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Flood Warning Assessment For The Farm River East Haven & North Branford Connecticut

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This study evaluated the flood history and hydrology of the Farm River watershed as well as the potential reduction in expected annual damages resulting from the implementation of a flood warning system and a corresponding response plan. The analysis included: a survey of all existing structures in the study area; an economic analysis of existing flood damages; an estimate of the damage reduction associated with the implementation of a flood warning system; and the development of necessary hydrologic information.

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FLOOD WARNING ASSESSMENT FOR THE FARM RIVER EAST HAVEN AND NORTH BRANFORD, CONNECTICUT

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FLOOD WARNING ASSESSMENT FOR THE FARM RIVER EAST HAVEN AND NORTH BRANFORD, CONNECTICUT

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FLOOD WARNING ASSESSMENT FOR THE FARM RIVER EAST HAVEN AND NORTH BRANFORD, CONNECTICUT

INTRODUCTION

At the request of the Connecticut Department of Environmental Protection (DEP) the New England Division of the U.S. Army Corps of Engineers conducted this evaluation of the Farm River in East Haven and North Branford. The work was conducted under the Corps' Flood Plain Management Services (FPMS) program. The FPMS program is authorized under Section 206 of the Flood Control Act of 1960 (PL 86-645).

STUDY PURPOSE AND SCOPE

Repeated flooding of the Farm River has resulted in moderate amounts of private, public, and commercial damage. The Connecticut DEP's Inland Water Resources Division is evaluating the potential for a flood warning system in the lower portion of the watershed that would alert homeowners and businesses of potential flooding. This would allow those alerted the opportunity to remove contents from potentially flooded areas and evacuate the flood plain if necessary.

This study evaluated the flood history and hydrology of the Farm River watershed as well as the potential reduction in expected annual damages resulting from the implementation of a flood warning system and a corresponding response plan. This analysis included: a survey of all existing structures in the study area; an economic analysis of existing flood damages; an estimate of the damage reduction associated with the implementation of a flood warning system; and the development of necessary hydrologic information. The Connecticut DEP can use the information contained in this report to make its own determination on the feasibility of installing a flood warning system in the Farm River watershed.

DESCRIPTION OF STUDY AREA

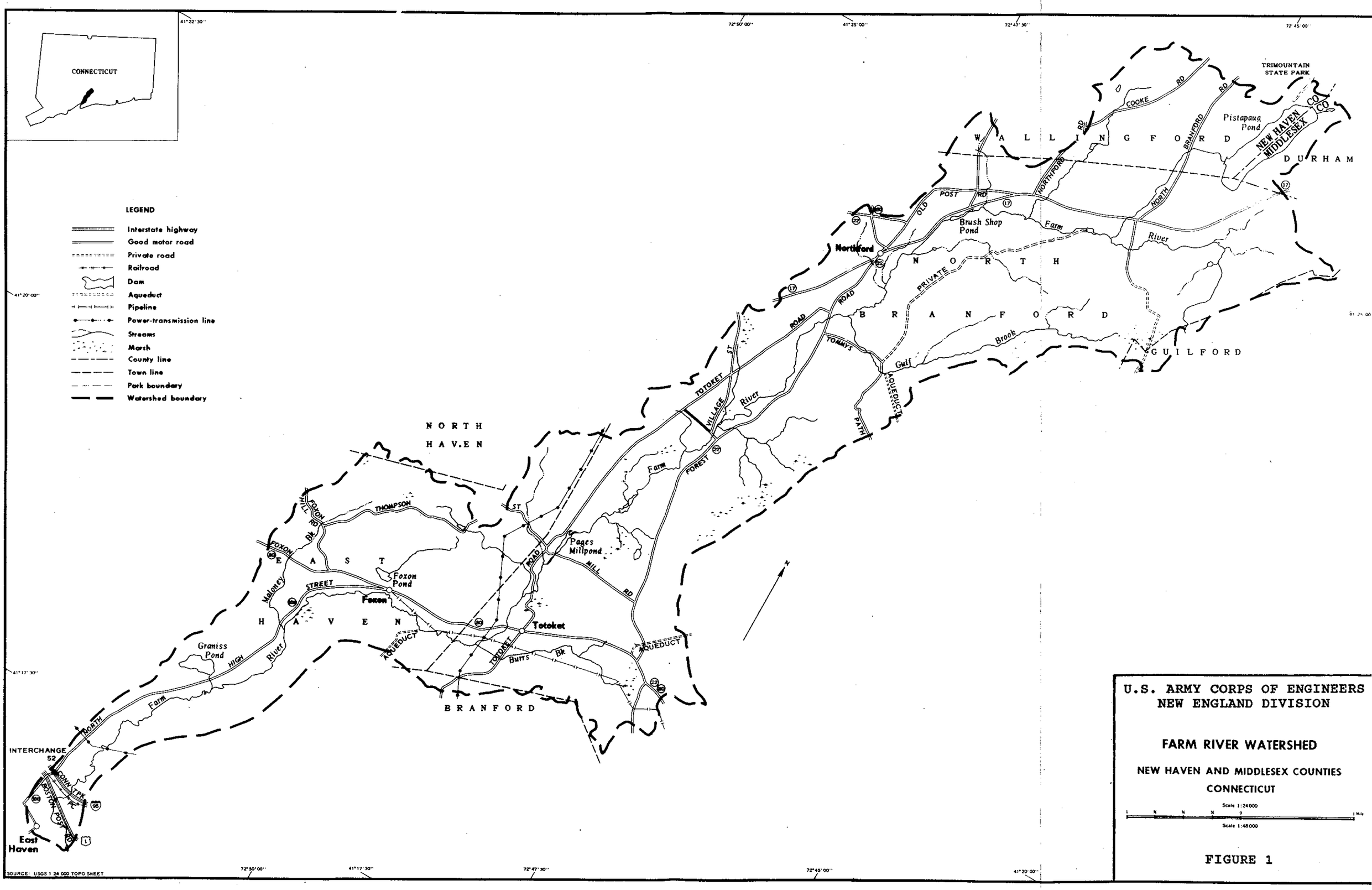
The Farm River watershed is located in New Haven county and is part of the Central Coastal River Basin. The Farm River watershed is long and narrow in shape and is 19.5 square miles in size (see Figure 1). The Farm River, running nearly through the center of the drainage area, is sixteen miles long. The watershed's width, however, varies from one half to two miles. The watershed begins at Pistapaug Pond and other tributaries in North Branford and Wallingford and ends about 1000 feet south of the Interstate 95 (I-95) bridge. It is in this area, around Hemingway Avenue, that tidal influence begins. The Farm River watershed lies mainly in the towns of East Haven and North Branford. Minor portions of the watershed are in Branford, Durham, Guilford, and Wallingford.

The Farm River flows in a southerly direction and empties into Long Island Sound, 2.5 miles south of I-95. The river is characterized by well defined channels and is crossed in several places by public and private bridges. Major tributaries of the Farm River include Lake Saltonstall, Burrs Brook, and Maloney Brook. The drainage areas of these tributaries are 3.95, 1.68, and 1.04 square miles respectively. At its headwaters the river has an elevation of about 350 feet National Geodetic Vertical Datum (NGVD). At the I-95 crossing the river's elevation is about 6 feet NGVD. Over the length of the river the average drop in elevation is about 21 feet per mile. In the upper reaches of the river in North Branford the drop in elevation is relatively steep at about 50 feet per mile. However, below the Route 80 bridge and through the East Haven area the drop in elevation averages only 6 feet per mile.

It is in the areas near and south of Route 80 that most of the development has taken place. Most of the development is in the form of residential housing. There is some commercial activity, but it is mostly concentrated in the Route 80 area, or Totoket section, of North Branford. Residential development is especially concentrated in the area between Willow Road and Corbin Road in East Haven. It is in this area where flood damage has occurred most frequently. Coincidentally, it is also in this area that the river flattens out and experiences a very slight gradient. The Connecticut DEP is exploring the potential for a flood warning system to prevent future flood damages. It is in this lower portion of the watershed that the study focussed.

FLOOD HISTORY

In this century, as recorded in various regional reports, several major storm events have affected the Farm River. In September 1938, following five days of rainfall that totalled 11.6 inches, a hurricane hit the region. This resulted in severe flooding and flood damage. In August 1955 a "double" hit from hurricanes "Connie" and "Diane" occurred. "Connie" dumped 3.5 inches of rainfall in East Haven causing minor flooding. During August 18-19 "Diane" brought torrential rains to the area. With the addition of four more inches of rainfall, already swollen rivers in the area overtopped their banks; causing widespread flood damage. The New Haven Water Company's recording station recorded 15.9 inches of rainfall during the month of June 1972; six inches of which fell in the East Haven area during a 24 hour period on June 19. Again, major residential flooding occurred. In January 1979 several storms resulted in 14 inches of rain being recorded at the nearby Quinnipiac River gaging station. Widespread flooding occurred again when about 3 inches of rain fell on January 24-26. One of the more significant flood events on the Farm River occurred in June 1982. About 12 inches of rain fell in the area during the period of June 4-6. A flooding event also occurred more recently as a result of heavy rain during June 5-6, 1992.



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NEW ENGLAND DIVISION

FARM RIVER WATERSHED

NEW HAVEN AND MIDDLESEX COUNTIES
CONNECTICUT

Scale 1:24000

Scale 1:48000

FIGURE 1

Flooding of the Farm River has been a problem for the communities of East Haven and North Branford for many years. Periodic floods have caused property damage and the temporary closure of several roads and bridges. Coordination with the Connecticut DEP and the Soil Conservation Service (SCS) revealed eight areas of flood damage (see Figure 2). Identification of affected structures and corresponding elevation information was obtained as a result of using past flood damage surveys performed by SCS. About 260 structures, mostly residential, were identified as being susceptible to flooding. The area of flood damage extends from the Totoket Road crossing, in North Branford, south to the I-95 crossing in East Haven.

WATERSHED HYDROLOGY

The first portion of the hydrologic analysis determined stage-frequency relationships for the Farm River. These were used later for determining expected annual damages. Due to the lack of historic flow data on the Farm River, a similar nearby watershed was sought that would yield comparable discharge information. A Corps of Engineer's study of the West River conducted in 1984 provided a hydrologically similar case. Discharge-frequency data was taken from this study and transferred to the mouth of the Farm River using the drainage area ratio technique. These results were then compared to the most recent Flood Insurance Studies for East Haven and North Branford and found to be in general agreement. This data was transferred upstream, again using the drainage area ratio technique, to the various areas of interest. A discharge-frequency curve for the Farm River is shown on plate A-3 in Appendix A.

