ANALYSIS OF FLOODING
LILLY RUN
HAVRE DE GRACE, MARYLAND

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Water Resources Administration

Flood Management Division

Maryland Department of Natural Resources

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ANALYSIS OF FLOODING
CITY OF HAVRE DE GRACE

1.0 INTRODUCTION

1.1 Purpose of Study

This analysis of flooding investigates the existence and severity of flood hazards in the City of Havre de Grace, Harford County, Maryland. The study will aid in the administration and promotion of sound floodplain management.

1.2 Authority and Acknowledgements

The authority for this study is the Flood Hazard Management Act of 1976. The hydrologic and hydraulic analyses were performed by the State of Maryland, Water Resources Administration (WRA), Flood Management Division.

The WRA Technical Services Division performed the field survey work necessary to develop the technical data. Graphics support was provided by the Waterway Improvement Division of the Department of Natural Resources, Tidewater Administration, and the WRA Water Supply Division.

1.3 Coordination

On September 13, 1984, the description and other relevant information on the flood hazard areas were identified and discussed at the initial consultation meeting attended by representatives of Havre de Grace and Maryland WRA. Further coordination occurred throughout the course of the study with the Federal Emergency Management Agency (FEMA), the City of Havre de Grace, and Harford County.

2.0 AREA STUDIED

2.1 Scope of Study

This study covers the incorporated area of the City of Havre de Grace. The vicinity map of the area is shown in Figure 1.

The floodplain areas studied by detailed methods were selected with priority given to flood hazard areas with projected development or proposed construction through December 1989.

Lilly Run and Ivy Run were studied by detailed methods. Lilly Run's study reach extends from its confluence with the Susquehanna River to the upland area above the Baltimore and Ohio Railroad. The Ivy Run study reach extends from its confluence with Lilly Run to the area above the Baltimore and Ohio Railroad.

The Susquehanna River and the Chesapeake Bay, which are also sources of flooding in the vicinity of Havre de Grace, have been studied by detailed methods by the Federal Emergency Management Agency (Reference 1), and the Virginia Institute of Marine Sciences (Reference 2).

2.2 Community Description

The City of Havre de Grace is located along the southeastern boundary of Harford County in northeastern Maryland. It lies at the mouth of the Susquehanna River on the Chesapeake Bay. Since 1900 the population of the City has experienced an average growth of 14.1 percent per decade in spite of a 9.7 percent decline from 1970 to 1980, and a 9.0 percent decline from 1920 to 1930. The total land area contained within the corporate limits is 2.7 square miles. The climate of the area is humid continental with warm summers.

Most of the floodplain in the study area is developed. A significant portion of this land is used for residential development. Businesses and publicly owned property also lie within the floodplain along Lilly Run. Much of the remaining floodplain along the Susquehanna River is used for gasoline storage tanks and marina facilities.

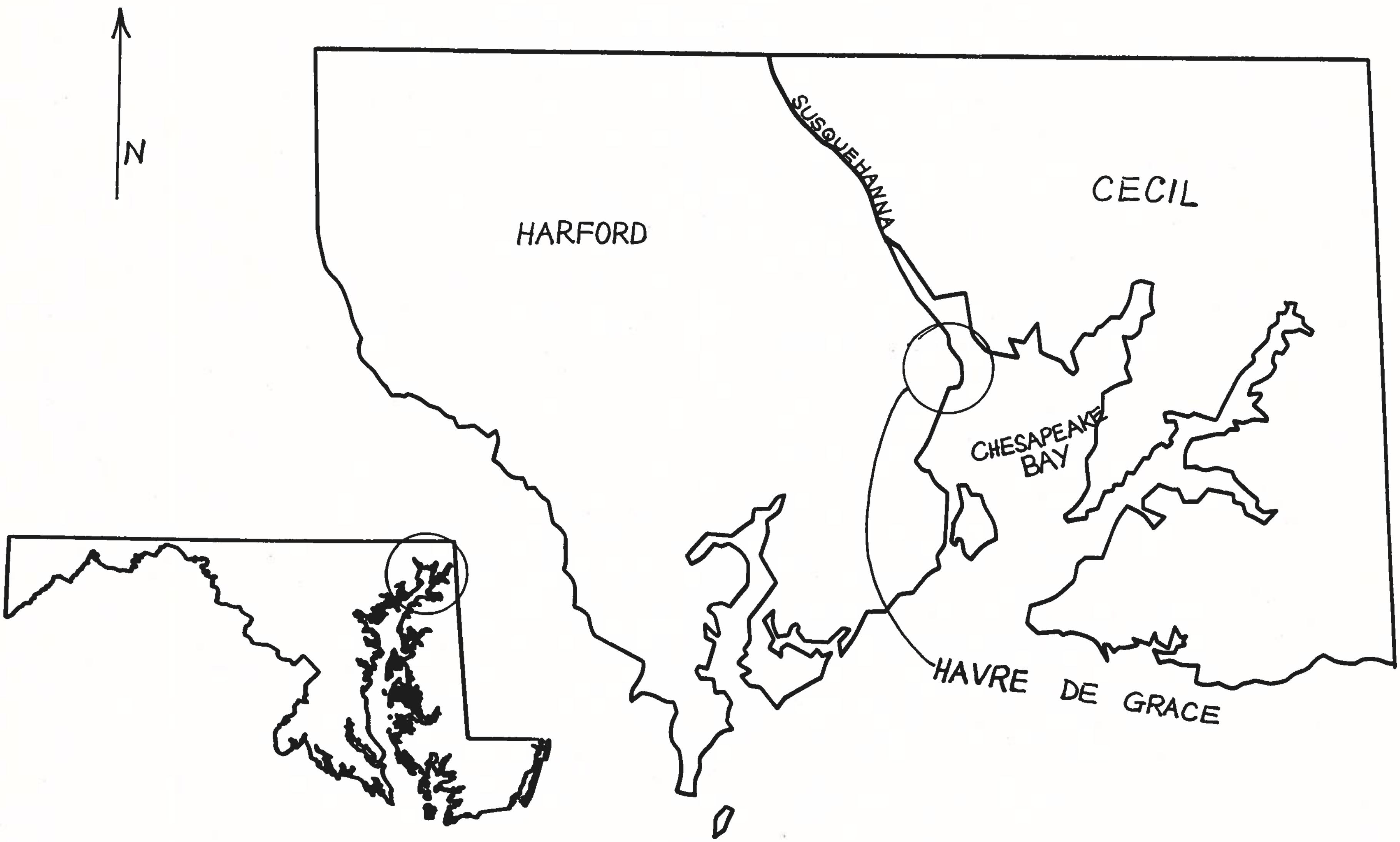

FIGURE 1
VICINITY MAP
CITY OF HAVRE DE GRACE
HARFORD COUNTY, MARYLAND

2.3 Principal Flood Problems

There are three distinct though related flooding problem areas within Havre de Grace (See Appendix A - Floodplain Map). The lower end of Lilly Run is completely enclosed from just upstream of the intersection of Juniata Street with Otsego Street. This drainage structure extends northward under Juniata Street for more than 800' before turning to the northeast to outlet below Locust Road at the Susquehanna River. Based on the hydraulic analysis described below in Section 3, this culvert has a maximum inlet discharge capacity of 520 cubic feet per second (cfs). This volume is exceeded by storms greater than the 2-year event as indicated in Figure 2. It is therefore apparent that relieving the flooding for any event of greater magnitude would require complete replacement and enlargement of the entire drainage structure in order to convey the discharges without resulting in street flooding. The difference in water surface elevations between the 2- and the 100-year storm events is 2.8 feet. However, the difference between the 10- and the 100-year events is only 1.2 feet. Thus it appears that the severity of street flooding through the City along the lower end of Lilly Run is relatively insensitive to changes in discharge for the less frequent events.

The middle reach of Lilly Run is generally defined as extending from the Pennsylvania Railroad (Amtrak) upstream to above Pusey Street. The flooding problems in this area are characterized by flooded homes and other structures as well as flooded streets causing restricted access. This stretch of stream is highly developed with numerous culverts, crossings, encroachments and poorly maintained channels. The flat channel grade below Revolution Street (Structure No. 7) compounds the flooding, resulting in a general spreading out of water and a decrease in velocity. The low grade does not allow for rapid drainage. The short distances between many of the drainage structures in this area also compound poor effective drainage. Optimum capacities are rarely achieved due to limitations caused by backwater from downstream culverts.

As will be shown in a later section, the stone arch culvert under the Amtrak railroad bed (Structure No. 2) has a capacity of 353 cfs which is limited by the backwater caused by Structure No. 1, the undersized

