed for this study, the SPF at Bloomington Lake and the SPF at Cumberland, Maryland. The Standard Project Storms (SPS) were developed in accordance with procedures described in EM 1110-2-1411. The SPS isohyetal patterns were situated over the basin to produce the most critical runoff hydrographs at Bloomington Lake and at Cumberland for the respective storms. Several SPS centerings were tried to determine the most critical location for each storm. Plate H-IV-3 shows the most critical pattern for the Bloomington Lake SPS and Plate H-IV-4, the Cumberland SPS pattern. Average sub-area rainfall was computed and then used as input to the HEC-1 model to compute the SPF. Loss rates of 1.0 inch initially and 0.05 inch per hour were considered reasonable for this area and were used in both SPF runoff computations. Table H-IV-5 gives the rainfall for each sub-area and Table H-IV-6 gives the peak SPF discharges at key locations on the North Branch Potomac River. Plate H-IV-5 shows the hydrograph for the SPS centered above Bloomington Lake. The flows in Table H-IV-6 reflect conditions without Bloomington Lake but include the effect of Savage River Dam. Flow reductions due to Bloomington Lake's flood control potential will be discussed in subsequent paragraphs.

PRELIMINARY RESERVOIR REGULATION PLAN

The hydrologic and hydraulic analysis was concerned primarily with the flood control purpose of the Bloomington Lake Project and the reservoir regulation plan developed to regulate this flood control storage. The drawdowns that might occur for other project purposes such as water quality and water supply have not been accounted for in these analyses for simplicity's sake, but are considered elsewhere in the report. For these analyses, the starting pool elevation was always assumed to be at the normal elevation shown on the appropriate rule curve (see Plate H-IV-1) in order to produce the largest effect on the project's flood control capability.

TABLE H-IV-5
SPS SUB-AREA RAINFALL

SUB-AREA	BLOOMINGTON LAKE SPS (Inches)	CUMBERLAND SPS (inches)
1	12.72	10.43
2	12.80	10.80
3	13.68	12.04
4	12.59	13.43
5	10.17	11.81
6	11.22	11.77
7	12.08	14.14
8	10.55	13.26
9	11.66	12.15
10	10.52	12.75
11	7.94	9.68
12	8.84	11.11
13	9.14	11.18

TABLE H-IV-6
SPF RUNOFF SUMMARY - PEAK DISCHARGES

	BLOOMINGTON LAKE SPF (CFS)	CUMBERLAND SPF (CFS)
Bloomington Lake	91,400	76,100
Luke	138,000	128,000
Pinto	168,000	168,000
Cumberland	188,000	195,000

The purpose of the reservoir regulation plan for flood control is to achieve the maximum reduction of the peak flood stages at key downstream population centers. The next paragraph describes the flood control reservoir regulation plan for Bloomington Lake that was assumed for this study.

As the inflow to Bloomington Lake increased, the discharge was increased to maintain the outflow equal to the inflow. When the flow at Luke reached 12,000 cfs, the outlet gages were closed. The gates remained closed until downstream conditions indicated that releases could be made. At that time, gradual releases were made so that the flow at Luke remained below 12,000 cfs until the lake returned to normal pool elevation. When the lake was at elevation 1,468 feet msl or greater, the reservoir regulation curves, Plate H-IV-6, were checked to see whether releases were required. These curves, which are a function of elevation and inflow, serve to reduce the maximum discharge by releasing smaller flows earlier in the flood event. If the maximum release required was greater than 12,000 cfs, that release was maintained as long as possible, with necessary reductions made to prevent secondary peaks downstream. The lake was drawndown from high pool elevations as quickly and safely as possible. When conditions permitted, the discharge was controlled to complete the drawdown by maintaining 12,000 cfs at Luke.

STORAGE FREQUENCY

Inflow hydrographs to Bloomington Lake for floods that occurred between 1924 and the present were computed or estimated from gage records and highwater marks. Each flood was routed through Bloomington Lake for each of the ten reformulation plans. Starting elevations were determined from the appropriate rule curve, see Plate H-IV-1. Reservoir routings for the October 1954, August 1955, July 1978 floods and the Bloomington Lake SPF are shown on Figures H-IV-35 to H-IV 39. Table H-IV-7 gives the maximum pool elevations for each flood and each reformulation plan. The maximum lake elevations were ranked for each plan and assigned Weibull's plotting positions based on 55 years of record. The resulting storage-frequency curves are shown on Figures H-IV-40 and H-IV-41.

PROBABLE MAXIMUM FLOOD (PMF)

The PMF presented in this study is that developed for the Bloomington Reservoir, Design Memorandum No. 2, Hydrology and Hydraulic Analysis, February 1965. The PMF has a probable maximum precipitation (PMP) of 22.2 inches and the peak inflow to Bloomington Lake is 227,000 cfs. The Bloomington Lake PMP based on Hydrometeorological Report (HMR) No. 51 (Probable Maximum Precipitation Estimates, United States East of the 105th Meridian) is 25.6 inches, and would likely produce a greater PMF peak than the 227,000 cfs previously determined. The PMF was not revised as HMR No. 52, which is

TABLE H-IV-7
BLOOMINGTON LAKE, MAXIMUM POOL ELEVATIONS (MSL)

FLOOD	PLAN NUMBER* 1	2	3	4	5	6	7	8	9	10
July 1978	1483.44	1485.23	1491.51	1497.04	1498.86	1483.44	1485.23	1491.51	1497.04	1498.86
March 1967	1469.39	1472.15	1476.66	1487.08	1495.33	1478.77	1480.61	1487.08	1494.93	1498.09
March 1963	1467.99	1470.78	1474.75	1484.85	1494.27	1477.90	1479.75	1486.25	1494.64	1498.17
August 1956	1472.99	1474.90	1481.60	1490.24	1497.05	1472.99	1474.90	1481.60	1490.24	1497.05
August 1955	1494.92	1495.71	1497.68	1499.31	1500.90	1494.92	1495.71	1497.68	1499.31	1500.90
October 1954	1494.01	1494.85	1497.78	1499.55	1501.16	1496.54	1497.25	1499.17	1500.45	1502.11
October 1942	1468.11	1469.94	1476.34	1485.73	1493.32	1472.89	1474.80	1481.51	1490.16	1496.83
October 1937	1484.06	1485.49	1491.84	1497.54	1500.06	1493.32	1494.52	1497.88	1500.59	1501.08
March 1936	1480.11	1482.46	1486.76	1495.70	1498.83	1486.41	1488.16	1493.98	1498.25	1500.21
March 1924	1490.93	1492.34	1495.51	1499.56	1501.15	1492.14	1493.46	1496.63	1500.24	1501.43
Bloomington Lake SPF	1505.85	1505.87	1506.27	1506.77	1506.92	1505.85	1505.87	1506.27	1506.77	1506.92
Cumberland, MD SPF	1504.36	1504.54	1505.13	1505.79	1506.03	1504.36	1504.54	1505.13	1505.79	1506.03
PMF	1509.19	1509.40	1510.19	1510.85	1511.36	1509.19	1509.40	1510.19	1510.85	1511.36

* See Table H-IV-1 for description of flood control plans.

designed to provide further guidance for estimating PMF, is still in the review stage. It should be noted that if the spillway is modified for providing higher permanent pool or for any other reason, a revised PMF may be required.

The PMF was routed through Bloomington Lake five days after the SPF for each of the ten reformulation plans assuming either summer pool or year round pool elevations for starting conditions. For all plans, Bloomington Lake returned to the starting pool elevations following the SPF, but prior to the start of the PMF. Figure H-IV-42 shows the PMF reservoir routing results for Plans 1 and 6. The PMF routing results for all plans are summarized in Table H-IV-8.

For Plan 1 (the authorized plan), the maximum pool elevation achieved by routing the PMF through Bloomington Lake was elevation 1508.9 feet msl according to DM No. 2. The current routing shows a maximum elevation of 1509.19 feet msl for Plan 1, yielding slightly less than five feet of freeboard to the top of dam (elevation 1514 feet msl). This difference is explained by the fact that in the DM No. 2 PMF reservoir routing, the outlet gates were never closed and a constant discharge of 15,000 cfs was maintained through the outlet works. For this study, the outlet gates were assumed to be closed when flood stage was first exceeded downstream. During an actual flood event, the knowledge that a PMF was about to occur could not have been forseen. Therefore, for this study, a more realistic reservoir regulation procedure was followed, accounting for the slightly higher maximum pool elevation.

PEAK FLOW FREQUENCY CURVES

EXISTING CONDITION

Frequency curves of maximum annual flows were determined for the stream gaging stations on the North Branch Potomac River shown in Table H-IV-9.

The frequency curves were developed in accordance with the procedures described in Water Resources Council Bulletin 17, Guidelines for Determining Flood Flow Frequency, by using the Hydrologic Engineering Center's (HEC) computer program HECWRC. To make the peak flow data homogeneous, the period of record at Luke, Pinto, and Cumberland, prior to the completion of Savage River Dam in January 1952, was adjusted to reflect actual operation of Savage River Dam. The Savage River Dam rule curve was used to determine the available flood control storage when the annual peaks occurred. If Savage River Dam's rule curve indicated that the lake was at or near spillway crest (approximately May to August), no adjustment was made in the downstream peak flows. If there would have been flood control storage available, the annual peaks downstream were reduced up to 25 percent to account for this storage. The existing condition frequency curves account for the effect of Savage River Dam and are shown on Figures H-IV-43 to H-IV-46.

Generalized skew values were taken from Figure 23 of the NAD Hydrologic Study, Tropical Storm Agnes Report, December 1975. The computer program, HECWRC, weighted the generalized skew with the computed station skews, based on the number of years of record, to determine the adopted skew coefficients used to compute the frequency curves (See Table H-IV-10).

TABLE H-IV-8
PMF ROUTING
DATA SUMMARY

PLAN	YEAR ROUND OR SUMMER POOL ELEVATION (feet msl)	PEAK INFLOW (cfs)	PEAK DISCHARGE (cfs)	PEAK ELEVATION (feet msl)	FREEBOARD (feet)
1 & 6	1466.0	227,000	194,000	1509.19	4.81
2 & 7	1468.0	227,000	194,000	1509.40	4.60
3 & 8	1475.0	227,000	195,100	1510.19	3.81
4 & 9	1484.0	227,000	202,500	1510.85	3.15
5 & 10	1492.0	227,000	204,100	1511.36	2.64

TABLE H-IV-9
STREAM GAGES FOR WHICH FREQUENCY CURVES WERE DEVELOPED

LOCATION	USGS STREAM GAGE NUMBER	DRAINAGE AREA
Kitzmiller, Maryland	01595500	225 square miles
Luke, Maryland	01598500	404 square miles
Pinto, Maryland	01600000	596 square miles
Cumberland, Maryland	01603000	875 square miles

TABLE H-IV-10
SKEW COEFFICIENTS

STREAM GAGE LOCATION	PERIOD OF RECORD	YEARS OF RECORD	GENERALIZED SKEW	COMPUTED STATION SKEW	ADOPTED WEIGHTED SKEW
Kitzmiller	1950-1978	29	0.50	1.14	0.70
Luke	1950-1979	30	0.50	1.04	0.50
Pinto	1936-1979	44	0.50	0.42	0.50
Cumberland	1930-1979	50	0.50	0.66	0.60

The holdout that resulted from the Bloomington Lake reservoir routings was routed downstream to Luke, Pinto, and Cumberland using Muskingum routing coefficients. The routed holdout hydrographs for each plan were subtracted from or added to (depending on positive or negative holdouts) the observed or existing condition (without Bloomington Lake) hydrographs to produce the regulated hydrographs at each location. Figures H-IV-47 to H-IV-64 show the flood hydrographs as affected by flood control regulation of Bloomington Lake for the following floods.

October 1954
August 1955
July 1978
Bloomington Lake SPF
Cumberland SPF

Bloomington Lake was under construction at the time of the July 1978 flood and a small diversion cofferdam was overtopped and failed. The secondary peaks resulting from the failure are distinctly seen on the Luke and Pinto observed hydrographs (Figures H-IV-56 and H-IV-57). For this study, the hydrographs used at Luke and Pinto are those indicated by the dotted lines. No adjustment was made to account for the small volume temporarily stored behind the Bloomington cofferdam. The Cumberland hydrograph was not adjusted because the surge, caused by the dike failure, had diminished by the time the flood reached Cumberland.

EFFECT OF FLOOD CONTROL STORAGE REALLOCATION

The regulated hydrograph peak flows obtained by methods previously described were plotted on the existing condition frequency curves at the frequencies of the observed flood peaks at Luke, Pinto, and Cumberland. Curves were drawn through these points to determine peak flow frequency curves which include the effect of Bloomington Lake. Peak flow frequency curves that include the effect of Bloomington Lake were then developed for all ten reformulation plans. The resulting frequency curves are shown on Figures H-IV-65 to H-IV-70. These curves show that the effect of the reformulation Plans 1 through 4 and 5 through 9 are relatively minor. Plans 5 and 10, however, could have significant consequences on the degree of flood control protection at Luke and Pinto.

EFFECT OF FLOOD STORAGE REALLOCATION AT KITZMILER, MARYLAND

Kitzmiller, Maryland, is located on the North Branch Potomac River, approximately eight miles upstream from the Bloomington Lake damsite. This section addresses the concern that raising the Bloomington Lake normal pool elevation could cause increased water surface elevations at Kitzmiller during floods. Kitzmiller is the closest damage center upstream from Bloomington Lake. The Kitzmiller Local Flood Protection Project, built by the Corps of Engineers, was completed in 1964 and consists of 5,800 feet of levee, 30 feet of retaining wall, and 4,700 feet of channel improvement. The project protects Kitzmiller, Maryland, on the left bank of the North Branch Potomac River and Blaine, West Virginia, on the right bank against a design flood of 52,000 cfs. This is a flood that has about 0.17 percent chance of occurrence in any year.

To determine the impact of raising the normal elevation of Bloomington Lake on the level of flooding from Bloomington Lake, upstream to Kitzmiller, a series of water surface profiles were computed. The computer program, HEC-2, Water Surface Profiles, was used for these computations. Seventeen cross-sections were obtained from 5-foot contour Topographic Survey Sheets 1, 2, and 3 of 16, Bloomington Reservoir Project. The USGS gage, No. 01595500, North Branch Potomac River at Kitzmiller, is located 0.6 mile downstream from the State Highway 38 bridge. The hydraulic model was calibrated by comparing computed water surface elevations with the USGS rating at the gage. Table H-IV-11 shows the calibration results. Manning's "n" values vary from 0.03 to 0.065 for the channel and from 0.07 to 0.09 in the overbank areas.

Eight different flows, 20,000, 30,000, 40,000, 60,000, 80,000, 93,000, 150,000 and 227,000 cfs were analyzed. Using the slope-area method to determine a starting water surface elevation, each flow was run to simulate natural streamflow conditions. Each flow was also run assuming starting elevations 1480, 1490, 1500, and 1510 feet msl to simulate a range of Bloomington Lake elevations. The elevation of any reasonable combination of flood flow and Bloomington Lake elevation could be interpolated from the computed water surface profiles at any location along the reach of river from Bloomington Lake to the Kitzmiller gage. Plate H-IV-6 shows the water surface profiles for two discharges, 60,000 cfs and 227,000 cfs for all starting conditions. None of the flow-starting elevation combinations, including the most severe case, 227000 cfs and starting elevation 1510.0, had any effect on the water surface elevation at Kitzmiller. The elevation of the stream bed at the Kitzmiller gage is 1574 feet msl and at the damsite 1220 feet msl which is a stream slope of about 44 feet per mile or 8 percent. For very large flows (SPF, PMF, etc.) the relocated railroad bridge controls the water surface elevations upstream. The most upstream point that is affected by higher reservoir elevations is approximately two miles downstream from the Kitzmiller gage. There will be no effect to any upstream damage center resulting from raising Bloomington Lake normal pool elevations.

EFFECTS OF HIGHER POOL LEVEL ON PROJECT STRUCTURES

Raising the normal pool elevation of the Bloomington Lake, as a result of flood control storage reallocation, could have other effects besides the reduction of freeboard for the PMF and reducing the degree of downstream flood protection. More frequent and higher discharges would occur over the gated spillway. This causes increased concern about possible erosion at the toe of the dike to the left of the spillway. Also, at the higher pool elevations it would become more difficult to regulate the reservoir for flood control. While trying to prevent the lake from overtopping the tainter gates (elevation 1500 feet msl) with a reasonable factor of safety, it would be possible to increase downstream flooding over what would have occurred under natural conditions.

ADDITIONAL HYDROLOGIC AND HYDRAULIC EXAMINATIONS

As mentioned elsewhere in this report, a progress report for the Bloomington Lake Reformulation Study was prepared in November 1980 and was circulated for review and comment. One comment suggested that the reliability of the HEC-1 model in terms of the entire North Branch Basin would be enhanced by reconstruction of floods of record at Cumberland, Maryland, as well as Kitzmiller, Maryland. In response to this comment, additional hydrologic and hydraulic examinations were made to determine impact of reconstructed floods using data from gage at Cumberland, Maryland. The following paragraph describe these additional examinations.

TABLE H-IV-11
HYDRAULIC MODEL CALIBRATION RESULTS

DISCHARGE (cfs)	DATE OF OCCURRENCE	GAGE HEIGHT (feet)	OBSERVED ELEVATION (feet msl)	COMPUTED ELEVATION (feet msl)	ERROR (feet)
6,000	8 Nov 78	7.61	1579.87	1579.43	.44
8,910	9 Oct 77	8.20	1580.46	1580.52	-.06
17,900	3 Jul 78	10.78	1583.04	1583.04	.00
33.400	15 Oct 54	13.73	1585.99	1586.07	-.08

The March 1936 flood has been reconstructed using the HEC-1 computer program employing the same procedure as used for original examinations. Rainfall distribution was determined using actual six-hour rainfall data from the gage at Cumberland, Maryland. Total rainfall amounts for each sub-area were approximated by averaging actual data from several rain gaging stations throughout the basin using the Thiessen polygon method. Precipitation amounts for sub-areas are included in Table H-IV-12. The observed and reconstituted hydrographs for Cumberland, Maryland, are shown in Figures H-IV-71 and H-IV-72.

TABLE H-IV-12
SUB-AREA RAINFALL AMOUNTS
(RECONSTRUCTED MARCH 1936 FLOOD)

SUB-AREA	RAINFALL (inches)
1	3.91
2	4.02
3	4.57
4	6.70
5	5.40
6	4.90
7	5.50
8	5.30
9	6.70
10	5.60
11	5.40
12	5.46
13	5.40

Using data obtained from the HEC-1 model, the reconstructed flood was routed through the Bloomington Lake using an in-house reservoir routing program. The flood was routed for each of the ten reformulation plans (Table H-IV-1) with starting elevations determined from the appropriate rule curve. Maximum pool elevations for each plan are included in Table H-IV-13. Reservoir hydrographs are shown on Figures H-IV-73 and H-IV-74.

TABLE H-IV-13
MAXIMUM LAKE ELEVATIONS
(RECONSTRUCTED MARCH 1936 FLOOD)

PLAN	STARTING ELEVATION (feet msl)	MAXIMUM ELEVATION (feet msl)
1	1461.00	1487.65
2	1463.00	1489.34
3	1469.00	1494.00
4	1479.00	1497.56
5	1488.00	1499.28
6	1466.00	1491.71
7	1468.00	1493.14
8	1475.00	1496.56
9	1484.00	1498.79
10	1492.00	1500.17

The holdout that resulted from the Bloomington Lake Reservoir routings was routed downstream to Cumberland using an in-house river routing program. The routed holdout hydrograph for each plan was substracted from the computed hydrographs to produce the regulated hydrograph at Cumberland, Maryland. These hydrographs are shown on Figures H-IV-75 and H-IV-76.

FLOOD DAMAGE ESTIMATES

Flood control benefits are customarily calculated as the difference in annual flood damages with and without a project. Because the current Bloomington Lake Reformulation Study may result in a decrease in the expected flood control benefits, it was necessary to determine any difference in benefits that would be attributable to reduced flood control storage. The intent of the following sections is to provide a general discussion of the methodology for evaluating the flood control effects of various conservation pools in Bloomington Lake, and to present the results of the analysis in terms of average annual benefits foregone.

FLOOD IMPACT AREA

The initial Bloomington Lake economic analysis considered flood damage reduction benefits in the North Branch only, from the damsite downstream to the junction with the South Branch. This evaluation was therefore limited to those same reaches (see Figure H-IV-77). In addition, preliminary hydrologic and hydraulic analyses indicated that none of the pool levels under consideration would have an adverse effect on flood potential upstream from the reservoir. The nearest damage center is Kitzmiller, Maryland, located about 8 miles above the damsite. The most severe change in flood control storage (meaning a higher permanent pool) would reach only 6 miles upstream, thus precluding a need for an impact analysis in this area.

DETERMINATION OF AVERAGE ANNUAL DAMAGES

Average annual damages are an economic tool used by the Corps of Engineers and other Federal agencies having water resources development responsibilities to evaluate the relative seriousness of flood problems. They also are used to compare the cost of flood reduction measures against the reduced damages (benefits) that would be expected from a project. Because this reformulation study evaluated the effects of reducing the existing flood control storage in the reservoir, the net result would be flood control benefits potentially "lost" or "foregone." Thus, the objective of the analysis was to estimate the "foregone" flood control benefits caused by reducing flood control storage in the project.

Average annual damages for a river reach or community are calculated by combining the stage-damage curve for that area with the stage-discharge and discharge-frequency curves for a nearby stream gaging station or index point. Having developed these three curves, a fourth curve can be derived which relates damage (dollars) to frequency of occurrence in any one year. Figure H-IV-78 shows the typical interrelationship of the four curves. The damage-frequency curve is integrated mathematically to arrive at the average annual damages which are represented as the area under the curve. Because the scale of frequencies is 100 percent, or unity, the mean ordinate of the damage-frequency curve is also numerically equivalent to the area under the curve (or the average annual damages).

For the Bloomington Lake Reformulation Study, the stage-discharge and stage-damage curves remain the same with or without storage reallocation. However, the discharge-frequency curve may be modified slightly, and this modification would affect the damage-frequency curve as well. Figure H-IV-79 displays, in conceptual form, the possible effect of a reduction in reservoir storage for flood control. The discharge-frequency curve may show an increase in discharge for a given frequency of occurrence, and the damage-frequency curve would show a corresponding increase in damage for the same given frequency of occurrence. The area between the original and modified damage-frequency curves would represent the change in average annual damages resulting from reservoir storage reallocation, or, in different words, the foregone average annual benefit of the lost flood control storage.

FLOOD DAMAGE SURVEYS

A key component required in the flood benefit analysis was an estimate of flood damages that could be expected for various flood stages. These flood stage versus dollar damage relationships were prepared for each major community and for segments of the river referred to as "reaches."

As the last flood damage survey in this portion of the Potomac River Basin had been conducted about 25 years ago, it was decided to do a completely new survey and reinventory the current floodplain development. This would take into account the recent growth and/or changes in use and provide an updated basis for compiling project benefits following future flood events.

Flood damage surveys to collect the necessary information normally are conducted in the following manner. Mapping for the area and historical data on the extent and heights of past flood events are collected. An inventory is made of the development in the floodplain up to several feet above the largest known flood. Properties are classified in one of the categories discussed below. Additional parameters such as size, condition, floor elevation, and business use are recorded. For residential and most commercial strucutres, generalized damage estimates are prepared based upon empirical data collected from various sources such as individual interviews and past flood reports prepared by other agencies and organizations. To obtain data on industrial, large commercial, public properties, and public utility facilities, individual interviews are usually conducted with owners or managers. In the few instances where current data are not available, information collected after recent floods, together with estimates used in previous reports are adjusted to current price levels and included in the damage summary. Using this compiled data, stage-damage relationships are developed for each river reach and each community. For the Bloomington Lake Reformulation Study, the field survey included all properties up to the largest flood of record plus an additional 8 feet. Upstream from Pinto the March 1924 flood is the flood of record while downstream the March 1936 flood is the largest of record.

Classification of Flood Damages

Flood damages are broadly classified as tangible damages (those that can be estimated in monetary terms) and intangible damages. Intangible flood damages are those detrimental effects of floods that cannot be given market or monetary values. These include loss of human life, health, security, and good will by business establishments. Tangible flood damages are classed as physical damage, emergency costs, and business losses, and include both recurring and non-recurring damages. The latter are those losses which are not likely to recur for various reasons, such as destruction and non-replacement or replacement in such manner as to avoid or minimize further damages. Various types of recurring damages are discussed below.

Physical damage includes the cost of clean-up following a flood, damages to buildings and other property, and damages to building contents including furnishings, equipment, decorations, materials in stock and in process, and completed products. Emergency costs include the costs of evacuation and reoccupation, flood fighting, disaster relief, increased expense of normal operations during a flood, increased costs of police, fire, or military patrol, and abnormal wear and tear on alternative routes of traffic. Business loses include fixed operating costs, non-productive labor costs, employee wage losses, and net profit loss which is not compensated for by postponed sales or alternate sales by competition. Each of these three categories of tangible recurring damages - physical, emergency, and business - are applied to the following types of properties:

1. Residential;
2. Commercial;
3. Industrial production (mining & manufacturing);
4. Public properties and services;
5. Transportation facilities;
6. Communications and utilities;
7. Relief and public health services;
8. Agricultural.

Flood Survey Results

Using the method just presented, current stage-damage data were compiled for Luke and Westernport, Maryland; for Piedmont and Keyser, West Virginia; for the protected portions of Cumberland, Maryland - Ridgley, West Virginia; and for the floodplain areas along the North Branch Potomac River from Savage River downstream to the South Branch Potomac River junction.

The stage-damage relationship for the North Branch between the mouth of the Savage River and Cumberland, Maryland, is shown as a sample in Table H-IV-14. This information was then used to develop a stage-damage curve which is typically represented in Quadrant I of Figure H-IV-78.

STAGE-DISCHARGE

Quadrant II in Figure H-IV-78 represents a typical stage-discharge relationship. This curve relates the amount, or volume, of discharge to the stage or height of a flood occurrence. Data used in the development of this relationship are based on historical stream gage records maintained by the United States Geological Survey. A sample of the data used in determining the curve is presented in Table H-IV-15 for the stream gage at Pinto, Maryland. The stream gage is the reference point for the stage-damage data collected for the North Branch Potomac River reach between the Savage River and Cumberland, Maryland. A mathematical relationship is then developed between the reference elevations in Table H-IV-14 and the gage heights in Table H-IV-15 to relate all elevations to the river stage.

DISCHARGE-FREQUENCY

Reservoir flood control effectiveness is generally reflected in the frequency or probability of occurrence of floods at downstream gaging stations. Quadrant III of Figure H-IV-78 shows a typical discharge-frequency curve, and Figure H-IV-79 displays the effects of storage reallocation in a flood control reservoir.

For the Bloomington Lake Reformulation Study, recorded or historical flood flows were first routed through the project assuming different starting lake elevations. Peak flows were then computed at downstream gaging stations for each flood and lake elevation, as modified by Bloomington Lake's available flood control storage. A discharge-frequency curve was then developed showing the relationship between flooding and probability of occurrence at each of the downstream gages. As samples, Figures H-IV-80 and H-IV-81 show the discharge-frequency curve for the stream gage at Pinto, Maryland (reference gage for Tables H-IV-14 and H-IV-15). The upper line shows the discharge-frequency curve for the "without Bloomington" condition with only the Savage River Reservoir in place. The lower series of lines shows a family of modified discharge-frequency curves, but now accounting for different volumes of flood control storage in Blomington Lake. It is apparent from the relative positions of these curves that Plans 2, 3, 6, and 7 have no measurable impact at Pinto since they are equal to Plan 1 which represents the existing plan. Plans 4, 5, 8, 9, and 10, which represent progressively greater reductions in flood control storage, move closer to the without project curve. Detailed information concerning the development of discharge-frequency curves, as well as the actual curves which were prepared for the Luke, Pinto, and Cumberland gages, were presented in the previous section titled "Hydrology and Hydraulics Examinations."

TABLE H-IV-14
STAGE-DAMAGE RELATIONSHIP FOR POTOMAC RIVER REACH
BETWEEN SAVAGE RIVER AND CUMBERLAND, MD
($1000 at April 1980 price levels)

Damage Category	Elevation (feet) referenced to March 1924 Flood															
	-13	-12	-10	-8	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Residential	0	5	18	36	59	77	98	128	161	196	233	267	303	339	369	401
Commercial				0	28	77	687	1505	2184	2827	3424	3847	4086	4235	4291	4400
Industrial			0	70	396	557	871	1296	1734	2187	4703	6067	9795	15795	21687	27666
Public						NONE										
Transportation				0	11	15	178	398	523	657	749	941	1342	2251	2730	2957
Utilities				0	1	2	4	6	7	40	122	222	339	468	600	695
Pubic Health	Included in the residential estimate above															
TOTAL	0	5	18	106	495	728	1836	3333	4609	5907	9874	11344	15865	23088	29677	36119

TABLE H-IV-15
EXPANDED RATING TABLE,
USGS GAGE AT PINTO, MARYLAND

GAGE HEIGHT (GH) IN FEET	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) .0	.1	.2	.3	.4	.5	.6	.7	.8	.9	DIFF IN DISCHARGE PER FOOT GH
1.00								82.0	106.0	130.8	
2.00	154.0	178.0	207.0	236.0	268.8	302.0	340.5	380.0	420.0	470.2	368.1
3.00	522.2	576.1	631.8	689.3	748.4	809.2	871.6	935.5	1001	1068	613
4.00	1136	1206	1278	1350	1425	1500	1575	1651	1728	1807	750
5.00	1886	1967	2048	2131	2215	2300	2391	2483	2577	2671	881
6.00	2767	2864	2963	3062	3163	3265	3372	3481	3590	3701	1047
7.00	3814	3927	4042	4159	4276	4395	4515	4636	4759	4882	1193
8.00	5007	5133	5261	5389	5519	5650	5779	5910	6042	6174	1301
9.00	6308	6443	6579	6716	6854	6993	7133	7274	7416	7560	1396
10.00	7704	7849	7995	8142	8291	8440	8589	8739	8890	9042	1491
11.00	9195	9349	9504	9659	9816	9974	10130	10290	10450	10610	1585
12.00	10780	10940	11100	11270	11430	11600	11760	11920	12080	12240	1620
13.00	12400	12560	12720	12880	13050	13210	13370	13540	13710	13870	1640
14.00	14040	14210	14380	14550	14720	14890	15060	15230	15400	15580	1710
15.00	15750	15920	16100								

DAMAGE-FREQUENCY

When data from these modified discharge-frequency curves were combined with stage-damage estimates and stage-discharge relationships, a damage-frequency relationship was developed for each reach as shown in Quadrant IV of Figure H-IV-79. It is from these data that average annual damages are determined.

A sample calculation of the average annual damages without Bloomington Lake is provided in Table H-IV-16. The gage height and discharge data in columns 1 and 2, respectively, are taken from Table H-IV-15. The stage data in column 3 for the 1924 flood are taken from Table H-IV-14 as are the damage data in column 7. The frequency data in column 5 are derived from Figure H-IV-80, and the frequency interval in column 6 is calculated along with the average damages for each interval in column 8. Column 6 is then multiplied by column 8 to arrive at the average annual damage for each interval as shown in column 9. By adding all of the intervals, the average annual damage of $556,630 associated with the pre-Bloomington conditions for the river reach is computed in column 10. The summation of the average annual damages for all reaches then provides an estimate of the total average annual damages.

In the normal case of a proposed new reservoir, the predicted average annual damage without a reservoir minus the predicted average annual damage with the reservoir in operation represents the damages prevented by the reservoir. The difference in average annual damages between the "with" and "without condition" is, therefore, a measure of the average annual benefit furnished by the reservoir. In the case of the Bloomington Lake Reformulation Study, the "without condition" is represented by Plan No. 1, the present plan of operation, and the "with condition" is a higher lake elevation associated with water supply storage. Because some of the benefits initially provided by the existing reservoir may be lost with the higher lakes, some portion of the average annual benefits may be reduced or "foregone." The following section estimates these foregone flood control benefits.

ESTIMATE OF FOREGONE FLOOD CONTROL BENEFITS

The benefits normally credited to a flood control project consists primarily of flood damages prevented to existing development. In addition, there may be added to this an amount that is attributable to future floodplain development. Future conditions benefits were excluded from the analysis for the Bloomington Lake Reformulation Study for the following reason. The political subdivisions where the measurable impact of reallocated flood control storage would be felt, namely the towns of Westernport, Piedmont and Keyser, and all of Allegany County, Maryland, along the North Branch of the Potomac River, are enrolled in the Federal flood insurance program. They, thus, have floodplain regulations in effect which should prevent significant future increase in the damage base. Under the flood insurance program guidelines, any new development permitted within the 100-year flood zone would not appreciably change the averge annual damage potential for these areas. Therefore, the minimal amount of benefits to be evaluated could not justify the effort required to collect data, to analyze future trends, and to compute this additional impact. The effects of storage reallocation on the agricultural property classification were not investigated. Previous studies determined that there is a relatively small damage potential associated with flooding of agricultural areas. Less than 2 percent was identified in the initial project benefit analysis.

TABLE H-IV-16

SAMPLE OF AVERAGE ANNUAL DAMAGE CALCULATION

CALCULATION OF AVERAGE ANNUAL DAMAGES	BASIN: POTOMAC	REACH: RURAL	LT. RT. BANK
	TRIBUTARY: NORTH BRANCH	UPSTREAM LIMIT OF REACH: SAVAGE RIVER	
TYPE OF DAMAGE	STREAM	DOWNSTREAM LIMIT OF REACH: CUMBERLAND, MARYLAND	

PRICE LEVEL OF	CONDITIONS OF	REFERENCE GAGE OR POINT	DRAINAGE AREA	COMPUTED BY	DATE	CHECKED BY	DATE
APRIL 80	1980	PINTO, MARYLAND	596 SQ.MI.				

GAGE ~~FLOOD~~ HEIGHT (1)	(1000) DISCHARGE (cfs) (2)	STAGE (Ft.) RF (3)	STAGE (Ft.) MSL (4)	FREQUENCY % (5)	FREQUENCY Interval (6)	DAMAGES (1000) (Dollars) At Stage (7)	DAMAGES Average (8)	AVE. ANNUAL DAMAGES Interval (9)	AVE. ANNUAL DAMAGES Summation (10)
12	11.0	-12		66	0.2	5	11.5	2300	2300
14	14.0	-10		46	.09	18	30.5	2740	5040
15	15.7	-9		37	.07	43	74	5180	10220
16	17.3	-8		30	.07	106	188	13160	23380
17	19.2	-7		23	.05	271	383	19150	42530
18	21.2	-6		18	0.045	495	612	27540	70070
19	23.6	-5		13.5	.045	728	1283	57740	127810
20	26.6	-4		9	.033	1838	2586	85340	213150
21	31.0	-3		5.7	.027	3333	3971	107220	320370
22	38.0	-2		3.0	.016	4609	5258	84130	404500
23	47.0	-1		1.4	.006	5907	7890	47340	451840
24	55.0	1924	672.2	0.8	.003	9873	10608	31820	483660
25	63.0	+1		0.5	.0022	11344	13604	29930	513590
26	72.0	+2		0.28	.0009	15865	19476	17530	531120
27	80.0	+3		0.19	.0006	23088	26382	15830	546950
28	88.0	+4		0.13	.0003	29677	32254	9680	556630
28.8	96.0	+4.8		0.10		34830			

REMARKS:
PINTO RATING CURVE AND FREQUENCY CURVE WITHOUT BLOOMINGTON HAVE BEEN USED FOR THESE CALCULATIONS

WITHOUT BLOOMINGTON AA DAMAGES = $ 556.6
RESIDUAL DAMAGES WITH PLAN I − 54.2
BENEFIT TO PLAN I (April 80 prices) 502.4
update to oct. 81 Prices × 1.13
567

NAD Form 797
Sept 75

The flood damage analysis included those areas along the North Branch Potomac River between the junction of the Savage River and the junction of the South Branch Potomac River (see Figure H-IV-77). It included the communities of Luke and Westernport, Maryland and Piedmont, West Virginia, (sometimes referred to as the tritown area) all of which have some limited flood protection provided by floodwalls. Because they are protected from low to moderate flood levels they are not sensitive to the smaller reductions in flood control storage at Bloomington Lake. The USGS gage at Luke, Maryland, is the point of reference for this area.

Keyser, West Virginia and the rural area between Westernport and Cumberland, Maryland, were evaluated independently. The point of refrence for these areas was the USGS gage at Pinto, Maryland. In Keyser, low to moderate flood levels affect mostly residential properties. However, flood stages near or above the 1924 flood of record would cause damage to commercial, industrial and public properties as well. Within the rural reach a significant portion of the damage potential is to industrial property. Moderate flood heights will affect the Allegany Balistics Laboratory near Pinto, Maryland and the Allegany County Industrial Park located several miles above Cumberland as well as some residences and transportation facilities. Due to some local protection works, the Celanese Fibers Plant and Kelley Springfield Tire complex are not affected until river stages approach the flood of record levels.

Cumberland, Maryland - Ridgely, West Virginia, are protected by the Corps of Engineers local flood protection project that was completed in 1959 and which provides a relatively high degree of protection. This area was treated independently to assess the effects of the Bloomington Lake Reformulation analysis. However, this area is also less sensitive to the smaller reductions in flood control storage. This is due in part to the local project as well as the increasing distances downstream from the dam. The point of reference for the Cumberland - Ridgely area and the rural reach between Cumberland, Maryland and the South Branch Potomac River junction is the USGS gage just downstream from Cumberland, Maryland.

The final rural reach contains the communities of South Cumberland, Oldtown, Maryland, and Greenspring, West Virginia. In addition, there are transportation facilities and the Chessie Railroad/Koppers Co. plant at Greenspring that processes railroad ties and steel rails. This complex alone accounts for a large portion of the flood damage potential in this reach. Low to moderate flood flows affect some scattered residences and transportation facilities along with this plant. Flood stages near or above the 1936 flood of record level would cause significantly increasing damages to all categories of property.

Total flood damage estimates and the foregone benefits were prepared for several representative flood levels for each reach for Plans 1, 8, 9 and 10. These are shown in Table H-IV-17. Average annual damages and benefits foregone were computed for each reach and the results are shown in Table H-IV-18. Values in both Tables H-IV-17 and H-IV-18 are shown at October 1981 price levels.

An examination of the modified frequency curves also shows that there is not a significant difference in downstream flood flows resulting from a permanent year-round pool as opposed to a seasonal pool. For a 100-year flood, the increase in stage at Luke would be about 0.3 feet, at Pinto about 0.7 feet, and at Cumberland about 0.5 feet.

These are the maximum differences in stage which would result from comparing Plan No. 5 with Plan No. 10. A comparison of other plans having equal pool levels but greater flood control storage, (i.e., No. 2 vs. No. 7; No. 3 vs. No. 8; and No. 4 vs. No. 9) shows even smaller differences at the downstream gages.

The decision was made to limit this analysis to only those plans having a permanent pool at the higher levels. This would reflect the "worst case" conditions with regard to flood control impacts.

SUMMARY OF BENFEFITS FOREGONE

This analysis to determine the sensitivity of flood-control benefits to decreasing storage capacities was conducted as follows. Benefits were computed for the without Bloomington Lake conditions based on existing development as determined by the 1980 flood damage survey. Plan No. 1, which represents the existing plan of operation, was then evaluated followed by Plans No. 8, 9 and 10 which reflect year-round pool levels and reductions in flood control storage of approximately 25, 50 and 75 percent respectively. As the data in Table H-IV-18 demonstrate, Plan No. 8 results in foregone benefits to existing development of $49,000 out of $1,498,000 or about 3 percent. Similarly, Plan No. 9 would lose $108,000 or about 7 percent, while Plan No. 10 would lose $467,000 in benefits or about 31 percent. This table also demonstrates that a great majority of these foregone benefits would accrue in the two rural reaches. The floodplain development including transportation facilities is scattered over about 54 miles of river on both banks. It would be impractical and nearly impossible to mitigate these losses by offering alternative means of protection such as levees or walls, floodproofing or raising, or other nonstructural measures. Table H-IV-19 presents the summary of benefits foregone at October 1981 price levels.

Table H-IV-20 displays the incremental changes in the level of fl ɔd protection, both in terms of flow and stage, for Plans 8, 9, and 10 as compared to Plan 1 (existing Bloomington Lake project without reallocation).

TABLE H-IV-17

SUMMARY OF FLOOD DAMAGE ESTIMATES AND INCREMENTAL INCREASES
FOR DIFFERENT PLANS AT BLOOMINGTON LAKE
($1,000 AT OCTOBER 1981 CONDITIONS AND PRICE LEVELS)

Location	Ref. Flood	Plan No. 1	Plan No. 8	Incr. Dam.	Plan No. 9	Incr. Dam.	Plan No. 10	Incr. Dam.
Luke Mill	100 yr.	0	0	0	0	0	0	0
	500 yr.	0	0	0	0	0	1,740	1,740
	1924	0	0	0	0	0	0	0
Westernport, MD	100 yr.	0	0	0	0	0	0	0
	500 ry.	0	0	0	0	0	650	650
	1924	0	0	0	0	0	0	0
Piedmont, WV	100 yr	0	0	0	0	0	0	0
	500 yr.	0	0	0	1,840	1,840	3,330	3,330
	1924	0	0	0	680	680	2,190	2,190
Keyser, WV	100 yr.	24	35	11	71	47	637	613
	500 yr.	1,900	2,610	710	3,830	1,930	4,690	2,790
	1924	29	41	12	96	67	904	875
Savage R. to Cumberland	100 yr	1,830	2,620	790	3,770	1,940	5,540	3,710
	500 yr.	7,240	9,480	2,240	11,570	4,330	12,200	4,960
	1924	2,230	3,010	780	3,970	1,740	5,850	3,620
Cumberland - Ridgely	100 yr.	0	0	0	0	0	0	0
	500 yr.	0	0	0	0	0	0	0
	1936	0	0	0	0	0	0	0
Cumberland to S. Br. Jct.	100 yr.	9,100	9,480	380	1,0280	1,180	13,880	4,780
	500 yr.	21,710	22,310	600	2,3050	1,340	25,700	3,990
	1936	12,840	13,200	360	1,4530	1,690	17,180	4,340
TOTALS	100 yr.	$10,954	$12,135	$1,181	$14,121	$3,167	$20,057	$9,103
	500 yr.	30,850	34,400	3,550	40,290	9,440	48,310	17,460
	'24/'36	15,099	16,251	1,152	19,276	4,177	26,124	11,025

NOTE - Increased damages represent benefits foregone due to reduced storage for a given event.

TABLE H-IV-18

EXISTING AND FOREGONE AVERAGE ANNUAL BENEFITS

BY REACH AND BY PALN

(October 1981 Price Level in $1000s)

Location	Present Project	Plan No. 8	Foregone Benefits	Plan No. 9	Foregone Benefits	Plan No. 10	Foregone Benefits
Luke Paper Mill	$ 45	$ 45	$ 0	$ 44	$ 1	$ 35	$ 10
Westernport, MD	8	8	0	8	0	6	2
Piedmont, WV	37	36	1	33	4	27	10
Keyser, WV	78	76	2	70	8	51	27
Savage R. to Cumberland	567	555	12	529	38	408	159
Cumberland - Ridgely	21	21	0	19	2	12	9
Cumberland to S. Br. Jct.	742	708	34	687	55	492	250
TOTAL	$1,498	$1,449	$ 49	$1,390	$ 108	$1,031	$ 467

NOTE - The above estimates reflect existing level of development only. Foregone benefits result from raising the existing seasonal pool to the higher year-round pool levels for Plans 8, 9 and 10.

TABLE H-IV-19
SUMMARY OF BENEFITS FOREGONE
(October 1981 Price Levels)

PLANS	AVAILABLE FLOOD CONTROL STORAGE AC. FT.	STORAGE REALLOCATED		BENEFITS FOREGONE*	
		VOLUME AC. FT.	PERCENT	AMOUNT	PERCENT
1	36,200	0	0	0	0
8	27,400	8,800	25	$ 49,000	3
9	18,000	18,200	50	$108,000	7
10	9,200	27,400	75	$467,000	31

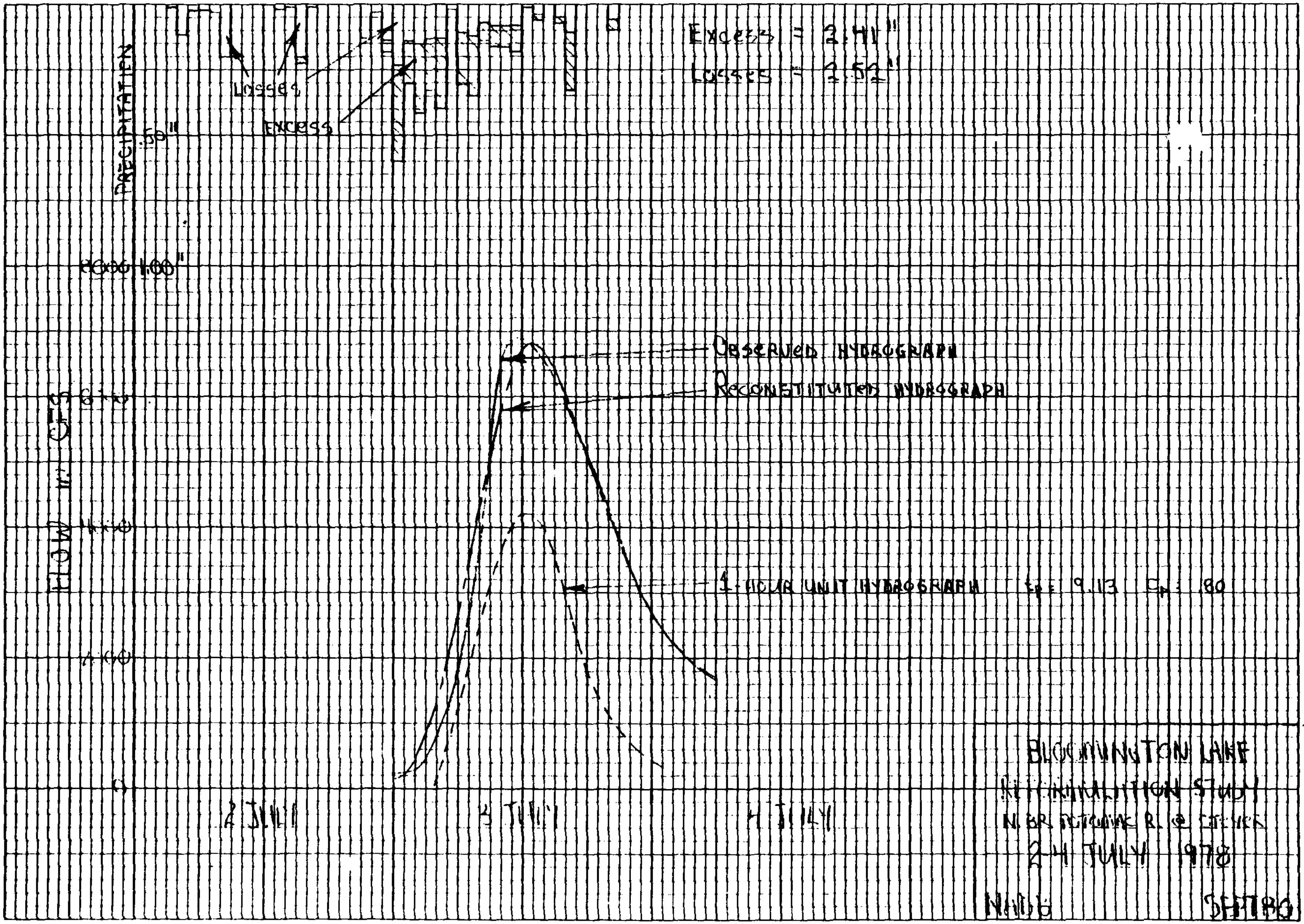
* Benefit Foregone means reduction in benefits or increase in damages due to reduction in flood control storage in the Bloomington Lake.

TABLE H-IV-20
COMPARISON OF FLOOD PROTECTION LEVELS
FOR PLANS 1, 8, 9 AND 10

REACH	RETURN PERIOD	PLAN 1 (Existing Project) FLOW IN CFS/ STAGE IN FT.	INCREASE IN FLOW/STAGE (cfs/ft.) FROM PLAN 1		
			PLAN 8 AT 1475	PLAN 9 AT 1484	PLAN 10 AT 1492
Luke	100	12,000/10.5	700/0.2	7,000/2.2	12,500/3.6
	200	13,700/11.1	4,500/1.3	11,300/3.1	17,300/4.4
Pinto	100	25,500/19.7	2,500/0.7	5,500/1.3	14,500/2.5
	200	34,000/21.5	2,500/0.3	6,000/0.7	17,000/2.1
Cumberland	100	52,000/24.2	1,000/0.2	2,500/0.5	12,000/1.8
	200	65,000/26.2	3,000/0.4	5,000/0.6	15,000/1.9

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



FIGURE

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

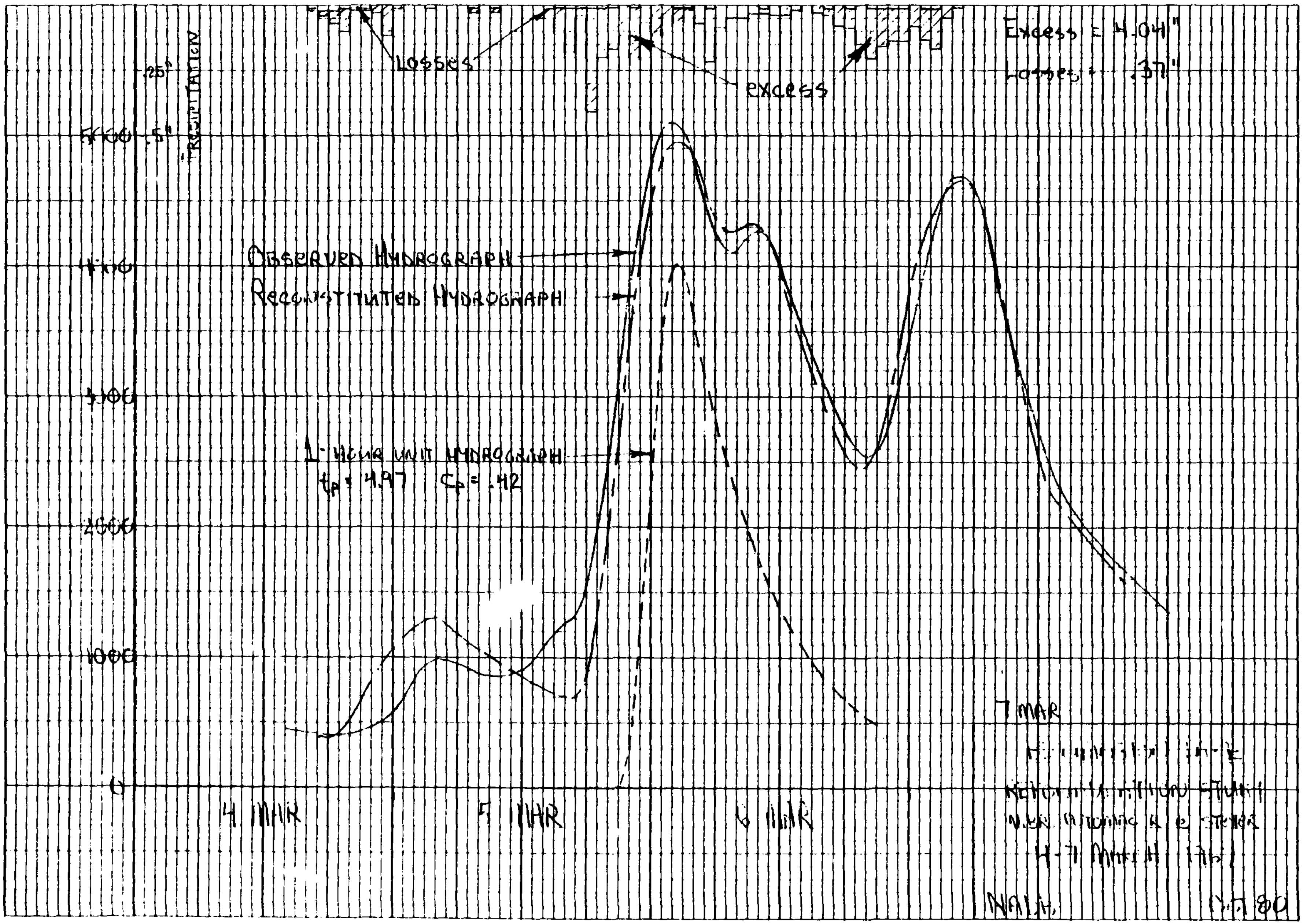
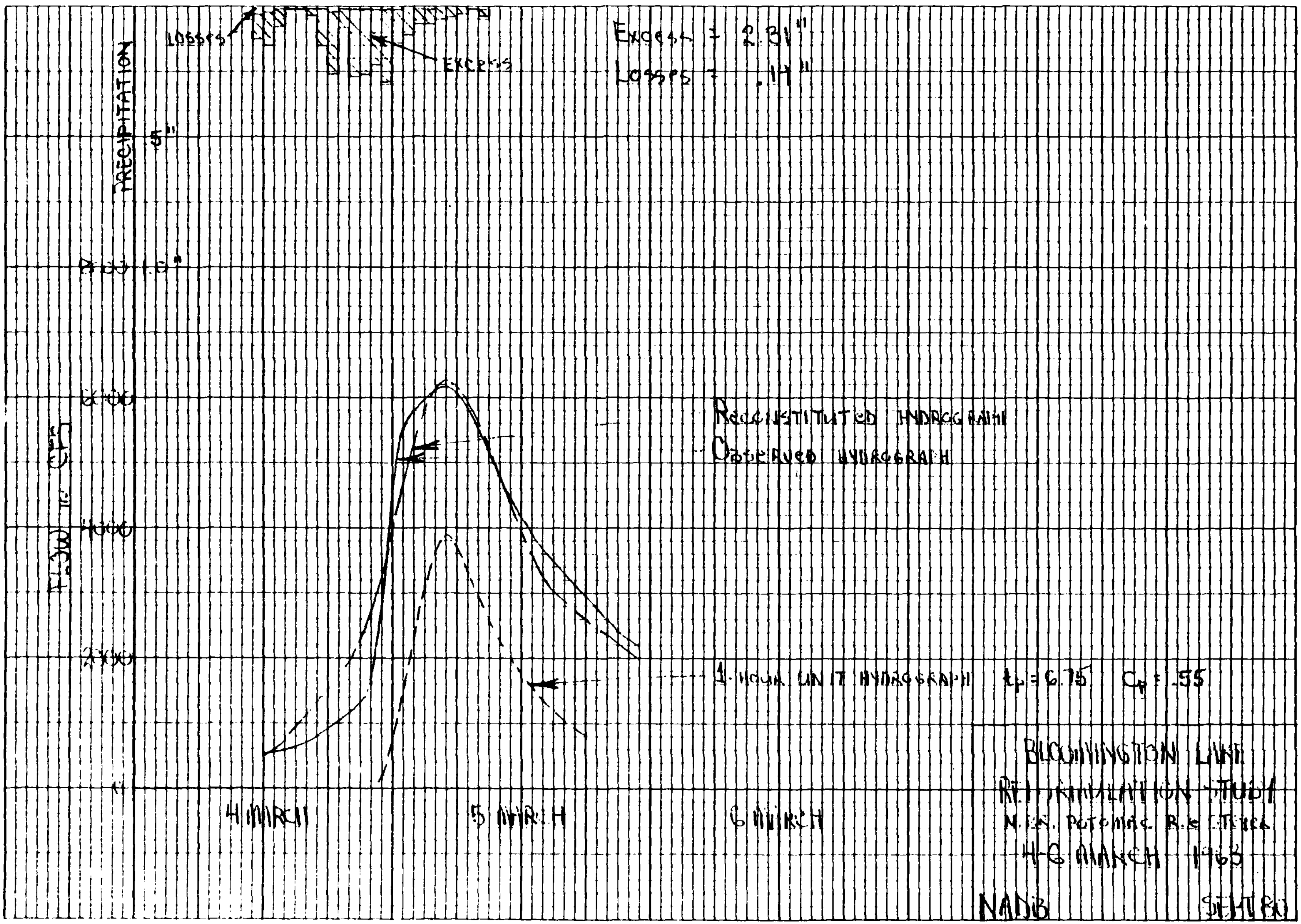
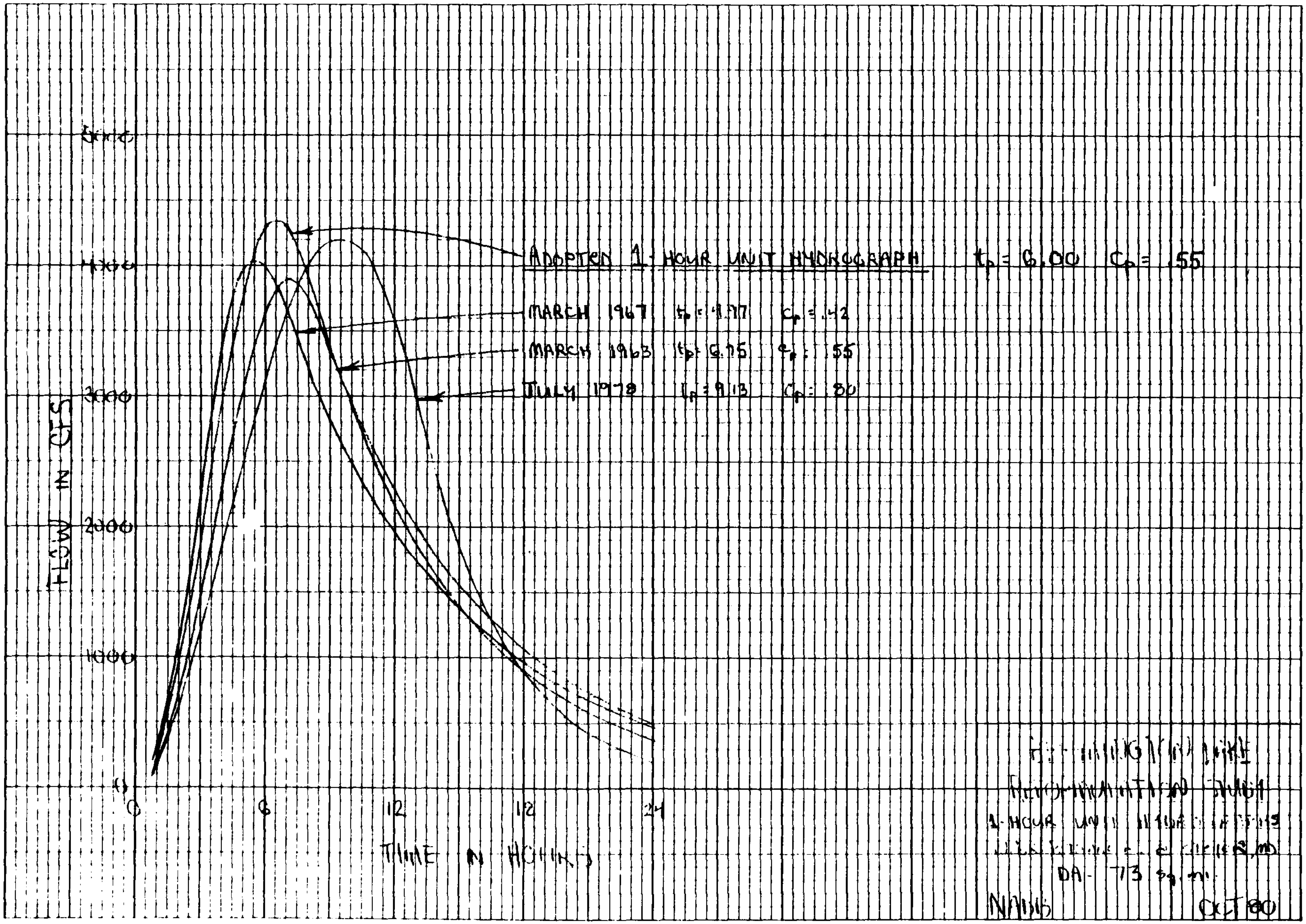


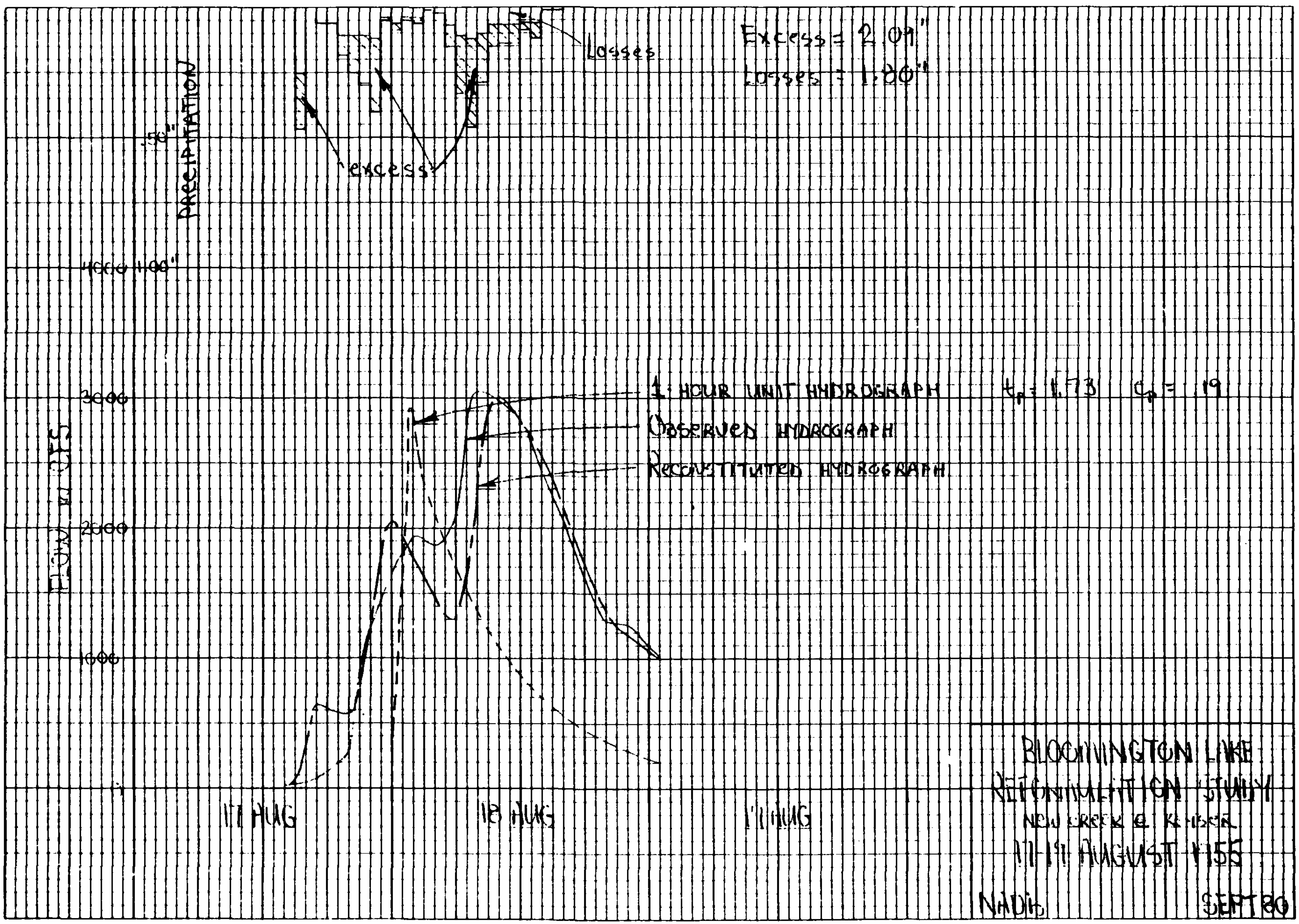
FIGURE H-IV-2

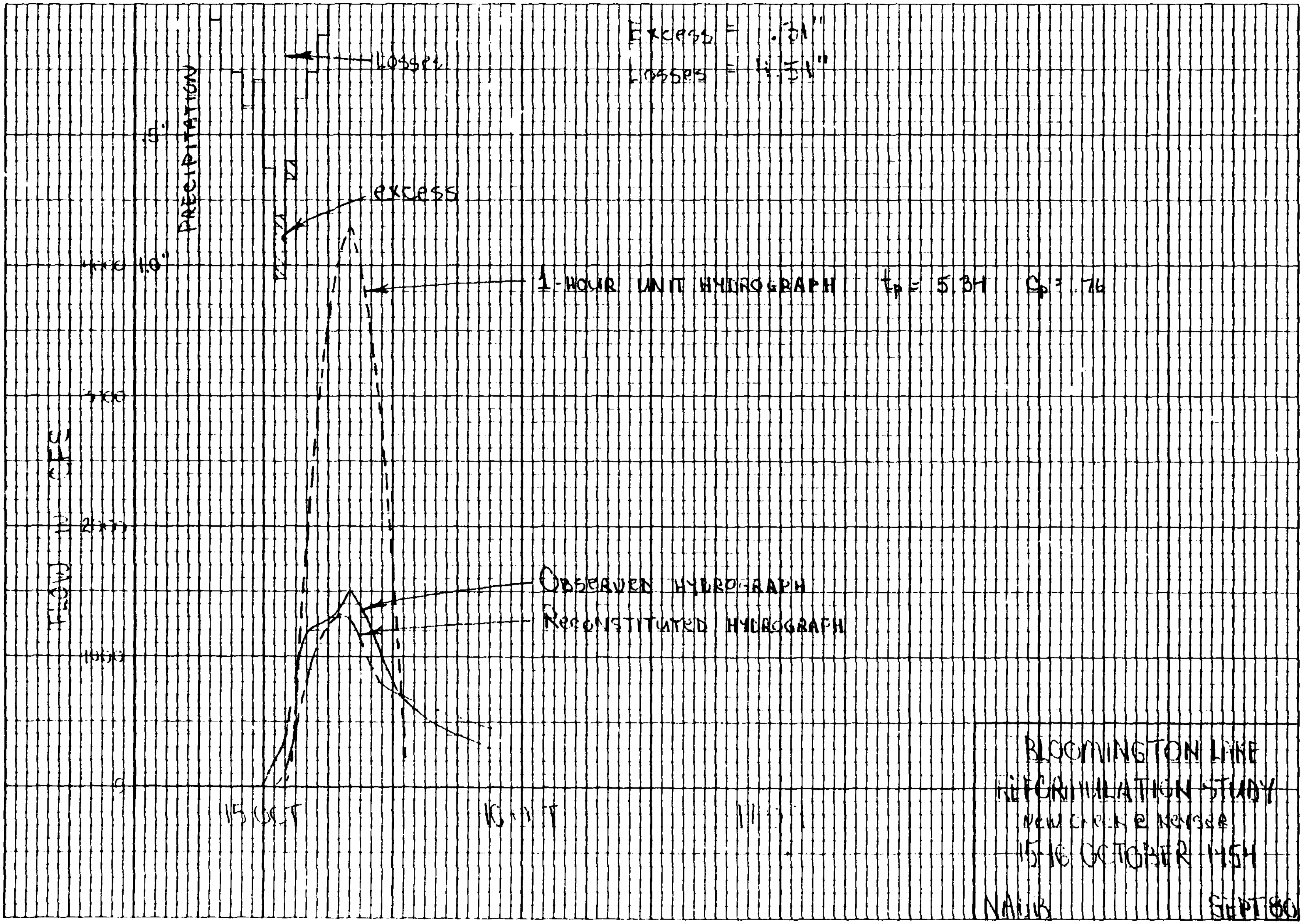
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.




ADOPTED 1-HOUR UNIT HYDROGRAPH t_p = 6.00 C_p = .55
MARCH 1967 t_p = 4.77 C_p = .42
MARCH 1963 t_p = 6.75 C_p = .55
JULY 1978 t_p = 9.13 C_p = .80
FLOW IN CFS
0
6
12
18
24
TIME IN HOURS
1-HOUR UNIT
DA-73
OCT 80


PRECIPITATION
.50"
1.00"
Excess = 2.09"
Losses = 1.80"
Losses
excess
1 HOUR UNIT HYDROGRAPH
t_p = 1.73 C_p = .19
OBSERVED HYDROGRAPH
RECONSTITUTED HYDROGRAPH
FLOW IN CFS
4000
3000
2000
1000
17 AUG
18 AUG
19 AUG
BLOOMINGTON LAKE
REFORMULATION STUDY
NEW CREEK @ KEYSER
17-19 AUGUST 1955
SEPT 80


Excess = .31"
Losses = 4.51"
Losses
PRECIPITATION
.5"
1.0"
excess
1-HOUR UNIT HYDROGRAPH tp = 5.3H Cp = .76
OBSERVED HYDROGRAPH
RECONSTITUTED HYDROGRAPH
FLOW IN CFS
2000
1000
0
15 OCT
16 OCT
BLOOMINGTON LAKE
RECONSTITUTION STUDY
15-16 OCTOBER 1954
NAB
SEPT 80

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

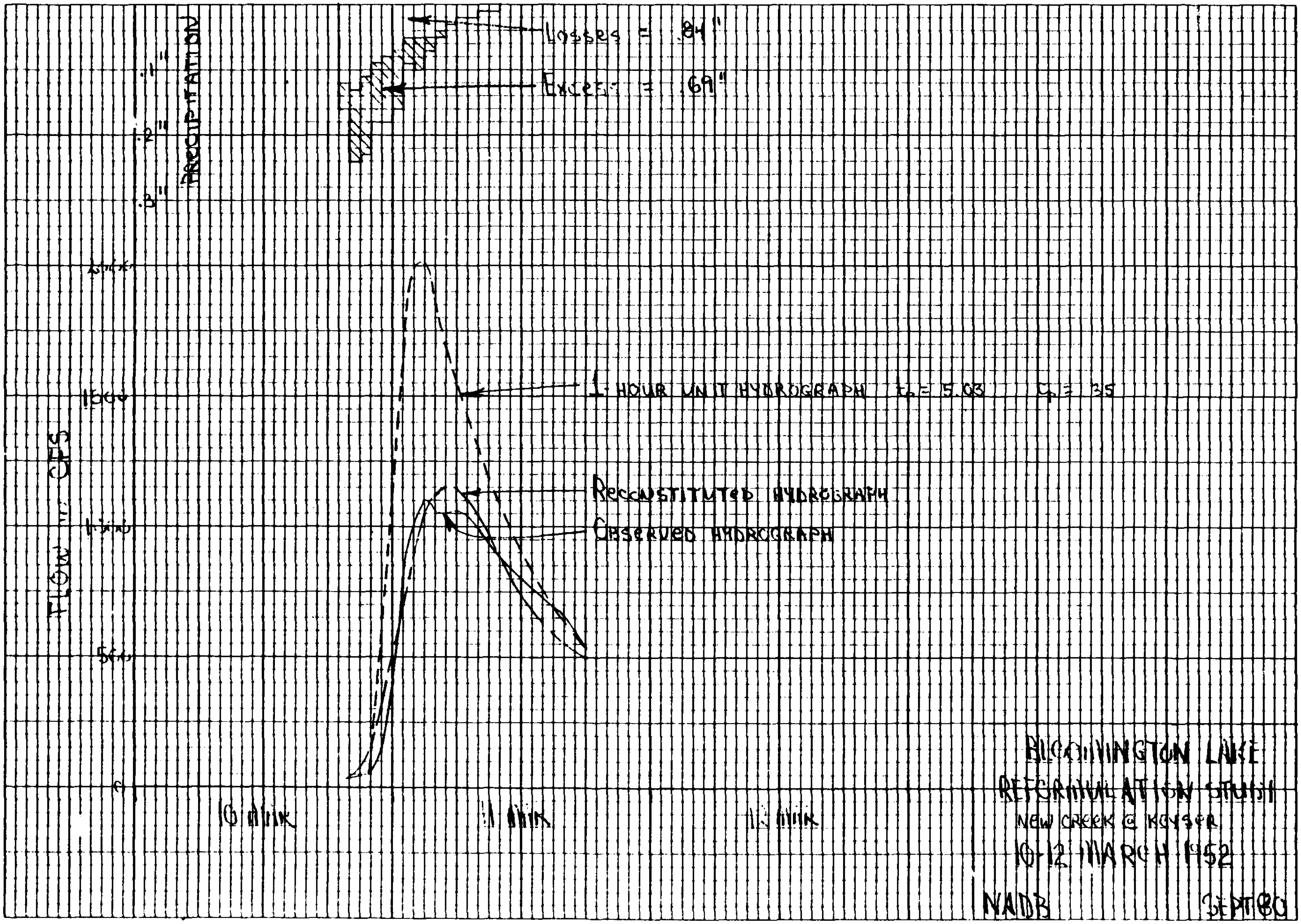
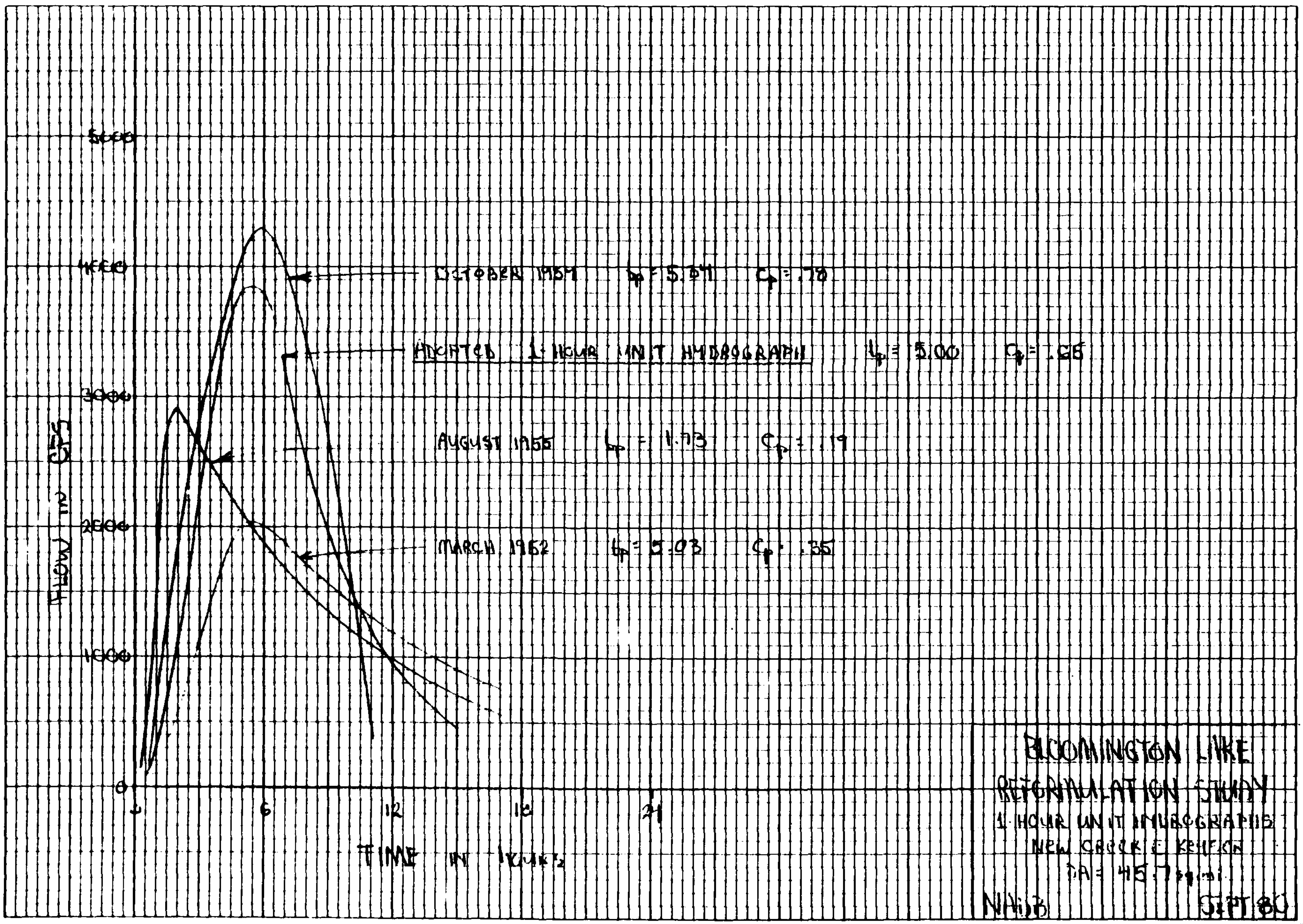
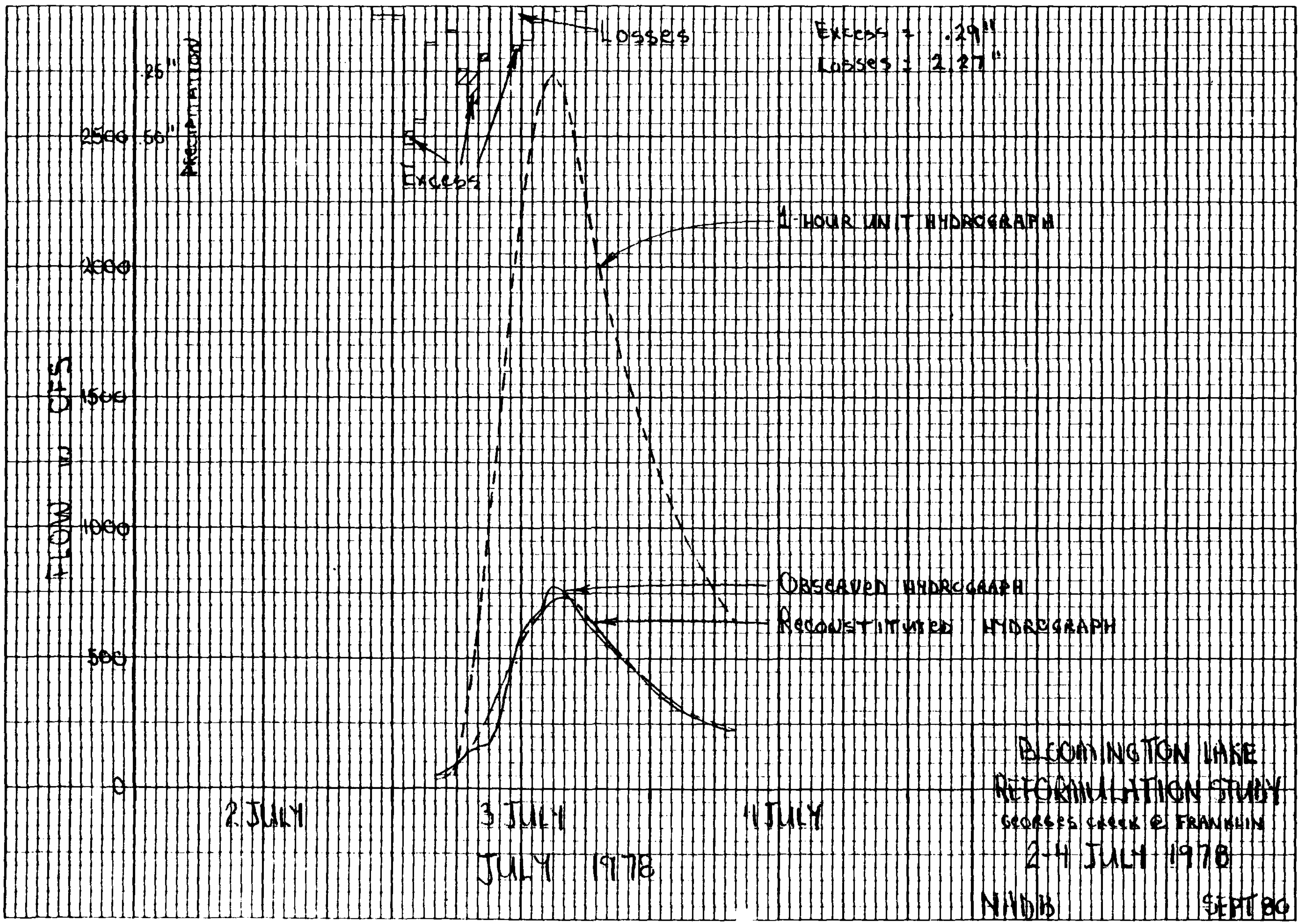


FIGURE H-IV-7

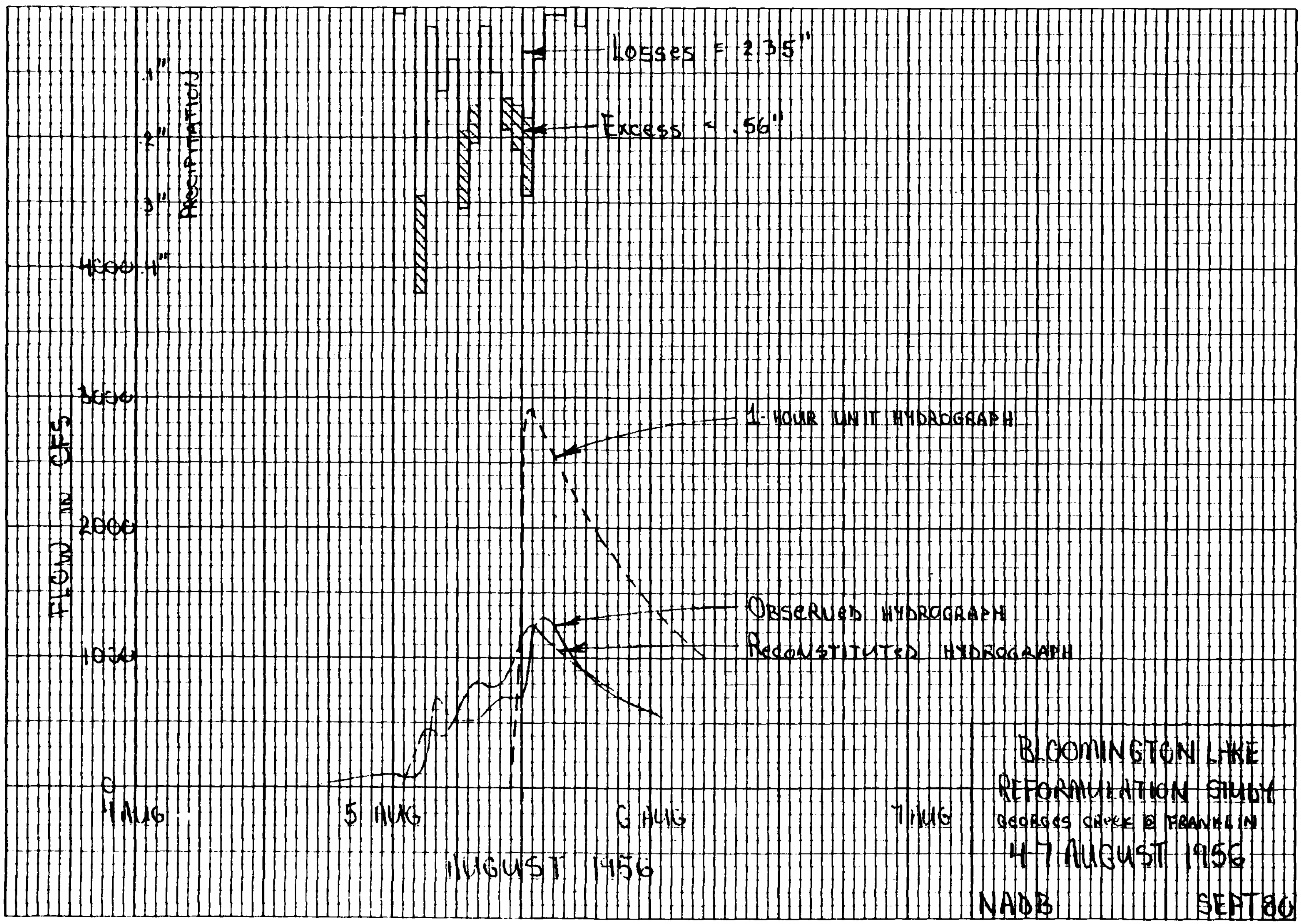

5000
4000
3000
2000
1000
0
FLOW IN CFS
0
6
12
18
24
TIME IN HOURS
OCTOBER 1954 tp = 5.04 Cp = .78
ADOPTED 1 HOUR UNIT HYDROGRAPH tp = 5.00 Cp = .65
AUGUST 1955 tp = 1.73 Cp = .19
MARCH 1962 tp = 5.03 Cp = .35
BLOOMINGTON LAKE
REFORMULATION STUDY
1 HOUR UNIT HYDROGRAPHS
NEW CREEK @ KEYSER
DA = 45.7 sq.mi.
NAB
SEPT 80

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



H-IV-36


Losses = 2.35"
Excess = .56"
PRECIPITATION
1"
2"
3"
4"
4000
3000
2000
1000
0
FLOW IN CFS
1-HOUR UNIT HYDROGRAPH
OBSERVED HYDROGRAPH
RECONSTITUTED HYDROGRAPH
4 AUG
5 AUG
6 AUG
7 AUG
AUGUST 1956
BLOOMINGTON LAKE
REFORMULATION STUDY
GEORGES CREEK @ FRANKLIN
4-7 AUGUST 1956
NADB
SEPT 80