Rating curves, or discharge-stage relationships, were then developed for the areas of interest. It was determined during the study that several bridge and channel improvements were made along the Farm River in East Haven (reaches 1 through 4 on Figure 2). These improvements are not reflected in the January 1991 Flood Insurance Study for East Haven. Therefore, additional calculations were needed in order to estimate stage-discharge relationships in these improved areas. Cross section and bridge section data taken from design drawings were modeled using the HEC-2 Water Surface Profile computer program to determine the revised data along the affected reaches. Elevations for the 100-year flow in these reaches were reduced by about 0.8 to 1.8 feet. Stage-discharge relationships for the unimproved areas were developed using the existing flood insurance study information. The rating curves, when combined with the previously adopted discharge-frequency curves, resulted in the eight required stage-frequency curves (see Appendix plates A-4 through A-7).

The second part of the hydrologic analysis involved calculating the basin's response to various size storm events. This step involved developing a 3-hour unit hydrograph for the Farm

River watershed. Since flood flow data is non-existent for the Farm River, hourly recorded flow data was taken from the nearby Muddy River, which is hydrologically similar. Hourly precipitation data was developed for several storm events using information from rain gages at Hartford Brainard Field, Bridgeport, Cockaponset Ranger Station, East Haven/Lake Saltonstall, and the U.S. Weather Bureau Technical Paper 40 (TP40).

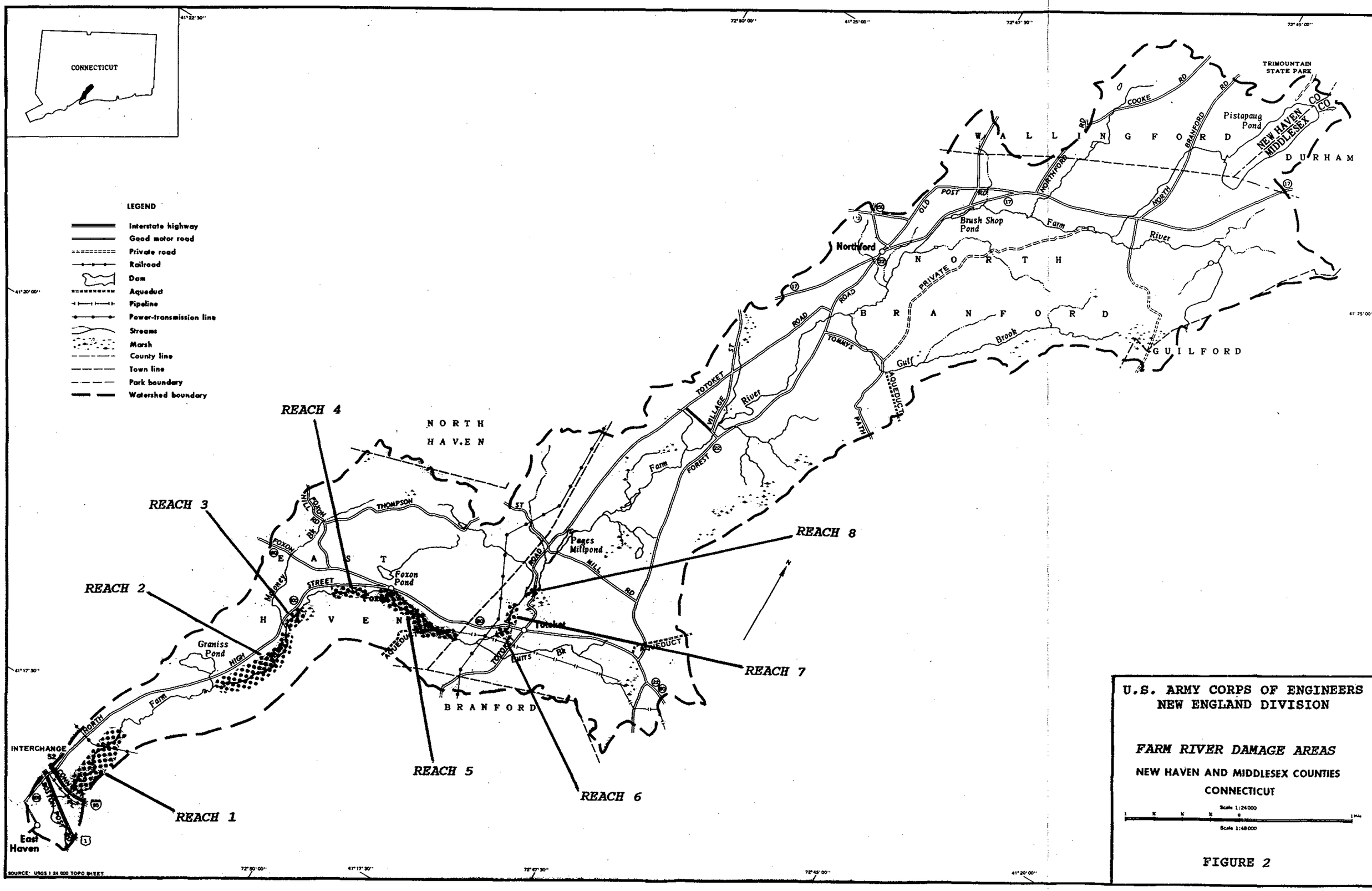
Three different storms were analyzed: the January 1979 storm, the TP40 50-year storm, and the June 1982 storm. The January 1979 storm was considered representative of a 2-year event and the June 1982 storm representative of a 100-year event. Rainfall values were applied to the 3-hour unit hydrograph previously developed, using the HEC-1 Flood Hydrograph Package. Mass rainfall curves, hyetographs, and resultant hydrographs for the three storm events are shown on plates A-8 through A-10, in Appendix A. The peak discharges calculated for the three storms are: 1,400 cubic feet per second (cfs) (January 1979); 3,400 cfs (TP40 50-year); and 4,600 cfs (June 1982). These figures generally coincide with the adopted discharge-frequency data. A more detailed description of the analysis is presented in Appendix A.

The hydrologic analysis revealed several important characteristics about the Farm River watershed. First, for the January 1979 (estimated 2-year event) and the TP40 50-year storms, the time from the centroid of the rainfall to peak discharge was about 10 hours. The June 1982 storm had a time to peak of 18 hours. A similar flood warning study of the nearby Muddy River found the time to peak for the June 1982 event to be about 15 hours. This may indicate the Farm River to be a less responsive or "sluggish" river than the Muddy River. The time to peak discharge for the various storms are also shown on plates A-8 through A-10, in Appendix A.

The time to peak is not the flood warning time. Flood warning time is defined as the time available after heavy rainfall for people to take action before flooding. If it is estimated that river flooding begins at 3,000 cfs (capacity of channel after improvements; an estimated 20-year flood event), then the warning time would be about 7 to 14 hours based on the TP 40 50-year and June 1982 events. Though the January 1979 event would not result in over-bank flooding, the time from heavy rainfall to peak discharge was about 8 hours. Due to the unusual rainfall pattern exhibited by the June 1982 event and the small size of the watershed, it was determined that a flood warning time of 7 hours is a reasonable estimate.

FLOOD DAMAGE ANALYSIS

A flood damage analysis was conducted for the subject areas along the Farm River in East Haven and North Branford. The flood damage area is so large it was broken into eight reaches. Reaches



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FARM RIVER DAMAGE AREAS

NEW HAVEN AND MIDDLESEX COUNTIES
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FIGURE 2

1-5 are located in East Haven and reaches 6-8 are located in North Branford (see Figure 2). Reach 1 contains 45 structures located between I-95 and a shooting range; 4 are commercial structures and the remaining 41 are residential structures. The 4 commercial structures are located at the end of Hudson Street. Reach 2 contains 94 residential structures located between Willow Street and North Hellstrom Road. Reach 3 contains 42 residential structures located between North Hellstrom Road and Corbin Road. Reach 4 contains 13 residential structures located on North High Street and Maple Street. Reach 5 contains 12 residential structures located from Maple Street up to the East Haven-North Branford town line. Reach 6, in North Branford, contains 8 commercial structures located along the south side of Route 80 (Foxon Road). Reach 7 contains 46 mobile homes (Pleasant Acres trailer park) and 4 commercial structures just north of Route 80. Reach 8 has 2 commercial structures located near the Totoket Road bridge crossing. The first floor elevation of each structure and the type of structure were obtained from a previous survey conducted by the Soil Conservation Service.

For the residential structures in the study area, the potential flood damages were estimated using the following methodology. Based on the information contained in the Soil Conservation Service's survey, the residential structures were categorized by type of structure. Typical stage-damage functions for each type of structure were then used to estimate the flood damage that would likely occur at various flood elevations. The typical damage functions used were developed from previous Corps of Engineers studies and are intended to reflect depreciated replacement costs. The damages are estimated in one foot increments from the basement up to six feet above the first floor and include damage estimates for the structure, contents (e.g. rugs and furniture), utilities, outside grounds, and non-physical losses such as costs for evacuation. All of these damage categories are included in Corps of Engineers flood damage reduction benefit analyses.

The typical damage functions were used only for the residential structures. For the commercial structures, each individual business was contacted, and data regarding the inventory, contents, and the extent of past flood damages were collected. Damage functions to reflect damages at various levels of flooding were then estimated based on the information provided by the business owners.

The damage function for each structure was then combined with the elevation for each structure, and a total stage-damage function was developed for each reach. The total stage-damage function for each reach was then combined with a corresponding stage-frequency curve in order to determine the total flooding damages that are estimated to occur in the entire study area for flood events of varying frequency. The damages expected to occur at each flood

event are termed the recurring losses for the study area. The recurring losses for the 5, 10, 25, 50, 100, and 500 year events are shown in Table 1. The damages are shown separated into contents, structure, and total damages.

Table 1
Recurring Losses
Farm River, East Haven and North Branford, CT

Frequency of Occurrence	Contents Damages	Structure Damages	Total Recurring Losses
1 year event	$ 600	$ 3,200	$ 3,800
5 year event	$ 4,100	$ 13,500	$ 17,600
10 year event	$ 28,900	$ 75,600	$ 104,500
25 year event	$ 132,900	$ 288,700	$ 421,600
50 year event	$ 448,100	$ 843,500	$1,291,600
100 year event	$1,214,000	$1,889,000	$3,103,000
500 year event	$3,685,000	$5,223,500	$8,908,500

The contents category includes only those contents which could be moved if flood warning was provided. The structure category includes utilities, which are contents, but which are not considered moveable. The structure category also includes non-contents categories such as damage to the grounds and non-physical losses, in order that all potential damages were included. The damages to contents were determined for the residential structures based on the backup showing derivation of damages for the typical damage functions. Based on interviews with the owners, contents damages for the commercial structures were estimated at 50 percent of the total damages.