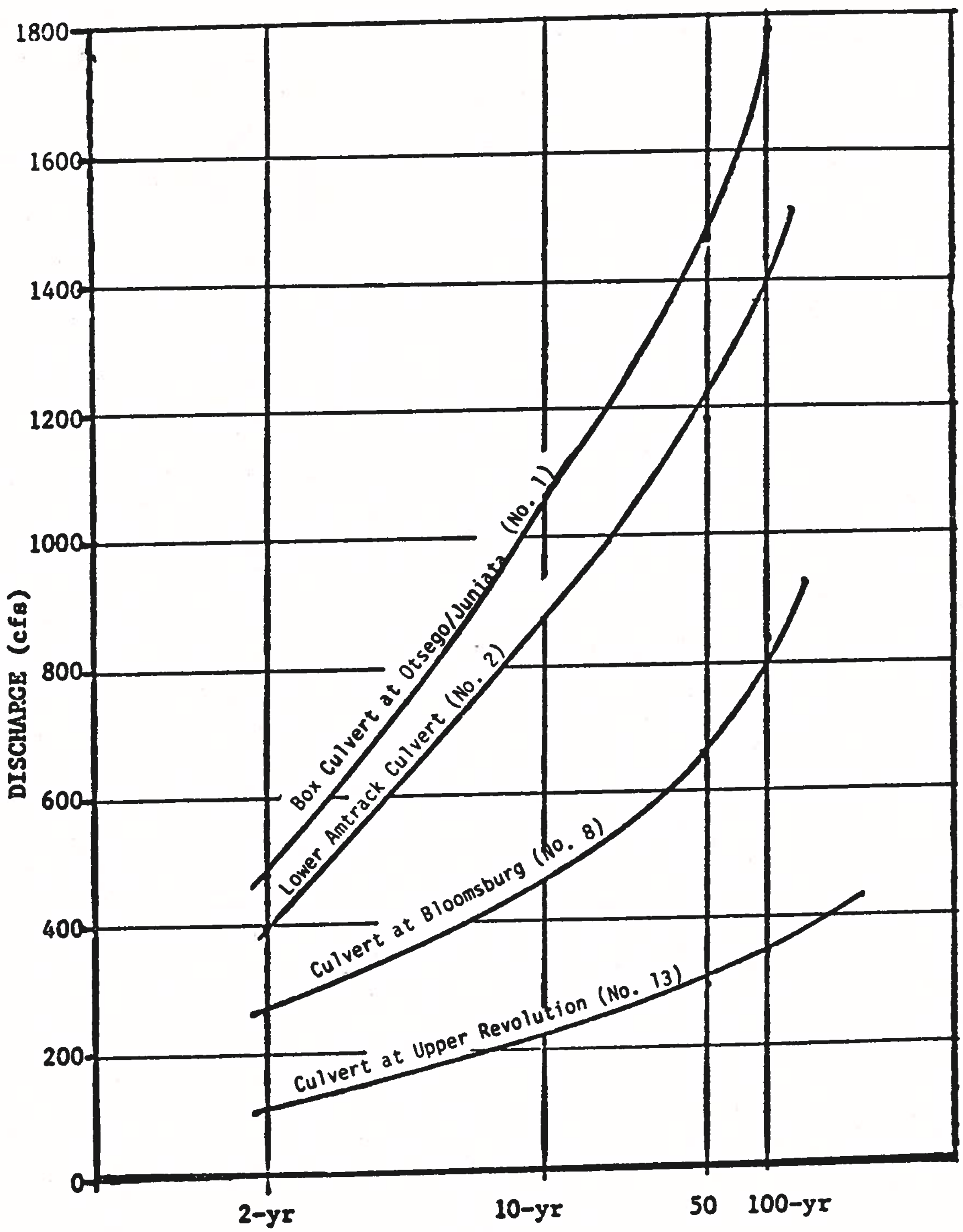

FIGURE 2

DISCHARGE-FREQUENCY CURVES

box culvert under the lower end of the City. The 100-year discharge at Structure No. 2 is 1,418 cfs. The water surface elevation difference at Structure No. 2 for the 2- and the 100-year events is 4.4 feet. Only a 0.6 foot difference occurs between the 10-year and the 100-year events. As mentioned, the flat grade above this area combines with the backwater resulting in flooding which extends upstream to Revolution Street (Structure No. 7). This backwater adversely affects the drainage performance of all structures within the reach. Further, it indicates that any solution to this problem will involve increasing the effective opening through the railroad embankment. It is very important to state here that increasing the drainage efficiency of the middle reach of Lilly Run may exacerbate the flooding problems in the lower reach by conveying greater volumes of water downstream. However, the insensitivity of the lower reach to increased discharges may result in an acceptable level of increase.

The upper reach of Lilly Run extends from the area where the stream parallels the railroad, upstream through the community of Baybrook above Bay Boulevard. The flooding in this area is attributable to undersized culverts and inefficient channel modifications which force the stream to make abrupt direction changes. Although no flooding of homes in this area has been reported, on several occasions water has approached that level. Both Bay Boulevard and Revolution Street experience approximately 1 foot of water over the road during the 100-year event. Although passage of some vehicles may be restricted for a short time, water depths of 1 foot or less are not considered dangerous. Though recognized as a potential problem, the flooding in this upper reach is not considered to present eminent danger to life and property.

Ivy Run, a tributary to Lilly Run, was included in this study because of possible hydraulic effects on Lilly Run. No problem flooding areas along Ivy Run were reported by the City of Havre de Grace. The flood profiles for this stream indicate that the existing storm drain system will not convey all flood volumes and may result in affecting some nearby structures.

This report and the investigations which were performed to support it will concentrate on the problems and alternative solutions for reducing the flood related hazards along the middle reach of Lilly Run.

2.4 Background

In 1966, Havre de Grace retained the Baltimore consulting firm of Hsi, Brenner and Day to investigate and report on storm drainage and improvements to Lilly Run (Reference 3). Although the methodologies used are now considered out-of-date, that report presented a thorough evaluation of the problem and the numerous complexities involved in making an assessment. It is critical to realize that the intent of that report and the alternatives investigated were to provide for improved storm drainage for only the 5-year storm. This frequency event was chosen because it is generally considered economically unsound to design storm drainage facilities for more extreme events such as the 100-year storm. While the 5-year event is indeed the standard normally adopted for storm drainage work, the circumstances and flooding history of Lilly Run preclude the application of this standard. Because flooding of streets, homes, and businesses does occur, the problem cannot be defined simply as a storm drainage issue. Application of alternatives to provide flood management for the 100-year event is required, even though flooding problems are evident during more frequent events such as the 10-year storm.

Several alternatives were presented in the Hsi, Brenner and Day report. Among them are the following:

1) Rebuild all existing inadequate drainage structures to accommodate the 5-year design flows; provide some channel improvements.

   While these actions would provide some relief, it is apparent that flooding would still occur. The alternative was also considered to be expensive.

2) Direct Lilly Run from just below the Pennsylvania Railroad (Amtrak), in its headwaters, to flow parallel to the railroad to rejoin the mainstem stream at the lower railroad drainage structure.

   This alternative was not recommended due to high initial costs as well as long term maintenance costs. Also, the report clearly states that this major diversion would not relieve flooding at the lower end of Lilly Run.

3) Divert Lilly Run from just below Bay Boulevard in Baybrook generally southward to outlet at the Chesapeake Bay adjacent to the sewage treatment plant.

   This alternative includes a very long (3,450') large culvert which was proposed to carry only the peak flow from the 5-year storm. Therefore, flows in excess of this would continue to cause flooding throughout the length of Lilly Run.

Inherent in all of the recommendations investigated was the establishment of a routine channel maintenance program. Such efforts would include silt removal as well as regular mowing to maintain improved flow of high waters.

3.0 ENGINEERING METHODS

Standard hydrologic and hydraulic study methods were used to determine the floodplain data for this study. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 2-, 10-, 50-, or 100-year period (recurrence interval) have been selected as having special significance for floodplain management and for establishing flood insurance rates. These events, commonly termed the 2-, 10-, 50-, and 100-year frequency floods, have a 50, 10, 2, and 1 percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at shorter intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than one year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1 percent chance of exceedance annually) in any 50 year period is approximately 40 percent (4 in 10). For any 90 year period, the risk increases to approximately 60 percent (6 in 10).

The analyses reported herein reflect flooding potentials based on stream conditions existing at the time of completion of this study. Maps and flood elevations can be amended periodically to reflect changes in land use and stream conditions.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge frequency and peak elevation frequency relationships for floods of the selected recurrence intervals for both Lilly Run and Ivy Run. The TR-20 computer program (Reference 4) was used to determine all peak discharges. Peak discharges for the 2-, 10-, 50-, and 100-year floods of each flooding source studied in detail are shown in Table 1.

TABLE 1 - SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area (sq. mi.)	Peak Discharges (cfs) 2-year	10-year	50-year	100-year
LILLY RUN					
Juniata & Otsego Streets	1.72	474	1067	1454	1772
Penn Railroad: Amtrak	1.4	394	868	1162	1418
Three-cell box culvert Huber Corp.	1.0	166	366	483	598
Revolution Street (above BayBrook)	0.80	258	457	619	815
Revolution Street	0.43	106	218	278	334
B & O Railroad	0.34	59	189	287	364
IVY RUN					
Confluence with Lilly Run	0.163	149	352	492	599
B & O Railroad	0.09	38	97	139	171

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of the streams in the community were carried out to provide estimates of the water surface elevations for corresponding discharges of the selected recurrence intervals. Input data for the backwater from the Susquehanna River analyses were developed from field surveys performed by WRA. Cross sections were surveyed directly above and below all bridges and culverts to accurately model the floodplain and to compute backwater effects from these structures. Additional information and supplemental cross sections were determined from detailed topographic maps prepared by the Susquehanna River Basin Commission with a scale of 1:200 and a contour interval of five feet (Reference 5).

Locations of selected cross sections and structures used in the hydraulic analyses are shown on the floodplain maps and flood profiles contained in the exhibit section and the appendices.

Roughness coefficients (Manning's "n") were assigned from information collected in the field regarding vegetation, type of channel lining, surface soils, and channel and bank irregularities. Higher "n" values reflect greater roughness, for example caused by overgrown vegetation or trees adjacent to the channel. The range of "n" values for each stream is shown in the following tabulation:

Stream	Channel "n"	Overbank "n"
Lilly Run	0.012-0.063	0.025-0.07
Ivy Run	0.012-0.064	0.025-0.06

Water surface elevations were computed through the use of the U.S. Army Corps of Engineers HEC-2 step-backwater computer program (Reference 6). The 100-year starting water surface elevation was obtained from the Susquehanna River Study prepared by FEMA (Reference 1).

The flood profiles shown in the exhibits were plotted showing the computed water surface elevations of floods for the selected recurrence intervals.

The hydraulic analyses for this study are based only on the effects of unobstructed flow. The flood elevations as shown on the profiles are therefore considered valid only if the hydraulic structures, in general, remain unobstructed and if the channel and overbank conditions remain essentially the same as ascertained during this study. Maintenance of the channel to minimize debris blockage will reduce the possibility of greater flooding impacts than depicted herein.

All elevations are referenced from the National Geodetic Vertical Datum of 1929. A summary of peak elevation-frequency relationships is shown in Table 2, in which the elevations are indicated for the upstream end of each culvert or crossing.