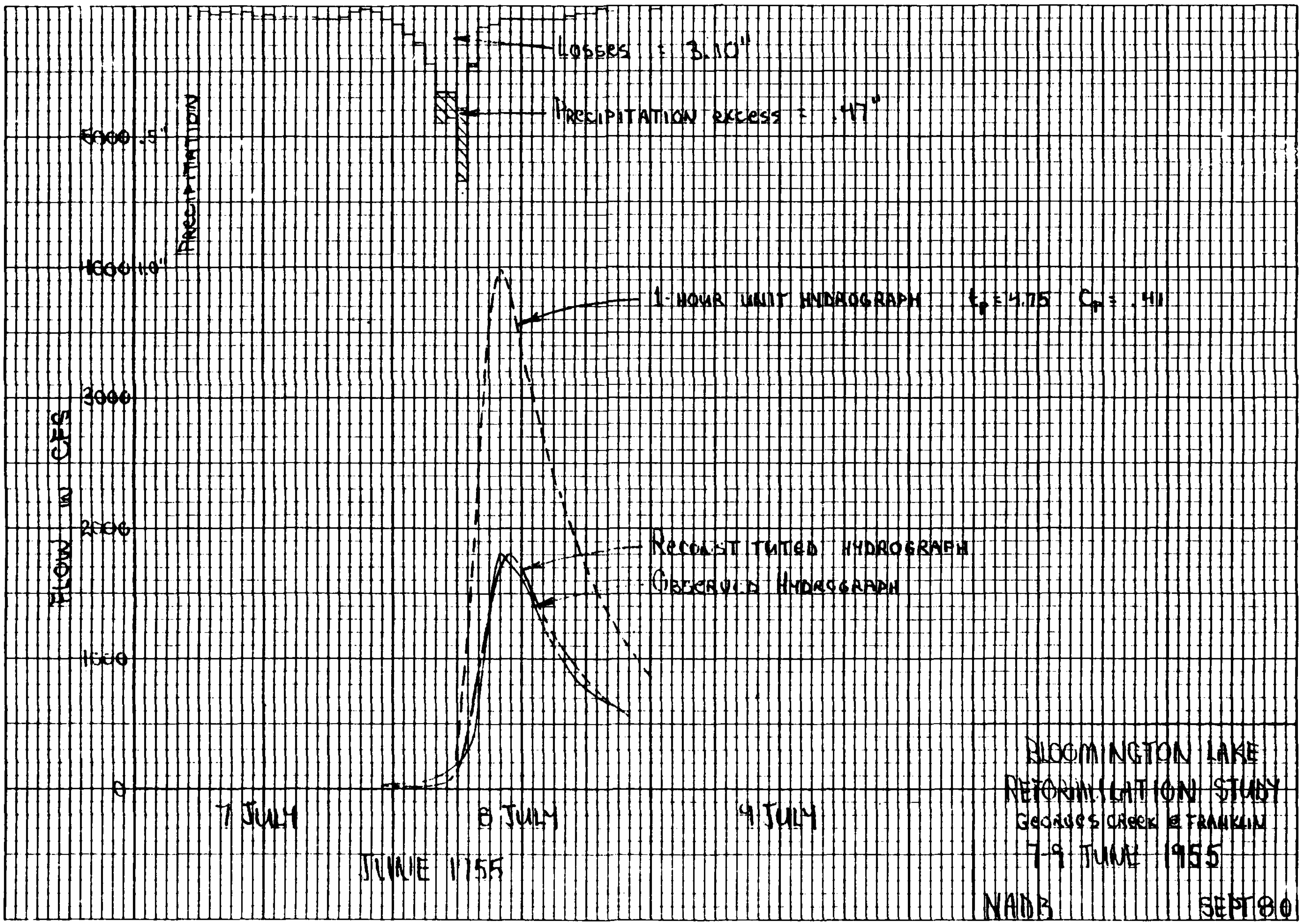


FIGURE H-IV-11

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

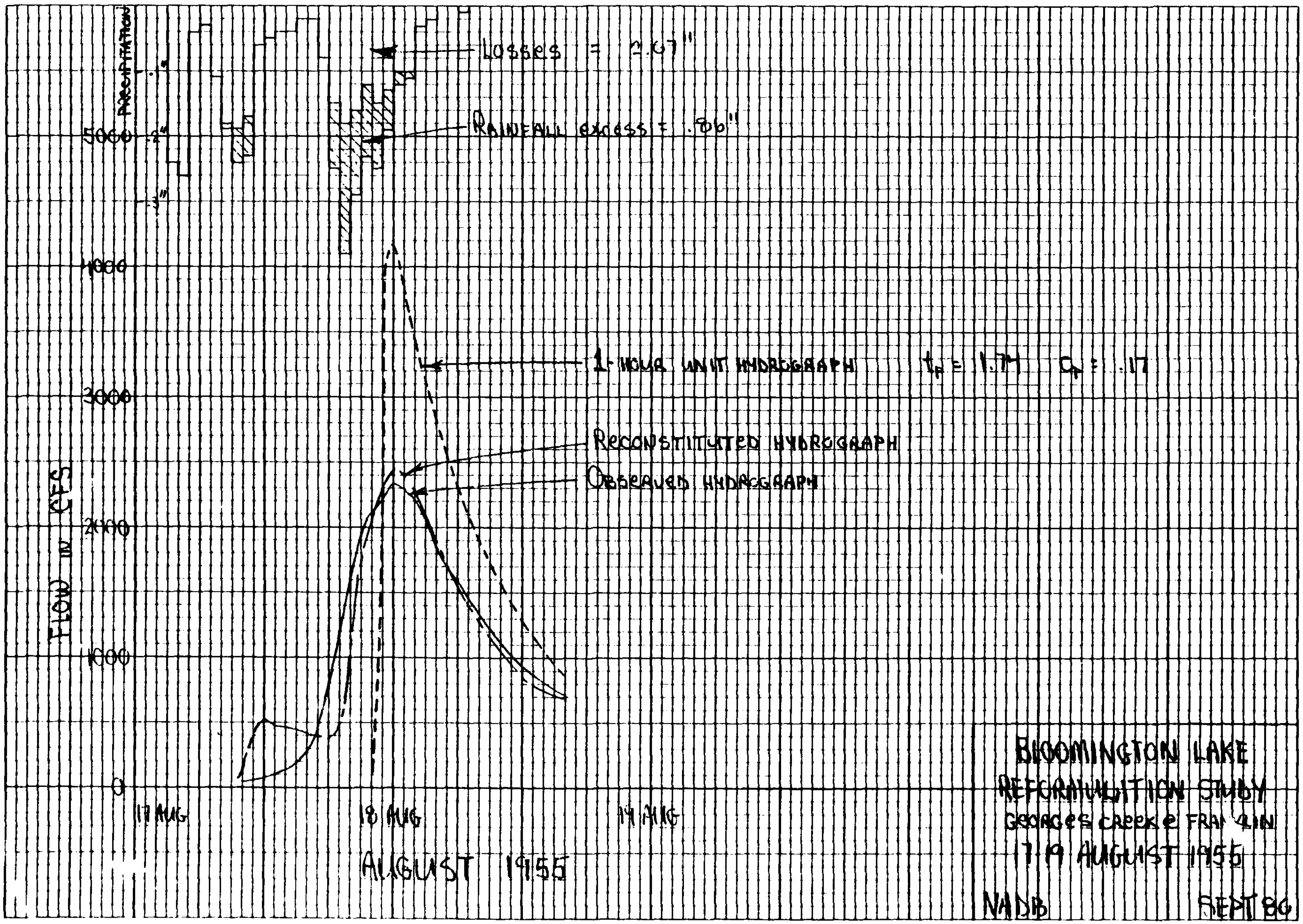


FIGURE H-IV-12

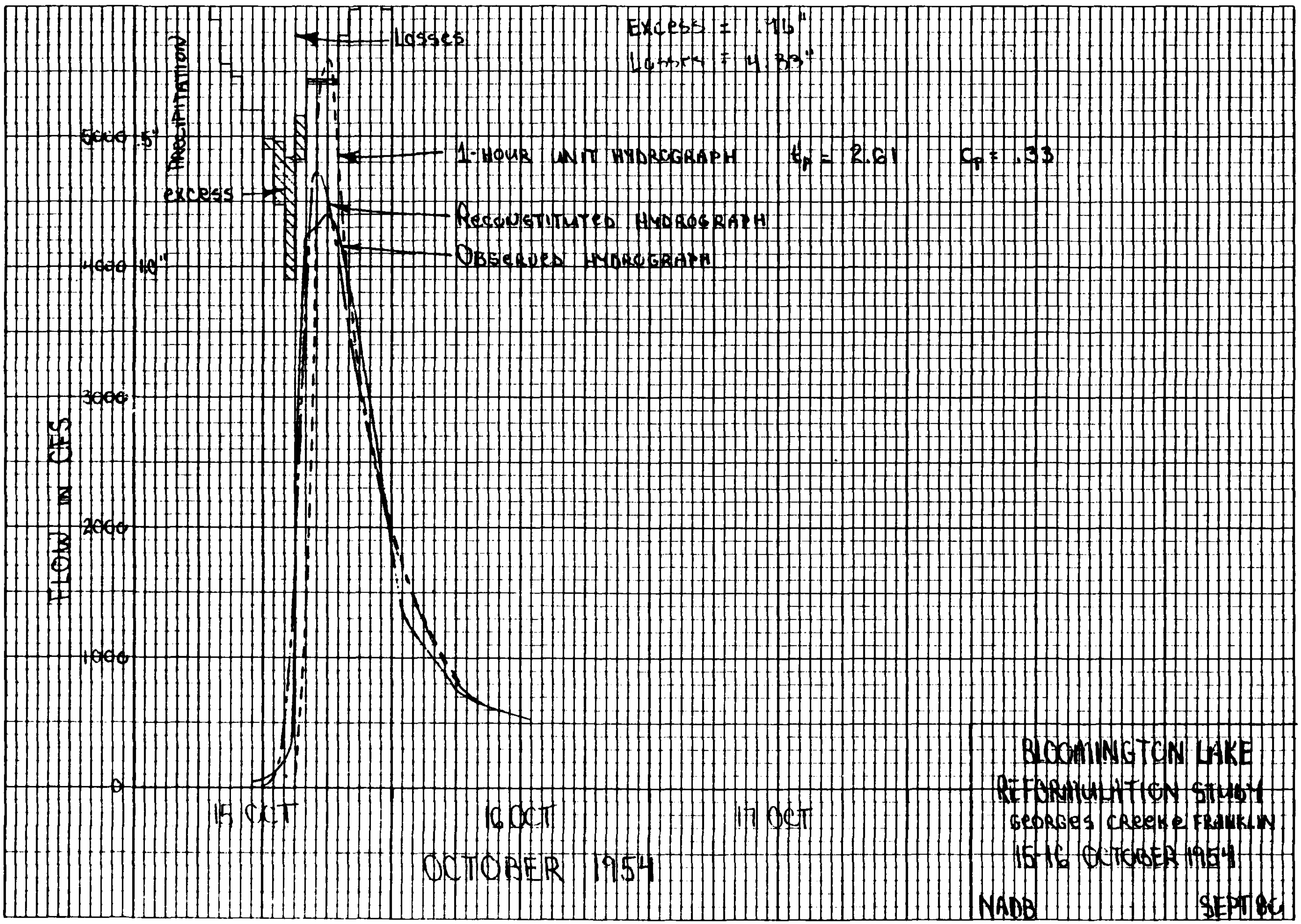
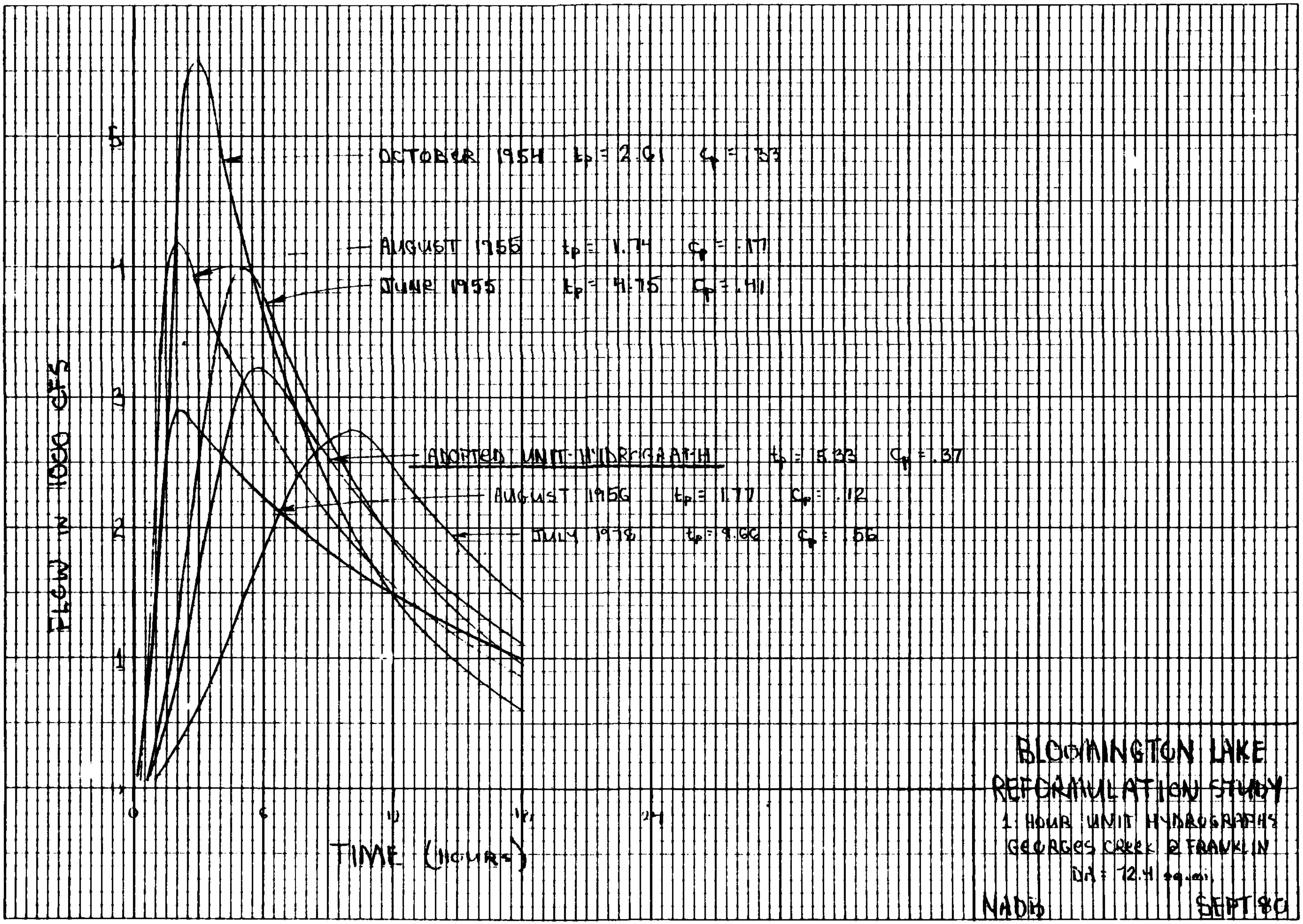


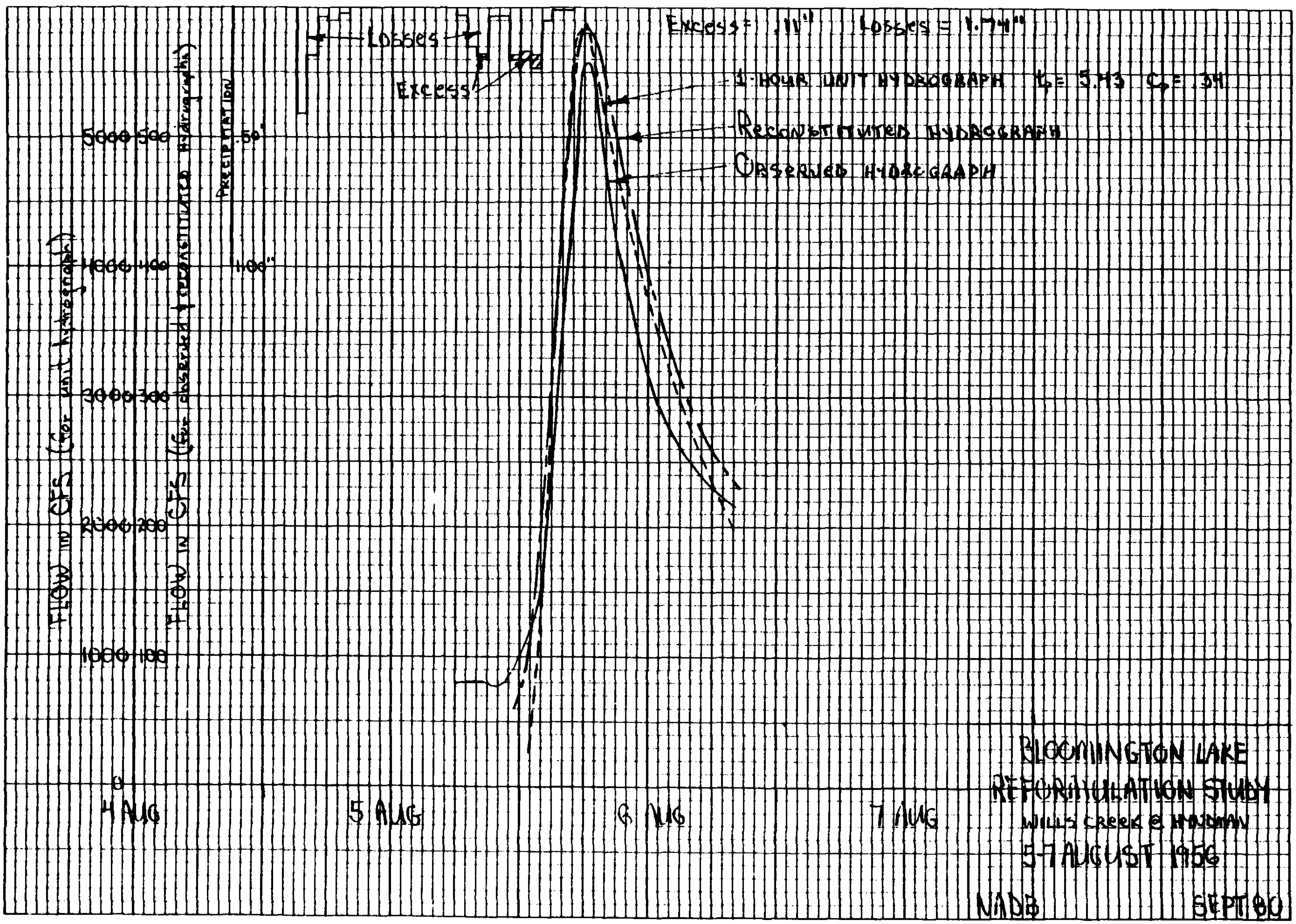
FIGURE H-IV-13

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



BLOOMINGTON LAKE
REFORMULATION STUDY
1 HOUR UNIT HYDROGRAPHS
GEORGES CREEK @ FRANKLIN
DA = 12.4 sq.mi.
NADED SEPT 80


Losses
Excess
Excess = .11" Losses = 1.74"
1-HOUR UNIT HYDROGRAPH t_p = 5.43 C_p = .34
RECONSTITUTED HYDROGRAPH
OBSERVED HYDROGRAPH
PRECIPITATION
.50"
1.00"
FLOW IN CFS (for unit hydrograph)
FLOW IN CFS (for observed & reconstituted hydrographs)
5000 500
4000 400
3000 300
2000 200
1000 100
0
4 AUG
5 AUG
6 AUG
7 AUG
BLOOMINGTON LAKE
REFORMULATION STUDY
WILLS CREEK @ HYNDMAN
5-7 AUGUST 1956
NADB
SEPT 80

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

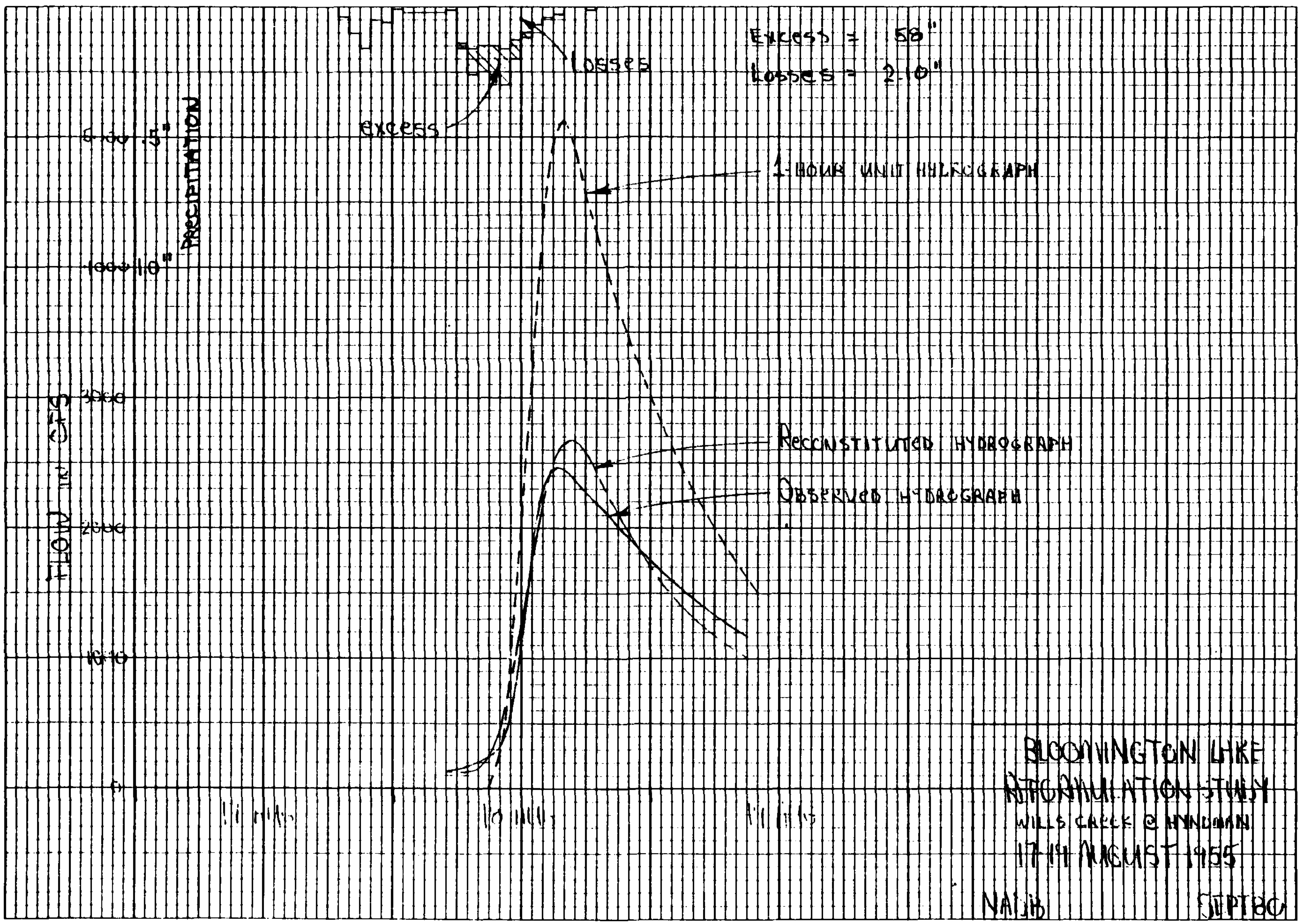
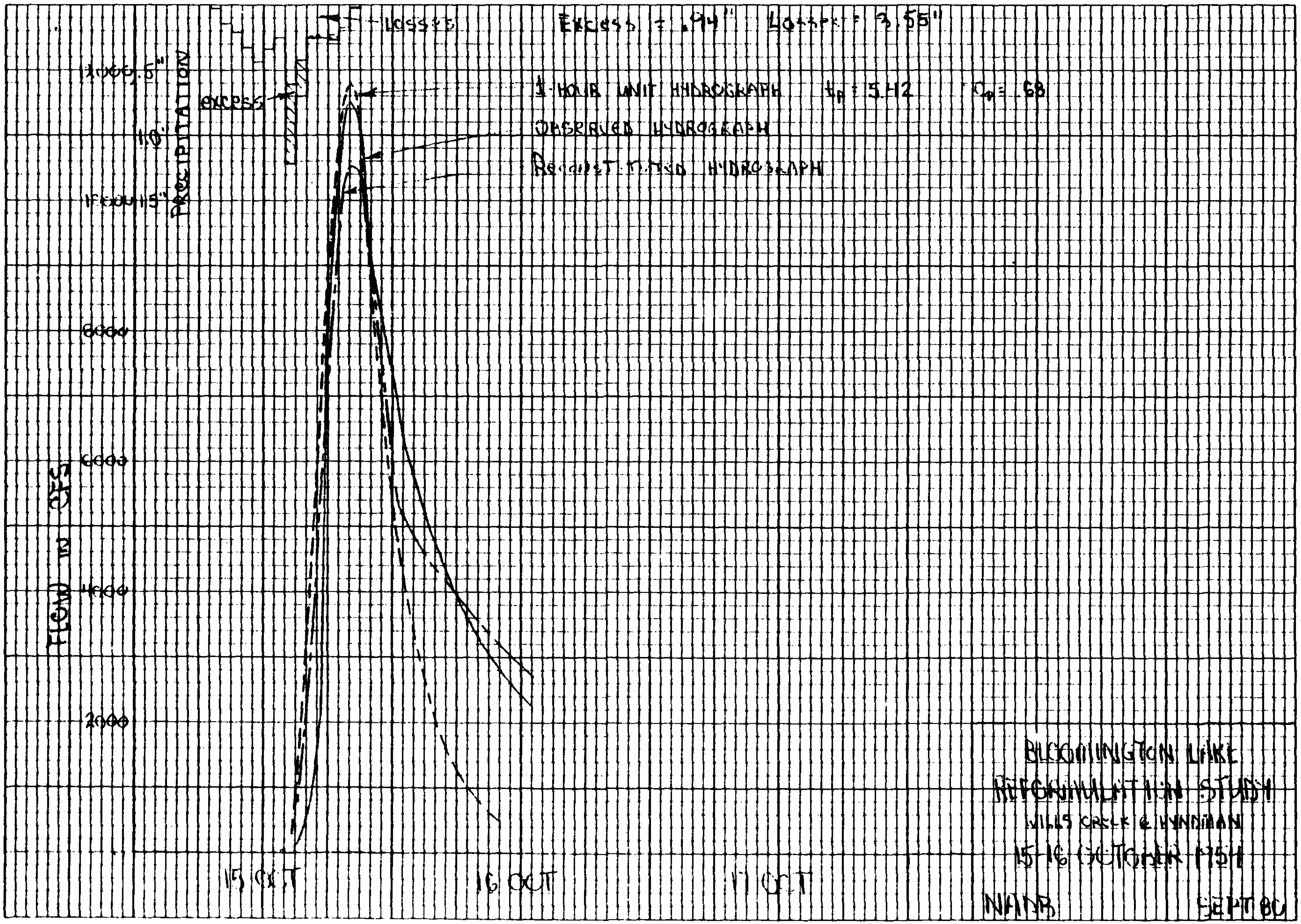


FIGURE H-IV-16

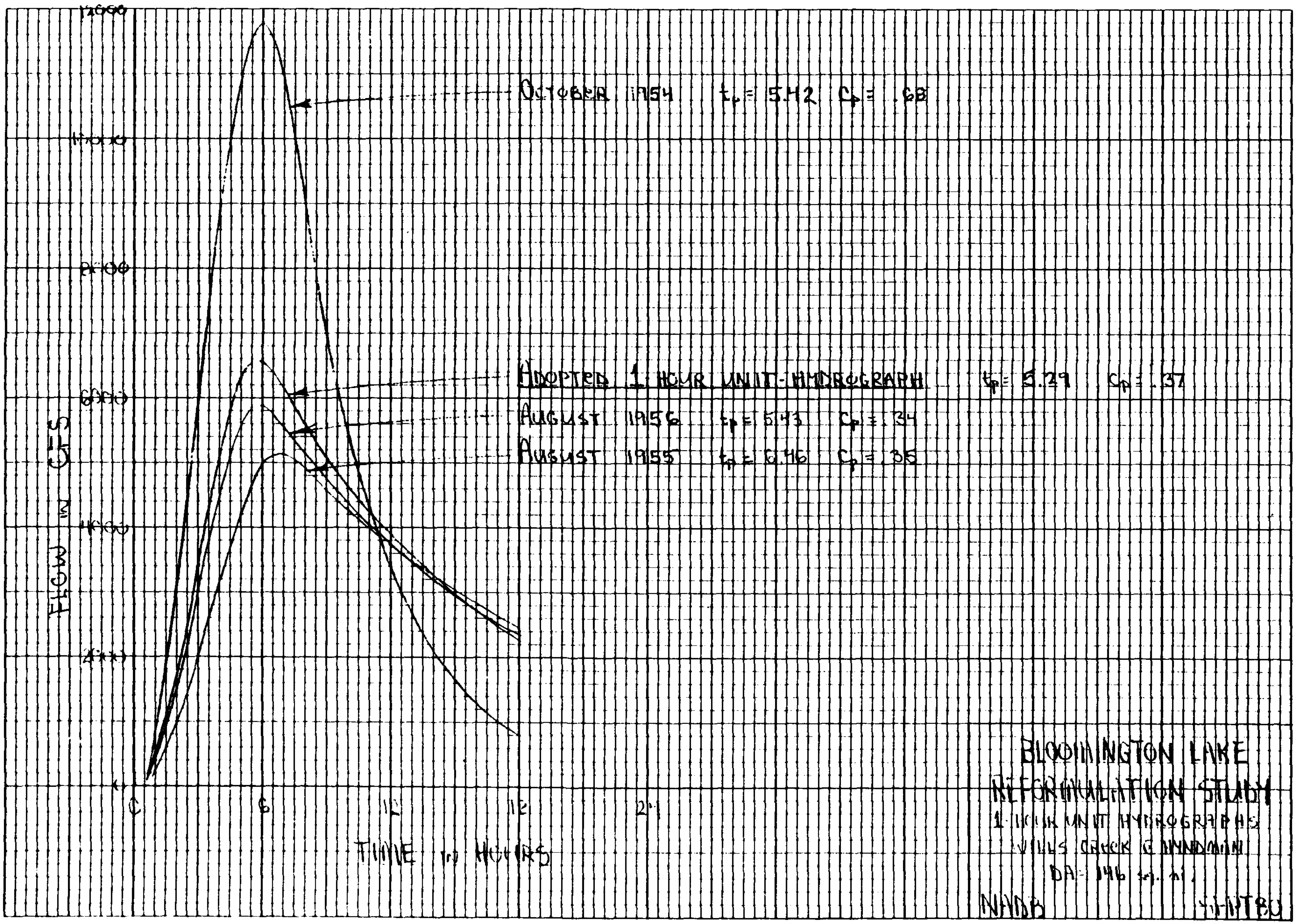
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



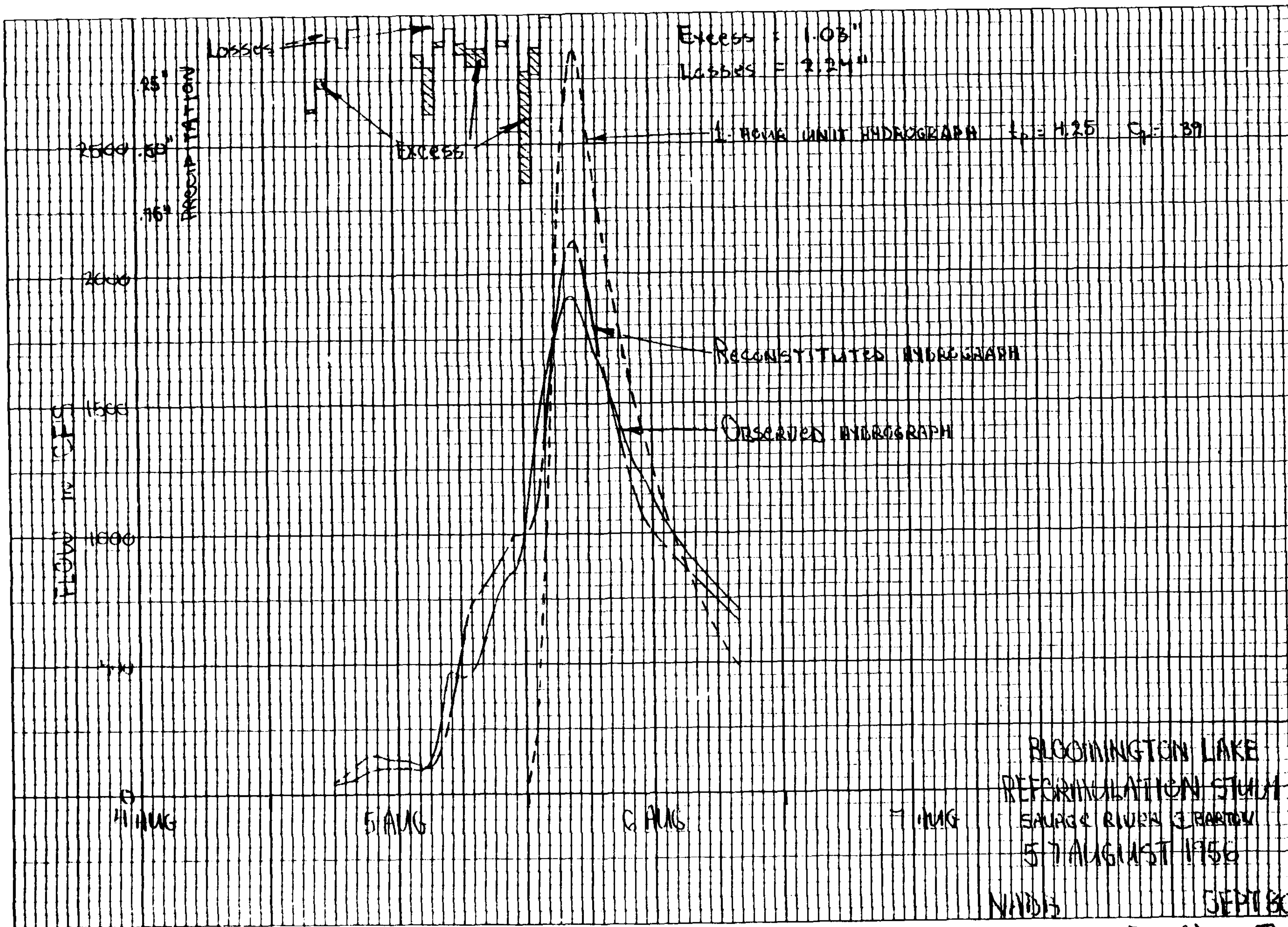
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



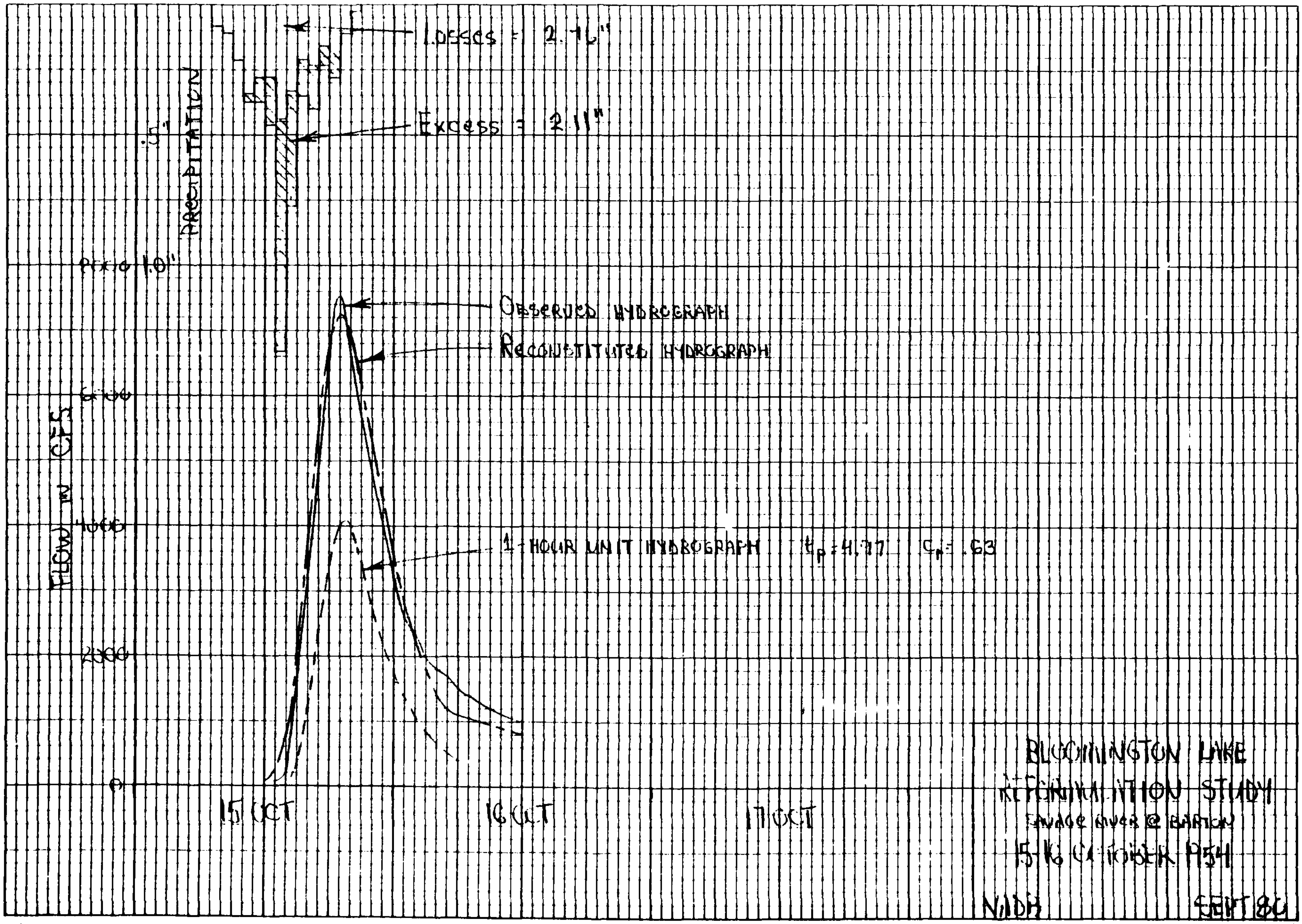
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

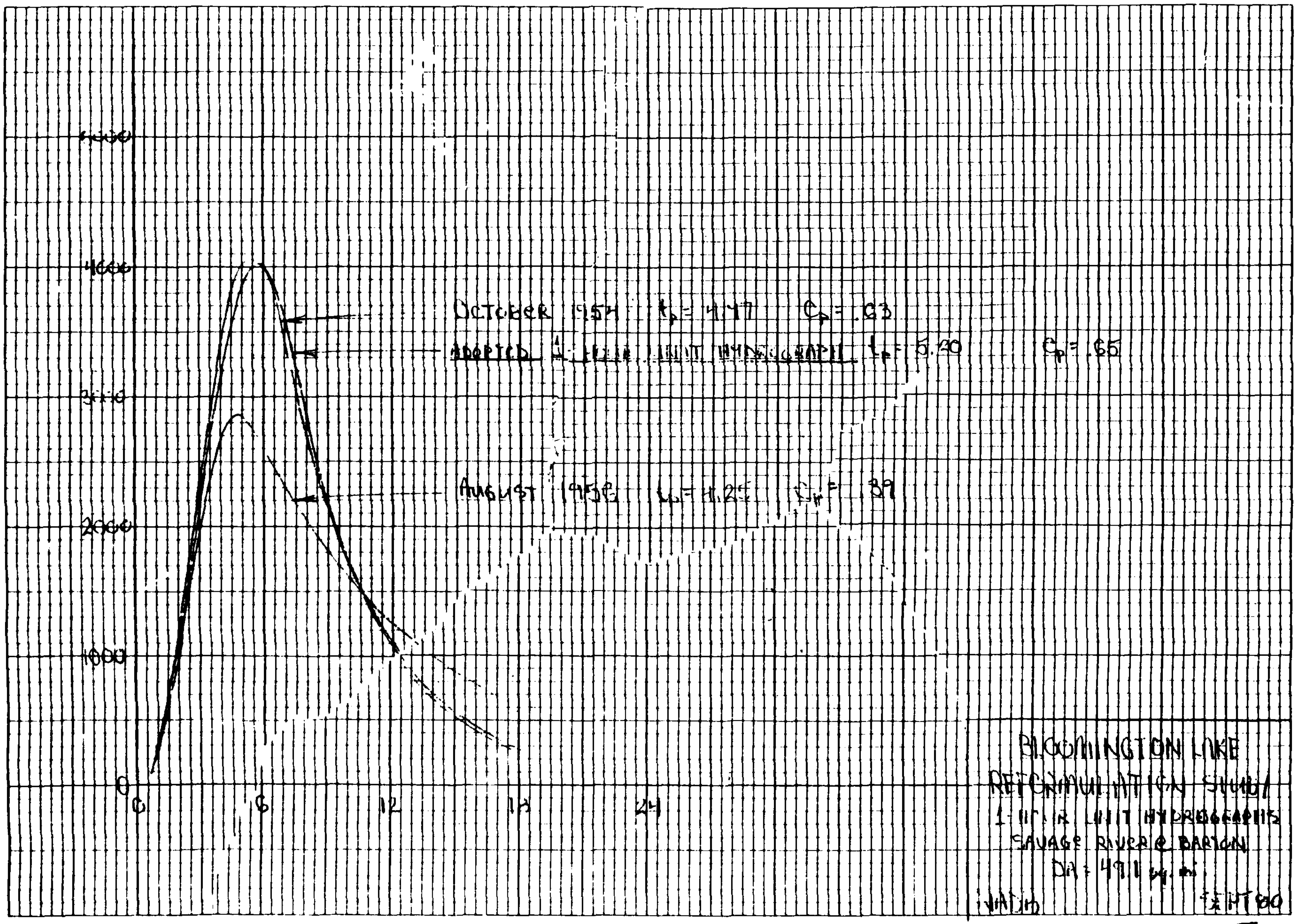


FIGURE H-IV-21

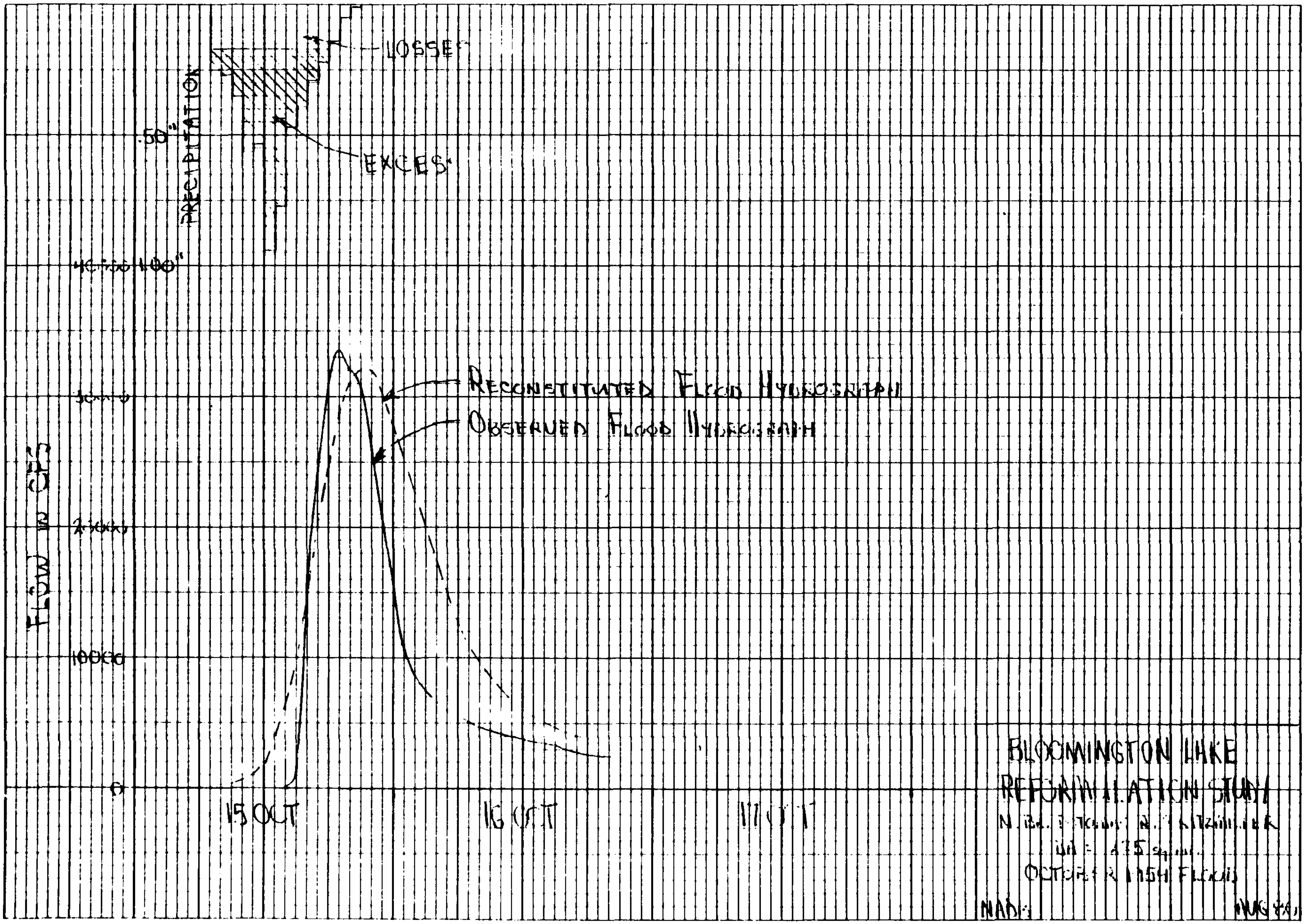
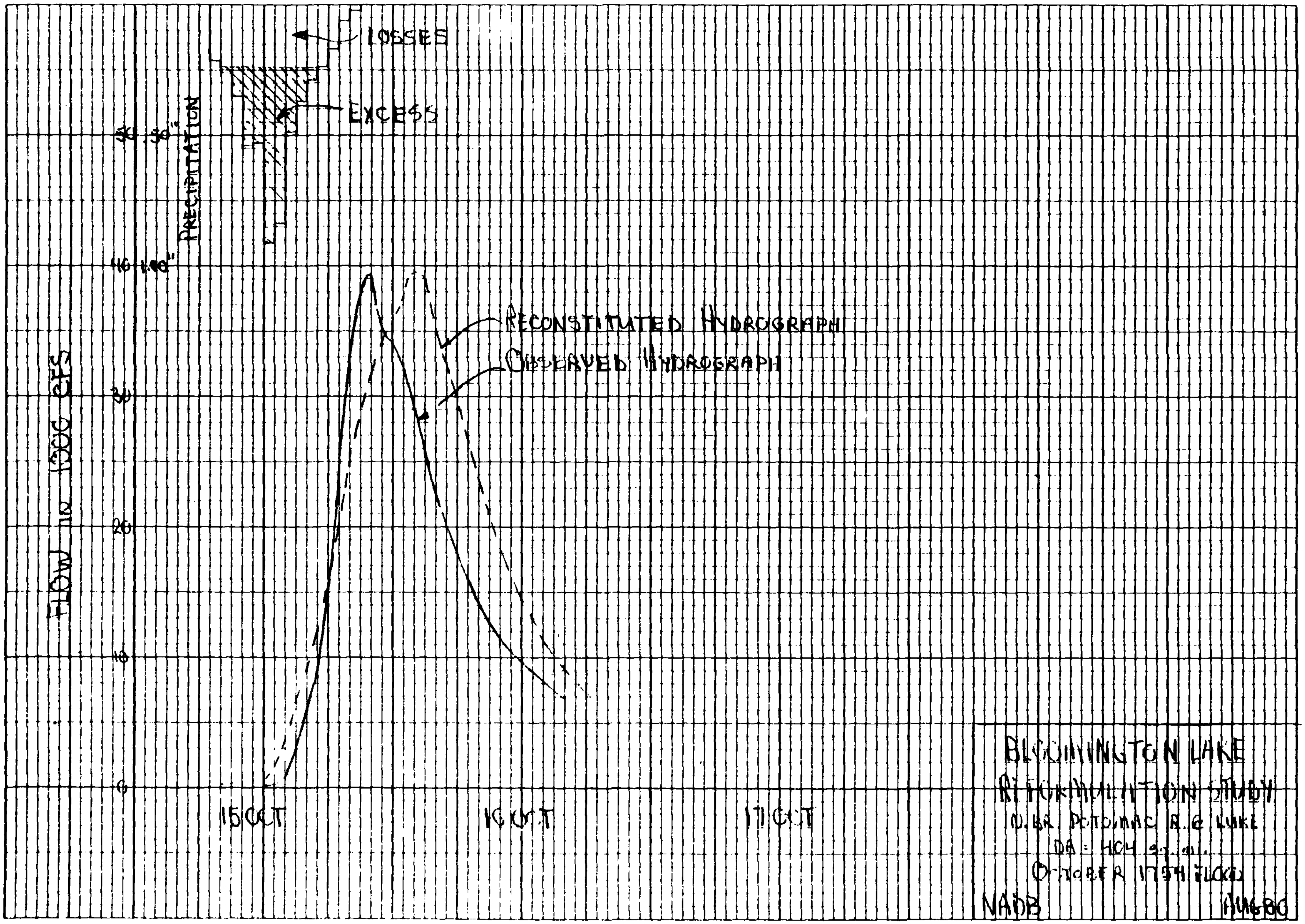
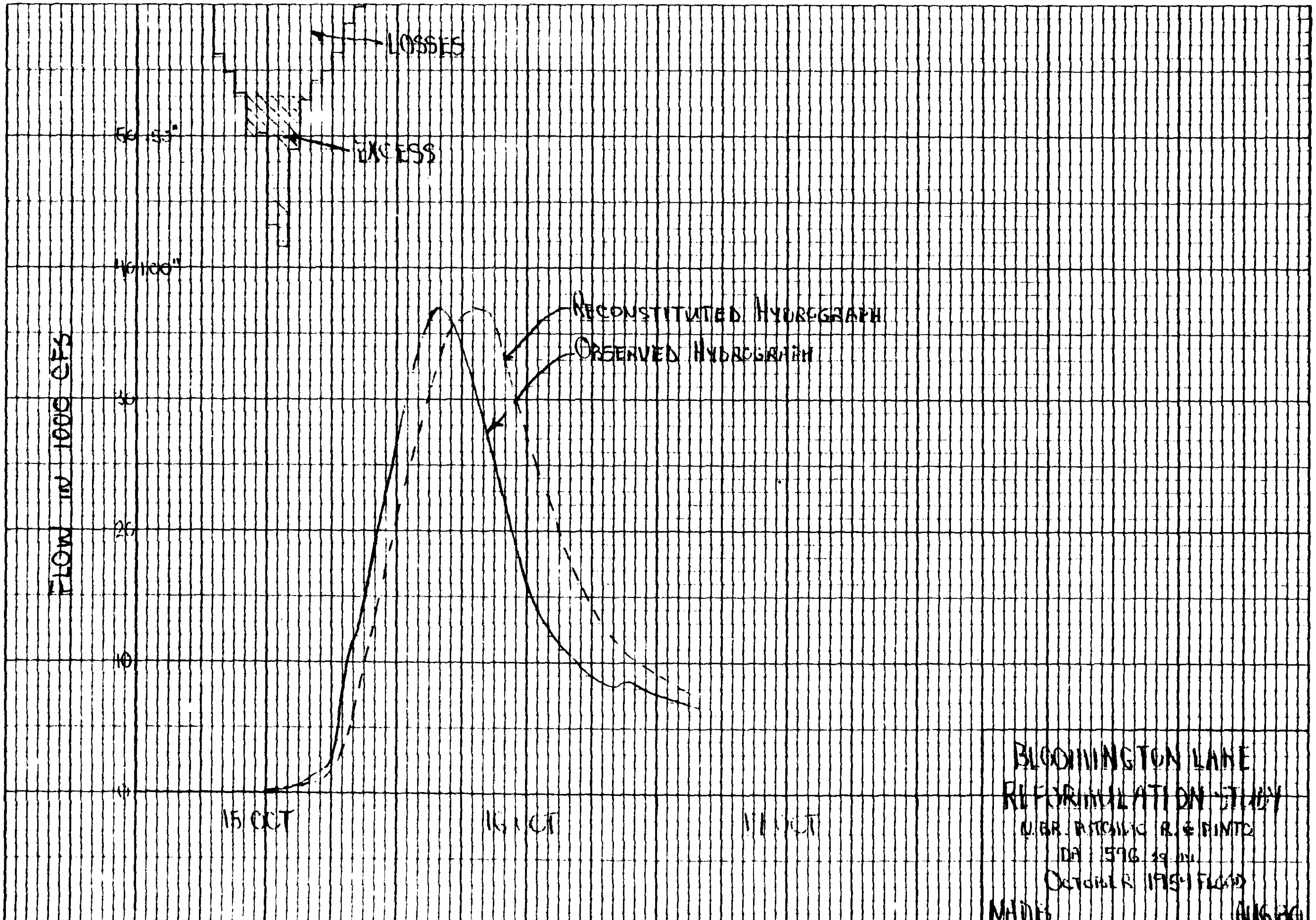


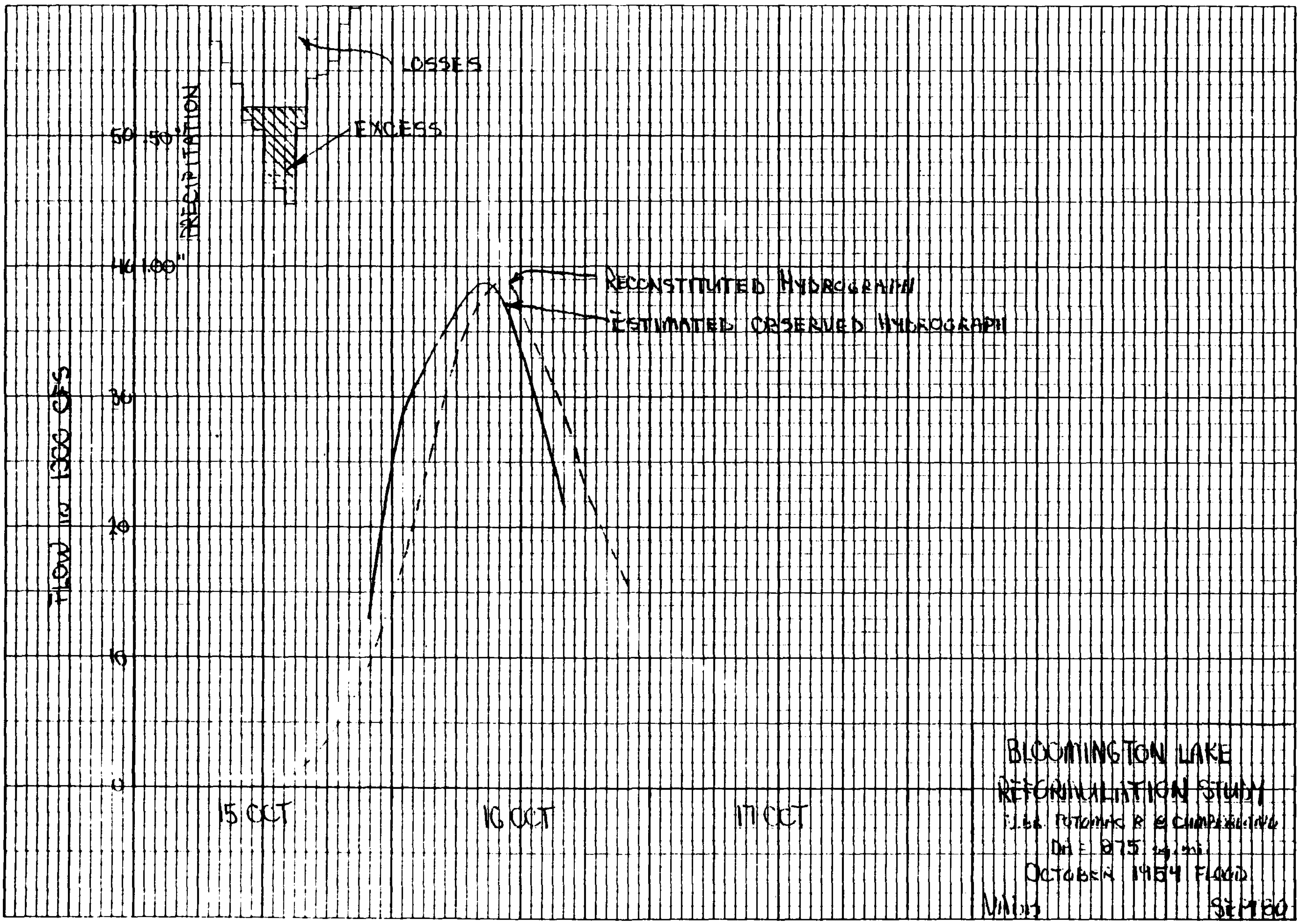
FIGURE H-IV-22

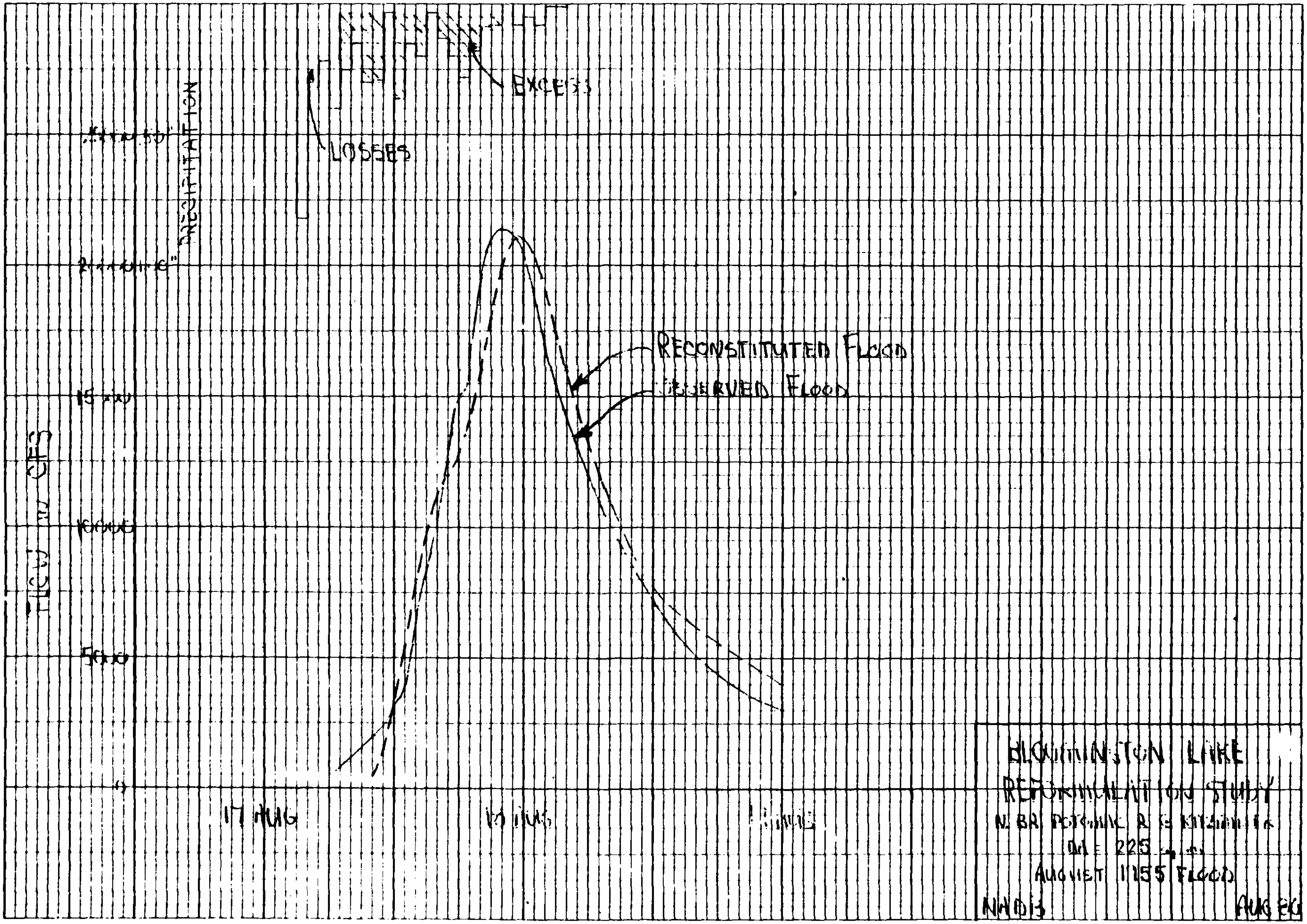

LOSSES
EXCESS
PRECIPITATION
.50"
1.00"
50
40
30
20
10
0
FLOW IN 1000 CFS
RECONSTITUTED HYDROGRAPH
OBSERVED HYDROGRAPH
15 OCT
16 OCT
17 OCT
BLOOMINGTON LAKE
RECONSTITUTION STUDY
N. BR. POTOMAC R. @ LUKE
DA: 404 sq. mi.
OCTOBER 1954 FLOOD
NADB
AUG 80

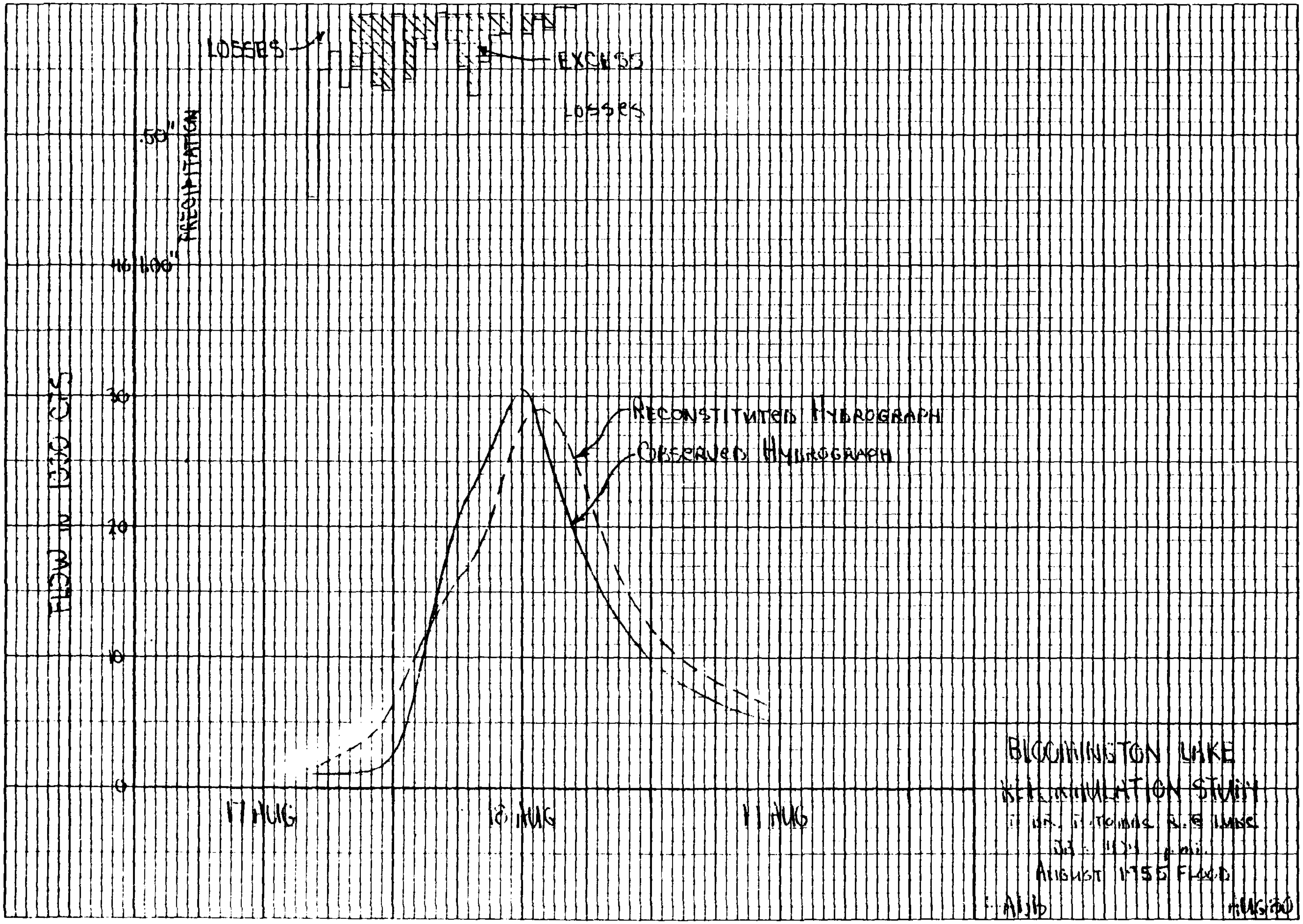

LOSSES
EXCESS
RECONSTITUTED HYDROGRAPH
OBSERVED HYDROGRAPH
FLOW IN 1000 CFS
30
20
10
0
15 OCT
16 OCT
17 OCT
BLOOMINGTON LAKE
REFORMULATION STUDY
DA 576 sq mi
OCTOBER 1954 FLOOD

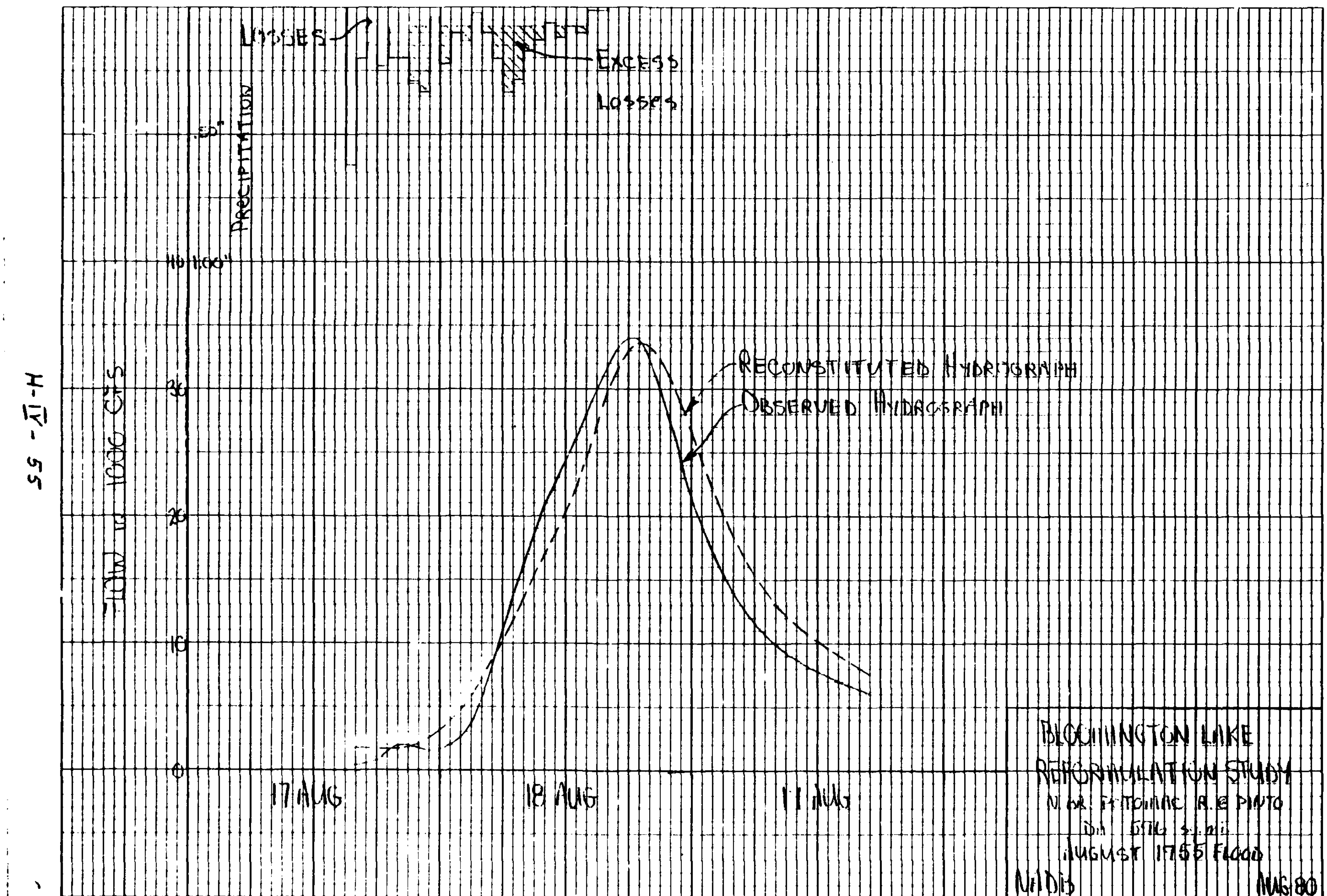
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.




PRECIPITATION
LOSSES
EXCESS
RECONSTITUTED FLOOD
OBSERVED FLOOD
FLOW IN CFS
15000
10000
5000
0
17 AUG
BLOOMINGTON LAKE
REFORMULATION STUDY
N. BR. POTOMAC R.
AUGUST 1155 FLOOD
AUG 80


LOSSES
EXCESS
LOSSES
.50"
1.00"
PRECIPITATION
FLOW IN 1000 CFS
30
20
10
0
RECONSTITUTED HYDROGRAPH
OBSERVED HYDROGRAPH
17 AUG
18 AUG
19 AUG
BLOOMINGTON LAKE
RECONSTITUTION STUDY
AUGUST 1955 FLOOD


LOSSES
EXCESS
LOSSES
.50"
PRECIPITATION
IN 1000'
30
20
10
0
RECONSTITUTED HYDROGRAPH
OBSERVED HYDROGRAPH
17 AUG
18 AUG
19 AUG
BLOOMINGTON LAKE
REFORMULATION STUDY
N BR POTOMAC R @ PINTO
AUGUST 1955 FLOOD
NADIS
AUG 80

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

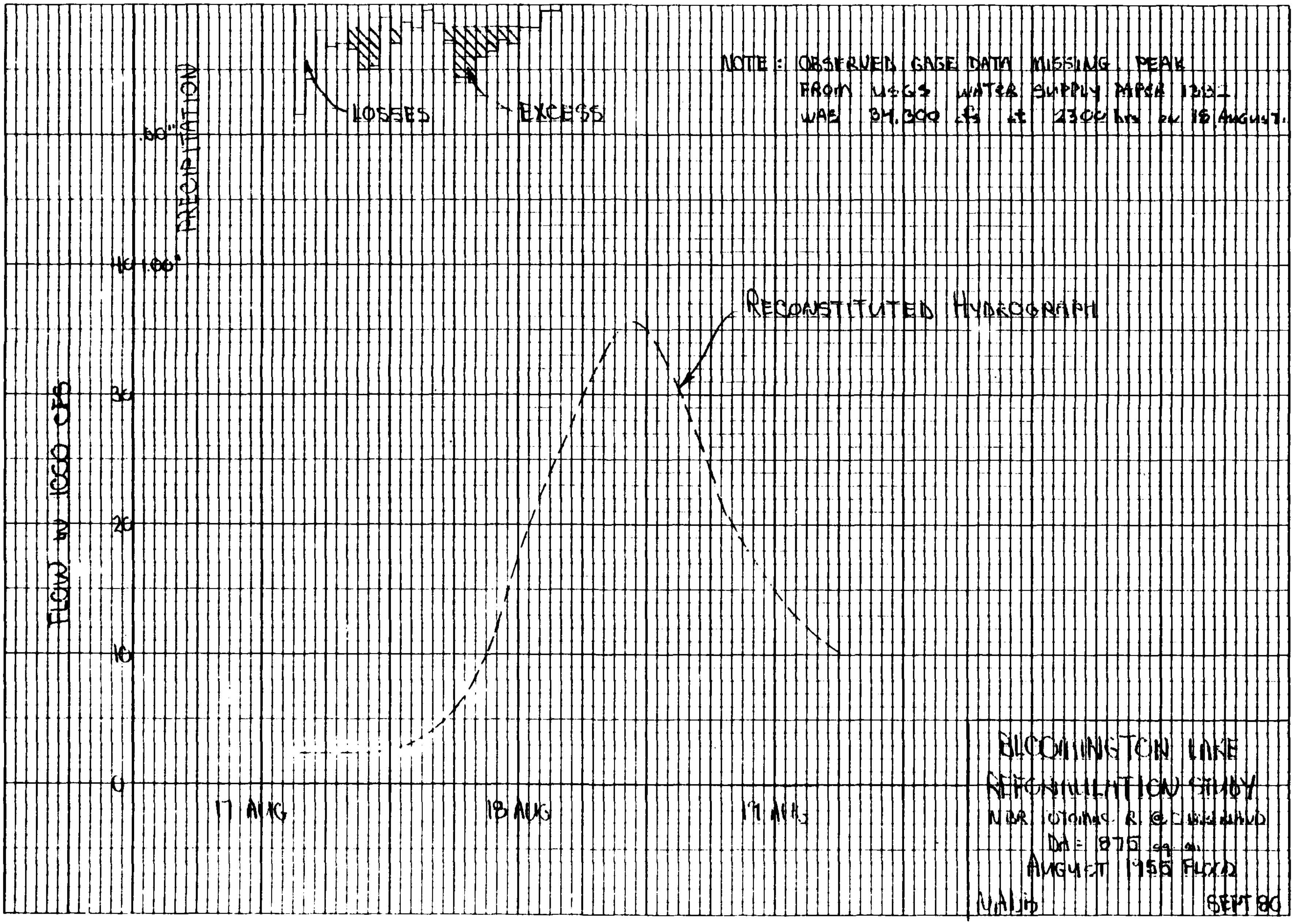


FIGURE H-IV-29

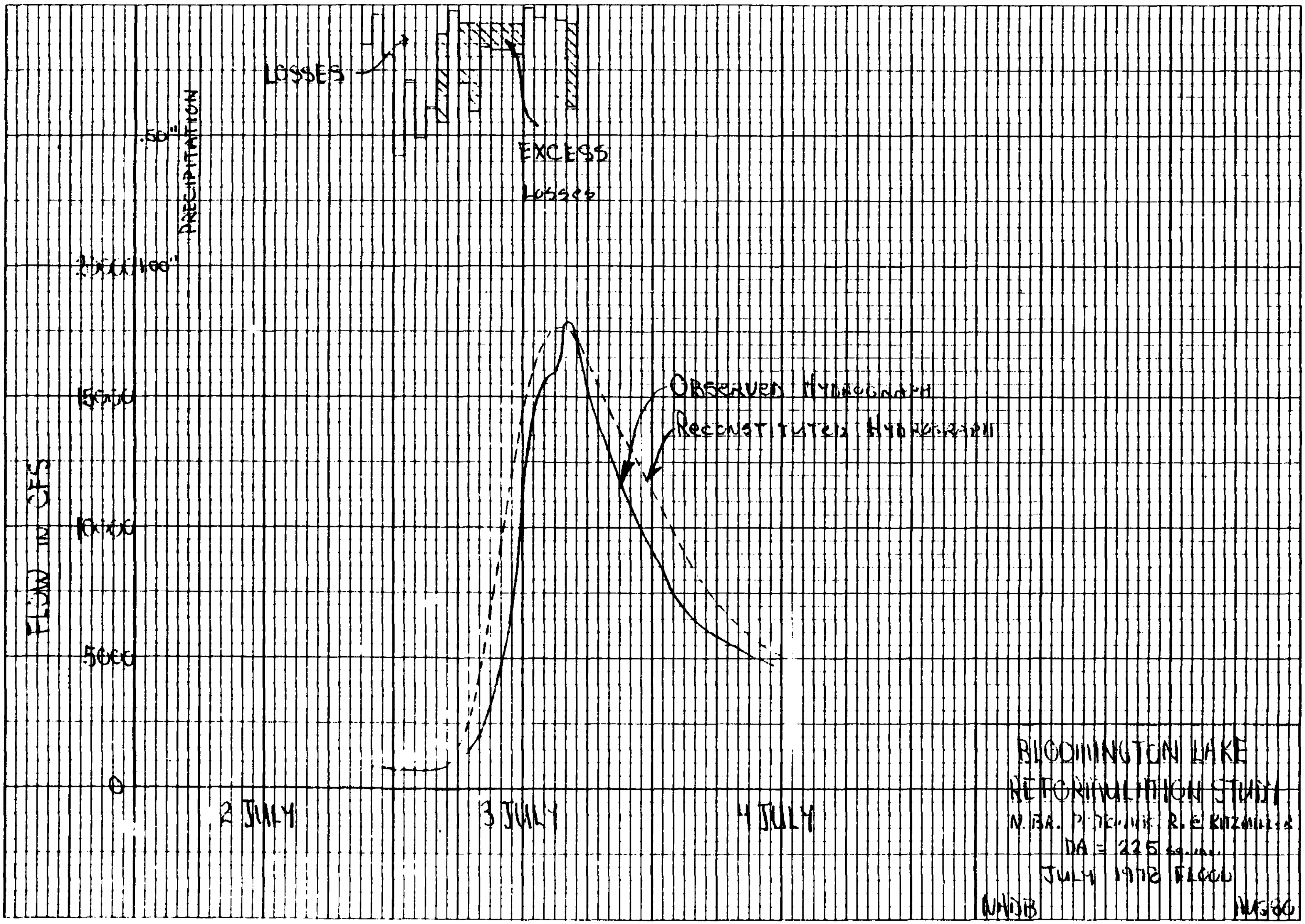
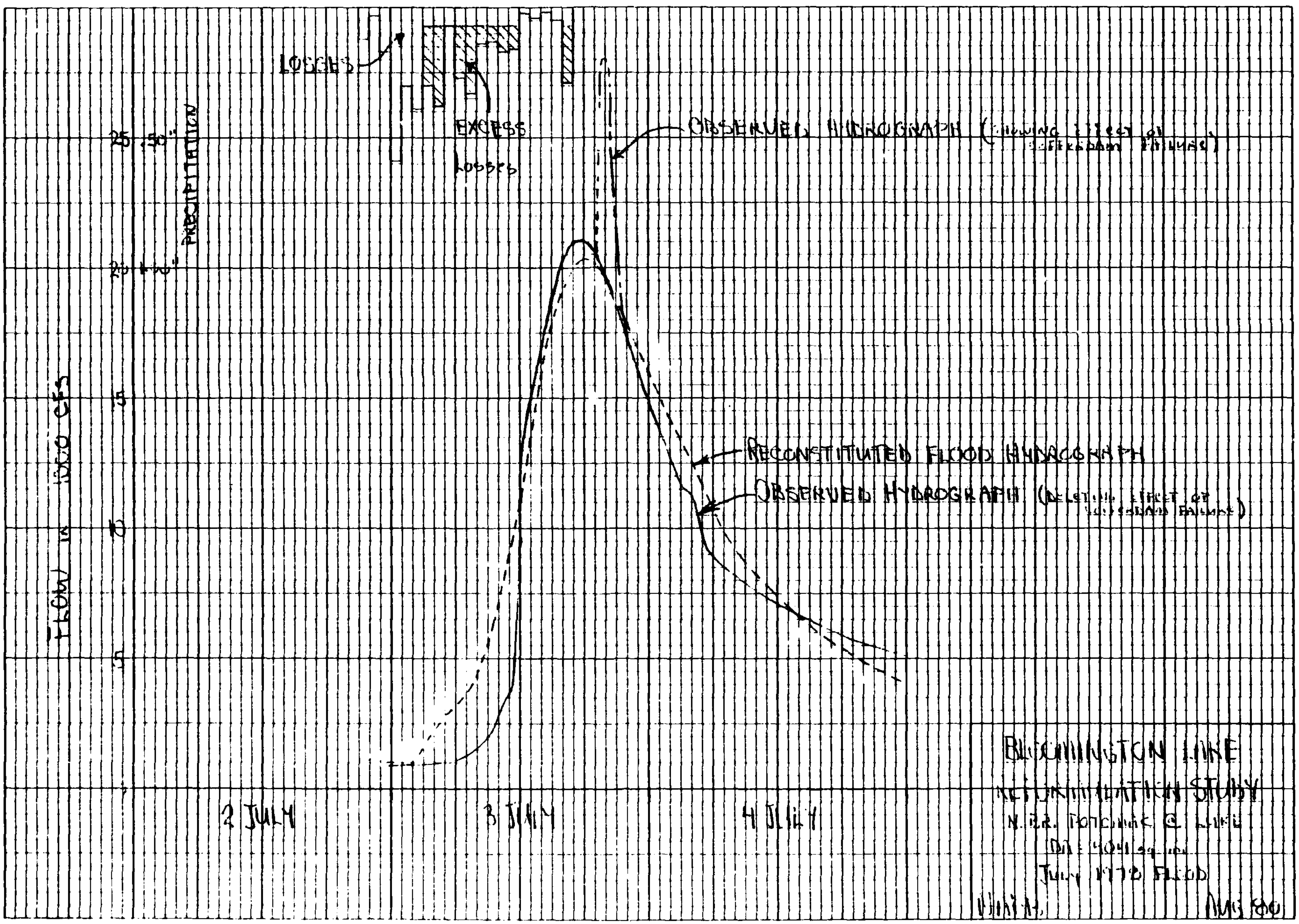


FIGURE H-IV-30

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



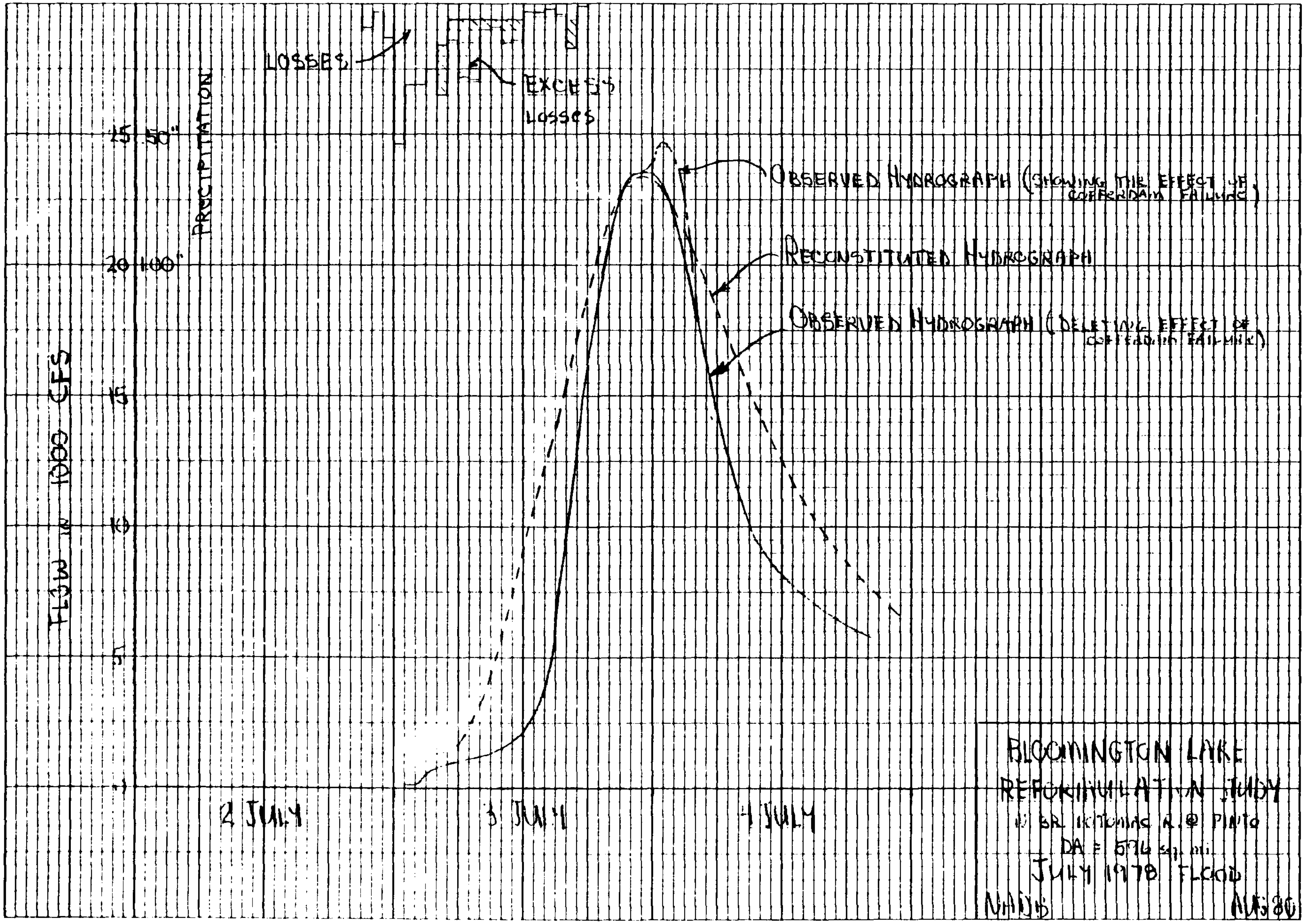


FIGURE H-IV-32

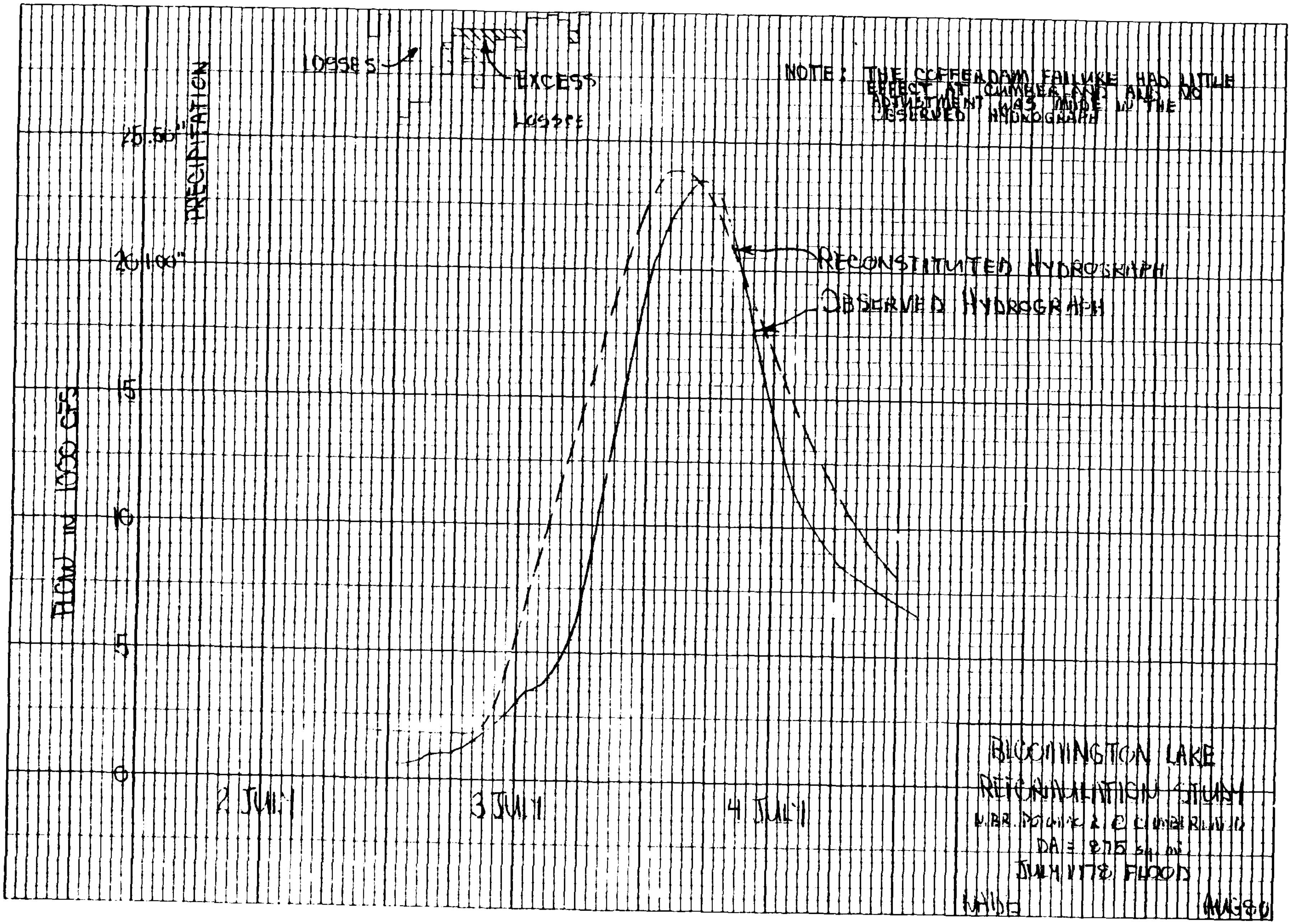
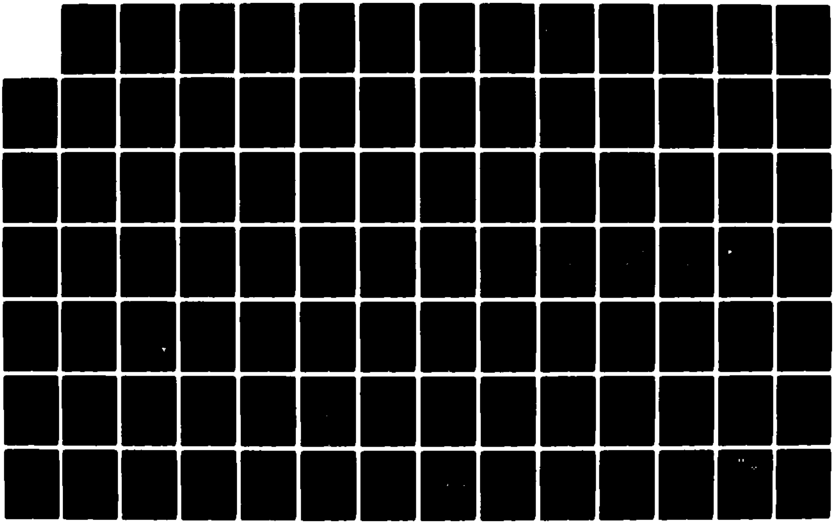
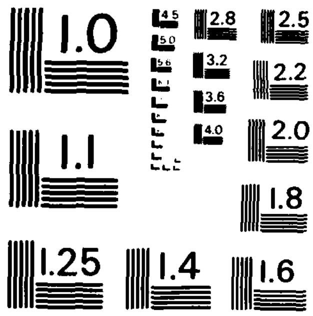


FIGURE H-IV-33

AD-A134 161 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX H BLOOMINGTON LA..(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83 3/5

UNCLASSIFIED MWA-83-P-APP-H-VOL-2 F/G 13/2 NL

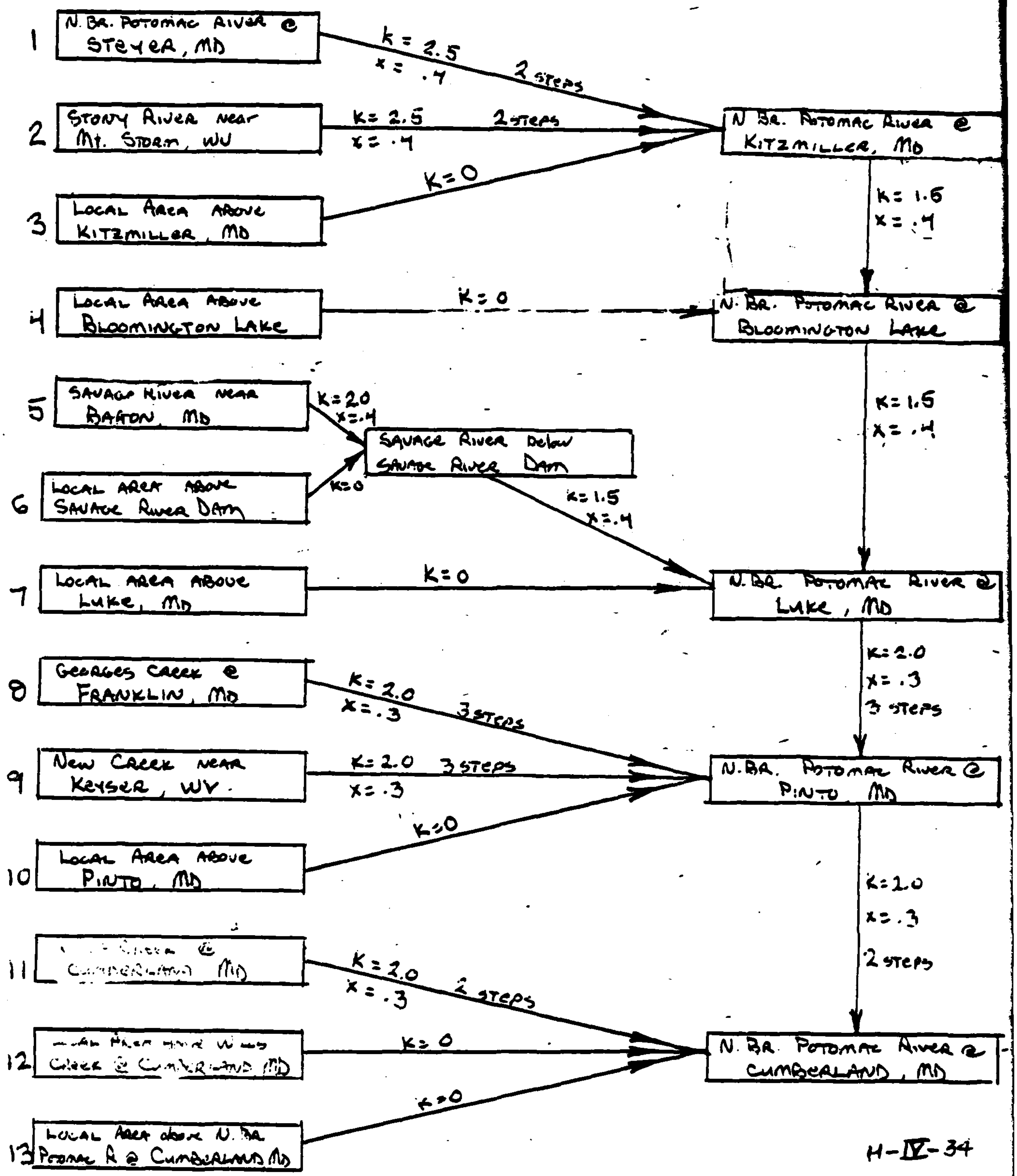




MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

North Branch Potomac River Basin
Above Cumberland, MD
HEC-1 Model Flow Chart

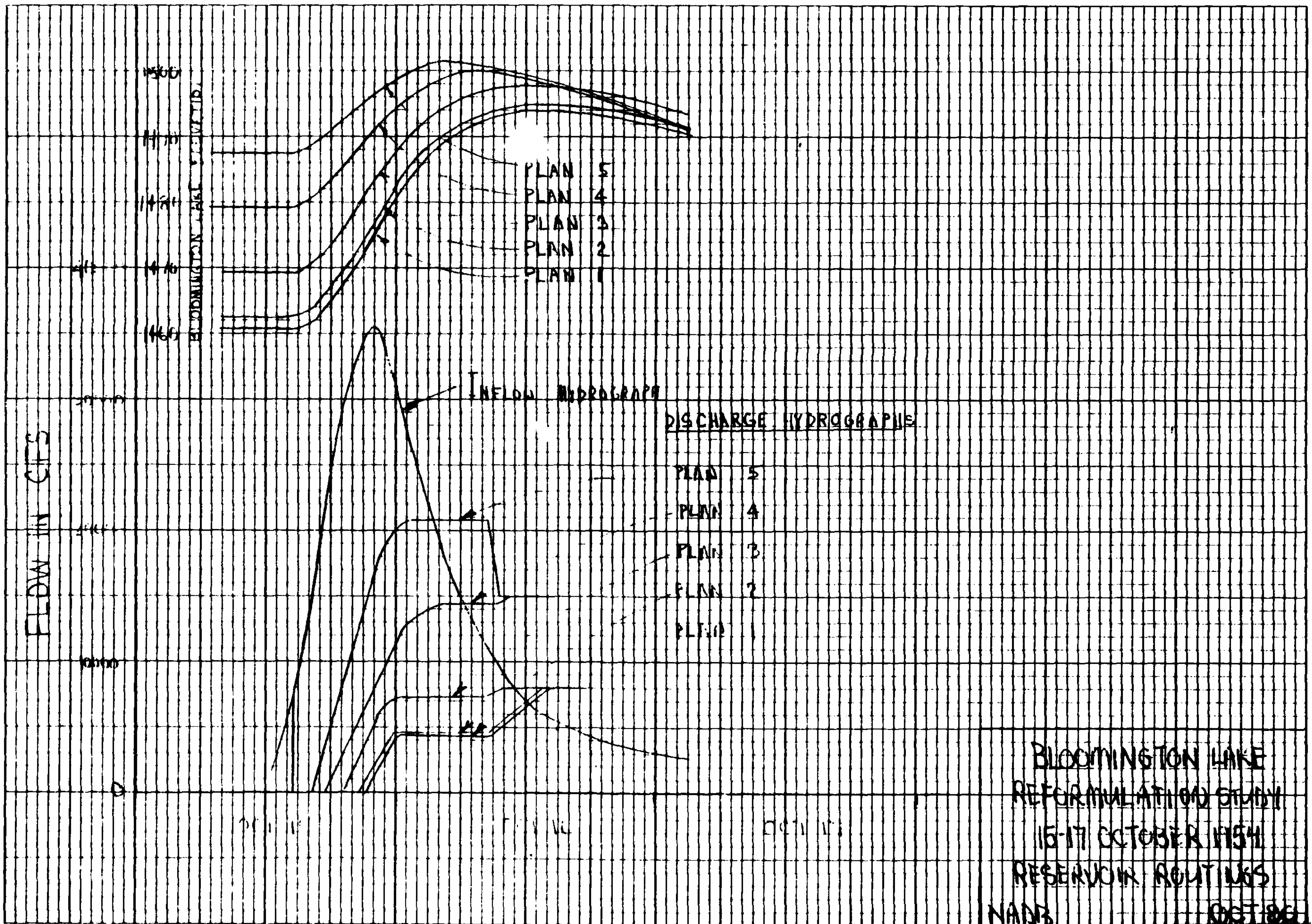


H-IV-34

Figure

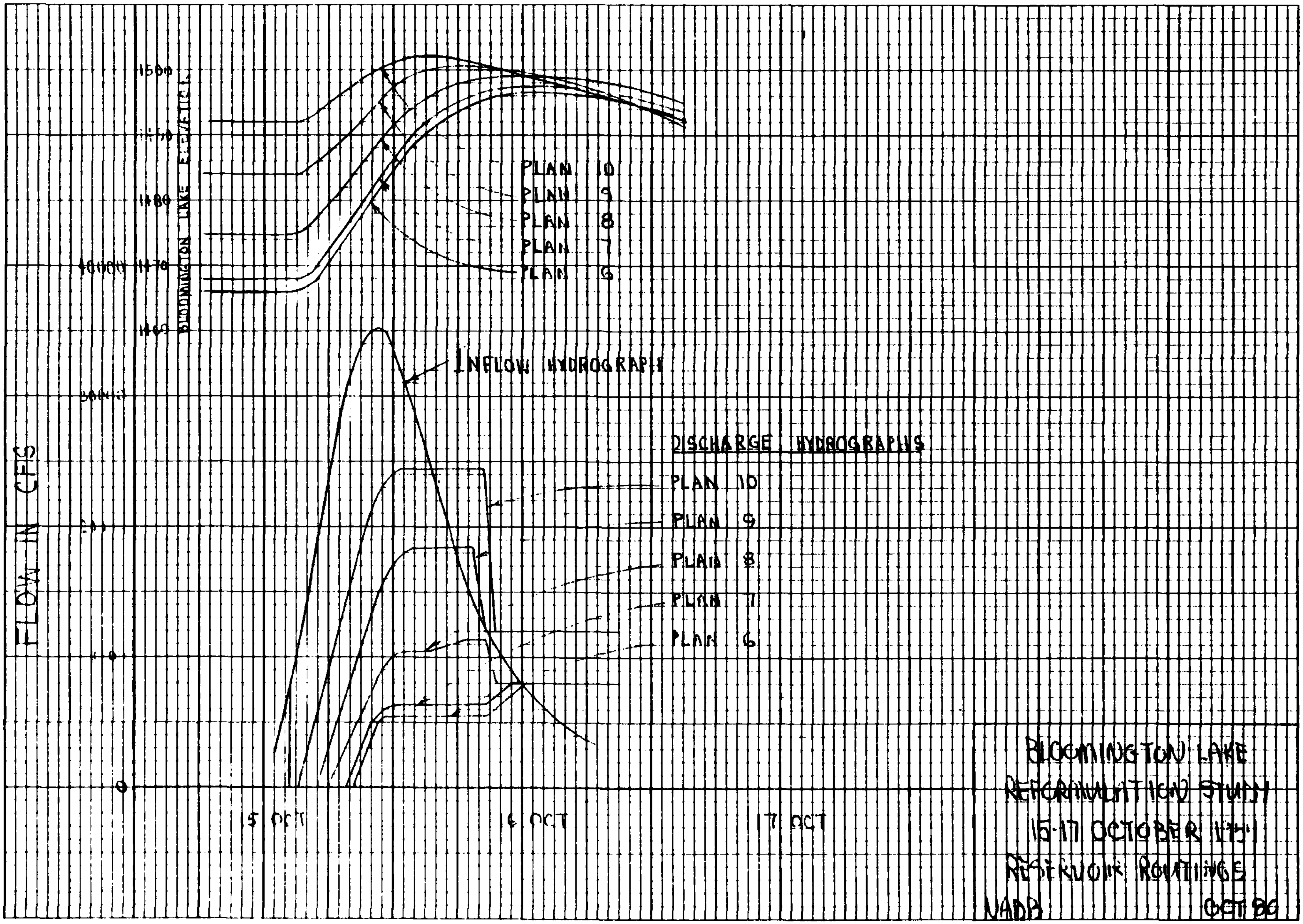
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



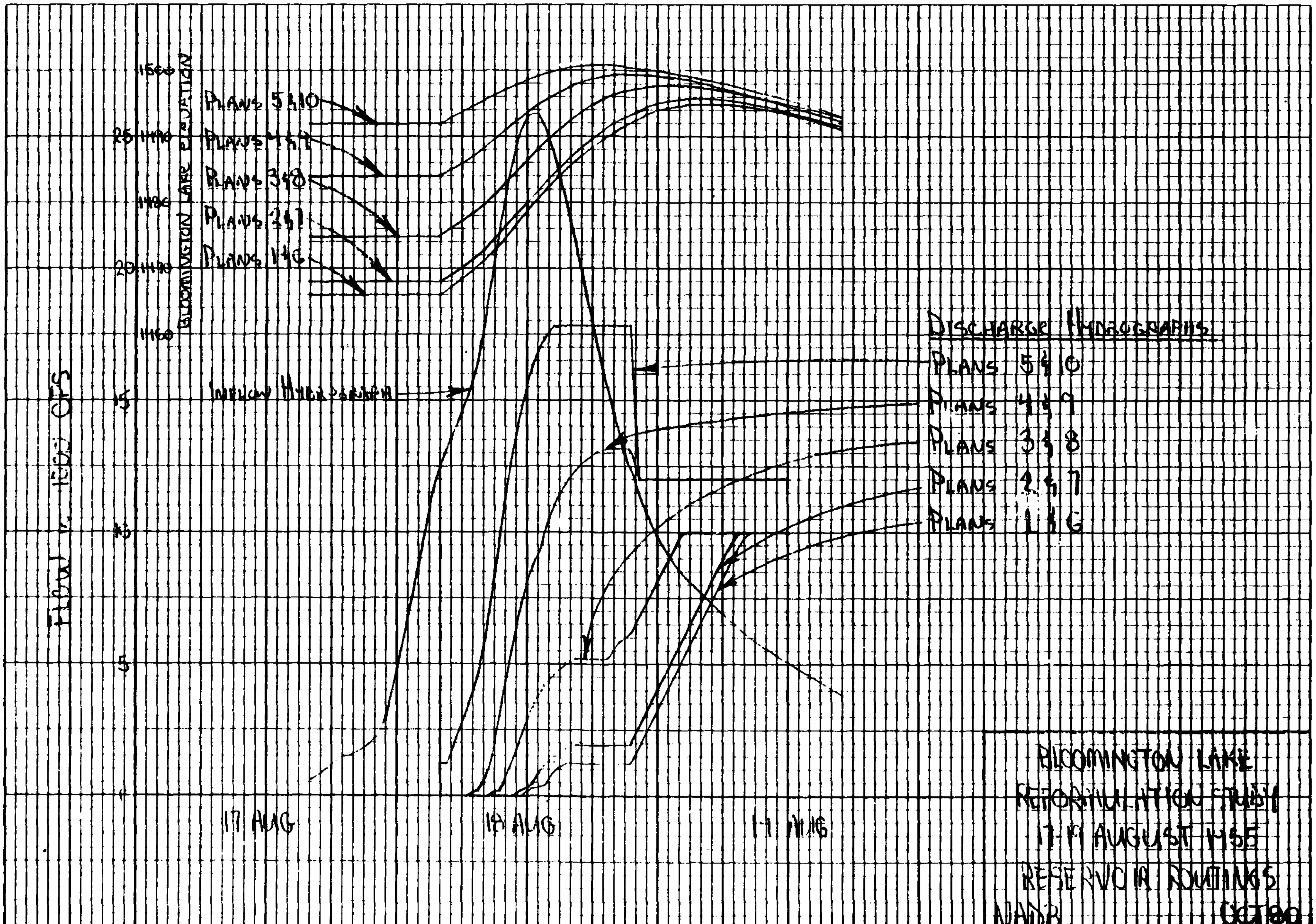
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



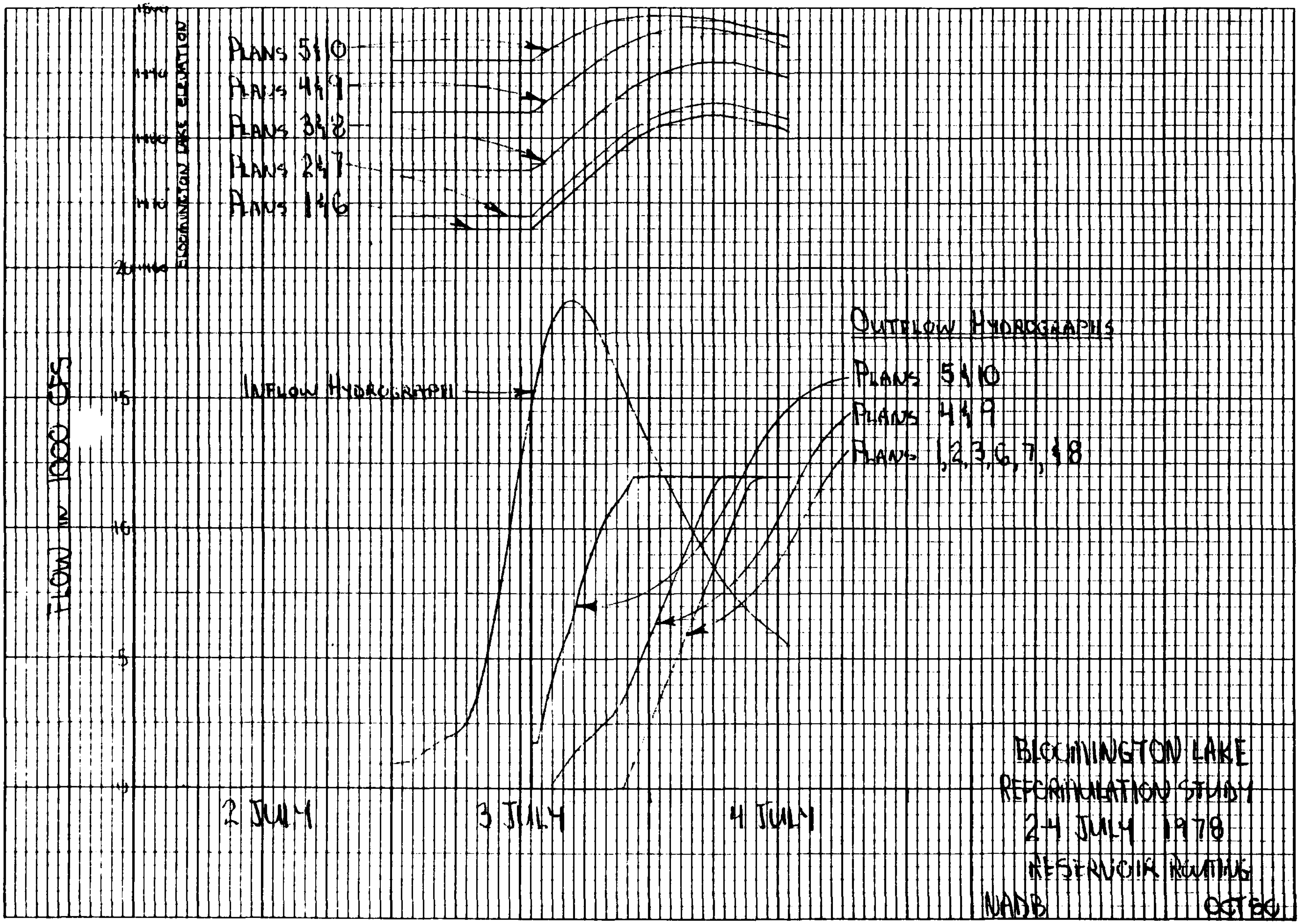
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

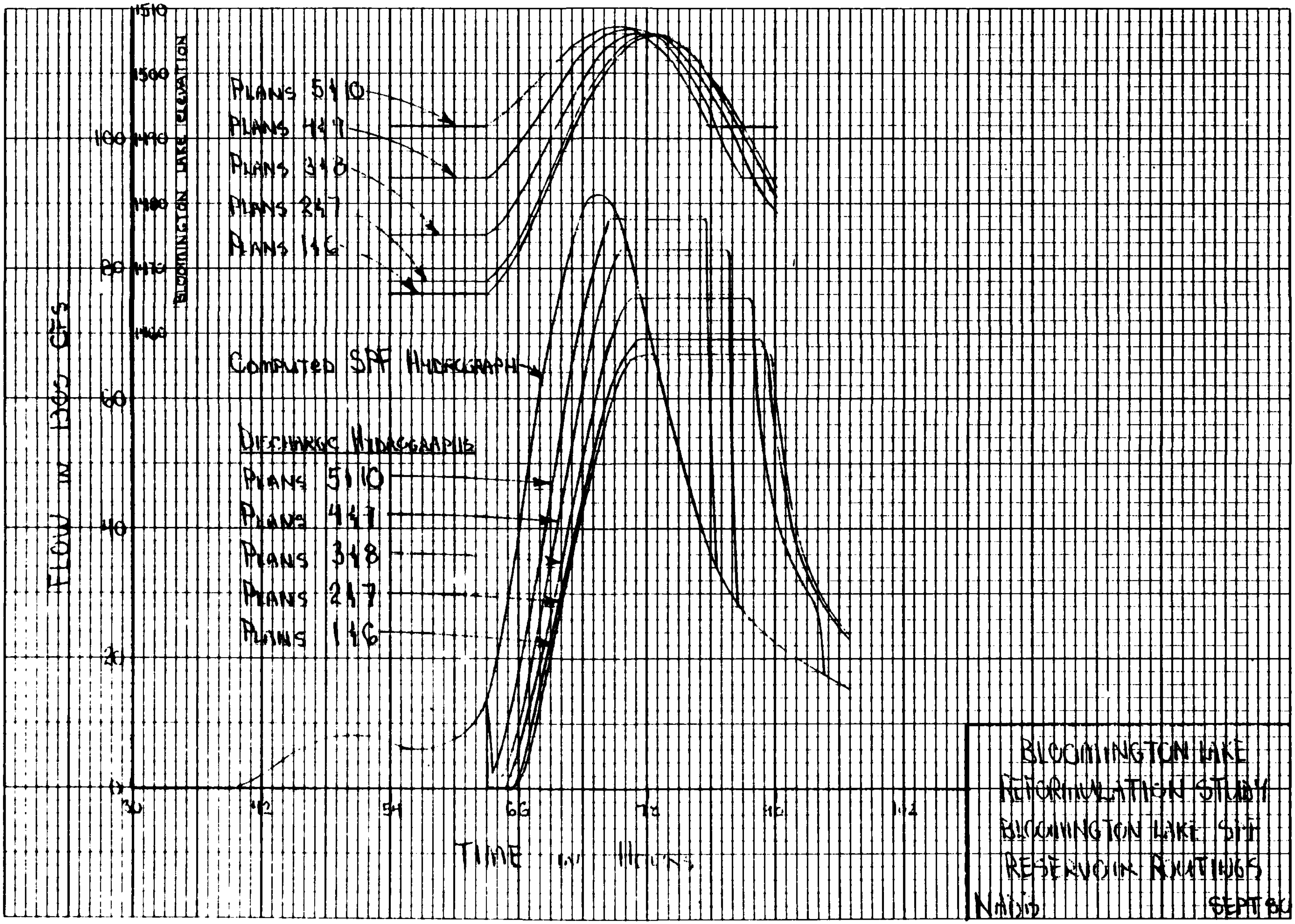
DIETZGEN CORPORATION
MADE IN U.S.A.