The effectiveness of a flood damage reduction plan is measured by the extent to which it reduces expected annual damages. Expected annual damages are calculated by multiplying the recurring loss at each elevation by the annual percent chance that each flood elevation will be reached. The resulting expected damages at each event are then added together, yielding the total annual damages that are projected to occur given each event's probability of occurrence. The expected annual damages for each damage reach, for contents only and for total damages, are shown in Table 2.

Table 2
Expected Annual Damages
Farm River, East Haven and North Branford, Connecticut

Damage Reach	Expected Annual Damages Contents Only	Total Expected Annual Damages
Reach 1 - Residential	$ 8,400	$25,300
Reach 1 - Commercial	$ 2,500	$ 5,100
Reach 2 - Residential	$19,200	$58,500
Reach 3 - Residential	$ 300	$ 1,000
Reach 4 - Residential	$ 300	$ 1,000
Reach 5 - Residential	$ 2,000	$ 6,300
Reach 6 - Commercial	$ 200	$ 300
Reach 7 - Residential	$ 8,000	$16,600
Reach 7 - Commercial	$ 1,000	$ 2,100
Reach 8 - Commercial	$ 2,500	$ 5,000
Total Study Area	$44,400	$121,200

DAMAGE REDUCTION ASSOCIATED WITH FLOOD WARNING

The final step in this assessment was to determine the potential flood damage reduction associated with a flood warning system. There are no commonly accepted or established methods for evaluating the benefits of a flood warning system. However, the following procedure has been used in the past and provides a reasonable approximation.

The benefits attributed to providing increased flood warning time are assumed to be entirely from reduced damages to contents in buildings. Although automobiles may also be moved out of the path of floodwaters the benefits associated with their removal was not calculated.

To accomplish this estimate a graph of percent reduction in total damages versus forecast lead time was utilized. This graph was initially published in a report prepared for the National Weather Service, but has since been used by many entities to show the general relationship of warning time to flood damage reduction. The curve is sometimes referred to as the "Day Curve", after Harold Day of the National Weather Service. Case studies of damage reduction versus warning time for residences in New York and Pennsylvania were used to develop the curve. The time parameter used in the graph is forecast lead time. The maximum possible reduction in total annual damage is 35 percent (see Figure 3).

Although forecast lead time and actual flood warning time may not be exactly the same, the substitution of the two terms for one another was felt to provide a result that could be used for the

preliminary assessment of the value of providing a warning system.

Using a forecast lead time of 7 hours in Figure 3 results in an estimated flood damage reduction of 15 percent. Using the total annual damage figure shown in Table 2, it is calculated that the reduction in flood damages with 7 hours of warning time would be about $18,000. Again, this is only an estimate. If more detailed plans for a warning system are developed, the Connecticut DEP can calculate a more refined estimate of warning time and subsequent flood damage reduction estimates.

CONCLUSIONS

Based on this analysis the following conclusions can be made. First, though small in size, the Farm River watershed responds more slowly than similar size basins, such as the nearby Muddy River. Time to peak for small to moderate storm events of 10 hours and for large storms of 18 hours are indicative of the nature of the basin's responsiveness. A flood warning time of 7 hours was also estimated, twice the time assigned to the Muddy River. It should be noted that the lack of historical flow data made it difficult to conduct the hydrologic analysis. Therefore, the feasibility of designing and installing a flood warning system in such a small basin will need to be considered carefully. Connecticut DEP should install a gage on the Farm River to monitor flows and confirm the estimated warning time. Second, a reconnaissance level analysis estimated about $18,000 in expected annual damages in the lower watershed, based on a warning time of 7 hours. Most of these benefits are attributable to the residential structures found in Reaches 1 and 2 in East Haven. Finally, reduction in flood damages due to a flood warning system assumes that response plans are implemented by the community to insure the timely notification of affected individuals and the development of plans for the safe removal of contents from the flood prone areas.

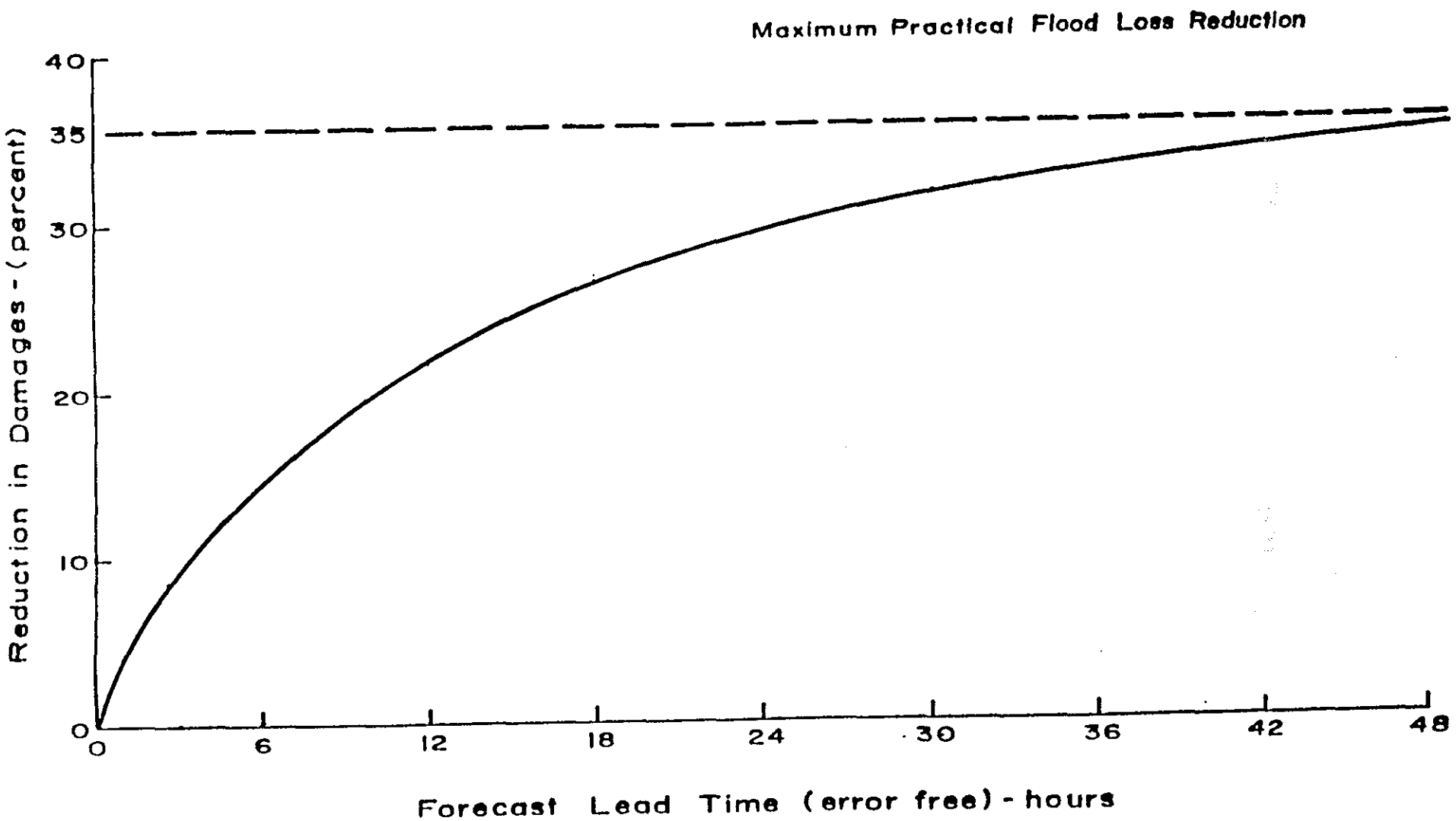

Figure 3 - Reduction in Total Flood Damages Versus Warning Time

APPENDIX A

FLOOD FREQUENCY AND FLOOD WARNING ASSESSMENT FOR THE FARM RIVER EAST HAVEN AND NORTH BRANFORD, CONNECTICUT

FLOOD FREQUENCY AND FLOOD WARNING ASSESSMENT FOR THE FARM RIVER EAST HAVEN - NORTH BRANFORD, CONNECTICUT

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10	June 1982 Flood Analysis

FLOOD FREQUENCY AND FLOOD WARNING ASSESSMENT FOR THE FARM RIVER *EAST HAVEN - NORTH BRANFORD, CONNECTICUT*

1. PURPOSE

This report presents hydrologic information and analysis pertinent to the Farm River in the communities of North Branford, and East Haven, Connecticut. Included are sections on basin description, climatology, analysis of floods, flood frequencies, and time of concentration analysis for areas subject to flooding along the Farm River. The report was prepared under the Flood Plain Management Services Authority to assist the State in evaluation of a potential flood warning system for the involved communities.

2. WATERSHED DESCRIPTION

a. General. The Farm River is a coastal basin, with a drainage area of approximately 19.72 square miles. It originates in the community of North Branford, Connecticut, and flows in a southwesterly direction for approximately 19 miles. Basin elevations range from sea level at the mouth of the river in the Long Island Sound to 340 feet NGVD at the river's source. Approximately the last 2.3 miles of the river are tidal. A map for the watershed is shown on plate A-1.

b. Tributaries to the Farm River. Major tributaries to the Farm River are a stream leading from the Pistapaug Pond located at the river's headwaters in the northern communities of Wallingford and Durham, the Burrs Brook in North Branford, and the Maloney Brook and an unnamed tributary from Graniss Pond in East Haven. An aqueduct pipe located 1,800 feet upstream of River Road bridge in East Haven diverts water to the Saltonstall Reservoir for water supply purposes.

c. Study Area. The Farm River watershed lies mostly in the towns of East Haven and North Branford, with minor areas in Branford, Durham, Guilford, and Wallingford. Development in the upper portion of the river, in the town of North Branford is mostly residential with some commercial and light industry concentrated along Route 80. In the city of East Haven, along the eastern side of the river, the region becomes more densely populated by single residences, commercial, and industrial development. The study area is shown on plate A-2.

3. CLIMATOLOGY

a. General. The Farm River Basin has a variable climate and frequently experiences periods of heavy precipitation produced by local thunderstorms, or larger weather systems of tropical and extratropical origin moving up the Atlantic Coast. The basin lies in the path of the prevailing "westerlies" that generally travel across the country in an easterly or northeasterly direction producing frequent weather changes. Due to its proximity to the Atlantic Ocean and to the Long Island Sound, the basin generally escapes the severity of cold and depth of snowfall experienced further inland. Mean maximum and minimum monthly precipitation as recorded in the nearby station of East Haven-Lake Saltonstall are listed in table A-1.