TABLE 2 - SUMMARY OF WATER SURFACE ELEVATIONS
(Existing Condition)

Flooding Source and Location	Elevation (feet above MSL) 2-Year	10-Year	50-Year	100-Year
LILLY RUN				
Susquehanna River	7.5	9.1	9.9	10.3
Juniata & Otsego Sts.	15.7	19.5	19.9	20.1
Confluence with Ivy	18.4	19.8	20.3	20.6
Penn Railroad (Amtrak)	18.4	19.8	21.2	21.4
Football Field	24.1	24.8	26.5	26.9
Three-cell box culvert Huber Corp.	24.5	25.3	26.5	26.9
Revolution Street	25.8	27.3	27.4	27.6
Bloomsbury Avenue	29.0	29.1	29.3	29.4
Pusey Street	31.4	32.1	32.3	32.4
Seneca Avenue	36.5	36.9	37.2	37.4
Bay Boulevard	37.6	37.8	37.9	38.1
Revolution Street	39.8	41.3	41.3	41.5
Penn Railroad (Amtrak)	48.2	49.3	50.4	51.2
U. S. Route 40	53.9	60.0	64.3	65.2
IVY RUN				
Confluence with Lilly	18.4	19.8	20.3	20.6
Storm Drain (outlet)	33.1	35.2	37.1	37.4
Lower Grid Top	36.7	40.0	40.5	40.7
Upper Grid Top	39.8	40.9	42.2	43.0
Man Hole	50.2	52.1	52.5	52.8
U.S. Route 40	66.2	69.1	69.3	69.4

4.0 RECOMMENDATIONS

4.1 The Problem

The headwaters of Lilly Run originate approximately one mile northwest of the city limits of Havre De Grace and run a stream length of about three miles to the Susquehanna River. The drainage area is approximately 1.8 square miles.

There are sixteen structures that cross Lilly Run, fourteen of which lie within the corporate limits of Havre De Grace. Within the city limits, 50% (7 of 14) of the structures are flooded by the 2-, 10-, 50-, and 100-year frequency storms. Seventy-nine percent (11 of 14) are flooded by the 10-, 50-, and 100-year storms, and 93% (13 of 14) are flooded by the 100-year storm. The channel areas between the structures are also inadequate to handle these flows. This indicates that flooding problems occur along the entire length of Lilly Run where it backs up and ponds above the structures and out of stream banks.

Conceivably, severe rain storms will flood major roads and limit access to the City from within and without. In emergency circumstances it is essential to maintain access for fire, medical, and police services. Those flooded areas where maintaining access is critical are Revolution Street near Parkway Avenue, Revolution Street at Lewis Lane, and along Revolution Street and Juniata Street. In the lower part of the City, street flooding described in Section 2.3 may restrict some traffic but does not limit critical emergency access. The range of flooding around the critical areas is shown in Table 3. As shown during the 100-year storm, flooding in excess of 1 foot occurs at the corner of Otsego and Juniata Streets, all along Juniata Street from Otsego Street to Revolution Street, and at Revolution Street near Lewis Lane. There is also flooding on Seneca Avenue and Bay Boulevard but these roads are not critical to emergency access.

The capacities of several culverts are affected by the flooding of downstream culverts. This occurs because the proximity of the culverts results in backwater which limits the ability of the upstream culvert to discharge water efficiently. The discharge capacities indicated in Table 4 reflect the effect backwater has on some culverts.

TABLE 3 - DEPTH OF FLOODING OVER DRAINAGE STRUCTURES ON LILLY RUN
(Existing Conditions)

Flooding Location	Depth of Water(feet) 2-Year	10-Year	50-Year	100-Year
Otsego/Juniata Streets	0.3	1.7	2.1	2.3
Revolution @ Juniata	--	0.6	0.7	0.9
Along Juniata St.	0.6 to 3 for all events			
Revolution @ Lewis Ln.	--	0.9	1.1	1.3
Seneca Avenue	1.0	1.4	1.7	1.9
Bay Boulevard	0.5	0.7	0.8	1.0

TABLE 4 - EXISTING DRAINAGE STRUCTURE CAPACITIES
(LILLY RUN, WITHIN CITY LIMITS)

Structure Number	Location	Type	Length (Feet)	Capacity (cfs)
1	Juniata/Otsego Sts.	7.5' x 5.9' RC Box	1610	520
2	Penn RR (Amtrak) near Juniata St.	11.6' x 13.7' Stone Arch	127	353*
3	Multiple RR sidings near Bourbon St.	8' w/ open top	169	525*
4	Athletic Field, near Bourbon St.	72' x 44' CMP	290	112*
5	Three-cell box Culvert (Huber)	10' x 5.4' RC	54	1470*
6	No Longer Exists		--	--
7	Revolution St. near Juniata St.	Dual 48" RCP	76	255*
8	Bloomsbury Ave.	Dual 48" RCP	51	225*
9	Pusey St.	Dual 48" RCP	37	220*
10	RR Siding	17.0' x 3.4' Bridge	17	450*
11	Seneca Ave.	Dual 48" C.I.P. 36" C.I.P.	45	210*
12	Bay Blvd.	Dual 50" x 31" CMP	150	108*
13	Revolution St. above Baybrook	48" RCP	50	110*
14	Junk Yard	By passed culvert	16	250
15	Penn RR (Amtrak) West of Lewis La.	13.6' x 3' bridge	58	165*

*These capacities are reduced due to backwater during the 100-year event.

Key to Type

RC - Reinforced Concrete

RCP - Reinforced Concrete Pipe

C.I.P - Concrete and Iron Pipe

CMP - Corrogated Metal Pipe

4.2 The Alternatives Considered

4.20 General

The complex interactive nature of the stream drainage through the City of Havre de Grace necessitated detailed evaluation of numerous alternatives. Altering even one drainage structure results in impacts both up and downstream. Increasing the capacity of a culvert results in a greater volume of water conveyed downstream which may aggravate flooding in that downstream reach. However, reduction of ponding and backwater may also lead to improvement of the efficiency of the next upstream structure.

The alternatives investigated are summarized below. Detailed descriptions and explanations are found in the following subsections.

1) Evaluate the impact of drainage from U.S. Route 40 and determine if management of this runoff provides relief of flooding along Lilly Run.

2) Determine the hydraulic feasibility of a detention structure located in the Harford County portion of the mainstem watershed above the Baltimore and Ohio Railroad.

3) Evaluate the flood management benefits of Alternative No. 2 described in the Hsi, Brenner and Day report: diversion of Lilly Run for approximately 4,600 feet parallel to the Pennsylvania Railroad (Amtrak).

4) Determine the flood management effectiveness of the recommended storm drainage alternative contained in Reference 1: a 3,450' diversion of the upper portion of Lilly Run to discharge south of the City into the Chesapeake Bay.

5) Improve all culverts to maximum efficiency during the 100-year storm. Suggested improvements also include stream maintenance and removal of some unused encroachments.

6) Investigate the feasibility of diverting Lilly Run along the abandoned railroad spur line on Board of Education property, from the vicinity of Lewis Lane downstream to join the existing channel just upstream of the stone arch culvert under the Amtrak mainline. This alternative also includes supplementing the capacity of the Amtrak drainage structure.

4.21 Drainage from U.S. Route 40

The impact of the drainage from this highway was evaluated by initially modeling the watershed assuming the entire area of the road and right of way surface is impermeable. All water which falls on the road results in direct runoff. For comparison, the model was run assuming the road was not in the watershed. The hydrologic model parameter which describes surface charateristics such as soil type, land use, and soil cover was changed to reflect increased permeability. This provides the data to evaluate the impact of runoff by assuming management of existing highway runoff to previous values.

Because the total area of the highway is small compared to the total acreage of the subareas affected, a relatively minor change in discharges resulted. The data in Table 5 indicate that the highway accounts for less than two percent of the total peak discharge.

TABLE 5 - DISCHARGES AFFECTED BY U.S. ROUTE 40

Location	100-Year Discharges (cfs) With Rt. 40	Without Rt. 40	Change
Penn. Railroad (Amtrak)	334	329	1.5%
Revolution Street (above Baybrook)	1418	1398	1.4%

Therefore, while there may be water quality benefits to be gained by management of the 2- and 10-year runoff, there will be no perceptible reduction in flood water volumes for the 100-year event.

4.22 Upstream Detention

The effects of a detention structure were modeled by assuming 100% retention of the runoff from the subwatershed defined by that area which drains to Lilly Run above the Baltimore and Ohio Railroad (Structure No. 16). This subwatershed contains 218 acres compared to the watershed areas of 512 acres and 896 acres at Bloomsbury Avenue (Structure No. 8) and the Amtrak culvert (Structure No. 2) respectively. The results of the hydraologic comparison are summarized in Table 6. As is clearly shown, the reduction in peak discharge in very minor throughout the entire middle reach.

TABLE 6 - DISCHARGES AFFECTED BY DETENTION STRUCTURE

Structure Number	Location	Frequency	Peak Discharge (cfs) W/O Detention	W/Detention	% Reduction
16	B & O RR	2-yr.	59	0	100%
		10-yr.	189	0	100%
		100-yr.	364	0	100%
13	Revolution St.	2-yr.	106	88	17%
	above Baybrook	10-yr.	218	178	18%
		100-yr.	334	280	16%
8	Bloomsbury	2-yr.	258	254	2%
		10-yr.	457	444	3%
		100-yr.	815	707	13%
2	Amtrak near	2-yr.	394	392	1%
	Juniata	10-yr.	868	851	2%
		100-yr.	1418	1386	2%
1	Juniata/Otsego	2-yr.	474	472	0%
		10-yr.	1067	1056	1%
		100-yr.	1772	1749	1%

4.23 Diversion Parallel to Amtrak (4,600' Channel)

The modeling of this alternative was performed primarily to determine the impact of the diversion on timing. It was possible that the diverted volume, though small, added cumulatively to the peak discharges. However, as suggested in the Hsi, Brenner and Day report, it was determined that flooding was not relieved in the lower reaches. As follows from the previous discussion of the impacts of detention, this diversion also fails to relieve flooding in the middle reach of Lilly Run. The very flat grade and numerous crossings and encroachments within this middle reach result in a very localized problem which is not relieved by this major diversion.