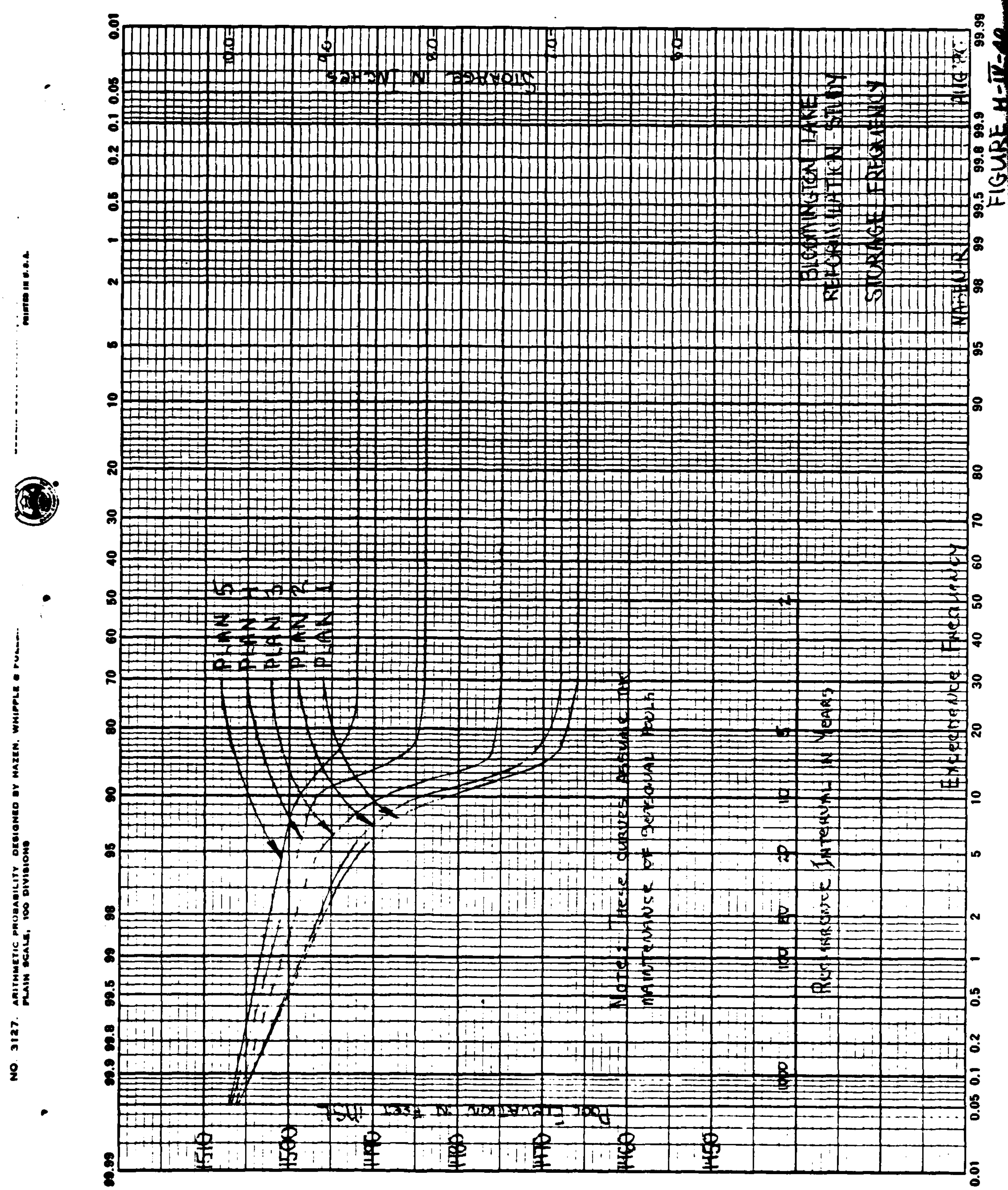
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

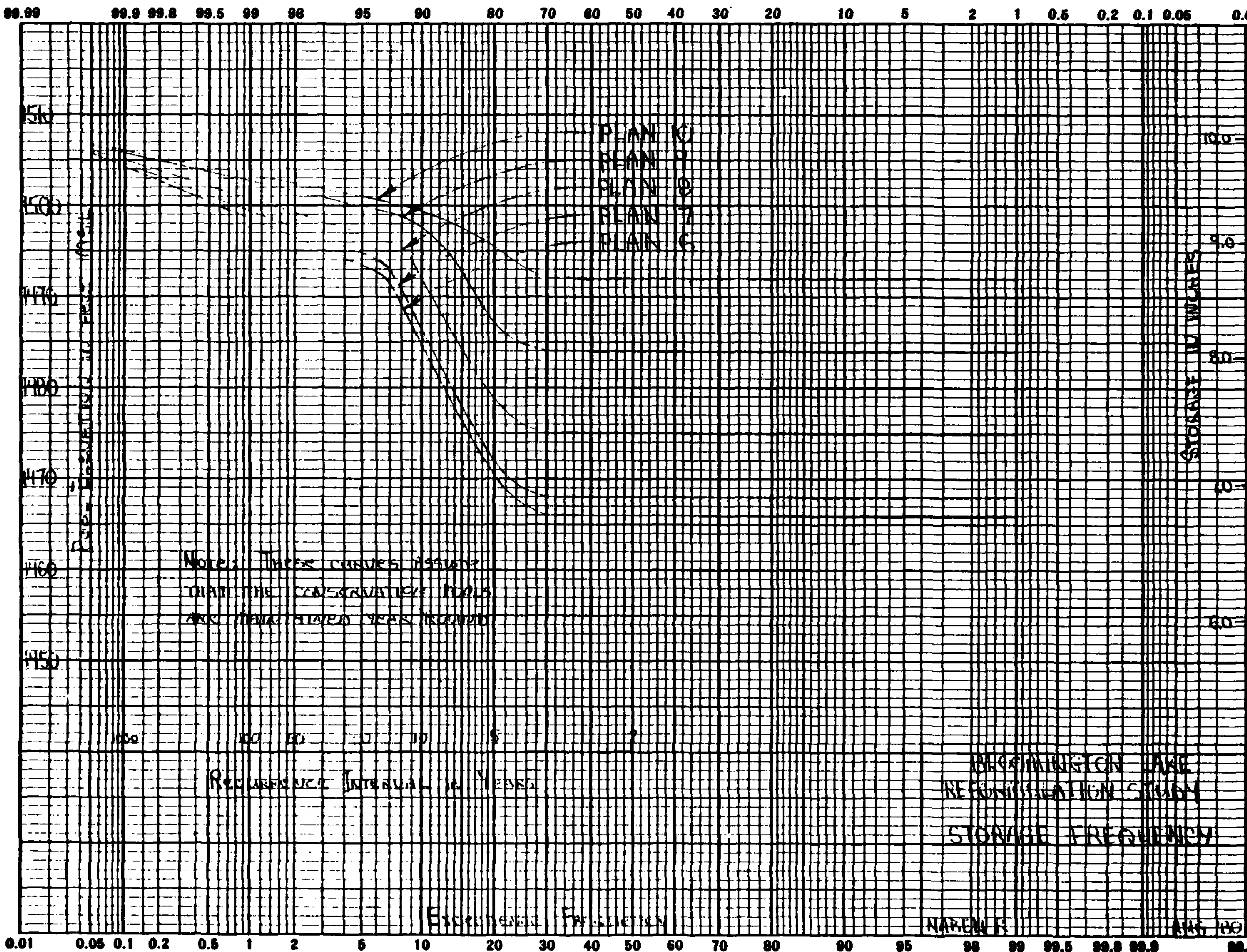



FLOW IN 1000s CFS
BLOOMINGTON LAKE ELEVATION
1510
1500
1490
1480
1470
1460
100
80
60
40
20
0
PLANS 5 & 10
PLANS 4 & 7
PLANS 3 & 8
PLANS 2 & 7
PLANS 1 & 6
COMPUTED SPF HYDROGRAPH
DISCHARGE HYDROGRAPHS
PLANS 5 & 10
PLANS 4 & 7
PLANS 3 & 8
PLANS 2 & 7
PLANS 1 & 6
30
42
54
66
78
90
102
TIME IN HOURS
BLOOMINGTON LAKE
REFORMULATION STUDY
BLOOMINGTON LAKE SPF
RESERVOIR ROUTINGS

H-XI-66


NO. 3127. ARITHMETIC PROBABILITY DESIGNED BY HAZEN, WHIPPLE & FULLER
PLAIN SCALE, 100 DIVISIONS
PRINTED IN U.S.A.
BLOOMINGTON LAKE
REFORMULATION STUDY
STORAGE FREQUENCY
FIGURE H-IV-40
STORAGE IN INCHES
POOL ELEVATION IN FEET MSL
PLAN 5
PLAN 4
PLAN 3
PLAN 2
PLAN 1
Note: These curves assume the maintenance of seasonal pools
Recurrence Interval in Years
Exceedance Frequency

PLAIN SCALE, 100 DIVISIONS



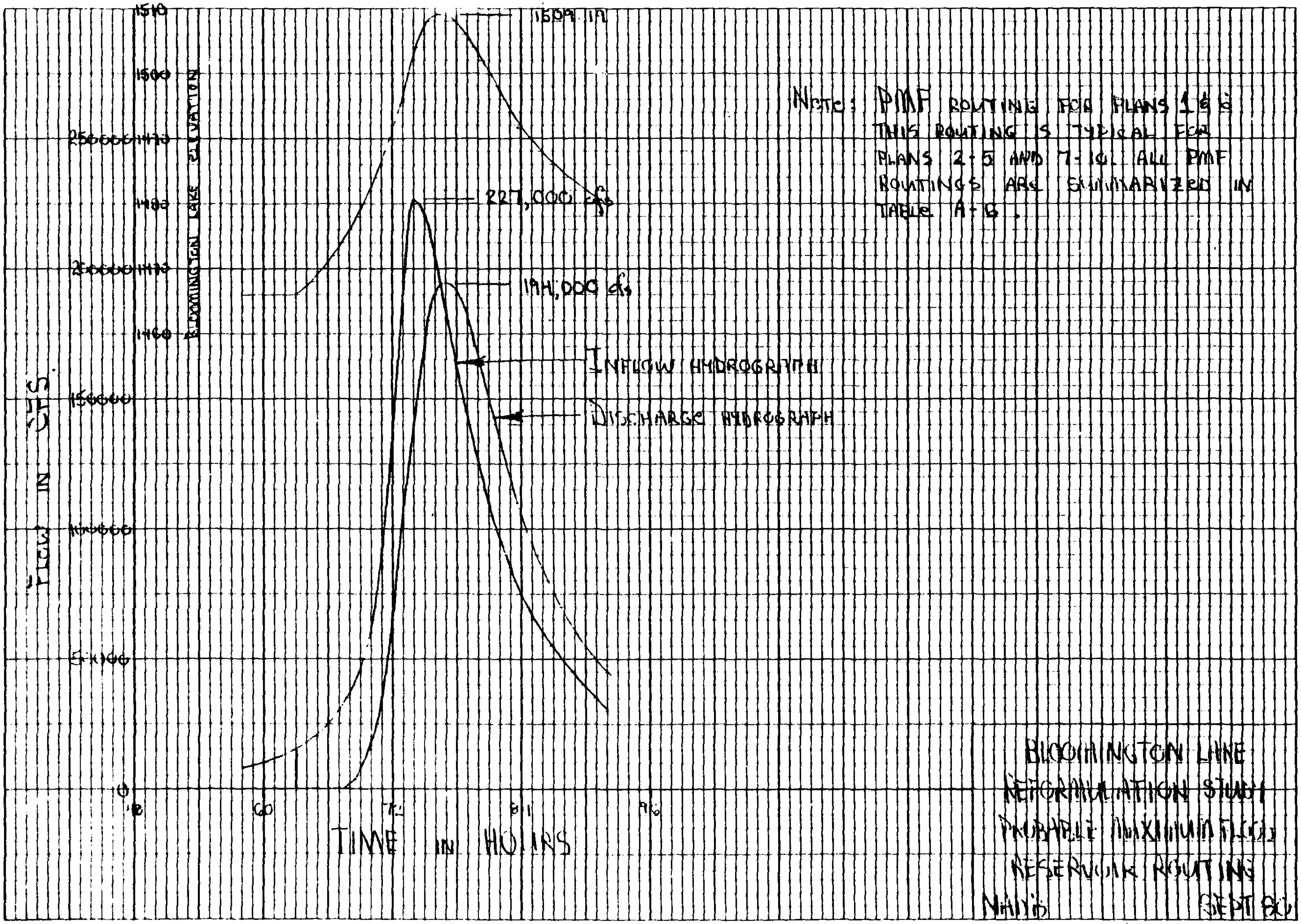


FIGURE H-IV-42

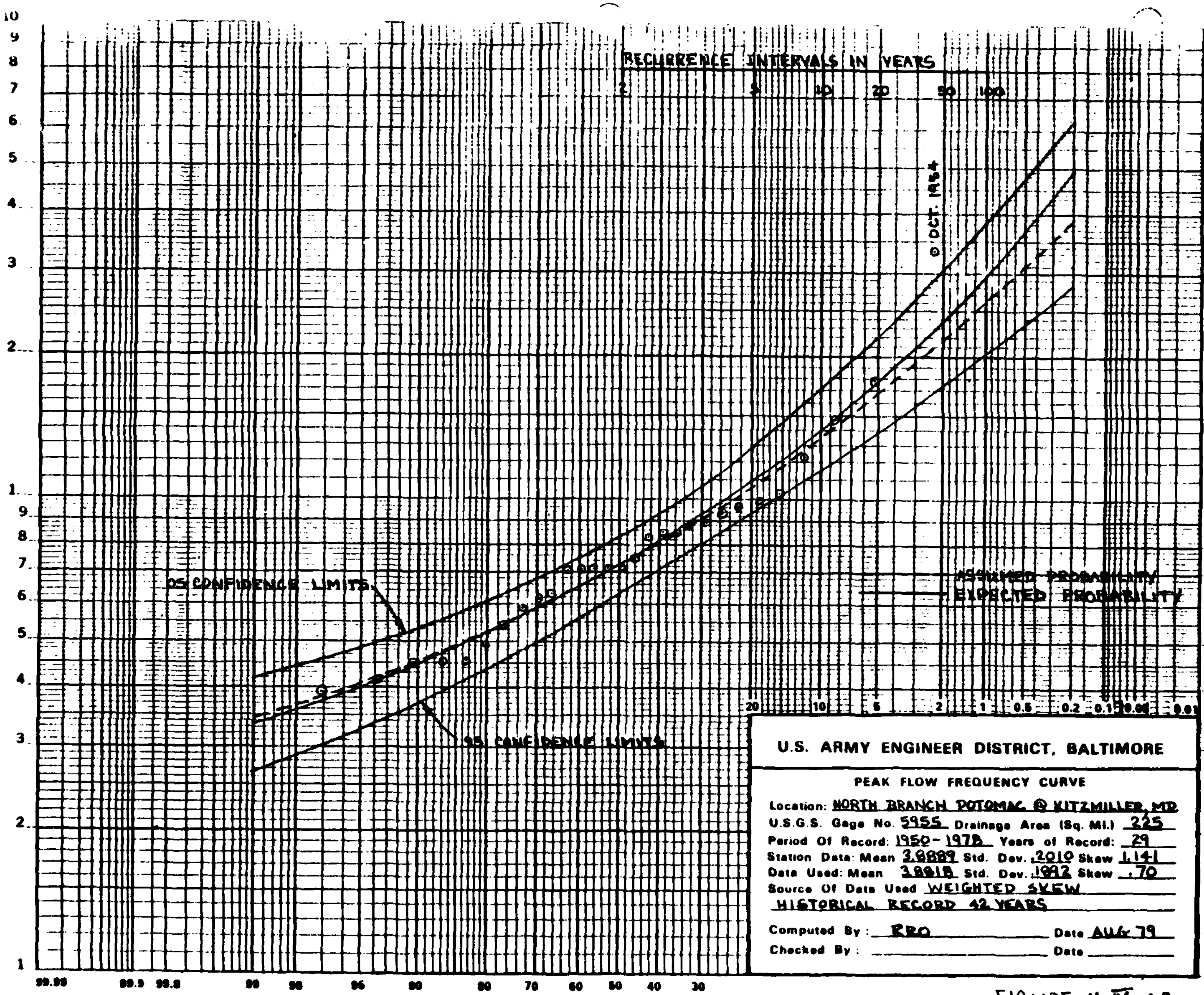


FIGURE H-IV-43

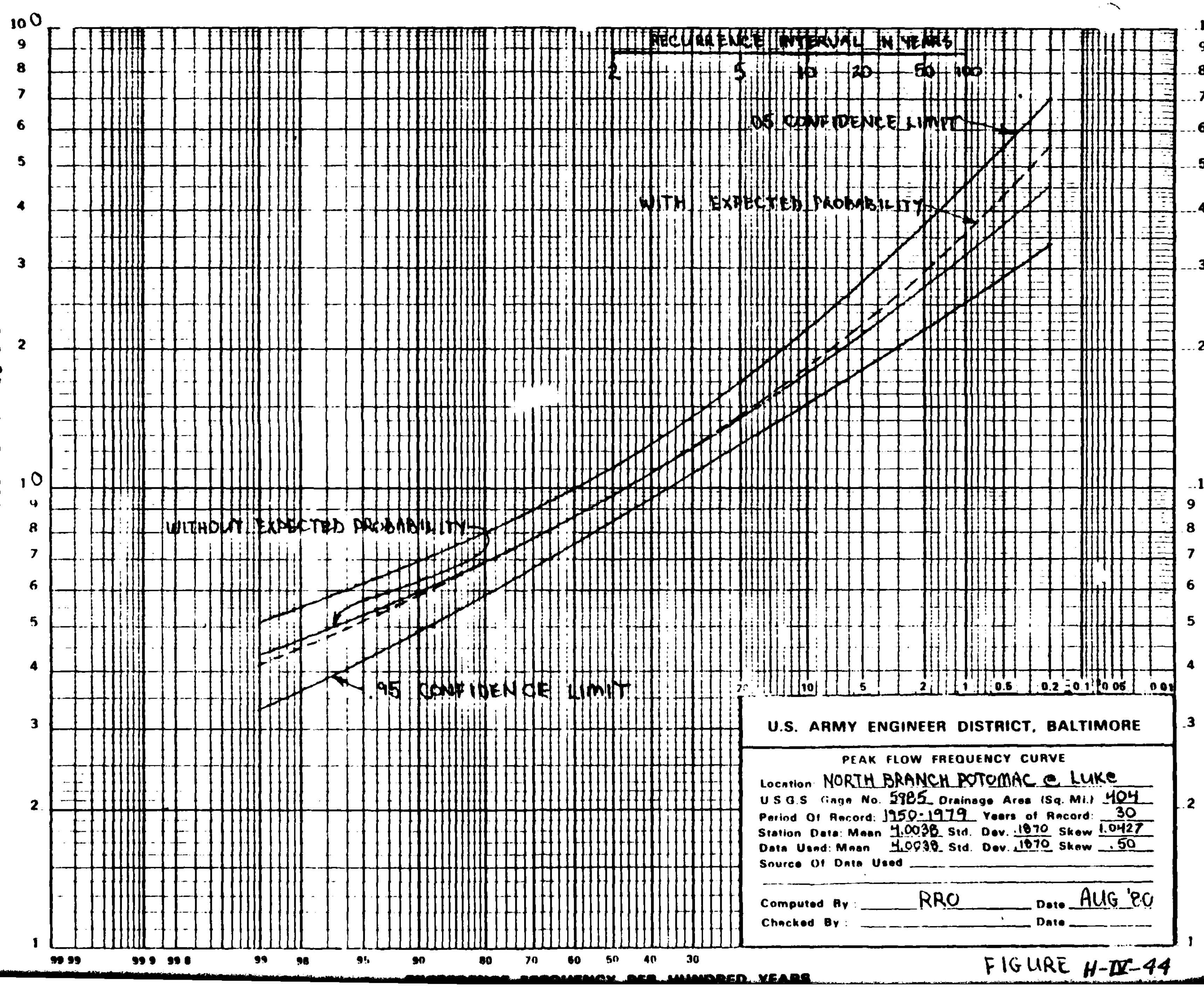
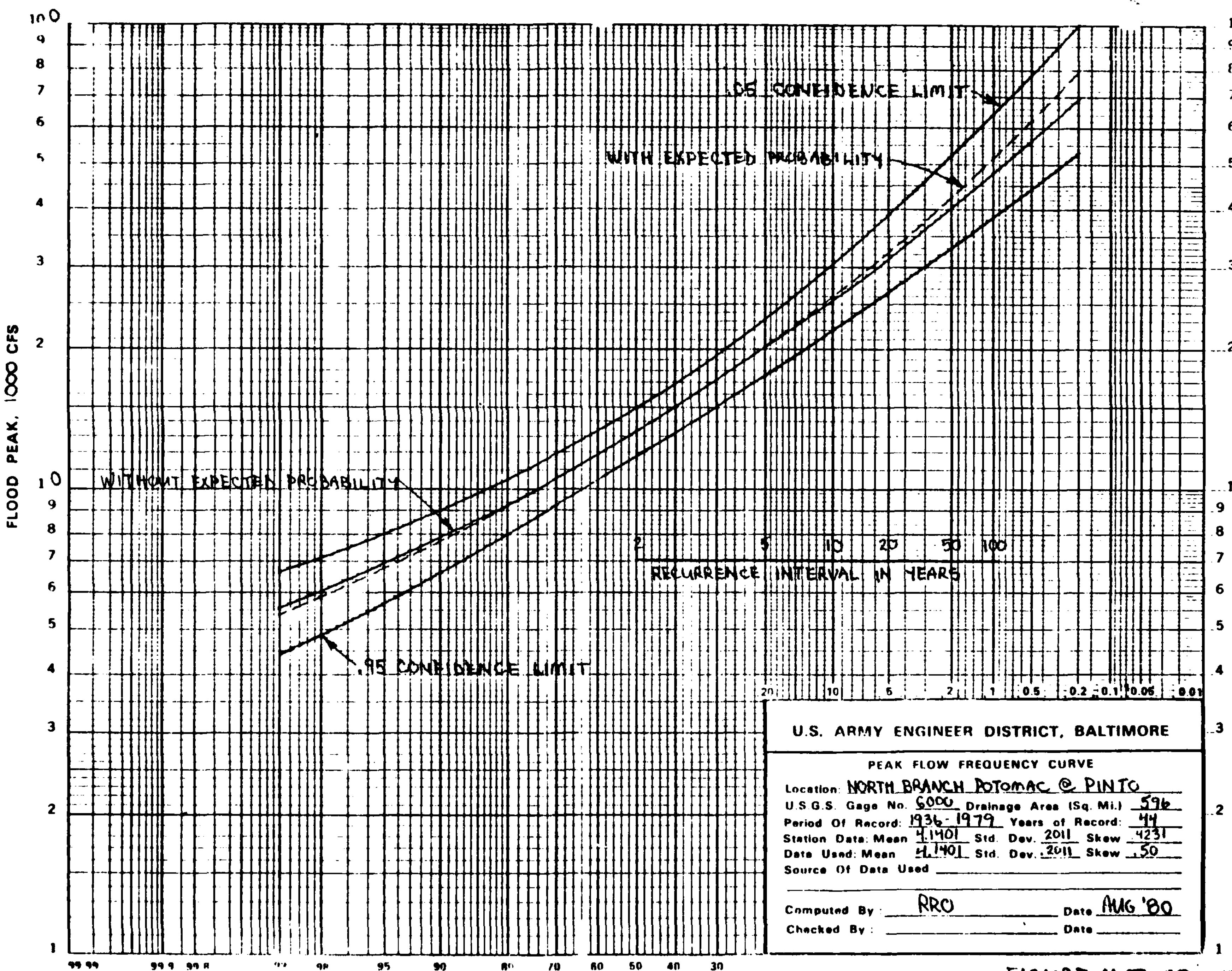
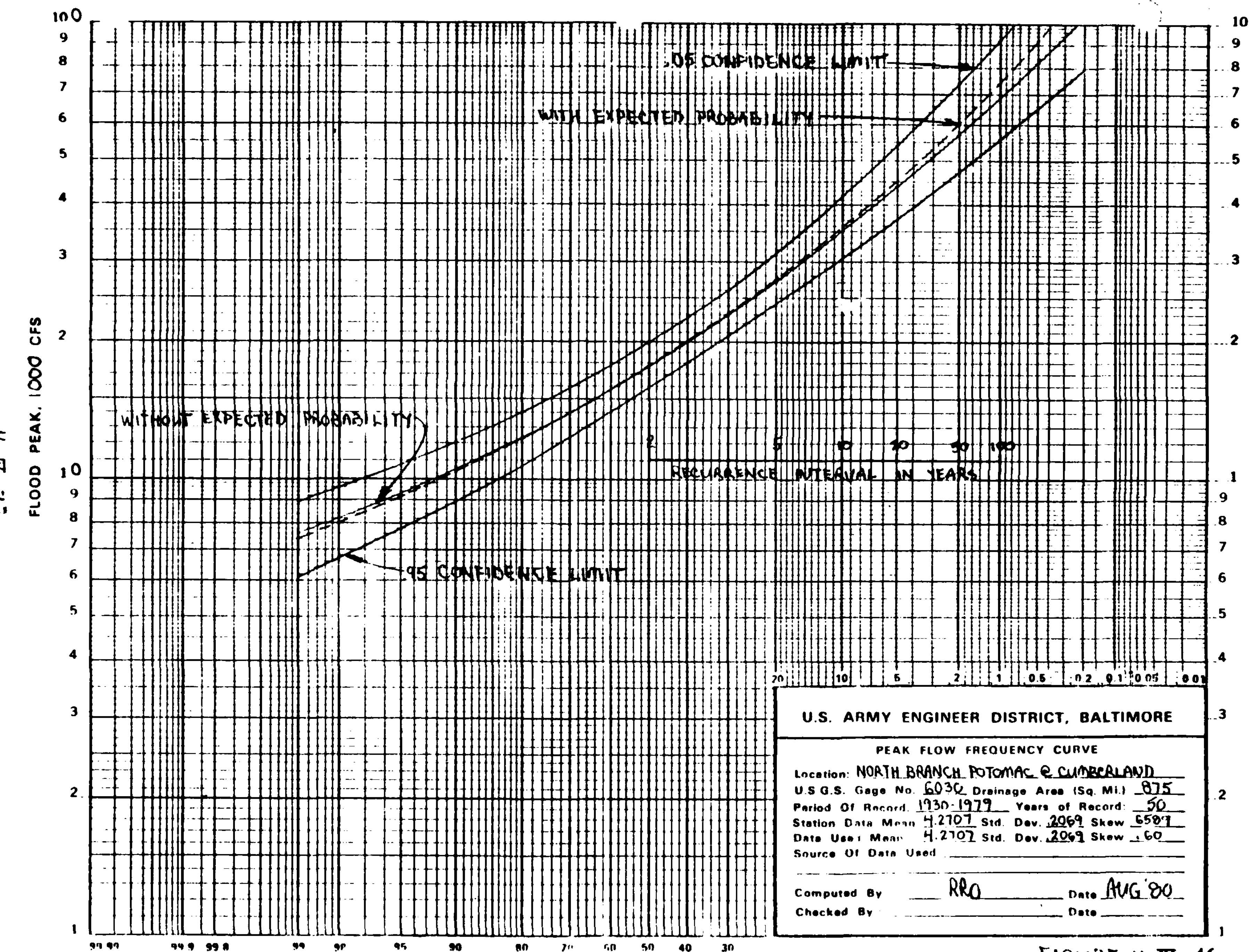


FIGURE H-IV-44



FLOOD PEAK, 1000 CFS
.05 CONFIDENCE LIMIT
WITH EXPECTED PROBABILITY
WITHOUT EXPECTED PROBABILITY
.95 CONFIDENCE LIMIT
RECURRENCE INTERVAL IN YEARS
2 5 10 20 50 100
U.S. ARMY ENGINEER DISTRICT, BALTIMORE
PEAK FLOW FREQUENCY CURVE
Location: NORTH BRANCH POTOMAC @ PINTO
U.S.G.S. Gage No. 6000 Drainage Area (Sq. Mi.) 596
Period Of Record: 1936-1979 Years of Record: 44
Station Data: Mean 4.1401 Std. Dev. .2011 Skew .4231
Data Used: Mean 4.1401 Std. Dev. .2011 Skew .50
Source Of Data Used
Computed By: RRO Date AUG '80
Checked By: Date



U.S. ARMY ENGINEER DISTRICT, BALTIMORE

PEAK FLOW FREQUENCY CURVE

Location: NORTH BRANCH POTOMAC @ CUMBERLAND
U.S.G.S. Gage No. 6030 Drainage Area (Sq. Mi.) 875
Period Of Record. 1930-1979 Years of Record: 50
Station Data Mean 4.2707 Std. Dev. .2069 Skew .6509
Date Used Mean 4.2707 Std. Dev. .2069 Skew .60
Source Of Data Used

Computed By RRO Date AUG '80
Checked By Date

FIGURE H-IV-46

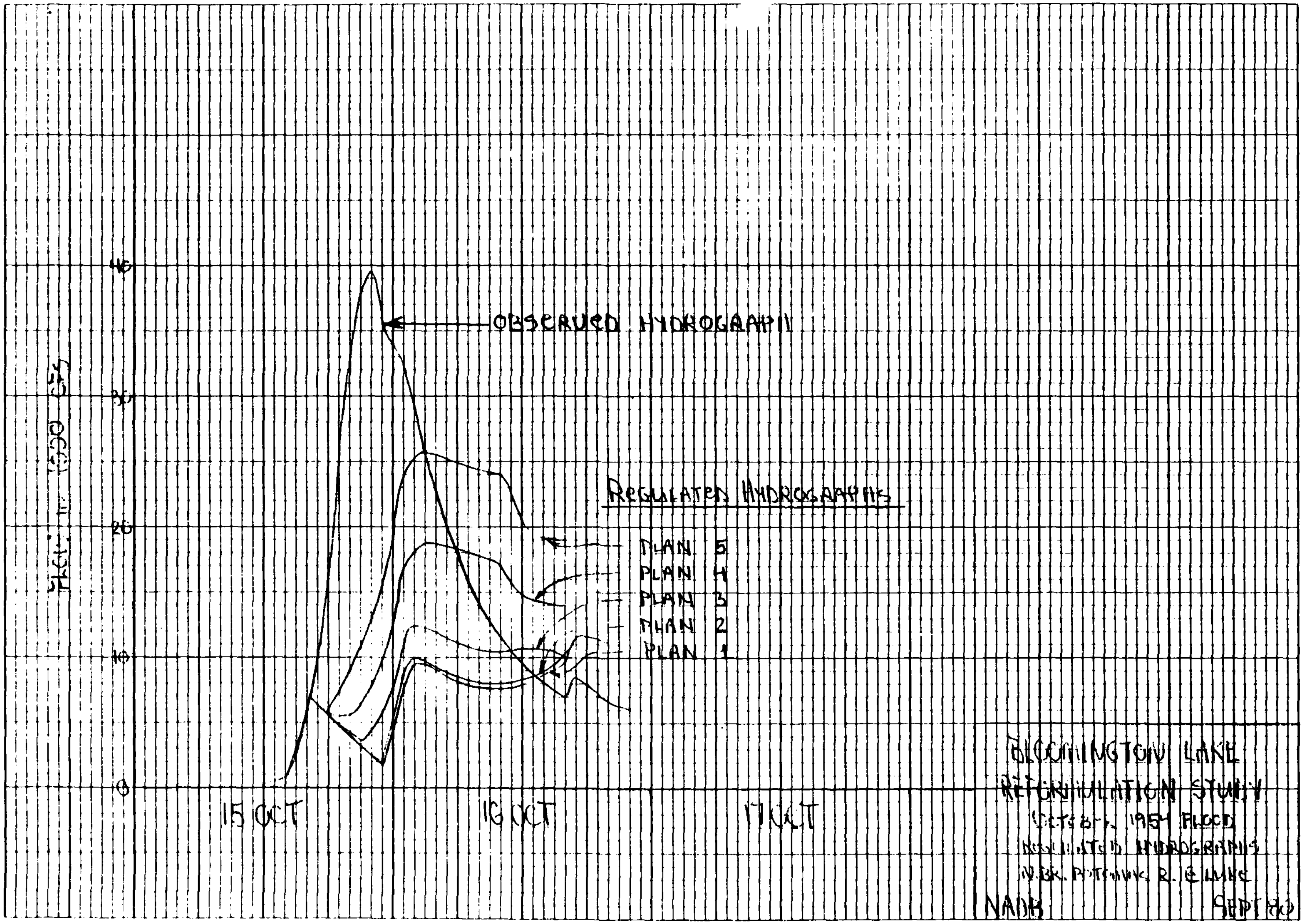
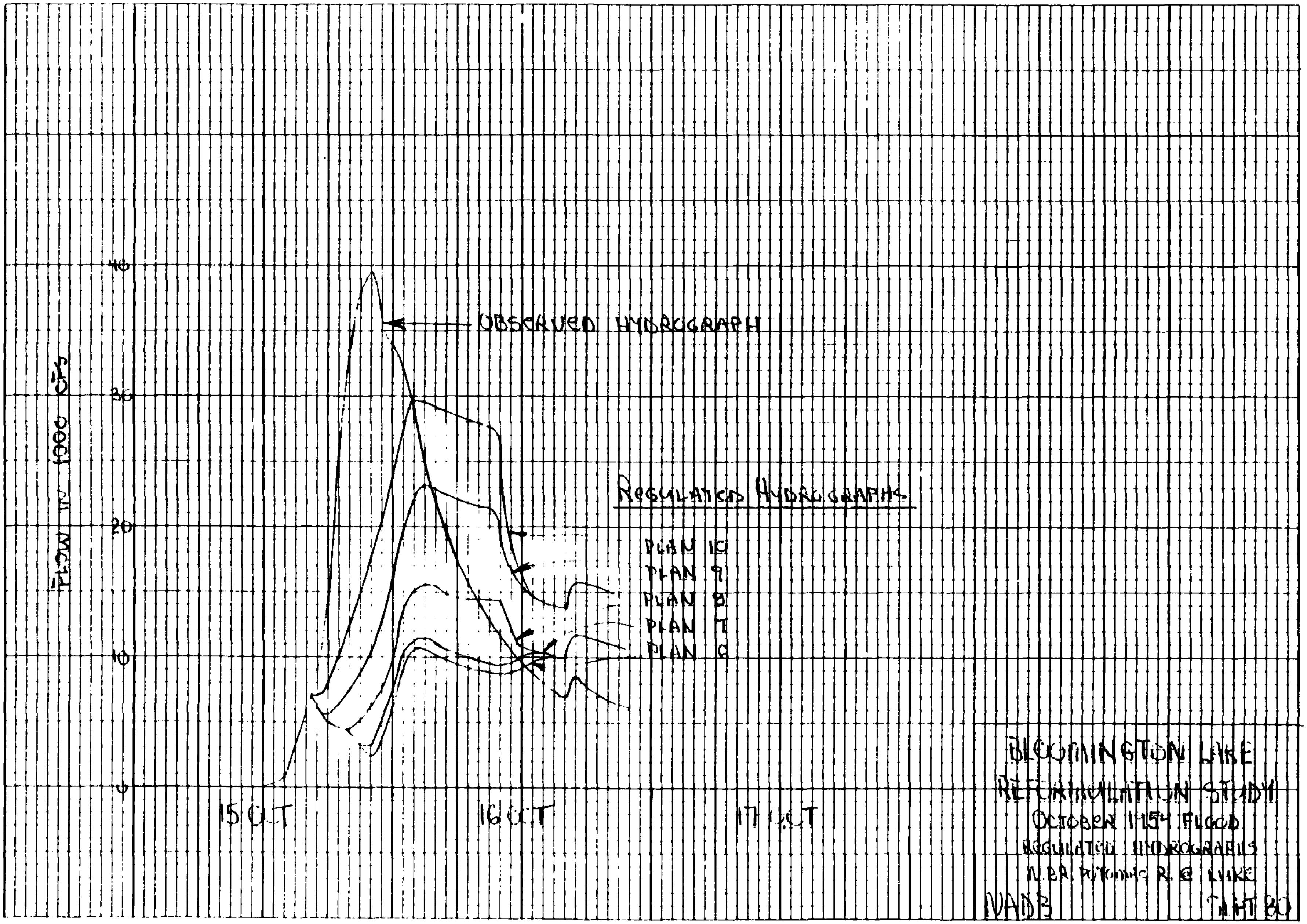


FIGURE H-IV-47

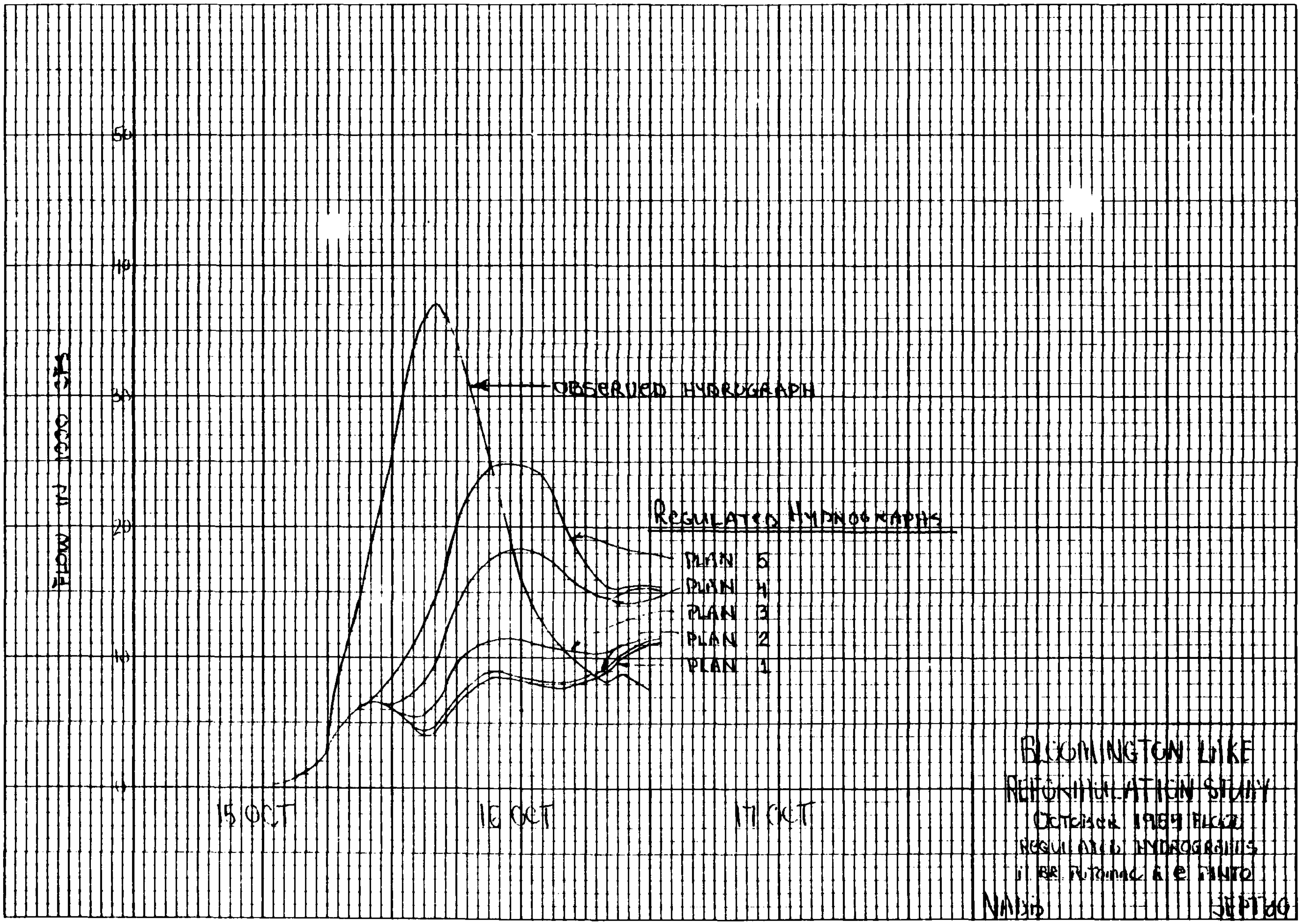
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

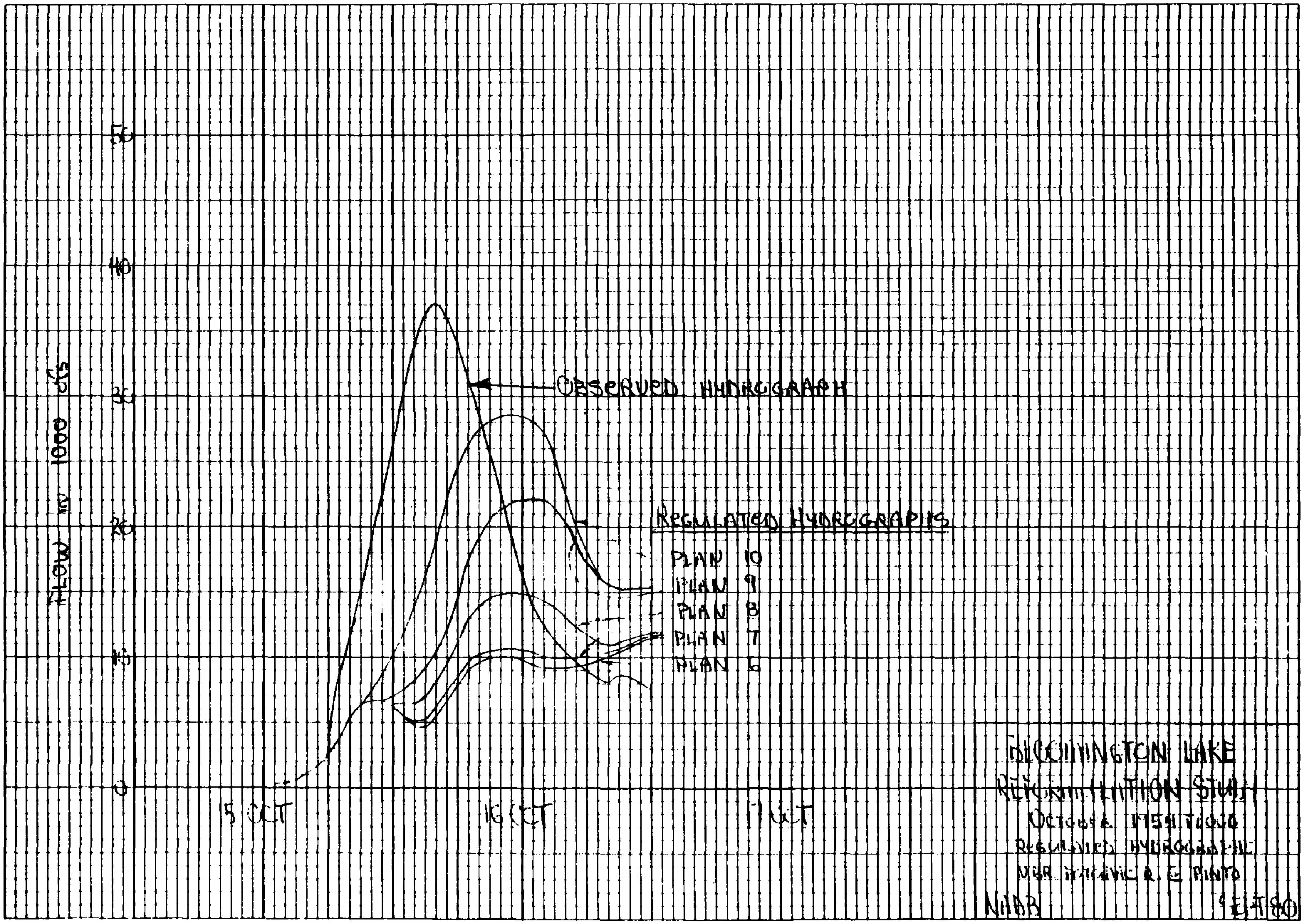
DIETZGEN CORPORATION
MADE IN U.S.A.



NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.




FLOW IN 1000 CFS
0
10
20
30
40
50
5 OCT
16 OCT
17 OCT
OBSERVED HYDROGRAPH
REGULATED HYDROGRAPHS
PLAN 10
PLAN 9
PLAN 8
PLAN 7
PLAN 6
BLOOMINGTON LAKE
REFORMULATION STUDY
OCTOBER 1954 FLOOD
REGULATED HYDROGRAPH
NAB
SEPT 80

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

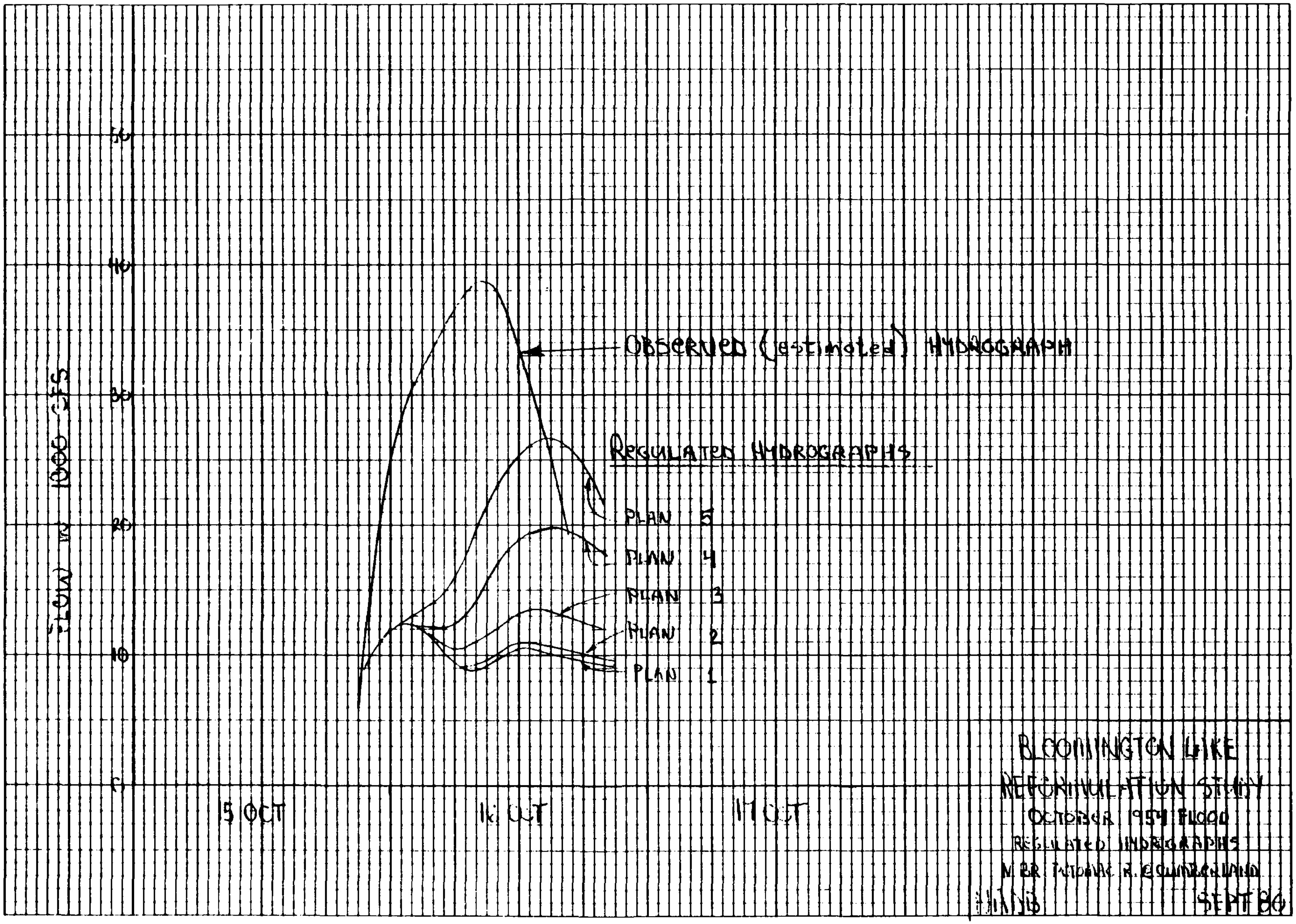


FIGURE H-IV-51

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

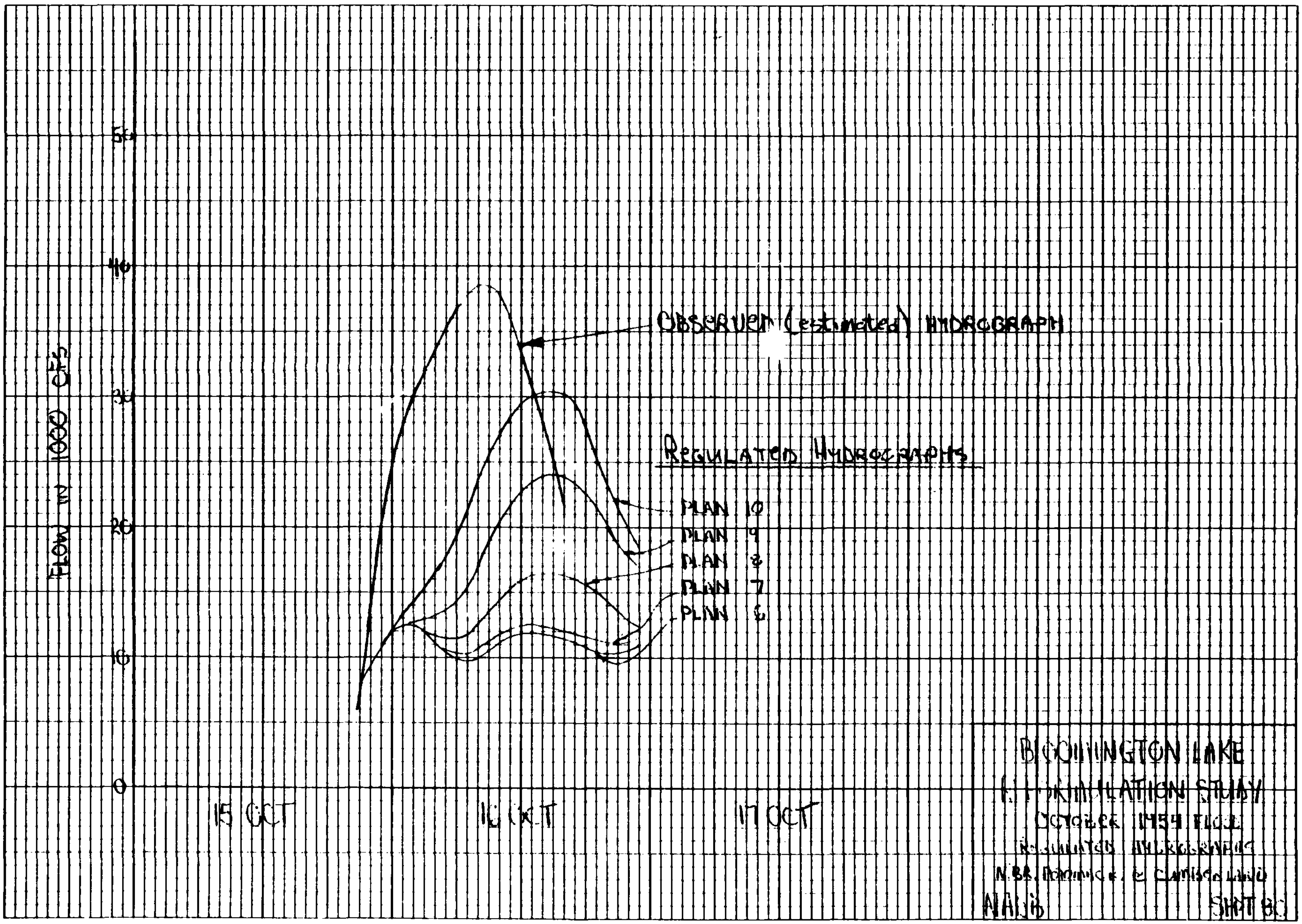


FIGURE H-IV-52

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

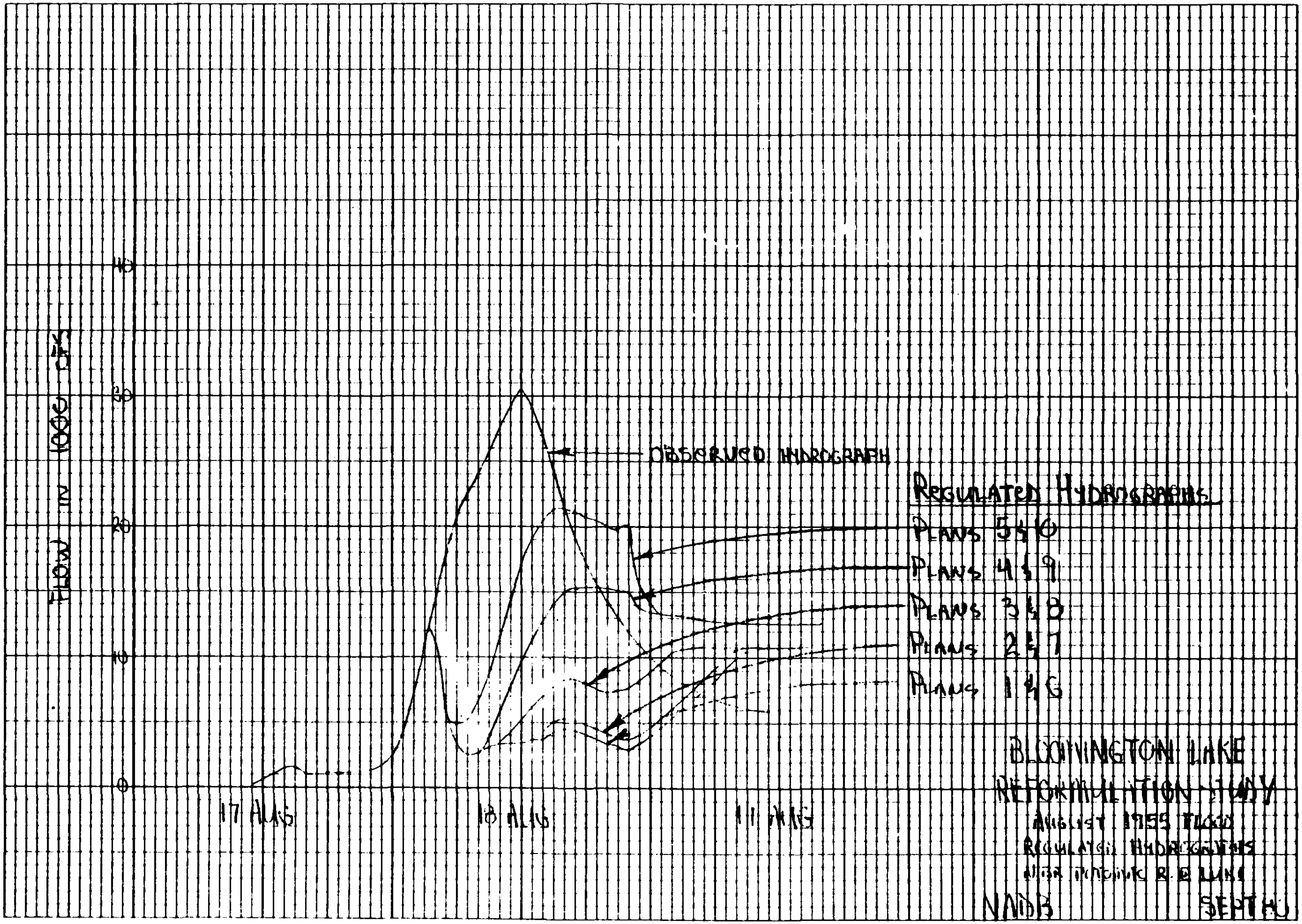
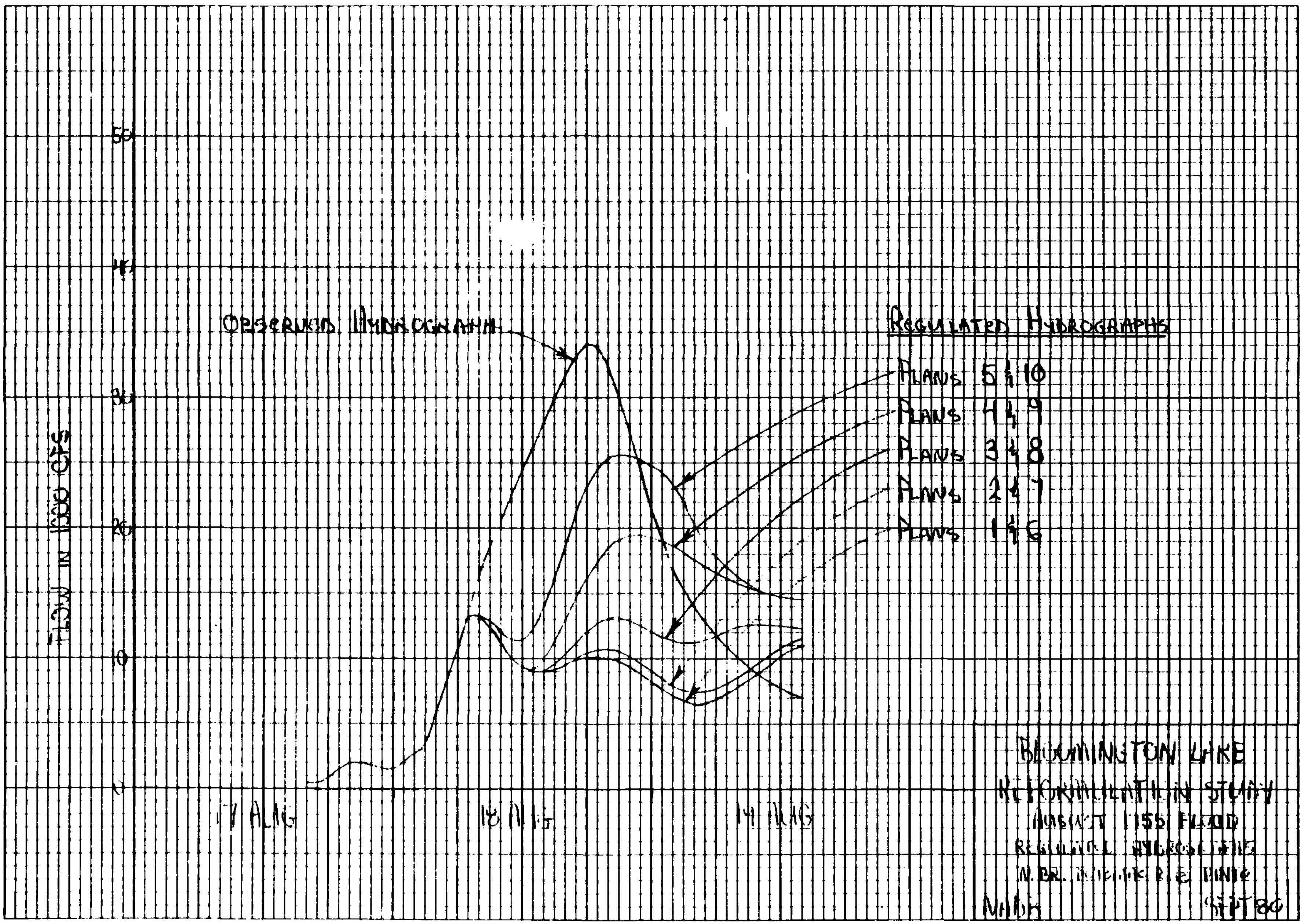


FIGURE H-IV-53

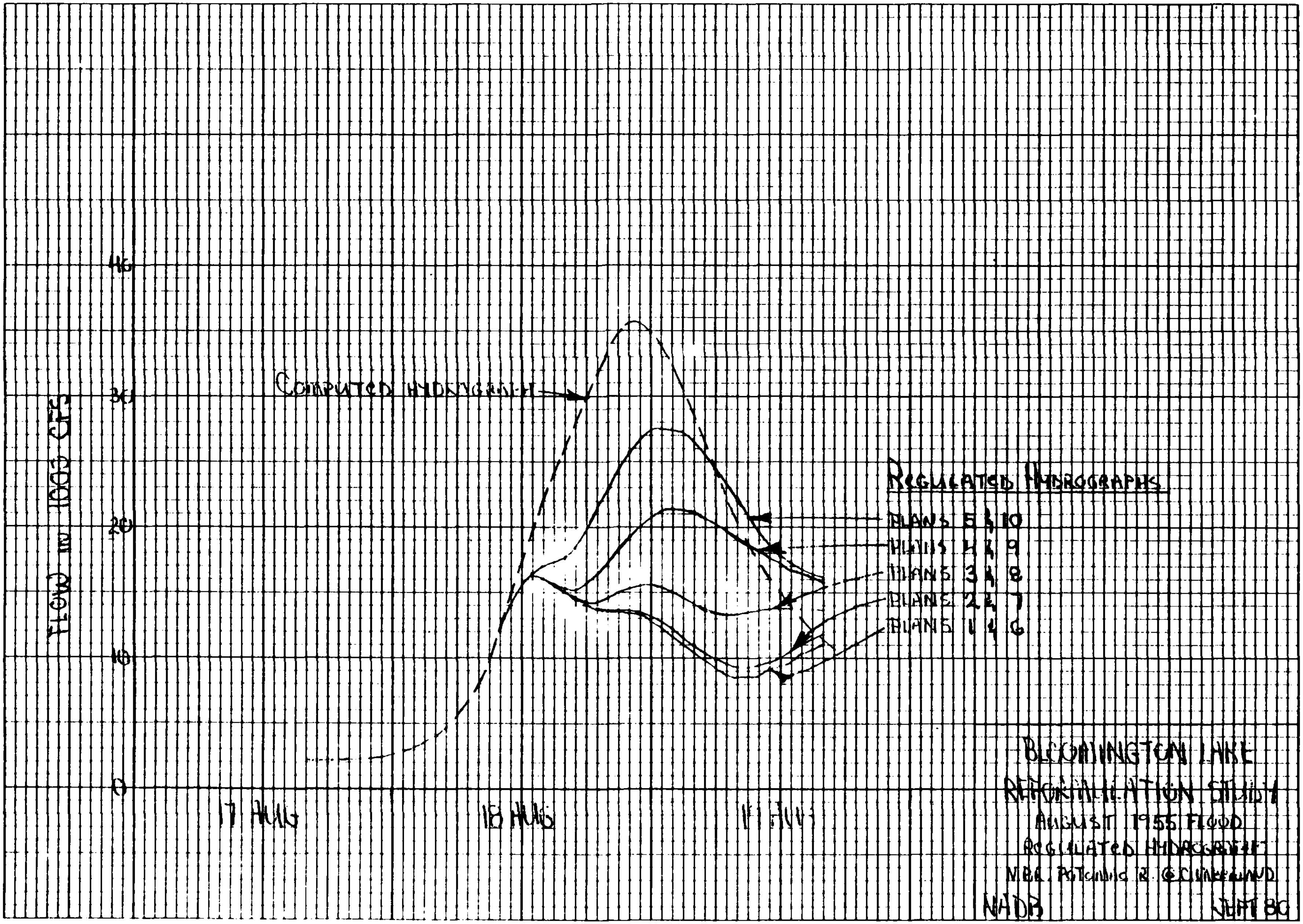
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



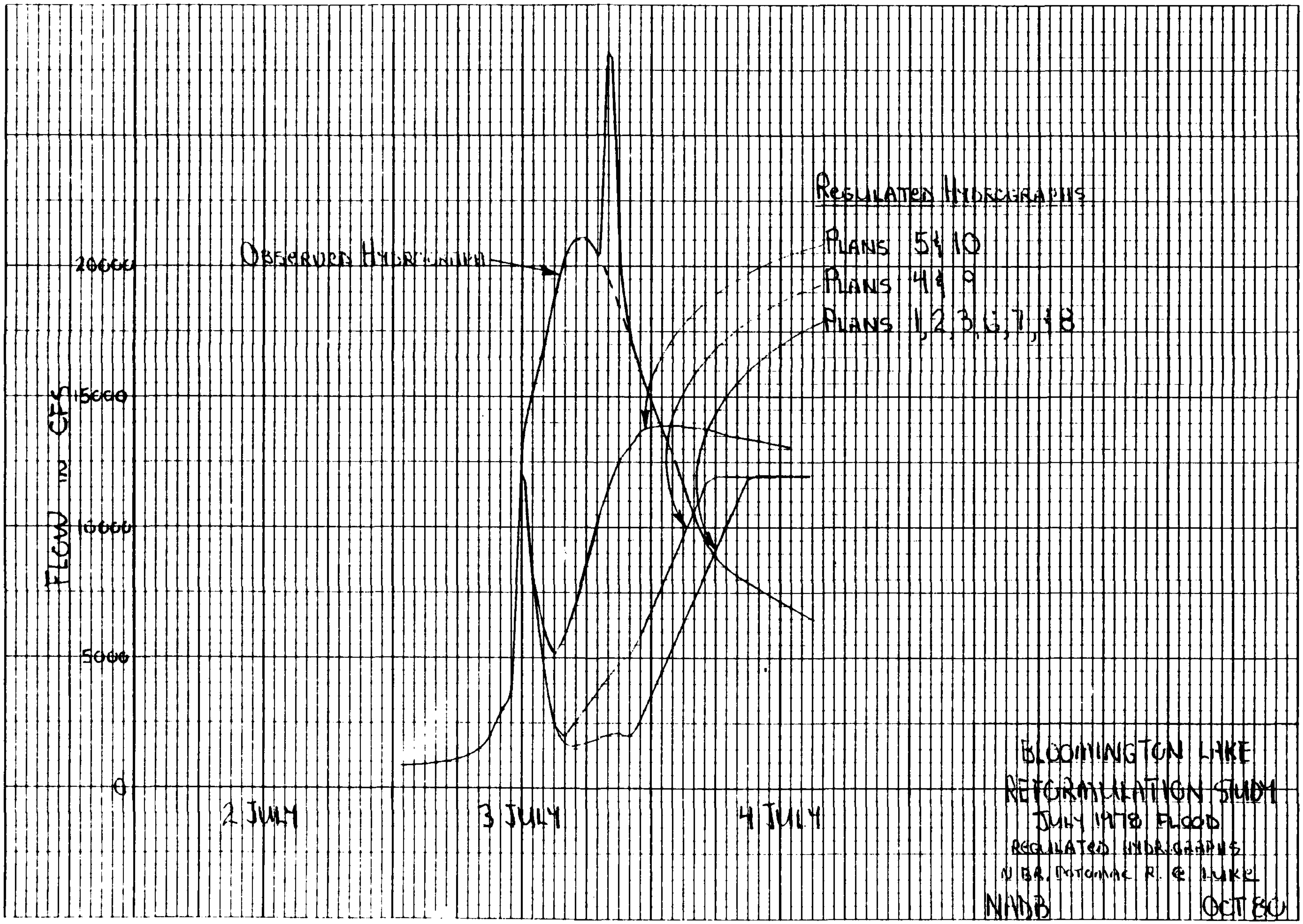


FIGURE H-IV-56

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

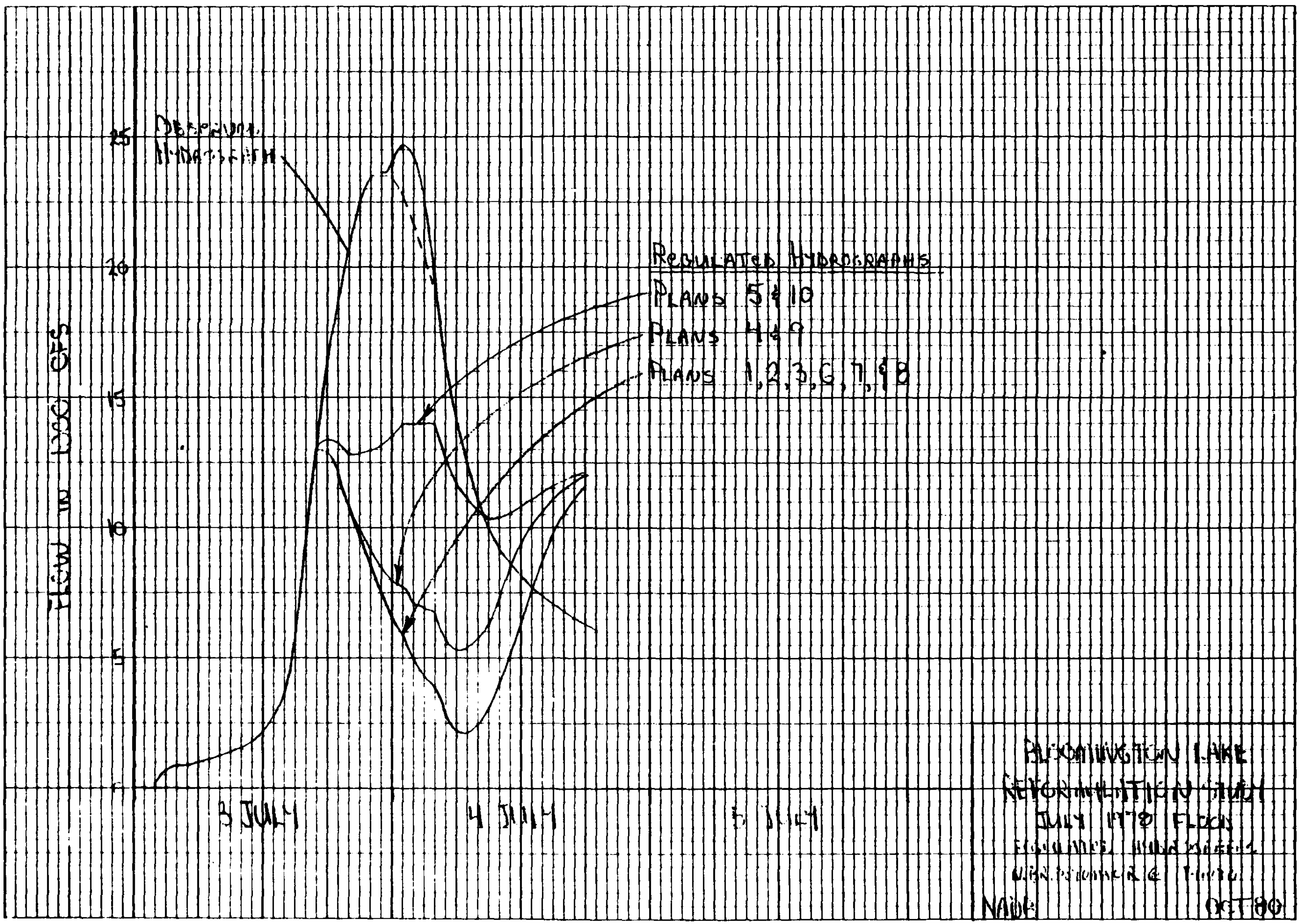


FIGURE H-IV-57

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

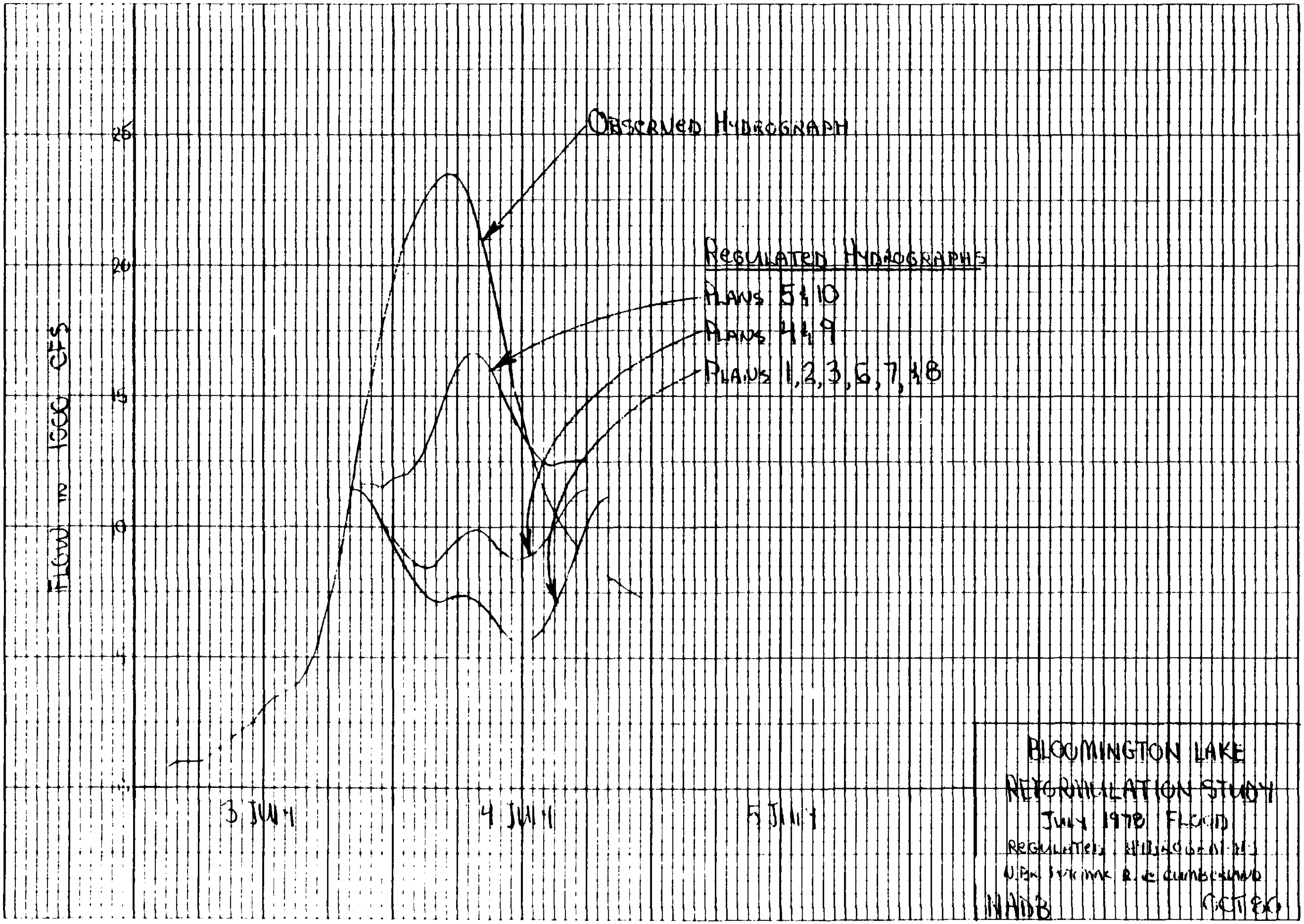
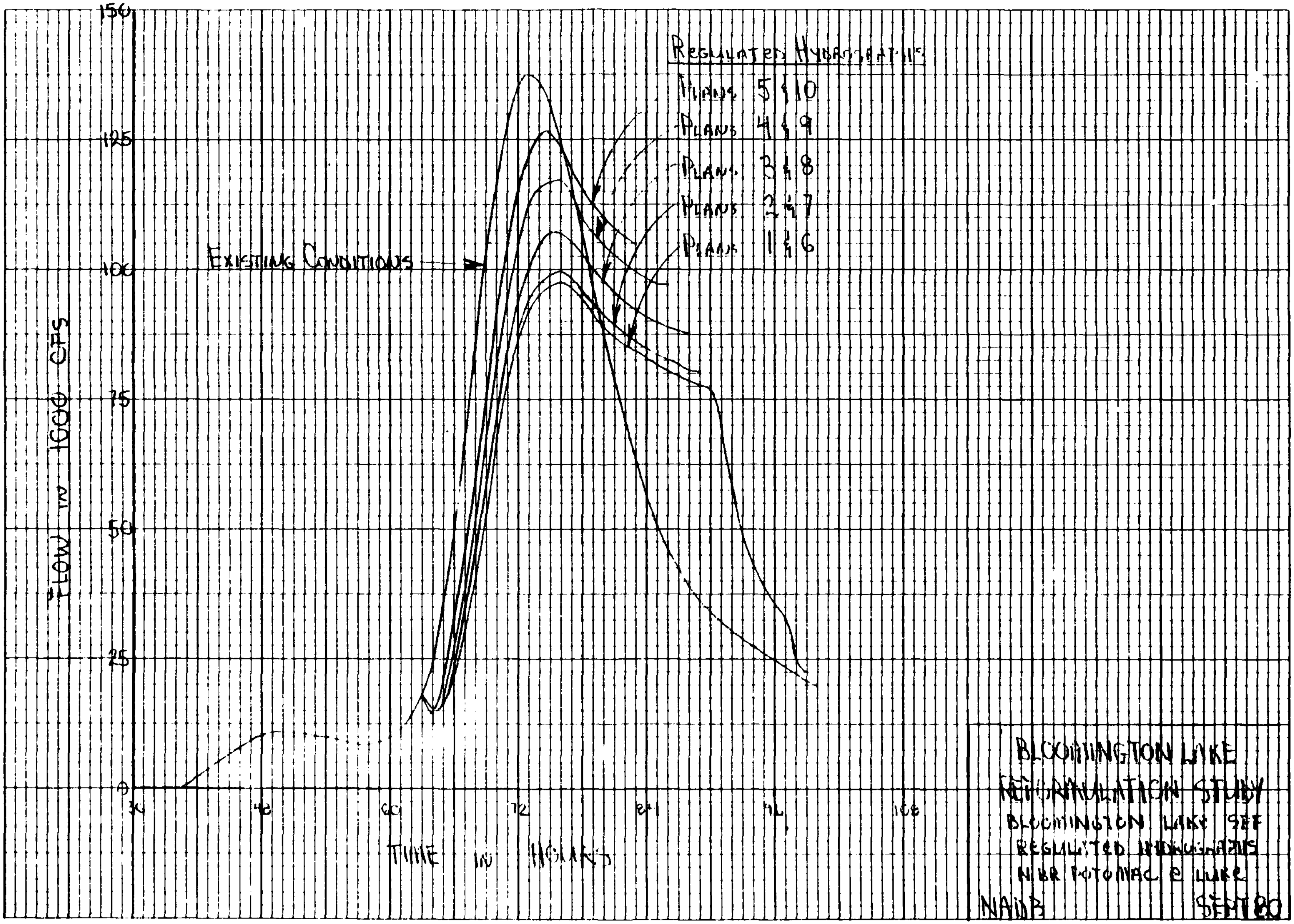
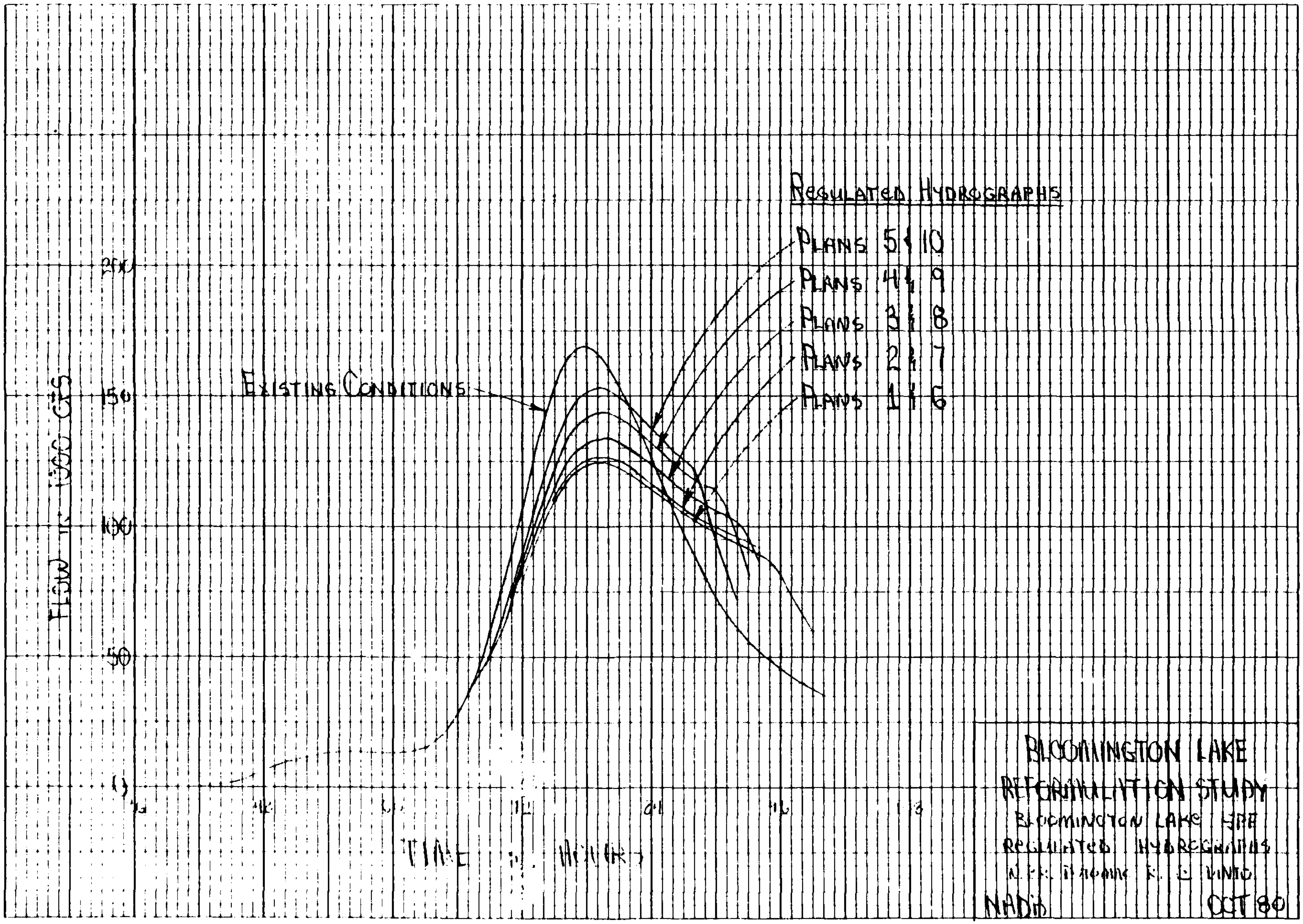