TABLE A-1

MONTHLY PRECIPITATION AT
EAST HAVEN LAKE SALTONSTALL, CT
(Period of Record 1948 - 1993)

Month	Maximum	Minimum	Mean
January	14.22	0.45	3.78
February	5.76	0.62	2.94
March	11.46	0.90	4.18
April	10.03	1.39	4.50
May	8.29	0.67	3.55
June	16.93	0.11	3.21
July	8.27	0.32	3.64
August	11.20	0.54	3.94
September	9.40	0.15	2.76
October	11.41	0.93	4.08
November	8.64	1.64	4.13
December	6.26	0.64	3.39
ANNUAL	**55.74**	**34.69**	**45.39**

b. Temperature. The average annual temperature in the Farm River Basin is approximately 50 degrees Fahrenheit, varying from average of 73 degrees in July to 29 degrees in January. Recorded temperature extremes have varied from occasional highs of over 100 to infrequent lows below minus 5 degrees Fahrenheit.

4. FLOOD HISTORY

a. General. The Farm River is an ungaged basin. Although there are no systematic records of flow for this basin it is estimated that the two greatest floods in recent history occurred in October 1955 and June 1982.

b. October 1955. The October 1955 flood was the result of almost 9 inches of rainfall in the vicinity between 14 and 17 October, with a maximum 24-hour rainfall of about 6 inches on the 15th and 16th. Antecedent conditions were also high as a result of heavy rainfall approximately two months earlier, associated with the August 1955 hurricane "Diane" storm.

c. June 1982. The greatest flood known in the area was the result of almost 13 inches of rainfall over the basin between 4 and 6 June 1982. Maximum 24-hour rainfall associated with the storm and recorded at Lake Saltonstall Station at East Haven, was approximately 9.4 inches on 5 and 6 June, which is in excess of the 1 percent chance (100-year) 24-hour rainfall of 7.1 inches, reported in U.S. Weather Bureau Technical Paper 40 (U.S. TP40).

5. *FLOOD DAMAGE AREAS*

The portion of the Farm River analyzed in this study is located north of I-95, and has a drainage area of 19.48 square miles. During the 1970s, extensive hydrologic analysis of this river was conducted by the Soil Conservation Service (SCS), Connecticut DEP, and Griswold & Fuss, Inc. (reference 1). According to Griswold & Fuss, Inc., no tidal effects are observed north of Connecticut Turnpike (I-95) for the 100-year or 50-year frequency tidal events due to the many obstacles downstream of I-95. Three damage areas have been identified as flood prone and are shown on plate A-2. Areas 1 and 2 are located in the community of East Haven. Area 3 is located in the community of North Branford. A short description of each follows.

a. Area 1, located immediately upstream of I-95 and extending to the end of the National Guard Gunnery Range (private drive 2) is the most southern flood area. The lowest elevation within this zone, adjacent to I-95, is occupied by the East Haven Middle School and various private

residences. Due to the proximity of these residences to the river and I-95, which is a restriction to floodflows, area 1 is subject to periodic flooding. It has a drainage area of 19.48 square miles.

b. Area 2, is the largest flood prone area identified during this study. It has a drainage area of 17.16 square miles and is located between the upstream end of Willow Road and the East Haven corporate limits with North Branford.

c. Area 3, with a drainage area of 13.6 square miles, is located in North Branford between the downstream end of Route 80 and 1,300 feet upstream of Totoket Road. Development in this area consists mainly of private homes and a few commercial buildings in the vicinity to Totoket Road. In addition, several commercial buildings are located in the vicinity of Route 80.

6. STAGE-DISCHARGE RELATIONSHIPS

During research of existing information for this study, it was determined that channel improvements and bridge replacements have occurred along the Farm River in some areas in East Haven. These improvements were completed during the early 1980s. This work, designed by Flaherty and Giavara, Associates (reference 2), was done to improve flows in the two damage areas in East Haven and is detailed as follows. In area 1, the work consisted of floodway and channel improvements between I-95 and Gloria Place (2,400 feet upstream of I-95). In area 2, the work consisted of replacement of four bridges-Willow, Hellstrom (south end), Hellstrom (north end) and Corbin Roads, as well as channel and floodway improvements between Corbin Road and Maple Street. A design discharge of 3,000 cfs was used to size the bridges and channel's cross sections. This design discharge was determined to be the 100-year flow, based on expected implementation of flood control work in North Branford as recommended by SCS. The SCS work was not constructed; therefore, as a result, the unmodified 100-year frequency flood discharge is 4,800 cfs. Elevations in areas 1 and 2 for the unmodified 100-year flow were reduced approximately 0.8 to 1.8 feet due to the improvements.

The channel improvements mentioned above are not referenced in the January 1991 revision of the East Haven FIS (reference 3). Two updates have been made to the initial 1975 FIS report to include coastal hydraulics and coastal erosion analysis; the riverine analysis was not updated at either time.

Due to this discrepancy with the East Haven FIS, additional calculations were necessary to estimate

stage-discharge relationships in the areas that have been affected by channel improvement. Cross section information taken from design drawings and maps, as well as new bridges and sections information were modeled using the HEC-2 Water Surface Profile computer program to determine the revised hydraulic characteristics along the affected reach.

Stage-discharge relationships for areas unaffected by the flood control improvement were developed from the previously mentioned flood insurance study.

7. FLOOD FREQUENCY ANALYSIS

a. Discharge-Frequency Relationships. There are no long term streamflow records for the Farm River Basin. For this reason, discharge frequencies were derived using a basin that is hydrologically similar. Discharge-frequency data previously developed for the West River Basin, located in the community of New Haven, were used to derive discharges of the Farm River Basin using a drainage area ratio to the 0.7 exponential power. These discharges were then compared to values developed by SCS for Flood Insurance Studies (FIS) in both East Haven and North Branford. The developed discharges, based on the West River analysis, were found to be in general agreement with those developed by SCS, but slightly lower. Discharges developed by SCS were adopted as representative for the present study due to the extensive hydrologic analysis done by SCS in this river basin. A discharge-frequency curve for the Farm River is shown in plate A-3.

b. Stage-Frequency Relationships. Eight stage-frequency curves, one at each index location, were developed for the three damage areas and are shown in plates A-4, through A-7. Since area 1 has relatively constant flood profiles, one curve, developed at Hudson Street, was considered representative of this area and is shown in plate A-4.

Area 2 has a total drop of 22 feet in elevation. Flow in this area is restricted by nine bridges, and a small dam at the Saltonstall Aqueduct. Four stage-frequency curves, 2 through 5, were considered necessary to reflect the changes in flood levels of this area. These four zones are described as follows: (1) curve 2 represents the zone between Willow Road and the north end of Hellstrom Road, with an index location midway of these streets, (2) curve 3 represents the zone between the north end of Hellstrom Road and Corbin Road, with an index location at Navarro Street, (3) curve 4 represents the zone between Corbin road and Maple Street, with an index location midway of these streets and, (4) curve 5 represents the zone between Maple Street and the town line, with an index location at River Road. Curves 2 through 5 are

shown in plates A-5 and A-6. Due to changes in topography, three index locations were identified in area 3. Two major restrictions are located in this area-Route 80 and Totoket Road Bridge. Three curves, 6 through 8, were deemed necessary to represent stage frequencies in this zone. Curves 6 and 7 represent the area downstream and upstream of Route 80, respectively, and curve 8 represents the area downstream of Totoket Road. Stage-frequency curves for area 3 are shown in plate A-7.

8. FLOOD WARNING/TIME OF CONCENTRATION

a. General. Early in the study it was determined that rainfall runoff analyses for various frequencies was necessary to cover a representative spectrum of floods. The historic floods of January 1979 and June 1982, along with the flood determined as a result of the TP40 50-year rainfall, were chosen for analysis.

b. Unit Hydrograph. Since no long term streamflow records for the Farm River Basin are available, recorded flood flow information was obtained from the Muddy River Basin, which is hydrologically similar to the Farm River. Based on this recorded data, a 3-hour unit hydrograph was developed for the Farm River Basin, which was considered representative of the region and the physical characteristics of the watershed. Table A-2 lists some characteristics of the adopted 3-hour unit hydrograph.

TABLE A-2

3-HOUR UNIT HYDROGRAPH CHARACTERISTICS

Duration	3 hours
Peak Flow	760 cfs
Lag Time	10.5 hours
Time to Peak	12 hours

c. Rainfall Development. Precipitation data for the above mentioned storms were obtained using hourly precipitation readings from Hartford Brainard Field, Bridgeport, WSO AP, Cockaponset Ranger Station, and daily readings at the East Haven, Lake Saltonstall gaging stations as well as the TP40. A short description of these storms follows.

(1) January 1979 Storm. The 24-27 January 1979 flood was preceded by several minor storms which saturated the ground. Daily rainfall values recorded at the East Haven, Lake Saltonstall station reported a maximum 24-hour rainfall of 2.1 inches between the 24th and 25th. Hourly readings for this event were approximated using values for neighboring stations. Total rainfall was estimated to be 2.32 inches, which closely approximates the reported TP40 rainfall of 2.6 inches for the 1-year event. Infiltration losses were estimated to be 0.17 inch due to ground saturation, giving a total excess of 2.15 inches of rainfall.

(2) TP40 50-Year Storm. Rainfall for a 50-year event was determined to be a total of 6.2 inches in a 24-hour duration. Infiltration losses were estimated to be 1.21 inches, with 4.99 inches of rainfall excess.

(3) June 1982 Storm. The 5-6 June 1982 flood was chosen as good representative of a larger event. Rainfall, developed for the 1982 storm, was taken from daily readings at the East Haven, Lake Saltonstall station, which recorded a total of 10.67 inches by the end of 6 June. Maximum 24-hour rainfall associated with the storm was about 9.01 inches between the 5th and 6th, which is in excess of the 100-year 24-hour rainfall of 7.3 inches reported in the TP40. Total rainfall was estimated to be 11.93 inches, total infiltration losses were computed to be 2.33 inches, giving a total excess of 9.6 inches of rainfall.

d. Flood Hydrograph Determination. Rainfall excess values were applied to the 3-hour unit hydrograph previously developed using HEC-1 Flood Hydrograph Package. Table A-3 summarizes the storm events analyzed and information determined.

(1) January 1979 Flood. Peak discharges associated with this storm were estimated to be 1,400 cfs. This peak discharge approximates the 2-year event chance of occurrence. Plate A-8 shows the January 1979 rainfall runoff and hydrograph analysis.

(2) TP40 50-Year Flood. The 24-hour, 50-year event developed, using the adopted 3-hour unit hydrograph, produced a peak discharge of 3,400 cfs and 6.2 inches of runoff volume. Plate A-9 shows the rainfall runoff and computed hydrograph information for the TP40 50-year event.