4.24 Diversion South to the Chesapeake Bay (3,450' Culvert)

This diversion fails to relieve flooding in the middle and lower reaches of Lilly Run for the same reason the previous alternative was found inadequate. The volumes of water diverted do little to impact the peak discharge, especially for the greater flows such as the 100-year storm.

4.25 Improve Channel and All Culverts

An extensive evaluation of each drainage structure was performed to determine remedial actions required to pass the discharges necessary to reduce flooding. This alternative also included channel maintenance to remove sediment deposits and to clear debris and vegetative growth. Structures that are no longer in use are recommended for removal. In particular, the concrete walls identified as Structure No. 3, located immediately upstream of Structure No. 2, should be removed to facilitate flow. This alternative does not divert or detain water. Therefore it would not result in reducing road flooding reported along Revolution Street and Juniata Street which is not associated with undersized structures.

The results of this analysis indicate that the structure which exerts the most influence on the flooding in the middle reach of Lilly Run is the culvert under the Amtrak railroad, Structure No. 2. Improvements to the channel and all other structures will reduce flooding during frequent events, but the backwater caused by this culvert is sufficient to control the water surface elevation all the way upstream to Revolution Street during the 100-year storm.

As indicated in the 1966 report, improvement of all structures to accommodate the 5-year storm flow involves high costs. This is attributed in part to the type of construction and the high cost of rights-of-way for the channel work, as well as the complexities of reconstructing four culverts under active railroad tracks.

4.26 Diversion Along Abandoned Railroad, Improve Amtrak Culvert

In order to be effective in reducing flooding through the middle reach of Lilly Run, a diversion must redirect sufficient volumes of water to produce reductions in the peak discharges within this reach.

The diversions previously investigated failed to divert volumes in sufficient quantities to produce the desired effect. Since the area identified as the more pressing of the three flood impact areas lies in the middle reach of Lilly Run, it is likely that a short diversion around only that reach would be effective. The diversion modeled for this alternative is approximately 2,400 feet in length and begins at Structure No. 10 where the stream takes a 90% right hand turn under the abandoned railroad. It extends parallel on the northern side of the railroad embankment downstream to create a confluence just below Structure No. 3, where the existing stream flows back under the railroad. This diversion channel, combined with removal of the concrete walls (Structure No. 3) and increasing the capacity of Structure No. 2 under the Amtrak line will relieve most of the flooding through the middle reach. Table 7 indicates the depth of water over certain structures. It is notable, however, that the potential for problems in Baybrook in the upper reach as well as the flooding in the lower reach will be essentially unaltered by this alternative.

TABLE 7 - DEPTH OF FLOODING OVER DRAINAGE STRUCTURES ON LILLY RUN
(With Recommended Alternative)

Flooding Location	Depth of Water (feet) 2-Year	10-Year	50-Year	100-Year
Otsego/Juniata Streets	1.0	2.0	2.4	2.7
Revolution @ Juniata	--	0.5	0.7	0.8
Along Juniata St.	0.0 to 1 for all events			
Revolution @ Lewis Ln.	--	0.0	0.0	0.0
Seneca Avenue	0.8	1.5	1.8	2.0
Bay Boulevard	0.5	0.7	1.0	1.0

Hydraulically, the diversion channel results in bypassing sufficient volumes of water so that the existing Lilly Run main channel is able to convey local drainage without causing severe flooding. Because of the severe drainage limitation presented by the Amtrak culvert (Structure No. 2), this diversion is only successful if combined with enlargement of this opening. A proposed box culvert with a total waterway width of 32' and at least 10' in height will provide sufficient area to convey the 100-year discharge without causing a backwater. These improvements will prevent this structure from acting as the overriding control on this section of stream. As previously mentioned, increasing discharge capacities may result in increased downstream flooding. The hydraulic and hydrologic models indicate that implementation of this alternative will result in a discharge increase of 704 cfs which causes an increase of 0.4' at Structure No. 1 for the 100-year storm. The relative insensitivity of this box culvert to increases in discharge was discussed in Section 2.3.

4.3 Other Recommendations

Although it is not the intent of this study to endorse a particular alternative for implementation, the foregoing analyses are clear in that only one provides flood management benefits for the 100-year storm. It is certainly within the City's authority to select an alternative which does not provide this level of protection but which does satisfy the goals of improved drainage and the reduction of some flood hazards. This study is performed under the authority defined in §8-9A which states that studies shall at a minimum address the 100-year frequency event. Therefore the impacts of the various alternatives on that magnitude event were considered of primary importance. However, data are provided for the 2- and the 10-year events and some conclusions can be drawn from them.

The flood profiles shown in the exhibit section indicate those structures within the middle reach which cause backwater for the 2- and 10-year storms. Enlargement of these structures will reduce some of the flooding but will not improve overall drainage because the flat grade will continue to cause ponding. Regular channel maintenance will also facilitate drainage and result in some decrease in water surface elevations.

The recommended diversion channel without enlargement of the Amtrak culvert was examined for effects on flooding. As stated earlier, the backwater influence of the Amtrak culvert extends through nearly the entire middle reach. Therefore, the diversion channel alone will not reduce 100-year storm flooding.

4.4 The Recommended Alternative

Based on the evidence presented in this report, flooding in the middle reach of Lilly Run is not significantly reduced for any alternative other than that described in Subsection 4.26. A complete evaluation of costs and benefits of the diversion channel and new box culverts is recommended, although rough estimates of costs are provided below.

4.41 Description of the Recommended Alternative

This section contains a description of the proposed project beginning at the upstream limit and extending to the downstream limit.

1) Close structure No. 10 at the abandoned railroad just below the community of Baybrook to prevent flow from passing under the railroad embankment.

2) Install a 40' wide, 6' high multiple cell box culvert under Revolution Street near Lewis Lane.

3) Excavate a new 2,400 foot channel with a 40' bottom width, average depth of 4-6', and side slopes no greater than 2:1. Throughout the diversion channel gentler side slopes are recommended to facilitate maintenance and to help the project blend into the existing land use. This channel will extend from just above Structure No. 10 parallel to the railroad embankment down to its natural confluence with the main stem of Lilly Run. The new channel will be lined with riprap for stability and maintenance of smooth flow.

4) At the confluence, the existing main stem channel will require some channel improvement and stabilization with riprap to prevent streambank erosion. This riprap lining should extend the entire length of the section where improvements are made, and may result in a riprap channel partially down to Structure No. 1, above Otsego and Juniata Streets.

5) The existing main stem of Lilly Run will require some maintenance to facilitate local drainage. The only structural work required will be the removal of the concrete walls at Structure No. 3. These walls present a severe constriction and should be removed to avoid future problems.

6) The existing stone arch culvert under the Amtrak embankment is 11.6 feet in width and has been shown to be severely undersized in part because of backwater from Structure No. 1. In order to provide an adequate opening for the 100-year storm discharge, a parallel opening must be constructed. A 32' wide multiple cell box culvert, with the invert placed one to two feet above the existing stream invert will be required. The additional invert elevation is necessary to minimize sedimentation problems in the future. Normal flow as well as more frequent floods will be contained within the existing culvert and thus aid in preventing sediment build-up. Construction techniques have been developed to allow for installation of culverts without adversely affecting the railroad traffic.

4.42 Costs of the Recommended Alternative

The costs contained in this section are based on 1984 unit price estimates utilized for general highway construction and should be considered "ballpark" estimates only. Deviations in these estimates are anticipated based on actual field conditions. For example, if rock is encountered in the excavation, additional costs will be incurred. The computation of cost for the railroad culvert contains the greatest potential variability because there are no standard unit prices available for this type of unusual construction. This value was obtained by arbitrarily increasing the unit price of constructing new box culverts for highways. The high costs indicated in Table 8 are anticipated because of the difficulty of constructing while maintaining railroad traffic.

TABLE 8 - ESTIMATED COSTS OF THE RECOMMENDED ALTERNATIVE

1) Close Structure No. 10:	
Backfill	$ 4,000
2) Box culvert @ Revolution	115,000
Maintenance of Traffic	15,000
3) New channel (2,400' long)	
Excavation (17,500 cy)	27,000
Disposal	5,000
Filter cloth (14,000 sy)	15,000
Dumped/shaped riprap (4,800 cy)	140,000
Stabilization	12,000
4) Riprap existing channel (900' long)	
Filter cloth (6,500 sy)	6,500
Riprap (2,200 cy)	64,000
Stabilization	4,000
5) Concrete wall removal	5,000
Diversion Channel Subtotal	$ 471,000
6) New Amtrak Structure	
Box culvert	625,000
Maintain RR traffic	150,000
Amtrak Culvert Subtotal	$ 775,000
7) Engineering and Contingencies (10%)	$ 124,600
TOTAL	$1,370,600

KEY

cy - cubic yards

sy - square yards

5.0 REFERENCES AND BIBLIOGRAPHY

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5. Susquehanna River Basin Commission, Flood Plain Topographic Map, developed from aerial photographs, Scale 1:200, Contour Interval 5 feet: Havre de Grace, Maryland, 1973.