FIGURE H-IV-58


REGULATED HYDROGRAPHS
PLANS 5 & 10
PLANS 4 & 9
PLANS 3 & 8
PLANS 2 & 7
PLANS 1 & 6
EXISTING CONDITIONS
FLOW IN 1000 CFS
150
125
100
75
50
25
0
36
48
60
72
84
96
108
TIME IN HOURS
BLOOMINGTON LAKE
REFORMULATION STUDY
BLOOMINGTON LAKE SPF
REGULATED HYDROGRAPHS
N BR POTOMAC @ LUKE
NAOB
SEPT 80

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

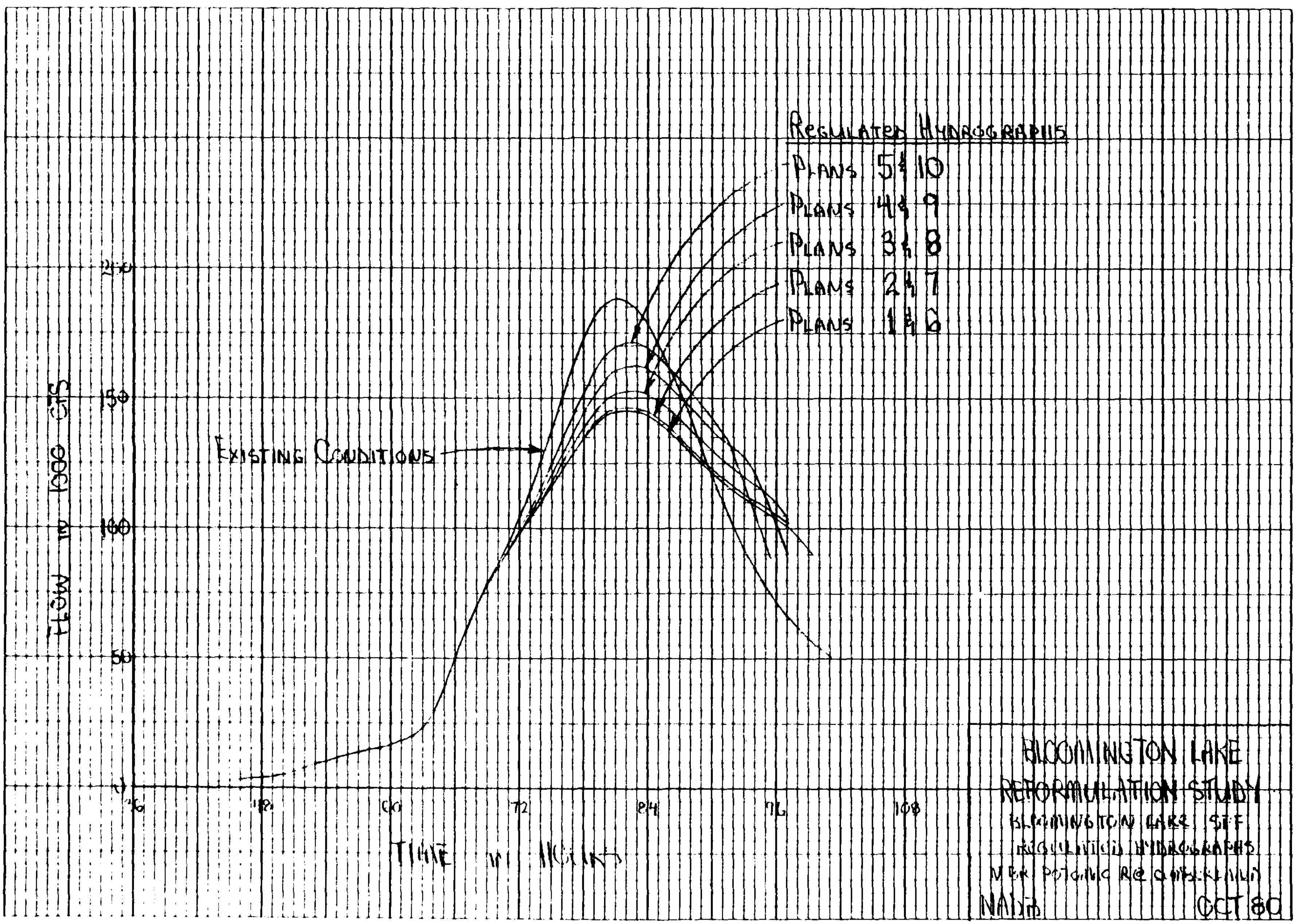
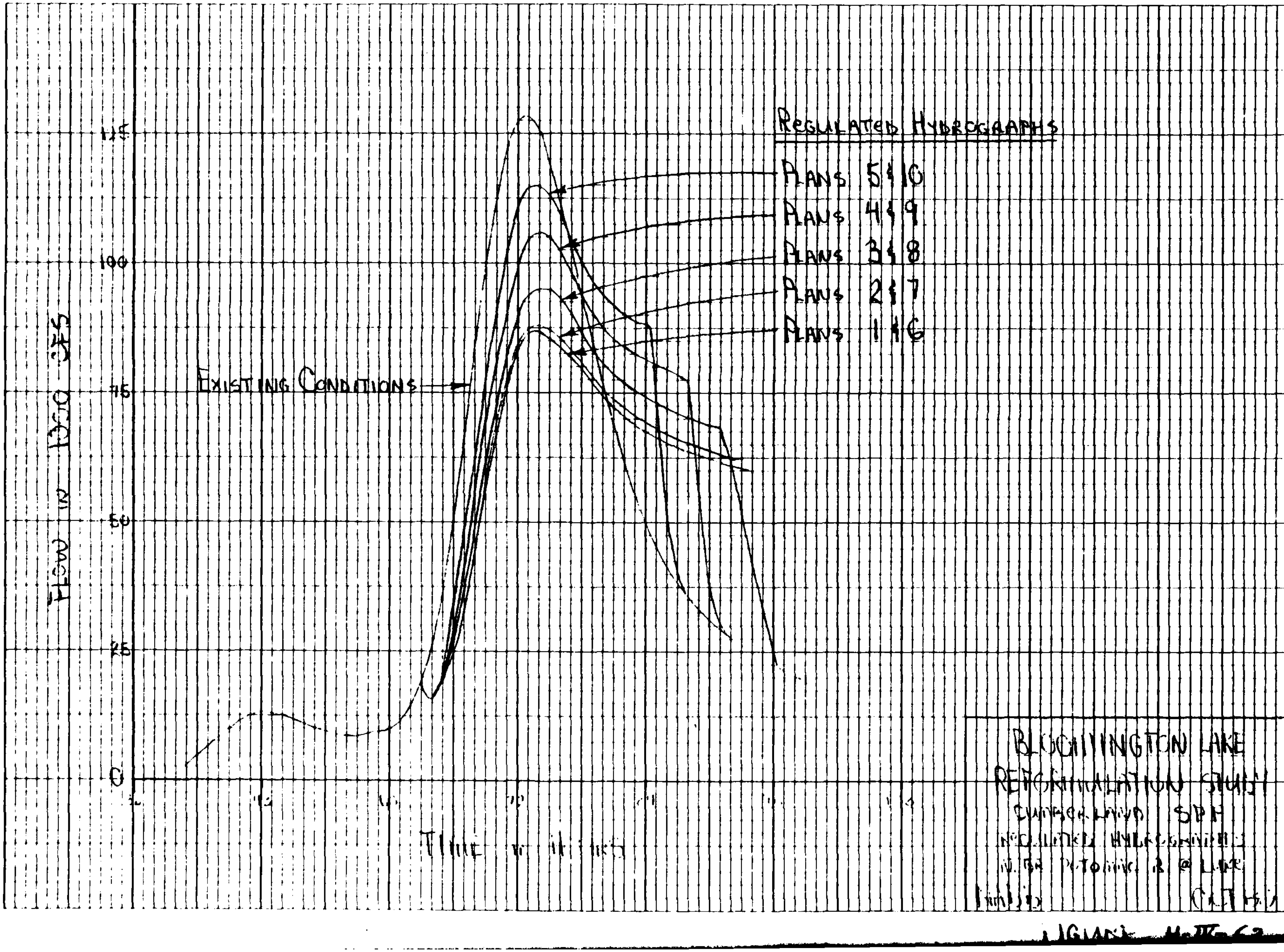


FIGURE H-IV-61


REGULATED HYDROGRAPHS
PLANS 5 & 10
PLANS 4 & 9
PLANS 3 & 8
PLANS 2 & 7
PLANS 1 & 6
EXISTING CONDITIONS
125
100
75
50
25
0
FLOW IN 1000 CFS
TIME IN HOURS
BLOOMINGTON LAKE
REFORMULATION STUDY

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

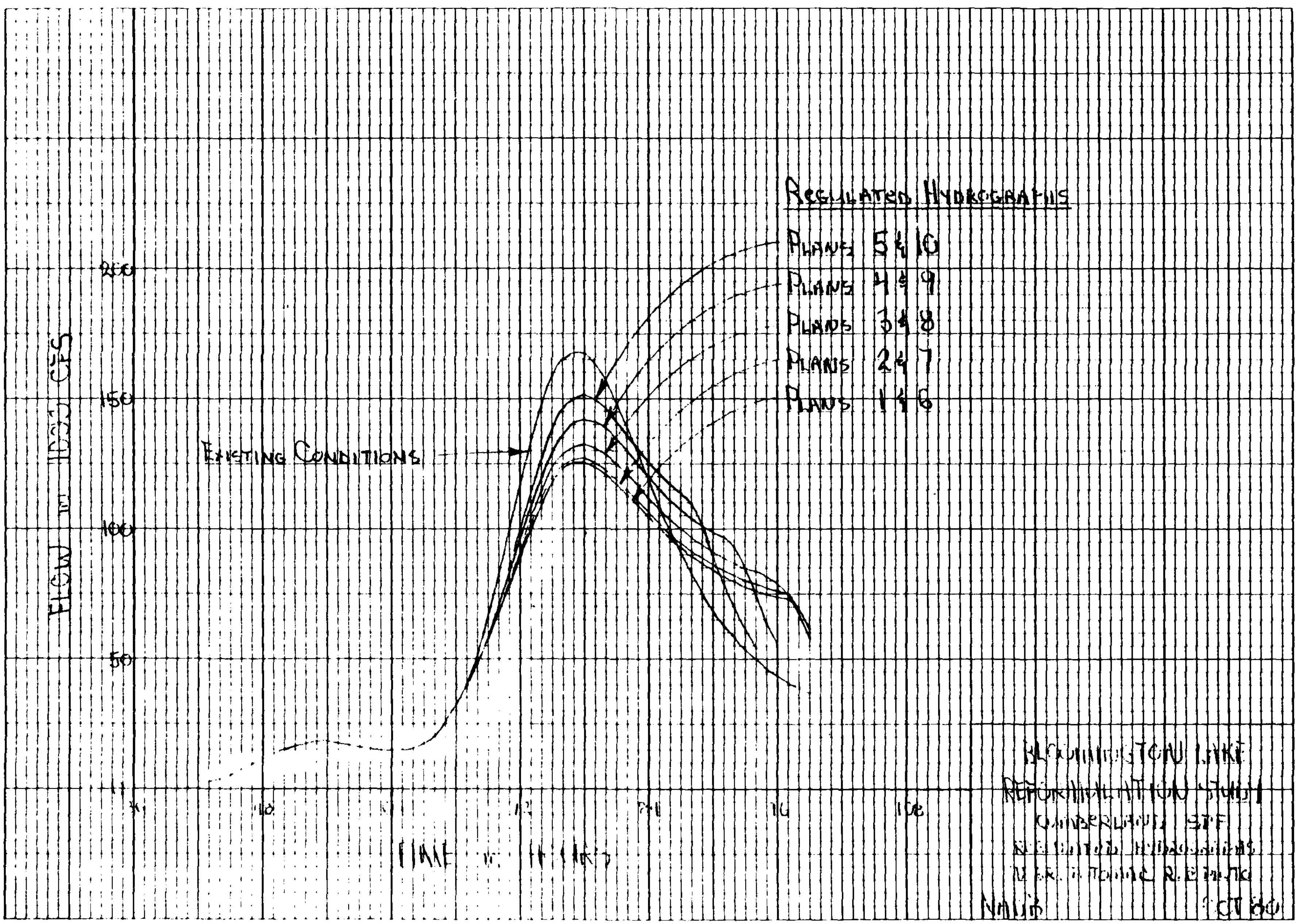


FIGURE H-IV-63

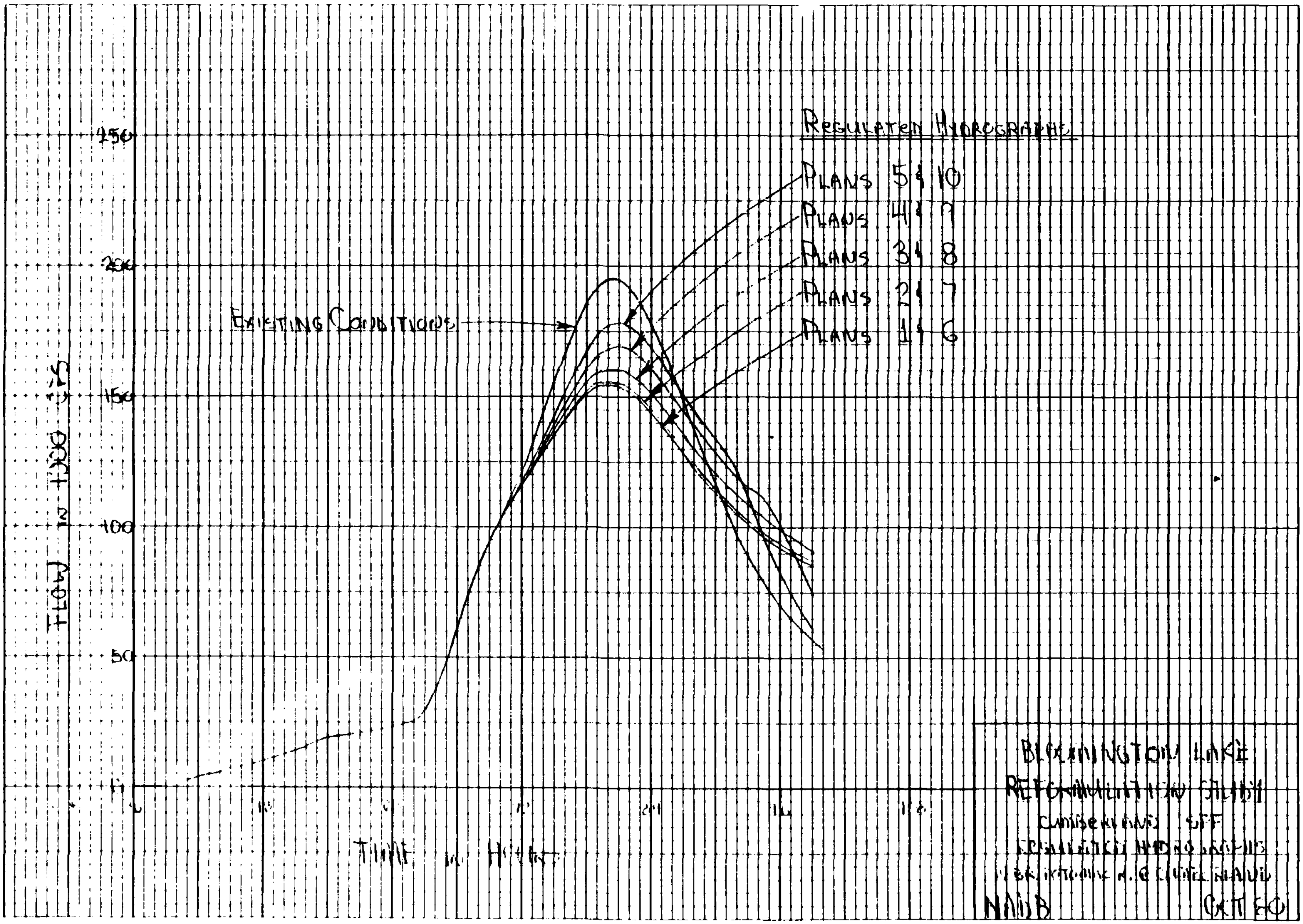


FIGURE H-IV-64

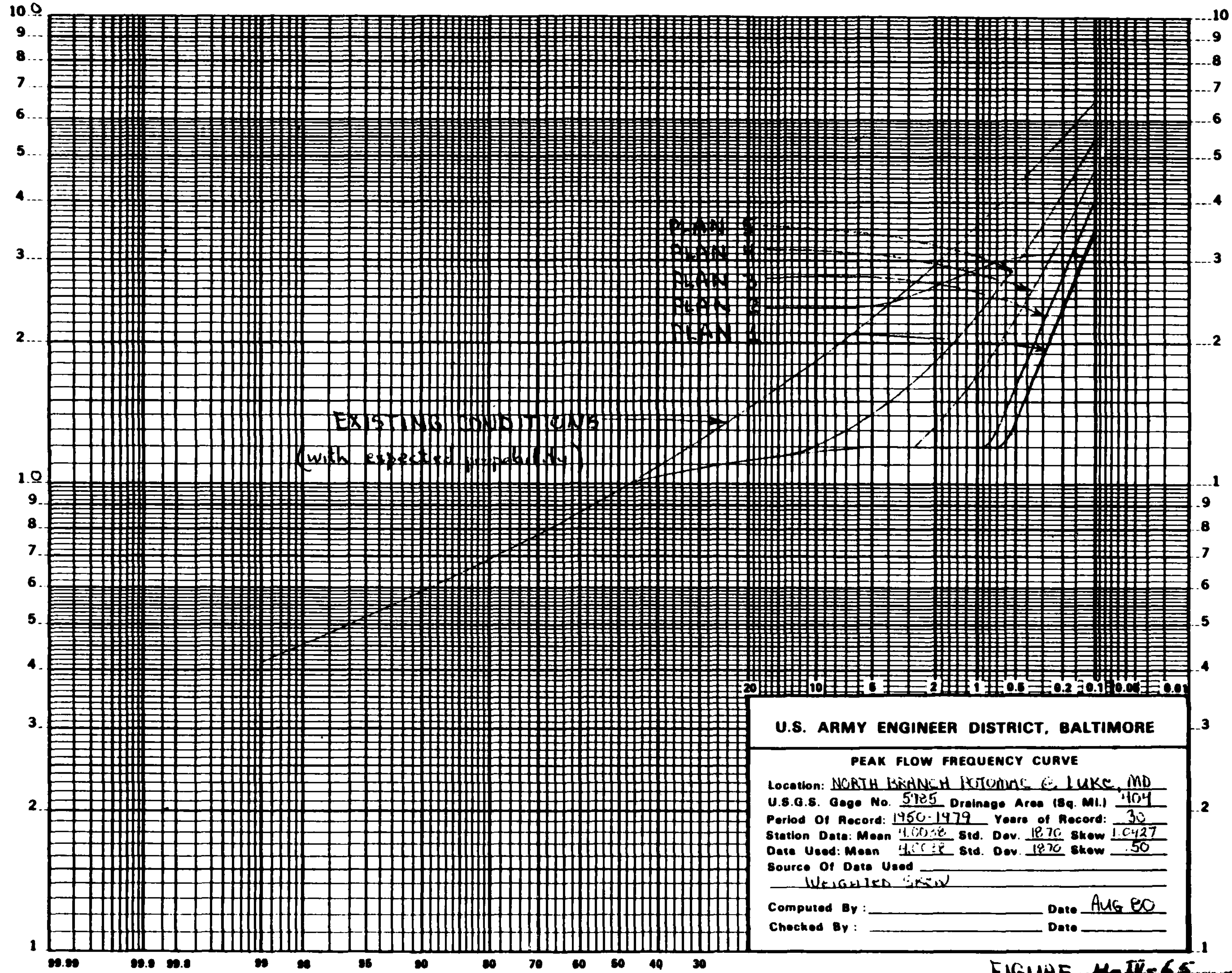


FIGURE H-IV-65

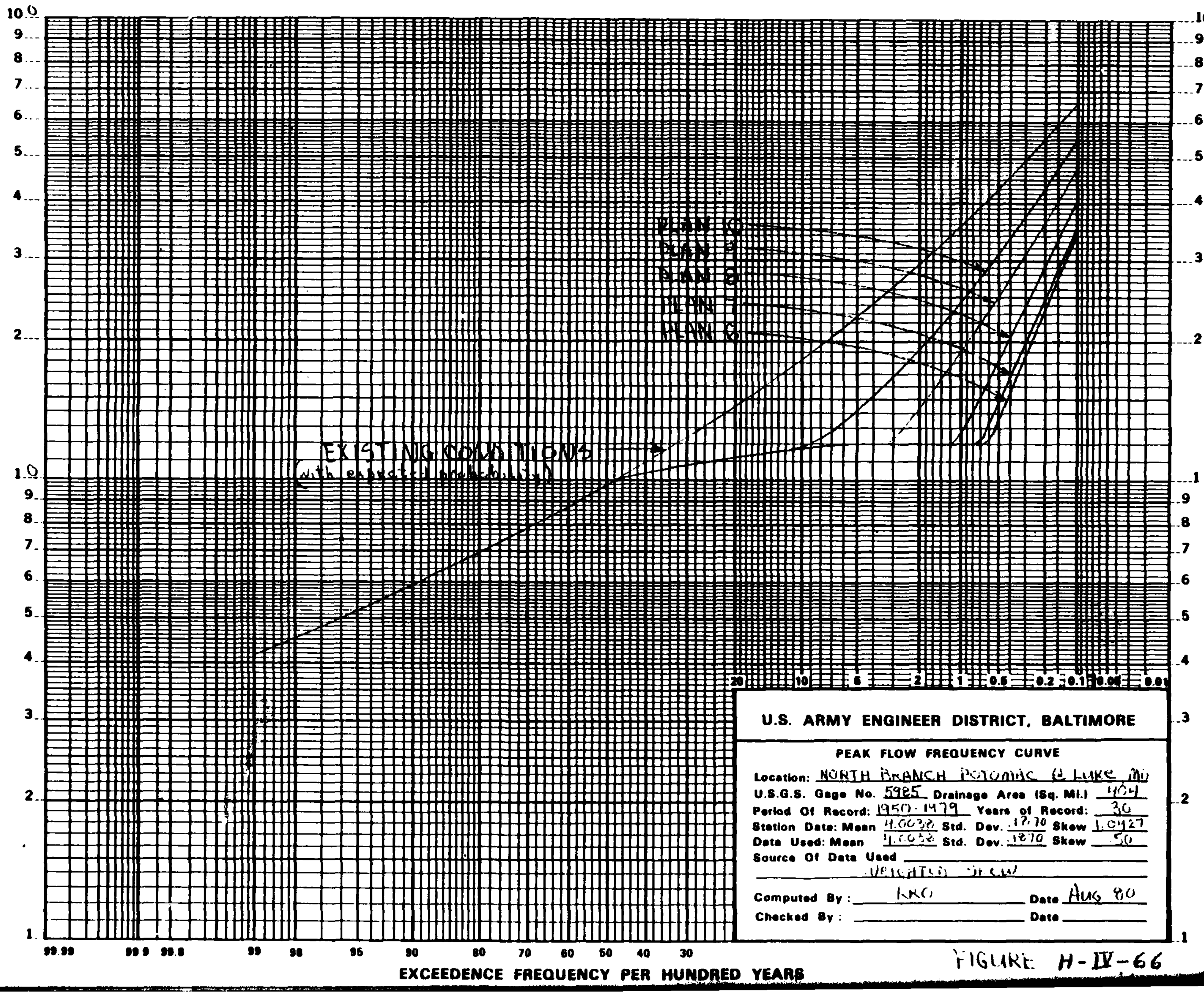


FIGURE H-IV-66

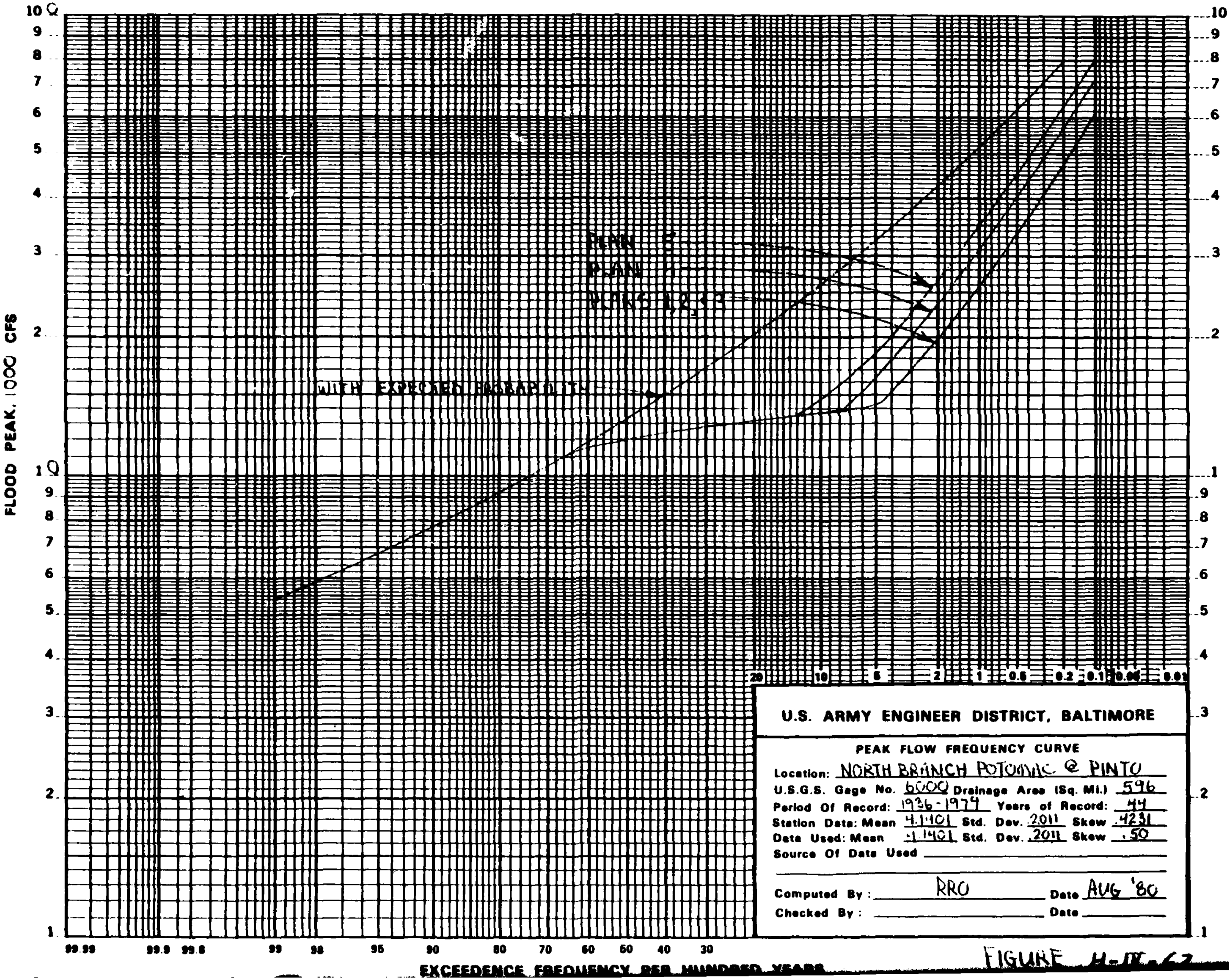


FIGURE H-IV-62

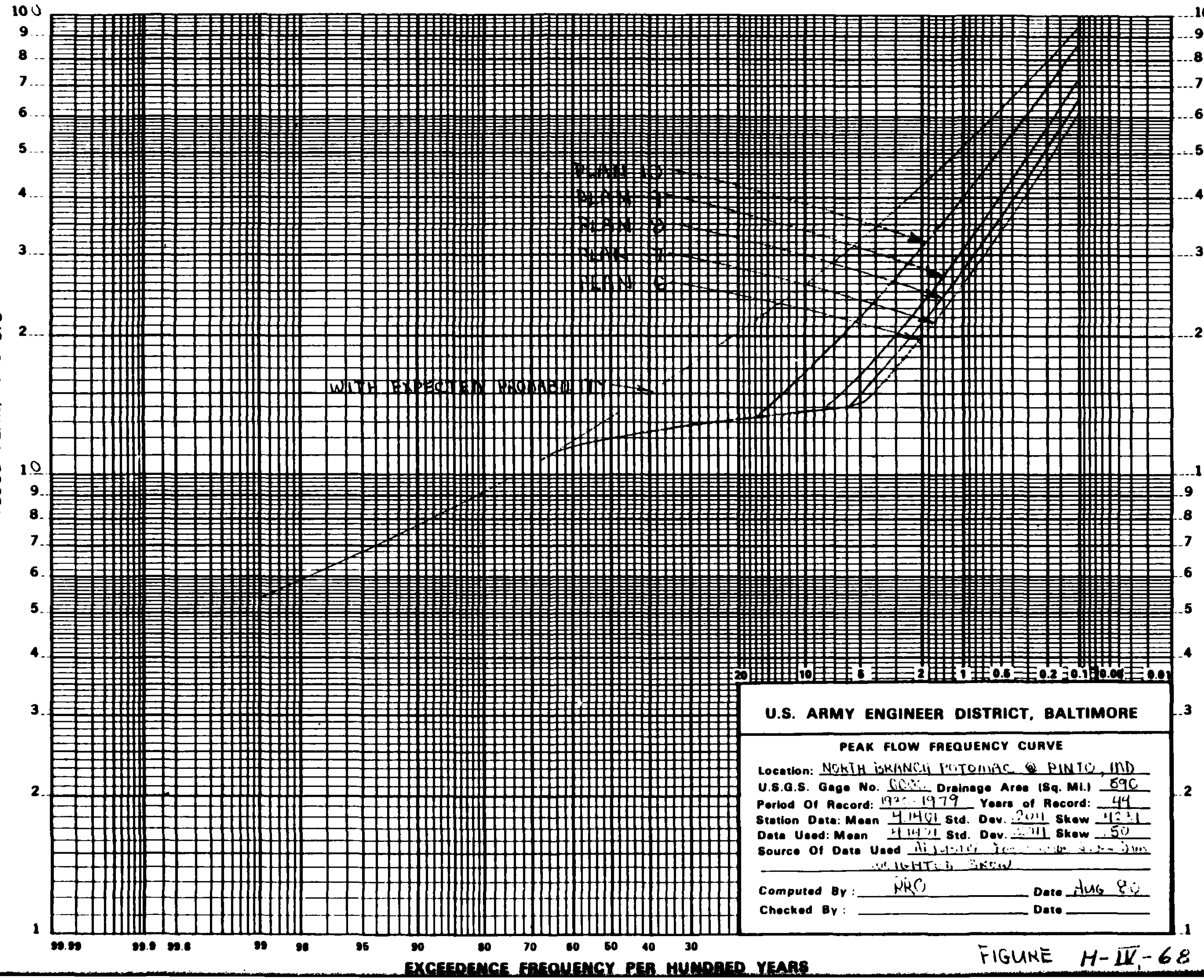


FIGURE H-IV-68

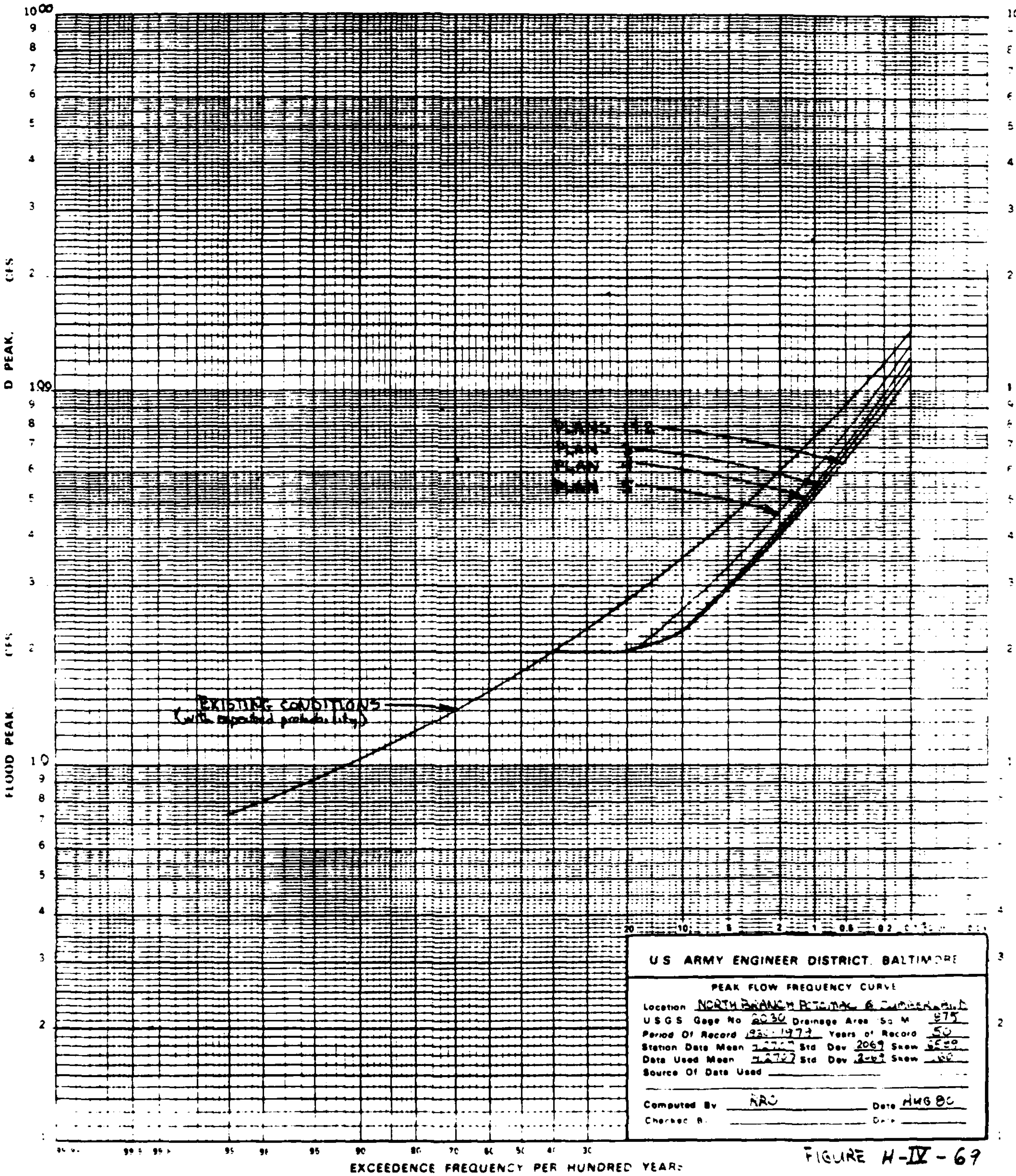


FIGURE H-IV-69

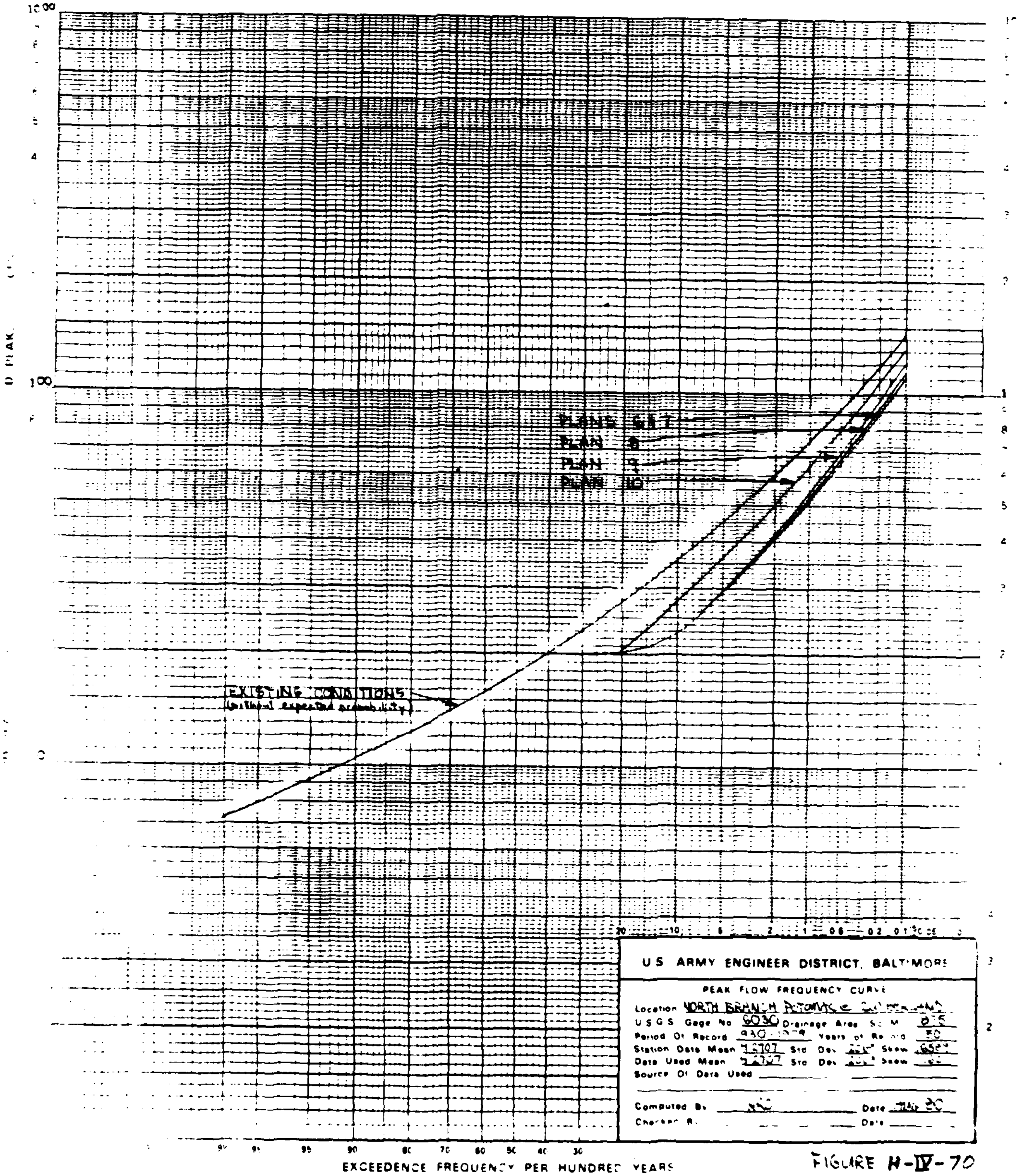
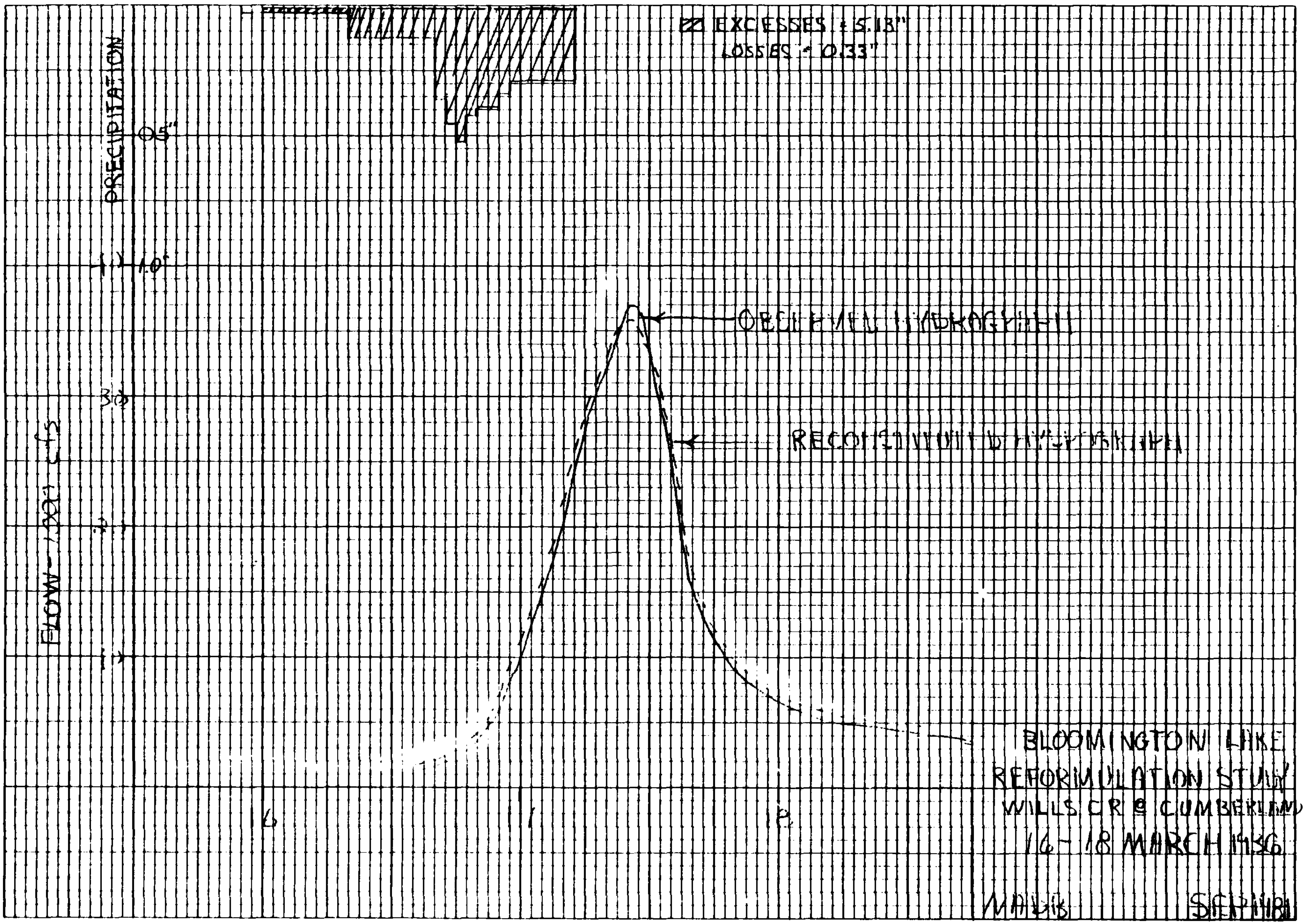


FIGURE H-IV-70

NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.



NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

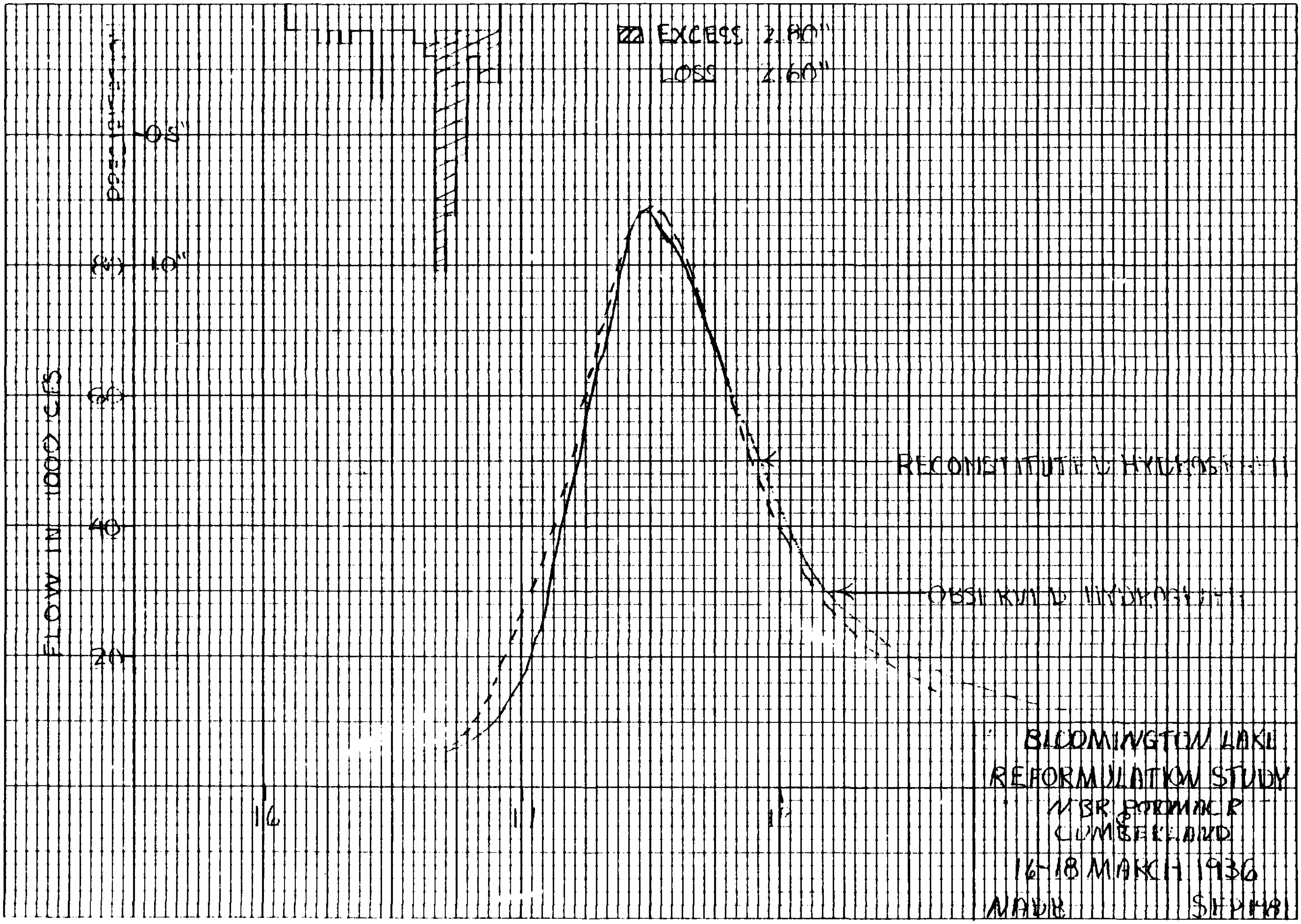


FIGURE H-IV-7

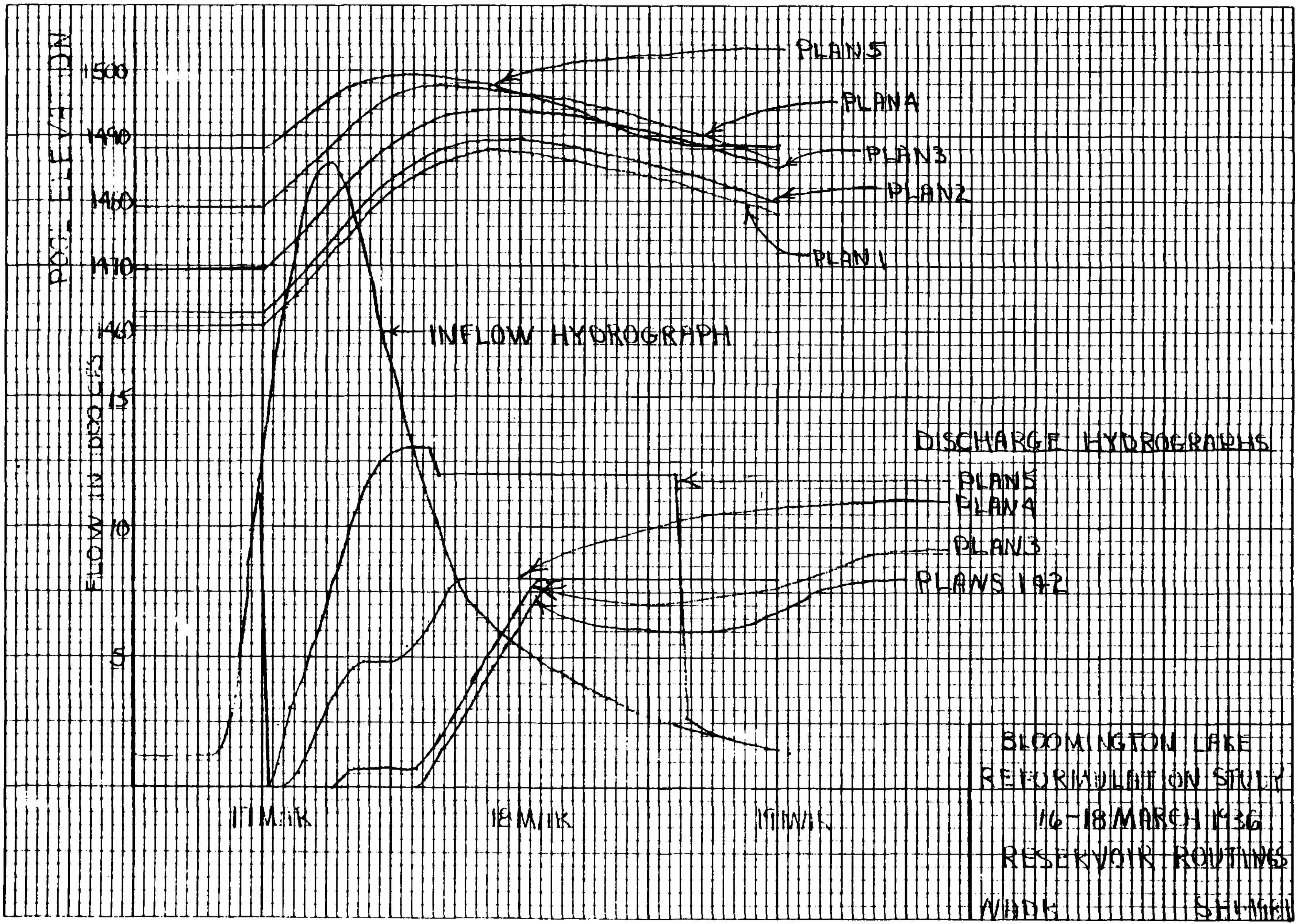
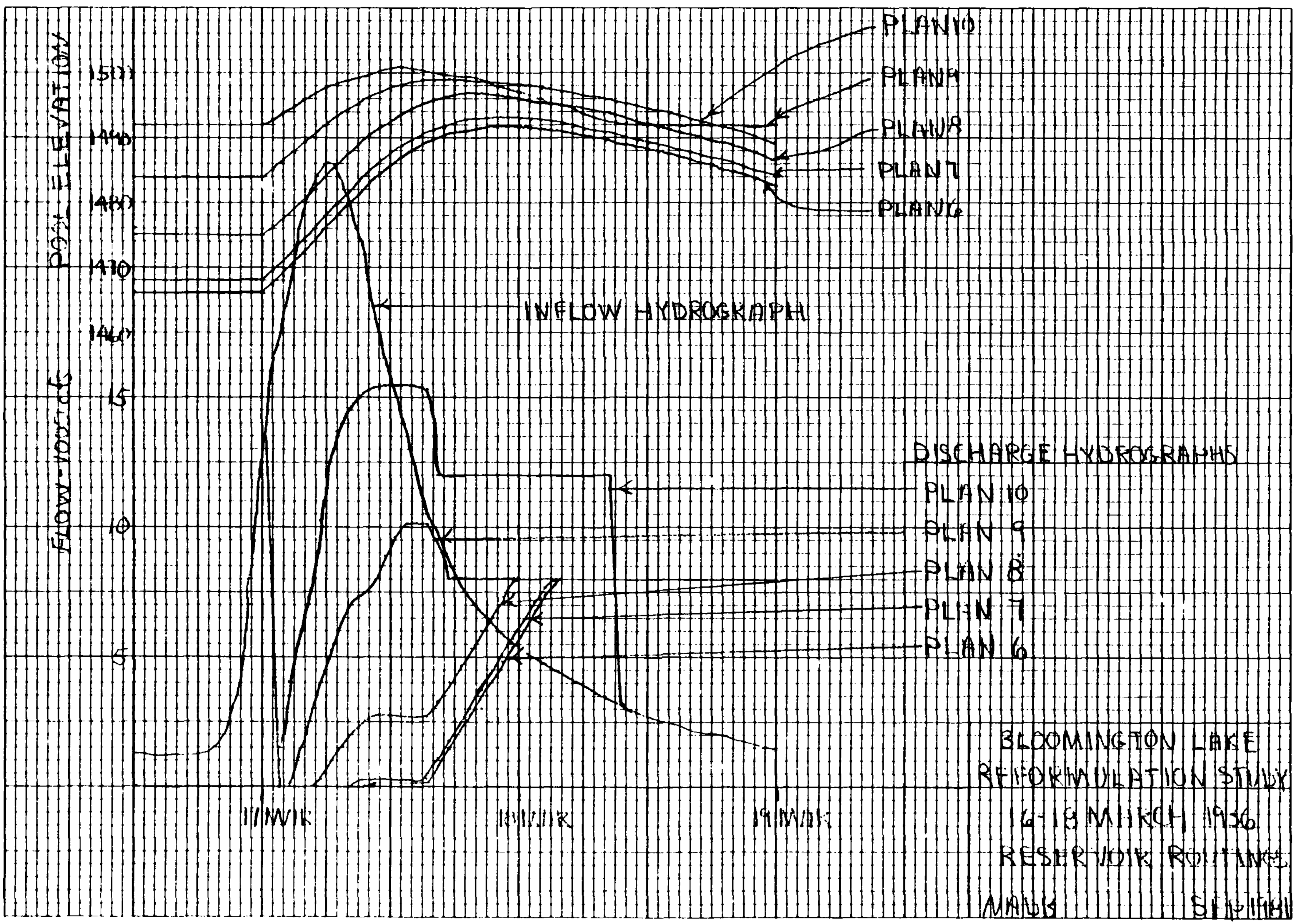
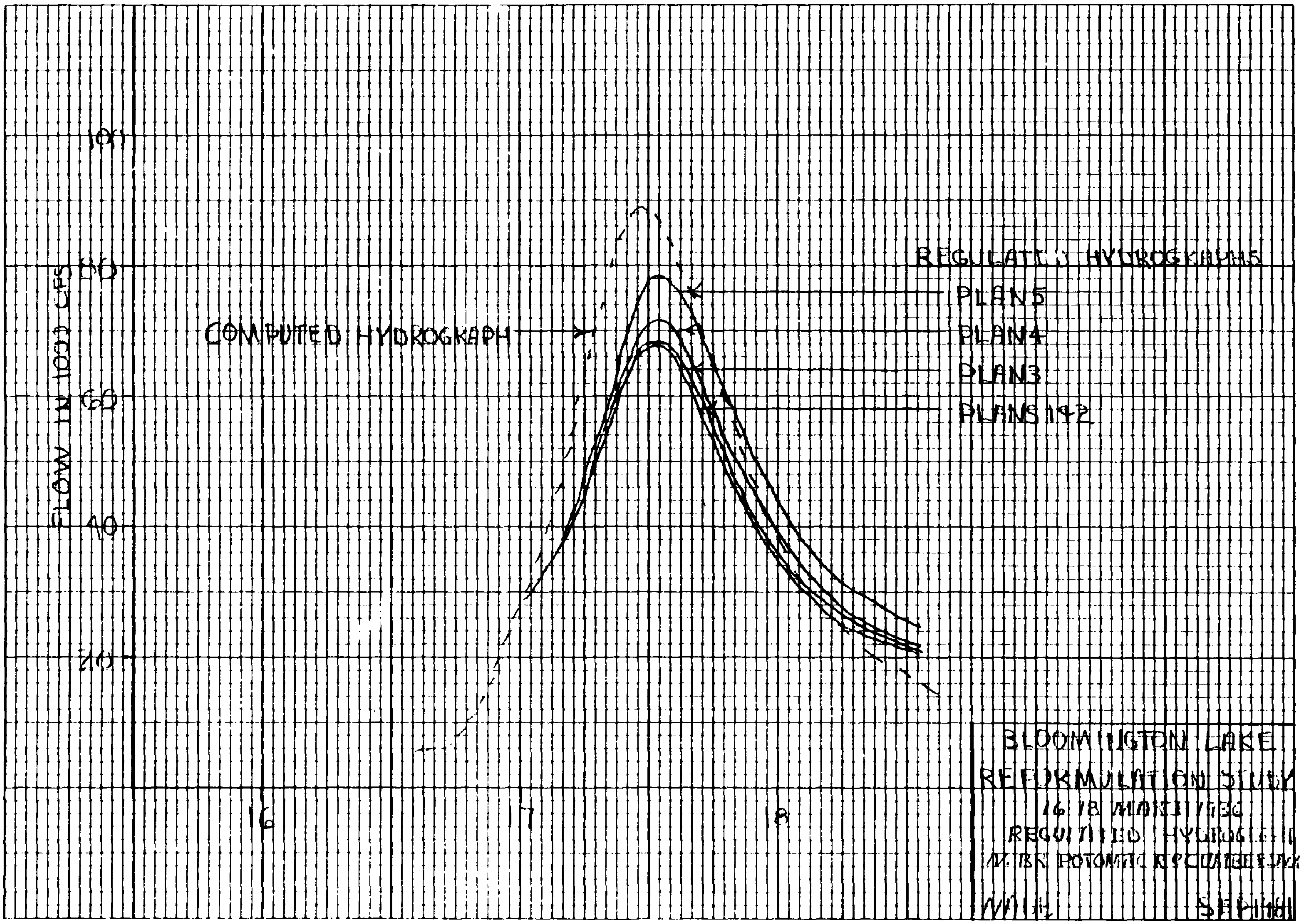

POOL ELEVATION
1500
1490
1480
1470
1460
FLOW IN 1000 CFS
15
10
5
PLAN 5
PLAN 4
PLAN 3
PLAN 2
PLAN 1
INFLOW HYDROGRAPH
DISCHARGE HYDROGRAPHS
PLAN 5
PLAN 4
PLAN 3
PLANS 1 & 2
17 MAR
18 MAR
19 MAR
BLOOMINGTON LAKE
REFORMULATION STUDY
16-18 MARCH 1936
RESERVOIR ROUTINGS
WBDH
SHMEI

FIGURE H-IV


POOL ELEVATION
FLOW-1000 CFS
1500
1490
1480
1470
1460
15
10
5
PLAN 10
PLAN 9
PLAN 8
PLAN 7
PLAN 6
INFLOW HYDROGRAPH
DISCHARGE HYDROGRAPHS
PLAN 10
PLAN 9
PLAN 8
PLAN 7
PLAN 6
17 MAR
18 MAR
19 MAR
BLOOMINGTON LAKE
REFORMULATION STUDY
16-18 MARCH 1936
RESERVOIR ROUTING

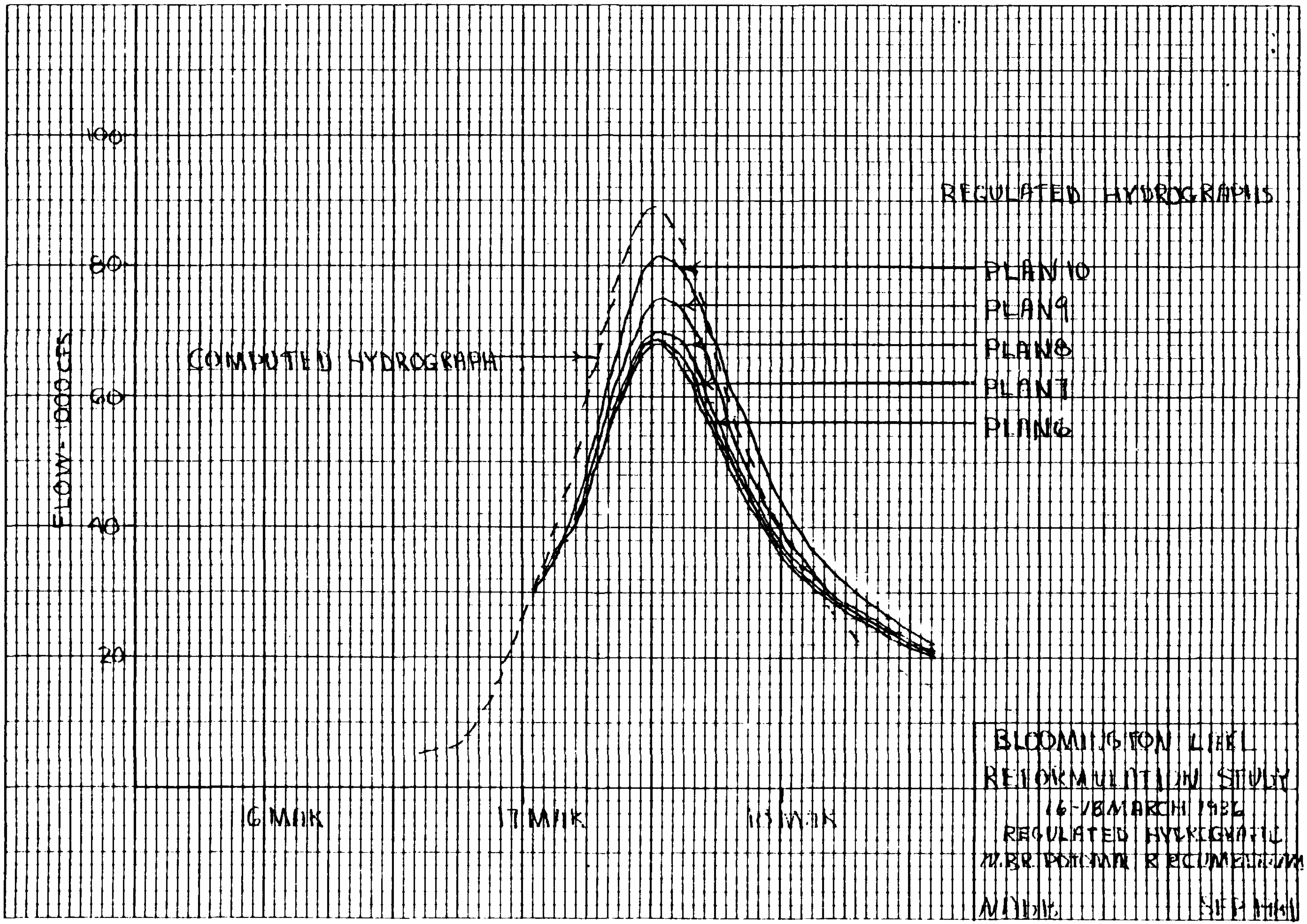
NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

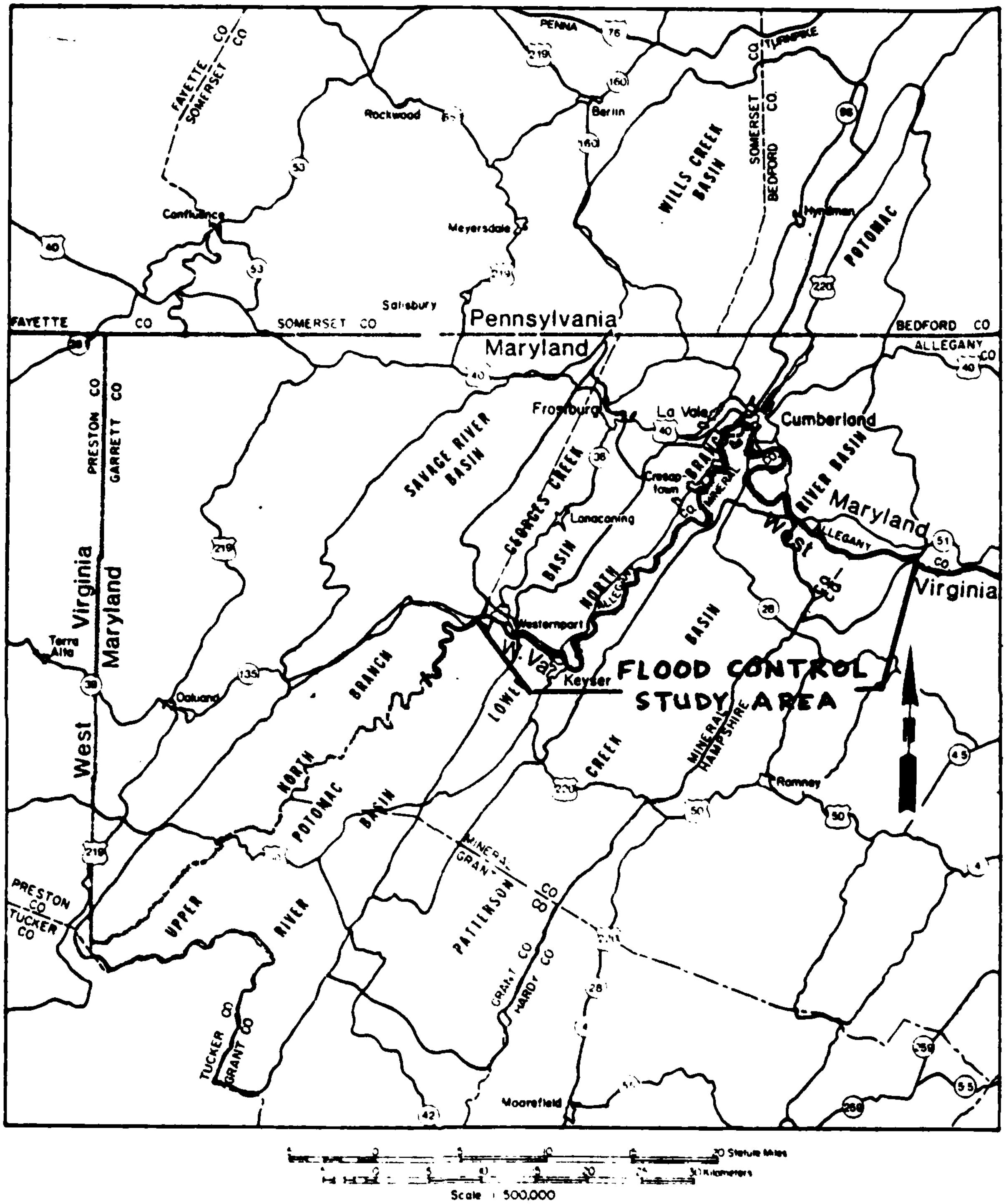
DIETZGEN CORPORATION
MADE IN U.S.A.



NO. 340-32 DIETZGEN GRAPH PAPER
10 X 12 PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.





Flood Control Study Area

Figure H-IV-77

Figure H-IV-78 Construction of a Typical Damage-Frequency Curve.

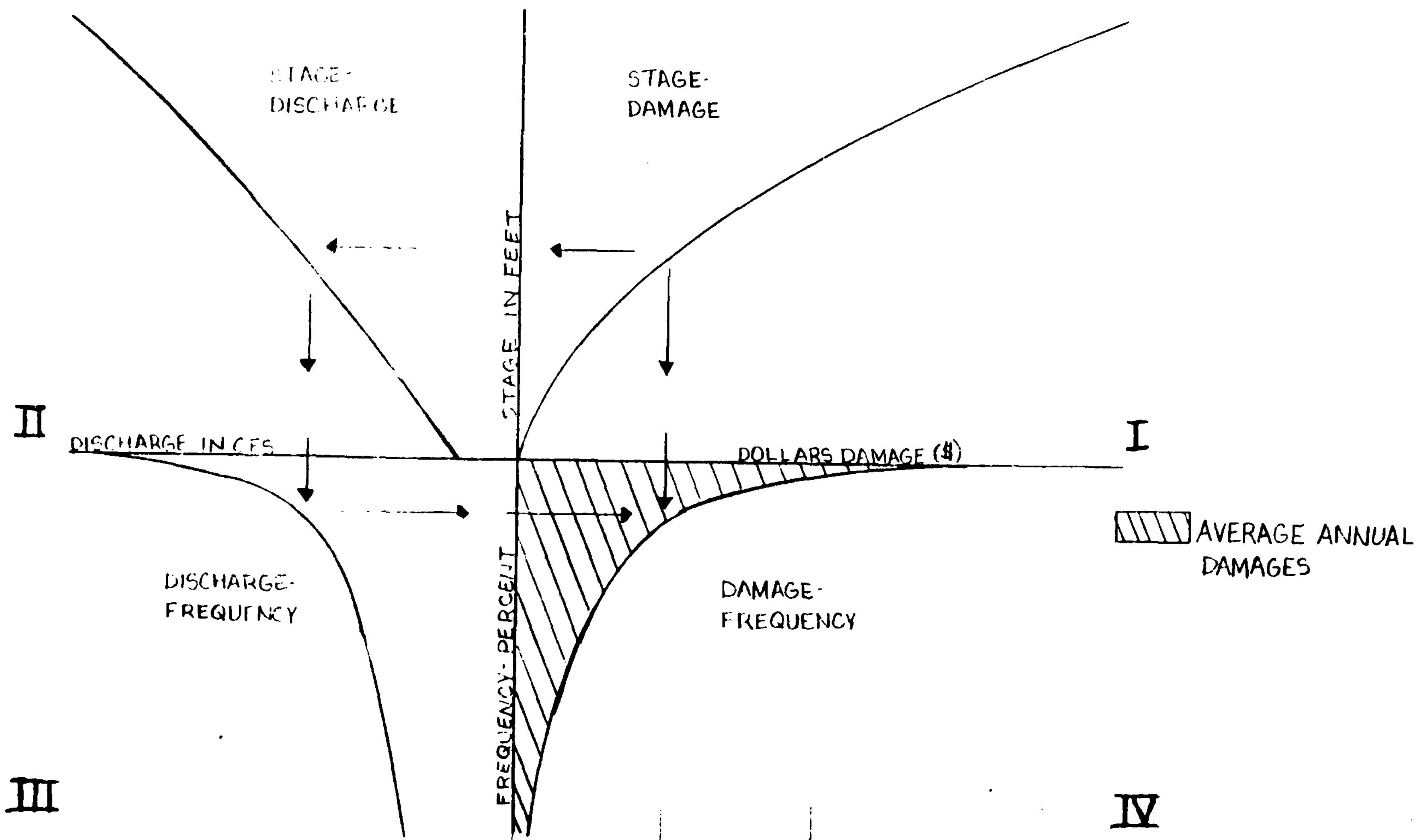
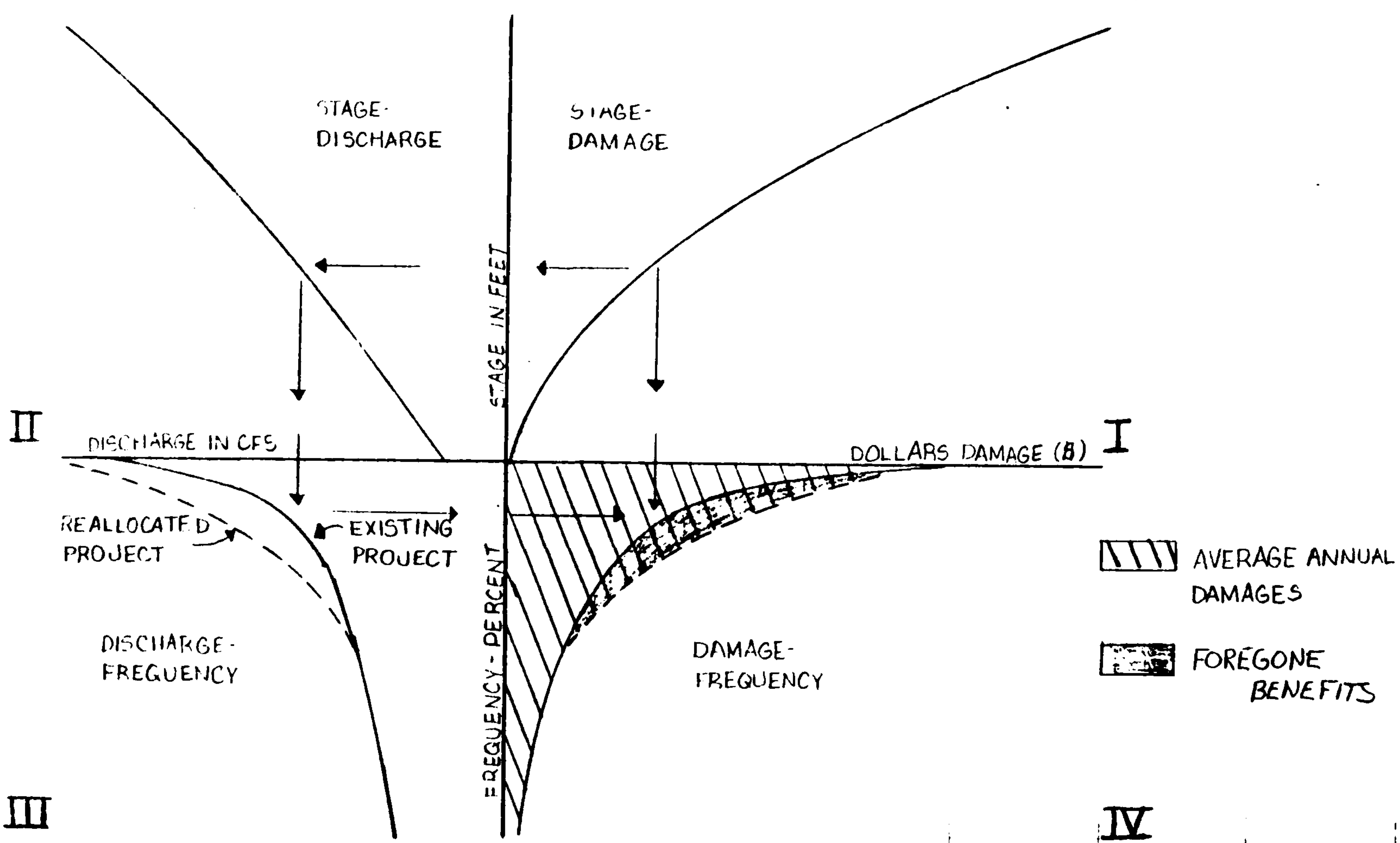
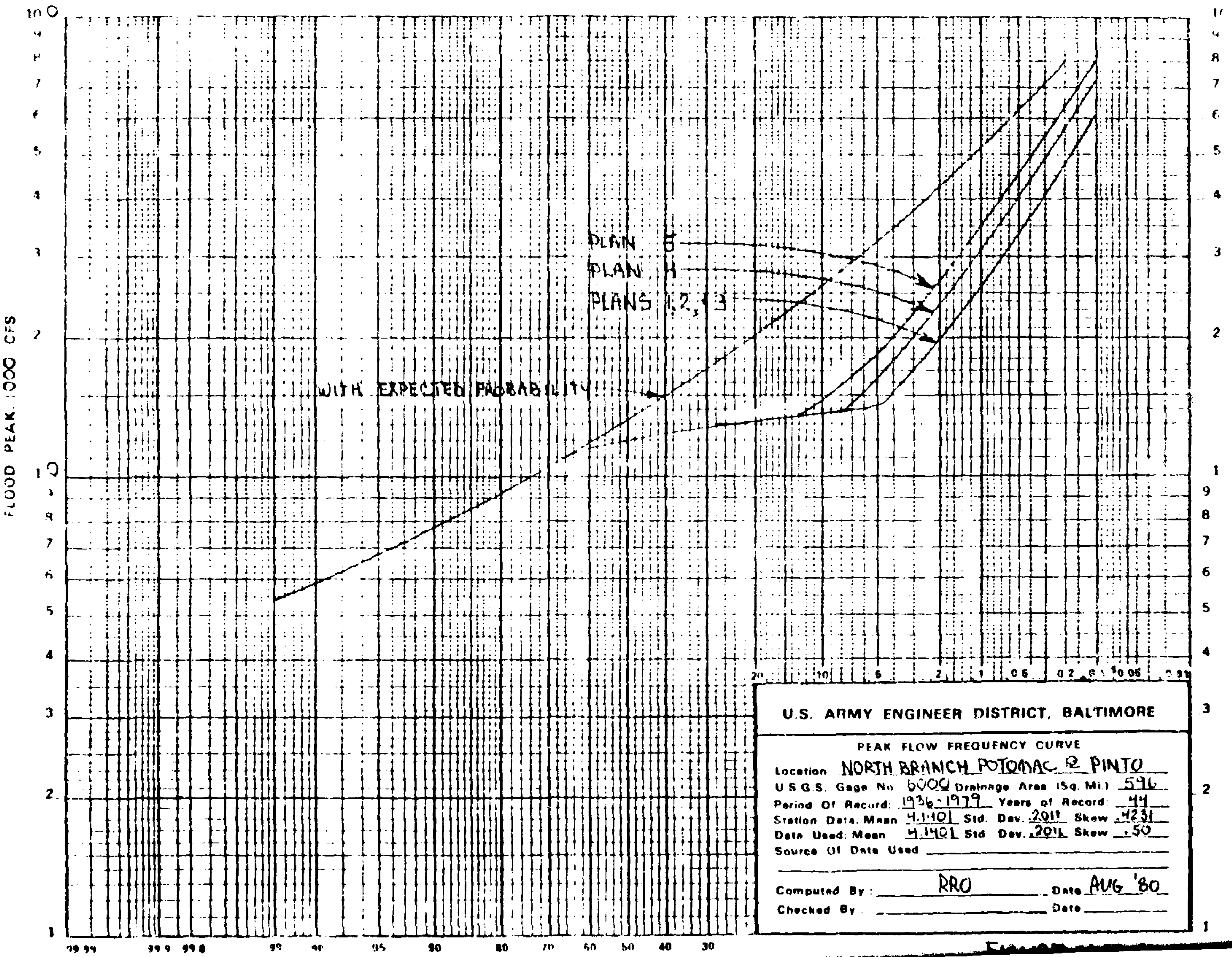
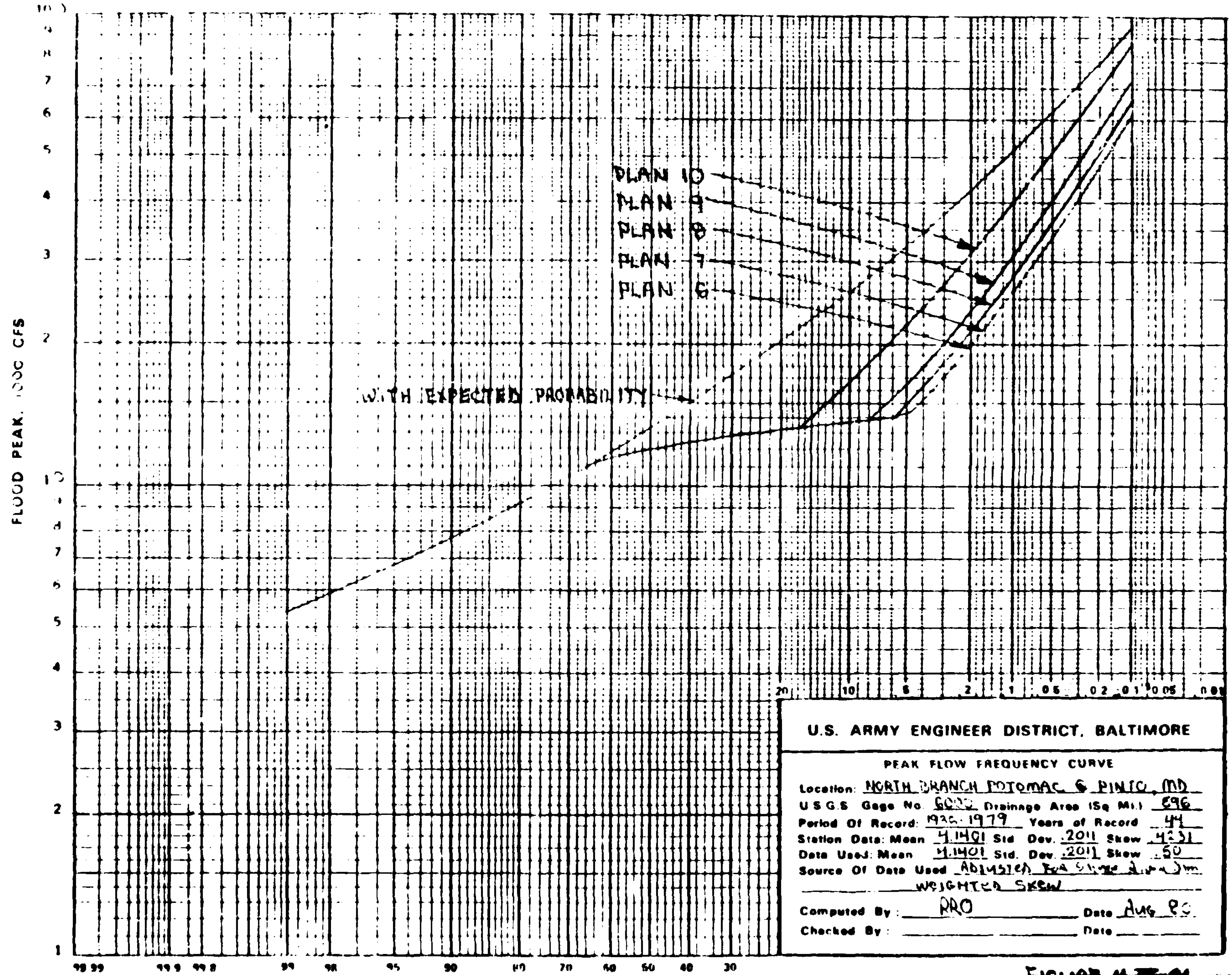


Figure H-IV-79 Effect of Reservoir Storage Reallocation




PLAN 5
PLAN 4
PLANS 1,2,&3
WITH EXPECTED PROBABILITY
FLOOD PEAK 1000 CFS
U.S. ARMY ENGINEER DISTRICT, BALTIMORE
PEAK FLOW FREQUENCY CURVE
Location NORTH BRANCH POTOMAC @ PINTO
U.S.G.S. Gage No 6000 Drainage Area (Sq. Mi.) 596
Period Of Record: 1936-1979 Years of Record: 44
Station Data: Mean 4.1401 Std. Dev. .2011 Skew .4231
Data Used: Mean 4.1401 Std Dev. .2011 Skew .50
Source Of Data Used
Computed By: RRO Date AUG '80
Checked By: Date



FLOOD PEAK, 1000 CFS
PLAN 10
PLAN 9
PLAN 8
PLAN 7
PLAN 6
WITH EXPECTED PROBABILITY
U.S. ARMY ENGINEER DISTRICT, BALTIMORE
PEAK FLOW FREQUENCY CURVE
Location: NORTH BRANCH POTOMAC & PINTO, MD
U.S.G.S. Gage No. 6000 Drainage Area (Sq Mi) 896
Period Of Record: 1936-1979 Years of Record 44
Station Data: Mean 4.1401 Std. Dev. .2011 Skew .4231
Data Used: Mean 4.1401 Std. Dev. .2011 Skew .50
Source Of Data Used: ADJUSTED FOR STORAGE
WEIGHTED SKEW
Computed By: PRO Date: AUG 80
Checked By: Date:

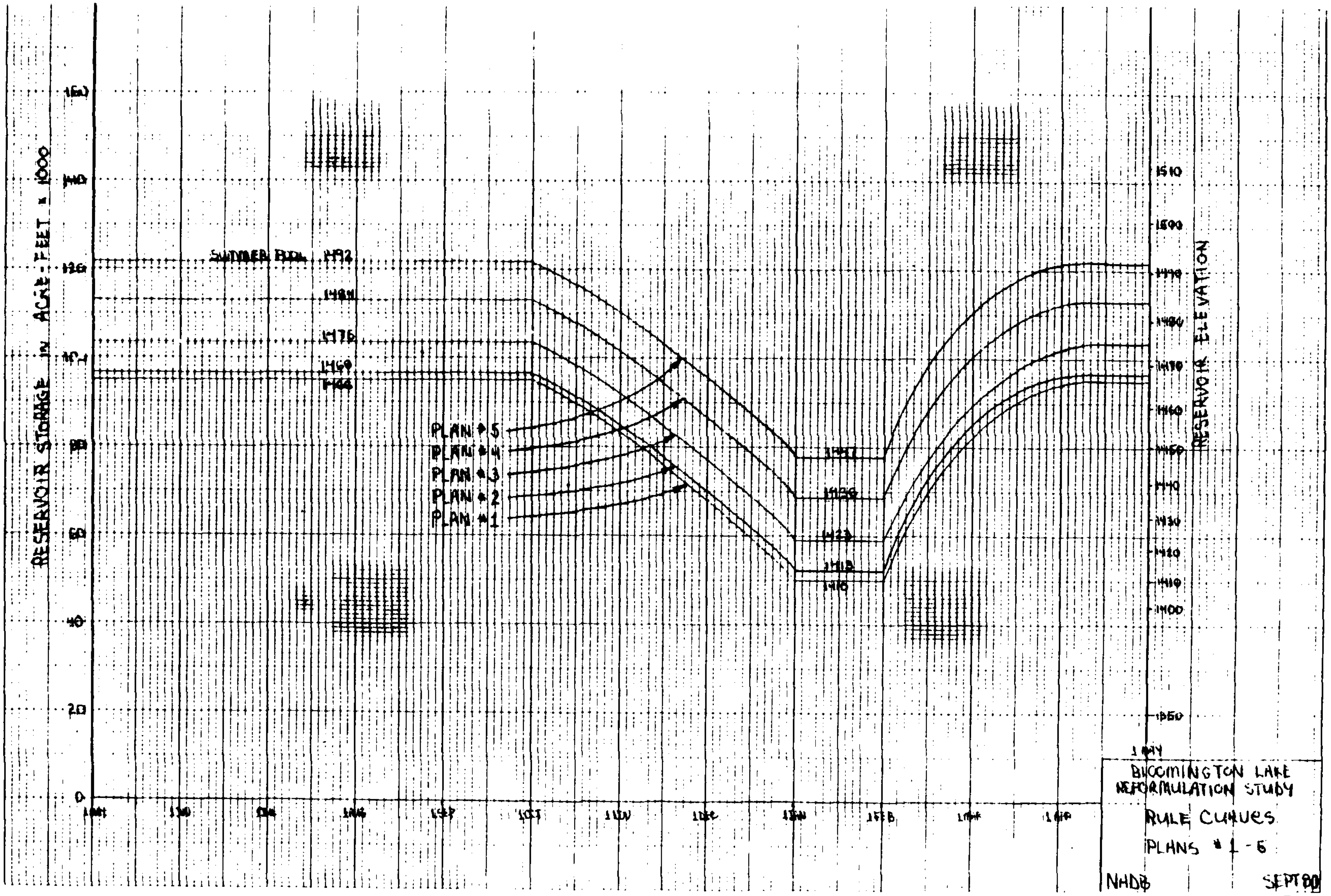
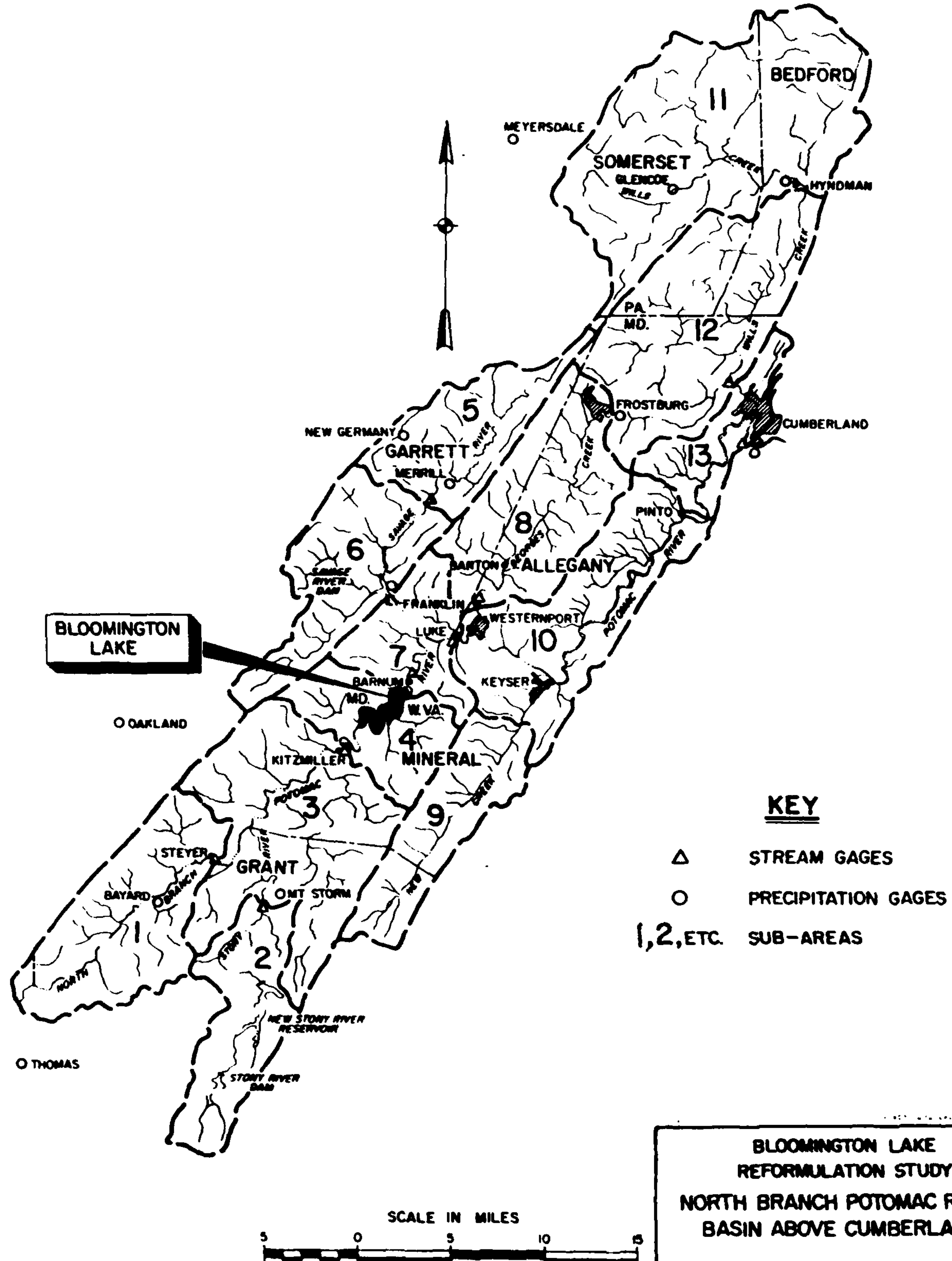