(3) June 1982 Flood. Peak discharge associated with this storm was estimated at 4,600 cfs, which is just below the 4,800 cfs discharge frequency for a 100-year event. The June 1982 rainfall-runoff and hydrograph analysis for the Farm River is shown on plate A-10.

TABLE A-3

STORM ANALYSIS SUMMARY

	Jan. 1979	50-Year	June 1982
Total Rainfall	2.3	6.2	11.9
Period of Rainfall (hrs.)	19	24	46
Peak Flow (cfs)	1,400	3,400	4,600
Time to Peak (hrs.)	10.5	10.5	18
Antecedent Flow Conditions (cfs)	60	40	60

9. CONCLUSIONS

Three storms were analyzed to assist in flood warning evaluation for different frequency and different antecedent conditions. Due to the size of the watershed, it is estimated that the time of concentration and warning time is the same for all flood areas under investigation.

Table A-3 summarizes pertinent study results. Large events, such as the June 1982 flood, produced an estimated peak discharge of 4,600 cfs, which has about 1 percent chance of occurrence. The 50-year storm, developed from TP40 rainfall has an estimated peak discharge of 3,400 cfs, which is slightly lower than adopted discharge frequencies but within allowable limits. A more frequent event, such as the January 1979 flood, produced a peak flow of 1,400 cfs, which would represent about a 2-year event. Time to peak for this storm was 10.5 hours.

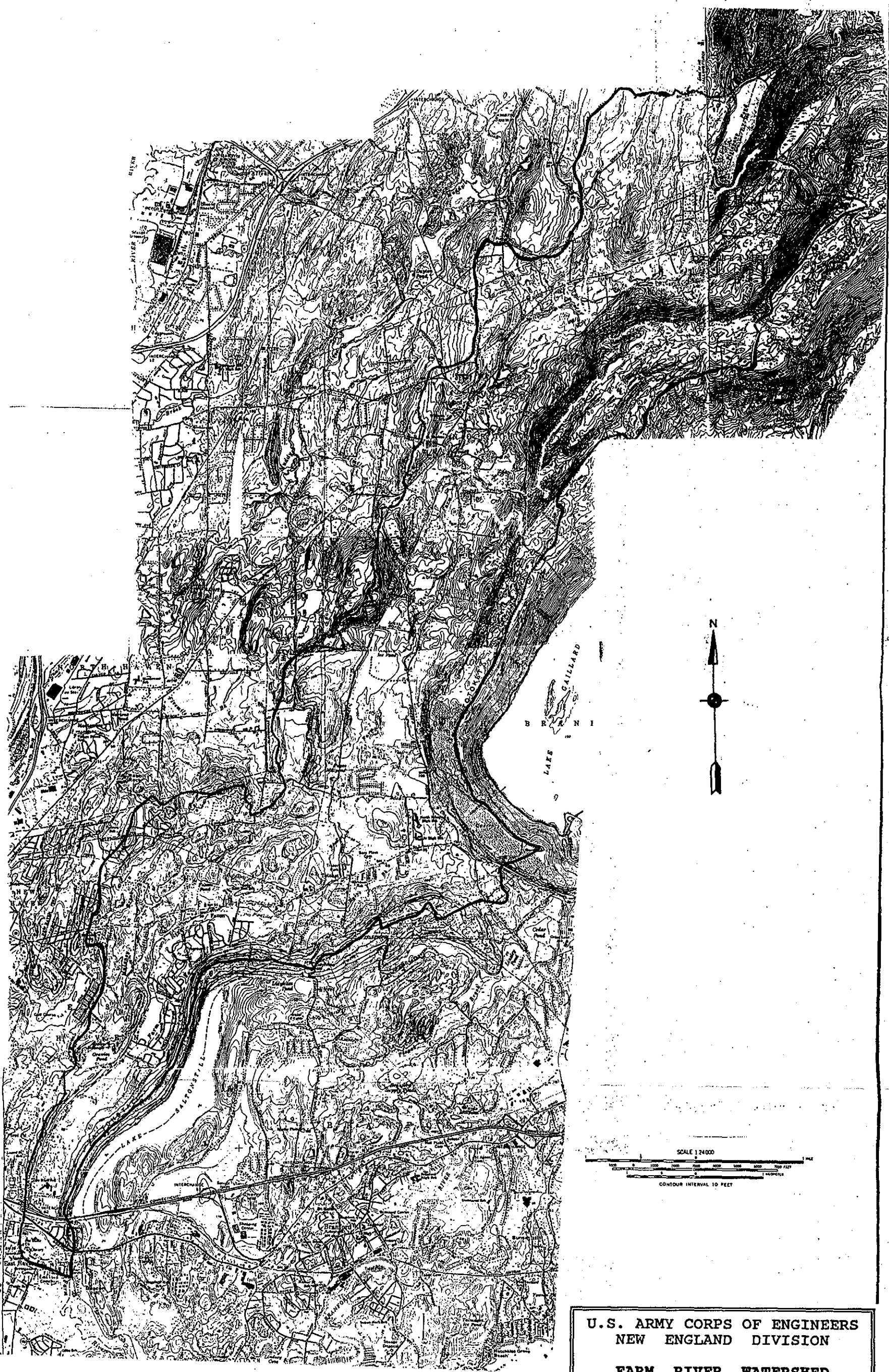
Analysis of the flood hydrographs on plates A-9 (50-year) and A-10 (June 1982) show times to peak from the centroid of the rainfall ranging from about 10 to 18 hours. From a flood warning perspective, however, we believe a more important time is from the recognition of significant rainfall to the point where river flooding begins. Assuming flooding begins at a 3,000 cfs discharge (channel capacity of improvements) and an approximate 20-year flood event, warning times based on the computed hydrographs would range from 7 to 14 hours. Therefore, for flood warning purposes we recommend to use flood warning times of 7 to 14 hours.

REFERENCES

1. Griswold & Fuss, Inc., Study for a Flood Protection Plan of the Farm River, East Haven, Connecticut, January 1975.

2. Flaherty Giavara Associates, P.C., Schematic Design Report, Farm River Flood Control Project for the Town of East Haven, Connecticut, and the Department of Environmental Protection, September 1977.

3. U.S. Department of Housing and Urban Development, Federal Insurance Administration. Flood Insurance Study for the Town of East Haven, Connecticut, January 1991.



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FARM RIVER WATERSHED
New Haven and
Middlesex Counties

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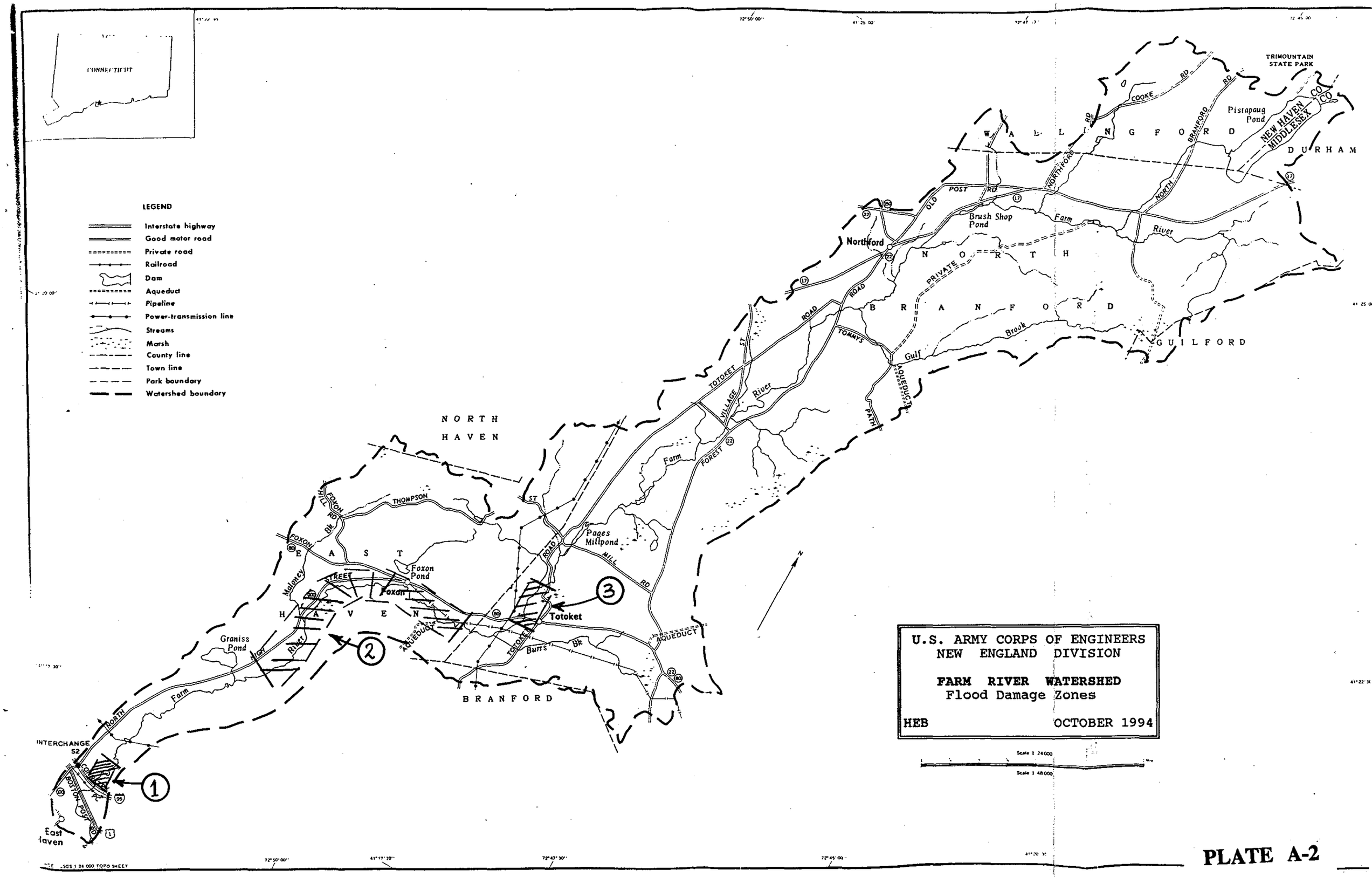
PLATE A-1



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FARM RIVER WATERSHED
Flood Damage Zones