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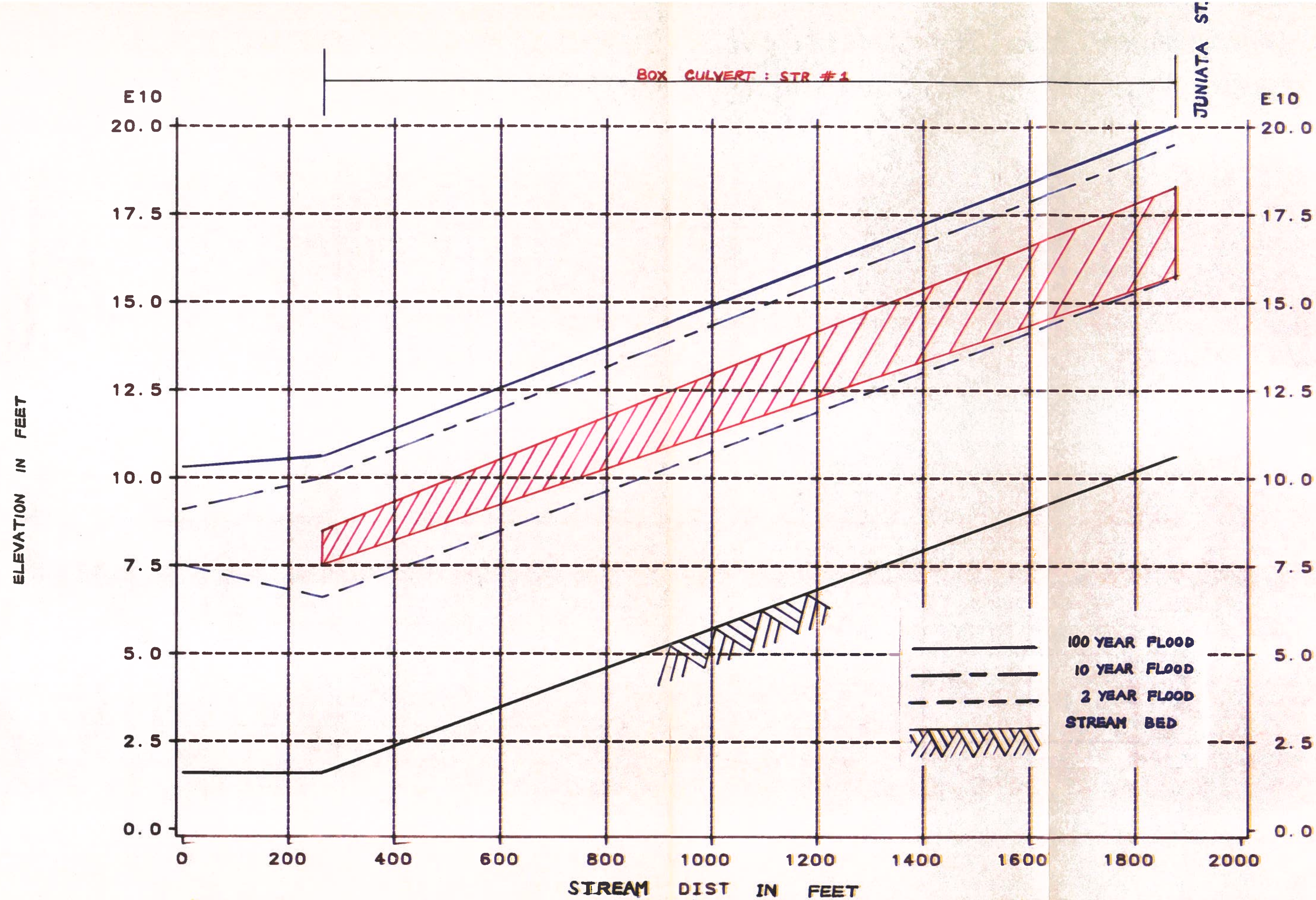
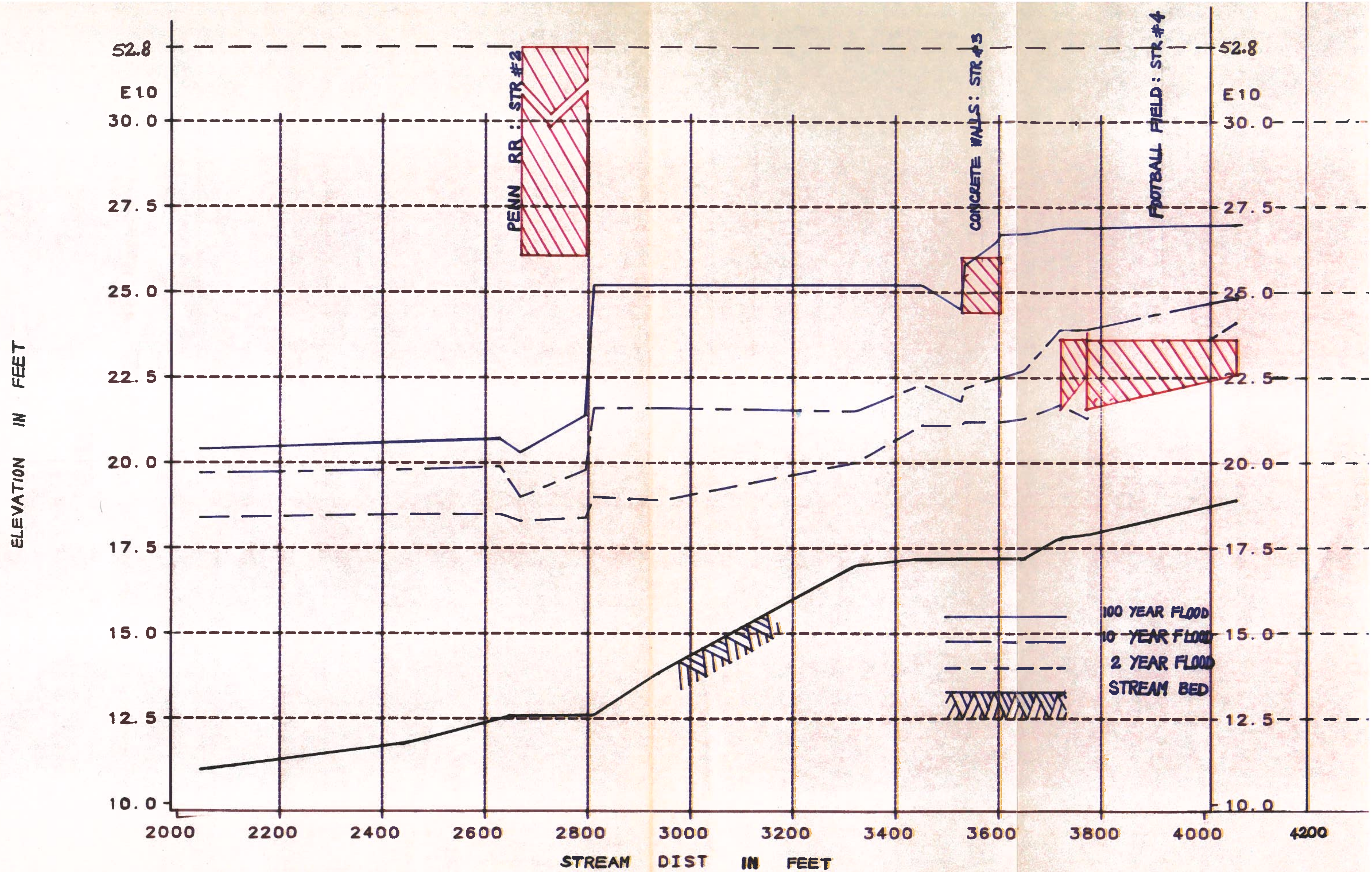
11. U. S. Geological Survey, 7.5 minute Series Topographic Map, Scale 1:24000, Contour Interval 20 feet, Havre de Grace, Maryland, 1975.