RESERVOIR STORAGE IN ACRE-FEET x 1000
RESERVOIR ELEVATION
SUMMER POOL 1492
1484
1476
1469
1466
PLAN #5
PLAN #4
PLAN #3
PLAN #2
PLAN #1
1510
1500
1490
1480
1470
1460
1450
1440
1430
1420
1410
1400
BLOOMINGTON LAKE
REFORMULATION STUDY
RULE CURVES
PLANS #1 - 5
NHDB
SEPT 80

PLATE H-IV-1

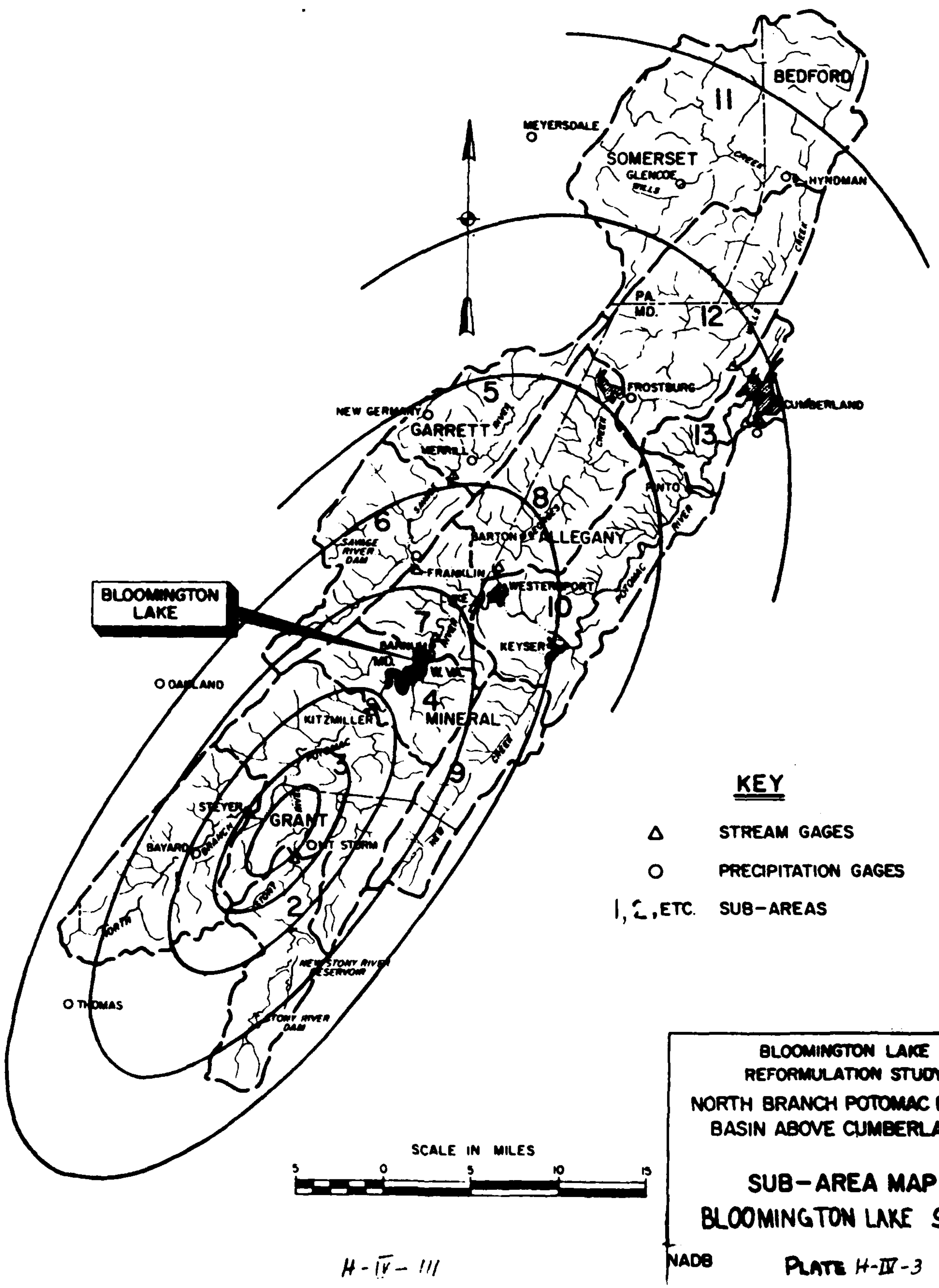


BLOOMINGTON LAKE
REFORMULATION STUDY

NORTH BRANCH POTOMAC RIV
BASIN ABOVE CUMBERLAND

SUB-AREA MAP

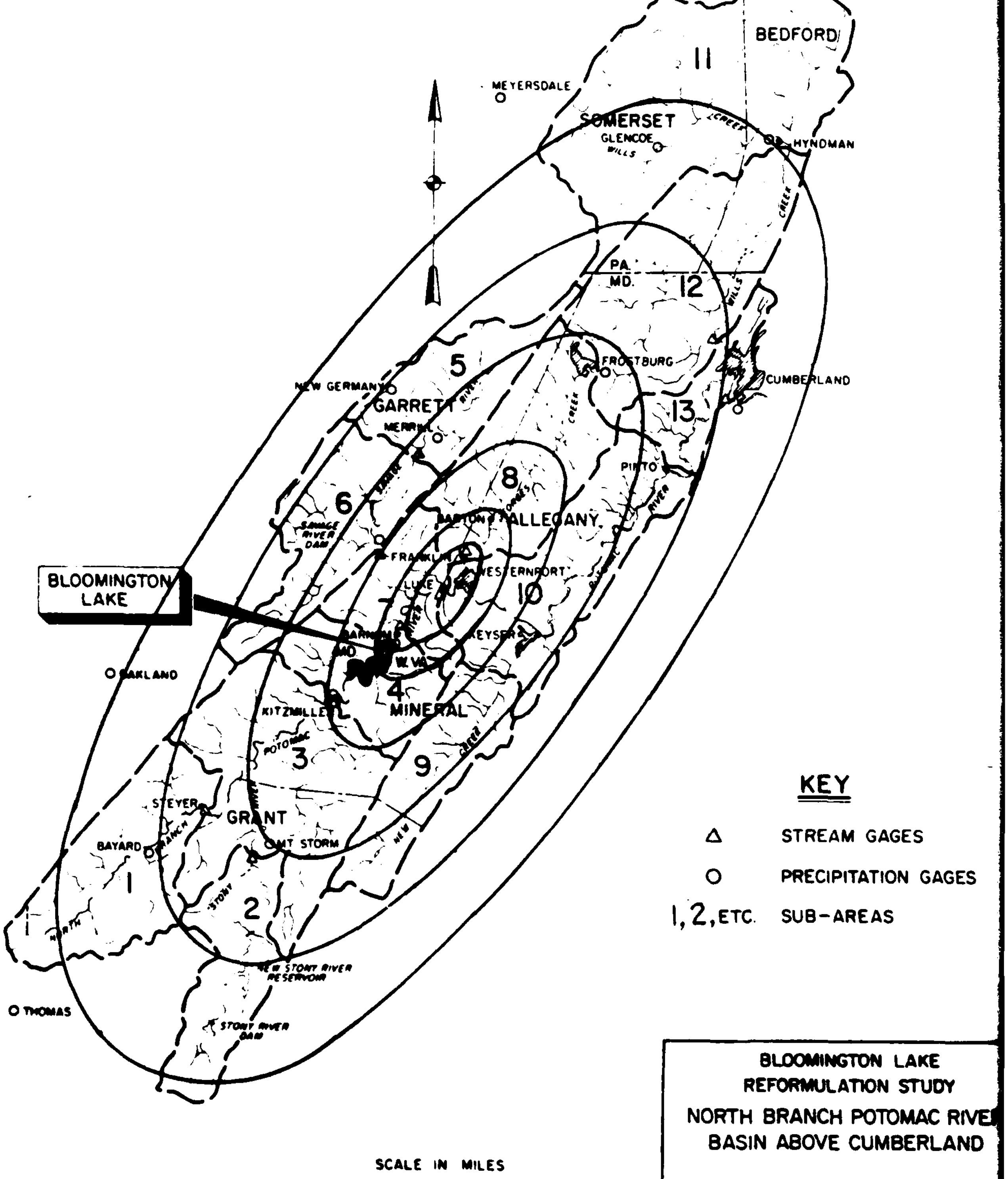
NADB PLATE H-IV-2



BLOOMINGTON LAKE
REFORMULATION STUDY
NORTH BRANCH POTOMAC RIVEI
BASIN ABOVE CUMBERLAND

SUB-AREA MAP
BLOOMINGTON LAKE SPS

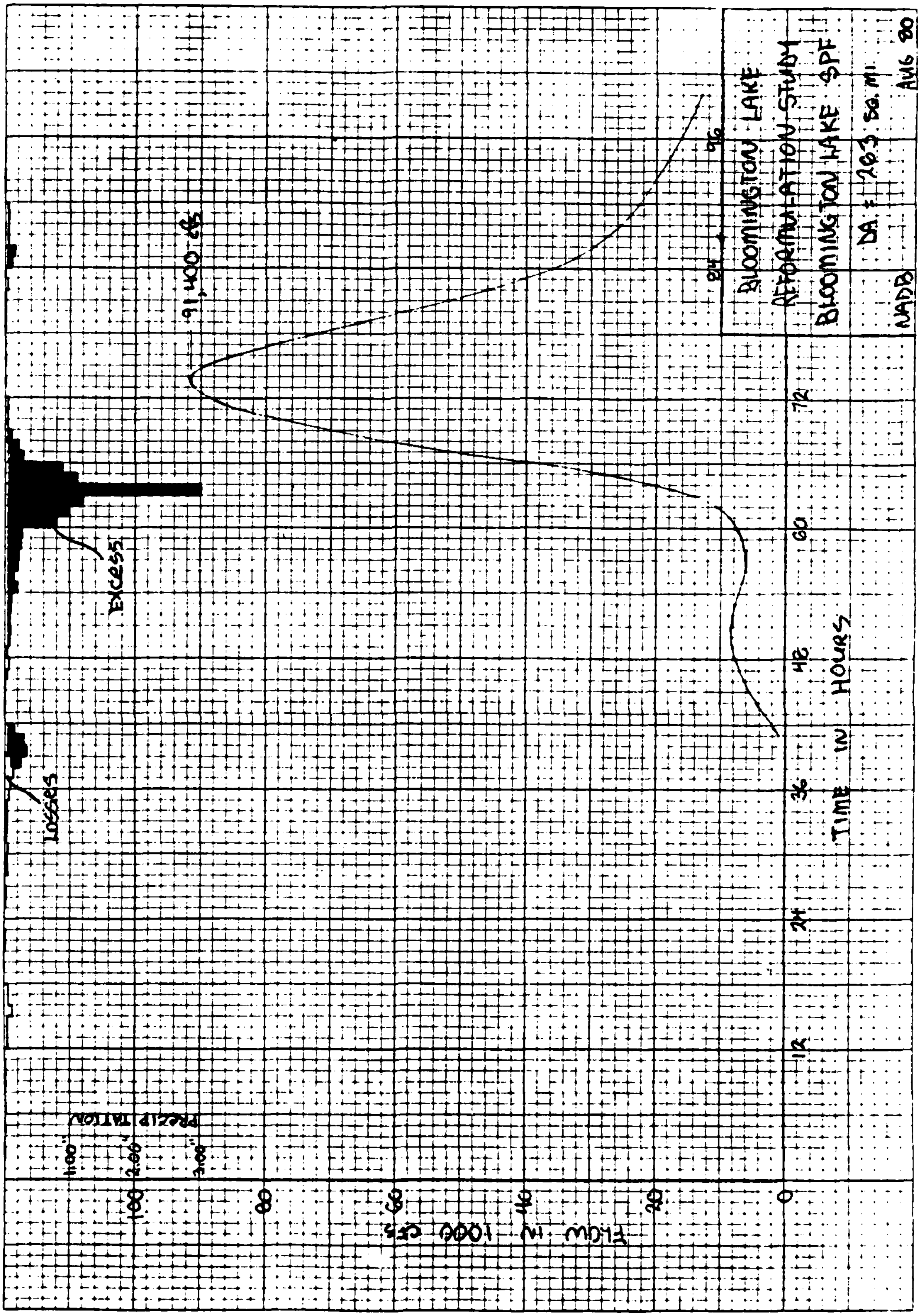
NADB PLATE H-IV-3 SE1



BLOOMINGTON LAKE
REFORMULATION STUDY
NORTH BRANCH POTOMAC RIVER
BASIN ABOVE CUMBERLAND

SUB-AREA MAP
CUMBERLAND, MD SPS

NADB PLATE H-IV-4 SE



BLOOMINGTON LAKE
REFORMULATION STUDY
BLOOMINGTON LAKE SPF
DA = 263 SQ. MI.
NADB
AUG 80
91,400 cfs
EXCESS
LOSSES
PRECIPITATION
1.00"
2.00"
3.00"
FLOW IN 1000 CFS
0
20
40
60
80
100
TIME IN HOURS
12
24
36
48
60
72
84
96

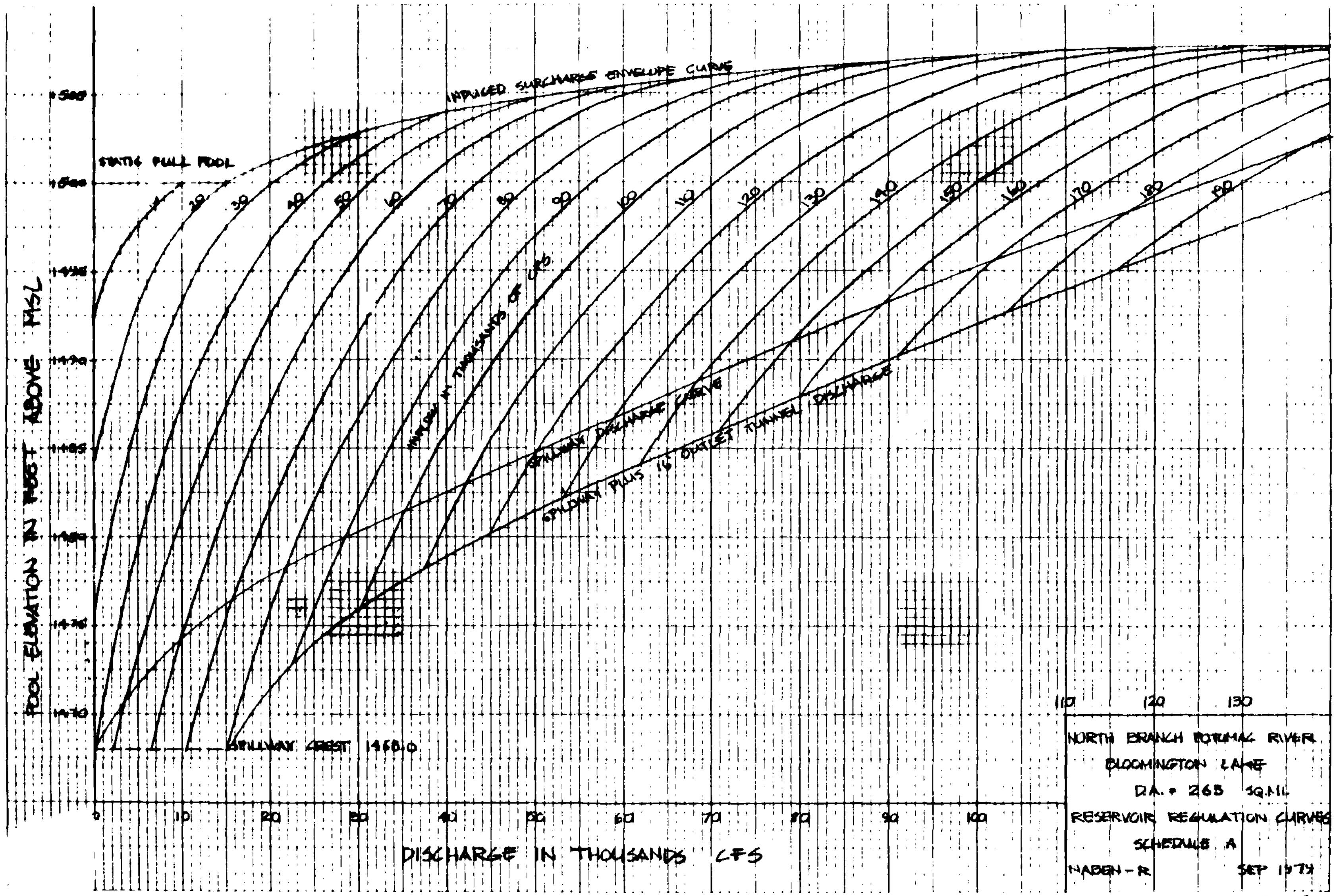

STATIC FULL POOL
INDUCED SURCHARGE ENVELOPE CURVE
INFLOW IN THOUSANDS OF CFS
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
SPILLWAY DISCHARGE CURVE
SPILLWAY PLUS 16 OUTLET TUNNEL DISCHARGE
SPILLWAY CREST 1468.0
POOL ELEVATION IN FEET ABOVE MSL
DISCHARGE IN THOUSANDS CFS
NORTH BRANCH POTOMAC RIVER
BLOOMINGTON LAKE
D.A. = 263 SQ.MI.
RESERVOIR REGULATION CURVES
SCHEDULE A
NABEN-R
SEP 1974

PLATE H-IV-6

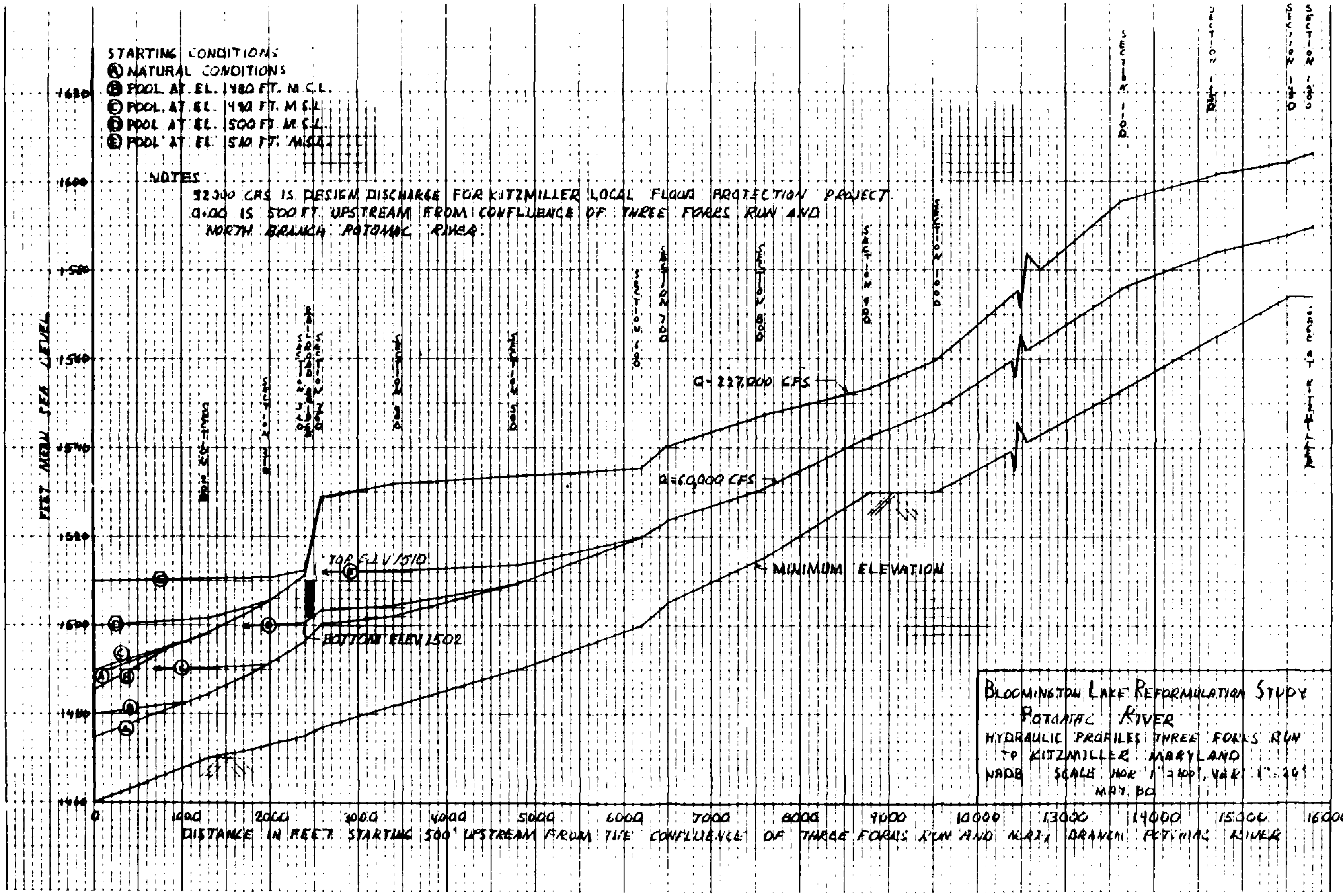

STARTING CONDITIONS
Ⓐ NATURAL CONDITIONS
Ⓑ POOL AT EL. 1480 FT. M.S.L.
Ⓒ POOL AT EL. 1490 FT. M.S.L.
Ⓓ POOL AT EL. 1500 FT. M.S.L.
Ⓔ POOL AT EL. 1510 FT. M.S.L.
NOTES:
32000 CFS IS DESIGN DISCHARGE FOR KITZMILLER LOCAL FLOOD PROTECTION PROJECT.
0+00 IS 500 FT. UPSTREAM FROM CONFLUENCE OF THREE FORKS RUN AND NORTH BRANCH POTOMAC RIVER.
Q=227,000 CFS
Q=60,000 CFS
MINIMUM ELEVATION
TOP ELEV 1510
BOTTOM ELEV 1502
FEET MEAN SEA LEVEL
DISTANCE IN FEET STARTING 500' UPSTREAM FROM THE CONFLUENCE OF THREE FORKS RUN AND N. BRANCH POTOMAC RIVER
BLOOMINGTON LAKE REFORMULATION STUDY
POTOMAC RIVER
HYDRAULIC PROFILES THREE FORKS RUN TO KITZMILLER MARYLAND
NAOB SCALE HOR. 1"=1000', VAR. 1"=20'
MAY 80

PLATE H-IV-7

ANNEX H-V

FLOW ROUTING IN THE POTOMAC RIVER BASIN FROM LUKE, MARYLAND TO WASHINGTON, D.C.

PREPARED BY

UNITED STATES GEOLOGICAL SURVEY

DOWNSTREAM EFFECTS OF RESERVOIR RELEASES TO THE POTOMAC RIVER FROM LUKE, MARYLAND, TO WASHINGTON, D.C.

By Thomas J. Trombley

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 82-4062

Prepared in cooperation with the

U.S. ARMY CORPS OF ENGINEERS

Towson, Maryland
August 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
208 Carroll Building
8600 La Salle Road
Towson, Maryland 21204

Copies of this report can be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Lakewood, Colorado 80225
(Telephone: (303) 234-5888)

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION OF MEASUREMENT UNITS

For those readers who may prefer to use metric units instead of inch-pound units, the conversion factors for units used in this report are listed below.

To convert from	Multiply by	To obtain
foot (ft)	0.3048	meter (m)
square foot per second (ft^2/s)	0.0929	square meter per second (m^2/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

DOWNSTREAM EFFECTS OF RESERVOIR RELEASES TO THE POTOMAC RIVER FROM LUKE, MARYLAND, TO WASHINGTON, D.C.

by Thomas J. Trombley

ABSTRACT

A digital computer flow-routing model was used to determine the downstream effects on the Potomac River of flow releases from the Bloomington and Savage River Reservoirs. Both reservoirs are located upstream from Luke, Maryland, approximately 230 miles upstream from Washington, D.C.

The downstream effects of reservoir releases were determined by using the unit-response method of flow routing implemented by a diffusion analogy. Results are in the form of unit-response coefficients which are used to route flows downstream from Luke, Maryland.

A 24-hour sustained reservoir release input at Luke will result in 35 percent of the flow arriving at Washington, D.C., during the fourth day after the beginning of the release, followed by 61 percent and 4 percent arriving on the fifth and sixth days, respectively. For a 7-day sustained reservoir release, 47 percent of the flow will arrive during the first week and 53 percent will arrive during the second week.

INTRODUCTION

Background

The Potomac River basin (fig. 1) has a drainage area of 11,560 mi^2 upstream from the gaging station near Washington, D.C. (station 01646500). Mean daily discharge (adjusted for diversions) at that gaging station was 11,490 ft^3/s for the period March 1930 through September 1980. A mean daily diversion of approximately 500 ft^3/s provides over 60 percent of the water supply for the Washington metropolitan area. These diversions are less than 5 percent of the mean daily flow.

The lowest observed streamflow at Washington, D.C., (adjusted for diversions) occurred in 1966 with 610 and 601 ft^3/s observed on September 9 and 10, respectively. Diversions for those 2 days were 489 and 449 ft^3/s, which is approximately three-fourths of the total flow. Obviously, if water-supply demands should increase and/or more severe droughts should occur, it may be impossible to satisfy the demands with the available streamflow. In addition, the remaining streamflow may not be adequate to prevent water-quality problems from developing downstream from Washington. To augment streamflow at Washington during low flow periods, the Bloomington Reservoir on the Potomac River and the Savage Reservoir on the Savage River are available. Both reservoirs are located upstream from Luke, Md., about 230 mi upstream from Washington (see fig. 1).

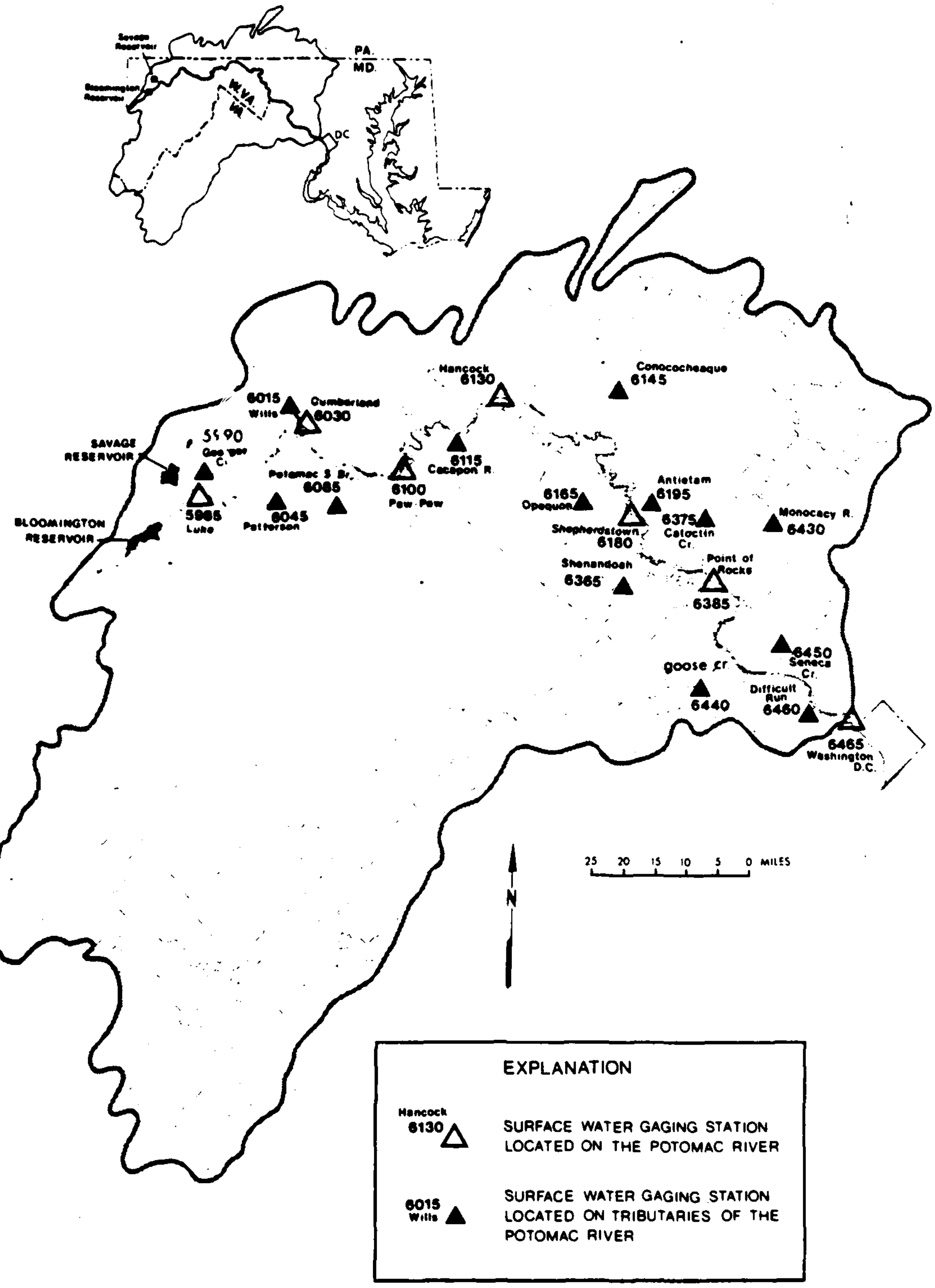


Figure 1.-- Location of study area and gaging stations used to model streamflow.

Purpose and Scope

This report describes a method of estimating downstream responses of reservoir releases from the Bloomington and Savage Reservoirs in the upper Potomac River basin. A flow-routing model is used to route reservoir releases down the river to Washington, D.C. The model yields unit-response coefficients that provide a simple method of estimating the time at which unit releases from the reservoirs will arrive at each of the following downstream stations:

Cumberland, Md.
Paw Paw, W.Va.
Hancock, Md.
Shepherdstown, W.Va.
Point of Rocks, Md.
Washington, D.C.

This study was conducted by the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, Baltimore District.

MODELING APPROACH

A flow-routing model was applied to six subreaches on the Potomac River using the unit-response method. The subreach models were then calibrated and linked together to produce a final model. The computer program used to model streamflow was developed by J. O. Shearman, Gloria Stiltner, and W. H. Doyle, Jr. (Shearman, 1980, written commun.).

Unit Response

Streamflow was modeled using the unit-response method of flow routing (Sauer, 1973). Unit response is defined as the downstream response to a unit flow input at the upstream end of the reach (fig. 2). It is analagous to the unit-hydrograph method of surface runoff. In this method, a unit-response function in the form of daily routing coefficients is applied to the input flow at the upstream end of the reach to route that flow to the downstream end of the reach (fig. 3). The discrete equation for the unit-response method of flow routing is:

$$y_t = \sum_{k=0}^{\infty} U_k X_{(t-k)}$$

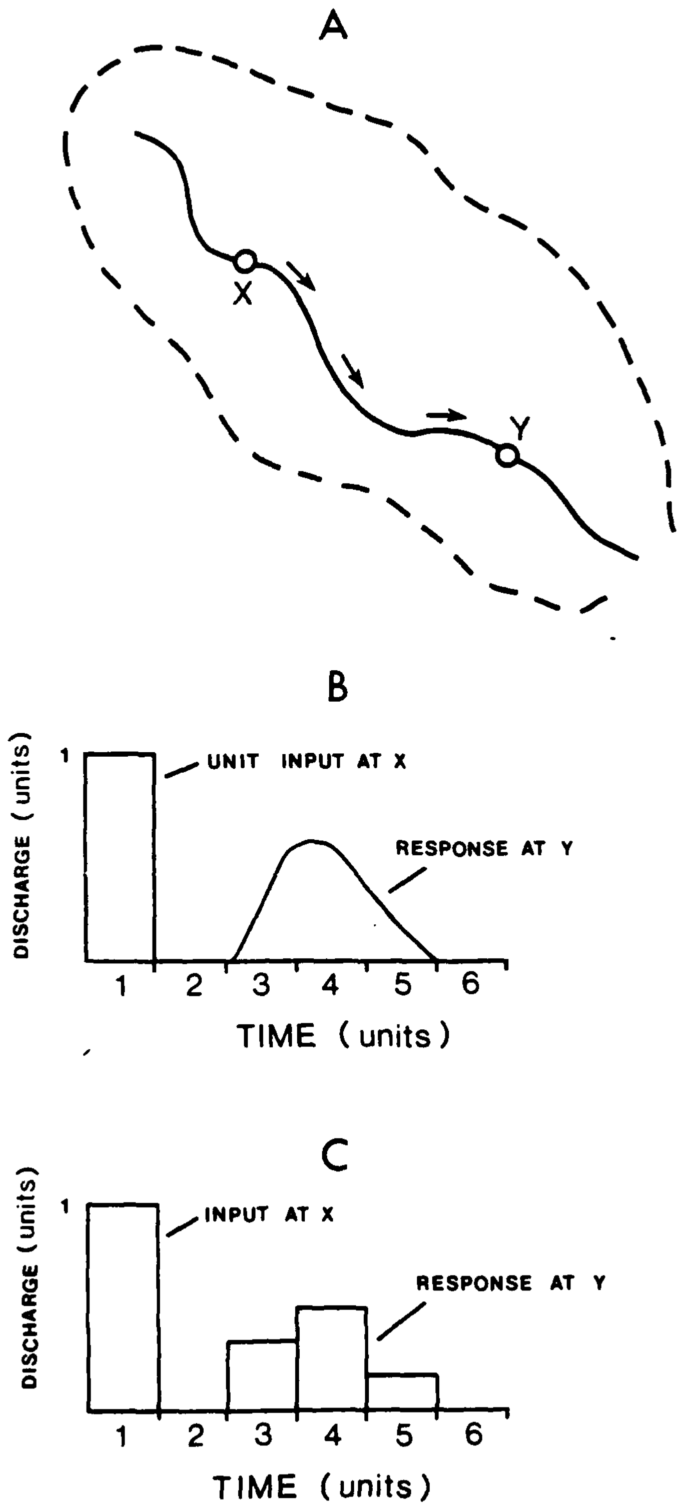
where

y_t = outflow at time (t);

$X_{(t-k)}$ = inflow at time (t-k); and

U_k = unit response coefficient for lag (k).

Any ungaged intervening flow or other gains or losses must be explicitly accounted for and added to, or subtracted from the routed flow.



A. Hypothetical drainage basin showing reach X – Y.

B. Unit flow input at x with unit duration, analog unit response function shows the Instantaneous flow at Y.

C. Same unit input at X, but unit response functions in terms of flow / unit time.

Figure 2.-- Development of the unit – response function.

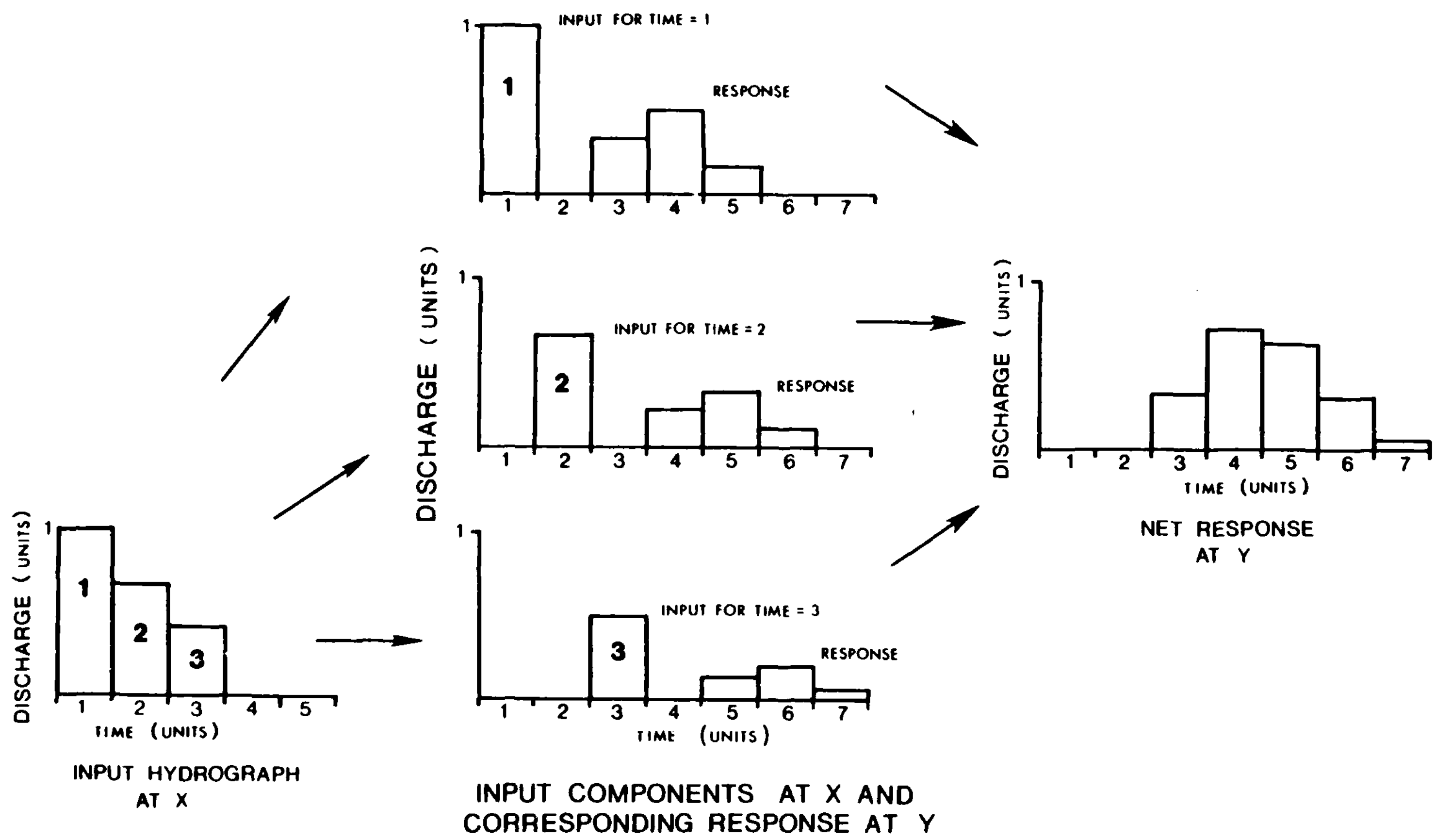


Figure 3 - - Application of the unit – response function to an input hydrograph to simulate the downstream response.

Unit-response functions were calculated using the diffusion approximation to the dynamic equations of open-channel flow (Keefer and McQuivey, 1974). This approximation describes the flow in terms of an input pulse that travels down the channel, spreading out or diffusing as it travels. Three parameters are needed to apply the diffusion analogy:

1.) Wave dispersion (K), which defines damping of the wave or flow pulse as it moves downstream,

$$K = \frac{Q}{(2SW)}$$

where

Q = reference discharge in ft^3/s;
S = average surface slope at Q; and
W = average channel width at Q.

2.) Wave celerity (C), which is the downstream velocity of the wave,

$$C = \frac{1}{W}\frac{dQ}{dy}$$

where $\frac{dQ}{dy}$ = slope of discharge/stage at Q.

3.) Reach length (X), which is the distance, in miles, that the flow has to travel.

The method used in this study combines system inputs with a unit-response function to produce a system output. In the final linked model, system input is the streamflow at Luke plus gaged tributary inflows, and inflows from ungaged areas between Luke and Washington, D.C. The unit-response function is a series of routing coefficients which convey daily flows through the system from Luke to Washington, D.C, and to intermediate points, with proper accounting for traveltime and dispersion. The system output is the total streamflow at Washington, D.C., and at the intermediate points. This model treats the system as if the unit-response is independent of discharge. That is, the response is the same for all flows.

Hydrologic Input Data

Streamflow records from 7 mainstem Potomac River gaging stations and 16 tributary gaging stations were used in the modeling process. Table 1 lists the station numbers, names, and drainage areas above the stations as well as the water years for which flow data were used for model calibration. The locations of these gaging stations within the Potomac River basin are shown in figure 1.

Table 1. -- Gaging stations used in modeling process

Station No.[1]	Station name[1]	Drainage area[1] (mi^2)	Period of record used
01598500	North Branch Potomac River at Luke, Md.	404	1950-78
01599000	Georges Creek at Franklin, Md.	72.4	.
01601500	Wills Creek near Cumberland, Md.	247	.
01603000	North Branch Potomac River near Cumberland, Md.	875	.
01604500	Patterson Creek near Headsville, W. Va.	219	.
01608500	South Branch Potomac River near Springfield, W. Va.	1,471	.
01610000	Potomac River at Paw Paw, W. Va.	3,109	.
01611500	Cacapon River near Great Capon, W. Va.	677	.
01613000	Potomac River at Hancock, Md.	4,073	.
01614500	Conococheague Creek at Fairview, Md.	494	.
01616500	Opequon Creek near Martinsburg, W. Va.	272	.
01618000	Potomac River at Shepherdstown, W. Va.	5,936	1950-53;1965-78
01619500	Antietam Creek near Sharpsburg, Md.	281	1950-78
01636500	Shenandoah River at Millville, W. Va.	3,040	.
01637500	Catoctin Creek near Middletown, Md.	66.9	.
01638500	Potomac River at Point of Rocks, Md.	9,651	.
01643000	Monocacy River at Jug Bridge near Frederick, Md.	817	.
01644000	Goose Creek near Leesburg, Va.	338	.
01645000	Seneca Creek at Dawsonville, Md.	101	.
01646000	Difficult Run near Great Falls, Va.	58	.
01646500	Potomac River near Washington, D.C.	11,560	1950-79

1 U.S. Geological Survey (1981).

SUBREACH MODELS

A flow-routing model was applied to six subreaches on the Potomac River. The endpoints of each subreach are at U.S. Geological Survey stream-gaging stations. The six subreaches modeled are:

Luke, Md., to Cumberland, Md.
Cumberland, Md., to Paw Paw, W. Va.
Paw Paw, W. Va., to Hancock, Md.
Hancock, Md., to Shepherdstown, W. Va.
Shepherdstown, W. Va., to Point of Rocks, Md.
Point of Rocks, Md. to Washington, D.C.

Luke, Md., was used as the most upstream input station because it is the furthest upstream gaging station below both Bloomington and Savage Reservoirs. The subreach models permitted maximum use of available observed streamflow data, and minimized modeling errors.

The subreach models were calibrated using the following steps:

1.) Each subreach model was run using initial values (table 2) for dispersion and celerity that were computed using methods suggested by Keefer (1974).

2.) Differences (errors) between simulated and observed flows for the 1950-78 water years were evaluated. Daily volume errors, total volume errors, and root mean square (rms) errors were considered.

3.) Adjustments were made to the input parameter values and estimates of the flow from the ungaged area. Additional model runs were made to:

   (a) reduce the total volume error as much as possible,

   (b) distribute the daily errors evenly about zero, and to

   (c) reduce the rms error as much as possible.

4.) Finally, a visual comparison was made of the simulated and observed hydrographs for the water years in which the errors were the highest, for 1966, which was a low flow year, and for 1972, which was a high flow year.

Table 2. -- Initial values for modeling parameters

Reach	X[1,2] (mi)	Q[1,3] (ft³/s)	S[1,4]	W[5] (ft)	K (ft²/s)	$\frac{dQ}{dy}$[6] (ft²/s)	C (ft/s)
Luke to Cumberland	33.7	990	0.0020	150	1,600	700	4.1
Cumberland to Paw Paw	27.0	2,300	.00067	220	7,000	1,200	5.5
Paw Paw to Hancock	38.0	3,700	.00052	320	11,000	1,500	4.7
Hancock to Shepherdstown	55.0	5,200	.00035	510	15,000	2,300	4.5
Shepherdstown to Point of Rocks	24.5	7,800	.00062	880	2,000	3,400	3.0
Point of Rocks to Washington	42.1	10,000	.00016	1,300	24,000	7,000	5.4

[1] U.S. Geological Survey (1981).

[2] Difference between downstream river mile and upstream river mile.

[3] Mean of the mean flow for period of record of upstream and downstream stations.

[4] Difference between gage datum for upstream and downstream stations divided by the reach length.

[5] Estimate based on stream widths shown on 1:24000 USGS topographic maps.

[6] Determined from rating tables for upstream and downstream stations.

Luke to Cumberland Calibration

The segment of the Potomac River between Luke and Cumberland, Md., is the most upstream subreach that was modeled (fig. 4). A detailed description of the calibration of this subreach follows in order to illustrate calibration of all the subreaches.

The drainage area upstream from Luke is 404 mi^2. At Cumberland the drainage area is 875 mi^2; therefore, the intervening drainage area of the subreach is 471 mi^2. There are two gaged tributaries which were used in the model. Georges Creek, which flows into the North Branch Potomac just downstream from Luke, has a gaged area of 72.4 mi^2. Wills Creek, with a gaged area of 247 mi^2, flows into the North Branch Potomac just upstream from Cumberland. The ungaged area upstream from Cumberland is 152 mi^2.

Georges Creek flow was added to the observed flow at Luke and the summed flow was then routed to Cumberland. Flow from Wills Creek and ungaged flow were then added to the routed flow.

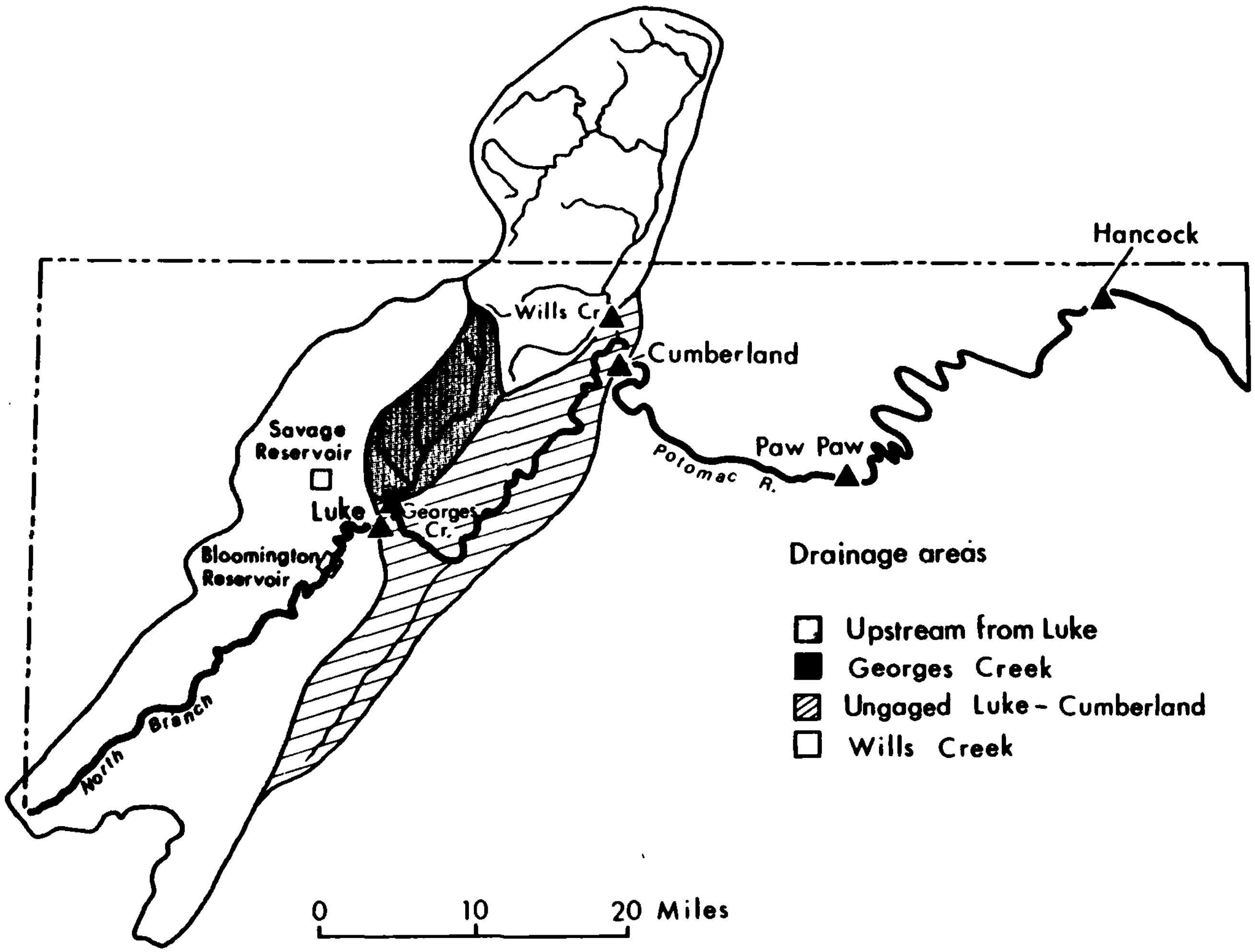


Figure 4.-- Potomac River basin upstream from Cumberland, Md.

The most significant problem with subreach calibration is determining the flow contribution from the ungaged area. Ungaged intervening flow was initially estimated by multiplying the flows from Georges Creek and Wills Creek by index values based on the areal ratio of their drainage basins to the ungaged area. Using the Georges Creek drainage area, a straight drainage-area ratio yields an index value of 152 mi^2/72.4 mi^2 = 1.10. Using the Wills Creek drainage area, the index is 152 mi^2/247 mi^2 = 0.615. Neither of the above index values accurately simulated ungaged flow. By adjusting the index values for which both Wills and Georges Creeks flows were multiplied, volume errors were eliminated, but the distribution of positive and negative errors was still unacceptable.

Because of the above factors, it was necessary to use a more complex method to estimate intervening ungaged flow. The result was an estimation of part of the ungaged flow by multiplying Georges Creek flows by an index of 1.2 before routing. The rest of the ungaged flow was accounted for by applying power curves to Wills Creek flows as follows:

$$QINTR1 = \begin{cases} 1.348\ WILLS^{0.758} & \text{if } WILLS \leq 290 \\ 0.175\ WILLS^{1.12} & \text{if } WILLS > 290. \end{cases}$$

where

QINTR1 = part of ungaged flow, in ft^3/s; and
WILLS = discharge at Wills Creek, in ft^3/s.

The calibrated subreach model for Luke to Cumberland is:

$$CUMBERLAND = (LUKE + 1.2\ GEORGES)route + WILLS + QINTR1$$

where

CUMBERLAND = discharge at the Cumberland gage;
LUKE = discharge at the Luke gage;
GEORGES = discharge at the Georges Creek gage; and
route = routing process demonstrated in figure 3.

The input parameters used for rcuting streamflow in this model are: Reach length (X) = 33.7 mi, dispersion (K) = 1,500 ft^2/s, and celerity (C) = 3.60 ft/s. The resulting routing coefficients for the unit-response function are: 0.42 for day 1, and 0.58 for day 2. This means that for any given day, 42 percent of the observed flow at Luke will pass Cumberland on the 1^{st} day and 58 percent will pass Cumberland on the 2d day.

Figures 5 through 8 are hydrographs of observed and simulated flows and modeling errors for the Luke to Cumberland subreach for the water years 1952, 1960, 1966, and 1972, respectively. Observed flows are plotted as lines on the hydrographs and simulated flows are plotted as points. Below each hydrograph, daily modeling errors are plotted as percentage deviations of simulated flow from observed flow.

The rms error for 1952 is the highest of all the water years modeled and most of the daily errors (66 percent) were negative. In 1960, most of the daily errors were positive. Flow was abnormally low in 1966 and was abnormally high in 1972. These hydrographs show that for the model of the Luke to Cumberland subreach, simulated flows closely match observed flows.

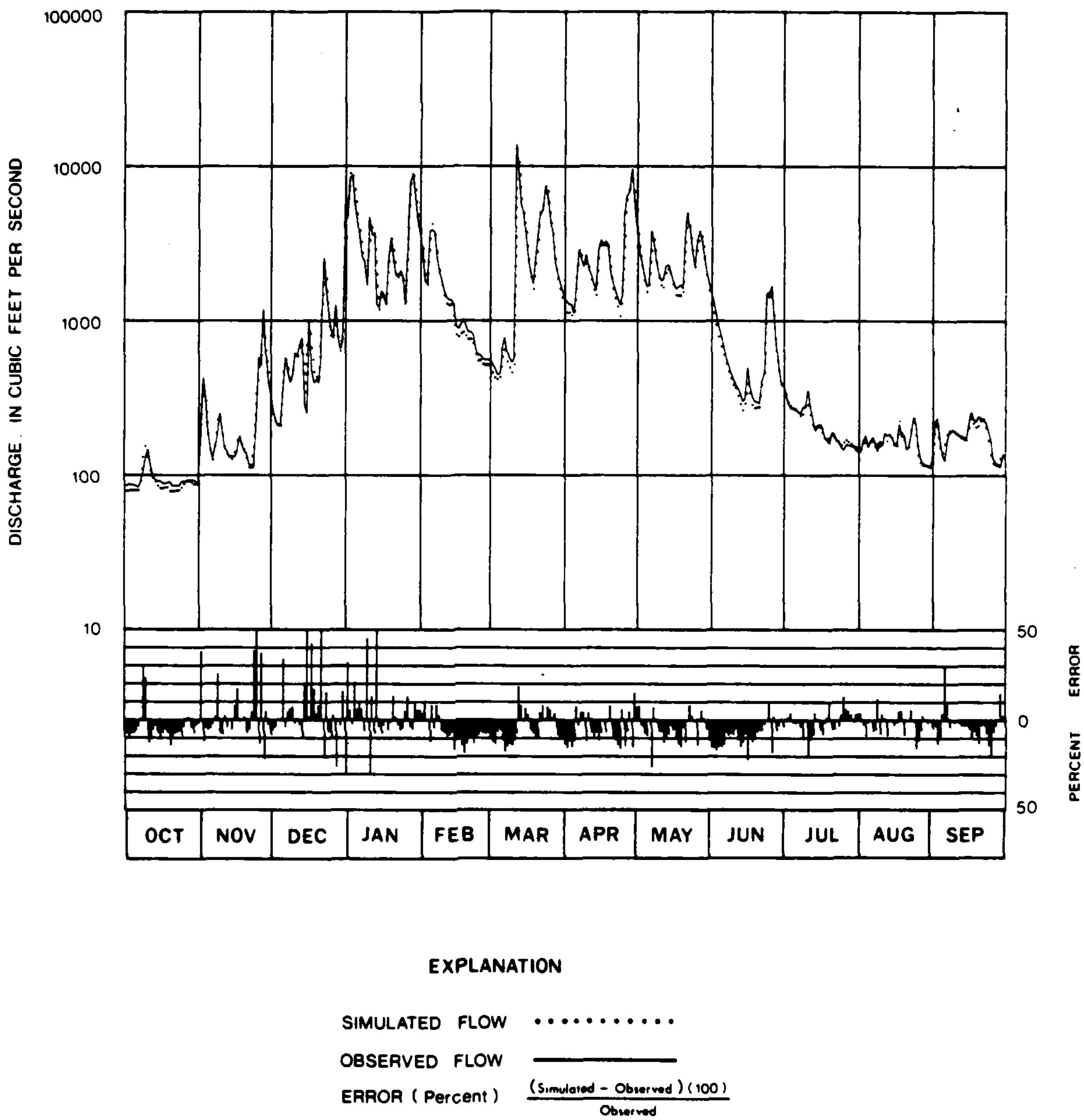


Figure 5.-- Observed and simulated flow and modeling errors at Cumberland Md., for the 1952 water year.

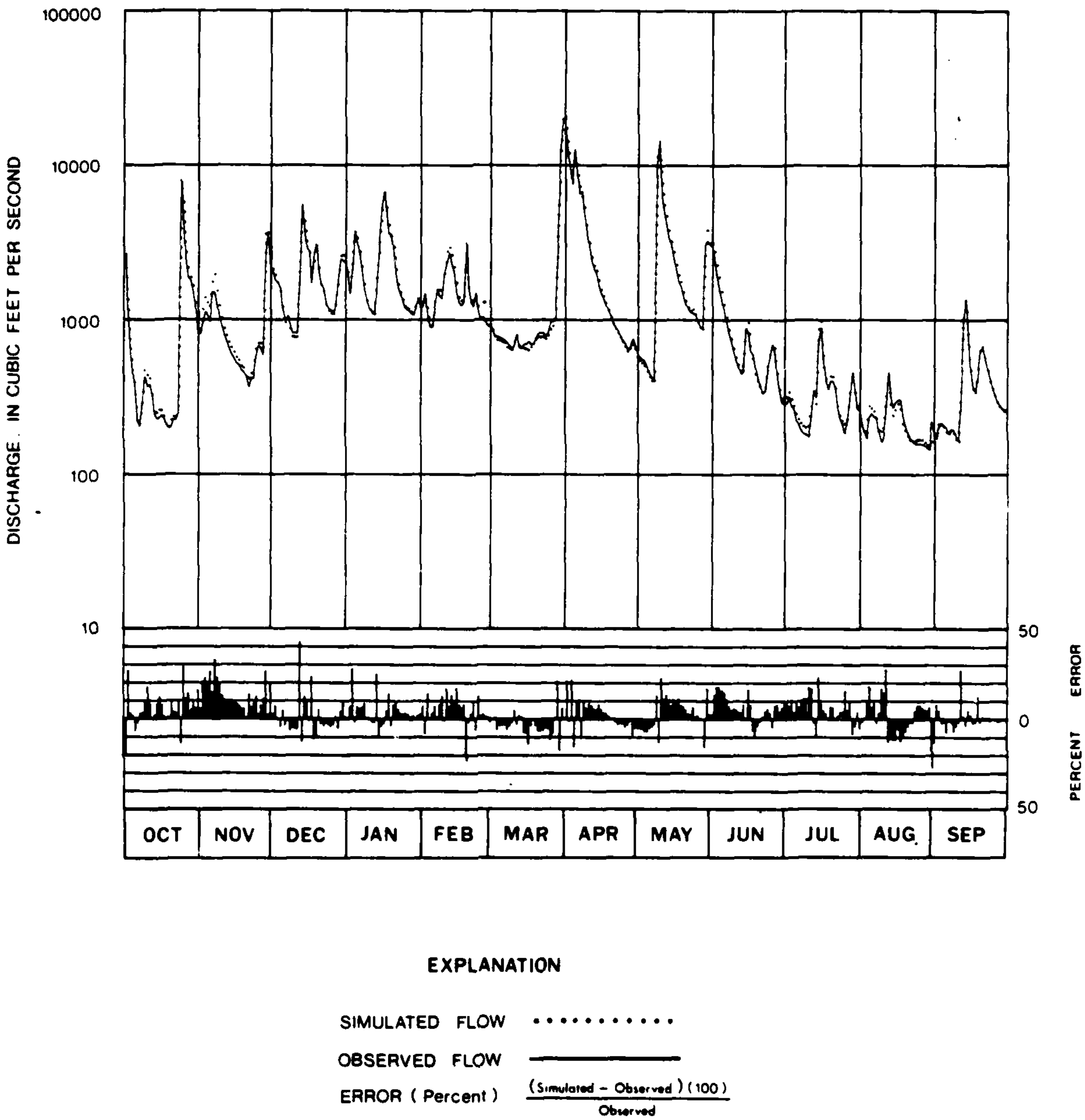
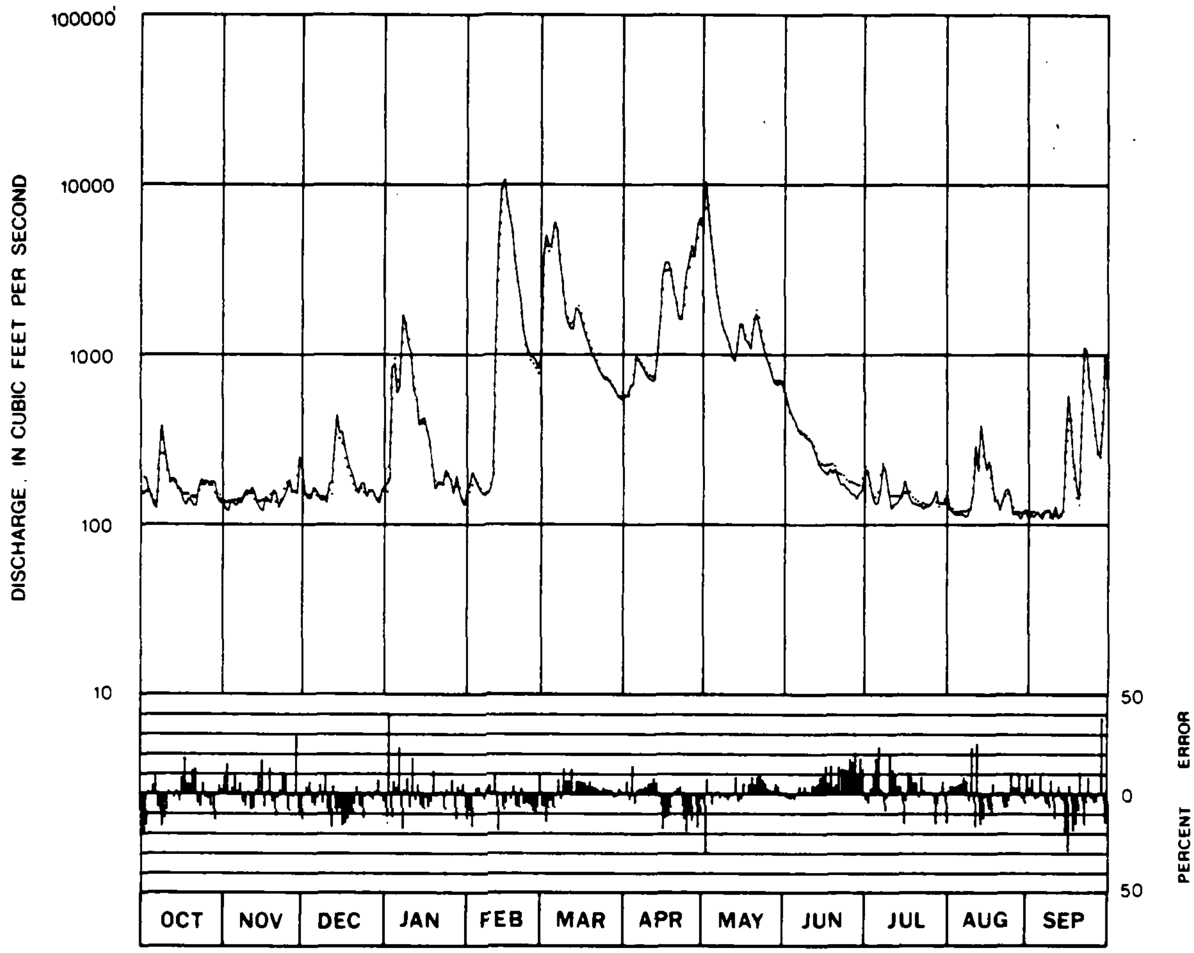


Figure 6.-- Observed and simulated flow and modeling errors at Cumberland Md., for the 1960 water year.



EXPLANATION

SIMULATED FLOW ....

OBSERVED FLOW ————

ERROR (Percent) $\frac{(\text{Simulated} - \text{Observed})(100)}{\text{Observed}}$

Figure 7.-- Observed and simulated flow and modeling errors at Cumberland Md., for the 1966 water year.

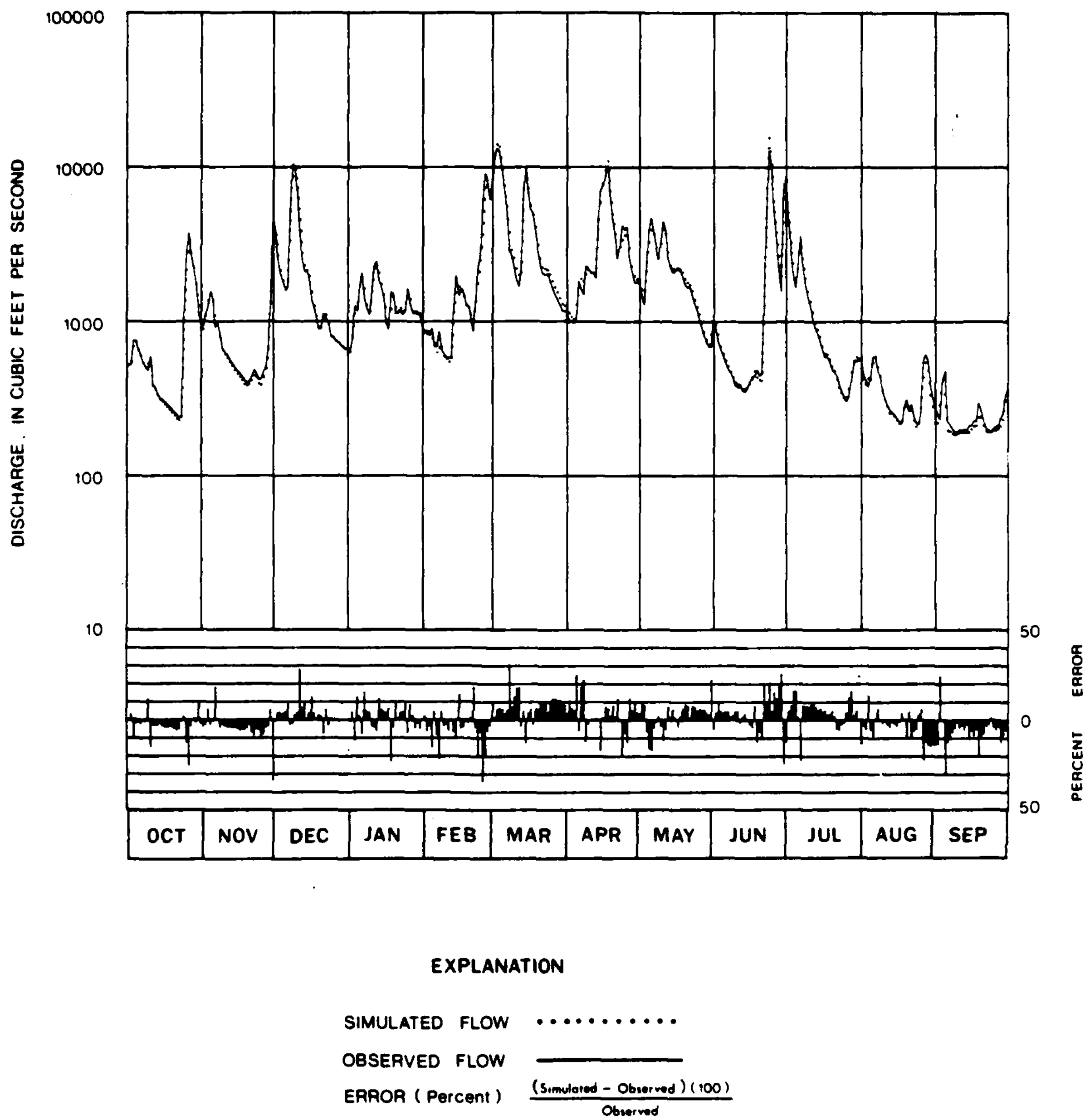


Figure 8.-- Observed and simulated flow and modeling errors at Cumberland Md., for the 1972 water year.

Table 3 summarizes modeling errors for each of the years modeled. During the 29 years over which the model was calibrated, approximately half of the daily errors are negative and half are positive; also, the mean absolute error is 7.33 percent, and the net yearly volume error is negative for 15 years and positive for 14 years, with a total volume error of -0.70 percent. The root mean square (rms) error for the final Luke-to-Cumberland subreach model over the 29-year calibration period appears to be minimized and is equal to 10.74 percent.

Table 4 summarizes the daily errors or deviations in terms of number of deviations between the indicated percentages over different discharge ranges. It is important to note that overall, the distribution of positive and negative errors is approximately equal, and that 46 percent of the time, deviations are between plus and minus 5 percent, and that 76 percent of the time, deviations are between plus and minus 10 percent.

The final routing model for the subreach between Luke and Cumberland was accepted because:

1.) Hydrographs of simulated and observed flows compare well for selected water years.

2.) Total volume error is small and the number of years in which net volume error was negative compares well with the number of years in which the net volume error was positive.

3.) Daily volume errors or deviations are evenly distributed with more than three-fourths of them falling between plus and minus 10 percent.

4.) The rms errors appear to be minimized.

Table 3. -- Annual summary of modeling errors (percent) for the Luke to Cumberland, Md., subreach.

Year	Mean error	Negative error days	Mean negative error	Positive error days	Mean positive error	Volume error	Rms error
1950	7.99	61	-7.25	39	9.14	-3.07	13.36
1951	6.80	62	-6.02	38	8.07	0.16	9.38
1952	8.81	67	-7.91	33	10.61	-1.50	14.97
1953	5.30	43	-4.80	57	5.68	1.48	7.61
1954	5.74	50	-5.68	50	5.79	-1.59	8.41
1955	8.00	64	-7.71	36	8.50	-1.68	13.84
1956	8.08	51	-7.54	49	8.65	-1.28	15.24
1957	6.99	52	-7.49	48	6.47	1.72	9.09
1958	7.29	42	-5.53	58	8.56	1.51	10.27
1959	7.46	50	-6.78	50	8.14	3.17	11.08
1960	7.42	37	-5.22	63	8.72	3.56	9.84
1961	7.43	53	-6.93	47	7.99	1.63	9.92
1962	8.67	63	-8.82	37	8.41	-4.42	11.84
1963	7.20	42	-7.28	58	7.15	-3.21	9.74
1964	6.38	38	-6.31	62	6.43	1.92	8.77
1965	5.93	52	-6.58	48	5.22	-3.42	9.00
1966	6.67	46	-6.94	54	6.44	-3.39	9.03
1967	6.53	35	-5.79	65	6.94	-0.54	9.09
1968	7.03	44	-5.26	56	8.40	2.11	9.83
1969	8.32	32	-6.99	68	8.94	3.16	10.93
1970	10.28	30	-6.78	70	11.79	4.43	13.83
1971	9.31	23	-7.30	77	9.91	2.44	12.83
1972	6.92	51	-6.68	49	7.19	0.55	9.21
1973	8.62	81	-8.99	19	7.01	-6.28	11.05
1974	7.70	69	-7.37	31	8.44	-4.34	11.12
1975	6.86	69	-7.36	31	5.75	-2.88	9.76
1976	5.83	60	-5.44	40	6.42	-2.41	8.57
1977	6.20	56	-5.56	44	7.01	-2.03	8.38
1978	6.72	50	-6.51	50	6.92	-1.98	9.94
Total 1950-78	7.33	51	-6.84	49	7.83	-0.70	10.74

Table 4. -- Distribution of daily error with discharge for Luke-to-Cumberland, Md. subreach model.

Discharge (ft^3/s)	Number of days that daily error was between specified percentages													
	< -30	-30 -25	-25 -20	-20 -15	-15 -10	-10 -5	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 >
0 - 83	0	0	0	0	3	19	7	3	0	1	1	0	0	0
83 - 98	0	0	0	1	2	8	18	59	34	7	3	1	7	1
98 - 120	0	0	0	3	7	26	89	125	71	17	7	1	2	1
120 - 140	0	0	1	1	20	45	104	142	63	17	17	5	4	4
140 - 160	0	0	0	10	47	101	125	151	105	42	23	12	2	11
160 - 190	1	2	4	20	53	103	176	167	78	40	15	8	2	7
190 - 230	0	2	4	16	41	102	150	106	64	22	15	6	2	8
230 - 270	0	0	3	13	45	99	132	114	52	21	10	8	4	7
270 - 320	0	1	1	12	29	89	127	116	46	25	11	11	1	8
320 - 380	1	0	1	9	25	[illegible]	139	116	70	30	12	5	6	6
380 - 450	2	2	4	9	27	81	149	125	78	36	14	6	2	8
450 - 540	1	2	4	13	23	91	134	126	70	50	13	3	3	9
540 - 640	0	0	9	7	26	89	158	118	67	37	16	11	4	1
640 - 750	0	0	5	16	48	91	116	114	41	32	15	6	2	4
750 - 890	3	1	11	21	60	112	135	117	75	42	16	15	9	6
890 - 1,100	3	3	9	15	40	92	110	97	73	31	17	8	4	3
1,100 - 1,300	0	4	5	12	30	52	86	73	61	36	15	5	4	3
1,300 - 1,500	0	2	4	10	33	79	120	105	56	33	17	5	3	10
1,500 - 1,800	2	2	4	8	27	63	21	85	55	25	11	4	4	6
1,800 - 2,100	3	4	7	11	24	57	85	87	42	30	14	8	4	1
2,100 - 2,500	3	1	5	6	21	32	66	56	43	11	9	8	2	3
2,500 - 2,900	3	2	4	12	30	40	57	59	57	25	8	4	0	4
2,900 - 3,500	2	4	8	8	18	25	34	47	47	19	2	2	2	1
3,500 - 4,100	3	3	5	6	9	27	32	45	30	16	5	1	4	3
4,100 - 4,900	3	3	0	6	13	12	24	19	24	13	2	4	1	2
4,900 - 5,800	1	2	4	7	5	21	18	18	13	6	3	3	0	3
5,800 - 6,800	0	3	2	4	10	11	18	28	5	5	1	2	1	2
6,800 - 8,100	3	1	3	2	7	5	12	11	11	4	2	0	0	0
8,100 - 9,600	1	0	0	2	3	3	4	6	4	1	0	1	0	0
9,600 - 11,000	1	0	2	6		5	6	3	3	2	0	2	0	0
11,000 - 13,000	0	2	1	1	3	4	1	3	2	0	1	0	0	0
13,000 - 16,000	1	1	0	0	1	2	0	1	1	0	0	0	0	0
16,000 - 19,000	0	1	1	0	0	0	0	1	0	0	0	0	0	0
19,000 - 22,000	0	1	0	0	1	0	0	0	0	0	0	0	0	0

															Total
SUM	38	49	106	267	739	1674	2511	2447	1439	676	295	155	74	122	10592
Percent of total	.4	.5	1.0	2.5	7.0	15.8	23.7	23.1	13.6	6.4	2.8	1.5	.7	1.2	100.2

Summary of Subreach Results

The other five subreaches were calibrated in the same manner as the Luke to Cumberland subreach. The results of the subreach calibration are shown in table 5, which lists the calibrated subreach models, input parameters, and the unit-response coefficients used for routing flows in each subreach.

The Hancock to Shepherdstown subreach was divided into two parts. In the first part, a reach length of 55 mi is used to route flows from the upper portion of the subreach to Shepherdstown. In the second part, a reach length of 25 mi is used to route flows from the central and lower portions of the subreach.

On the Shepherdstown to Point of Rocks subreach, flow from Catoctin Creek is lagged 6 hours. This is accomplished by the following:

$$Qlag_n = 0.75\ Q_{n-1} + 0.25\ Q_n.$$

where

Qlag = lagged flow;

n = day in which flow occurrs; and

Q = observed flow.

This lagging feature is a method of accounting for the traveltime of flows from the mouth of Catoctin Creek through the Potomac River to Point of Rocks.

Table 5. -- Subreach model summary

Subreach	Model[1]	Routing parameters: Dispersion K_2 ft^2/s	Routing parameters: Celerity C ft/s	Routing parameters: Length X mi	Routing coefficient: Day 1	Routing coefficient: Day 2	Routing coefficient: Day 3
Luke to Cumberland	(LUKE + 1.2 GEORGES)routed[2] + WILLS + QINTR1	1,500	3.00	33.7	0.418	0.582	
	QINTR1 = 1.35 $WILLS^{0.758}$ if WILLS ≤ 200 ft^3/s						
	0.175 $WILLS^{1.12}$ if WILLS > 200 ft^3/s						
Cumberland to Paw Paw	(CUMBERLAND + 2.0 PATTERSON + SOUTH BRANCH)routed + QINTR3	6,000	3.50	27.6	.518	.482	
	QINTR3 = 20.4 PATTERSON if PATTERSON ≤ 40 ft^3/s						
	4.60 PATTERSON if PATTERSON > 40 ft^3/s						
Paw Paw to Hancock	(PAW PAW) routed + 1.3 CACAPON	15,000	3.75	30.0	.364	.636	
Hancock to Shepherdstown	(HANCOCK + CONOCOCHEAGUE + 1.5 OPEQUON) routed (55 mi)	20,000	4.25	55.0 25.0	.216 .640	.778 .360	0.006
	+ 0.90 CONOCOCHEAGUE + OPEQUON)routed (25 mi)						
Shepherdstown to Point of Rocks	(SHEPHERDSTOWN + 1.5 ANTIETAM + SHENANDOAH)routed	15,000	4.25	24.5	.647	.353	
	+ CATOCTIN (lagged 6 hours) + 2.00 CATOCTIN						
Point of Rocks to Washington	(POINT OF ROCKS + MONOCACY + GOOSE)routed	30,000	3.00	42.1	.193	.756	.051
	+ SENECA + DIFFICULT + QINTR7						
	QINTR7 = 55.7 $GOOSE^{0.302}$ if GOOSE ≤ 350 ft^3/s						
	0.254 $GOOSE^{1.32}$ if GOOSE > 350 ft^3/s and if GOOSE ≤ 1,600 ft^3/s						
	2.15 GOOSE if GOOSE > 1,600 ft^3/s						

1 Station name used to represent flow at gage.

2 Routed = routing process demonstrated in figure 3.

Table 6 summarizes the modeling errors over the indicated calibration period for each subreach, and table 7 summarizes the daily errors. Four of the subreaches were calibrated for the 1950-78 water years. The Hancock, Md., to Shepherdstown, W. Va., and Shepherdstown to Point of Rocks, Md., subreaches could not be calibrated for this period because Shepherdstown has an incomplete record. These two subreaches were calibrated for the periods 1950-53 and 1965-78. As table 7 shows, mean error for each of the six subreaches is less than 10 percent. In each subreach, there are approximately the same percentage of negative-error and positive-error days, and the mean positive and mean negative errors have an absolute value of less than 10 percent. The rms errors all appear to be minimized.

Although all of the volume errors in table 6 are relatively low, they are all negative except for the 1950-53 water years on the Shepherdstown to Point of Rocks subreach. Volume errors are negative because the model tends to underestimate peak flows. Hence, there are many days of high flow showing a negative volume error. Because a small negative error for a day with high flow can represent a large quantity of water, a net negative volume error can occur with a few high flow periods.

Table 6. -- Summary of modeling errors (percent) for subreach models

Subreach	Calibration period (water years)	Mean error	Negative error days	Mean negative error	Positive error days	Mean positive error	Volume error	RMS error
Luke to Cumberland	1950 - 78	7.33	51	-6.84	49	7.83	-0.70	10.74
Cumberland to Paw Paw	1950 - 78	8.11	48	-7.46	52	8.71	-1.88	12.14
Paw Paw to Hancock	1950 - 78	6.16	49	-6.82	51	6.48	-1.48	12.38
Hancock to Sheperdstown	1950 - 53 1965 - 78	8.55 8.22	47 47	-7.39 -7.82	53 53	9.80 8.76	-3.40 -3.81	15.40 13.10
Shepherdstown to Point of Rocks	1950 - 53 1965 - 78	4.36 6.33	49 46	-3.32 -5.02	51 54	5.17 7.47	0.10 -0.17	6.70 9.42
Point of Rocks to Washington	1950 - 78	6.43	50	-6.29	50	6.66	-0.20	10.00

Table 7. -- Summary of daily errors for subreach models

Subreach	Calibration period	Percentage of days that daily error was between indicated percent error													
		< -30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	>
Luke to Cumberland	1950 - 78	0.4	0.5	1.0	2.5	7.0	15.0	23.7	23.1	13.6	6.4	2.8	1.5	0.7	1.2
Cumberland to Paw Paw	"	.9	.6	1.2	2.6	5.6	14.2	22.5	22.5	14.2	7.2	3.6	1.8	.9	1.6
Paw Paw to Hancock	"	.7	.3	.8	2.0	4.2	11.5	30.2	29.8	12.3	4.2	1.5	.8	.4	1.1
Hancock to Shepherdstown	1950 - 53 1965 - 78	1.0 1.7	.9 1.2	1.5 1.6	3.6 2.9	4.7 4.5	10.4 11.3	25.1 26.1	28.0 27.1	10.5 11.9	5.1 6.8	2.6 3.5	1.6 1.8	1.2 .8	3.6 2.8
Shepherdstown to Point of Rocks	1950 - 53 1965 - 78	0 0	0 0	.1 .2	.5 .8	2.1 3.5	7.9 15.8	30.3 27.7	32.8 25.3	11.6 14.8	3.4 6.1	1.6 2.4	.5 1.1	.5 .9	.4 1.2
Point of Rocks to Washington	1950 - 79	.5	.6	1.0	1.6	5.1	14.4	27.0	27.3	13.0	4.7	2.1	.9	.5	.9

LINKED MODEL

To implement the flow-routing model for the Potomac River between Luke, Md., and Washington, D.C., it was necessary to link the subreach models together. The linked model uses only the observed flow at Luke, observed tributary flow, and estimated ungaged intervening flow to simulate the flow at the downstream end of each subreach. The results of the model are the routing coefficients used to transport water downstream from Luke. The model was calibrated for the 1950-78 water years.

The standard method used to link subreach models is to use the simulated daily flow from an upper subreach model as input to the next lower subreach model. One of the problems with this method is that it can cause significant timing errors. These errors could be as much as 12 hours per reach.

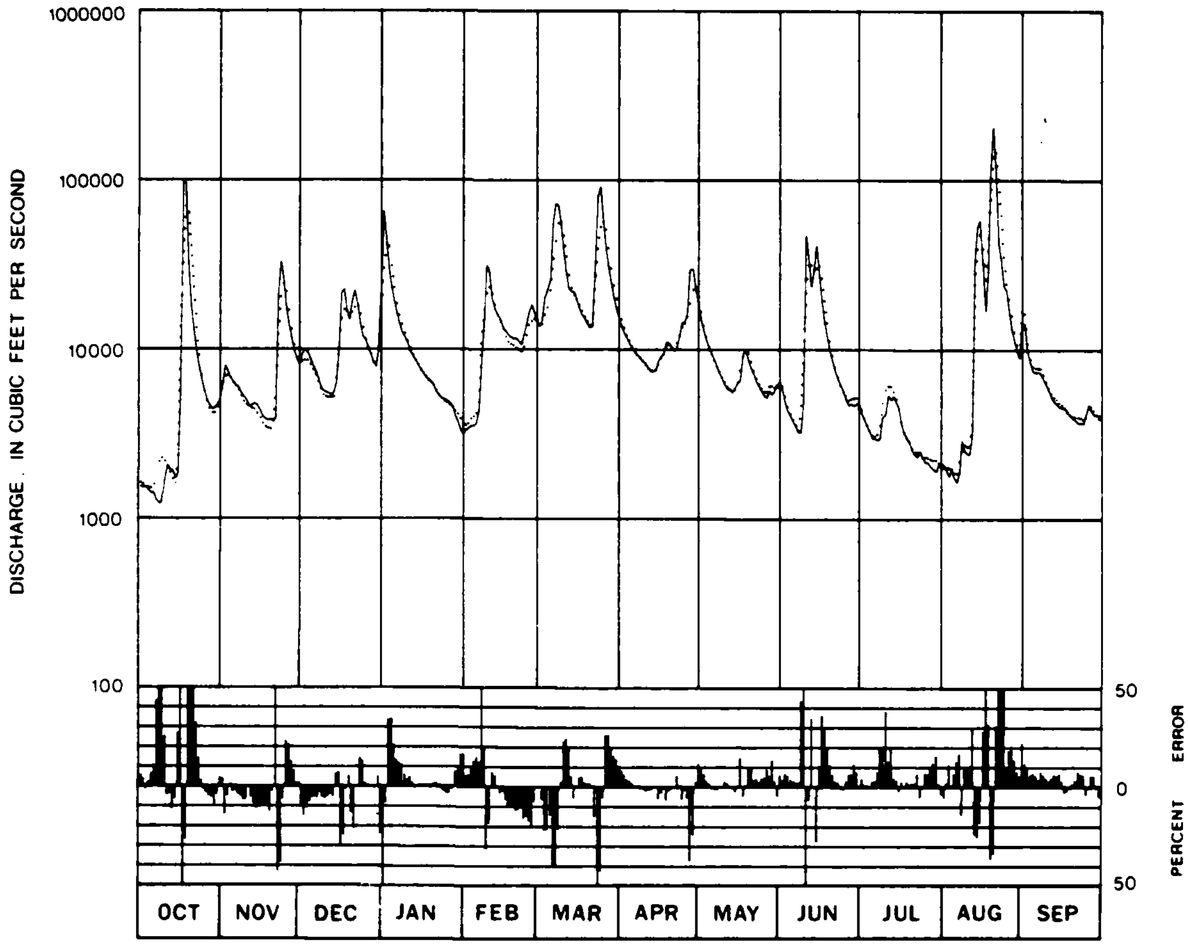
To link the subreaches in this study, hourly routing coefficients were generated by each of the subreach models. These hourly coefficients were then combined and re-expressed as daily routing coefficients for the linked model. Table 9 gives the daily coefficients resulting from the combined hourly coefficients.

Figures 9 through 12 are hydrographs of observed and simulated flows at Washington, D.C., for the 1955, 1966, 1972, and 1978 water years, respectively. For 1955, the rms errors are the highest of the water years modeled and most of the daily errors (60 percent) are positive. The hydrograph for 1966 is shown because that was the year of lowest flow. In 1972, flows were high. For 1978, most of the daily errors (57 percent) were negative. The fit of the simulated flows to the observed flows is generally good. Most of the excessively high errors occurred at or near peaks in the flow and were the result of 1-day timing errors. Because daily flows are used in the model, there is a loss of resolution, which results in these timing errors.

Table 8 summarizes the modeling errors for the linked model from Luke, Md., to Washington, D.C. As would be expected, the errors and deviations are somewhat higher in the linked model than in the subreach model. However, the difference does not appear to be significant.

Table 8. -- Summary of modeling errors (percent) for linked model (Luke, Md., to Washington, D.C.)

Calibration period	1950 - 78
Mean error	9.57
Negative error days	50
Negative error	-8.77
Positive error days	50
Positive error	10.36
Volume error	-3.66
RMS error	14.69



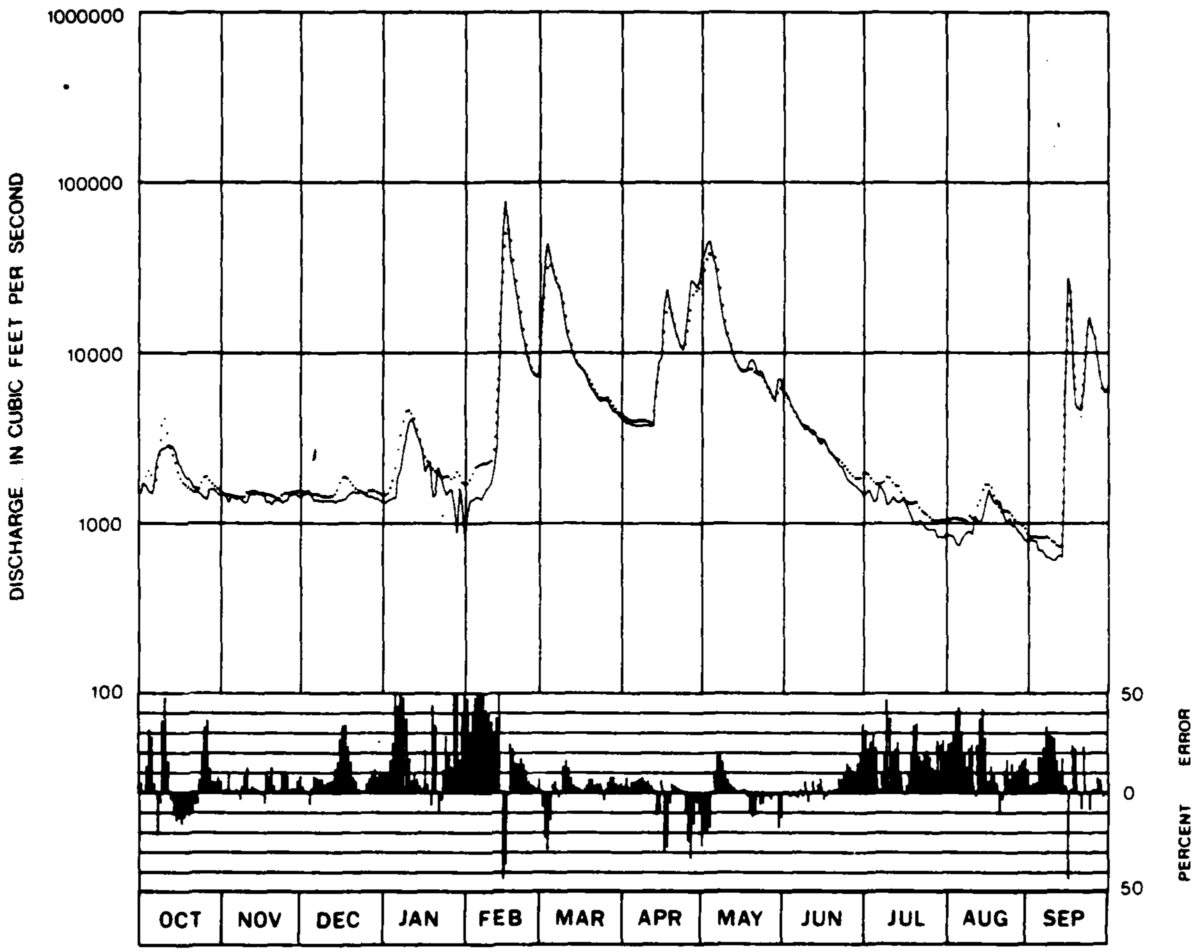
EXPLANATION

SIMULATED FLOW ....

OBSERVED FLOW ————

ERROR (Percent) $\frac{(\text{Simulated} - \text{Observed})(100)}{\text{Observed}}$

Figure 9.-- Observed and simulated flow and modeling errors at Washington, D.C., using the linked model for the 1955 water year.



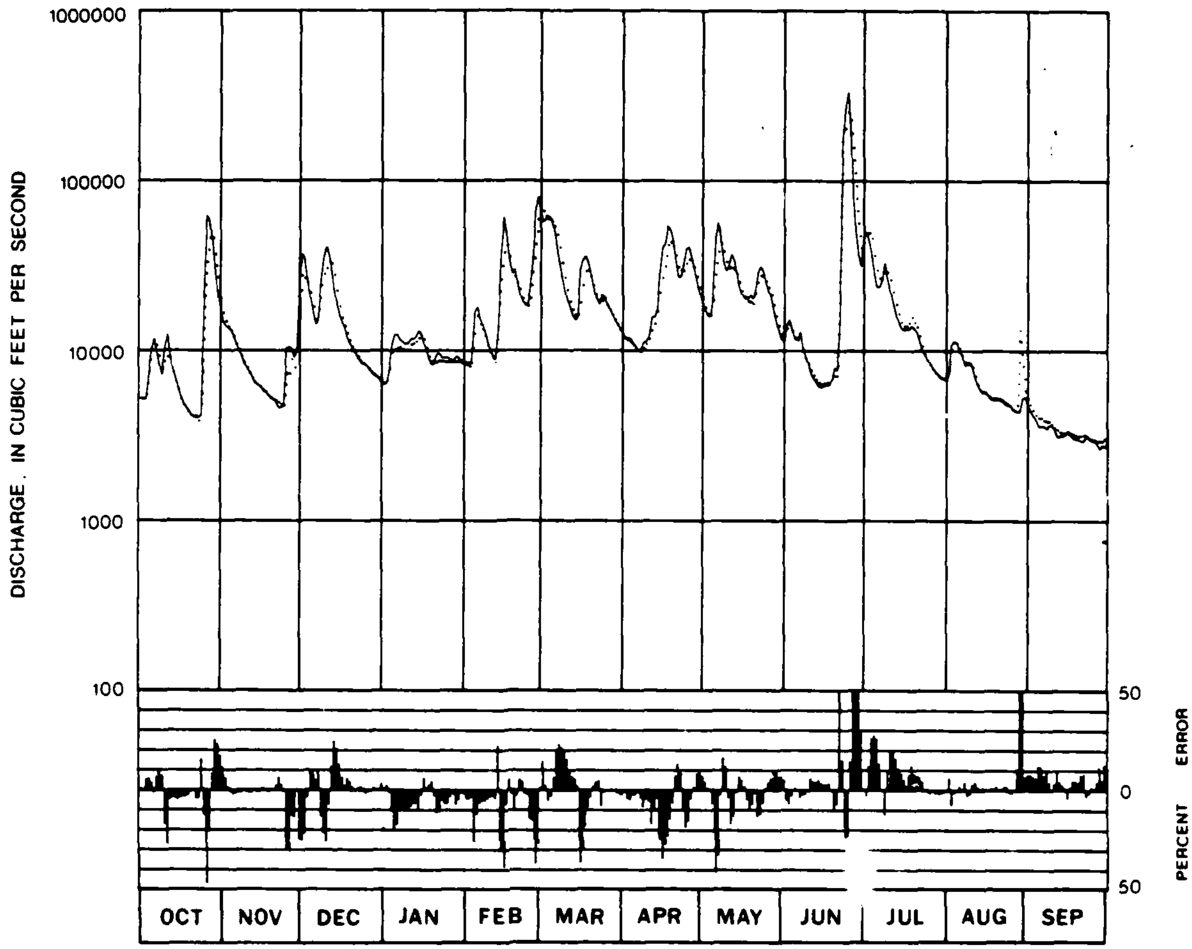
EXPLANATION

SIMULATED FLOW ....