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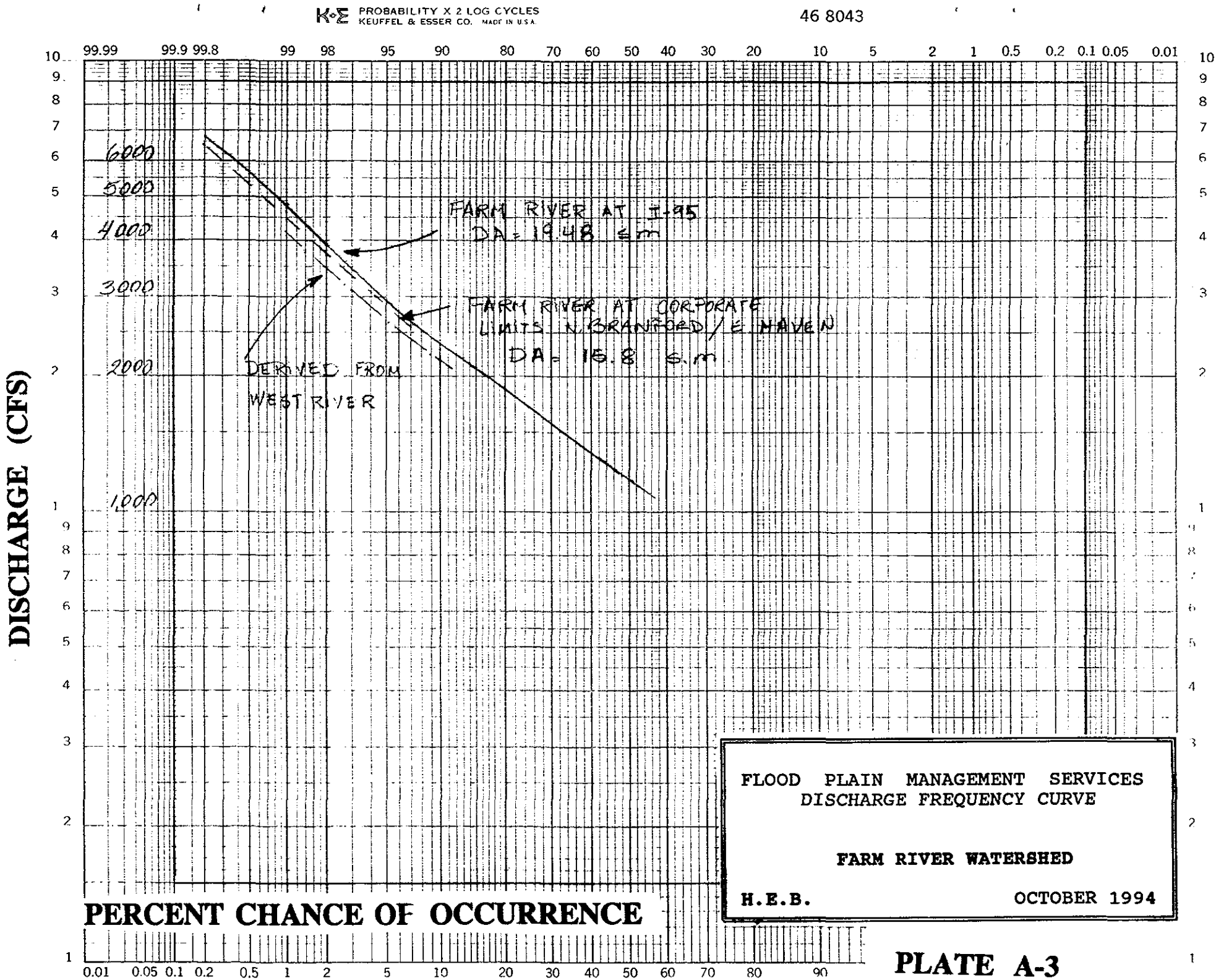
PLATE A-2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4000
3000
2000
1000
FARM RIVER AT I-95
DA = 19.48 s.m.
FARM RIVER AT CORPORATE LIMITS N. BRANFORD / E. HAVEN
DA = 16.8 s.m.
DERIVED FROM WEST RIVER
FLOOD PLAIN MANAGEMENT SERVICES
DISCHARGE FREQUENCY CURVE
FARM RIVER WATERSHED
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PLATE A-3

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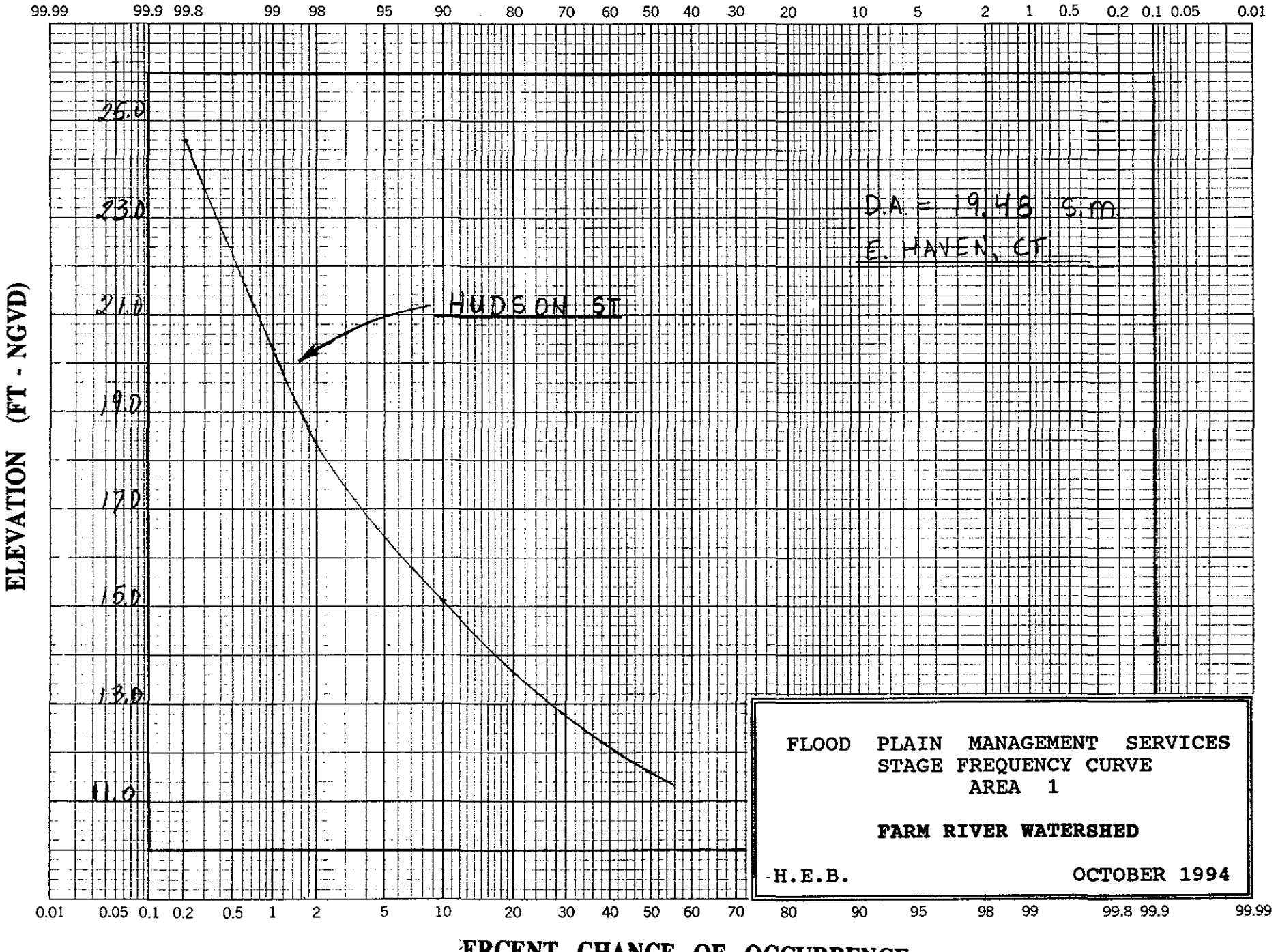

FLOOD PLAIN MANAGEMENT SERVICES
STAGE FREQUENCY CURVE
AREA 1

FARM RIVER WATERSHED

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PLATE A-4

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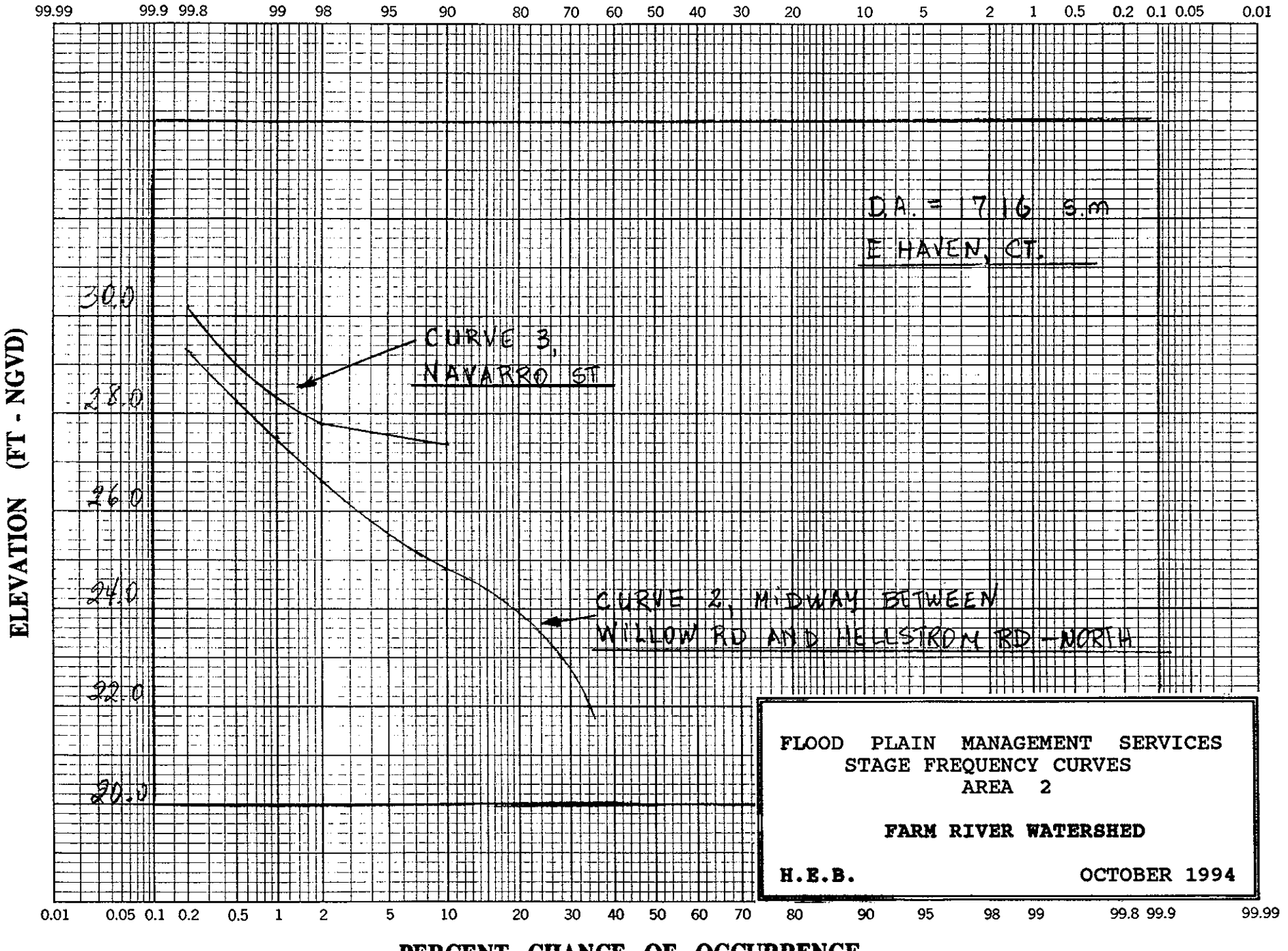