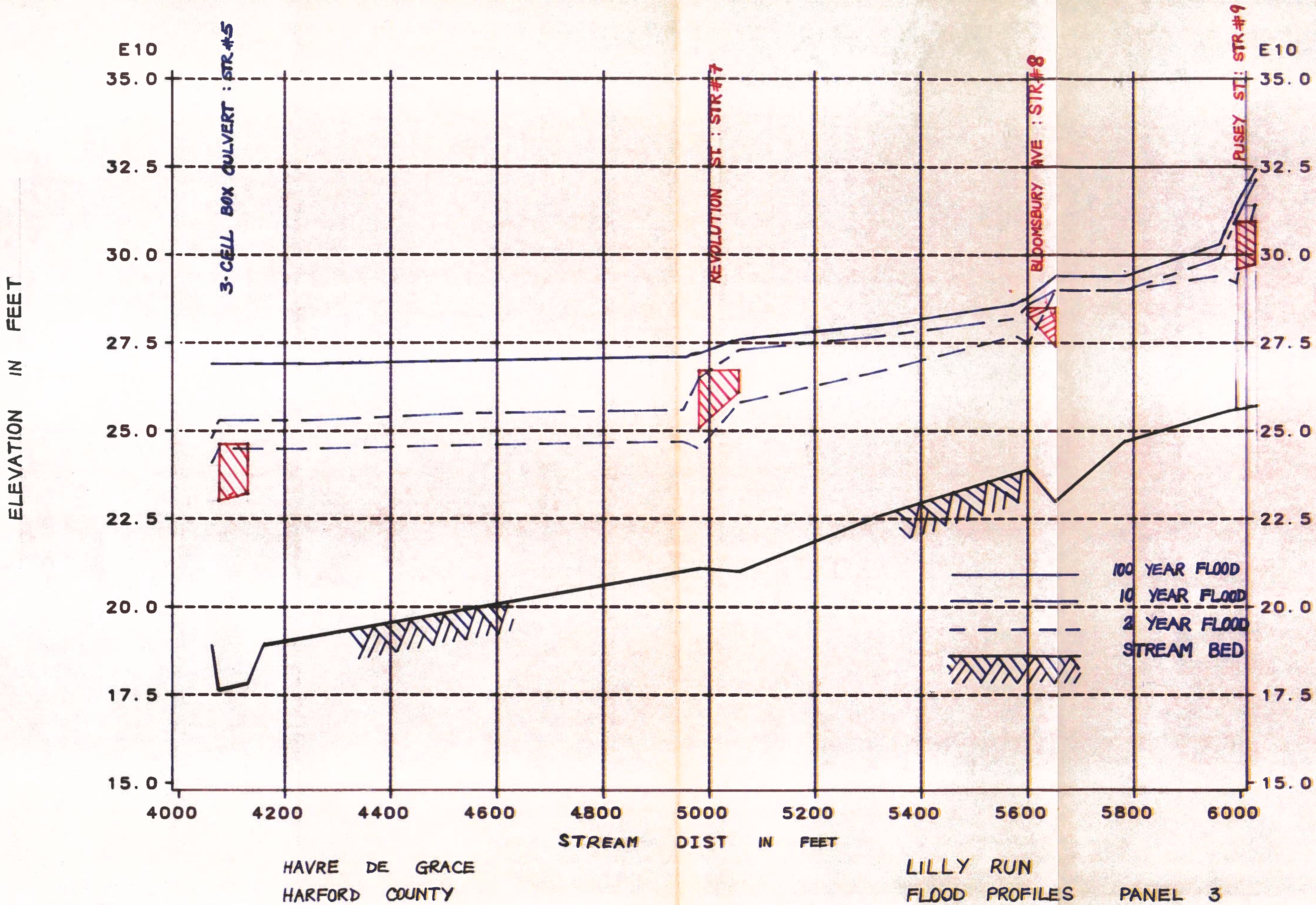
HAVRE DE GRACE
HARFORD COUNTY

LILLY RUN
FLOOD PROFILES PANEL 1

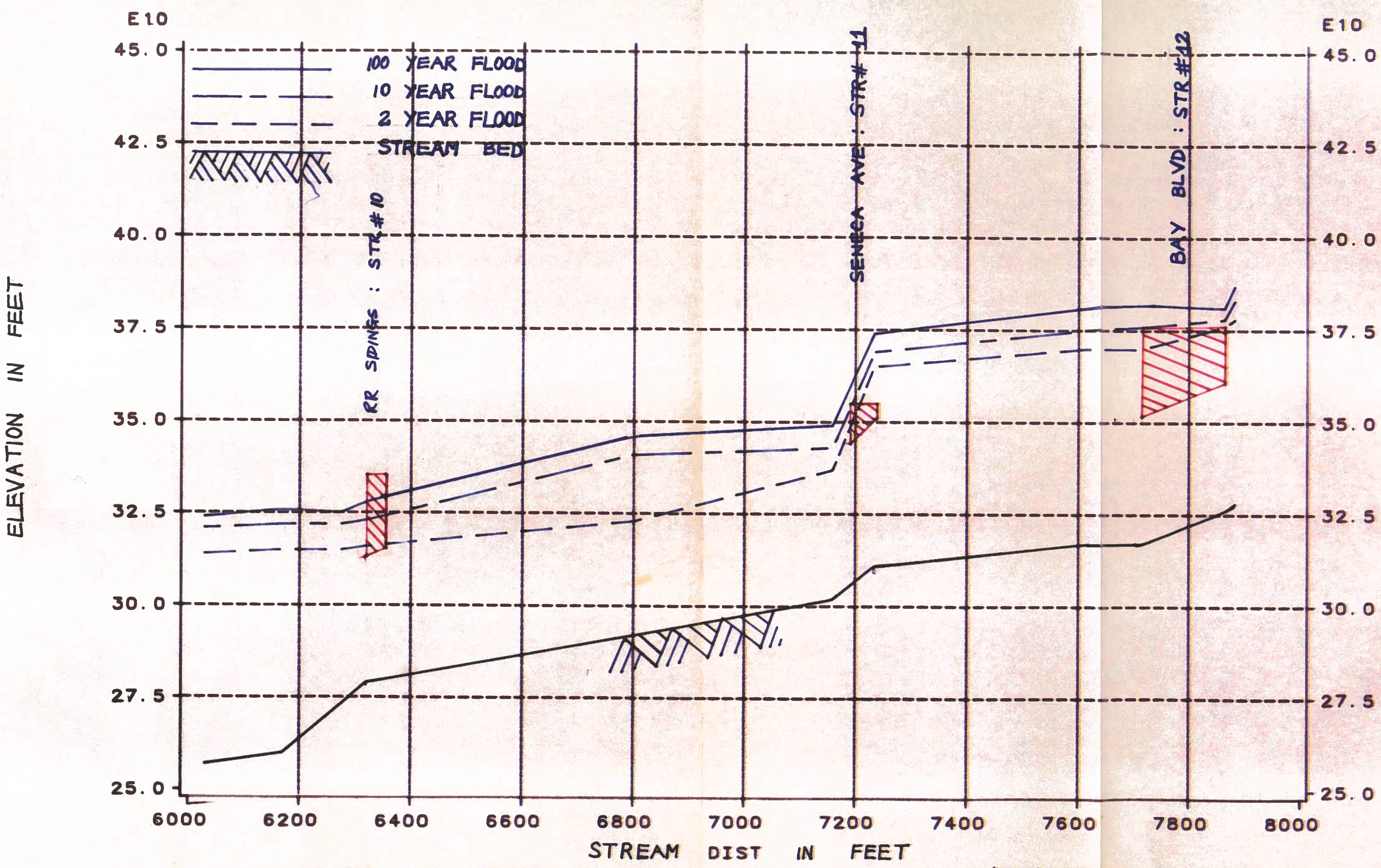


HAVRE DE GRACE
HARFORD COUNTY

LILLY RUN
FLOOD PROFILES PANEL 2

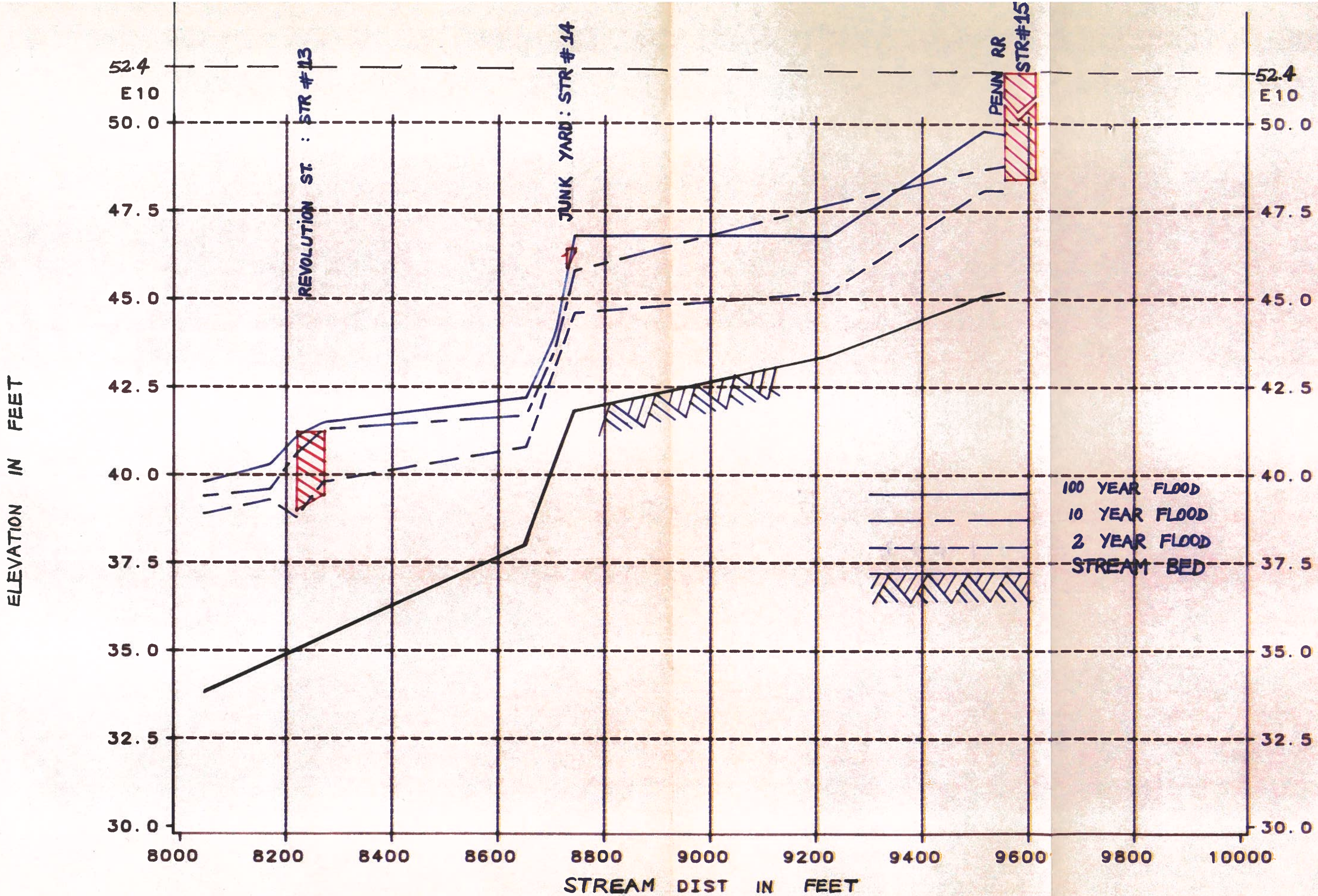


E10
35.0
32.5
30.0
27.5
25.0
22.5
20.0
17.5
15.0
ELEVATION IN FEET
3-CELL BOX CULVERT : STR#5
REVOLUTION ST : STR#7
BLOOMSBURY AVE : STR#8
PUSEY ST : STR#9
100 YEAR FLOOD
10 YEAR FLOOD
2 YEAR FLOOD
STREAM BED
4000
4200
4400
4600
4800
5000
5200
5400
5600
5800
6000
STREAM DIST IN FEET
HAVRE DE GRACE
HARFORD COUNTY
LILLY RUN
FLOOD PROFILES PANEL 3