OBSERVED FLOW ————

ERROR (Percent) $\frac{(\text{Simulated} - \text{Observed})(100)}{\text{Observed}}$

Figure 10.-- Observed and simulated flow and modeling errors at Washington, D.C., using the linked model for the 1966 water year.



EXPLANATION

SIMULATED FLOW ....

OBSERVED FLOW ————

ERROR (Percent) $\frac{(\text{Simulated} - \text{Observed})(100)}{\text{Observed}}$

Figure 11.-- Observed and simulated flow and modeling errors at Washington, D.C., using the linked model for the 1972 water year.

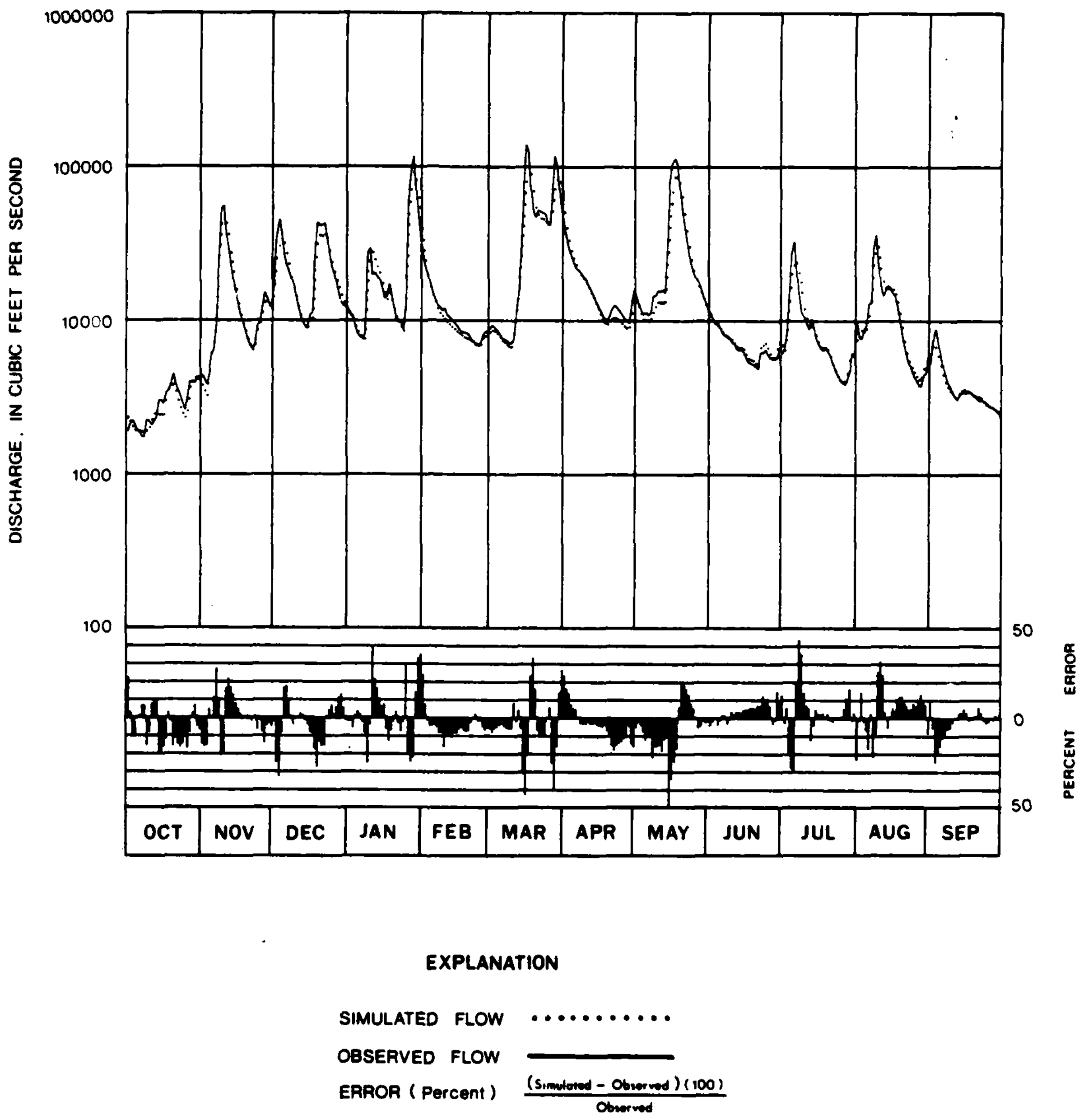


Figure 12.-- Observed and simulated flow and modeling errors at Washington, D.C., using the linked model for the 1978 water year.

UNIT RESPONSE TO RESERVOIR RELEASES

Unit response to reservoir releases developed by the linked model are expressed in table 9 as daily routing coefficients. The same unit response is expressed in table 10 as 12-hour routing coefficients, and in table 11 as weekly routing coefficients.

Daily coefficients can be used to estimate the response at each of the listed stations for releases made on a daily schedule. For example, if 100 ft^3s is released for one day, 35 ft^3/s will pass Washington, D.C., on the 4th day, 61 ft^3/s on the 5th day and 4 ft^3/s on the 6th day. The 12-hour and weekly routing coefficients can be used to determine downstream response in the same manner as the daily routing coefficients. The choice of which set of coefficients are used depends on the application and degree of precision required.

Figure 13 illustrates the results of routing a 3-day unit reservoir release from Luke to Washington using a 12-hour unit-response function. Releases for each 12-hour period are shaded to indicate the distribution of flows at Washington. The total 12-hour response is the summation of component responses for that 12-hour period. The daily response, again, is the mean flow for the two 12-hour periods for each day.

Using the model, figure 14 illustrates movement of a 7-day unit input at Luke, spreading out as it flows to Washington. Approximate hourly response is indicated by the curvature at the beginning and end of the response period. It should be noted that essentially all the water has passed Washington by the end of day 11 (4th day of 2d week).

Table 9. -- Daily routing coefficients for linked models

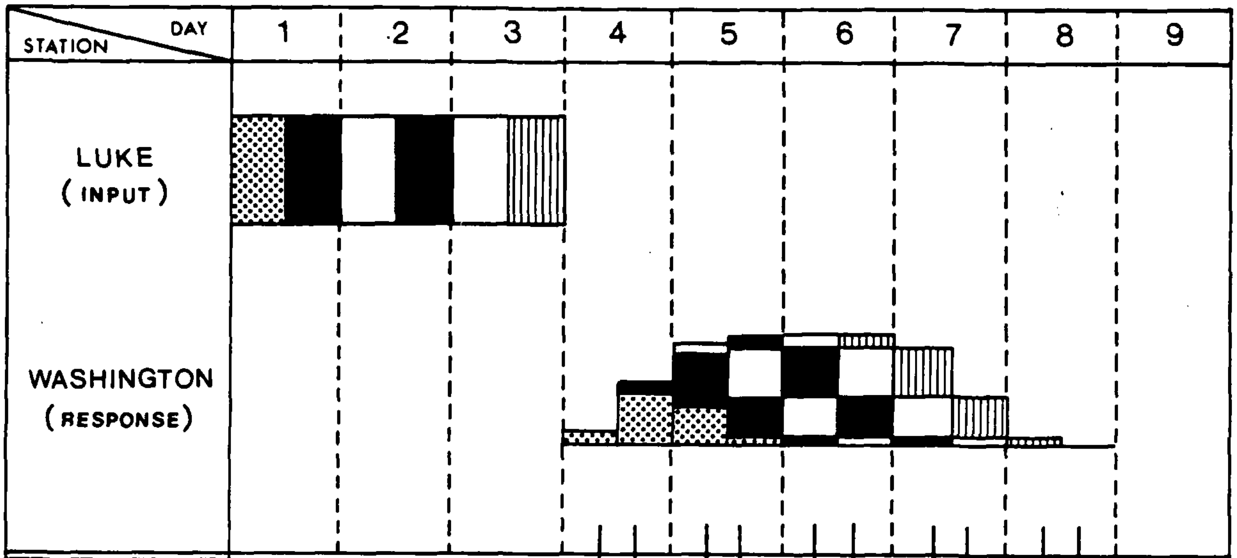
Reach Luke to:	Routing coefficients for day						
	1	2	3	4	5	6	7
Cumberland	0.42	0.58	--	--	--	--	--
Paw Paw	.02	.91	0.07	--	--	--	--
Hancock	--	.31	.69	--	--	--	--
Shepherdstown	--	--	.52	0.48	--	--	--
Points of Rocks	--	--	.20	.77	0.03	--	--
Washington	--	--	--	.35	.61	0.04	--

Table 10. -- Twelve-hour routing coefficients for linked models

Reach Luke to:	Routing coefficients for indicated 12-hour period										
	0-12	12-24	24-36	36-48	48-60	60-72	72-84	84-96	96-108	108-120	120-132
Cumberland	--	0.86	0.14	--	--	--	--	--	--	--	--
Paw Paw	--	.03	.83	0.14	--	--	--	--	--	--	--
Hancock	--	.01	.60	0.38	0.01	--	--	--	--	--	--
Shepherdstown	--	--	--	.19	.66	0.15	--	--	--	--	--
Point of Rocks	--	--	--	--	.01	.38	0.54	0.07	--	--	--
Washington	--	--	--	--	--	--	.11	.47	0.34	0.07	0.01

Table 11. -- Weekly routing coefficients for linked model

Reach Luke to:	Routing coefficients for week	
	1	2
Cumberland	0.92	0.08
Paw Paw	.85	.15
Hancock	.76	.24
Shepherdstown	.65	.35
Point of Rocks	.60	.40
Washington	.47	.53



NUMERICAL COMPUTATIONS		1	2	3	4	5	6	7	8	9
12 HOUR PERIOD RESPONSES	1				.11 .47	.34 .07	.01			
	2				.11	.47 .34	.07 .01			
	3					.11 .47	.34 .07	.01		
	4					.11	.47 .34	07 .01		
	5						.11 47	.34 .07	.01	
	6						.11	.47 .34	.07 .01	
Net 12 hour response (Summation)					.11 .58	.92 .99	1.0 1.0	.89 .42	.08 .01	
Mean daily Response					.35	.96	1.0	.65	.04	

EXPLANATION

FLOW AT LUKE FOR HOURS

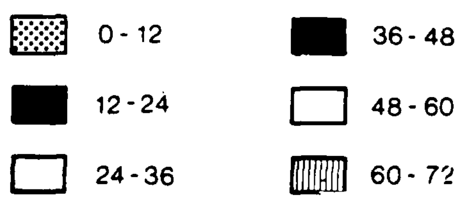


Figure 13.--12-Hour response at Washington, D.C. to a 3-day unit input to Luke, Md.

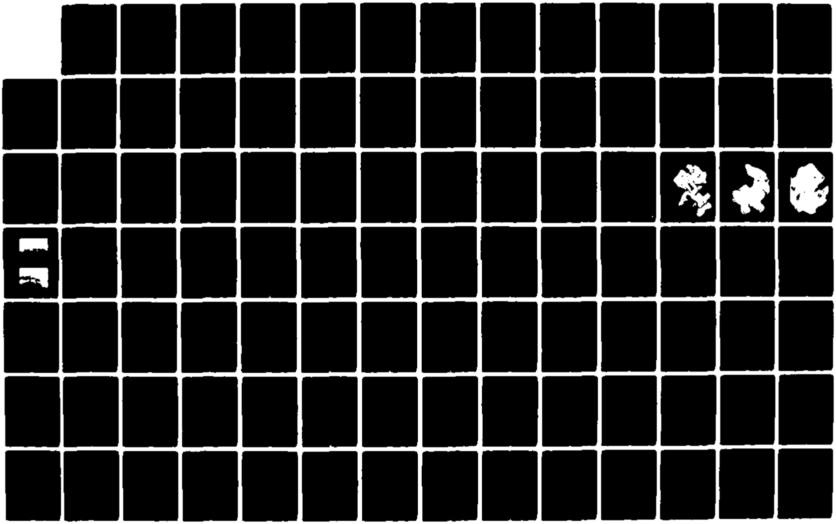
Station \ Day	First Week 1	2	3	4	5	6	7	Second Week 8	9	10	11	12
Luke (Input)	* 1.0	1.0	1.0	1.0	1.0	1.0	1.0					
Cumberland	.42	1.0	1.0	1.0	1.0	1.0	1.0	.58				
Paw Paw	.02	.93	1.0	1.0	1.0	1.0	1.0	.98	.07			
Hancock		.31	1.0	1.0	1.0	1.0	1.0	1.0	.69			
Shepherdstown			.52	1.0	1.0	1.0	1.0	1.0	1.0	.48		
Point of Rocks			.20	.97	1.0	1.0	1.0	1.0	1.0	.80	.03	
Washington				.35	.96	1.0	1.0	1.0	1.0	1.0	.65	.04

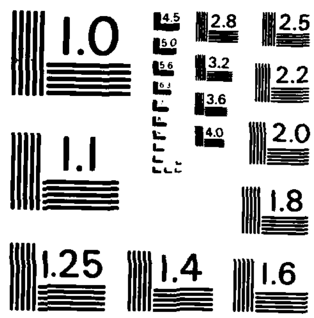
* NET DAILY FLOW

Figure 14.-- Response at downstream stations to a 7-day unit input at Luke, Md.

AD-A134 161 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY 4/6
APPENDIX H BLOOMINGTON LA..(U) CORPS OF ENGINEERS
BALTIMORE MD BALTIMORE DISTRICT SEP 83

UNCLASSIFIED MWA-83-P-APP-H-VOL-2 F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

CONCLUSIONS

A 24-hour sustained reservoir release input at Luke, Md., will result in 35 percent of the flow arriving at Washington, D.C., during the 4th day after the beginning of the release, followed by 61 percent and 4 percent arriving during the 5th and 6th days, respectively. A 7-day sustained reservoir release at Luke will result in 47 percent of the flow arriving at Washington during the 1st week and 53 percent of the flow arriving during the 2d week.

REFERENCES

Keefer, T. N., 1974, Desktop computer flow routing: American Society of Civil Engineers Proceedings, Journal of Hydraulics Division, HY7, Proceedings Paper 10669, p. 1047-1058.

Keefer, T. N., and McQuivey, R. S., 1974, Multiple linearization flow routing model: American Society of Civil Engineers Proceedings, Journal of Hydraulics Division, HY7, Proceedings Paper 10668, p. 1031-1046. Proc. Jour. Hydraulics Div., HY7, Proc. Paper 10668, p. 1031-1046.

Sauer, V. B., 1973, Unit-response method of open-channel flow routing: American Society of Civil Engineers Proceedings, Journal of Hydraulics Division, v.99, no. HY1, p. 179-193. Div., v. 99, no. HY1, p. 179-193.

U.S. Geological Survey, 1981, Water Resources Data for Maryland and Delaware: U.S. Geological Survey Water Data Report, MD-DE-80-1, 431 p.

ANNEX H - VI

ENVIRONMENTAL, SOCIAL, CULTURAL, AND RECREATIONAL RESOURCES

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H - VI

ENVIRONMENTAL, SOCIAL, CULTURAL, AND RECREATIONAL RESOURCES

TABLE OF CONTENTS

LISTS OF FIGURES

LIST OF TABLES

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H - VI

ENVIRONMENTAL, SOCIAL, CULTURAL, AND RECREATIONAL RESOURCES

BASELINE CONDITIONS

This section of Annex H-VI describes the major characteristics of the study area's natural and human resources to provide a general understanding of the physical, ecological, social, cultural, and economic conditions. Emphasis is placed in describing those resources that could possibly be affected by the reformulation of the Bloomington Lake project. This includes discussion of the North Branch Potomac River Basin as a whole with a site specific description of the Bloomington Lake. To a lesser extent, the environmental and recreation resources of the Savage River Reservoir, the Patuxent Reservoirs, and the Occoquan Reservoir are also discussed since they are an integral part of the system concept of the reservoir regulation. Also, where applicable, a projection of the ecological characteristics resulting from the Bloomington Lake project are provided since the project, as currently authorized, is part of the baseline conditions.

NORTH BRANCH POTOMAC RIVER BASIN

LOCATION

The North Branch Potomac River Basin includes all or part of six counties in three states; Garrett and Allegany counties in Maryland, Grant and Mineral Counties in West Virginia, and Somerset and Bedford counties in Pennsylvania, (see Figure H-VI-1). The North Branch Potomac River (NBPR) rises in West Virginia, near the historical Fairfax Stone and flows for 98 miles to join the South Branch and form the Potomac River near Oldtown, Maryland. The river has a drainage area of 1,328 square miles (at Oldtown, Maryland) which constitutes approximately nine percent at the entire Potomac Basin area.

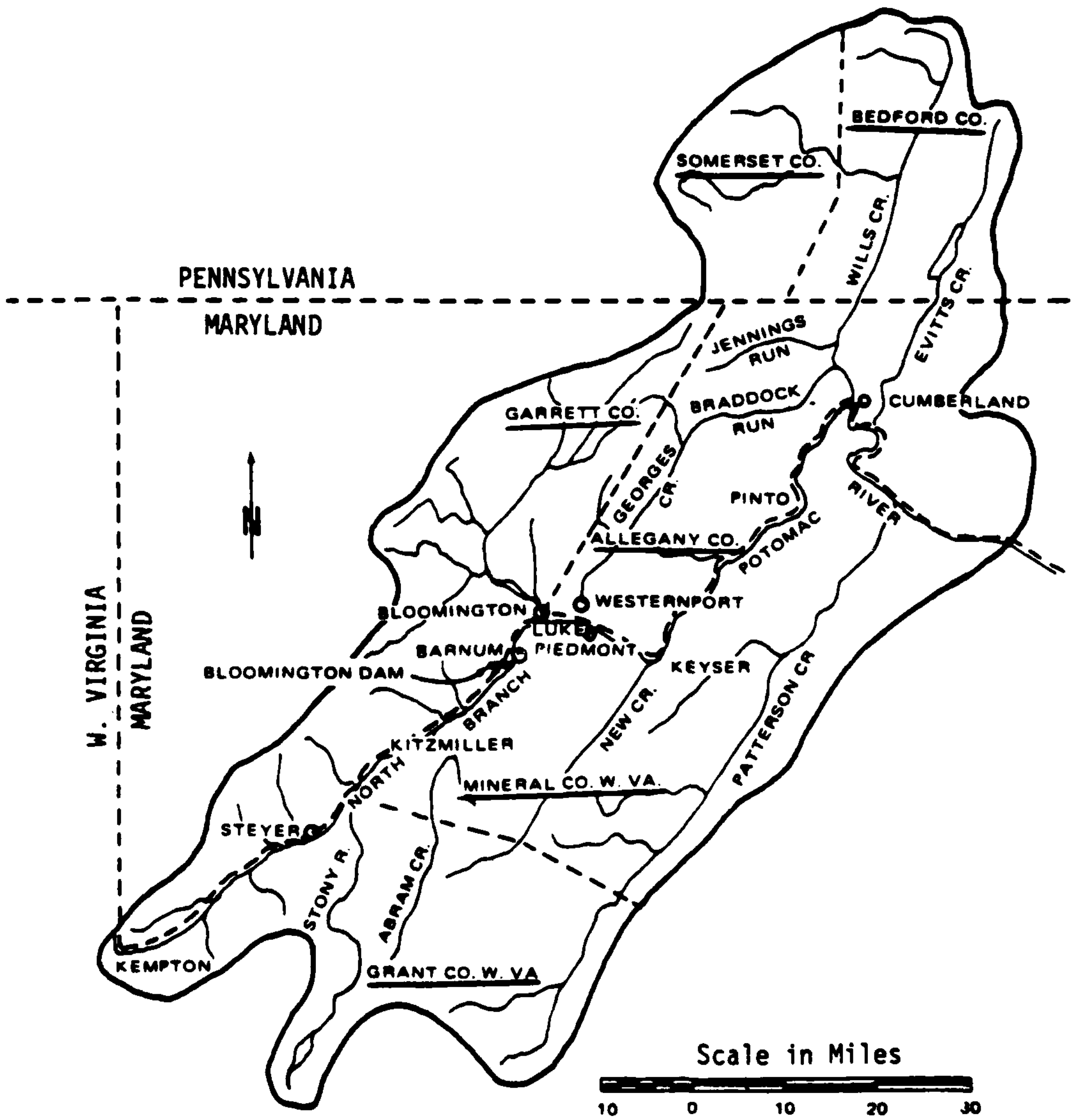
LAND USE

Land use in the NBPR Basin is primarily determined by physiography. The eastern half of the basin is included in the Ridge and Valley Province, where severe topography limits development to narrow, northeast-southwest stream valleys. The western half of the NBPR Basin lies in the Alleghany Plateau Province, a deeply dissected plateau which generally has flat, developable land in both stream valleys and upland areas.

In Garrett County, Maryland approximately seven of every ten acres of land is forested. About twenty-five percent is open farmland with one percent being classified as urban. Approximately 4,000 acres are actively mined or have been previously disturbed by strip-mining.

FIGURE H-VI-1

NORTH BRANCH POTOMAC RIVER BASIN



The area of Garrett County east of Backbone Mountain is almost completely forested. This section of the basin includes most of the 12,000 acres of the Potomac State Forest and many large stands of private forest. The communities of this area are Kempton, Vindex, Gorman, Kitzmiller, and Bloomington.

The area around the Savage River is distinctive for its rugged terrain. The majority of the land is owned by the State of Maryland and is known as the Savage River State Forest. The main feature of this area is the Savage River Reservoir which supplies water to the City of Westernport, Maryland and helps to regulate the flow of the NBPR.

The section of Allegany County, Maryland included in the NBPR Basin can be considered an industrial region. The Upper Potomac Industrial Park is located south of Cumberland, Maryland. The major industries are Allegany Ballistics Laboratory, Celanese Fibers Co., and Kelly-Springfield Tire Company.

Approximately sixty percent of Grant and Mineral Counties, West Virginia, are covered by forest. The remainder of the land is utilized for mining, farming, manufacturing and small rural communities. The mountain ridges and plateaus are not suitable for any commercial use except the hardwood saw timber industry and some mining. There are approximately 850 farms in the two counties.

Bedford and Somerset Counties, Pennsylvania, are generally rural in nature. In Somerset County there are 693 square miles (sq. mi.) of forest land, 200 sq. mi. of crop land, 66 sq. mi. of pasture land and 100 sq. mi. devoted to state parks and forest out of a total land area of 1,078 square miles. Approximately 4 square miles have been disturbed by coal mining activity. Bedford County has a total land area of 1,018 sq. mi. of which 657 sq. mi. are devoted to forest land, 201 sq. mi. to crop land and 69 sq. mi. to pasture land.

SOCIO-ECONOMIC RESOURCES

In general the socio-economic characteristics of the NBPR Basin are similar to the characteristics of the Appalachian region in which it is located. The counties show high percentages of people over the age of 65, have low in-migration rates and have significantly high levels of out-migration.

The economic base of the area is comprised of four activities: 1) mining, 2) agriculture - including forestry, 3) manufacturing, and 4) tourism. In terms of absolute numbers, manufacturing dominates the economic base of the area. The industries are mainly concentrated in the metropolitan areas and produce a diverse set of products. As is the case in the Appalachian region, there is a high concentration of work activity in a few economic sectors. Any fluctuations in the regional or national demand for their products leads to serious fluctuations in the local economy.

Income levels in the study area generally follow the dependence on manufacturing employment. However, in all cases, income levels are below the median income levels for the nation.

ARCHAEOLOGICAL AND HISTORIC RESOURCES

Numerous archaeological, historic, and aesthetic resources are associated with the area's history, spanning the periods of Indian occupancy, the French and Indian War, the Revolutionary War, westward expansion, and the Civil War. The frontier forts along the

North Branch played active roles in fighting the French and their Indian allies for control of the upper Potomac and the Ohio Rivers. Fort Ashby on Patterson Creek and the site of Fort Ohio near Cumberland, Maryland, are important historically. Elements of three important historical trade routes also exist in the area. They are the Cumberland Road (now U.S. Route 40), the Baltimore and Ohio Railroad, and the C & O Canal.

Within the basin, several sites, buildings and structures have been listed in the Federal Register of Historical Places.

They are:

Allegany County, Maryland	-	Chesapeake and Ohio Canal National Historical Park; La Vale Tollgate House, U.S. 40; and Oldtown, Michael Cresap House
Mineral County, West Virginia	-	Fort Ashby

Other sites of historic, aesthetic or archaeological interest include the Nancy Hanks Memorial and Prospect Park in Mineral County; Smoke Hole Caverns in Grant County; Backbone Mountain Scenic Overlook, Hayes Crest, and Crabtree Cove in Garrett County; the Narrows in Allegany County; and a number of Indian mound sites near Barnum, West Virginia and Folly Run.

WATER QUALITY

The water of the NBPR is of very poor quality. The major sources of pollution in the basin are acidic coal mine drainage and poorly treated wastes from cities, towns, and industries. The major characteristics of mine drainage are sulfuric acid, heavy metals, and high dissolved solids. At present, approximately 40 miles of the North Branch and 100 miles of tributaries streams are severely affected by acid mine discharges.

The water quality of the NBPR is being affected by the storage of water in the recently completed Bloomington Lake project. The impoundment will alter water quality because the hydraulic character is changed from a free-flowing stream to a slack water regime. Two considerations will affect the ultimate water quality in the impoundment and hence the discharge; (1) quality and volume of the water that enters the impoundment, and (2) the physical, chemical and biological changes that will take place in the impounded waters.

The character of the water entering the impoundment can be defined, but the changes that occur during impoundment are much more difficult to analyze. They will depend on a great many factors, some of which will ultimately improve the water quality and some of which will reduce water quality. Therefore, the quality of the impounded waters and the downstream reach can be predicted to some extent but an exact prediction is not possible.

Overall it has been estimated that as a result of the construction of Bloomington Lake, the general condition of the NBPR will improve. The project will moderate the pH fluctuations in the downstream reach by selective water quality releases and the elimination of the periodic "acid slugs." The impoundment will also trap iron and aluminum as well as affect dissolved oxygen levels. For a more detailed discussion of the present water quality condition as well as projected conditions for the Bloomington Lake project, refer to Annex H-II - Water Quality Investigations.

ENVIRONMENTAL RESOURCES

The NBPR Basin represents a region with a variety of forest, river, and stream communities which reflect the regions' diverse environmental conditions. This diversity is expected for an area with such extremes in topography, since the basin includes portions of the Allegheny and the Valley and Ridge Provinces. However, as a result of mining activities over the last 150 years the terrestrial and aquatic ecosystems in the basin have been seriously degraded because of the acid mine water and other undersirable aspects of coal mining.

The NBPR is the receiving stream for many of the acid laden tributaries. The greatest damage has occured between the headwaters and Luke, Maryland. Occasionally acid slugs have reached as far downstream as Oldtown, Maryland. Fortunately, the historic trend of degradation is slowly taking a turn for the better. Current regulations governing mining operations require that a number of pollution control measures be incorporated into the actual mining operation as well as post-operational land reclamation. Municipal and industrial effluents are regulated by the National Pollution Discharge Elimination System permit procedures. These measures should for the most part control the existing and future sources of pollution. However, the NBPR still reflects the past water quality problems of the basin.

The Bloomington Lake project should help to improve water quality conditions resulting from past problems and thus improve the aquatic community. The following sections provides a more detailed discussion of the existing conditions in the basin and a projection of conditions that could be expected with the operation of Bloomington Lake project as it is currently authorized.

Terrestrial Ecosystem

Forest lands cover nearly 60 percent of the North Branch Potomac River Basin. The mixed deciduous forest occupies the more humid, temperate low-lying valleys and consists primarily of beech, red maple and yellow poplar. This vegetative association extends to about elevation 2700 feet msl at which oak and hickory or maple forest type becomes predominant. Wild flowers found in the basin include jack-in-the-pulpit, painted trillium and fireweed. Mountain laurel also covers many acres through the area. Table H-VI-I is a list of some of the more important vegetation in the North Branch Potomac Basin.

The rich and diverse vegetative make-up of the basin provides abundant food and cover for wildlife. Three distinct layers supporting varied communities can be defined. The upper treetop or canopy supports an abundance of birds, invertebrates and small mammals. Lower-level tree communities serve as habitat for numerous birds and invertebrate species. The shrub-herb-grass community supports the majority of larger mammals and waterfowl.

TABLE H-VI-I
VEGETATION OF THE NORTH BRANCH
POTOMAC RIVER BASIN

Black Birch (Betula lenta)
Yellow Birch (Betula lutea)
Paper Birch (Betula papyrifera)
Speckled Alder (Alnus rugosa)
Beech (Fagus grandifolia)
Chestnut (Castanea dentata)
White Oak (Quercus alba)
Chestnut Oak (Quercus prinus)
Red Oak (Quercus rubra)
Black Oak (Quercus velutina)
Scrub Oak (Quercus ilicifolia)
Sugar Maple (Acer saccharum)
Red Maple (Acer runbrum)
Balsam Fir (Abies balsamea)
Hemlock (Tsuga canadensis)
Red Spruce (Picea rubens)
Table Mountain Pine (Pinus pungens)
White Ash (Fraxinus americana)
Black Alder (Ilex verticillata)
Aromatic Sumac (Rhus aromatica)
Smooth Azalea (Rhododendron arborescens)
Great Solomon Seal (Polygonatum canaliculatum)
Dutchman's Pipevine (Aristolochia durior)
Alternate Leaf Dogwood (Cornus alternifolia)
Redbud (Cercis canadensis)

Mountain Ash (Sorbus americana)
Yellow Poplar (Liriodendron tulipifera)
Fraser Magnolia (Magnolia fraseri)
Painted Trillium (Trillium undulatum)
Snow Trillium (Trillium nivale)
Allegheny fly-back Grass (Danthonia compressa)
Jack-in-the-Pulpit (Arisaema triphyllum)
Wood Lily (Lilium philadelphicum)
Pink Lady's Slipper (Cypripedium acaulae)
Mountain Whitlow-wort (Paronychia montana)
Columbine (Aquilegia canadensis)
Black Cherry (Prunus serotina)
Poison Ivy (Rhus radicans)
Winterberry Holly (Ilex montana)
Mountainholly (Nemopanthus mucronatus)
Jewelweed (Impatiens capensis)
Fireweed (Epilobium angustifolium)
Flowering Dogwood (Cornus florida)
Mountain Laurel (Kalmia latifolia)
Serviceberry (Amelanchier ovalis)
Burning Bush (Evonymus atropurpureus)
Bladderwort (Ultricularia sp.)
Black Ash (Fraxinus nigra)
Leatherwood (Dirca palustris)
Dutchman's Breeches (Dicentra cucullaria)

SOURCE: Corps of Engineers Design Memorandum No. 18, 1972. Department of the Army, Baltimore District, Bloomington Lake.

Due to the varied topography of the region, a large number of diversified habitats are available for bird life. The long valleys offer passageways and resting grounds to migratory species; the high ridges meet the nesting requirements of birds often considered more characteristic of northern climates; and the rivers, streams, and ponds support abundant waterfowl. Table H-VI-2 lists the birds most common to the region.

At least 21 species of prominent mammals live in the NBPR Basin (Table H-VI-3). Of the large mammals found in the area, the whitetailed deer is the prominent species. The common medium-sized mammals included red squirrel, red fox, gray fox, eastern cottontail, and racoon.

The terrestrial environment will be virtually unaffected by the improvement in water quality in the downstream reaches of the Bloomington Lake project. The organisms which are presently found in the basin will not benefit from or be further harmed by the conditions which will prevail.

Aquatic Ecosystem

The North Branch Potomac River is a prominent feature of the basin, however, it has been degraded by acid mine drainage which exerts a critical stress in the stream due to its biologically toxic nature. In a aquatic ecosystem the structure and population size of the community is related to the water quality and physical characteristics of the water body under consideration. Species composition, relative abundance and condition factors of the aquatic community are influenced by stream depth, width, velocity, substrate, habitat cover, turbidity, temperature, and chemical composition of the water. In the study area the parameter which most severely limits the aquatic ecosystem is the water chemistry. The stress caused by acid mine drainage results in a simplification of the community structure as individual species reach or exceed their tolerance level to the pH or the toxic precipates associated with mine drainage.

The toxic effects of pH differ among species as well as the age groups of species. Under favorable conditions most full developed fresh water fish can exist within a pH range of 5.0 to 9.0. Optional conditions are probably between 6.5 and 8.0. Less than optional conditions such as low pH or periodic fluctuations in pH affects the overall health of the fish. Studies have shown that less than optimal conditions could increase susceptibility to disease, result in reproduction failure, genetic damage, change predator-prey relationships etc.

Currently, there is very little biological activity in the NBPR according to a recent biological survey (Figure H-VI-2 and Table H-VI-4) and past studies. Many of the tributaries and segments of the main stem are polluted by acid water and have become biologically inactive. Other less severely polluted reaches only support a limited community. Conditions tend to improve further downstream. The following section will provide a more detailed discussion of the aquatic ecosystem from the headwaters of the NBPR to Paw Paw, West Virginia.

The 40-mile stretch of river from the headwaters of the NBPR to the confluence of the NBPR and Savage River accounts for the major portion of acid load and thus is almost completely devoid of any biological activity. The stretch is characterized by low pH and high levels of sulfates, acidity and iron. The benthic community is severely depressed both in terms of number of individuals and species diversity. Similarly, there is little evidence of resident fish populations.

TABLE H-VI-2
BIRDS OF THE NORTH BRANCH POTOMAC RIVER BASIN

Common Loon (Gavia immer)
Pied-billed Grebe (Podilymbus podiceps)
Green Heron (Butorides virescens)
Black-crowned Night Heron (Nycticorax nycticorax)
Blue-winged Teal (Anas discors)
Wood Duck (Aix sponsa)
Lesser Scoup (Aythya affinis)
Bufflehead (Bucephala albeola)
Ruddy Duck (Oxyura jamaicensis)
Hooded Merganser (Lophodytes cucullatus)
Red-brested Merganser (Mergus serrator)
Cardinal (Richmondena cardinalis)
Rose-breasted Grosbeak (Pheucticus ludovicianus)
Evening Grosbeak (Hesperiphona vespertina)
Purple Finch (Carpodacus purpureus)
Pine Siskin (Spinus pinus)
American Goldfinch (Spinus tristis)
Red Crossbill (Loxia curvirostra)
White-winged Crossbill (Loxia leucopteraa)
Grasshopper Sparrow (Ammodramus savannarum)
Song Sparrow (Melospiza melodia)
Turkey Vulture (Carthartes aura)
Black Vulture (Coragyps atratus)
Red-tailed Hawk (Buteo jamaicensis)
Red-shouldered Hawk (Buteo lineatus)
Broad-winged Hawk (Buteo platypterus)
Golden Eagle (Aquila chrysaetos)
Sparrow Hawk (Falco sparverius)
Ruffled Grouse (Bonasa umbellus)
Bobwhite (Colinus virginianus)
Wild Turkey (Meleagris gallopavo)
American Woodcock (Philophela minor)
Common Snipe (Capella gallinago)
Mourning Dove (Zenaidura macroura)
Screech Owl (Otus asio)
Great Horned Owl (Bubo virginianus)
Barred Owl (Strix varia)
Whip-poor-will (Carprimulgus vociferus)
Ruby-throated Hummingbird (Archilochus colubris)
Belted Kingfisher (Megaceryle alcyon)
Piliated Wooupecker (Hylatomus pileatus)
Red-bellied Woodpecker (Centurus carolinus)
Cliff Swallow (Petrochelidon pyrrhonota)
Purple Martin (Progne subis)
Blue Jay (Cyanocitta cristata)
Common Raven (Corvus corax)
Tufted Titmouse (Parus bicolor)
White-breasted Nuthatch (Sitta carolinensis)
Red-breasted Nuthatch (Sitta canadensis)
Golden-winged Warbler Vermivora chrysoptera)
Yellow Warbler (Dendroica petechia)

Source: Smith, Lawrence J., The Potomac Naturalist, 1968.

TABLE H-VI-3
MAMMALS IN THE NORTH BRANCH BASIN

Opossum (Didelphis marsupialis)	Red squirrel (Tamiasciurus hudsonicus)
White-tailed deer (Odocoileus virginianus)	Gray squirrel Sciurus carolinensis)
Snowshoe hare (Lepus americanus)	White-footed mouse (Peromyscus leucopus)
Eastern cottontail (Sylvilagus floridanus)	Woodchuck (Marmota monax)
Black bear (Ursus americanus)	Eastern chipmunk (Tamias striatus)
Star-nosed mole (Condylura cristata)	Northern flying squirrel (Glaucomys sabrinus)
Raccoon (Procyon lotor)	Deer mouse (Peromyscus maniculatus)
Common mink (Mustela vison)	Muskrat (Ondatra zibethicas)
Spotted skunk (Spilogale putorius)	Red Fox (Vulpes fulva)
Striped skunk (Mephitis mephitis)	Gray Fox (Urocyon cineroargenteus)
Red squirrel (Tamiasciurus hudsonicus)	Bobcat (Lynx rufus)

Source: Adapted from Collin, H. H. Complete Field Guide to American Wildlife, 1959.

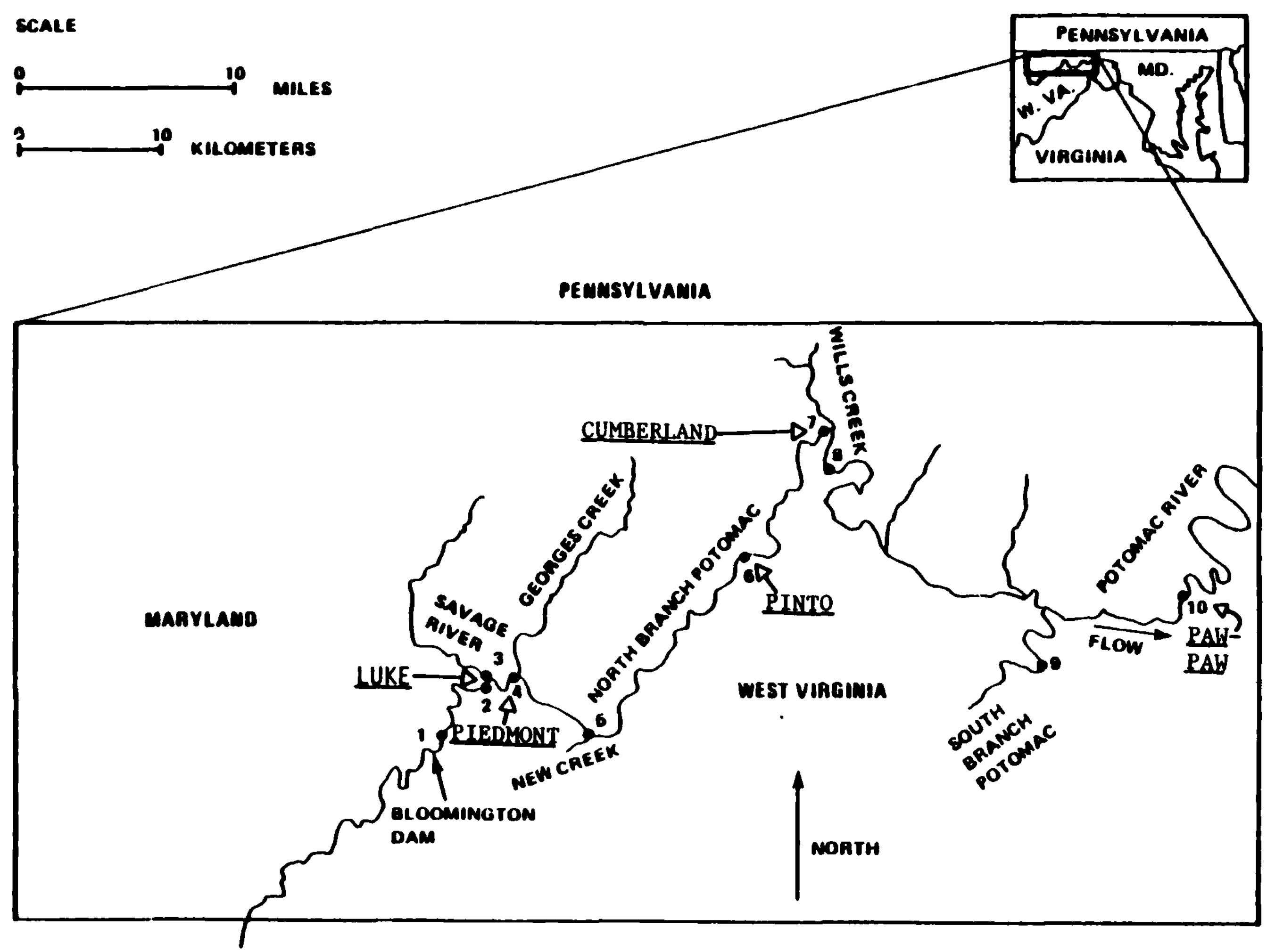


FIGURE H-VI-2

MAP OF STUDY AREA SHOWING SAMPLE SITES FOR BIOLOGICAL SURVEY

TABLE H-VI-4

RESULTS OF BIOLOGICAL SURVEY NORTH BRANCH POTOMAC RIVER (1980)

	Macroinvertebrate Community		Fish Community	
	Number of TAXA	Number of Organisms	Number of TAXA	Number of Organisms
1. North Branch Potomac at Barnum	2	2	0	0
2. North Branch Upstream of Savage River Confluence	1	1	0	0
3. Savage River at Mouth[1]	21	294	1	1
4. North Branch Upstream of Georges Creek	9	12	0	0
5. North Branch at Keyser	7	11	0	0
6. North Branch at Pinto	10	68	3	28
7. North Branch Upstream of Wills Creek	17	73	4	20
8. North Branch at Wiley Ford	21	270	8	30
9. South Branch Potomac[2]	27	589	4	19
10. Potomac River at Paw Paw[3]	20	81	4	16

1. Clear water and irregular bottom at this site made seining difficult. Past studies with electroshocking have shown excellent fish populations.

2. Clear water made seining difficult. Past studies have shown excellent fish populations.

3. Past studies revealed excellent fish and macroinvertebrates communities. Possibility of some degradation during the sampling year.

Between Luke, Maryland and Pinto, Maryland the river begins to show signs of recovery due to a movement towards normalization of the acid waters. The improvement in pH is a result of the alkaline discharges from the WESTVACO Pulp and Paper Mill; a waste treatment plant, and the flow of the Savage River. With this improvement in water quality is an associated improvement in the biological community. However this reach still does not support a healthy benthic community or fishery since the improvement in pH is partially offset by the industrial and municipal discharges which increases the organic load of the stream.

From Pinto, Maryland downstream to Paw Paw, West Virginia, the biological community becomes more diverse, reflecting the improving water quality. Good populations of fish and macroinvertebrates are found upstream of Wills Creek. The inflow from the South Branch Potomac River and several tributaries, which have excellent water quality and thus, a healthy biota contributes to the improving conditions of the river. During normal flows, this results in an almost complete disappearance of the symptoms of the acid mine drainage that prevails in most of the North Branch Potomac River.

In summary, the North Branch Potomac River currently does not support a healthy aquatic community due to the seriousness of the acid mine drainage problem. The river supports a very limited number of species with those represented in few numbers. The organisms which are present are either indigenous to acid streams or are acid tolerant forms which have become acclimated to the prolonged stress. The North Branch does not begin to recover biologically until Oldtown, Maryland. At this point the water quality is such that it supports a moderately diverse community. Even this area is, however, periodically subjected to acid slugs which can result in fish kills. Table H-VI-5 is a list of some of the more common species of fish found in the NBPR Basin.

With the recently constructed Bloomington Lake project in place, some water quality improvements are expected in the downstream reaches. The impoundment should trap iron and aluminum which exist in the river in high concentrations because of acidic conditions. Dissolved oxygen in the downstream reach, which sometimes reaches low levels during low flows because of high BOD due to industrial and municipal discharges, will be enhanced by the augmented flows containing relatively high levels of dissolved oxygen from the reservoir. The most significant water quality impact of the Bloomington Lake revolves around the moderation of the pH fluctuations downstream. As a result, there should be a expansion in the biotic community, both in numbers of individuals and species in stretches of the river that now have a marginal population. Following is a more detailed discussion of conditions expected with the operation of Bloomington Lake as it is presently constructed.

From the headwaters of the NBPR to the Bloomington Lake project the flow of the river will not be altered; therefore, this reach will remain very much the same as it was before the dam was built. The pH level and associated constituents of acid mine drainage will not permit the development of a healthy stream flora and fauna. Higher species of fish, even the more tolerent forms such as brook trout, white sucker, and river chub, will not be able to survive.

TABLE H-VI-5

FISHES OF THE NORTH BRANCH POTOMAC RIVER BASIN

Rainbow trout (Salmo gairdneri)	White sucker (Catostomus commersoni)
Brown trout (Salmo trutta)	Creek chubsucker (Erimyzon oblongus)
Brook trout (Salvelinus fontinalis)	Northern hog sucker (Hypentelium nigricans)
American eel (Anguilla rostrata)	Shorthead redhorse (Moxotoma macrolepidotum)
Chain pickerel (Esox niger)	Yellow bullhead (Ictalurus natalis)
Stoneroller (Campostoma anomalum)	Brown bullhead (Ictalurus nebulosus)
Rosyside dace (Clinostomus funduloides)	Channel catfish (Ictalurus punctatus)
Carp (Cyprinus cario)	Margined madtom (Noturus insignis)
Silverjaw minnow (Ericymba buccata)	Rock bass (Ambloplites rupestris)
Cutlips minn w (Exoglossum maxillingua)	Redbreast sunfish (Lepomis auritus)
River chub (i ocomus micropogon)	Green sunfish (Lepomis auritus)
Golden shiner (Notemingonus crysoleucas)	Pumpkinseed (Lepomis gibbosus)
Comely shiner (Notropis amoenus)	Warmouth (Lepomis gulosus)
Common shiner (Notropis cornutus)	Bluegill (Lepomis macrochirus)
Spottail shiner (Notropis hudsonius)	Longear sunfish (Lepomis megalotis)
Swallowtail shiner (Notropis procne)	Smallmouth bass (Micropterus dolomieui)
Rosyface shiner (Notropis rubellus)	Largemouth bass (Microterus salmoides)
Spotfin shiner (Notropis spilopterus)	Black crappie (Pomoxis migromaculatus)
Bluntnose minnow (Pimiphales notatus)	Greenside darter (Etheostoma blenniodes)
Longnose dace (Rhinichthys atratulus)	Fantail darter (Etheostoma flaballare)
Creek chub (Semotilus atromaculatus)	Tessellated darter (Etheostoma olmsteidi)
Fallfish (Semotilus corporalus)	Mottled scalpin (Cottus bairdi)

Source: Davis, R. M. Fishes of the Appalachian Region of Maryland 1978.

At the dam site, water quality will vary depending on the time of year but it is expected that the reservoir resulting from the impounding of the North Branch will be too acidic to support a resident lentic community. There is the possibility that some of the vascular plants that are relatively pH independent as far as growth factor is concerned may become established in shallow areas; but the plants would not contribute to an improvement of the aquatic community. Also, there is the possibility that in several of the arms of the lake that have relatively good water quality due to feeder streams small fisheries could be established.

The NBPR from the Bloomington Lake project to Piedmont, West Virginia will no longer be subjected to "acid slugs." However, the overall water quality of this reach will not be significantly altered. The elimination of "acid slugs" will facilitate minimal colonization in the lower stretch of this reach by some acid tolerant forms, but fish populations of any significance are not expected. This section of the reach is characterized by increase in pH but overall water quality will still be below the limits required for a healthy stream community. This reach will still be subjected to organic pollution by domestic and industrial waste in addition to acid mine drainage. Thus water quality and hence stream life will remain poor.

The aquatic community from Piedmont, West Virginia to Pinto, Maryland will most likely show a gradual increase in species and numbers of individuals; however, it is not expected to show any appreciable improvement over the existing conditions before the Bloomington Lake project. The pH level of this reach often approaches neutrality but the overall water quality is very poor. The "acid slugs" will be eliminated by the presence of the Bloomington Lake project; however, these "slugs" only intensify the existing stress which will continue to persist.

Between Pinto and Oldtown the river should demonstrate a significant improvement over the present conditions. The community structure should become slightly more complex due to the absence of "acid slugs" and the loss of moderately acid tolerant macroinvertebrates and microorganism. The reestablishment of a more diversified community will be further facilitated by the recolonization of organisms from nearby unpolluted sources such as the South Branch Potomac River and the Potomac River below Oldtown. The distance over which recolonization will be effective is dependent upon the extent of improvement in water quality upstream from Oldtown. A small fish population will probably develop in the river between Pinto and Oldtown, an area which now supports a limited aquatic community except near Oldtown.

RECREATION

The North Branch Potomac River Basin offers a variety of recreational opportunities in addition to those provided at the Bloomington Lake project. Allegany and Garrett counties in Maryland have numerous State Parks and Forests that offer a range of recreational activities. (See Table H-VI-6). In addition to the State Parks and Forests, Deep Creek Lake is located in Garrett County. Deep Creek Lake was constructed in 1925 as a source of hydroelectric power. It is twelve miles long, has approximately sixty-five miles of shoreline, and has approximately surface area of 3,673 acres. The area offers boating, camping, fishing, swimming, and related activities.

TABLE H-VI-6

CHARACTERISTICS OF STATE PARKS AND FORESTS
GARRETT AND ALLEGANY COUNTIES, MARYLAND

NAME OF FACILITY	CHARACTERISTICS OF RECREATIONAL FACILITY						
	COUNTY	SWIMMING	FISHING	BOATING	HUNTING	OVERNITE	ACREAGE
DANS MOUNTAIN STATE PARK	A		X		X		467
GREEN RIDGE STATE FOREST	A		X		X		25,559
ROCKY GAP STATE PARK	A	X				X	3,500
BIG RUN STATE PARK	A,G		X	X			300
NEW GERMANY STATE PARK	A	X	X		X	X	220
SAVAGE RIVER STATE FOREST	A,G		X		X		52,770
CASSELLMAN BRIDGE STATE PARK	A,G		X				5
DEEP CREEK LAKE STATE PARK	A,G	X	X	X			1,776
HERRINGTON MANOR STATE PARK	A,G	X	X	X	X	X	365
SWALLOW FALLS STATE PARK	A	X	X		X		257
POTOMAC STATE FOREST	A						12,052
FORT TONOLOWAY STATE PARK	A						26
SWALLOW FALLS STATE FOREST	A						9,248
BROADFORD RUN PARK	G	X	X	X			343
MT. NEBO WILDLIFE MANAGEMENT AREA	G		X		X		1,791
PLEASANT VALLEY REC. AREA	G	X	X	X		X	1,904

Source: Department of Natural Resource, Maryand Park Service, Annapolis, Maryland.

Bedford and Somerset Counties of Pennsylvania have facilities similar to Allegany and Garrett Counties in Maryland. A brief summary of these facilities is presented in Table H-VI-7.

In Grant and Mineral Counties, West Virginia the extent of public recreation facilities is limited to the Petersburg and Spring Run trout hatcheries and the Spuce Knob-Seneca Rock National Recreation Area.

BLOOMINGTON LAKE PROJECT

ENVIRONMENTAL RESOURCES

The Bloomington Lake project is a 952 acre impoundment located on the NBPR approximately 8 miles upstream of Luke, Maryland. The area is typical of the conditions previously described for the NBPR Basin. The project area is characterized by steep forested slopes. A mixed deciduous forest type predominates with oak, yellow poplar, red maple and beech being common species. Mountain laurel is the common understage shrubs. The fauna is typical of the temperate forest biome. Mammals present included whitetail deer, red fox, gray fox, red squirrel, and bob cat.

RECREATION

Because of the acid-polluted waters and low flows, the North Branch has limited recreation use at present, although some canoeing is done. There are presently no fishing or water-contact activities of any significance in the river, the latter probably due to the social unacceptance of acid water for swimming rather than from a health standpoint. At the present time, hunting and hiking are the only activities of any significance

The major attractions offered at Bloomington Lake will be sightseeing, picnicking, overnight camping, and boating. The initial plan of development will provide facilities to accommodate an initial annual visitation of 110,000. Additional development is planned to accommodate an ultimate annual visitation of 150,000 in year 25 of the project. Figure H-VI-3 shows the locations of the areas planned for initial development and the areas proposed for future development.

The High Timber Camping area, which is located on the West Virginia shore on a high ridge overlooking the damsite, has approximately 70 campsites. Facilities include: fresh water, showers, and comfort stations. Below the High Timber area, and between Route 46 and the shoreline, the Howell Run picnic area and the Howell Run boat launch are located. The picnic area will have approximately 100 tables, with several of the tables located under a pavilion. The boat launch has approximately 60 car-trailer spaces.

In addition to the camping, picnicking, and boat launching areas there are three overlooks providing various views of the project. Two overlooks are on the Maryland side and one will be on the West Virginia side. One of the overlooks in Maryland provides a view of the gated spillway and lake from the downstream side of the dam. The other overlook in Maryland provides a view of lake and the upstream sides of the gated spillway and dam. The overlook in West Virginia provides a view of the dam, lake, and stilling basin.

TABLE H-VI-7
RECREATIONAL AREAS AND FOREST LANDS FOR
BEDFORD AND SOMERSET COUNTIES, PENNSYLVANIA

COUNTY	ACREAGE	BOATING	CAMPING	FISHING	HUNTING	PICNICKING	RIDING	SKIING	SWIMMING
BEDFORD COUNTY									
State Parks:									
Blue Knob	5430		X	X	X	X	X	X	X
Shawnee	3840	X	X	X	X	X	X		X
Warriors Path	294	X		X		X			
State Forest Lands:	29,600			X	X				
State Forest Picnic Areas:									
Blankley	6.4				X	X			
Sweet Root	19.2				X	X			
State Forest Natural Areas:									
Martins Hill	6.4				X	X			
State Game Lands:	44,100			X	X				
SOMERSET COUNTY									
State Parks:									
Kooser	173		X	X	X	X			X
Laurel Hill	4160	X	X	X	X	X			X
State Forest Lands:	29,200			X	X				
State Forest Picnic Areas:									
Babcock	51				X	X			
Mount Davis	12.8				X	X			
State Forest Mountain Areas:									
Mount Davis	103				X	X			
State Game Lands:	26,800			X	X				

Source: Department of Commerce, State of Pennsylvania

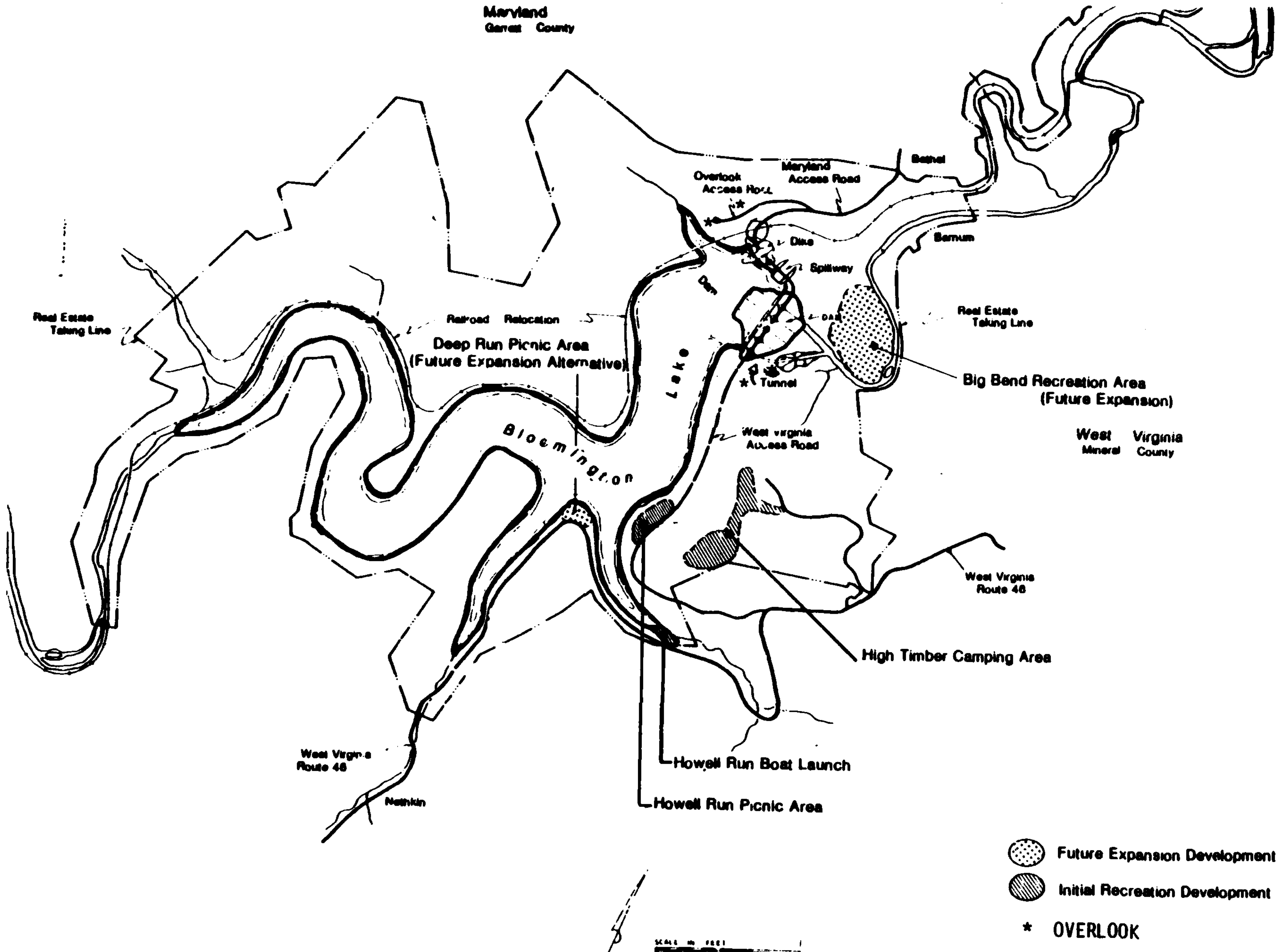


FIGURE II-VI-3
RECREATION AREAS

SAVAGE RIVER RESERVOIR

ENVIRONMENTAL RESOURCES

The Savage River is located within the Alleghany Plateau physiographic province. The upland resources are similar to those described for the NBPR Basin. However, unlike the North Branch the drainage area for the Savage River has not been mined for coal and consequently, does not have the acid mine drainage problems which occur in many other tributaries of the NBPR.

Savage River Reservoir is located approximately five miles above the confluence of the Savage River with the North Branch. The impoundment is approximately 450 acres in size and has a maximum depth of 150 feet. It has steep sides with relatively few shallow water areas. It supports both coldwater and warmwater species. Water temperatures in the summer may be 44°F at depth of 148 feet. The impoundment maintains adequate levels of dissolved oxygen (DO) at all depths. Rainbow, brook and brown trout are the main coldwater species inhabiting the reservoir. Their reproduction is limited due to the lack of suitable spawning areas. Management efforts over the last few years have focused on the stocking of rainbow trout. Other species present include largemouth and smallmouth bass, black and white crappie, pumpkinseed and bluegill sunfish, rock bass, yellow perch, white sucker, yellow bullhead and golden shiner. These warmwater species are reproducing naturally but most spawning is limited to the relatively few shallow water areas in some coves and in the upper end of the reservoir.

The free flowing river above the reservoir has good water quality and supports an excellent cold water trout fishery. The stretch of the river downstream from the dam to Aaron Run has good water quality, but species diversity is significantly reduced, possibly due to the low water temperatures caused by the bottom release design of the dam. This stretch is stocked with rainbow trout and also contains a few brook and brown trout. Other species present include longnose dace and mottled sculpin. Since Aaron Run is heavily contaminated by acid mine drainage, the water quality in the Savage River below this point is stressed.

RECREATION

The land surrounding the Savage Reservoir forms part of the Savage State Forest and New Germany State Park. The State Forest provides hiking trails upstream of the reservoir and primitive camping areas and a canoe launch downstream of the reservoir. The State Park, at its Big Run Campground located at the upper end of the reservoir, provides primitive camping, picnic tables, hiking trails, and a fishermans boat launch (electric motors or rowboats only, gasoline powered motors not permitted). Two other fisherman boat launches are provided at different locations around the reservoir. Downstream of the dam an important white water canoing area is located. A variety of kayak races have been held there including Olympic trials and Pan-American races. Canoists and kayakees either use high spring flows or request releases from Savage Reservoir if water is available. The length of river used varies from 1/2 mile for the slalom races to 5 miles (nearly the entire distance from the dam to the mouth) for the white water courses.

PATUXENT RESERVOIRS

ENVIRONMENTAL RESOURCES

Rocky Gorge and Triadelphia reservoirs are located on the Patuxent River just above Laurel, Maryland. They each cover approximately 800 surface acres and are separated by about 5.5 miles of unflooded stream (3.5 miles direct overland distance). Rocky Gorge, which is the downstream reservoir, has a maximum depth of 120 feet and is about 7 miles long. Triadelphia Reservoir has a maximum depth of 65 feet and is about 5 miles long. Both reservoirs have very good water quality and are best suited for warm water species. Summer water temperatures in the Triadelphia Reservoir range between 82°F at the surface, 68°F at 30 feet below the surface and 58°F at 65 feet below the surface. Dissolved oxygen varies from 7 ppm at the surface, 4.0 ppm at 20 feet below the surface, 2.9 ppm at 30 feet below the surface and close to 0 at a depth of 50 feet.

The fishery resources of both reservoirs are quite similar and are listed in Table H-VI-8. Almost 6,000 acres of land bordering the reservoirs is owned by the Washington Suburban Sanitary Commission (WSSC). About 80 percent of this is woodland (mostly hardwood forest) and approximately 20 percent is pasture and evergreen plantation. Use of this land is tightly controlled by WSSC to prevent erosion and other consequences which could adversely affect the reservoirs.

RECREATION

Both reservoirs have similar type of recreation facilities. The sport fishery is fair to good and is controlled by the WSSC. Both reservoirs have boat launches, mooring areas, picnic areas, and horse trails. No swimming is allowed at either reservoir. Boating is limited to craft powered by paddles, sails or electric motors. Fisherman and recreational boaters are required to have a special WSSC permit, which is obtainable by anyone for a nominal fee, in addition to the regular State license. Public hunting is permitted at Triadelphia Reservoir. Game species included squirrel, rabbit, deers, quail, pheasant and woodcock.

OCCOQUAN RESERVOIR

ENVIRONMENTAL RESOURCES

The Occoquan Reservoir has a normal conservation pool covering 1720 surface acres and extends approximately 16 miles upstream along the Occoquan River. Most of the land bordering the reservoir is forested with such species as oak, hickory, Virginia pine, dogwood, holly, beech, birch, poplar, and red maple. Common wildlife species include rabbit, squirrel, chipmunk, raccoon, and song birds. Populations of deer, fox and turkey have declined to very low levels as a result of development. Development along the Fairfax County side of the impoundment is being limited by the Northern Virginia Regional Park Authority which includes Fairfax County, City of Fairfax, Alexandria, Arlington County and Loudoun County. However, on the Prince William County side residential development is proceeding. Much development has taken place in other portions of the drainage area, and has been accompanied by erosion and sedimentation problems. It appears that future development pressure will remain strong.

Table H-VI-8

FISHERY RESOURCES OF TRIADELPHIA AND ROCKY GORGE RESERVOIRS

Species	Abundance
Walleye	Low
Yellow perch	High
Largemouth bass	Moderate
Smallmouth bass	Low
Northern pike	Low
Crappie	High
Chain pickerel	Moderate
Bluegill	High
Pumpkinseed	Moderate
Tiger musky	Low
Brown bullhead	High
White sucker	Moderate
Carp	High
Golden shiner	Moderate
American eel	Low

Over the years water quality within the reservoir has been relatively poor. The reservoir has exhibited eutrophic conditions due to excessive concentrations of nitrogen and phosphorous from sewage plant discharges and storm water runoff from developed areas within the drainage basin. High nutrient levels have led to algal blooms and low dissolved oxygen. Artificial aeration of the bottom water is conducted at the main dam in the summer. A few years ago in an attempt to alleviate the water quality problems, eleven of the sewage treatment plants discharging into tributaries of the Occoquan were consolidated into one plant with advanced wastewater treatment. While this has no doubt helped the situation, water quality problems still persist. The Occoquan Monitoring Laboratory has found that much of the current water quality problems can be traced to non-point pollution sources created by urbanization. Their studies have shown that 54 to 60 percent of the total nutrient load to the reservoir was derived from stormwater runoff from urban/suburban development. Since developmental pressures within the watershed are strong, the water quality of the reservoir will be under continual stress.

RECREATION

The Occoquan Reservoir is located on the border of Fairfax and Prince William Counties. A large tract of land on the Fairfax County side is maintained by the Northern Virginia Regional Park Authority. The Park Authority operates two pubic launch ramps for sailing, rowing, and power boats of 10 horsepower or less. Hiking trails are also provided in the park. No facilities are provided on the Prince William County side.

Despite the water quality problems the reservoir is a major sport fishing resource for the Northern Virginia area. The Virginia Commission of Game and Inland Fisheries stocks tiger musky, striped bass and channel cat, and conducts periodic creel surveys. Other fish species present include largemouth bass, bluegill and pumpkinseed sunfish, white bass, crappie, yellow perch, flathead catfish, various bullheads and carp. There is also some fishing in the downstream reach which becomes tidally influenced a few hundred yards downstream from the lower Occoquan dam. Anadromous fish (herring and perhaps some shad) collect near the dam in the spring.

EFFECTS OF STORAGE REALLOCATION

This section of Annex H-VI discusses the likely effects of modifying the Bloomington Lake project to provide additional water supply storage. This modification would be accomplished by reallocating some existing flood control storage to water supply storage; two elevations (at 1475 and 1484 feet msl) above the existing conservation pool (at elevation 1466 feet msl) were examined to provide a range of impacts. Also associated with this discussion is the possible use of Bloomington Lake's water supply storage to satisfy MWA flowby levels higher than 100 mgd. The analysis is based primarily on a comparison of the baseline conditions (which includes Bloomington Lake at elevation 1466 feet msl) and the higher lake elevations, all assuming year 2030 water demands. Thus, the analysis represents a worst case condition. (See Annexes H-III, H-IV,and H-VIII for related technical data).

SOCIAL IMPACTS

As previously indicated, one of the project purposes for Bloomington Lake is flood control. As explained in Annex H-IV, the major damage areas downstream of Bloomington Lake are the reach of the NBPR between the Savage River and Cumberland, Maryland and the reach of the NBPR between Cumberland, Maryland and the South

Branch Potomac River. Based on the technical analysis in Annex H-IV, the hydraulic and economic effects of the reallocation of flood control storage to water supply storage would be minimal, thus the social effect should likewise be minimal. However, if the public should perceive a significant reduction in the project's flood control capability, the reallocation could represent an important adverse social impact.

In terms of cultural resources, the impact of raising the conservation pool would have no effect. A cultural resources investigation was completed for the existing project in 1979. No intact prehistoric cultural resources were found in either the literature or field reconnaissance. Most of the habitable areas have been greatly disturbed by strip mining and dam related construction. Data indicated that no significant features or structures would be impacted by raising the conservation pool from 1466 feet msl to 1475 or 1484 feet msl.

ENVIRONMENTAL IMPACTS

The environmental impacts will be primarily associated with the following three types of effects: 1) increases in the elevation of the conservation pool of Bloomington Lake; 2) drawdown in the various reservoirs; and 3) changes in water quality.

RAISING BLOOMINGTON LAKE CONSERVATION POOL

For the environmental analysis, two plans to raise the conservation pool of Bloomington Lake were considered. One plan would raise the pool elevation from 1466 feet to 1475 feet, while the second plan would raise it to 1484 feet. This would result in the conversion of terrestrial habitat to aquatic habitat. Since the water quality of Bloomington Lake is expected to preclude fish habitation, the ecological benefits associated with the creation of additional aquatic habitat would be negligible. On the other hand, the higher pool elevations would result in a loss of terrestrial habitat. The land which would be inundated consists primarily of steep wooded terrain. It provides habitat for various mammals and birds which occur in the area. Because of the steep sides around Bloomington Lake, the loss of upland habitat would be relatively small. At elevation 1475 feet msl, the pool would enlarge from 952 acres to 1009 acres (57 acre increase). The pool at elevation 1484 feet msl would only encompass 1069 acres, or an increase of 117 acres over the existing pool at elevation 1466 feet msl. As a consequence, the ecological impact of raising the pool elevation would be relatively minor.

RESERVOIR DRAWDOWNS

There are many factors which would affect the impact of drawdowns on a reservoir's fishery resources. Such factors include the reservoir's size, depth configuration, temperature profile, fish species composition, and fishery management goals. The magnitude of the drawdown, its duration, rate of development, frequency of occurrence, and the time of year would also affect the degree of impact. Drawdowns would have the most severe impact if they occur during fish spawning periods. The falling water level can expose spawning areas and eggs. It can also expose weed beds and shallow water nursery areas, leaving the fry valunerable to predation. The major spawning period for many of the commonly occurring reservoir fish is from spring to early summer. Most species should be able to tolerate moderate drawdowns in the late summer and fall, but as water levels fall the effects of crowding and increased predation would also increase.

As developed in Annex H-III, the PRISM/COE runs simulating 1966 drought conditions and 2030 water supply demand with Conservation Scenario 3 indicated that when compared to the base plan, none of the alternative plans would have any significant effect on the drawdowns in the Occoquan and Patuxent Reservoirs. Several plans affect the water levels in Bloomington Lake, but the biological impact to the Lake would be minimal because it is not expected to support a fishery. Schemes with 300 and 500 mgd flowby values would cause Savage Reservoir to be drawndown earlier in the summer and at a faster rate. However, even with a 500 mgd flowby, the drawdown does not take significant effect until mid-July which is after the primary spawning time for most species, especially smallmouth and largemouth bass. The magnitude of drawdown is comparable to the normal winter drawdown. Since the Savage Reservoir is relatively steep sided, the loss of aquatic habitat would be relatively small. However, a large summer drawdown could alter the thermal regime of the reservoir and downstream areas by depleting the coldwater in the hypolimnion. This could be detrimental to the existing trout fishery.

When the PRISM/COE model was used to simulate 1930 drought conditions, all the alternative plans resulted in very large drawdowns of all reservoirs. The baseline condition (with 2030 demands) would cause the reservoirs to experience very low water levels (approximately 20 percent of their normal volume). The drawdowns would be even more severe with the plans using 300 and 500 mgd flowby; the Savage and Occoquan Reservoirs would be emptied and the Patuxent Reservoirs would be close to empty. This trend would not be substantially altered by changing the water supply/water quality storage ratio in Bloomington Lake, or by increasing the elevation of the conservation pool of Bloomington Lake by 9 or 18 feet. Although the drawdowns would not take place during the spring/early summer spawning period, they would be so severe that extensive depletion of the fishery resources in the reservoirs other than Bloomington would be expected. However, the significance of this impact should be evaluated in light of the rare frequency of occurrence of drawdowns of this magnitude.

WATER QUALITY

The reallocation of the Bloomington Lake Project and plans which utilize higher flowby levels could possibly change the water quality conditions and thus the aquatic community in the NBPR.

Results of the water quality investigations (Annex H-II) indicate that reallocation of the Bloomington Lake Project in itself will have a minimal effect on the water quality conditions immediately downstream, except that acid slugs will be moderated. Therefore, the aquatic community should remain at levels projected for the existing project.

The plans that utilize higher flowby values, would result in extended water supply release periods that would have an effect on water quality conditions by reducing the moderation effect that the Bloomington project was having on pH and other water quality parameters. The higher the flowby value, the more significant the fluctuations in pH would be and thus the effect on the aquatic community. Extended water supply releases associated with the higher flowby levels may cause severe adverse downstream impacts if Savage Reservoir storage is depleted and undiluted Bloomington releases are still being made. However, it should be noted that the frequency of occurrance of extended water releases would be rare, therefore the impacts of plans that utilize higher flowby values in the long run will be minimal.

RECREATION IMPACTS

The recreation impacts of storage reallocation or higher flowby levels would be primarily associated with 1) the raising of the conservation pool at Bloomington Lake and 2) the effects of increased frequency of drawdowns on the recreation facilities at all the reservoirs.

RAISING BLOOMINGTON LAKE CONSERVATION POOL

The impacts to the existing recreation facilities at Bloomington Lake would be as follows:

(1) High Timber Campground

There would be no significant impact to the campground should any of the proposed water levels be chosen, due to its location at a higher elevation.

(2) Howell Run Picnic Area

There would be little or no impact to this picnic area should any of the proposed water levels be chosen. The picnic area is located between elevations 1550 feet msl and 1675 feet msl and therefore would not be affected.

(3) Howell Run Boat Launch

The existing boat launch was constructed for the 1466 pool. As presently constructed, the launch can accommodate a 25 foot drawdown. The two water levels under consideration (1475 and 1484) would each have a unique impact on the facility, but in both cases modifications to the boat launch would be required. Annex H-VII provides a more detailed discussion of the extent of modifications required for the 1475 and 1484 pool.

(4) Future Sites

Future sites which have been presented in the master plan are: the Big Bend Recreation Area, expansion of the High Timber Camping Area, expansion of the Howell Run Picnic Area, and additional picnicking facilities located at the Deep Run Area. None of these proposed future sites would be affected by a water level change. This is due to the fact that they all, with the exception of Big Bend, are located at a higher elevation than the flood pool. The Big Bend area would not be affected because it is located downstream of the dam.

An analysis was also made of possible creation of new recreation sites due to the higher lake levels that had not been previously identified. By increasing the lake level to the 1484 feet msl, a potential boat launch site is created at the western end of the lake. It has been determined that this recreational site would not be feasible at the elevations 1466 or 1475 due to insufficient water depth. Although the area is sufficiently large for parking, launching, and picnicking facilities, a new access road almost one mile in length would have to be constructed along the existing abandoned railroad bed.

Also, all higher water levels (1475, 1484) would allow for the possibility of creating a boat-in campground which could be located on a large peninsula uplake of Deep Run.

Site modification and improvements would be minimal but would include a vault station. Boat tie downs would also be required.

RESERVOIR DRAWDOWNS

Drawdowns of the conservation pool at Bloomington Lake during the recreation season would affect the use of the boat launch as well as dewatering large areas of the reservoir which is aesthetically unpleasing. The impacts associated with the drawdowns are limited to those operating schemes furnishing flowby values higher than 100 mgd. The reallocation of flood control storage to water supply storage in itself has little effect upon the timing, duration, frequency, and depth of drawdowns.

Flowby values higher than 100 mgd will result in extended water supply releases in excess of those projected for the Baseline Condition, and these extended releases would cause more severe drawdowns in the pool. In order to analyze this effect, a recreation drawdown frequency curve (1 May to 30 September) was developed for the 1466 msl, 100 mgd flowby, scenario (baseline condition), as well as the 1466 msl 300 mgd and 500 mgd flowby scenarios. Table H-VI-9 compares the drawdown frequencies for the three scenarios, (see Annex H-VIII for additional information on drawdowns). Additionally, it was determined that the frequency of occurrance for the 100 mgd, 300 mgd and 500 mgd flowby scenarios for the lower limit of the existing boat launch (1441 msl) was less than 2 percent, 8 percent and 27 percent, respectively.

TABLE H-VI-9

DRAWDOWN FREQUENCY COMPARISON
BLOOMINGTON LAKE

Scheme	*Recurrence Interval (Years)*				
	2	4	10	20	50
1466 msl/100 mgd	1464	1462	1457	1454	1449
1466 msl/300 mgd	1464	1460	1446	1417	1384
1466 msl/500 mgd	1460	1436	1393	1385	1381

Though the data does not reflect the duration of drawdowns, it can be concluded that higher flowby scenarios, particularly the 500 mgd scenario, would impact the recreation resources of the Bloomington Lake project. Also, even though drawdown curves were not developed, the conclusions would also be valid for the 1475 msl and 1484 msl pool with the higher flowby values. The Savage Reservoir would also be affected by higher flowby values since it would be used in conjunction with the Bloomington project. The Patuxent and Occoquan Reservoirs, since they are located off the Potomac River and are limited by the capacity of their water treatment plants would not be as sensitive to changes in flowby as Bloomington Lake would be. However, the overall adverse impacts on recreation in these downstream reservoirs would still be significant with the higher flowby levels, particularly when considering the duration of the drawdowns.

ANNEX H-VII

DESIGN DETAILS AND COST ESTIMATES

BLOOMINGTON LAKE REFORMULATION STUDY

ANNES H-VII - DESIGN DETAILS AND COST ESTIMATES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

BLOOMINGTON LAKE REFORMULATION STUDY
ANNEX H-VII

DESIGN DETAILS AND COST ESTIMATES

The purposes of Annex H-VII are to describe the effects of the proposed higher pools (elevations 1475 and 1484) on the main dam embankment, dike embankment, relocated highway, railroad embankments, recreational facilities, reservoir slopes, and other parts of the Bloomington Lake Project. These evaluations included foundation and materials investigations and design and cost estimates for the modifications which woul . be required due to higher pools. A basic description of the Bloomington Lake project is provided in Annex H-I - Background Information.

FOUNDATIONS AND MATERIALS INVESTIGATIONS

The foundations and materials investigations were accomplished through a combination of analytical analyses and field inspections. The following paragraphs describe these investigations.

ASSESSMENT OF EMBANKMENT STABILITY - MAIN DAM AND DIKE

SUDDEN DRAWDOWN AND STEADY SEEPAGE ANALYSES

Since the maximum design flood surcharge pool with the project reformulation would increase by only 1.85 feet (from elevation 1509.0 feet msl to 1510.85 feet msl), the original limiting design calculations for sudden drawdown and steady seepage were considered appropriate and no further analysis for these conditions were considered necessary.

PARTIAL POOL ANALYSIS

New stability analyses for the partial pool condition were performed for both the dam and dike at both higher pool elevations (1475 and 1484 feet msl) that were being considered under the Bloomington Lake Reformulation Study. A check of calculations was also made for the critical pool elevation (1400 feet msl for the dam and 1465 feet msl for the dike) as determined in Design Memorandum (DM) 8, Part II, "Embankment and Foundation Treatment," to confirm compliance of data with the original analysis. A check was also made on the conservation pool elevation (1466) for the dam. Analyses were performed using the Modified Swedish Circle Method of finite slices in accordance with EM 1110-2-1902, dated 1 April 1970. Shear strength and unit weight values were the same as those indicated in DM 8, Part II. The minimum allowed factor of safety for the partial pool condition was 1.50.

Main Dam Embankment

As indicated on Figure H-VII-1, the lowest factor of safety obtained was 1.48 for the 1400 pool elevation. Higher safety factors were obtained for the proposed higher pools.

ARC NO.	COORDINATES OF ARC CENTERS		MINIMUM ELEVATION OF ARC	POOL ELEVATION	FACTOR OF SAFETY	FACTOR OF SAFETY WITH SEISMIC FACTOR OF 0.08
	HORIZONTAL	VERTICAL				
1	-288	1697	1325	1400 1466 1475 1484	1.48* 1.59 1.63 1.68	1.16* 1.17 1.19 1.21
2	-780	2477	1200	1400 1466 1475 1484	1.75 1.84 1.86 1.89	
3	-803	2827	1200	1400 1466 1475 1484	1.74 1.81 1.82 1.85	
4	-730	2442	1225	1400 1466 1475 1484	1.73 1.82 1.84 1.86	
5	-740	2430	1200	1400 1466 1475 1484	1.74 1.86 1.88 1.91	
6	-880	3124	1200	1400 1466 1475 1484	1.73 1.78 1.80 1.82	
7	-330	2188	1279	1400 1466 1475 1484	1.85 1.79 1.78 1.81	

NOTES:
1. * DENOTES CRITICAL ARC
2. ORIGIN OF COORDINATES IS THE CENTER OF THE TOP OF DAM AND MEAN SEA LEVEL

MATERIALS	STRENGTH VALUES		UNIT WEIGHTS (pcf)				SHEAR STRENGTH DESIGN ENVELOPES PARTIAL POOL CASE
	R	S	γ_d	γ_m	γ_{sat}	γ'	
IMPERVIOUS	$\phi = 12.0°$ $C = 0.2$ tsf	$\phi = 16.0°$	105	125	128	66	S, $\frac{R+S}{2}$
RANDOM ROCK	$\phi = 13.5°$ $C = 1.75$ tsf	$\phi = 33.0°$	125	130	138	75	S
MINUS 3-INCH ROCK	$\phi = 14.0°$ $C = 2.6$ tsf	$\phi = 34.0°$	135	140	148	86	S, $\frac{R+S}{2}$
SELECT ROCK	—	$\phi = 35.0°$	115	120	135	72	S

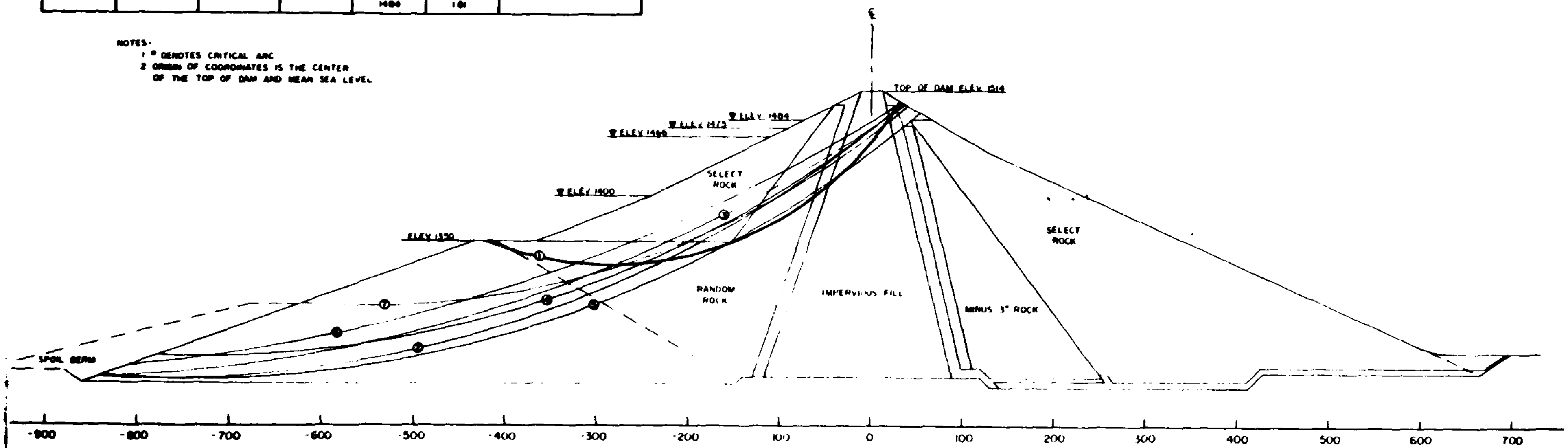


FIGURE H-VII-1
FACTOR OF SAFETY DETERMINATION
MAIN DAM EMBANKMENT

DEPARTMENT OF
BALTIMORE DISTRICT CO
BALTIMORE

Dike Embankment

As with the dam embankment, the lowest factor of safety obtained for the dike was 1.85 for the original critical pool (elevation 1465 feet msl), with higher safety factors obtained for the proposed higher pools. Results of this analysis are shown in Figure H-VII-2.

SEISMIC ANALYSIS

Checks were made on the critical arc utilizing the seismic acceleration (0.08 g) associated with the maximum credible earthquake as determined in the Seismic Report published in March 1982. The safety factors obtained for all pools studied were greater than the 1.00 required.

RESULTS

Based on the analyses performed, it was evident that no stability problems on the dam and dike embankments would be realized if either of the higher pool levels were maintained. On this basis, no modifications to the embankments would be required.

ASSESSMENT OF THE RESERVOIR SLOPES INCLUDING RAILROAD AND HIGHWAY EMBANKMENTS

GENERAL

The reservoir slopes, including railroad and highway embankments which infringed upon these slopes, were analyzed as one unit. To assist in this analysis, new aerial photography was flown at low altitude (2400 feet) while the pool was at elevation 1441.36 feet msl. Landslides which had been identified prior to construction of the dam were examined to see if they had been treated or stabilized or if they were still active. New zones of probable instability were marked on the photographs and then confirmed by a site visit. A photomosaic with accompanying overlays (Figures H-VII-3 through H-VII-5) summarize the results of these investigations.

DESCRIPTION OF THE PHOTOMOSAIC AND OVERLAYS

As the aerial photographs were trimmed and fitted together for the photomosaic, care was taken to keep the reservoir shorelines and adjacent land as undistorted as possible. Railroads, highways, and other major structures were traced on a clear overlay and then a contour line representing the maximum proposed pool (elev 1484) was added. Because of the distortion inherent in aerial photographs, the location of this contour line had to be estimated by extrapolating between points of known elevation, such as the pool level at the time of the photography, road and railroad grades, etc. Additional adjustments as required were made after the site visit. All areas of movement or slope failure, identified from the photographs or subsequent field visit, were plotted on the overlay. These unstable areas were classified in four general categories.

Debris Slides and Small Earth Slumps

This category includes small gravity failure areas such as the collapse of unconsolidated materials along steep shoreline banks or very small slumps along strip mines or highways (see photograph #1, Figure H-VII-6).

ARC NO	COORDINATES OF ARC CENTERS		MINIMUM ELEVATION OF ARC	POOL ELEVATION	FACTOR OF SAFETY	FACTOR OF SAFETY WITH SEISMIC FACTOR OF 0.08
	HORIZONTAL	VERTICAL				
1	-390	2079	[illegible]	1465 1475 1484	1.96 [illegible] 2.17	
2	-186	1702	1425	1465 1475 1484	1.91 1.91 2.01	
3	-203	1716	1412	1465 1475 1484	1.87 1.92 2.04	
4	-203	1736	1425	1465 1475 1484	1.88 1.90 2.00	
5	-218	1869	1385	1465 1475 1484	2.18 2.29 2.43	
6	-206	1719	1415	1465 1475 1484	1.85* 1.91 2.03	
7	-281	1831	1400	1465 1475 1484	2.10 2.21 2.36	
8	-220	1781	1421	1465 1475 1484	1.85* 1.90 2.01	
9	-221	1764	1425	1465 1475 1484	1.85* 1.90 2.01	1.22 1.21* 1.23

NOTES:
1. * DENOTES CRITICAL ARC
2. ORIGIN OF COORDINATES IS THE CENTER OF THE TOP OF DIKE AND MEAN SEA LEVEL

MATERIALS	STRENGTH VALUES		UNIT WEIGHTS (pcf)				SHEAR STRENGTH DESIGN ENVELOPES PARTIAL POOL CASE
	R	S	γ_d	γ_m	γ_{sat}	γ'	
IMPERVIOUS EARTH	ϕ = 12.0° C = 0.2 tsf	ϕ = 18.0°	105	125	128	65	S, $\frac{R+S}{2}$
RANDOM EARTH	ϕ = 12.0° C = 0.2 tsf	ϕ = 18.0°	105	125	128	66	S, $\frac{R+S}{2}$
RANDOM ROCK	ϕ = 13.5° C = 1.75 tsf	ϕ = 33.0°	125	130	138	75	S, $\frac{R+S}{2}$
EARTH FOUNDATION	ϕ = 14.0° C = 0.7 tsf	ϕ = 25.0°	110	128	132	70	S, $\frac{R+S}{2}$

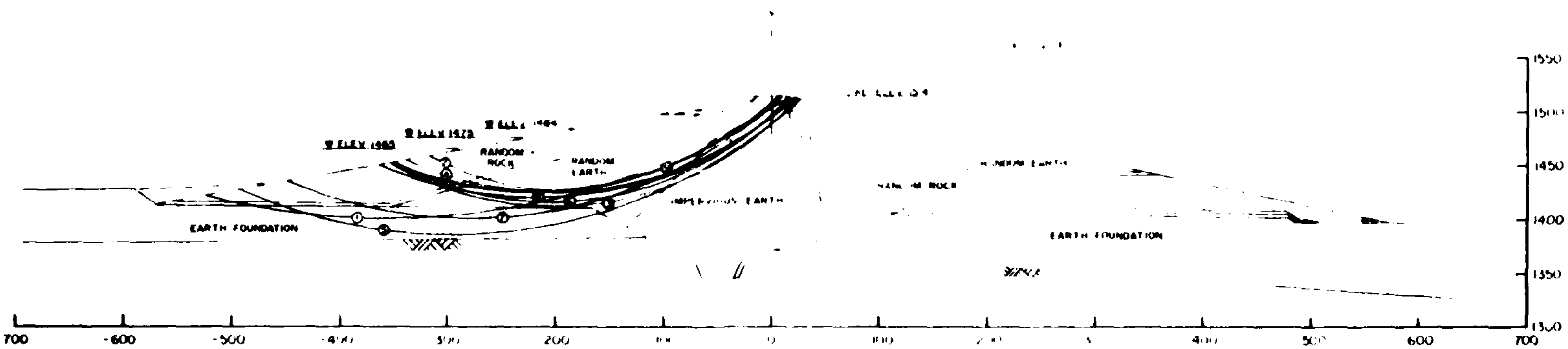


FIGURE H-VII-2
FACTOR OF SAFETY DETERMINATION
DIKE EMBANKMENT

FIGURE H-VII-3
SLOPE STABILITY ANALYSIS - PHOTOMOSAIC

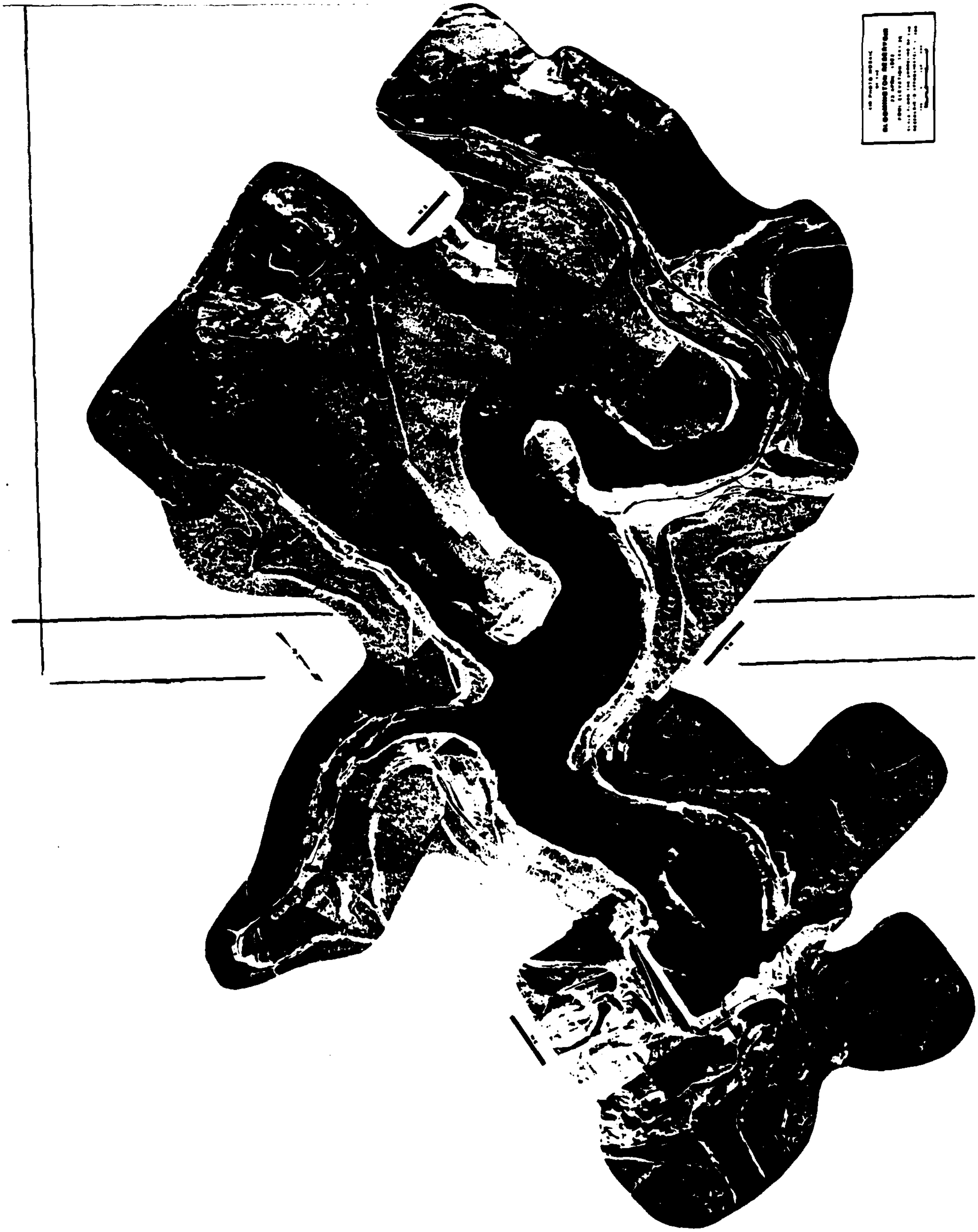


FIGURE H-VII-4
SLOPE STABILITY ANALYSIS
PHOTOMOSAIC OVERLAY WITH 1484 CONTOUR

FIGURE H-VII-5
SLOPE STABILITY ANALYSIS
PHOTOMOSAIC OVERLAY OF SHORELINE

FIGURE H-VII-6
PHOTOS SHOWING DEBRIES SLIDES AND EARTHFLOWS

PHOTOGRAPH #1
Small debris slump along reservoir shoreline.