PLATE A-5

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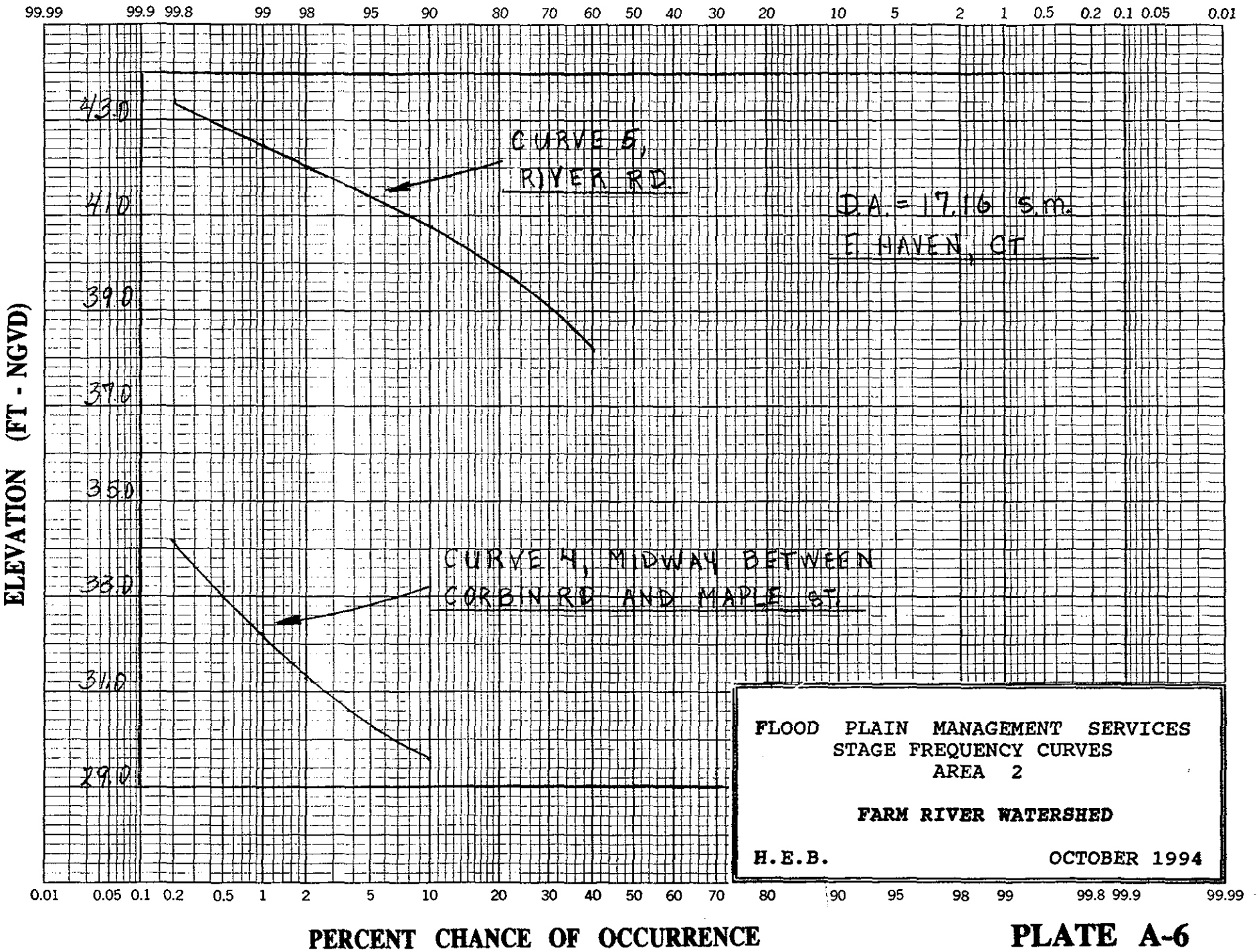

FLOOD PLAIN MANAGEMENT SERVICES
STAGE FREQUENCY CURVES
AREA 2

FARM RIVER WATERSHED

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PLATE A-6

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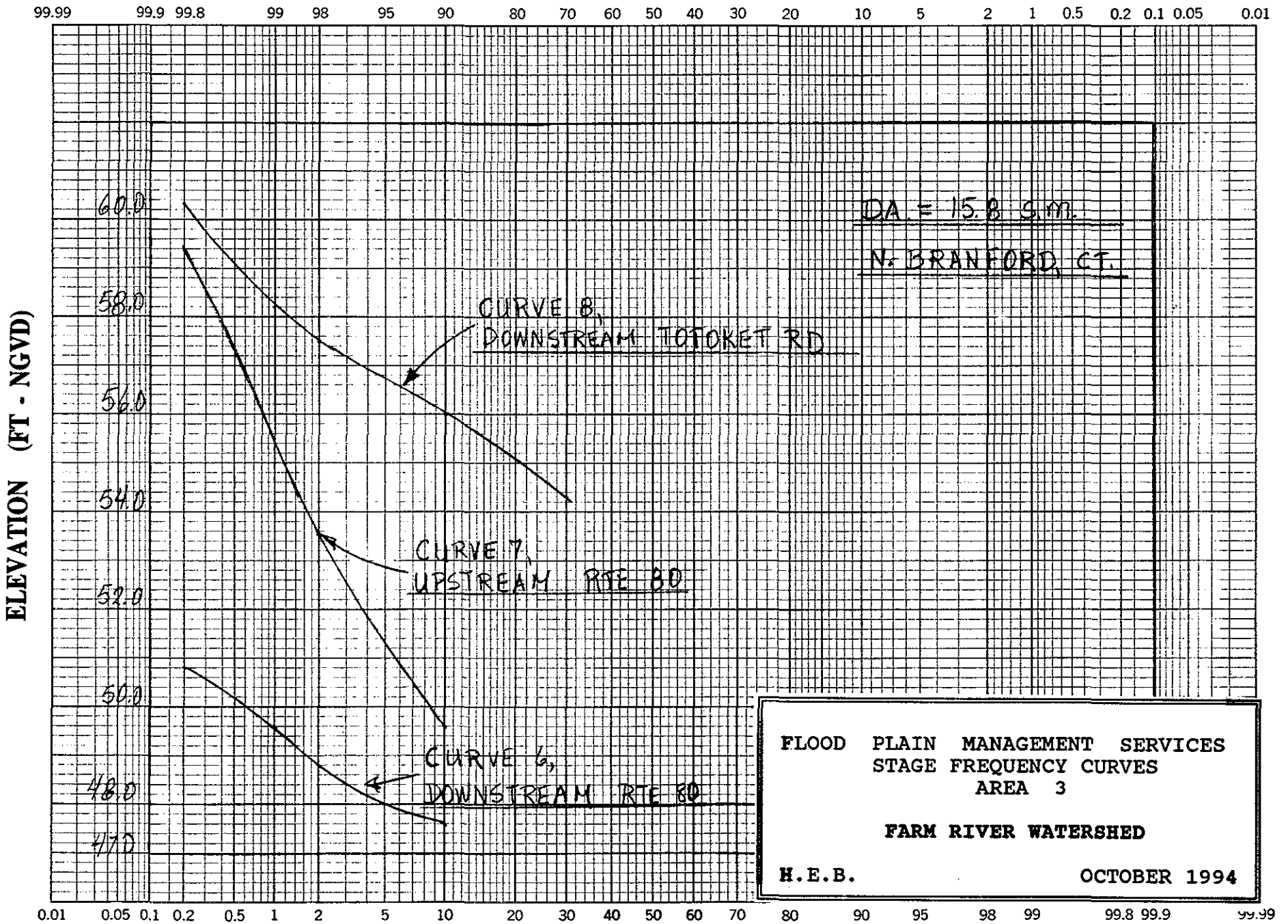
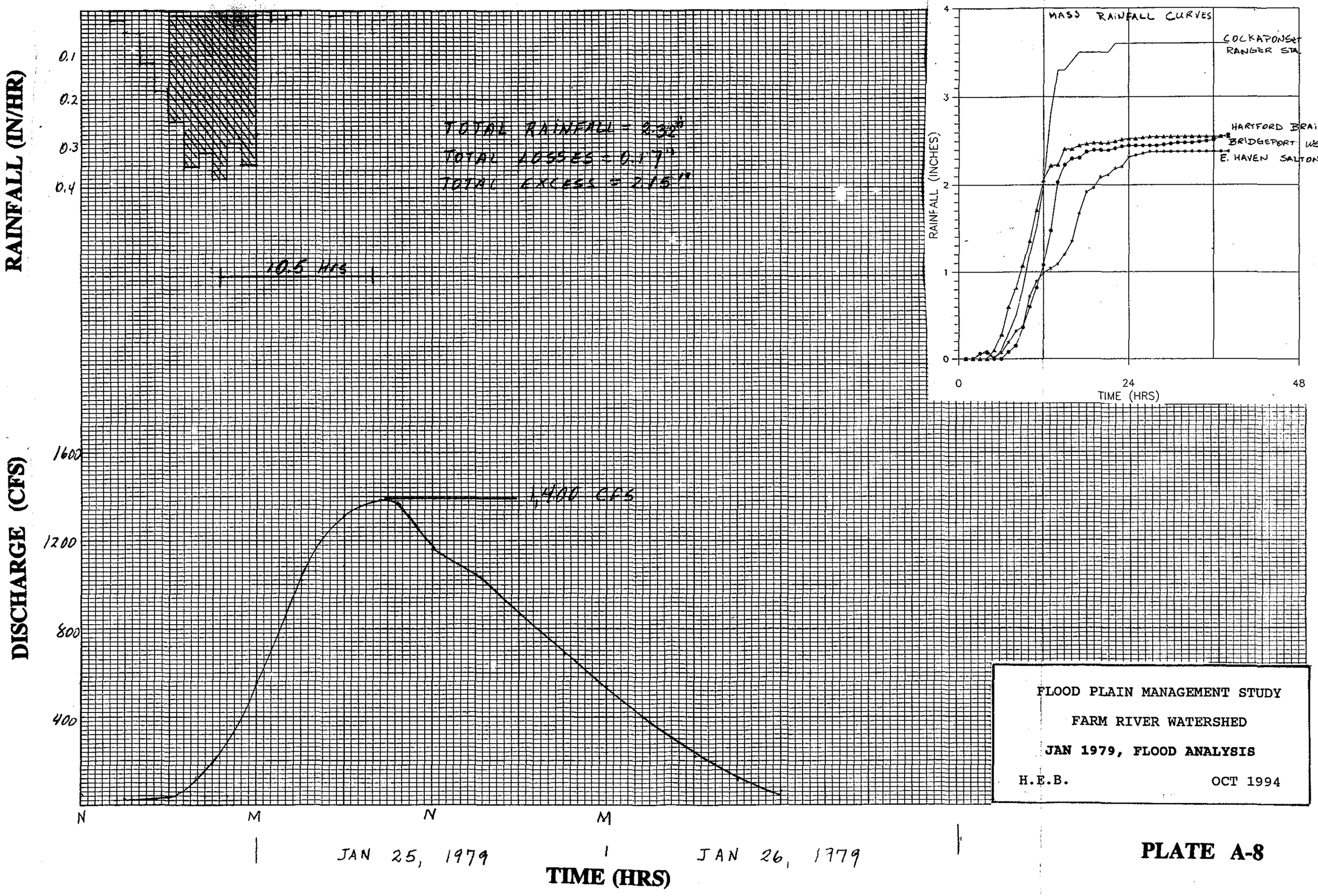