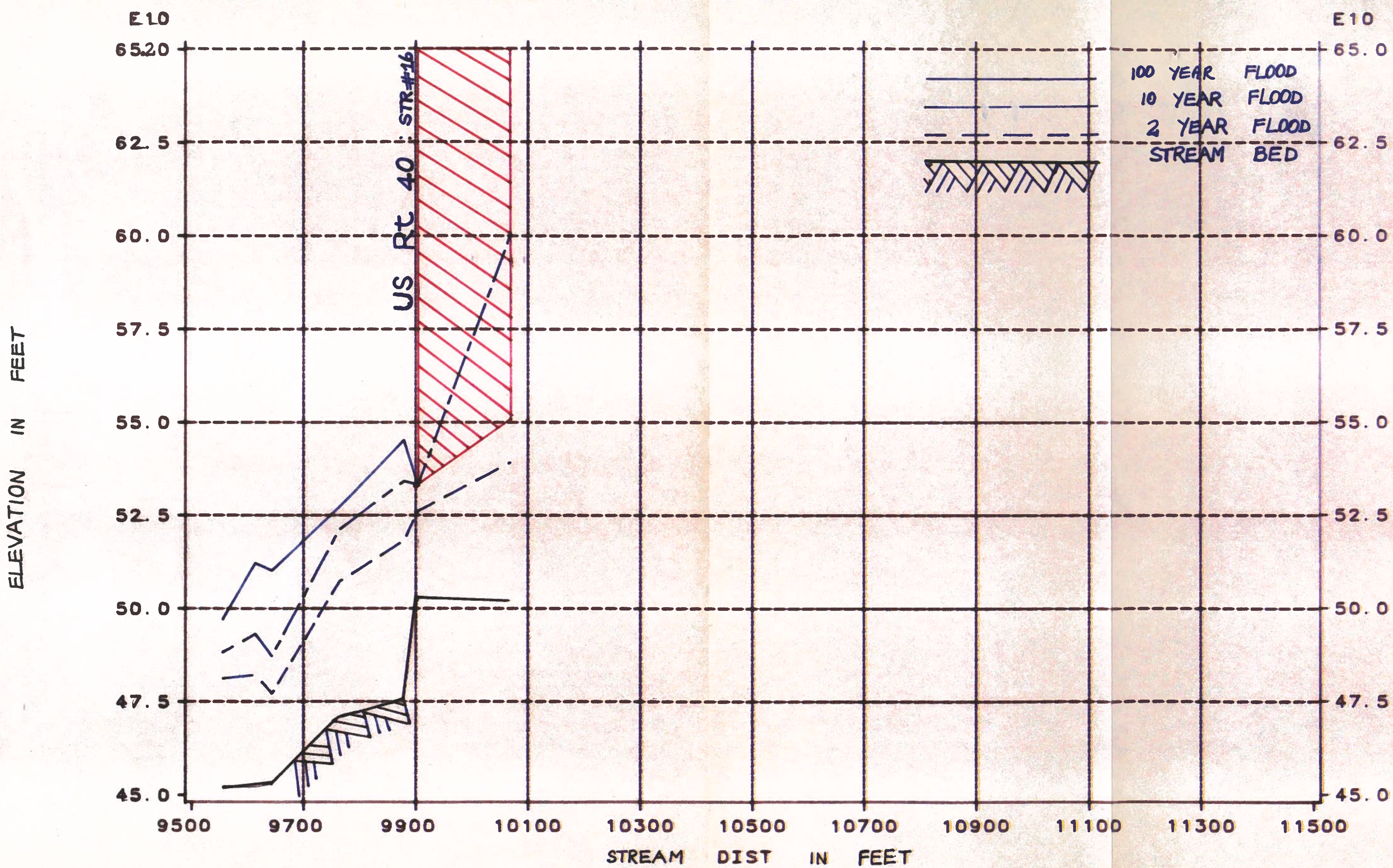
HAVRE DE GRACE
HARFORD COUNTY

LILLY RUN
FLOOD PROFILES PANEL 4



HAVRE DE GRACE
HARFORD COUNTY

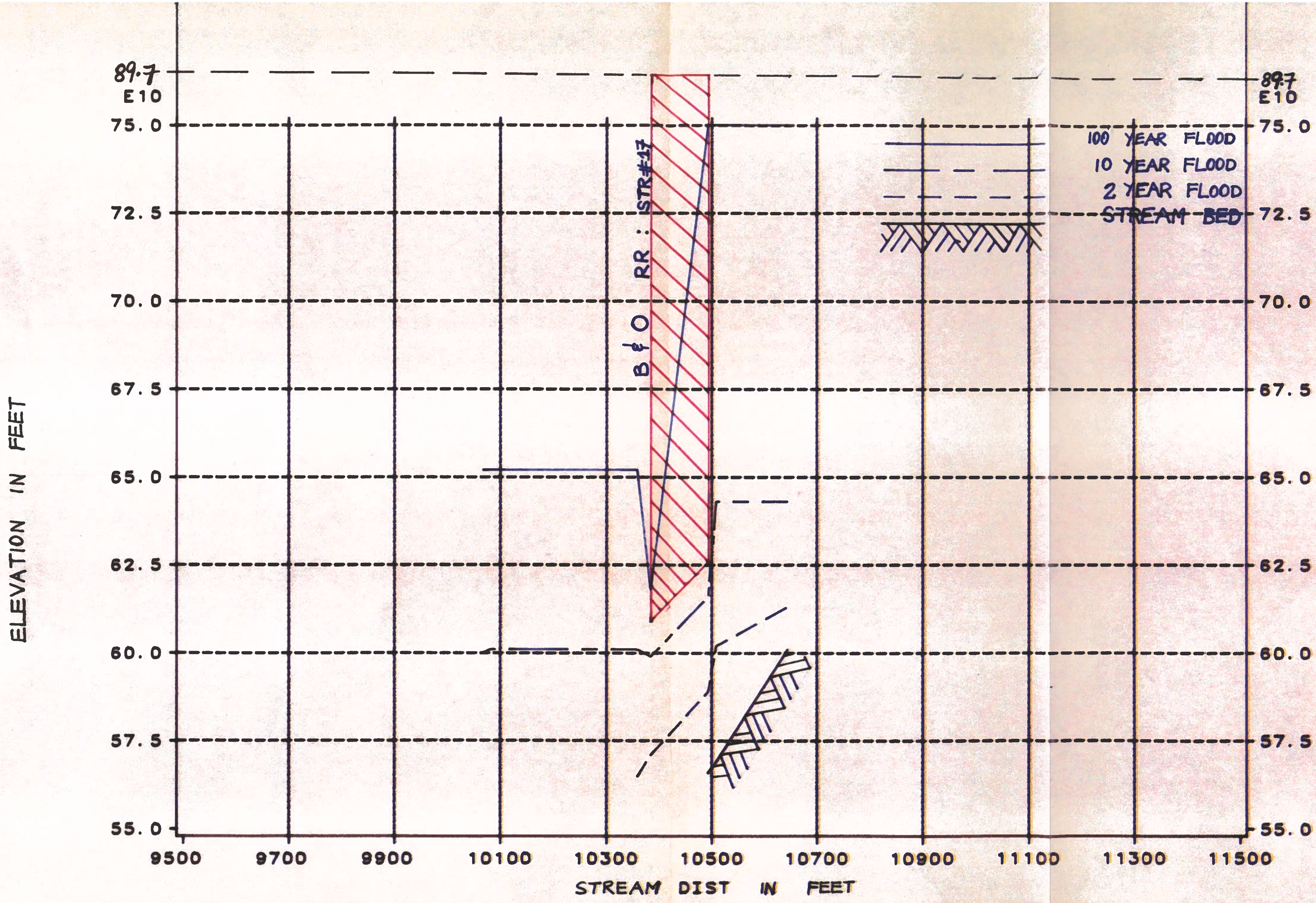
LILLY RUN
FLOOD PROFILES PANEL 5



HAVRE DE GRACE
HARFORD COUNTY

LILLY RUN
FLOOD PROFILES

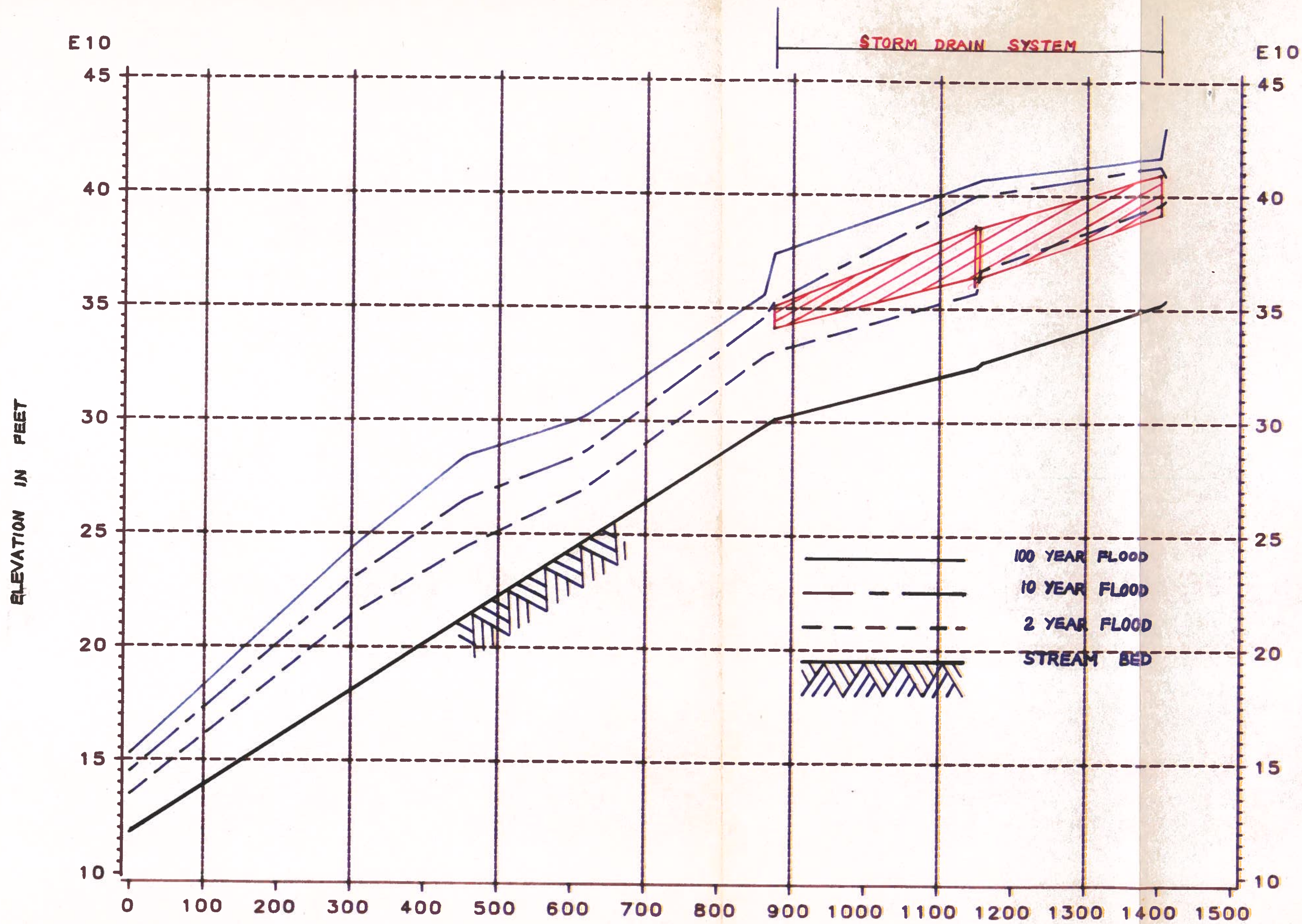
PANEL 6



HAVRE DE GRACE
HARFORD COUNTY

LILLY RUN
FLOOD PROFILES

PANEL 7

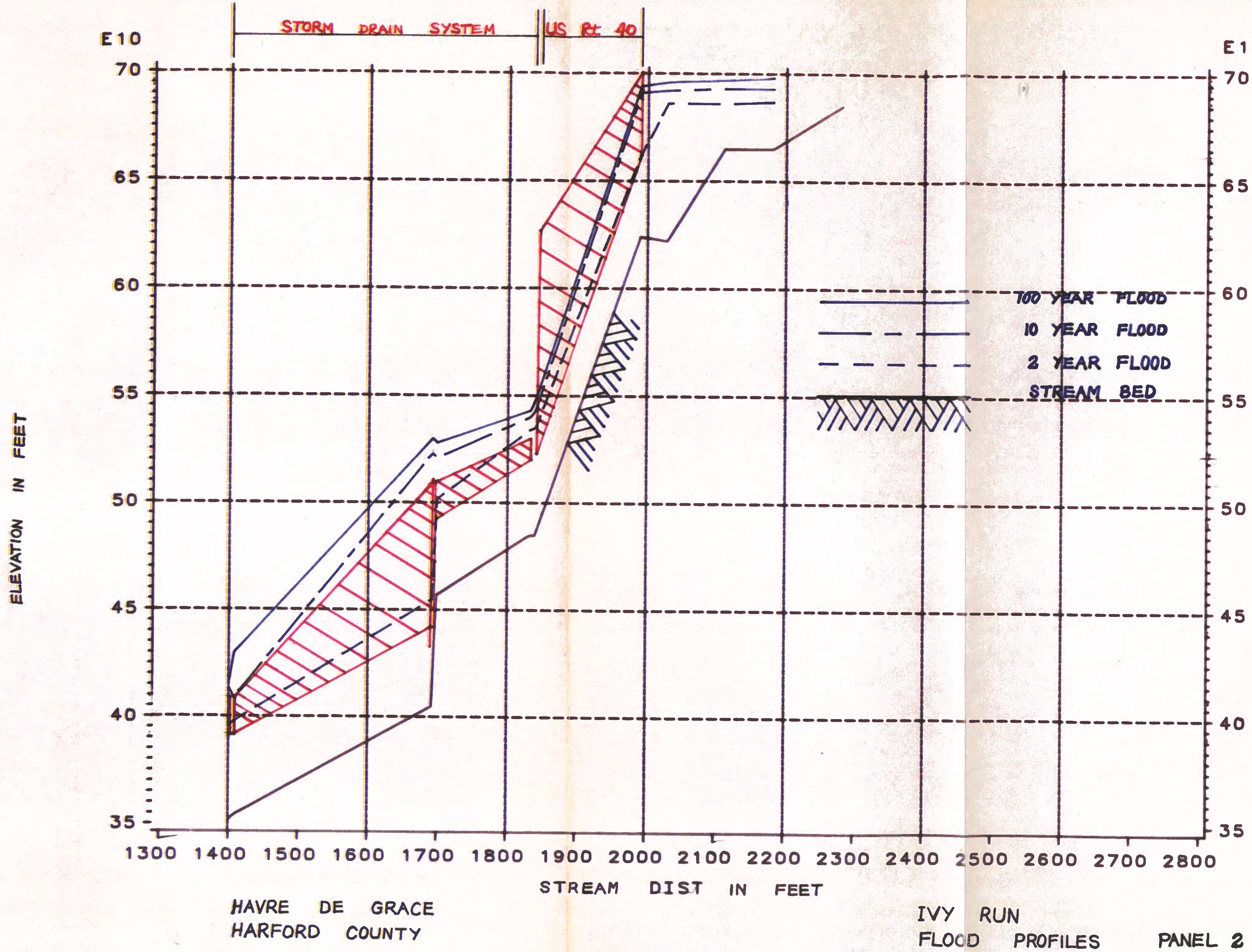


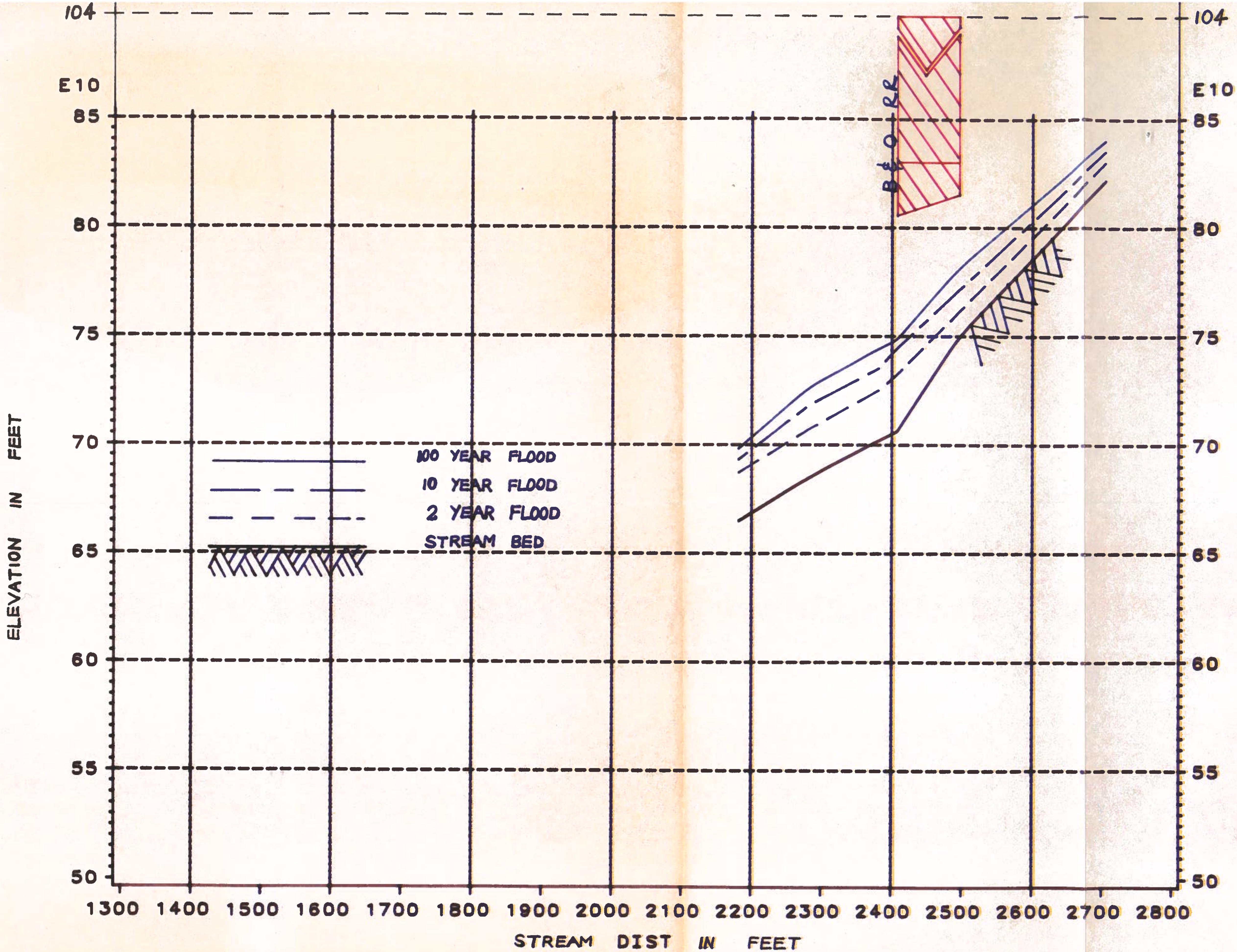
STREAM DISTANCE IN FEET

HAVRE DE GRACE
HARFORD COUNTY

FLOOD PROFILES
IVY RUN

PANEL 1


STORM DRAIN SYSTEM
US Rt 40
E10
70
65
60
55
50
45
40
35
ELEVATION IN FEET
1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800
STREAM DIST IN FEET
100 YEAR FLOOD
10 YEAR FLOOD
2 YEAR FLOOD
STREAM BED
HAVRE DE GRACE
HARFORD COUNTY
IVY RUN
FLOOD PROFILES
PANEL 2



HAVRE DE GRACE
HARFORD COUNTY

IVY RUN
FLOOD PROFILES

PANEL 3

DEPARTMENT OF NATURAL RESOURCES
FLOOD STUDY MAP

CITY OF HAVRE DE GRACE
HARFORD COUNTY, MARYLAND
FEBRUARY 1986

APPENDIX A-FLOODPLAIN MAP-EXISTING CHANNEL

APPENDIX B - FLOODPLAIN MAP- Recommended Alternative