PHOTOGRAPH #2
Earthflow above the reservoir.

Earthflows

Earthflows include the downward and outward movement of unconsolidated material which usually occurs where the original slope has been sharply steepened, either naturally or artificially. The point where the material pulls away from the slope is marked by an abrupt scarp or cliff (see photograph #2, Figure H-VII-6). Earthflows occur in unconsolidated material lying on solid bedrock and are usually activated by the presence of excessive moisture. They may involve from a few to several million cubic yards of earth materials; however, because the top of rock is at a shallow depth at Bloomington, the earthflows are commonly less than 10,000 cubic yards.

Potential rockfalls

Although most rock slopes at Bloomington appeared stable, in a few places the jointing is such that a potential for rockfalls exists.

Treated/stabilized areas

These areas were formerly unstable (generally of the earthflow type), but have since either been regraded, riprapped, or stabilized in some manner or they have been recognized as problem areas and are currently having remedial treatment designed for them.

RESULTS

There were no deep-seated, large land slides in the vicinity of Bloomington Reservoir. Most of the earthflows were in areas where natural slopes had been altered to accommodate railroads and highways. Along the reservoir shoreline, the majority of the failures were of the debris slide or small slump type; however, where the banks are steep, future drawdowns may continue to undercut the hillsides enough to create an eventual earthflow hazard. A soon-to-be published landslide map of Maryland and West Virginia, by Bill Davies of the US Geological Survey, indicates that many of the slopes upriver of the confluence of Deep Run and the Potomac have the potential for large slides if the topography is altered.

In some locations, notably southwest of the Elklick Run Bridge, at the outlet of Stoney Hollow, and along Route 46 at Deep Run, the pool elevation 1484 feet msl would be either on or very close to the railroad/highway fill.

During design, typical proposed railroad embankments were analyzed for sudden drawdown from elevations 1500 to 1466 and for long-term stability at a static pool elevation of 1500. The results of these studies showed acceptable factors of safety as outlined in Design Memorandum 7, Railroad Relocation.

No formal stability analyses were done for relocated Route 46, but the design included an outer shell of select rock to be placed on the reservoir side of the fill portions of the highway. Coincidentally, this rock was to be placed up to elevation 1485 or 1 foot above the proposed high pool. It is possible that the select rock would be adequate slope protection during repeated drawdowns; however, further investigations would be necessary for stability analyses.

An accurate controlled survey of elevation 1484 is required to assess the higher pool effect on structures such as the boat dock, the sewage leach field below the damtender's residence, and drainage culverts.

DESIGN DETAILS AND COST ESTIMATES

RESERVOIR CLEARING

Clearing should generally conform to the requirements of ER 415-2-1 dated 3 April 1978 for multiple purpose reservoirs. Clearing would include removal of all trees, stumps and brush from the existing upper limit of clearing to three feet above the proposed water supply pool elevation; i.e., to El.1478 or El.1487.

CONTROL TOWER MODIFICATIONS

Increased selective withdrawal requirements would necessitate modifications to the intake control tower. With a water supply pool at elevation 1475 feet msl, new intake ports would be installed at elevation 1461; and, with a water supply pool at elevation 1484 feet msl, new intake ports would be installed at elevation 1461 and at elevation 1479 feet msl. Work items included in the modifications would be as follows:

a. Demolition and removal of existing concrete and of steel wet well vent piping.

b. Extension of steel wet well piping and reinforced concrete encasement.

c. Installation of intake ports (including trash racks, six-ft. diameter piping and six-ft. diameter butterfly valves).

d. Installation of new floor slab(s).

e. Installation of additional isolators upstream of the intake ports at elevation 1461 feet msl.

f. Modification of the elevator, elevator shaft and elevator controls to provide access to the new floor slab(s).

g. Electrical and mechancial modifications for valve controls, motors, sensors, wiring and lighting.

Figures H-VII-7 and H-VII-8 show the locations of the new intake ports.

SPILLWAY MODIFICATIONS

Raising the water supply pool to elevation 1475 feet msl or 1484 feet msl would result in a permanent pool against the tainter gates since the existing sill is at elevation 1468 feet msl. This condition would require 7.5 KW side seal heaters for all five tainter gates. A 125 KW generator and fuel tank would be required to provide for emergency power for the heaters. A generator building of approximately 225 square feet (with associated heat, light and ventilation) would be required to house the unit. Also, bottom seals would be required for each of the tainter gates.

FIGURE H-VII-7
LOCATION OF NEW INTAKE PORTS FOR POOL ELEVATION 1475

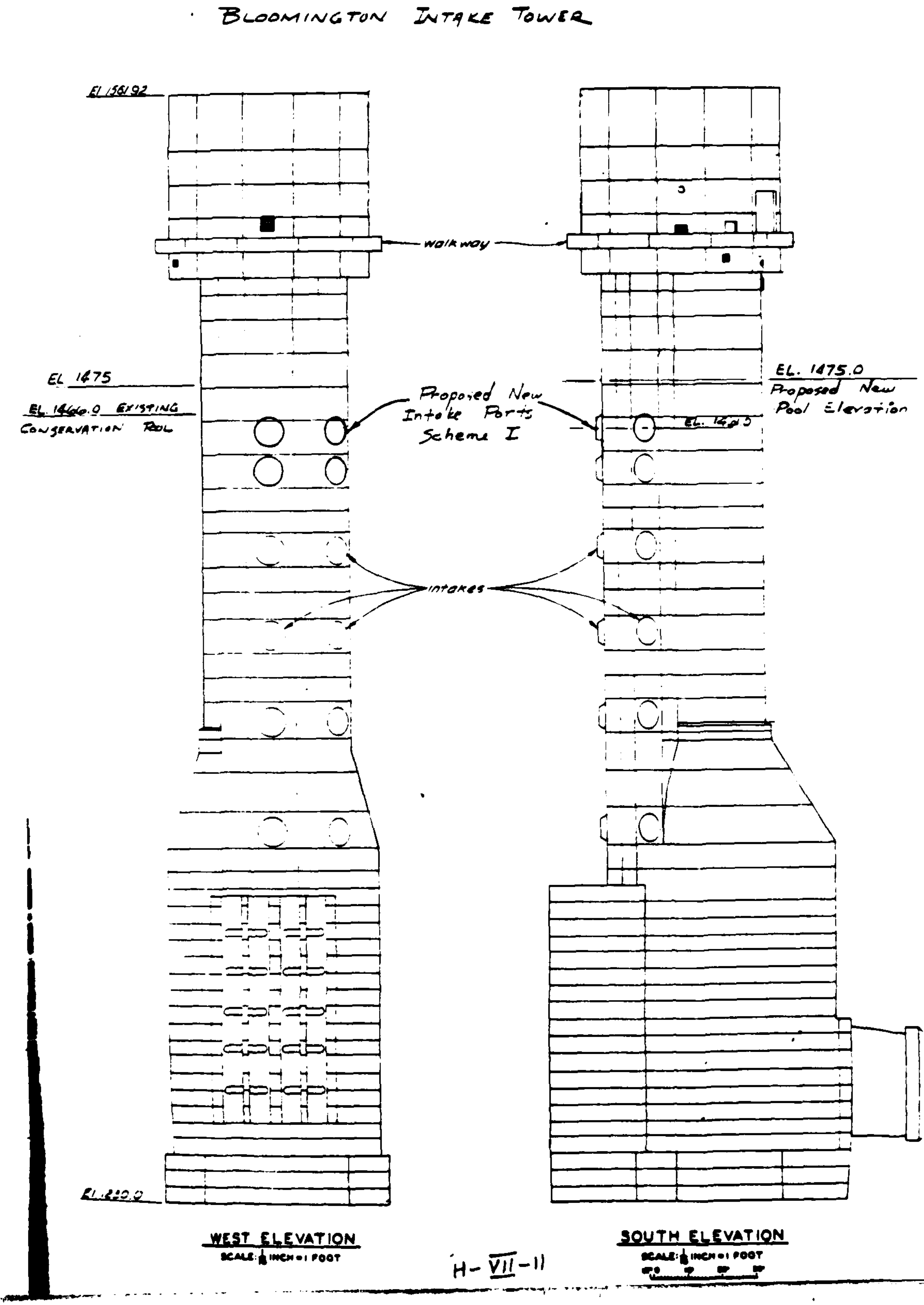
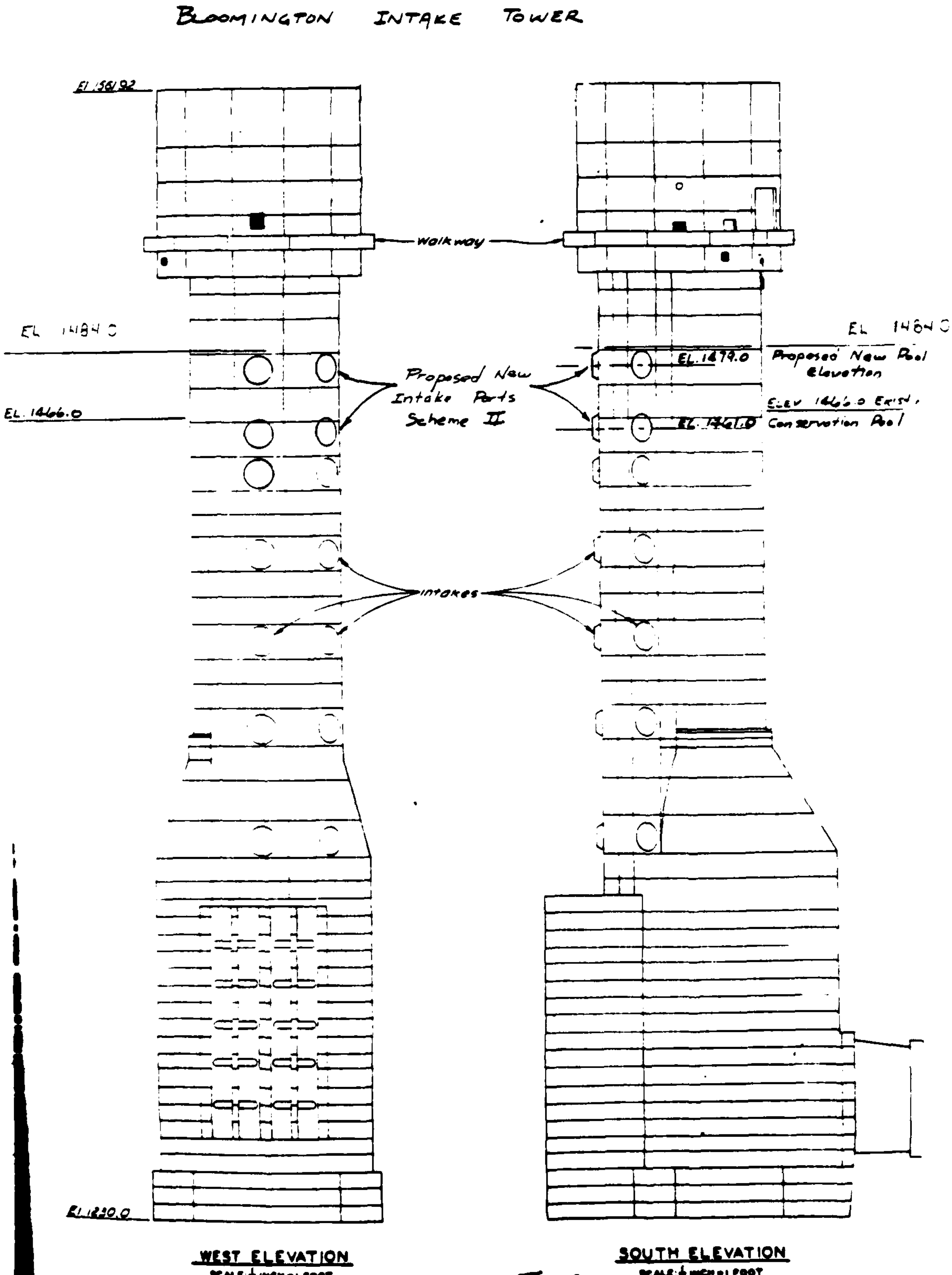


FIGURE H-VII-8
LOCATION OF NEW INTAKE PORTS FOR POOL ELEVATION 1484



BOAT LAUNCH MODIFICATIONS

The higher permanent pool elevations would require relocation of a considerable portion of the boat launch facility. Reconstruction of the ramp, permanent docks, turnaround area and a portion of the access road would be necessary. A plan of the new facility is shown in Figure H-VII-9. Figures H-VII-10 and H-VII-11 show the profiles along the proposed alignment for the access road and the turnaround, respectively, for a new water supply pool at elevation 1475 feet msl; Figures H-VII-12 and H-VII-13 show the profiles along the proposed alignment for the access road and the turnaround, respectively, for a new water supply pool at elevation 1484 feet msl. Work required to reconstruct the facility to accommodate a pool at elevation 1475 feet msl would include demolition and/or removal of guard rail, paving, concrete docks and retaining walls, and paved swale; excavation (both unclassified and structural); fill (both random and select rock); bituminous concrete paving (including subbase, base and surface course); concrete paving for the ramp and sidewalks (with associated crushed aggregate base courses); shoulder material; reinforced concrete retaining walls and boat docks and steel beam guard rail. Work required for a permanent pool at elevation 1484 feet msl would include all of the above items plus the following additional items: 18-inch gabions, filter cloth, 54-inch diameter BCCM culvert pipe and an outlet structure.

COST ESTIMATES

Table H-VII-1 presents the cost estimates for the modifications of dam and other project facilities of the Bloomington Lake Project which would be required under higher pool elevations.

TABLE H-VII-1
COST ESTIMATES FOR MODIFICATIONS
(October 1981 Price Levels)

Pool Elevation 1475 feet msl

Reservoir Clearing	$ 50,000
Tower Modifications	744,000
Spillway Modifications	85,000
Boat Launch Modifications	405,000
Sub Total	$ 1,284,000
Contingencies 20%	256,000
Total	$ 1,540,000

Pool Elevation 1484 feet msl

Reservoir Clearing	$ 60,000
Tower Modifications	1,435,000
Spillway Modifications	85,000
Boat Launch Modifications	459,000
Sub Total	$ 2,039,000
Contingencies 20%	408,000
Total	$ 2,447,000

FIGURE H-VII-9
PLAN VIEW OF BOAT LAUNCH MODIFICATIONS FOR ELEVATIONS 1475 AND 1484

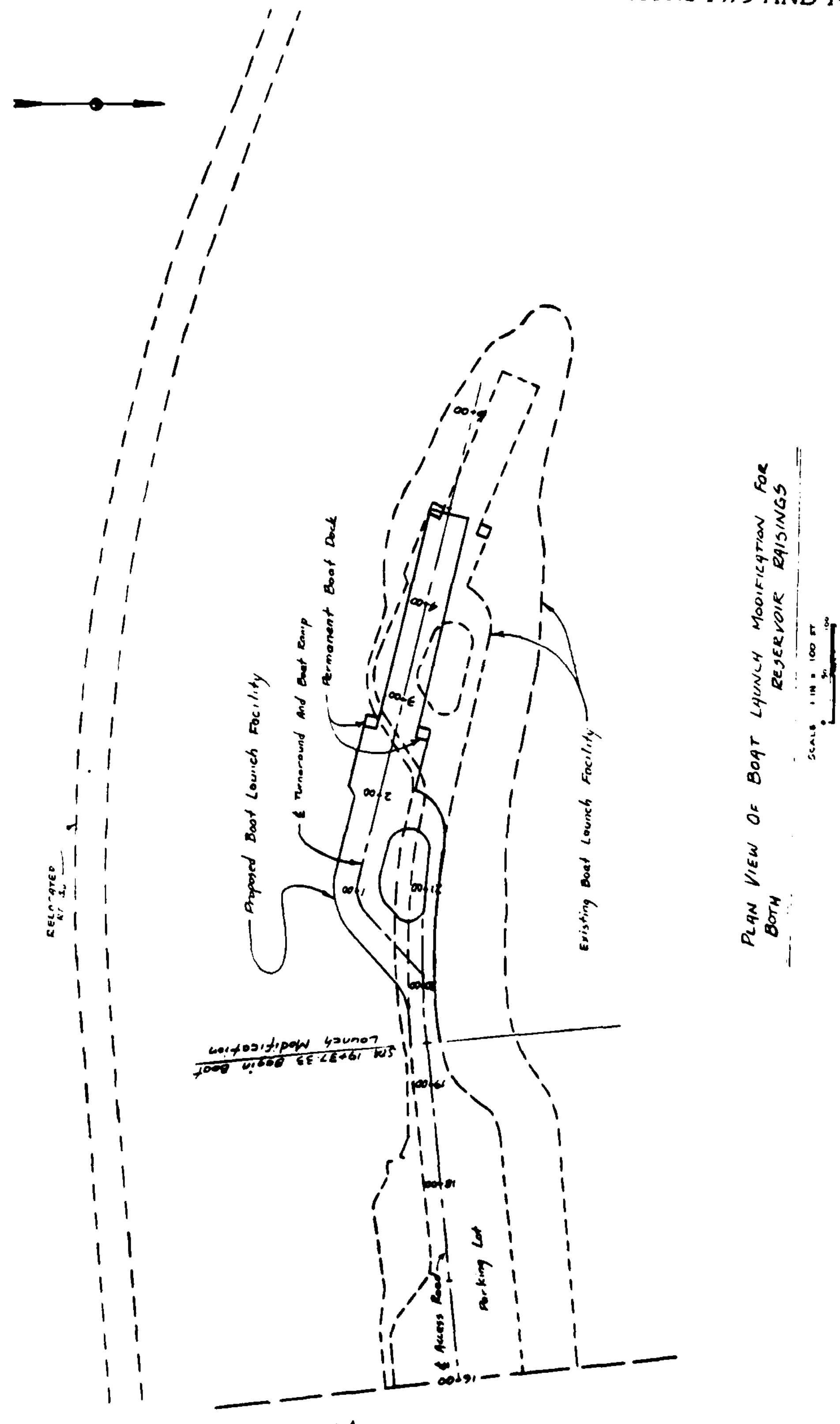
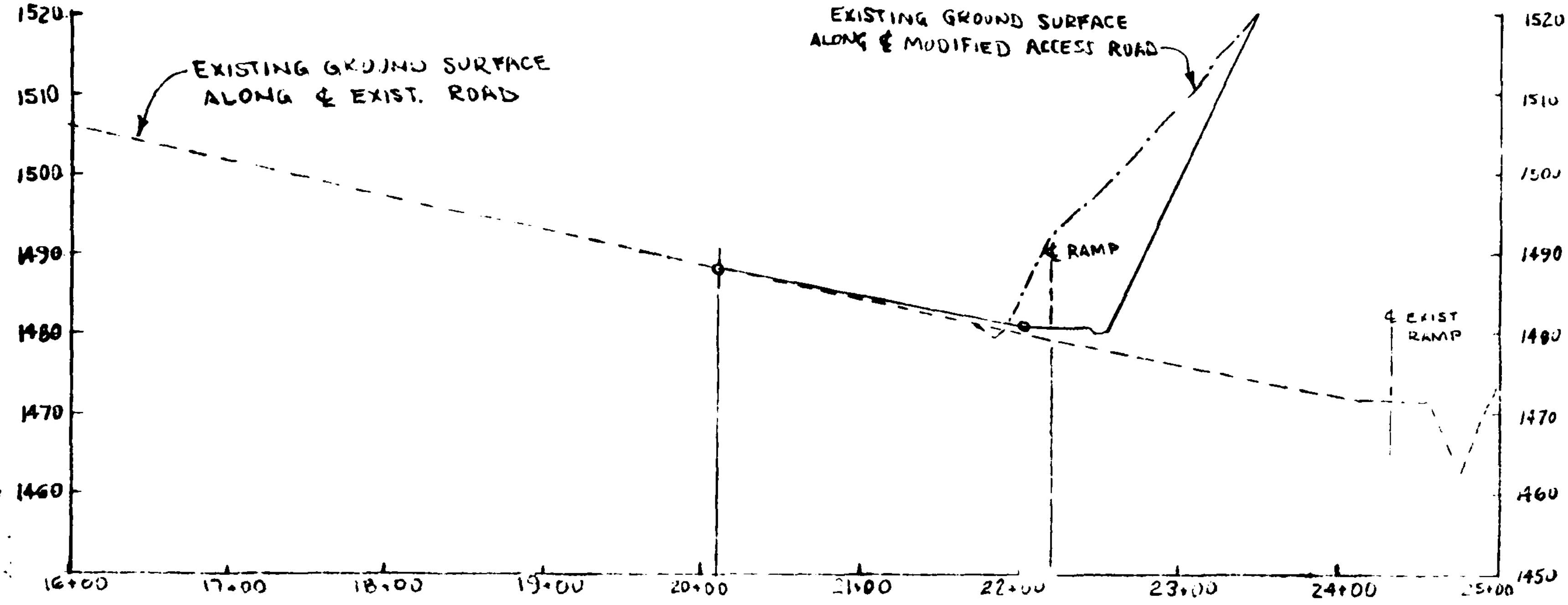


FIGURE H-VII-10
PROFILE ALONG CENTERLINE OF ACCESS ROAD - ELEVATION 1475



PROFILE ALONG ℄ ACCESS ROAD

FIGURE H-VII-11
PROFILE ALONG CENTERLINE OF TURNAROUND AND RAMP - ELEVATION 1475

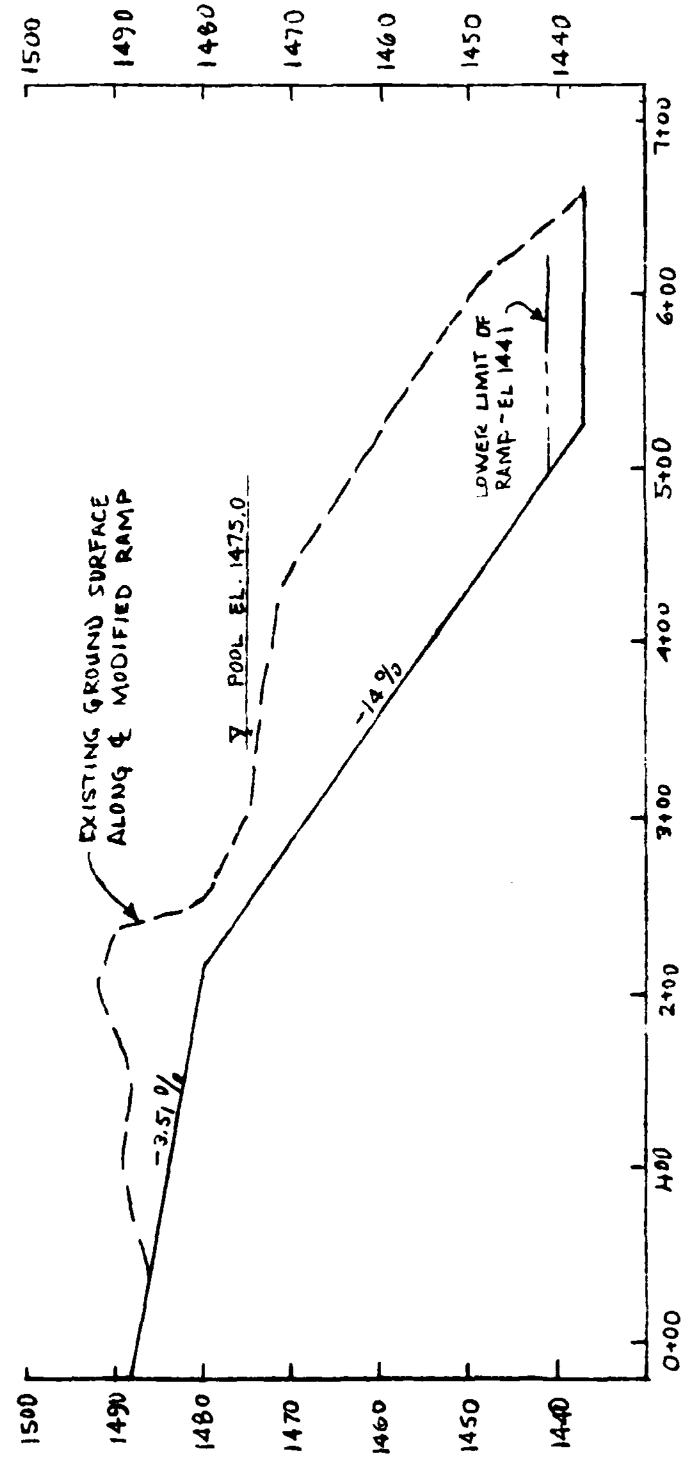
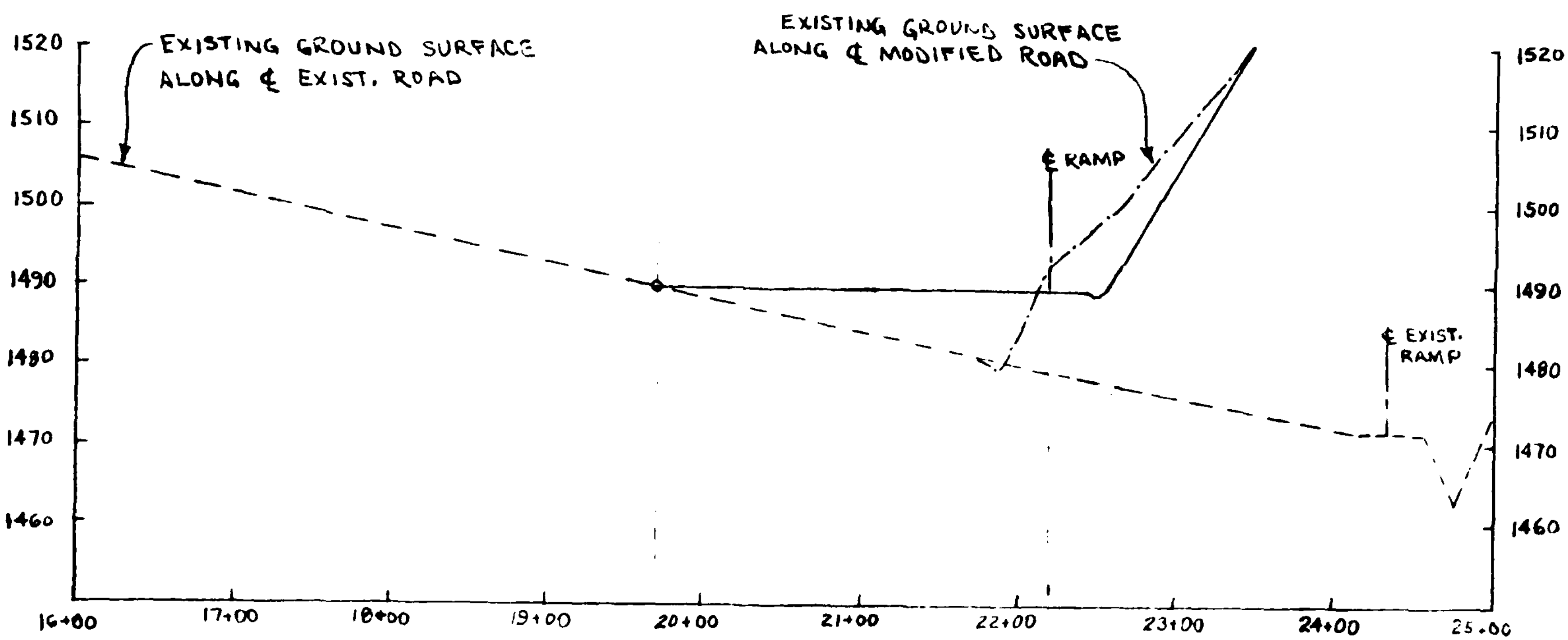
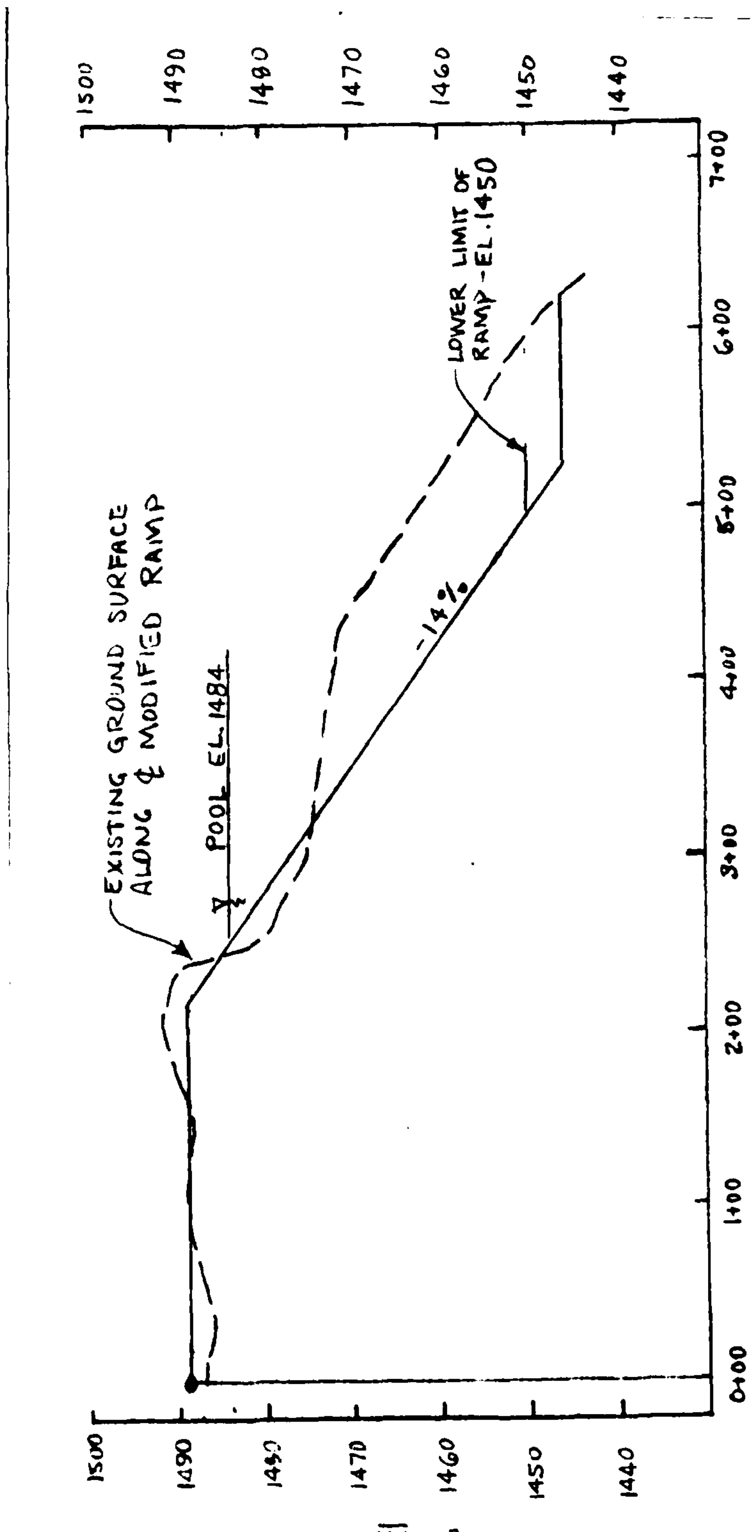


FIGURE H-VII-12
PROFILE ALONG CENTERLINE OF ACCESS ROAD - ELEVATION 1484



PROFILE ALONG ℄ ACCESS ROAD

FIGURE H-VII-13
PROFILE ALONG CENTERLINE OF TURNAROUND AND RAMP - ELEVATION 1484



ADDITIONAL INVESTIGATION NEEDED

During any advanced studies, additional investigations for the following would be needed.

TREATMENT OF THE CHANNEL DOWNSTREAM OF THE SPILLWAY

A recent study indicated that, under current operating procedures, the tainter gates would rarely be operated. The study also revealed that, if they were opened, as much as 1.3 million cubic yards of material (overburden) in the ravine below the spillway might be washed downstream into the Potomac River. No provisions are currently included in the project to prevent this erosion. If, under the reformulation, more frequent operation of the tainter gates might be expected, some means of controlling the potential erosion may be necessary to preclude adverse environmental effects.

AIR VENTS FOR LOW FLOW GATES

The adequacy of the existing low flow gate air vents to accommodate requirements resulting from the higher pool levels were not investigated. Further analysis would be required to determine whether larger vents would be required.

ADDITIONAL MAINTENANCE PAINTING OF TAINTER GATES

The tainter gate skin plates were fabricated of ASTM A441 steel protected by a No. 4 paint system (vinyl). This material and coating offered good protection for intermittent exposure to fresh water; however, this combination might not be satisfactory for extended exposure to the waters of Bloomington Lake which are contaminated by mine waste. A study would be required to determine whether more frequent repainting with the existing coating or its removal and application of a 6-A-Z (coal tar epoxy) paint system would be the appropriate solution.

ANNEX H-VIII

DRAWDOWN FREQUENCY AND YIELD DEPENDABILITY ANALYSES

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H-VIII - DRAWDOWN FREQUENCY AND YIELD DEPENDABILITY ANALYSES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H-VIII

DRAWDOWN FREQUENCY AND YIELD DEPENDABILITY ANALYSES

DRAWDOWN FREQUENCY ANALYSIS

A drawdown frequency curve was developed for 13 different schemes for the Bloomington Lake Project. The Potomac River Interactive Simulation Model/COE (PRISM/COE) was used to simulate the regulation of Bloomington Lake and Savage River Reservoir for water supply (Bloomington Lake only) and water quality, for various starting lake levels and downstream demands. Details of PRISM/COE Model are given in Annex H-III - PRISM Development and Application.

Briefly, the PRISM/COE model is a basin-specific, flow-balance model simulating the weekly operation of the water supply system which serves the MWA. The water supply system includes the Patuxent Reservoirs (Triadelphia and Rocky Gorge) in Maryland, the Occoquan Reservoir in Virginia, and the Bloomington Lake Project and Savage River Reservoir in western Maryland. Detailed data about these reservoirs are given in Annex H-I - Background Information and Appendix D - Supplies, Demands, and Deficits.

ASSUMPTIONS

For this analysis, several assumptions were made for each of the 13 schemes. These assumptions were:

a. The minimum releases from Bloomington Lake Project and Savage River Reservoir would be 50 cfs (32 MGD) and 20 cfs (13 MGD) respectively.

b. The minimum flow on the North Branch Potomac River at Luke, Maryland, (the upstream target) would be 120 cfs (78 MGD). This flow would be the sum of the Bloomington Lake and Savage River Reservoir releases. A small area of uncontrolled flow exists between the dams and Luke; however, the magnitude of this flow is insignificant and was not included in this analysis. The derivation of the 120 cfs flow target at Luke is described in Annex H-II - Water Quality Investigations. Although the 120 cfs target was established as a minimum, the actual flow at Luke would normally be greater except in extreme low flow situations.

c. To estimate water quality releases, variable flow-dependent release ratios between Savage River Reservoir and Bloomington Lake were used to simulate the mixing of Savage releases with the acidic Bloomington releases. These ratios are discussed in Annex H-III - PRISM Development and Application.

d. Based on the results of the Flow Loss and Travel Time Study for the Potomac River prepared by the United States Geological Survey, 47 percent of the water released from the Bloomington Lake and Savage River Reservoir projects was estimated to arrive in the Washington, DC area within one week. The remaining 53 percent would arrive during the following week. See Annex H-V for details of these studies.

e. A downstream target factor of 0.6 was used, as developed in Annex H-III. This factor represents the degree of dependency of the MWA on the downstream reservoirs (Patuxent and Occoquan Reservoirs) for water supply. For instance, a lesser factor, say

0.4, would result in less reliance on the downstream reservoirs and more on Bloomington Lake.

f. Releases would be made from water supply storage in Bloomington Lake to satisfy the need for environmental flowby into the Potomac River estuary for flowby levels greater than 78 mgd (120 cfs). See assumption "b" and Annex H-II - Water Quality Investigations for more information.

SCHEMES

As previously mentioned, 13 schemes were tested for this drawdown frequency analysis. The parameters that were changed from scheme to scheme included the Bloomington Lake starting elevation and rule curve, the allocation of water supply and water quality storage within Bloomington Lake, and the environmental flowby requirement. Scheme 1 considered seasonally-varied pool elevations at Bloomington Lake (elevation 1466 for summer, elevation 1410 for winter), and assumed the rule curve used for the Bloomington Lake Reservoir Regulation Manual. The total conservation storage of 92,000 acre-feet (30,000 MG) in the Bloomington Lake was sub-allocated, 51,000 acre-feet (16,630 MG) for water quality and 41,000 acre-feet (13,370 MG) for water supply. Table H-VIII-1 summarizes the 13 schemes in terms of the parameters used to describe Scheme 1 above.

DATA BASE

Weekly average flow data for water years 1930-1979 were used in this analysis. Flow data beginning in October 1929 were used so that the 1930's drought, the worst of record for the Potomac River, could be accurately modeled. Data before 1930 were not determined because there were very few stream gaging stations in operation prior to that time, and no recording gages were located on the North Branch Potomac River. Details concerning the development of the flow data are given in the report, "Policy Analysis of Reservoir Operation in the Potomac River Basin" by Richard Palmer, Jeffrey Wright, and James Smith, The Johns Hopkins University, Baltimore, Maryland.

RESULTS

The drawdown frequency curves for Bloomington Lake were developed based on 50 years of flow data. The climatological year, 1 April - 31 March, was used instead of the water year, 1 October - 31 September, so that each annual drawdown would be as independent as possible from the previous or following year. A drawdown frequency curve was developed for each of the 13 schemes. Additionally, drawdown frequency curves were developed for Schemes 1, 4, 7, and 8 using the recreational season (1 May - 30 September).

In addition to the water supply requirements, the drawdown frequency curves include the effect of estimated water quality releases, evaporation, minimum flow requirements, and environmental flowby. The drawdown frequency curves are shown on Figures H-VIII-1 through H-VIII-8. (For convenience, all figures have been placed at the end of the Annex). Extrapolation of the drawdown frequency curves beyond the 2 percent chance of occurrence may not yield valid results because of the unusual shape and occasional slope changes of some of the curves. Table H-VIII-2 compares the drawdown frequencies for each of the 13 schemes. Table H-VIII-3 gives the elevation and conservation storage remaining for the maximum drawdown for the period 1930-1979 for all schemes based on simulations performed using PRISM/COE.

TABLE H-VIII-1

SUMMARY OF SCHEMES

Scheme #	Bloomington Lake Summer Pool/Winter Pool or Year-Round Pool (elev. msl)	Water Supply Storage Acre-Feet	(MG)	Water Quality Storage Acre-Feet	(MG)	Environmental Flowby CFS	(MGD)
1	1466/1410	41000	(13370)	51000	(16630)	155	(100)
2	1466/1410	41000	(13370)	51000	(16630)	464	(300)
3	1466/1410	41000	(13370)	51000	(16630)	774	(500)
4	1466	41000	(13370)	51000	(16630)	155	(100)
5	1466	41000	(13370)	51000	(16630)	464	(300)
6	1466	41000	(13370)	51000	(16630)	774	(500)
7	1466	46000	(15000)	46000	(15000)	464	(300)
8	1466	46000	(15000)	46000	(15000)	774	(500)
9	1475	53000	(17260)	48000	(15640)	464	(300)
10	1475	53000	(17260)	48000	(15640)	774	(500)
11	1484	62000	(20260)	48000	(15640)	464	(300)
12	1484	62000	(20260)	48000	(15640)	774	(500)
13 *	1466/1410	0	(0)	92000	(30000)	155	(100)

* SCHEME 13 - The upstream target (flow requirement at Luke) was 305 cfs (197 MGD) instead of 120 cfs (78 MGD) as used in the other schemes.

TABLE H-VIII-2

DRAWDOWN FREQUENCY COMPARISON

Scheme	Starting Lake Elev. (Ft. msl)	Frequency of Event: 10% Reservoir Elev. (feet msl)	10% Remaining Storage (acre-feet)	5% Reservoir Elev. (feet msl)	5% Remaining Storage (acre-feet)	2% Reservoir Elev. (feet msl)	2% Remaining Storage (acre-feet)
I. ANNUAL							
1	1466/1410	1410	47500	1410	47400	1409	46800
2	1466/1410	1410	47500	1408	46500	1370	25500
3	1466/1410	1399	40600	1392	36700	1358	20500
4	1466	1456	82500	1450	77500	1442	71000
5	1466	1444	72000	1423	56000	1359	21000
6	1466	1398	40000	1387	34000	1349	17000
7	1466	1441	70000	1419	53000	1347	16000
8	1466	1389	35000	1375	28000	1335	12000
9	1475	1452	79000	1431	62000	1362	22000
10	1475	1394	38000	1377	29000	1341	14000
11	1484	1464	90000	1444	72000	1367	24000
12	1484	1400	41500	1379	30000	1344	15000
13	1466/1410	1374	27300	1335	12000	--*	--*
II. RECREATION SEASON							
1	1466/1410	1433	83800	1454	80700	1449	76300
4	1466	1433	83800	1454	80700	1449	76300
7	1466	1446	74000	1417	52000	1384	32500
8	1466	1393	37000	1385	33000	1381	31000
RETURN PERIOD (YEARS)		10		20		50	

* Bloomington Lake is empty.

TABLE H-VIII-3

MAXIMUM DRAWDOWN COMPARISON

Scheme	Starting Lake Elev. (Ft. msl.)	Maximum Drawdown: Elevation (Ft. msl.)	Maximum Drawdown: Storage Remaining Acre-feet (MG)	Maximum Drawdown: Date
I. ANNUAL				
1	1466/1410	1409	46990 (15311)	January 1931
2	1466/1410	1364	23000 (7496)	January 1931
3	1466/1410	1363	22290 (7262)	January 1931
4	1466	1441	70320 (22914)	November 1930
5	1466	1364	23000 (7496)	January 1931
6	1466	1363	22290 (7262)	January 1931
7	1466	1351	17470 (5693)	January 1931
8	1466	1346	15750 (5131)	January 1931
9	1475	1354	18690 (6090)	January 1931
10	1475	1349	16820 (5480)	January 1931
11	1484	1350	17230 (5618)	January 1931
12	1484	1344	15220 (4961)	January 1931
13	1466/1410	1282	0 (0)	January 1931
II. RECREATION SEASON				
1	1466/1410	1449	76280 (24857)	September 1930
4	1466	1449	76280 (24857)	September 1930
7	1466	1384	32280 (10519)	September 1930
8	1466	1382	31290 (10195)	September 1965

YIELD DEPENDABILITY ANALYSIS

For the purposes of this analysis, the dependable yield was defined as the discharge or release (yield) from a reservoir or lake which could be maintained for 95 percent of the time, given the inflow to and conservation storage in that reservoir or lake. Four different dependable yields were determined for each of two different reservoir system scenarios. For the first scenario, the dependable yield was determined for the Bloomington Lake only; and, for the second scenario, the Bloomington Lake was combined with Savage River Reservoir and a combined yield was calculated.

DATA BASE

Monthly average streamflow data (reservoir inflow) for water years 1928 through 1976 were used for this analysis. These data were generated by the Johns Hopkins University as part of the development of the PRISM Model (see Annex H-III for more details on PRISM/COE development). Other data included pool elevations, storage, reservoir area, discharge capacity, and evaporation for both Bloomington and Savage reservoirs. The computer program HEC-5, Simulation of Flood Control and Conservation Systems, developed by the Corps of Engineers' Hydrologic Egnineering Center, Davis, California, was used to model Bloomington Lake and Savage River Reservoir for the yield dependability analysis. The HEC-5 program has the capability to model a reservoir or reservoir system to meet a set of constraints identified in the input data.

SCENARIO I - BLOOMINGTON LAKE ONLY

The yield analysis for Bloomington Lake acting alone was performed with two major constraints. The first constraint was to set a minimum discharge (yield) from the project. The Lake would then function to meet this minimum flow as long as there was conservation storage available in the lake. The second constraint was to maintain the lake between the top of conservation storage and the top of dead storage (essentially the gate sill elevation). Therefore, the lake was regulated to meet the minimum outflow requirement from reservoir inflows and the available conservation storage. Four conditions were analyzed:

a. 1466-1410 seasonal pools (scheme 1)
b. 1466 year-round pool (scheme 4)
c. 1475 year-round pool (scheme 9)
d. 1484 year-round pool (scheme 11)

The minimum release (yield) in the HEC-5 model was varied from 215 cfs to 600 cfs. This range of flows was sufficient to develop yield dependability curves (yield versus percent time exceeded).

SCENARIO II - BLOOMINGTON LAKE AND SAVAGE RIVER RESERVOIR

A yield analysis was performed for Bloomington Lake and Savage River Dam combined. The HEC-5 model was set up to operate a two-reservoir system to meet a minimum flow requirement at Luke. The same four conditions as stated above were analyzed again with the addition of Savage River Reservoir. Savage River Reservoir was assumed to operate under the current rule curve. The HEC-5 model operated the parallel reservoirs to meet a minimum flow (yield) that was equal to the sum of the reservoir discharges. The release from each reservoir was computed by the model so that during periods of drawdown, each reservoir would be in nearly the same state of drawdown (i.e., eac reservoir would have about the same percentage of its conservation storage remaining).

For each condition, Bloomington Lake and Savage River Reservoir were regulated to meet a combined minimum flow requirement that ranged from 325 cfs to 800 cfs.

RESULTS

Table H-VIII-4 summarizes the yield dependability for Bloomington Lake and Table H-VIII-5 summarizes the yield dependability for Bloomington Lake and Savage River Reservoir combined. The yield dependability curves show yield versus percent time exceeded based on the ability to meet a specified yield on both an annual basis and on a monthly basis. These curves are based on 49 years (588 months) of flow data. Plotting positions were determined by dividing the number of years (months) that the yield was met without shortages by the number of years (months) of flow data. Figure H-VIII-9 through H-VIII-12 show the yield dependability for Bloomington Lake alone and Figures H-VIII-13 through H-VIII-16 show the yield dependability for Bloomington Lake and Savage River Reservoir combined.

This yield dependability analysis does not reflect the reservoir regulation plan described in the recently approved Reservoir Operation Manual for the Bloomington Lake Project. This analysis was based on a constant yield throughout the year. In fact, the water supply storage in Bloomington Lake has been purchased under contract and will be released only upon demand. Long range flow forecasts for the Potomac River and expected demands will provide the basis for requested water supply releases. These parameters and the likelv effects on Bloomington Lake's regulation are discussed elsewhere in the report.

TABLE H-VIII-4

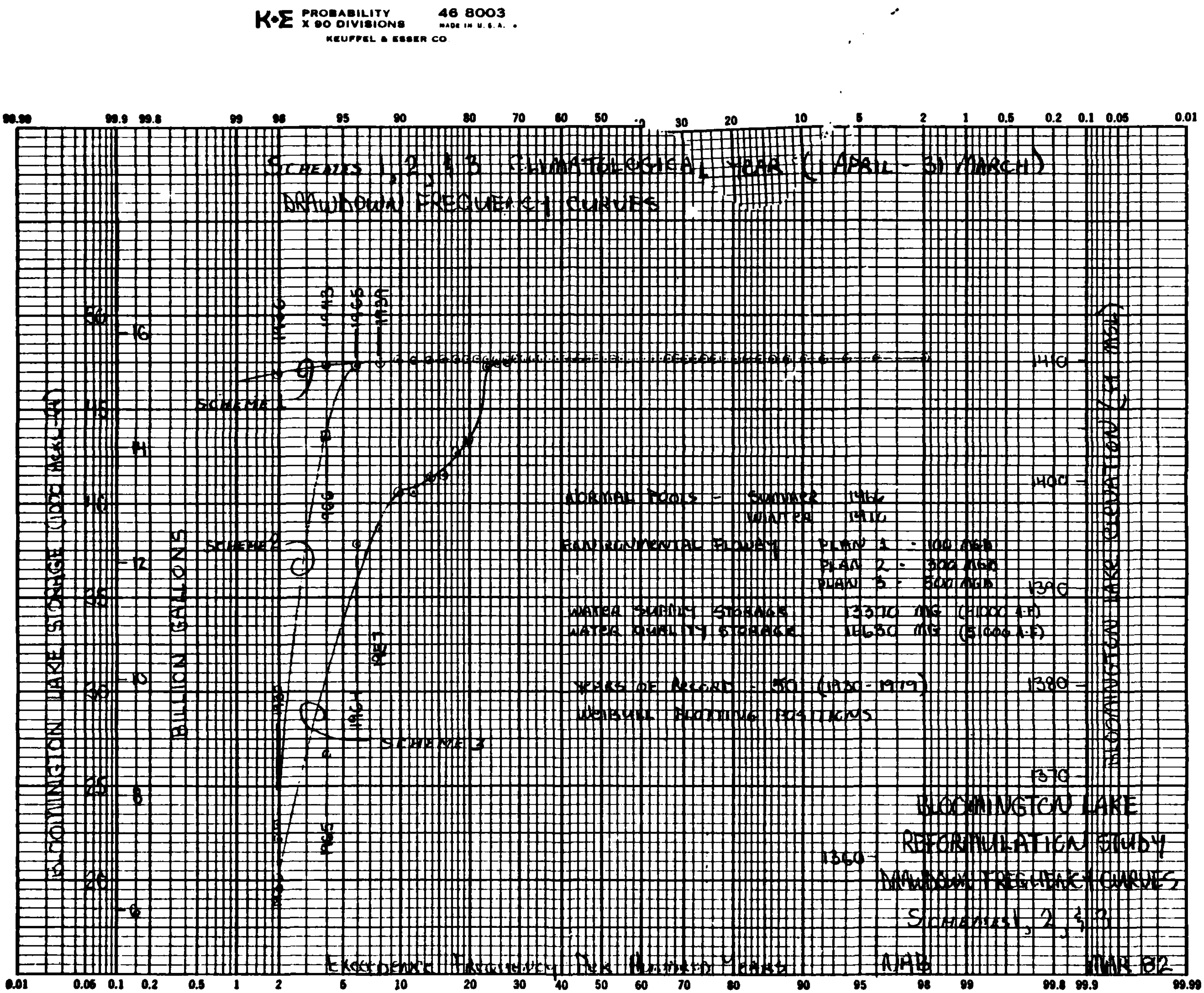
YIELD DEPENDABILITY - BLOOMINGTON LAKE ONLY

Plan	Yield (cfs)	Number of months yield not met	% of months yield is met	% of years yield is met
1466-1410, seasonal (Scheme 1)	275	2	99.7	98.0
	300	6	99.0	93.9
	325	8	98.6	93.9
	350	16	97.3	85.7
	400	36	93.9	71.4
	500	116	80.3	20.4
	600	200	66.0	8.2
1466, year-round (Scheme 4)	275	2	99.7	98.0
	300	5	99.1	93.9
	325	8	98.6	93.9
	350	14	97.6	87.8
	400	36	93.9	71.4
	500	112	81.0	26.5
	600	196	66.7	8.2
1475, year-round (Scheme 9)	275	No deficits	— —	
	300	2	99.7	98.0
	325	6	99.0	93.9
	350	11	98.1	91.8
	400	25	95.7	80.0
	500	93	84.2	36.7
	600	187	68.2	10.2
1484, year-round (Scheme 11)	275	No deficits	— —	
	300	No deficits	— —	
	325	3	99.5	95.9
	350	8	98.6	91.8
	400	20	96.6	83.7
	500	83	85.9	40.8
	600	180	69.4	10.2

TABLE H-VIII-5

YIELD DEPENDABILITY
BLOOMINGTON LAKE AND SAVAGE RIVER RESERVOIR

Plan	Yield (cfs)	Number of months yield not met	% of months yield is met	% of years yield is met
1466-1410, seasonal (Scheme 1)	300	No deficits		
	325	3	99.5	95.9
	350	5	99.1	93.9
	400	11	98.1	91.8
	450	27	95.4	75.5
	500	46	92.2	57.1
	600	112	81.0	20.4
	700	177	69.9	10.2
	800	241	59.0	4.1
1466, year-round (Scheme 4)	300	No deficits		
	325	2	99.7	98.0
	350	5	99.1	93.9
	400	11	98.1	91.8
	450	25	95.7	77.6
	500	44	92.5	61.2
	600	106	82.0	22.4
	700	172	70.7	12.2
	800	235	60.0	4.1
1475, year-round (Scheme 9)	300	No deficits		
	325	1	99.8	98.0
	350	3	99.5	95.9
	400	8	98.6	93.9
	450	18	96.9	81.6
	500	39	93.4	69.4
	600	95	83.8	32.7
	700	162	72.4	14.3
	800	226	61.6	6.1
1484, year-round (Scheme 11)	325	No deficits		
	350	2	99.7	98.0
	400	7	98.8	93.9
	450	16	97.3	87.8
	500	30	94.9	75.5
	600	83	85.5	36.7
	700	157	73.3	14.3
	800	218	62.9	6.1



K•E PROBABILITY X 90 DIVISIONS 46 8003 MADE IN U.S.A. KEUFFEL & ESSER CO
SCHEMES 1, 2, & 3 CLIMATOLOGICAL YEAR (1 APRIL - 31 MARCH)
DRAWDOWN FREQUENCY CURVES
NORMAL POOLS - SUMMER 1466
WINTER 1410
ENVIRONMENTAL FLOWS PLAN 1 - 100 MGD
PLAN 2 - 300 MGD
PLAN 3 - 500 MGD
WATER SUPPLY STORAGE 13370 MG (41000 A-F)
WATER QUALITY STORAGE 16630 MG (51000 A-F)
YEARS OF RECORD - 50 (1930-1979)
WEIBULL PLOTTING POSITIONS
SCHEME 1
SCHEME 2
SCHEME 3
BLOOMINGTON LAKE STORAGE (1000 ACRE-FT)
BILLION GALLONS
BLOOMINGTON LAKE ELEVATION (FT MSL)
EXCEEDENCE FREQUENCY PER HUNDRED YEARS
BLOOMINGTON LAKE
REFORMULATION STUDY
DRAWDOWN FREQUENCY CURVES
SCHEMES 1, 2, & 3
AHB
MAR 82

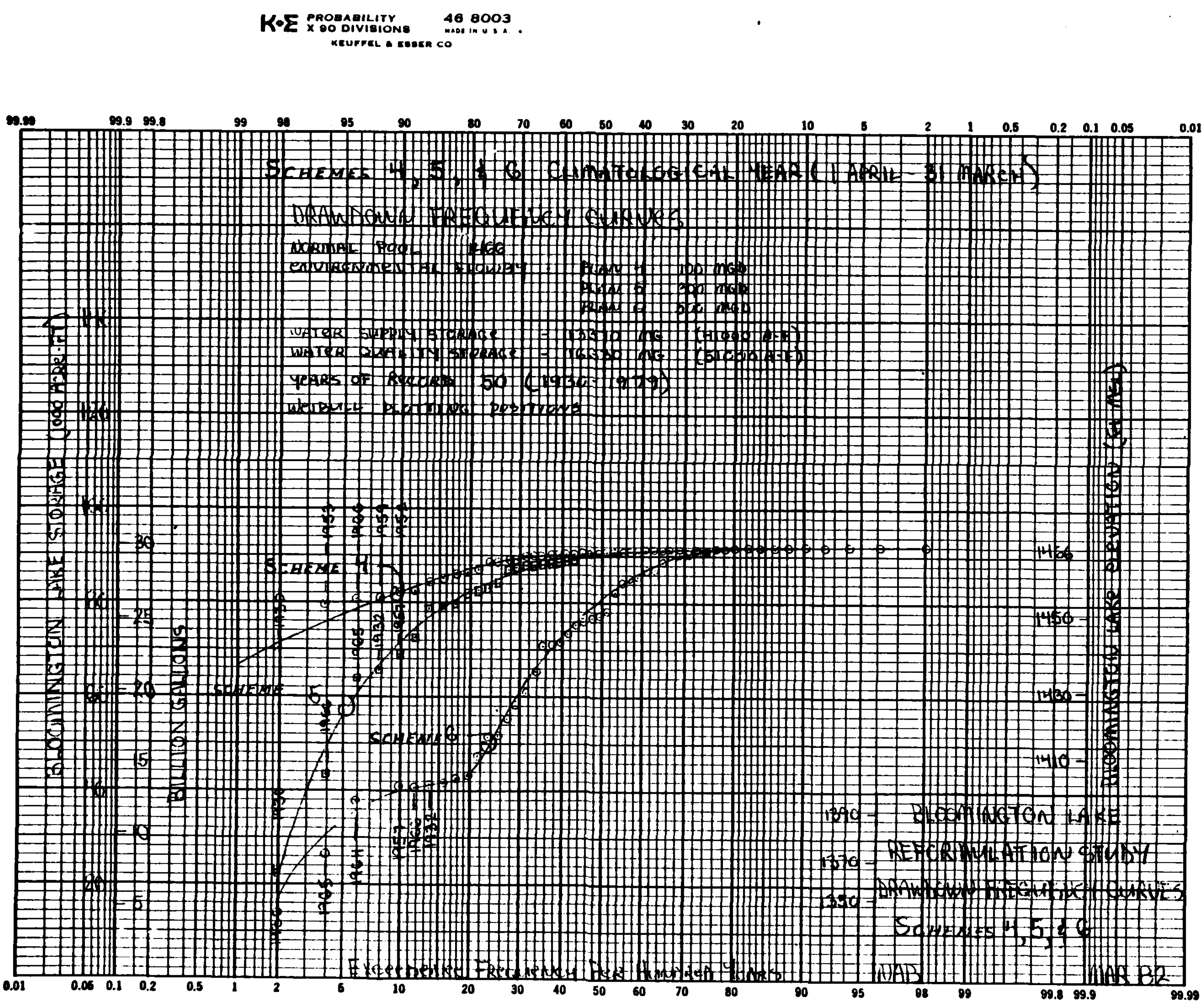


FIGURE H-VII-2

H-VII-11

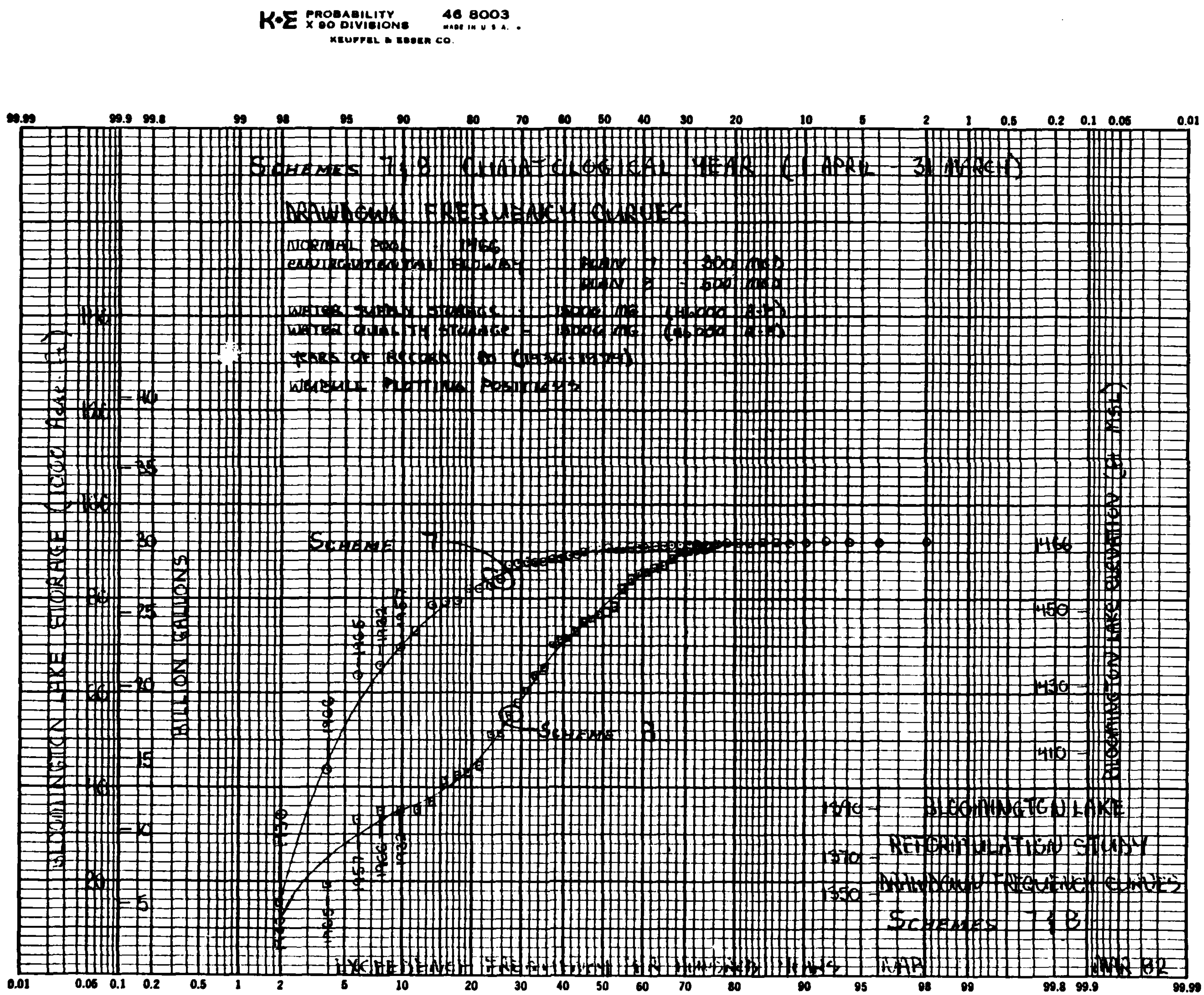
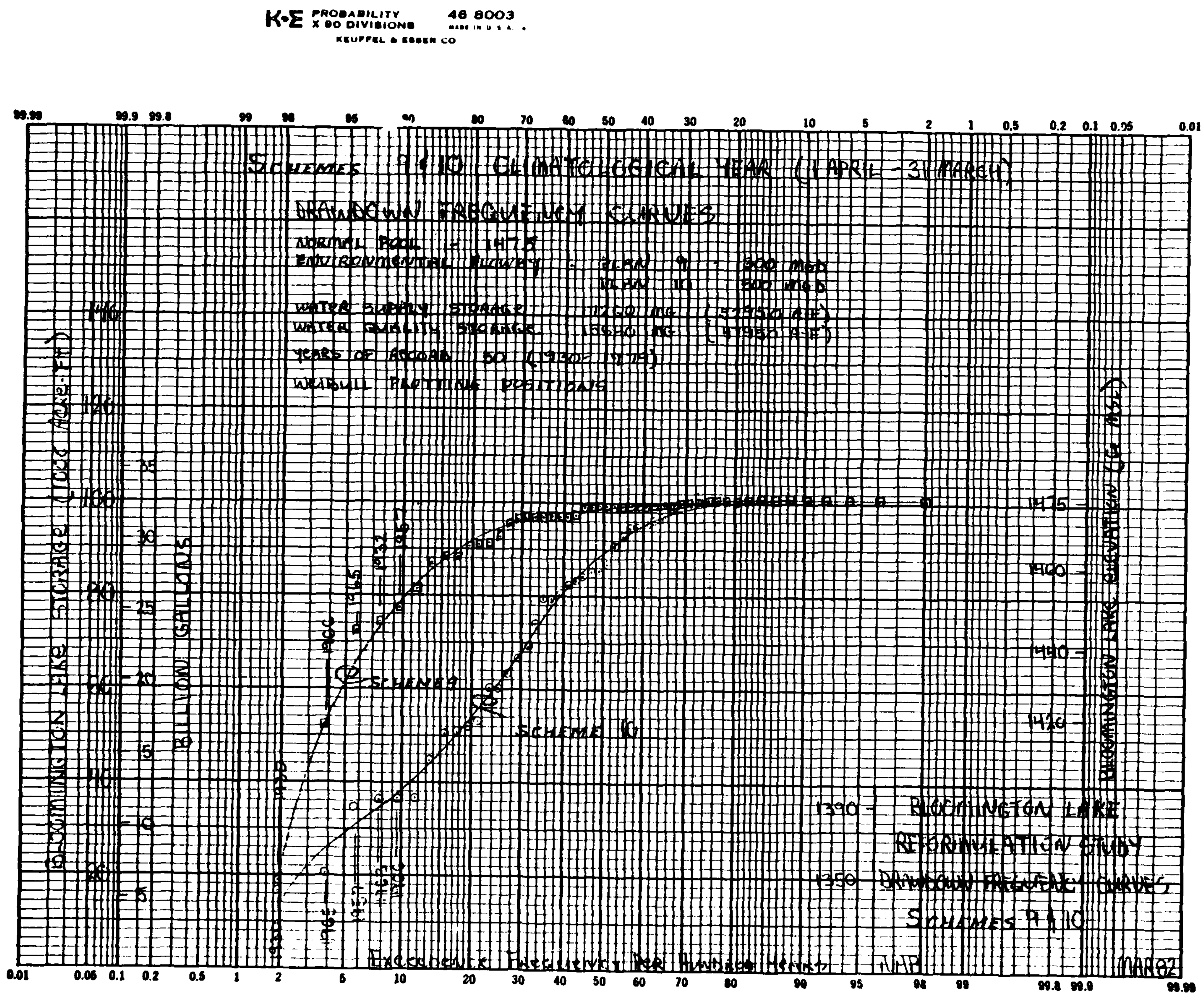


FIGURE H-VII-3



H-VII-35

FIGURE H-VII-4

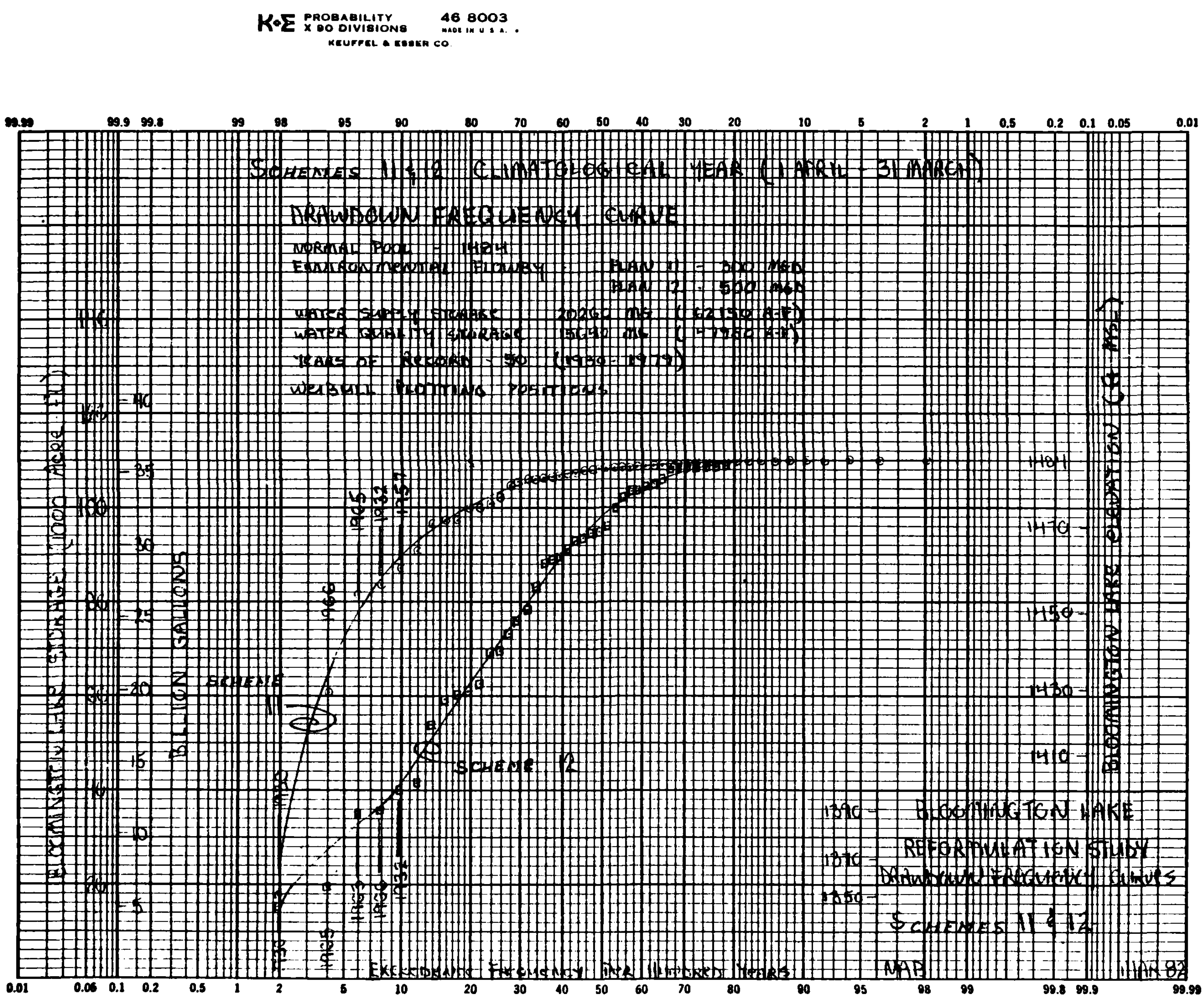
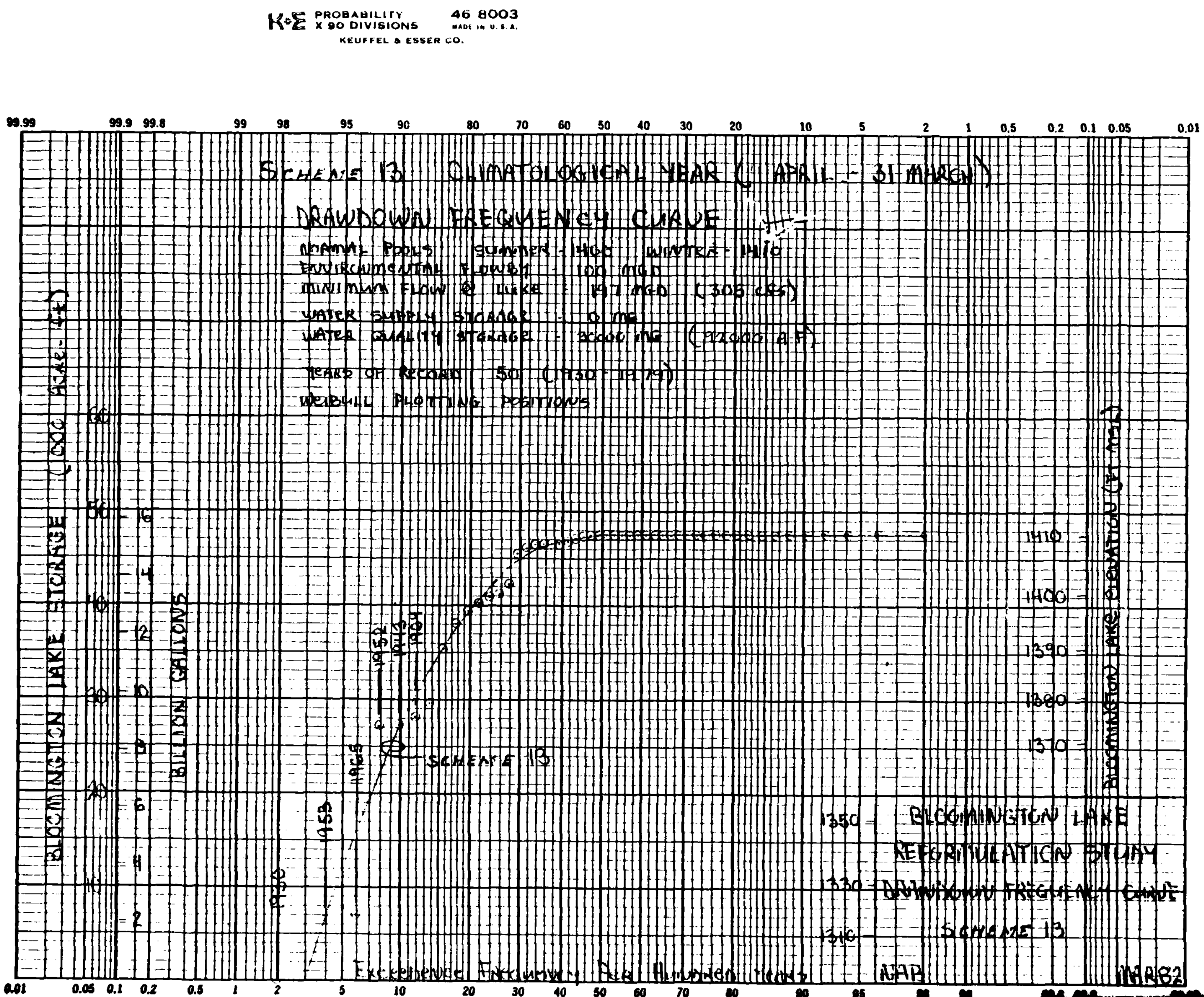
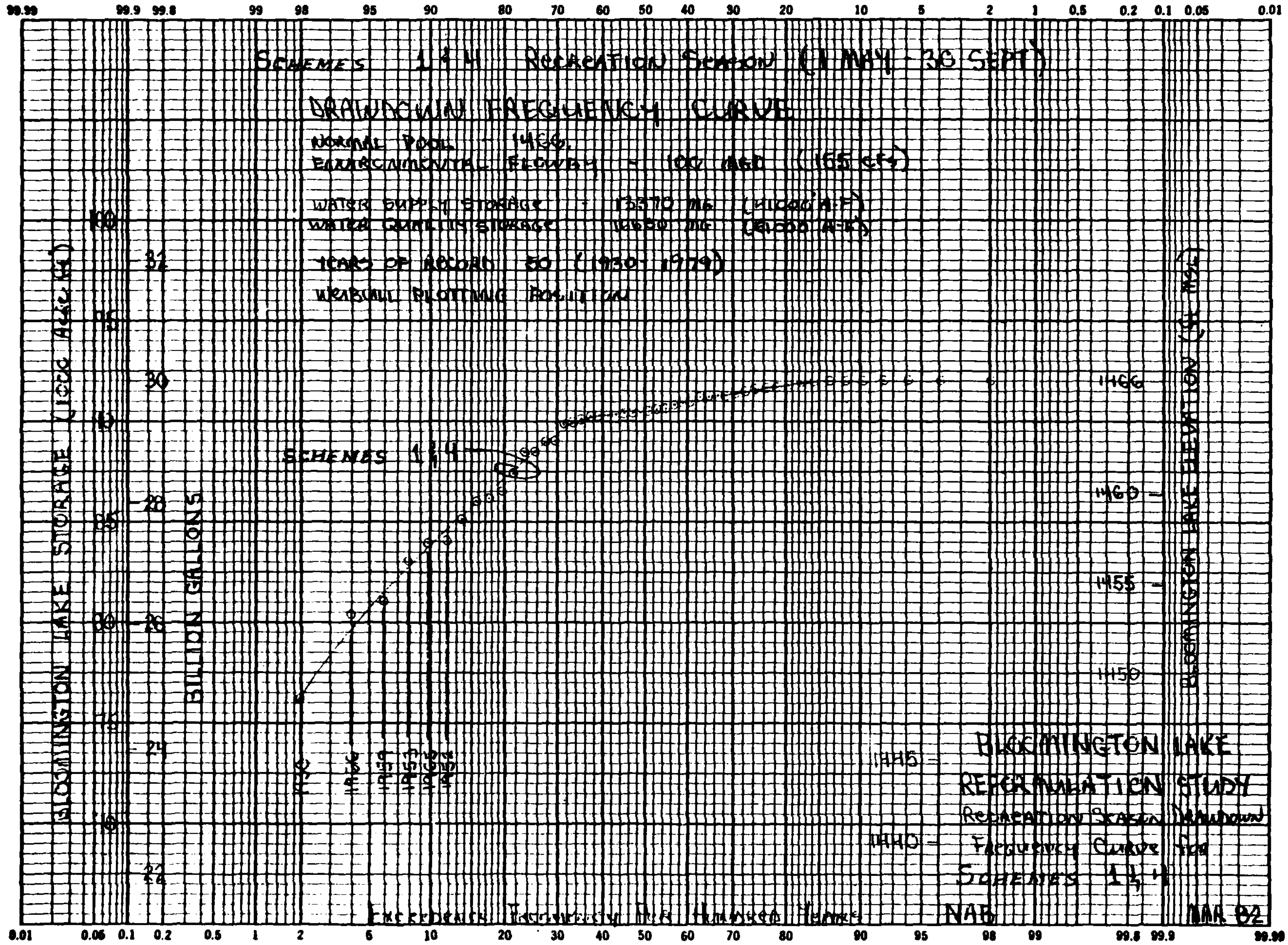


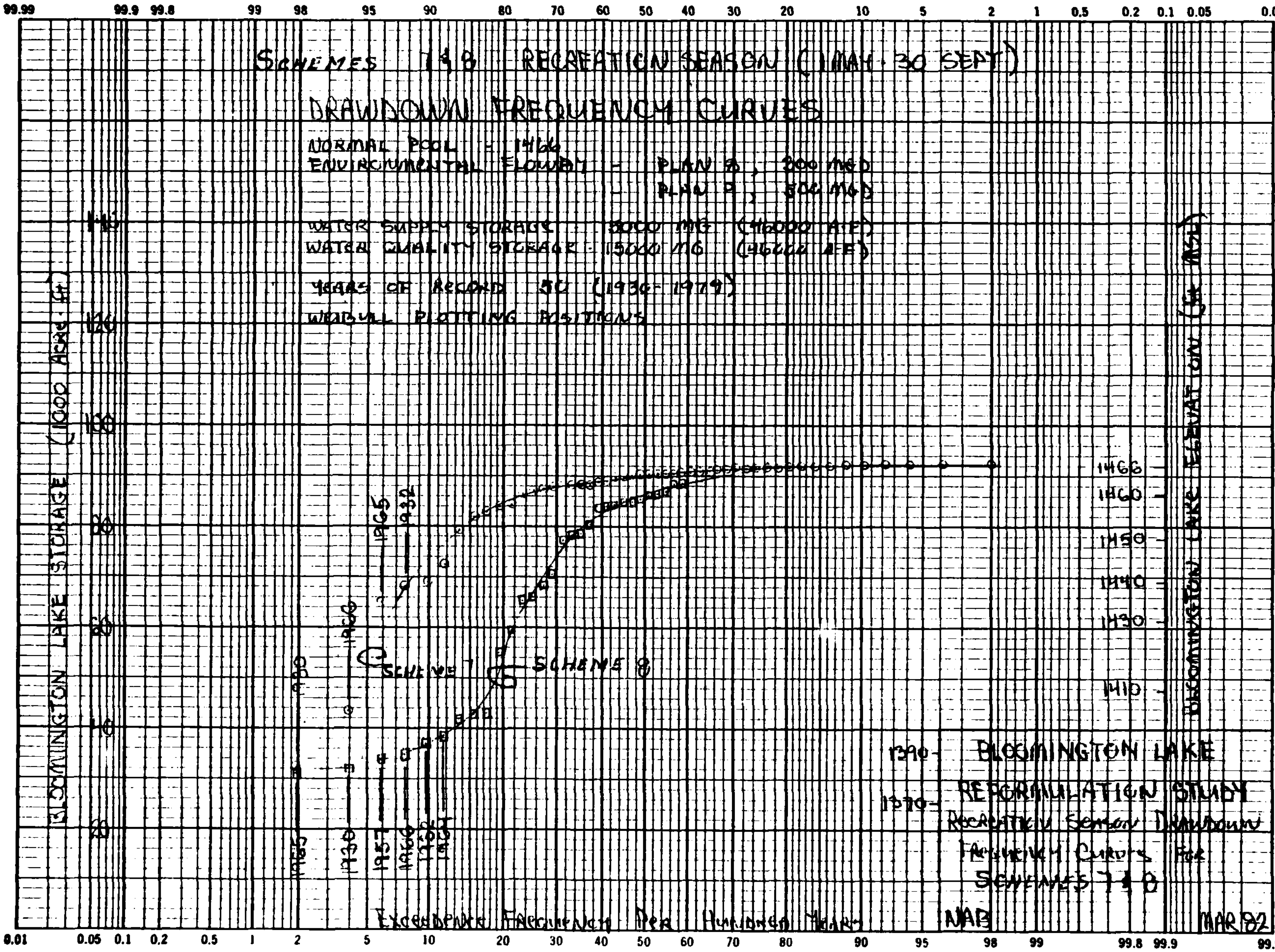
FIGURE H-XIII-5


K+E PROBABILITY X 90 DIVISIONS 46 8003 MADE IN U.S.A. KEUFFEL & ESSER CO.
SCHEME 13 CLIMATOLOGICAL YEAR (1 APRIL - 31 MARCH)
DRAWDOWN FREQUENCY CURVE
NORMAL POOLS SUMMER - 1466 WINTER - 1410
ENVIRONMENTAL FLOWBY - 100 MGD
MINIMUM FLOW @ LUKE - 197 MGD (305 CFS)
WATER SUPPLY STORAGE - 0 MG
WATER QUALITY STORAGE - 30000 MG (92000 A.F.)
YEARS OF RECORD 50 (1930 - 1979)
WEIBULL PLOTTING POSITIONS
BLOOMINGTON LAKE STORAGE (000 ACRE-FT)
BILLION GALLONS
BLOOMINGTON LAKE ELEVATION (FT MSL)
SCHEME 13
EXCEEDENCE FREQUENCY PER HUNDRED YEARS
BLOOMINGTON LAKE
REFORMULATION STUDY
DRAWDOWN FREQUENCY CURVE
SCHEME 13
NAB
1MAR82

K•E PROBABILITY X 90 DIVISIONS 46 8003 MADE IN U.S.A. KEUFFEL & ESSER CO



K+E PROBABILITY X 90 DIVISIONS 46 8003 MADE IN U.S.A.
KEUFFEL & ESSER CO.