PLATE A-7



FLOOD PLAIN MANAGEMENT STUDY

FARM RIVER WATERSHED

JAN 1979, FLOOD ANALYSIS

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PLATE A-8

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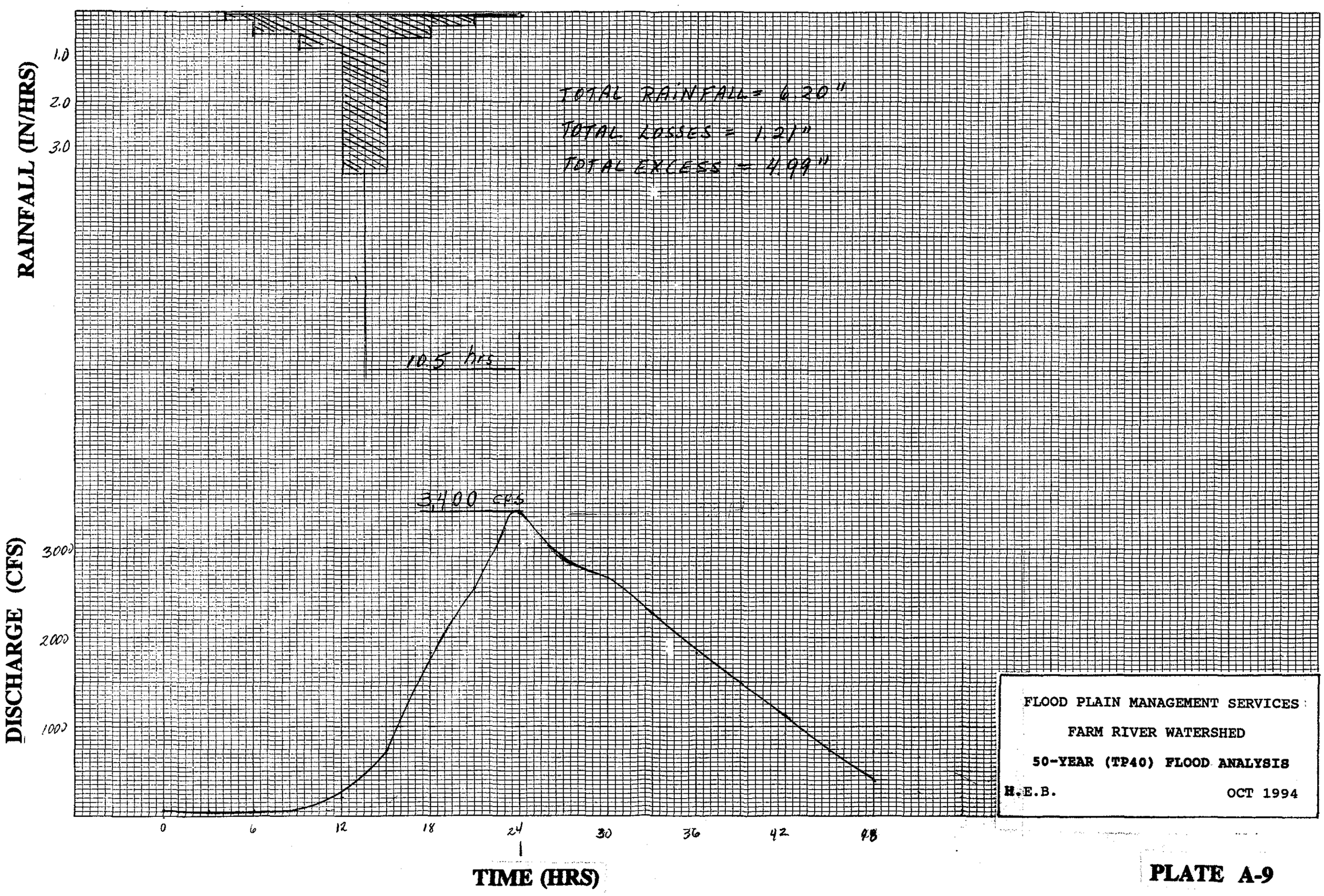
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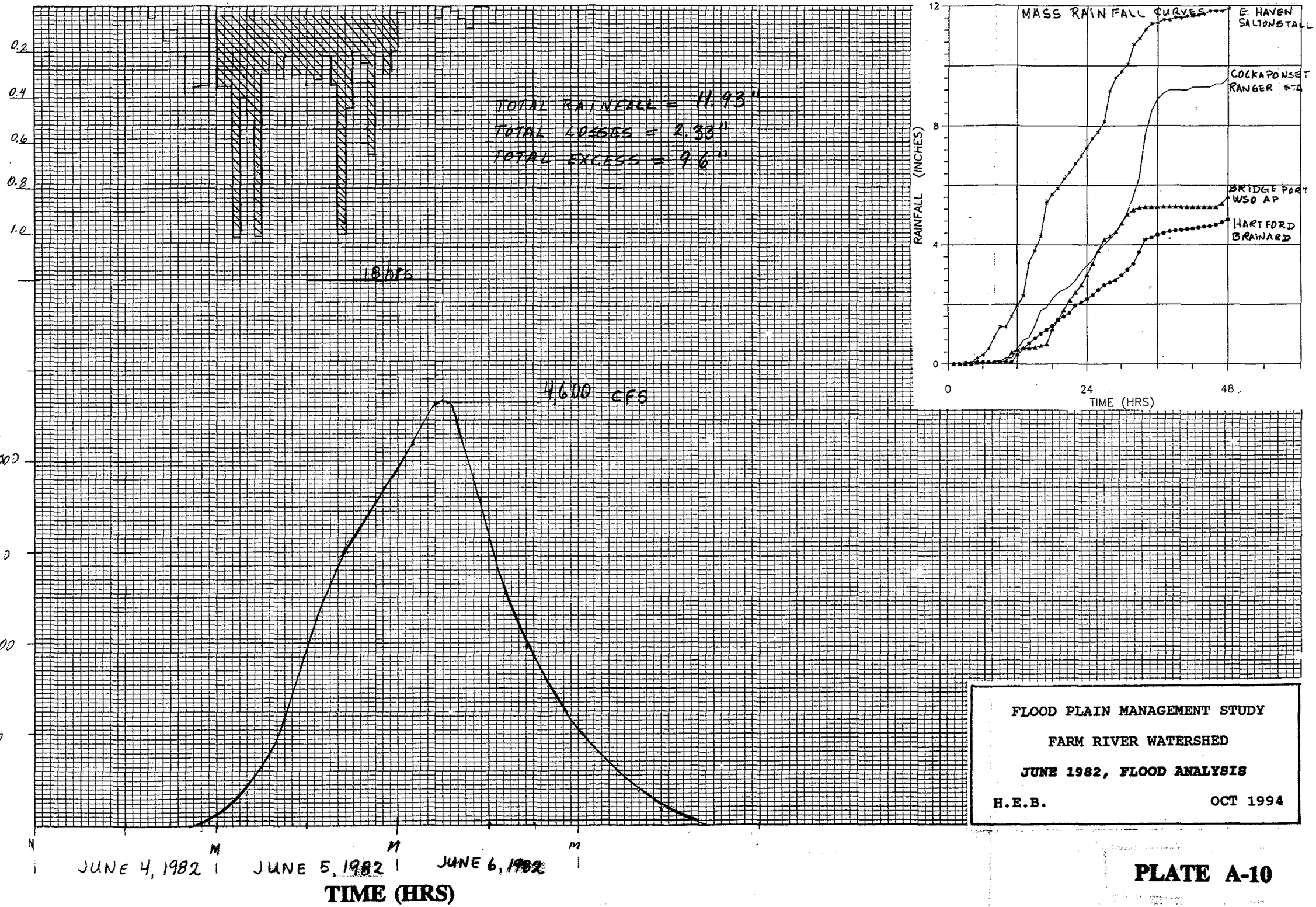
2.0
3.0
TOTAL RAINFALL = 6.20"
TOTAL LOSSES = 1.21"
TOTAL EXCESS = 4.99"
10.5 hrs
3,400 CFS
DISCHARGE (CFS)
3000
2000
1000
0
6
12
18
24
30
36
42
48
TIME (HRS)
FLOOD PLAIN MANAGEMENT SERVICES
FARM RIVER WATERSHED
50-YEAR (TP40) FLOOD ANALYSIS
H.E.B.
OCT 1994

PLATE A-9



FLOOD PLAIN MANAGEMENT STUDY

FARM RIVER WATERSHED

JUNE 1982, FLOOD ANALYSIS

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PLATE A-10

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