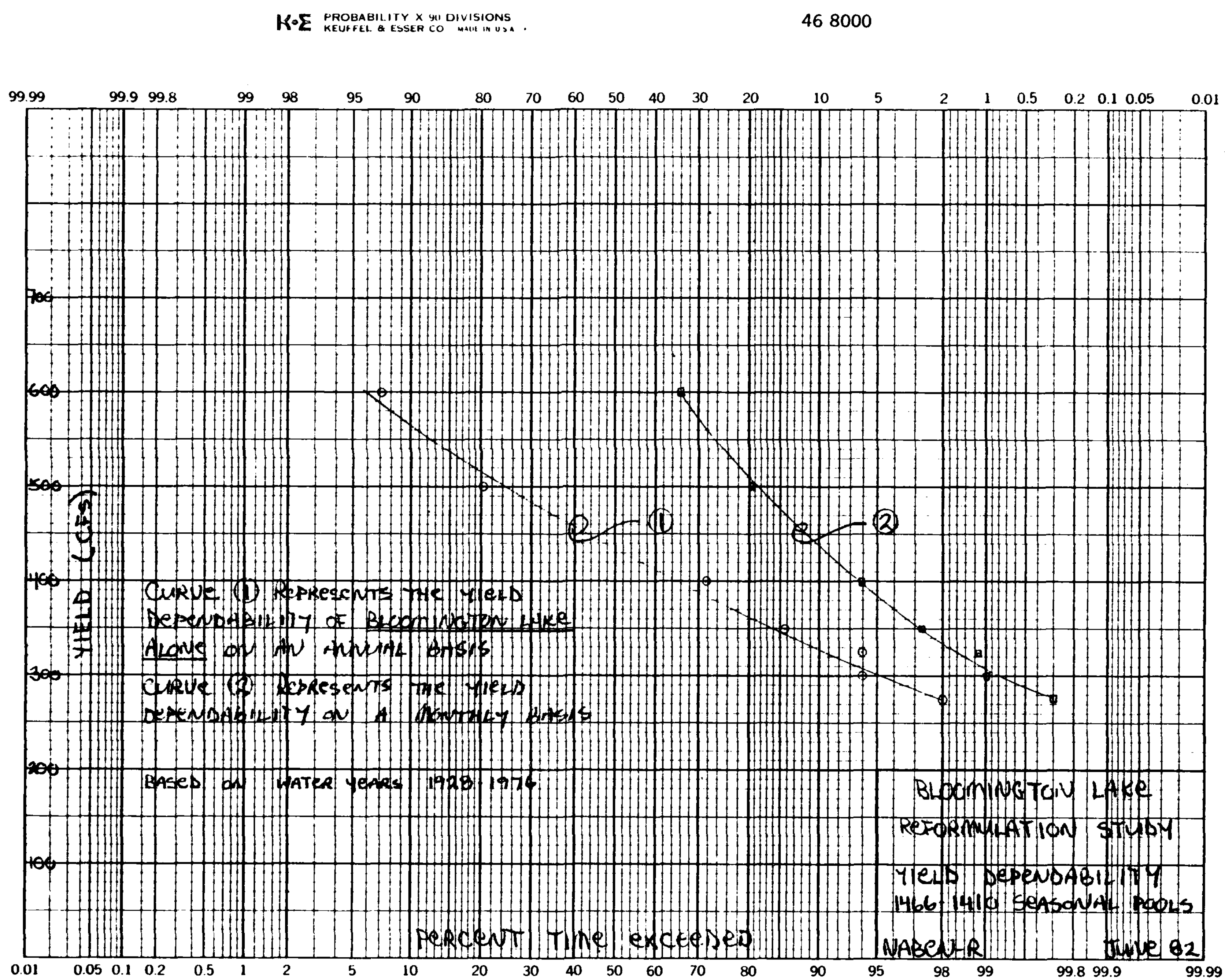


FIGURE H-VIII-9

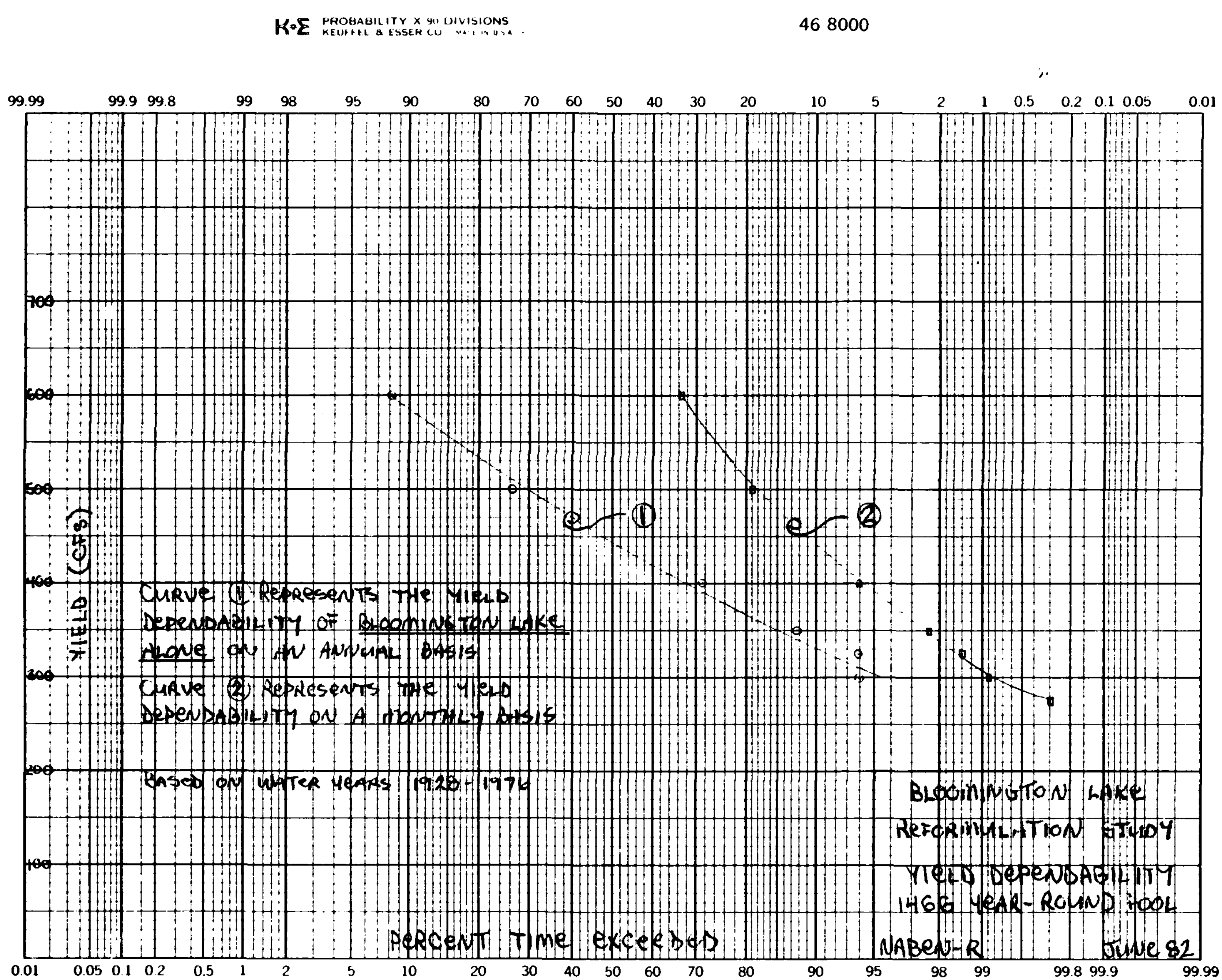


FIGURE H-VIII - 10

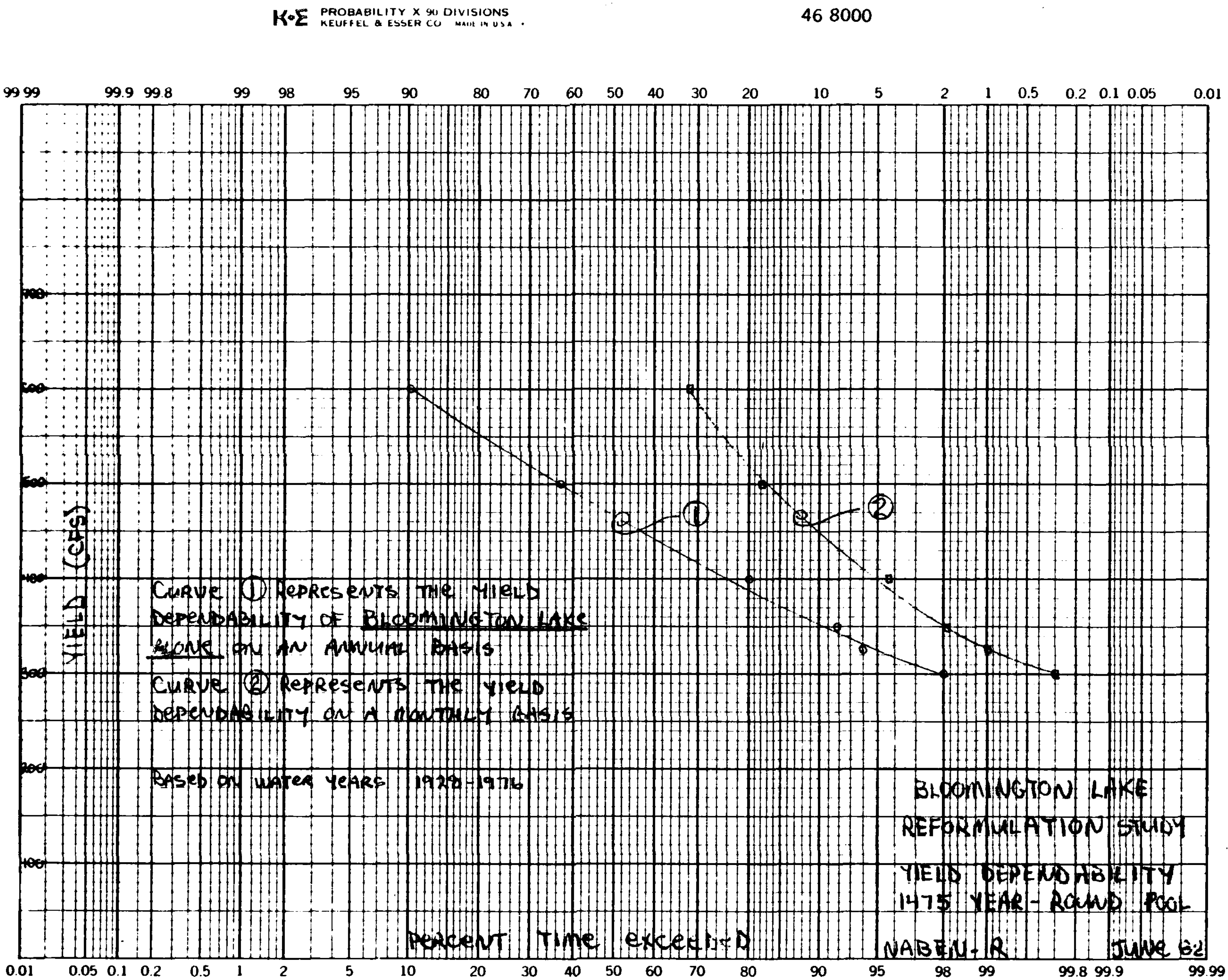


FIGURE H-VIII-11

K•E PROBABILITY X 90 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 8000

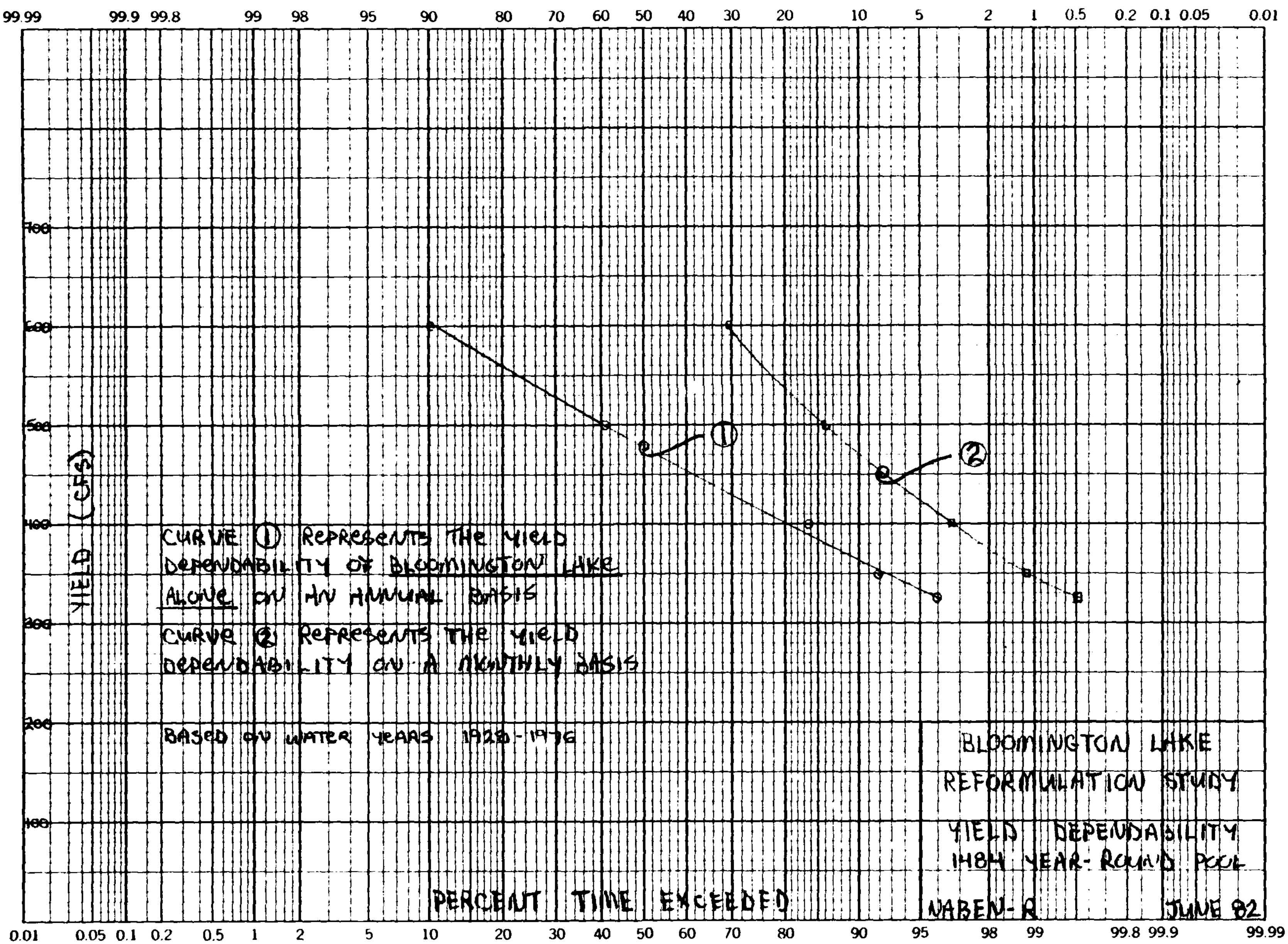
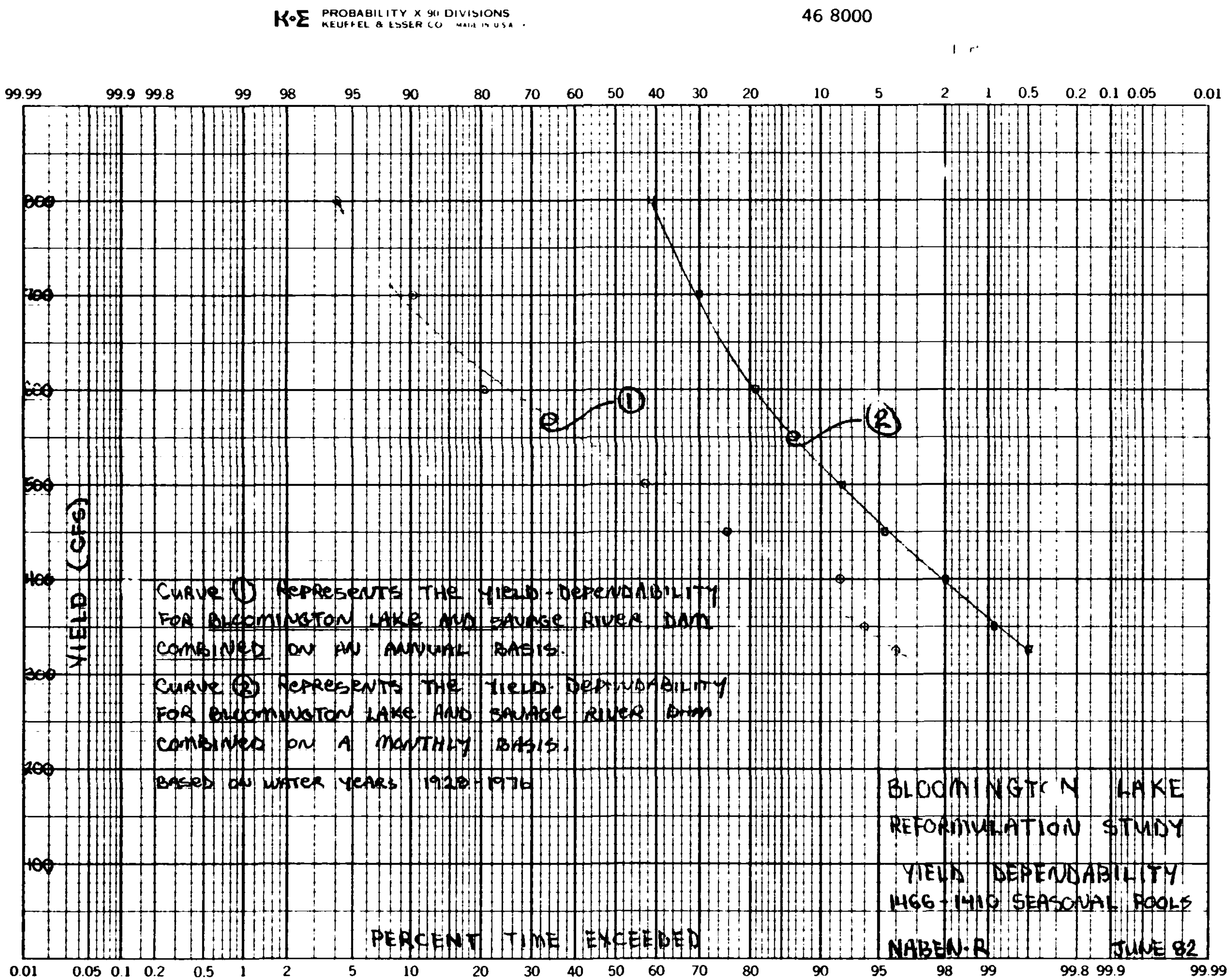


FIGURE H-VIII-12



H-VIII-22

FIGURE H-VIII-13

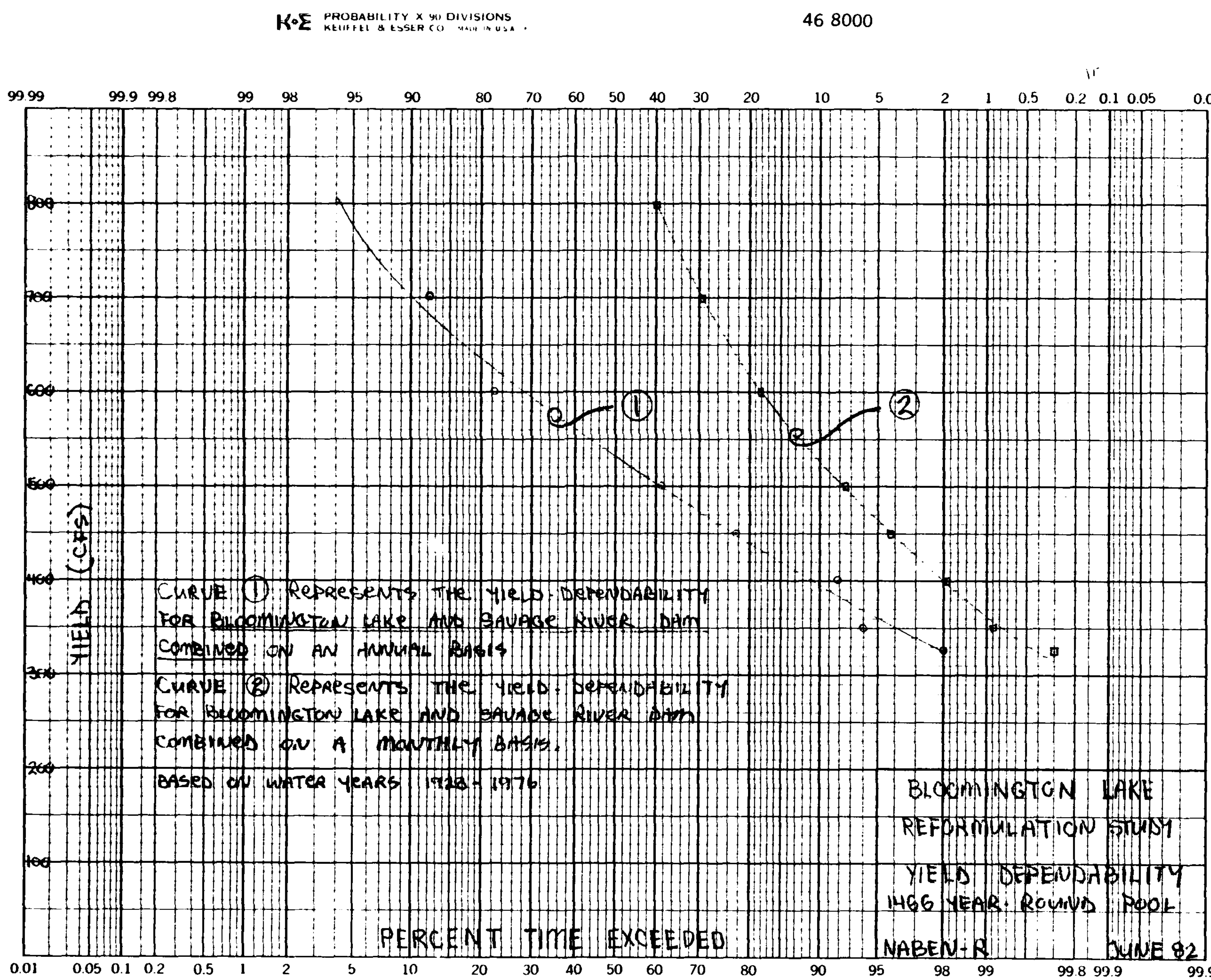
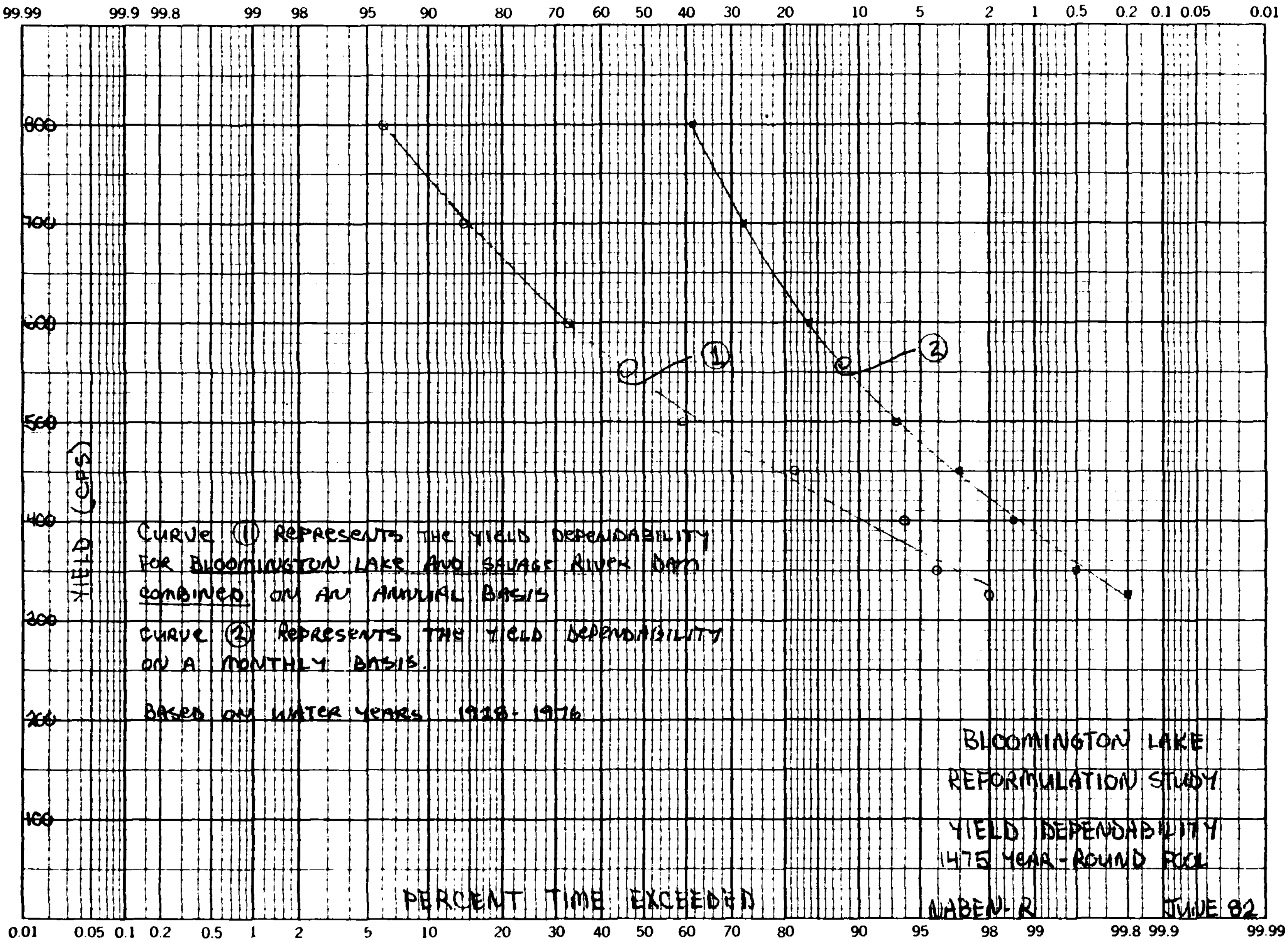


FIGURE H-VIII-14

K·E PROBABILITY X 90 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8000



H-VIII-24

FIGURE

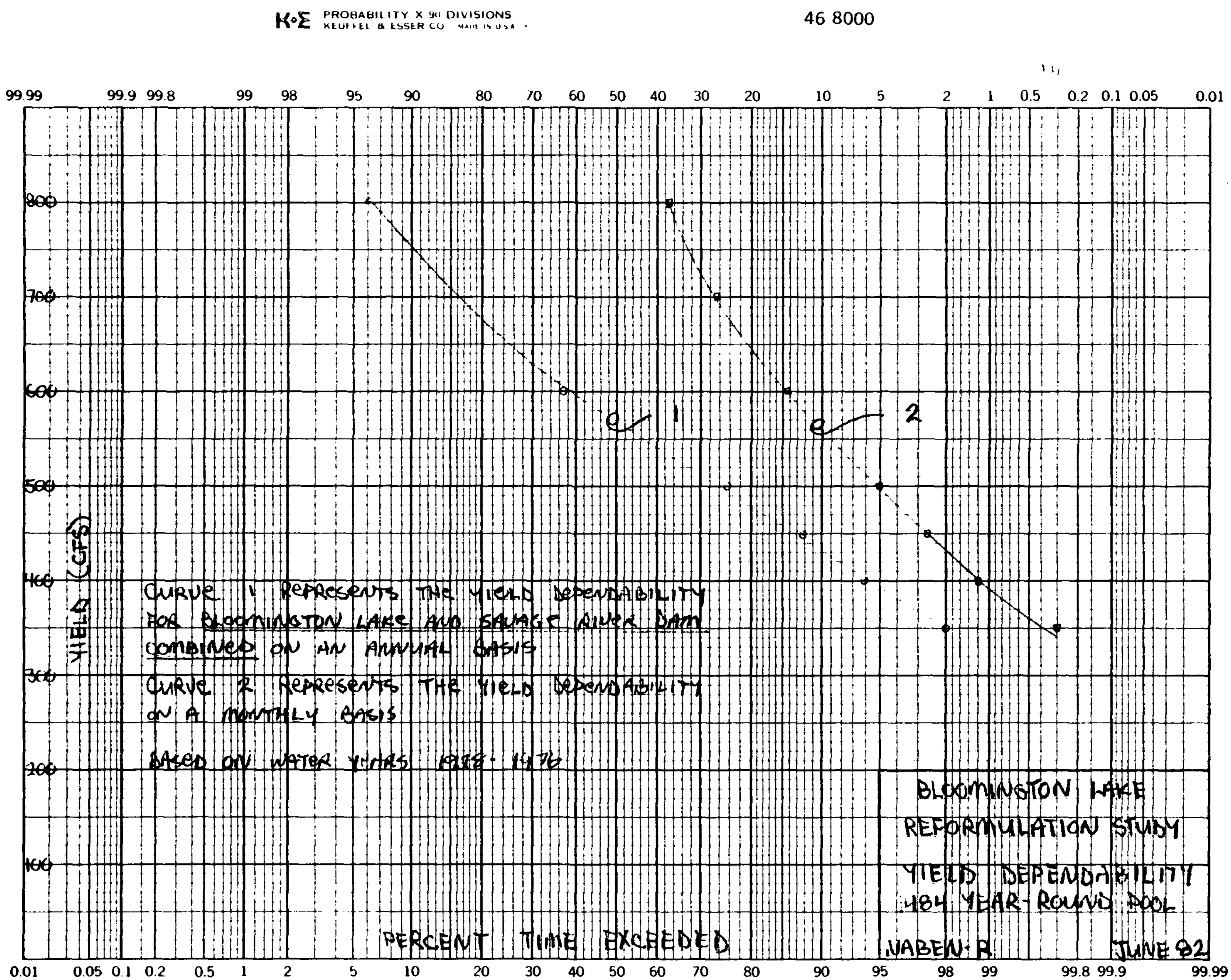


FIGURE H-VIII-16

ANNEX H-IX

BLOOMINGTON FUTURE WATER SUPPLY

STORAGE CONTRACT

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA

AND

THE DISTRICT OF COLUMBIA, THE WASHINGTON SUBURBAN SANITARY COMMISSION AND THE FAIRFAX COUNTY WATER AUTHORITY

FOR

FUTURE WATER SUPPLY STORAGE SPACE IN THE BLOOMINGTON RESERVOIR, MARYLAND AND WEST VIRGINIA

THIS AGREEMENT, entered into this 22nd day of July, 1982, by and between THE UNITED STATES OF AMERICA (hereinafter called the "Government") represented by the Contracting Officer executing this contract, and the DISTRICT OF COLUMBIA (hereinafter called the "District"), represented by the Mayor, the WASHINGTON SUBURBAN SANITARY COMMISSION (hereinafter called the "Commission") represented by its General Manager, and the FAIRFAX COUNTY WATER AUTHORITY (hereinafter called the "Authority") represented by its Chairman, (hereinafter collectively called the "Users");

WITNESSETH THAT:

WHEREAS, the Flood Control Act of 1962 (Public Law 87-874), authorized the construction, operation, and maintenance of the Bloomington Reservoir on the North Branch Potomac River, Maryland and West Virginia (hereinafter called the "Project"), substantially in accordance with the recommendations of the Chief of Engineers, in House Document Numbered 469, Eighty-seventh Congress; and

WHEREAS, the Users desire to contract with the Government for that portion of the water supply storage for municipal and industrial water supply designated in the project documents as future water supply storage, and

WHEREAS, the Users desire to contract for repayment of the costs allocated to water supply storage on the basis of future requirements in accordance with the Congressional authorization and the provisions of the Water Supply Act of 1958, as amended (43 U.S.C. 390b-f); and

WHEREAS, the Users are entering into a separate agreement with the United States and the Maryland Potomac Water Authority to assume and undertake the obligations in their proportionate shares imposed by Contract No. DACW31-71-C-0006, dated 25 August 1970, by which the Authority acquired from the United States the exclusive right to utilize an undivided 7.78% of the water supply storage space in the Project (called the "initial water supply storage space"), and became obligated to pay to the United States in 50 consecutive annual installments that portion (5.8%) of the Project construction costs attributable to initial water supply storage space, plus interest; 6.05% of annual experienced operation and maintenance costs as therein defined; and 7.35% of the cost of major replacements and sedimentation resurveys; and

WHEREAS, the Users have agreed among themselves to share all costs allocated to water supply storage in the Bloomington Reservoir in the following proportions: 50% is to be paid by the Commission, 30% by the District, and 20% by the Authority; and

WHEREAS, the Users are empowered to contract with the Government and are vested with all necessary powers for accomplishment of the purposes of this agreement; and

WHEREAS, the Users and the Washington Aqueduct are entering into a Water Supply Coordination Agreement which provides for the regional management by the Commission, the Authority and the Washington Aqueduct of their water supply facilities for the benefit of the Washington Metropolitan Area;

NOW, THEREFORE, the Government and the Users agree as follows:

ARTICLE 1 - Water Storage Space

(a) Project Construction. The Government, subject to the directions of Federal law and any limitations imposed thereby, has designed and constructed the Project so as to include therein space for the storage of water by the Users.

(b) Rights of Users

(1) The Users shall have the right to utilize an undivided 36.78 percent (estimated to contain 33,837 acre-feet after adjustment for sediment deposits) of the usable water supply storage space in the Project between elevations 1255 feet above mean sea level (outlet gate sill elevation) and 1466 feet above mean sea level (summer pool). The usable conservation storage space between these elevations is estimated to contain 92,000 acre-feet of which 51,005 acre-feet is for water quality control storage and 40,995 acre feet is for water supply storage.

(2) The Users shall have the right to have releases made by the Government through the outlet works in the Dam in accordance with Article 5, subject to the provisions of Article 1(c) and 1(d) and to the extent the aforesaid storage space will provide.

(c) Rights Reserved. The Government reserves the right to maintain at all times minimum downstream releases of 50 cubic feet per second through the gates of the outlet tower of the dam to meet established water requirements and to lower the water in the Project to elevation 1466 feet (summer pool) or 1410 feet (winter pool) above mean sea level during such periods of time as are deemed necessary, in its sole discretion, for flood control purposes. The Government further reserves the right to take such measures as may be necessary in the operation of the Project to preserve life and/or property, including the right not to make downstream releases during such periods of time as are deemed necessary, in its sole discretion, in order to inspect, maintain, or repair the Project.

(d) Distribution of inflows and allocation of storage. The inflows to Bloomington Lake will be computed based on the change in the lake volume and the discharge from the project. This method will automatically account for evaporation and seepage losses. The first 50 cubic feet per second (cfs) of the inflow shall be used to meet the minimum release requirement from Bloomington Lake. If the inflow is less than 50 cfs, water quality storage will be used to make up the additional flow. The inflows in excess of 50 cfs will be distributed to water quality and water supply based upon the percentage of the total allocated storage. The Users will receive a minimum of 36.78 percent of the inflow in excess of 50 cfs when they have less than 100 percent of their allocated storage.

(e) Quality or Availability of Water. The Users recognize that this agreement provides storage space for raw water only. The Government makes no representations with respect to the quality or availability of water and assumes no responsibility therefor, or for the treatment of the water.

(f) Sedimentation Surveys.

(1) Sedimentation surveys will be made by the Contracting Officer during the term of this agreement at intervals not to exceed fifteen (15) years unless otherwise agreed to in writing by all the parties. When, in the opinion of the Contracting Officer, the findings of such survey indicate any project purpose will be affected by unanticipated sedimentation distribution, there shall be an equitable redistribution of the sediment reserve storage space among the purposes served by the Project including municipal and industrial water supply. The total available remaining storage space in the Project will then be divided among the various Project features in the same ratio as was initially utilized. Adjusted pool elevations will be rounded to the nearest one-half foot. Such findings and the storage space allocated to municipal and industrial water supply shall be defined and described in an amended Exhibit "A" which will be made a part of this agreement, and the reservoir regulation manual will be modified accordingly.

(2) The Government assumes no responsibility for deviations from estimated rates of sedimentation, or the distribution thereof. Such deviations may cause unequal distribution of sediment reserve storage greater than estimated, and/or encroachment on the total storage at the project.

ARTICLE 2 - Regulation of and Right to Use of Water. The Users have the full responsibility to acquire in accordance with State laws and regulations, and, if necessary, to establish or defend, any and all water rights needed for utilization of the storage provided under this agreement. The Government shall not be responsible for diversions by others, nor will it become a party to any controversies involving the use of the storage space by the Users except as such controversies may affect the operations of the Government.

ARTICLE 3 - Regulation of Reservoir By the United States. The Government's primary interests in this Project are flood control, water quality, water supply and recreation. Regulation of the reservoir storage capacity allocated for these purposes shall be the sole responsibility and under the sole authority of the United States. The Government will make releases from Bloomington Lake to enhance water quality based upon the following considerations:

1. Satisfaction of the requirements in the authorizing legislation (the Flood Control Act of 1962, Public Law 89-874),

2. The need for flow-by in the Potomac River,

3. The optimum overall quality of the Potomac River for all project purposes and for the benefit of all users downstream from Bloomington Lake.

The Government may adjust any water quality releases upon a determination that such adjustment is in the public interest.

ARTICLE 4 - Operation and Maintenance. The Government shall operate and maintain the Project and the Users shall pay to the Government such share of the costs of such operation and maintenance as provided in Article 6. The Users shall be responsible for operation and maintenance of all installations and facilities which they may construct for the diversion or withdrawal of water, and shall bear all costs of construction, operation and maintenance of such installations and facilities.

ARTICLE 5 - Releases from Water Supply. In accordance with the Water Supply Coordination Agreement providing for the regional management of the water supply facilities of the Commission, the Washington Aqueduct and the Authority, the Interstate Commission on the Potomac River Basin (ICPRB) CO-OP Section or its successors will direct water supply releases through the Project outlet works by notifying the Hydrology - Hydraulics Section, Engineering Division, U.S. Army Engineer District, Baltimore. Notification shall be in accordance with the Bloomington Lake Reservoir Regulation Manual. Water will be released from the water supply storage space through the Project outlet works in accordance with the direction furnished by CO-OP or its successors and shall be subject to Article 1(c)and 1(d). Such releases shall be approved by the Contracting Officer. The measure of all such releases shall be by such suitable means as may be agreed to by CO-OP and the Government prior to use of the water supply storage space.

ARTICLE 6 - Payments. In consideration of the rights provided in Article 1 of this agreement the Users shall pay the sums required by Sections (a), (b), (c) and (d) of this Article to the Government in the following proportions: 50% shall be paid by the Commission, 30% by the District, and 20% by the Authority. The District of Columbia shall take all necessary actions to procure the required appropriations to meet its cost sharing obligations hereunder; provided, however, that no payments shall be made by the District until appropriations for such purposes have been made pursuant to the requirements of the Budget and Accounting (Anti-Deficiency) Act of 1921 (31 U.S.C. §.665) as amended.

(a) Project Investment Costs.

(1) The Users shall repay to the Government in their proportionate shares, as indicated in this Article, at the times and with interest on the unpaid balance as hereinafter specified, the amounts stated below which, as shown in Exhibit "A" attached to and made a part of this agreement

constitute the entire estimated amount of the construction costs, including interest during construction, allocated to the water storage right acquired by the Users under this agreement. The interest rate to be used for purposes of computing interest during construction and interest on the unpaid balance is that determined by the Secretary of the Treasury as of the beginning of the fiscal year in which construction of the Project was initiated, on the basis set forth in the Water Supply Act of 1958, as amended. For the Project, construction of which was initiated in FY68, this interest rate is 3.253 percent. The Users shall repay:

27.4 percent of the total Project construction costs, allocated to water supply on the basis of future requirements evaluated at	$47,758,200
Interest during construction, estimated at	$ 6,420,920
Total estimated amount of Project investment costs allocated to water supply on the basis of future requirements	$54,179,120

(2) The amount of the Project investment costs allocated to the portion of the storage space provided for future use is currently estimated at $54,179,120 on the basis of the costs presented in Exhibit "A". Payment of this portion of the Project investment costs with interest on the unpaid balance shall begin either upon the first use of the water in the storage space designated as future water supply storage, or on 30 July 1991, whichever occurs first. Final payment shall be made on or before 30 July 2041. No interest will be charged for the first 10 years after the project is first available for water supply purposes if no use is made of the water supply. The last annual installment for any portion of the storage for future water supply shall be adjusted upward or downward when due to assure repayment of all of the investment costs allocated to such portion within the repayment period.

(3) An estimated schedule of annual payments for the storage provided for future water supply is attached as Exhibit "B" of this agreement. Payments as provided therein shall be made subject to Article 7.

(b) Major Replacement Cost. The Users will be required to pay 34.75 percent of the cost of major replacement items in their proportionate shares as indicated in this Article. Payment of costs, including interest during construction, shall be made either incrementally during construction, in lump sum upon completion of construction, or annually with interest on the unpaid balance. If paid annually, the Users' share shall be paid within the life of the Project in not to exceed 25 consecutive annual installments with the first payment to be made with the first annual payment as set forth in Article 6(a)(2) on the Project investment costs becoming due after the date said major replacement costs are incurred or, if no annual payment is being paid, thirty days after the next succeeding 30th day of July. The first annual payment shall include interest on the investment cost accruing until the payment

date. Annual payments thereafter will be due and payable on the anniversary of this repayment date. All annual payments shall include accrued interest on the unpaid balance at the interest rate as determined by the Secretary of the Treasury on the basis as set forth in the Water Supply Act of 1958, as amended, for use in the Government fiscal year in which the major capital replacement is initiated. The last annual payment shall be adjusted upward or downward when due to assure repayment of all the incurred costs within the repayment period.

(c) Annual Operation and Maintenance (O&M) Expense. The Users will be required to pay 28.56 percent of the annual experienced joint-use O&M expense of the Project in their proportionate shares as indicated in this Article. Payments for O&M expense are due and payable in advance on the date for payment of project investment costs as set forth in Article 6(a)(2) or, if no annual payment of project investment costs is being made, the payment is due thirty days from the 30th day of July of each year and shall be based on O&M expense for the Project in the Government fiscal year most recently ended. The amount of each annual payment will be based on the actual experienced O&M expense for the preceding fiscal year or an estimate thereof when actual expense information is not available.

(d) Major Rehabilitation and Dam Safety Assurance Programs Costs. For cost associated with major rehabilitation programs, the percentages of costs which the Users will be required to pay will be in accordance with Article 6(c). For costs associated with dam safety assurance programs, the percentages of costs which the Users will be required to pay will be in accordance with Article 6(a). Payments for the costs associated with both programs shall be in accordance with Article 6(b).

(e) Prepayment. The Users shall have the right at any time they so elect to prepay the indebtedness under this Article, subject to redetermination of costs as provided for in Article 7, in whole or in part, with accrued interest thereon to the date of such prepayment.

(f) Delinquent Payments. If the Users shall fail to make any of the aforesaid payments when due, then the overdue payments shall bear interest compounded annually until paid. The interest rate to be used for overdue payments due under the provisions of Articles 6(a), 6(b), 6(c), and 6(d) above shall be that determined by the Department of Treasury's Treasury Fiscal Requirements Manual (1 TFRM 6-8000 "Cash Management"). The amount charged on payments overdue for a period of less than one year shall be figured on a monthly basis. For example, if the payment is made within the first month after being overdue after a 15 day grace period from the anniversary date of the date of notification, one month's interest shall be charged. Thereafter a month's interest will be charged for any portion of each succeeding month that the payment is delinquent. This provision shall not be construed as giving the Users a choice of either making payments when due or paying interest, nor shall it be construed as waiving any other rights of the Government, at law or in equity, which might result from any default by the Users.

ARTICLE 7 - Adjustment to Project Investment Cost. The investment cost shown in this agreement and the exhibits is based on the Government's best estimates. Within five years after 30 July 1981, the Contracting Officer shall make a revised interim estimated determination of investment costs. Further interim determination of cost will be made at intervals considered necessary by the Contracting Officer. All interim cost estimates will take into account the actual costs to the extent they are then known. Such further interim determinations will be performed at such periods so as to keep the Users reasonably informed as to the required payment. On each occasion of a cost adjustment, *the annual payments thereafter due shall be adjusted upward* or downward so as to provide for repayment of the balance due in equal installments during the remaining life of the repayment period. The last such investment cost adjustment will be made when the last of the construction general funds have been expended. Such final determination will include the Government's approved estimate of any pending real estate items and any known claims not previously accrued. Any further investment cost accruing to the Users' water storage right shall be repaid under major replacement costs if capitalized or under operation and maintenance expense if not capitalized.

ARTICLE 8 - Duration of Agreement. This agreement shall be effective when approved by the Secretary of the Army or his duly authorized representative and shall continue in full force and effect for the life of the Project.

ARTICLE 9 - Permanent Rights to Storage. Upon completion of payments by the Users, as provided in Article 6(a) herein, the Users shall have a permanent right, under the provisions of the Act of 16 October 1963 (Public Law 88-140, 43 U.S.C. 390e), to the use of the water supply storage space in the Project as provided in Article 1, subject to the following:

(a) The Users shall continue payment of annual operation and maintenance costs allocated to water supply.

(b) The Users shall bear the costs allocated to water supply of any necessary reconstruction, rehabilitation, or replacement of Project features which may be required to continue satisfactory operation of the Project. Such costs will be established by the Contracting Officer and repayment arrangements shall be in writing in accordance with the terms and conditions set forth in Article 6(b) for Major Replacement Costs, and be made a part of this agreement.

(c) Upon completion of payments by the Users as provided in Article 6(a), the Contracting Officer shall redetermine the storage space for municipal and industrial water supply in accordance with the provisions of Article 1(e). Such redetermination of reservoir storage capacity may be further adjusted from time to time as the result of sedimentation resurveys to reflect actual rates of sedimentation and the exhibit revised to show the revised storage space allocated to municipal and industrial water supply.

(d) The permanent rights of the Users under this agreement shall be continued so long as the Government continues to operate the Project. In the

event the Government no longer operates the Project, such rights may be continued subject · the execution of a separate contract, or additional supplemental agreement providing for:

(1) Continued operation by the Users of such part of the facility as is necessary for utilization of the water supply storage space allocated to them;

(2) Terms which will protect the public interest; and

(3) *Effective absolvement of the Government by the Users from* all liability in connection with such continued operation.

ARTICLE 10 - Release of Claims. The Users shall hold and save the Government, including its officers, agents and employees harmless from liability of any nature or kind for or on account of any claim for damages which may be filed or asserted as a result of the storage in the Project, or withdrawal or release of water from the Project, made or ordered by the Users except for damages due to the fault or negligence of the United States or its contractors.

ARTICLE 11 - Assignment. The Users shall not transfer or assign this agreement or any rights acquired thereunder, nor sub-allot said water supply storage space or any part thereof, nor grant any interest, privilege or license whatsoever in connection with this agreement, without the approval of the Secretary of the Army or his duly authorized representative, provided that, unless contrary to the public interest, this restriction shall not be construed to apply to any water that may be obtained from the water supply storage space by the Users and furnished to any third party or parties, nor any method of allocation thereof.

ARTICLE 12 - Officials Not to Benefit. No member of or delegate to Congress, or Resident Commissioner, shall be admitted to any share or part of this agreement, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this agreement if made with a corporation for its general benefit.

ARTICLE 13 - Covenant Against Contingent Fees. The Users warrant that no person or selling agency has been employed or retained to solicit or secure this agreement upon an agreement or understanding for a commission, percentage, brokerage, or contingent fee excepting bona fide employees or bona fide established commercial or selling agencies maintained by the Users for the purpose of securing business. For breach or violation of this warranty the Government shall have the right to annul this agreement without liability or in its discretion to add to the contract price or consideration, or otherwise recover the full amount of such commission, percentage, brokerage, or contingent fee.

ARTICLE 14 - Environmental Quality. During any construction, operation, and maintenance by the Users of any facilities, specific actions will be taken to control environmental pollution which could result from such activity and to comply with applicable Federal, State, and local laws and regulations concerning environmental pollution. Particular attention should be given to (1) reduction of air pollution by control of burning, minimization of dust, containment of chemical vapors, and control of engine exhaust gases, and of smoke from temporary heaters; (2) reduction of water pollution by control of sanitary facilities, storage of fuels and other contaminants, and control of turbidity and siltation from erosion; (3) minimization of noise levels; (4) onsite and offsite disposal of waste and spoil; and (5) prevention of landscape defacement and damage.

ARTICLE 15 - Federal and State Laws.

(a) In acting under its rights and obligations hereunder, the Users agree to comply with all applicable Federal and State laws and regulations, including but not limited to the provisions of the Davis-Bacon Act (40 U.S.C. 276a et seq.); the Contract Work Hours and Safety Standards Act (40 U.S.C. 327-333); Title 29, Code of Federal Regulations, Part 3; and Sections 210 and 305 of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646).

(b) The Use . furnish, as part of this agreement, an assurance (Exhibit C) that they will comply with Title VI of the Civil Rights Act of 1964 (78 Stat. 241, 42 U.S.C. 2000d, et seq.) and Department of Defense Directive 5500.11 issued pursuant thereto and published in Part 300 of Title 32, Code of Federal Regulations.

(c) Any discharges of water or pollutants into a navigable stream or tributary thereof resulting from the Users' facilities and operations undertaken under this agreement shall be performed only in accordance with applicable Federal, State, and local laws and regulations.

ARTICLE 16 - Definitions.

(a) Project investment costs - The initial cost of the Project, including: land acquisition; construction; interest during construction on the value of land, labor, and materials used for planning and construction of the Project.

(b) Interest during construction - An amount of interest which accrues on expenditures for the establishment of Project services during the period between the actual outlay and the time the Project is first made available to the Users for water storage.

(c) Joint-use costs - The costs of features used for any two or more Project purposes.

(d) *Plant-in-service date* - This date (30 July 1981) is the date that the Project was physically available to initiate deliberate impoundment for water supply purposes.

H-IX-5

(e) Annual operation and maintenance (O&M) expense - Annual expenses funded under the O&M, General account. These expenses include the daily project O&M costs as well as those O&M costs which are capitalized.

(f) *Major replacement cost* - Costs funded under the Construction, General account but not associated with initial Project investment costs.

(g) Fiscal Year - Refers to the Government's fiscal year. This year begins on 1 October and ends on 30 September.

(h) Life of the Project - This is the physical life of the Project.

(i) Major Rehabilitation - This program is to facilitate accomplishment of significant, costly infrequent rehabilitation work at the project without unduly distorting the Operation and Maintenance, General budget.

(j) Dam Safety Assurance Program - This program is to provide for modification of the completed Project to rectify potential safety hazards in light of present day standards, technology, and circumstances.

ARTICLE 17 - Approval of Contract. This agreement shall be subject to the written approval of the Secretary of the Army or his duly authorized representative and shall not be binding until so approved.

IN WITNESS WHEREOF, the parties have executed this agreement as of the day and year first above written.

APPROVED:

William R. Gianelli
Assistant Secretary of the Army
(Civil Works)

DATE: 13 AUG 1982

ATTEST:

[signature]

THE UNITED STATES OF AMERICA

By Gerald C. Brown
GERALD C. BROWN
Colonel, Corps of Engineers
District Engineer
Contracting Officer

DATE: 22 July 1982

THE DISTRICT OF COLUMBIA

By [signature]
MARION BARRY, Mayor

DATE: 7-22-82

ATTEST:

William S. Lindung

THE WASHINGTON SUBURBAN SANITARY COMMISSION

By Robert S. McGarry
ROBERT S. MCGARRY, General Manager

DATE: 22 July 82

THE FAIRFAX COUNTY WATER AUTHORITY

By Fred C. Morin
FRED C. MORIN, Chairman

DATE: July 22 '82

CERTIFICATION

I Edward L Curry, Attorney for the District of Columbia hereby certify that the foregoing agreement executed by the Mayor of the District of Columbia is within the scope of his authority to act upon behalf of the District and that in my capacity as Attorney for the District, I have considered all applicable law and find that the District is legally and financially capable of entering into the contractual obligations contained in the foregoing agreement and that, upon acceptance, it will be legally enforceable.

Given under my hand, this 22 day of July, 1982.

Attorney for the District of Columbia

CERTIFICATION

I Henderson J Brown, Attorney for the Washington Suburban Sanitary Commission hereby certify that the foregoing agreement executed by Robert S McGarry, of Washington Suburban Sanitary Commission is within the scope of his authority to act upon behalf of the Commission and that in my capacity as Attorney for the Commission I have considered all applicable law and find that the Commission is legally and financially capable of entering into the contractual obligations contained in the foregoing agreement and that, upon acceptance, it will be legally enforceable.

Given under my hand, this 22nd day of July, 1982.

Attorney for the Washington Suburban Sanitary Commission

H-IX-6

CERTIFICATION

I Randolph W Church Jr., Attorney for the Fairfax County Water Authority hereby certify that the foregoing agreement executed by Fred C. Morin of Fairfax County Water Authority is within the scope of his authority to act upon behalf of the Authority, and that in my capacity as Attorney for the Authority, I have considered all applicable law and find that the Authority is legally and financially capable of entering into the contractual obligations contained in the foregoing agreement and that, upon acceptance, it will be legally enforceable.

Given under my hand, this 22nd day of July, 1982.

Randolph W Church

Attorney for the Fairfax County Water Authority

EXHIBIT A

I - LAKE STORAGE

Feature	Elevation (ft., m.s.l.)	Usable Storage* (ac. ft.)	Percent of Conservation Storage	Percent of Water Supply Storage
Flood control	1466 - 1510	36,200		
Conservation	1255 - 1466	92,000	100.00	
Water Supply	1255 - 1466	(40,995)	44.56	100.00
Users		(40,995)	44.56	100.00
Future		(33,837)	36.78	82.54
Present		(7,158)	7.78	17.46
Water Quality	1255 - 1466	(51,005)	55.44	
Total		128,200		

*Storage remaining after 100 years of sedimentation from the date the project is operational.

II - ALLOCATION OF ESTIMATED CONSTRUCTION COST

Feature	Cost ($)	Percent of Project Construction Cost
Flood control	38,520,000	22.1
Recreation	5,926,000	3.4
Water Supply	57,868,000	33.2
Water Quality	71,986,000	41.3
Total	174,300,000	100.00

III - INVESTMENT COSTS TO BE REPAID BY USER FOR WATER SUPPLY STORAGE DESIGNATED AS FUTURE WATER SUPPLY

Future Use:	
Cost of 33,837 acre-feet of water supply storage (27.4% x $174,300,000)	= $ 47,758,200
Interest during construction "Based on actual construction expenditures by fiscal year and an interest rate of 3.253%"	= 6,420,920
Total investment future use	= $ 54,179,120

IV - TOTAL ANNUAL COST TO USERS FOR USE OF WATER SUPPLY STORAGE DESIGNATED AS FUTURE WATER SUPPLY

Interest and amortization	
$54,179,120 x .039469 factor based on 50 payments, 49 with interest at 3.253%	= $2,138,393.75
Operation and maintenance[1]/	
Estimated 28.56% x $163,000	= 46,552.80
Major replacement[2]/	
34.75% x $125,000	= 43,437.50
TOTAL ESTIMATED ANNUAL COST	$2,228,384.05

Notes:
1/ Payment due and payable on the date specified in Article 6(c)(2).
2/ Major replacement costs are payable only when incurred as specified in Article 6(b). It is suggested that the amount shown be placed in a reserve or sinking fund for future contingency.

H- IX -9

EXHIBIT B
AMORTIZATION SCHEDULE
FUTURE DEMAND

TOTAL INVESTMENT COST	$54,179,120
NUMBER OF PAYMENTS	50
INTEREST RATE, PERCENT	3.253

		APPLICATION		
ANNUAL PAYMENT NUMBER	AMOUNT OF PAYMENT $	INTEREST $	ALLOCATED COST $	BALANCE ALLOCATED COST $
				$54,179,120.00
1	$2,138,393.75	$ 0.00	$2,138,393.75	52,040,726.25
2	"	1,692,884.82	445,508.93	51,595,217.32
3	"	1,678,392.42	460,001.33	51,135,215.99
4	"	1,663,428.58	474,965.17	50,660,250.82
5	"	1,647,977.96	490,415.79	50,169,835.03
6	"	1,632,024.73	506,369.02	49,663,466.01
7	"	1,615,552.55	522,841.20	49,140,624.81
8	"	1,598,544.53	539,849.22	48,600,775.59
9	"	1,580,983.23	557,410.52	48,043,365.07
10	"	1,562,850.67	575,543.08	47,467,821.99
11	"	1,544,128.25	594,265.50	46,873,556.49
12	"	1,524,796.79	613,596.96	46,259,959.53
13	"	1,504,836.48	633,557.27	45,626,402.26
14	"	1,484,226.87	654,166.88	44,972,235.38
15	"	1,462,946.82	675,446.93	44,296,788.45
16	"	1,440,974.53	697,419.22	43,599,369.23
17	"	1,418,287.48	720,106.27	42,879,262.96
18	"	1,394,862.42	743,531.33	42,135,731.63
19	"	1,370,675.35	767,718.40	41,368,013.23
20	"	1,345,701.47	792,692.28	40,575,320.95
21	"	1,319,915.19	818,478.56	39,756,842.39
22	"	1,293,290.08	845,103.67	38,911,738.72
23	"	1,265,798.86	872,594.89	38,039,143.83
24	"	1,237,413.35	900,980.40	37,138,163.43
25	"	1,208,104.46	930,289.29	36,207,874.14
26	"	1,177,842.15	960,551.60	35,247,322.54
27	"	1,146,595.40	991,798.35	34,255,524.19
28	"	1,114,332.20	1,024,061.55	33,231,462.64
29	"	1,081,019.48	1,057,374.27	32,174,088.37
30	"	1,046,623.09	1,091,770.66	31,082,317.71
31	"	1,011,107.80	1,127,285.95	29,955,031.76
32	"	974,437.18	1,163,956.57	28,791,075.19
33	"	936,573.68	1,201,820.07	27,589,255.12
34	"	897,478.47	1,240,915.28	26,348,339.84

35	"	857,111.50	1,281,282.25	25,067,057.59
36	"	815,431.38	1,322,962.37	23,744,095.22
37	"	772,395.42	1,365,998.33	22,378,096.89
38	"	727,959.49	1,410,434.26	20,967,662.63
39	"	682,078.07	1,456,315.68	19,511,346.95
40	"	634,704.12	1,503,689.63	18,007,657.32
41	"	585,789.09	1,552,604.66	16,455,052.66
42	"	535,282.86	1,603,110.89	14,851,941.77
43	"	483,133.67	1,655,260.08	13,196,681.69
44	"	429,288.06	1,709,105.69	11,487,576.00
45	"	373,690.85	1,764,702.90	9,722,873.10
46	"	316,285.06	1,822,108.69	7,900,764.41
47	"	257,011.87	1,881,381.88	6,019,382.53
48	"	195,810.51	1,942,583.24	4,076,799.29
49	"	132,618.28	2,005,775.47	2,071,023.82
50	$2,138,394.22	67,370.40	2,071,023.82	0.00

H - IX - 10

EXHIBIT C

I - THE WASHINGTON SUBURBAN SANITARY COMMISSION ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

The Washington Suburban Sanitary Commission (hereinafter called "Applicant-Recipient")

HEREBY AGREES THAT it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from the Department of the Army and HEREBY GIVES ASSURANCE THAT it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the Department of the Army, this assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

Dated 22 Jul '82

The Washington Suburban Sanitary Commission

By Robert S. McGarry
Robert S. McGarry
General Manager

4017 Hamilton Street
Hyattsville, Maryland 20781

H - IX - 11

EXHIBIT C

II - THE DISTRICT OF COLUMBIA
ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

The District of Columbia (hereinafter called "Applicant-Recipient")

HEREBY AGREES THAT it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from the Department of the Army and HEREBY GIVES ASSURANCE THAT it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the Department of the Army, this assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

Dated 7-22-82 The District of Columbia

By [signature] Marion Barry, Mayor

District Building
14th & E Streets, N.W.
Washington, D.C. 20004

EXHIBIT C

III - THE FAIRFAX COUNTY WATER AUTHORITY ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

The Fairfax County Water Authority (hereinafter called "Applicant-Recipient")

HEREBY AGREES THAT it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from the Department of the Army and HEREBY GIVES ASSURANCE THAT it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the Department of the Army, this assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

Dated July 22 '82 The Fairfax County Water Authority

By [signature] Fred C. Morin, Chairman

P.O. Box 1500
Merrifield, Virginia 22116

H-IX-12

ANNEX H-X

NOVATION AGREEMENT

NOVATION AGREEMENT

THIS AGREEMENT, entered into this 2nd day of July, 1982, by and between the United States of America (hereinafter referred to as the "United States"), and the Maryland Potomac Water Authority (hereinafter referred to as the "Transferor"), and the Washington Suburban Sanitary Commission, the Fairfax County Water Authority, and the District of Columbia (hereinafter referred to collectively as the "Transferees").

WITNESSETH:

WHEREAS, the United States owns and operates the Bloomington Dam and Reservoir on the North Branch of the Potomac River (hereinafter referred to as the "Project"), and is authorized to contract with responsible local interests for their acquisition of water supply storage space in the Project in return for sharing costs of the Project; and

WHEREAS, by contract of August 25, 1970 (No. DACW31-71-C-0006), a copy of which is attached hereto, incorporated herein, and shall hereinafter be referred to as the "Contract"), the Transferor acquired from the United States the exclusive right to utilize an undivided 7.78% of the storage space in the Project between elevations 1255 and 1466 feet above mean sea level (hereinafter the "initial water supply storage space") and became obligated to pay to the United States in 50 consecutive annual installments: that portion (5.8%) of Project construction costs attributable to initial water supply storage space, plus interest; 6.05% of annual experienced operation and maintenance costs as therein defined; and 7.35% of the cost of major replacements and sedimentation resurveys; and

WHEREAS, the first annual payment owed by the Transferor to the United States under the contract was paid in full in August 1981, and no other present obligations of the Transferor are outstanding or unfulfilled as of the date of this Agreement; and

WHEREAS, the Washington Suburban Sanitary Commission is a public authority established pursuant to the laws of Maryland (Article 67, Annotated Code of Maryland), is charged with the responsibility of providing a safe and adequate water supply within the Counties of Montgomery and Prince George's, Maryland and is also authorized to enter into agreements to purchase and provide water, and for that purpose is operating and maintaining water treatment facilities and a water distribution system; and

WHEREAS, the Fairfax County Water Authority is an authority established pursuant to the laws of the Commonwealth of Virginia (Section 15.1-1239 et. seq., Code of Virginia) charged with responsibility for providing a safe and adequate public water supply within certain geographic areas of northern Virginia, and is also authorized to enter into agreements to purchase and provide water, and for that purpose is operating and maintaining water treatment facilities and a water distribution system; and

WHEREAS, the District of Columbia, is authorized and empowered to contract to provide a safe and adequate water supply to the inhabitants and entities within its jurisdiction and accomplishes this purpose through cooperation with the Washington Aqueduct Division, Corps of Engineers, United States Army, and is also authorized to contract for the purposes described herein (Act of Dec. 24, 1973, Pub. L. No. 93-198, 87 Stat. 774), and

WHEREAS, the Transferees have entered into a Water Supply Coordination Agreement, dated 22 July 1982 which provides for operation of their water supply systems in a coordinated manner so as to provide the optimal utilization of all available water supply facilities for the benefit of the inhabitants of the Washington Metropolitan Area; and

WHEREAS, the Transferees and the United States have entered into an Agreement for Future Water Supply Storage Space in the Bloomington Reservoir, dated 22 July 1982, by which the Transferees have obtained the exclusive right to utilize that portion of the water supply storage for municipal and industrial water supply designated in Project documents as future water supply storage space; and

WHEREAS, the Transferees desire to obtain from the Transferor its exclusive right under the Contract to utilize the initial water supply storage space, and desire to hold and exercise said right jointly and indivisibly in accordance with the aforementioned Water Supply Coordination Agreement and consistently with the aforementioned Agreement for Future Water Supply Storage Space in the Bloomington Reservoir; and

WHEREAS, the Transferees are willing and able to assume and undertake, each according to its proportionate share, the obligations imposed on the Transferor by the Contract; and

WHEREAS, it is consistent with the interests of the United States to assent to substitution of the Transferees for the Transferor with regard to all rights and obligations imposed upon the Transferor by the Contract.

WHEREAS, Transferee District of Columbia and Transferor simultaneously with the signature of this Agreement, have entered into a Novation terminating their contract dated December 8, 1978, which obligated Transferee District of Columbia to pay its equitable share of costs of Transferor for initial water supply storage under the Contract.

NOW, THEREFORE, in consideration of the faithful performance by each party of the mutual convenants and agreements hereinafter set forth, the parties hereto do mutually agree as follows:

1. The Transferor hereby assigns, conveys and transfers to the Transferees all of its rights, duties and obligations under the Contract, and does hereby release and discharge the United States from, and does hereby waive, any and all claims, demands and rights against the United States which it now has or may hereafter have in connection with, the Contract.

H-X-2

2. The Transferees hereby assume, agree to be bound by, and undertake to perform each and every one of the terms, covenants, and conditions contained in the Contract, except as modified by this paragraph and paragraphs 3, 4 and 5. The payments provided for in Articles 6 and 7 of the Contract shall be made according to the proportionate share of each Transferee as provided herein. The Transferees further assume, each according to its proportinate share as provided herein, all obligations and liabilities of, and all claims and demands against, the Transferor under the Contract, in all respects as if the Transferees were the original parties to the Contract. The proportionate shares of the Transferees in any obligation of the Contract are as follows: 50% shall be paid by the Washington Suburban Sanitary Commission; 30% by the District of Columbia; and 20% by the Fairfax County Water Authority. The District of Columbia shall take all necessary actions to procure the required appropriations to meet its cost sharing obligations hereunder; provided, however, that no payments shall be made by the District until appropriations for such purposes have been made pursuant to the requirements of the Budget and Accounting (Anti-Deficiency) Act of 1921 (31 U.S.C. §665) as amended.

3. Article 7 of the Contract entitled METHOD OF PAYMENT, is modified to the extent that the payee of any check is now "FAO-USAED, Baltimore."

4. The Transferees and the United States hereby agree that Article 11 of the Contract, entitled RELEASE OF CLAIMS shall be deleted in its entirety and the following substituted in lieu thereof:

ARTICLE 11: RELEASE OF CLAIMS.

The Transferees shall hold and save the United States, including its officers, agents and employees harmless from liability of any nature or kind for or on account of any claim for damages which may be filed or asserted as a result of the storage in the Project, or withdrawal or release of water from the Project, made or ordered by the Transferees except for damages due to the fault or negligence of the United States or its contractors.

5. The Transferees and the United States hereby agree that Article 16 of the Contract, entitled APPROVAL OF CONTRACT, shall be deleted in its entirety and the following substituted in lieu thereof:

ARTICLE 16: APPROVAL OF CONTRACT

This contract shall be subject to the written approval of the Secretary of the Army or his duly authorized representative and shall not be binding until so approved.

6. In accordance with the Water Supply Coordination Agreement providing for the regional management of the water supply facilities of the Washington Suburban Sanitary Commission, the Washington Aqueduct and the Fairfax County Water Authority, the Interstate Commission on the Potomac River Basin (ICPRB) CO-OP Section or its successors will direct water supply releases through the project outlet works by notifying the Hydrology - Hydraulics Section, Engineering Division, U. S. Army Engineer District, Baltimore. Notification shall be in accordance with the Bloomington Lake Reservoir Regulation Manual.

Water will be released from the water supply storage space through the Project outlet works in accordance with the direction furnished by CO-OP or its successors and shall be subject to Article 5 of the Contract. Such releases shall be approved by the Contracting Officer. The measure of all such releases shall be by such suitable means as may be agreed to by CO-OP and the United States prior to use of the water supply storage space.

7. The Transferees hereby ratify and confirm all actions heretofore taken by the Transferor with respect to the Contract with the same force and effect as if the action had been taken by the Transferees.

8. The United States hereby recognizes the Transferees as the Transferor's successors in interest in and to the Contract. The Transferees hereby become entitled jointly and indivisibly to all right, title, and interest of the Transferor in and to the Contract in all respects as if the Transferees were the original parties to the Contract. The term "Authority" as used in the Contract shall be deemed to refer to the Transferees rather than the Transferor.

9. The Transferor and the Transferees hereby agree that the United States shall not be obligated to pay or reimburse any of them for, or otherwise give effect to, any costs, taxes or other expenses, or any increases therein, directly or indirectly arising out of or resulting from the assignment, conveyance and transfer effected by this Agreement, other than those which the United States, in the absence of this Agreement, would have been obligated to pay or reimburse under the terms of the Contract.

10. Except as herein modified, the Contract shall remain in full force and effect.

11. This Agreement shall be subject to the written approval of the Secretary of the Army or his duly authorized representative and shall not be binding until so approved.

IN WITNESS WHEREOF, each of the parties hereto has executed this Agreement as of the day and year first above written.

APPROVED

William R. Gianelli
ASSISTANT SECRETARY OF THE ARMY
(Civil Works)

Date: 13 AUG 1982

THE UNITED STATES OF AMERICA

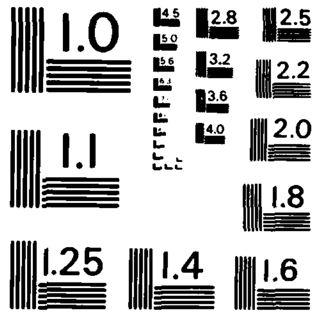
By: Gerald C. Brown
GERALD C. BROWN
Colonel, Army Corps of Engineers
District Engineer
Contracting Officer

Date: 22 July 1982

AD-A134 161 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX H BLOOMINGTON LA..(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83 5/5

UNCLASSIFIED MWA-83-P-APP-H-VOL-2 F/G 13/2 NL

END
DATE
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

ATTEST:

THE MARYLAND POTOMAC WATER AUTHORITY

By: James R. Worsley, Jr.
JAMES R. WORSLEY, JR., Chairman

Date: July 23, 1982

THE DISTRICT OF COLUMBIA

By: Marion Barry
MARION BARRY, Mayor

Date: 7-22-82

THE WASHINGTON SUBURBAN SANITARY COMMISSION

By: Robert S. McGarry
ROBERT S. MCGARRY, General Manager

Date: 22 Jul 82

FAIRFAX COUNTY WATER AUTHORITY

By: Fred C. Morin
FRED C. MORIN, Chairman

Date: July 22 '82

CERTIFICATION

I, Thomas A. Deming, Attorney for the Maryland Potomac Water Authority hereby certify that the foregoing agreement executed by James R. Worsley of the Authority, is within the scope of his authority to act upon behalf of the Maryland Potomac Water Authority, and that in my capacity as Attorney for the Transferor, I have considered all applicable law and find that the Transferor is legally capable of entering into the contractual obligations contained in the foregoing agreement, that the transfer is properly effected, and that, upon acceptance, it will be legally enforceable.

Given under my hand, this 22 day of July, 1982.

Thomas A. Deming
Attorney for the Maryland Potomac Water Authority

CERTIFICATION

I, Edward L. Curry, Attorney for the District of Columbia hereby certify that the foregoing agreement executed by Marion S. Barry, of the District of Columbia, is within the scope of his authority to act upon behalf of the District of Columbia, and that in my capacity as Attorney for the District of Columbia I have considered all applicable law and find that the District is legally and financially capable of entering into the contractual obligations contained in the foregoing agreement that the transfer is properly effected, and that, upon acceptance, it will be legally enforceable.

Given under my hand, this 22 day of July, 1982.

Attorney for the District of Columbia

CERTIFICATION

I, [illegible], Attorney for the Washington Suburban Sanitary Commission hereby certify that the foregoing agreement executed by [illegible], of the [illegible] is within the scope of his authority to act upon behalf of the Washington Suburban Sanitary Commission, and that in my capacity as Attorney for the Commission, I have considered all applicable law and find that the Commission is legally capable of entering into the contractual obligations contained in the foregoing agreement, that the transfer is properly effected, and that, upon acceptance, it will be legally enforceable.

Given under my hand, this 22nd day of July, 1982.

[signature]
Attorney for the Washington Surburban Sanitary Commission

CERTIFICATION

I, Randolph W. Church Jr., Attorney for the Fairfax County Water Authority hereby certify that the foregoing agreement executed by Fred C. Morin, of the Fairfax County Water Authority, is within the scope of his authority to act upon behalf of the Fairfax County Water Authority, and that in my capacity as Attorney for the Authority, I have considered all applicable law and find that the Authority is legally and financially capable of entering into the contractual obligations contained in the foregoing agreement that the transfer is properly effected, and that, upon acceptance, it will be legally enforceable.

Given under my hand, this 22nd day of July, 1982.

Randolph W Church Jr.
Attorney for the Fairfax County Water Authority

H-X-4

EXHIBIT A

I - LAKE STORAGE

Feature	Elevation (ft., m.s.l.)	Usable Storage (ac. ft.)	Percent of Conservation Storage*	Percent of Water Supply Storage
Flood control	1466 - 1510	36,300		
Conservation	1255 - 1466	92,000	100.00	
Water Supply	1255 - 1466	(40,995)	44.56	100.00
Users		(40,995)	44.56	100.00
Future		(33,837)	36.78	82.54
Present		(7,158)	7.78	17.46
Water Quality	1255 - 1466	(51,005)	55.44	
Total		128,200		

*Storage remaining after 100 years of sedimentation from the date the project is operational.

II - ALLOCATION OF ESTIMATED CONSTRUCTION COST

Feature	Cost ($)	Percent of Project Construction Cost
Flood control	38,520,000	22.1
Recreation	5,926,000	3.4
Water Supply	57,868,000	33.2
Water Quality	71,986,000	41.3
Total	174,300,000	100.00

III - INVESTMENT COSTS TO BE REPAID FOR WATER SUPPLY STORAGE DESIGNATED AS INITIAL WATER SUPPLY

Initial Use:	
Cost of 7,158 acre-feet of water supply storage (5.8% x $174,300,000)	= $10,109,400
Interest during construction "Based on actual construction expenditures by fiscal year and an interest rate of 3.253%"	= 1,250,181
Total investment initial use	= $11,359,000

H-X-5

IV - TOTAL ANNUAL COST FOR USE OF WATER SUPPLY STORAGE DESIGNATED AS INITIAL WATER SUPPLY

Interest and amortization $10,913,417 x .0410908 1/	=	$448,441.00
Operation and Maintenance 2/ 6.05% x $16,000	=	9,862.00
Major replacement 3/ 7.35% x $125,000	=	9,188.00
		$467,491.00

Notes:

1/ Payment one of $446,164 (all to principal) has been made based on previously estimated costs of $173,400,000. Repayment factor, 49 equal payments, principal and interest at 3.253% = .0410908.

2/ $163,000 is the current estimate of annual "joint-use" operation and maintenance costs. The actual costs, and therefore the required payment, will likely differ.

3/ $125,000 is the current estimate of the average annual value of major replacement costs. Major replacement costs are payable only when incurred. It is suggested that the amount shown as the Users share be placed in a reserve or sinking fund for future contingency.

H-X-6

EXHIBIT B

AMORTIZATION SCHEDULE

INITIAL DEMAND

TOTAL INVESTMENT COST	$11,359,581.00
NUMBER OF PAYMENTS	50
INTEREST RATE, PERCENT	3.253

Annual Payment Number	Annual Payment	APPLICATION: Interest	APPLICATION: Principal	APPLICATION: Balance
				$11,359,581.00
1 *	$446,164.00	$ 0.00	$446,164.00	10,913,417.00
2	448,441.04	355,013.45	93,427.59	10,819,989.41
3	448,441.04	351,974.26	96,466.78	10,723,522.63
4	448,441.04	348,836.19	99,604.85	10,623,917.78
5	448,441.04	345,596.05	102,844.09	10,521,072.79
6	448,441.04	342,250.50	106,190.54	10,414,882.25
7	448,441.04	338,796.12	109,644.92	10,305,237.33
8	448,441.04	335,299.37	113,211.67	10,192,025.66
9	448,441.04	331,546.59	116,894.45	10,075,131.21
10	448,441.04	327,744.02	120,697.02	9,954,434.19
11	448,441.04	323,817.74	124,623.30	9,829,810.89
12	448,441.04	319,763.75	128,677.29	9,701,133.60
13	448,441.04	315,577.88	132,863.16	9,568,270.44
14	448,441.04	311,255.84	137,185.20	9,431,085.24
15	448,441.04	306,793.20	141,647.84	9,289,437.40
16	448,441.04	302,185.40	146,255.64	9,143,181.76
17	448,441.04	297,427.70	151,013.34	8,992,168.42
18	448,441.04	292,515.24	155,925.80	8,836,242.62
19	448,441.04	287,442.97	160,998.07	8,675,244.55
20	448,441.04	282,205.71	166,235.03	8,509,009.22
21	448,441.04	276,798.07	171,642.97	8,337,336.25
22	448,441.04	271,214.52	177,266.52	8,160,139.73
23	448,441.04	265,449.35	182,991.69	7,977,148.04
24	448,441.04	259,496.63	188,944.41	7,788,203.63
25	448,441.04	253,350.26	195,090.78	7,593,112.85
26	448,441.04	247,003.96	201,437.08	7,391,675.77
27	448,441.04	240,451.21	207,989.83	7,183,685.94
28	448,441.04	233,685.31	214,755.73	6,968,930.21
29	448,441.04	226,699.30	221,741.74	6,747,188.47
30	448,441.04	219,486.04	228,955.00	6,518,233.47
31	448,441.04	212,038.13	236,402.91	6,281,830.56
32	448,441.04	204,347.95	244,093.09	6,037,737.47
33	448,441.04	196,407.60	252,033.44	5,785,704.03

Annual Payment Number	Annual Payment	Interest	Principal	Balance
34	$448,441.04	$188,208.95	$260,232.09	$5,525,471.94
35	448,441.04	179,743.61	268,697.43	5,256,774.51
36	448,441.04	171,002.87	277,438.17	4,979,336.34
37	448,441.04	161,977.81	286,463.23	4,692,873.11
38	448.441.04	152,659.16	295,781.88	4,397,091.23
39	448,441.04	143,037.38	305,403.66	4,091,687.57
40	448,441.04	133,102.60	315,338.44	3,776,349.13
41	448,441.04	122,844.64	325,596.40	3,450,752.73
42	448,441.04	112,252.98	336,188.06	3,114,564.67
43	448,441.04	101,316.79	347,126.25	2,767,440.42
44	448,441.04	90,024.84	358,416.20	2,409,024.22
45	448,441.04	78,365.56	370,075.48	2,038,948.74
46	448,441.04	66,327.00	382,114.04	1,656,834.70
47	448,441.04	53,896.83	394,544.21	1,262,290.49
48	448,441.04	41,062.31	407,378.73	854,911.78
49	448,441.04	27,810.28	420,630.76	434,281.00
50	448,441.04	14,127.16	434,281.00	0.00

* Payment number one has been made based on previously estimated construction costs of $173,400,000.00.

EXHIBIT C

I - THE WASHINGTON SUBURBAN SANITARY COMMISSION ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

The Washington Suburban Sanitary Commission (hereinafter called "Applicant Recipient")

HEREBY AGREES THAT it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from the Department of the Army and HEREBY GIVES ASSURANCE THAT it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the Department of the Army, this assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the

Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

Dated 22 July 82

The Washington Suburban Sanitary Commission

By [signature]
ROBERT S. MCGARRY, General Manager

4017 Hamilton Street
Hyattsville, Maryland 20781

EXHIBIT C
II - THE DISTRICT OF COLUMBIA
ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

The District of Columbia (hereinafter called "Applicant-Recipient")

HEREBY AGREES THAT it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from the Department of the Army and **HEREBY GIVES ASSURANCE THAT** it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the Department of the Army, this assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the

Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

Dated 7-22-82

The District of Columbia

By [signature]
MARION BARRY, Mayor

District Building
14th & E Streets, N.W.
Washington, DC 20004

H-X-9

EXHIBIT C
III - THE FAIRFAX COUNTY WATER AUTHORITY
ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

The Fairfax County Water Authority (hereinafter called "Applicant Recipient")

HEREBY AGREES THAT it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from the Department of the Army and **HEREBY GIVES ASSURANCE THAT** it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the Department of the Army, this assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the

Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

Dated July 22 '82

The Fairfax County Water Authority

By Fred C. Morin
FRED C. MORIN, Chairman

P.O. Box 1500
Merrifield, Virginia 22116

H-X-10

Contract No. DACW31-71-C-0006

CONTRACT BETWEEN THE UNITED STATES OF AMERICA

AND

THE MARYLAND POTOMAC WATER AUTHORITY FOR

WATER SUPPLY STORAGE SPACE IN THE BLOOMINGTON RESERVOIR,

MARYLAND AND WEST VIRGINIA

THIS CONTRACT is made this 25th day of August 1970, by and between the United States of America (hereinafter called the "United States"), represented by the Contracting Officer executing this contract, and the Maryland Potomac Water Authority (hereinafter called the "Authority"), represented by the Chairman.

WITNESSETH:

WHEREAS, the Flood Control Act of 1962 (76 Stat. 1173), authorized the construction, operation, and maintenance of the Bloomington Reservoir on the North Branch Potomac River, Potomac River Basin, 23 October 1962 (hereinafter called the "Project"); and

WHEREAS, the Authority was created by Chapter 411, Laws of Maryland, 1969, as a governmental agency and body politic and corporate under the Laws of the State of Maryland, and empowered thereunder to conserve, control and utilize to beneficial service the storm and flood waters of the rivers and streams of the Potomac River Watershed in the district comprising the Maryland counties of Allegany, Frederick, Garrett, Montgomery, Prince George's and Washington, and to contract directly with the Federal Government to provide the non-Federal cost share of the project and to equitably allocate the cost thereof among the beneficiaries of the project; and

WHEREAS, the Authority desires to contract with the United States for inclusion in the Project of storage for municipal and industrial initial water supply, and for payment of the cost thereof in accordance with the provisions of the Water Supply Act of 1958, as amended (43 U.S.C. 390b-f); and

WHEREAS, the Authority is empowered so to contract with the United States, and is vested with all necessary powers for accomplishment of the purposes of this contract.

NOW, THEREFORE, in consideration of the faithful performance of each party of the mutual covenants and agreements hereinafter set forth, the parties hereto do mutually agree as follows:

ARTICLE 1. WATER STORAGE SPACE.

a. The Authority shall have the exclusive right to utilize an undivided 7.78 percent of the storage space in the Project between elevations 1255 and 1466 feet above mean sea level (which 7.78% of such storage space shall be not less than 7,158 acre feet) as deemed necessary by the Authority to impound water for use, and to make such diversions as granted to the Authority by the State of Maryland, to the extent such storage will provide, subject to the retention by the United States and others of the remaining undivided 92.22 percent of the storage space between said elevations for such purposes as the United States may deem desirable.

b. The Authority shall have the right to withdraw water from the aforesaid 7.78 percent of the storage space, so long as the elevation of the water within the Project is above elevation 1255 feet above mean sea level, provided that such releases when combined with local runoff below the dam will not cause flooding.

c. The Authority recognizes that this contract provides storage only, as stated above, and that any water that may be impounded therein will be raw water. The United States makes no representation with respect to the quality or availability of water and assumes no responsibility therefor, or for treatment of the water; further, the United States reserves the right to take all measures to preserve life, health, and property.

ARTICLE 2. MEASUREMENT OF WITHDRAWALS AND RELEASES.

The Authority desires releases through the Project outlet works and water will be released through the Project outlet works from the aforesaid water supply storage space in accordance with schedules prescribed in writing from time to time between the Authority and the United States. The measure of all such releases shall be by means of a rating curve of the outlet works, or by other suitable means, agreed upon in advance of the commencement of operation of the Project for initial water supply purposes.

H-X-11

ARTICLE 3. RESPONSIBILITY FOR WATER RIGHTS.

The Authority has the full responsibility to acquire in accordance with State laws and regulations, and if necessary to establish or defend, any and all water rights needed for utilization of the storage provided under this contract. The United States shall not be responsible for diversions by others, nor will it become a party to any controversies involving the use of the storage space by the Authority, except as such controversies may affect the operations of the United States.

ARTICLE 4. FEDERAL AND STATE LAWS.

The Authority shall utilize the aforesaid storage space in a manner consistent with Federal and State laws.

ARTICLE 5. REGULATION OF RESERVOIR BY THE UNITED STATES.

a. The United States primary interest in this Project is flood control and water quality control, and regulation of the reservoir storage capacity allocated for these purposes shall be the sole responsibility and under the sole authority of the United States.

b. Notwithstanding any of the aforegoing provisions, the United States shall have the right to regulate the releases from the reservoir as the needs of flood control protection dictate in order to prevent damage and dangerous conditions downstream and in order to maintain the safety of the structure.

ARTICLE 6. CONSIDERATION AND PAYMENT.

In consideration of the payment provided in this contract to be paid by the Authority to the United States, it is agreed that the United States will provide storage space in the Project, as provided in Article 1a. In consideration of the United States providing the aforesaid storage space to the Authority, it is agreed that the Authority shall pay the following sums to the United States:

a. Project Investment Costs.

The Authority shall repay to the United States, at the times and with interest during construction and with interest on the unpaid balance as hereinafter specified, the amounts stated below which, as shown in Exhibit "A" attached to and made a part of this contract, constitute the entire amount of the estimated Project investment costs allocated to the storage space provided for municipal and industrial initial water supply under this contract. The interest rate to be used for purposes of computing interest during construction and interest on the unpaid balance shall be determined by the Secretary of the Treasury as of the beginning of the fiscal year in which construction of the Project was initiated, or lands acquired, whichever occurs first, on the basis set forth in the Water Supply Act of 1958, as amended, which interest rate shall not exceed 3.253 percent per annum. The Authority shall repay:

5.80% of the construction cost of the Project, presently estimated to be	$4,709,600.00
Interest during construction, presently estimated to be	$ 440,800.00
Total estimated amount to be repaid under this contract	$5,150,400.00

The sum of $5,150,400.00 and interest thereon shall be paid in 50 consecutive annual installments. Except for the first payment, which shall be applied solely to the retirement of principal, all installments shall include accrued interest at the rate not exceeding 3.253 percent per annum. Payments shall be in the amount of $203,240.00 per annum, except for the last installment which shall be increased or decreased when due, to assure repayment of all capital costs within the contract period. A schedule of annual payments is shown on Exhibit "B", attached hereto and made a part hereof. The first annual payments will be due and payable within 30 days after the date the Authority is notified that the Project is in operation. Payments thereafter will be due and payable within 30 days of the yearly anniversary date of the first payment under the contract. Payment for any fractional part of a year which may result from termination of the contract shall be prorated on the basis of the annual charge.

(1) The date the Project is first placed in operation for initial water supply shall be the date on which water in the Project first reaches elevation 1255 above mean sea level as the result of deliberate impoundment by the Government for initial water supply use or the date water is first used by the Authority, whichever occurs first.

(2) In the event the actual construction cost of the Project exceeds the estimated cost, as set forth in Exhibit "A", the aforesaid annual payments shall be increased to reflect the actual

cost, including interest during construction, as determined by the Contracting Officer. In the event such actual first cost is less than that set forth in Exhibit "A", the aforesaid annual payments shall be decreased to reflect the actual cost, including interest during construction, as determined by the Contracting Officer.

(3) In the event the annual payments are increased or decreased, as provided above, an adjustment, as determined by the Contracting Officer, of payments made prior to the determination of the final Project cost shall be made in the payments due after such costs are determined. At the time that the final Project costs are determined, Exhibits "A" and "B" will be modified to reflect the increased or decreased annual payments and such modifications will form a part of this contract.

b. Operation and Maintenance Costs.

The Authority shall pay 6.05% of the annual experienced operation and maintenance costs as herein defined. Payments due prior to availability of actual operation and maintenance costs shall be equal to the percentage herein before stated, presently estimated at $5,143.00 annually. Payments thereafter shall be equal to the percentage herein before stated of the actual experienced cost of operation and maintenance for the preceding United States fiscal year. The first annual payment will be due and payable on the date set forth in paragraph a of this Article. Annual payments thereafter will be due and payable on the anniversary date of the first payment under this contract.

(1) The extent of operation and maintenance of the Project shall be determined by the Contracting Officer, and all records and accounting shall be maintained by the Contracting Officer. Records of cost of operation and maintenance of the Project shall be available for inspection and examination by the Authority.

(2) In the event that the Authority requests additional operation and maintenance for the initial water supply storage over and above that determined by the Contracting Officer and over and above that which formed the basis for determination as set out in Exhibit "A", the Authority shall bear the entire cost of such additional expense.

c. Major Replacement Costs.

The Authority shall pay 7.35 percent of the cost of major replacements and sedimentation resurveys, when incurred and presently estimated at $3,895.00 annually over the life of the Project. Payment shall be made with the first annual payment becoming due after the date said cost is incurred.

d. In the event of default in the payment of the costs contained in paragraphs a, b, and c of this Article, the Authority shall pay interest on such overdue payments at the rate of 3.253 percent per annum. Such amount of interest shall be compounded annually and charged from the date such payment is due until paid. Interest for a fractional part of the year will be figured on a monthly basis. For example, if the payment is made within the first month after being overdue, 31 to 60 days after anniversary date, one month's interest will be charged.

ARTICLE 7. METHOD OF PAYMENT.

Cash payments, sufficient to cover the Authority's share of each pertinent item contained in this contract, shall be deposited with the United States upon request. Such payments shall be made as soon as possible, after written request, by properly drawn Authority check made payable to the Treasurer of the United States and transmitted to the officer, or person, or office designated in the written request. Said payments shall be made annually on or before the first Monday of each succeeding anniversary date.

ARTICLE 8. PERIOD OF CONTRACT.

This contract shall become effective as of the date of approval by the Secretary of the Army and shall continue in full force and effect under the conditions set forth herein, not to exceed the life of the Project.

ARTICLE 9. PERMANENT RIGHTS TO STORAGE.

Upon completion of payments by the Authority, as provided in Article 6 herein, the Authority shall have a permanent right, under the provisions of Public Law 85-140, to the use of the initial water supply storage space in the Project as provided in Article I, subject to the following:

a. The Authority shall continue payment of annual operation and maintenance costs allocated to initial water supply.

b. The Authority shall bear the costs allocated to initial water supply of any necessary reconstruction, rehabilitation or replacement of Project features which may be required to continue satisfactory operation of the Project. Such costs will be established by the Contracting Officer. Repayment arrangements including schedules will be in writing and will be made a part of this contract.

c. Upon completion of payments by the Authority as provided in Article 6a herein, the Contracting Officer shall

redetermine the storage space for municipal and industrial initial water supply, taking into account such equitable reallocation of reservoir storage capacities among the purposes served by the Project as may be necessary due to sedimentation. Such findings, and the storage space allocated to municipal and industrial initial water supply, shall be defined and described in an exhibit which will be made a part of this contract. Following the same principle, such reallocation of reservoir storage capacity may be further adjusted from time to time as the result of sedimentation resurveys to reflect actual rates of sedimentation and the exhibit revised to show the revised storage space allocated to municipal and industrial initial water supply.

d. The permanent rights of the Authority under this contract shall be continued so long as the United States continues to operate the Project. In the event the United States no longer operates the Project, such rights shall be continued subject to the execution of a separate contract, or additional supplemental agreement providing for:

(1) Continued operation by the Authority of such part of the facility as is necessary for utilization of the water supply storage space allocated to it;

(2) Terms which will protect the public interest; and

(3) Effective absolvement of the United States by the Authority from all liability in connection with such continued operation.

ARTICLE 10. RIGHTS-OF-WAY.

The grant of an easement for rights-of-way over, across, in and upon United States-owned lands, under control of the Secretary of the Army, required for transmission of water from point of withdrawal, shall be by separate instrument in a form satisfactory to the Secretary of the Army, without additional cost to the Authority, under the authority and in accordance with the provisions of 10 U.S.C. 2669.

ARTICLE 11. RELEASE OF CLAIMS.

The Authority shall and does hereby release the United States, its officers, agents and employees from any and all causes of action, suits at law or equity, or claims or demands, and from any liability of any nature whatsoever for and on account of any damage or injury arising out of the withdrawal or release of water from the Project as ordered by the Authority, the operation and/or maintenance of the water supply storage features of the Project, and the construction, operation or maintenance of the features or appurtenances owned and operated by the Authority.

No hold harmless or indemnity provision in this contract shall be binding upon the State of Maryland or its political subdivisions. The members of the Authority shall not be liable as individuals, either jointly or severably, in actions arising from any contract made by or on behalf of the Authority.

ARTICLE 12. TRANSFER OR ASSIGNMENT.

The Authority shall not transfer or assign this contract nor any rights acquired hereunder, nor sub-allot said water or any part thereof, nor grant any interest, privilege or license whatsoever in connection with this contract, without the approval of the Secretary of the Army; provided that this restriction shall not be construed to apply to any water which may be obtained from the water supply storage space by the Authority and furnished to any third party or parties or the rates charged therefor.

ARTICLE 13. OFFICIALS NOT TO BENEFIT.

No member of or delegate to Congress, or Resident Commissioner, shall be admitted to any share or part of this contract, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this contract if made with a corporation for its general benefit.

ARTICLE 14. COVENANT AGAINST CONTINGENT FEES.

The Authority warrants that no person or selling agency has been employed or retained to solicit or secure this contract upon an agreement or understanding for a commission, percentage, brokerage, or contingent fee, excepting bona fide employees or bona fide established commercial or selling agencies maintained by the Authority for the purpose of securing business. For breach or violation of this warranty, the United States shall have the right to annul this contract without liability or, in its discretion, to add to the contract price or consideration the full amount of such commission, percentage, brokerage, or contingent fee.

ARTICLE 15. DEFINITIONS.

a. The term "major replacement costs", as used herein, shall mean all costs resulting from any necessary reconstruction, rehabilitation or replacement of Project features which is determined by the Contracting Officer of the United States at any time during the term of this contract to be necessary for continued satisfactory operation of the Project.

b. The term "interest", as used herein, shall mean the Federal water supply interest rate as established by the Secretary of the Treasury pursuant to authority contained in the Water Supply Act of 1958, Title III, Public Law 85-500, as amended, at the beginning of the fiscal year in which construction is first initiated. Construction will be considered as having been initiated on the date when first lands for the Project are acquired or on the date when the first construction contract is let, whichever is the earlier.

c. The term "construction costs", as used herein, shall mean the total costs expended by the United States in completion of the construction of the Project, including but not restricted to, the cost incurred under a construction contract or contracts for the Project, all modifications issued pursuant thereto, all United States supervision and inspection expended in connection with the construction, all costs of design of the Project, all costs of United States administrative overhead allocable to the Project, and all costs of real estate necessary for the construction and operation of the Project.

d. The term "operation costs", as used herein, shall mean the total costs expended by the United States in connection with the operation of the completed Project, covering all routine operating repairs and recurring minor or ordinary maintenance work and expenses incidental to continuous functioning of the Project, less those operation costs specifically attributable to project purposes other than water supply.

e. The term "maintenance costs", as used herein, shall mean the total costs expended by the United States in connection with annual and periodic repairs (other than minor or ordinary) of structures or their components to preserve the useful life of such a structure or facility, as constructed or rehabilitated, including such betterments or improvements as would conform to modern design and practice, all within the scope of the authorized Project or activity, less those maintenance costs specifically attributable to purposes other than water supply.

f. The term "interest during construction", as used herein, shall mean the cost of capital incurred during the construction period, computed as simple interest from the middle of the month in which it occurs until the first of the month following the availability of water supply storage.

g. The term "construction period", as used herein, shall mean the period extending from the time the first lands for the Project are acquired, or on the date when the first construction contract is let, whichever is earlier, until water supply storage is first available.

h. The term "Contracting Officer", as used herein, shall mean the person executing this contract on behalf of the United States and includes a duly-authorized successor or authorized representative.

ARTICLE 16. APPROVAL OF CONTRACT.

This contract shall be subject to the written approval of the Secretary of the Army, and shall not be binding until so approved.

This contract shall be binding upon any assignee of or successor to the United States of America.

The terms of this contract may be renegotiated upon mutual agreement of the parties at any time.

IN WITNESS WHEREOF, the parties hereto have executed this agreement, as of the day and year first above written.

APPROVED: 4 NOV 1970 THE UNITED STATES OF AMERICA

Secretary of the Army

By (Contracting Officer)

DATE 25 AUG 70

GERALD M. BOYD
Lt. Colonel, Corps of Engineers
Acting District Engineer

MARYLAND POTOMAC WATER AUTHORITY

By
Chairman

APPROVED AS TO LEGAL FORM AND SUFFICIENCY
THIS ___ day of July, 1970

By
Assistant Attorney General of Maryland

H-X-15

Exhibit A

Estimated Annual Costs

Estimated First Cost of Project

Construction Cost	$ 81,200,000.00
Interest During Construction* (.09375)	7,600,000.00
Total Estimated First Cost of Project	$ 88,800,000.00

* 1/2 of 6 years @ 3-1/8%

Project Annual Costs

Interest @ 3-1/8%	$ 2,775,000.00
Amortization 3-1/8% for 100 yrs. (.00151)	134,000.00
Economic Cost of Land	13,000 00
Maintenance and Operation**	85,000.00
Major Replacements	53,000.00
Total Annual Costs**	$ 3,060,000.00

**Less maintenance and operation costs specifically attributable to project purposes other than water supply.

Percent of water supply cost to total estimated first cost of the Project.	33.20 percent
Percent of initial water supply cost to total estimated first cost of the Project.	5.80 percent
Percent of annual operation and maintenance costs allocated to initial water supply.	6.05 percent
Percent of major replacement costs allocated to initial water supply.	7.35 percent
Cost of municipal and industrial initial water supply storage.	$ 5,150,400.00

Contract No. DACW31-71-C-0006

Exhibit A

Estimated Annual Costs

Estimated Annual Charges for Municipal and Industrial Initial Water Supply

Interest and amortization for fifty (50) years at 3.253 percent interest (1)	$ 203,280.00
Maintenance and Operation	5,143.00
Major Replacements	3,895.00
Total estimated annual costs for initial water supply	$ 212,318.00

(1) Based on annual payments in advance, with the entire first payment credited to retirement of principal. Factor for computing annual charges is 0.03947.

Exhibit B

Payment Schedule

Interest Rate = 3.2530 Percent

Payment No	Payment To Interest	Payment To Principal	Total Payment	Principal Due
				5150400.00
1	0.00	203280.00	203280.00	4947120.00
2	160929.81	42350.19	203280.00	4904769.81
3	159552.16	43727.84	203280.00	4861041.97
4	158129.70	45150.30	203280.00	4815891.67
5	156660.96	46619.04	203280.00	4769272.63
6	155144.44	48135.56	203280.00	4721137.07
7	153578.59	49701.41	203280.00	4671435.66
8	151961.80	51318.20	203280.00	4620117.46
9	150292.42	52987.58	203280.00	4567129.88
10	148568.73	54711.27	203280.00	4512418.61
11	146788.98	56491.02	203280.00	4455927.59
12	144951.32	58328.68	203280.00	4397598.91
13	143053.89	60226.11	203280.00	4337372.80
14	141094.74	62185.26	203280.00	4275187.54
15	139071.85	64208.15	203280.00	4210979.39
16	136983.16	66296.84	203280.00	4144682.55
17	134826.52	68453.48	203280.00	4076229.07
18	132599.73	70680.27	203280.00	4005548.80
19	130300.50	72979.50	203280.00	3932569.30
20	127926.48	75353.52	203280.00	3857215.78
21	125475.23	77804.77	203280.00	3779411.01
22	122944.24	80335.76	203280.00	3699075.25
23	120330.92	82949.08	203280.00	3616126.17
24	117632.58	85647.42	203280.00	3530478.75
25	114846.47	88433.53	203280.00	3442045.22
26	111969.73	91310.27	203280.00	3350734.95
27	108999.41	94280.59	203280.00	3256454.36
28	105932.46	97347.54	203280.00	3159106.82
29	102765.74	100514.26	203280.00	3058592.56
30	99496.02	103783.98	203280.00	2954808.58
31	96119.92	107160.08	203280.00	2847648.50
32	92634.01	110645.99	203280.00	2737002.51
33	89034.69	114245.31	203280.00	2622757.20
34	85318.29	117961.71	203280.00	2504795.49
35	81481.00	121799.00	203280.00	2382996.49
36	77518.88	125761.12	203280.00	2257235.37
37	73427.87	129852.13	203280.00	2127383.24
38	69203.78	134076.22	203280.00	1993307.02
39	64842.28	138437.72	203280.00	1854869.30

H-X-16

Contract No. DACW31-71-C-0006

(Cont'd)

Exhibit B

Payment Schedule

Interest Rate = 3.2530 Percent

Payment No	Payment To Interest	Payment To Principal	Total Payment	Principal Due
40	60338.90	142941.10	203280.00	1711928.20
41	55689.02	147590.98	203280.00	1564337.22
42	50887.89	152392.11	203280.00	1411945.11
43	45930.57	157349.43	203280.00	1254595.68
44	40812.00	162468.00	203280.00	1092127.68
45	35526.91	167753.09	203280.00	924374.59
46	30069.91	173210.09	203280.00	751164.50
47	24435.38	178844.62	203280.00	572319.88
48	18617.57	184662.43	203280.00	387657.45
49	12610.50	190669.50	203280.00	196987.95
50	6408.02	196987.95	203395.97	0.00

H-X-17

CERTIFICATE

ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

THE MARYLAND POTOMAC WATER AUTHORITY (hereinafter called "Applicant-Recipient") HEREBY AGREES THAT it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from the Department of the Army and HEREBY GIVES ASSURANCE THAT it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the Department of the Army, this assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

DATED: Sept. 29, 1970

MARYLAND POTOMAC WATER AUTHORITY

By James R. Worsley Jr.
JAMES R. WORSLEY, JR.
Chairman

710 Ring Building
Washington, D. C. 20036

H-X-18