ENVIRONMENTAL INVESTIGATIONS AT THE PADUCAH GASEOUS DIFFUSION PLANT AND SURROUNDING AREA McCRACKEN COUNTY, KENTUCKY

VOLUME V FLOODPLAIN INVESTIGATION

PART A RESULTS OF FIELD SURVEY

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Preface

An engineering investigation was made for the entire PGDP reservation to determine and map the 100-year and 500-year floodplains for all streams with drainage areas greater than one square mile. This investigation included collection of field-surveyed stream cross sections and backwater computer modeling. The results of the study are presented in two forms: as flood profiles (a plot of computed flood elevations vs. stream miles) and as flood inundation boundary maps (shown on 1-foot or 2-foot contour interval topographic maps).

There are three major streams that can cause flooding at the PGDP reservation: the Ohio River, Bayou Creek, and Little Bayou Creek. The flood inundation maps represent the controlling flood elevations from all three streams; however, only flood elevations for the two creeks were computed for this study as the Ohio River elevations were determined previously by the Louisville District Corps of Engineers. Approximately 9.7 miles of Bayou Creek and 6.8 miles of Little Bayou Creek were modeled through the reservation to determine flood elevations. The flood elevations in the lower reaches of both creeks are controlled by backwater flooding from the Ohio River. This backwater flooding is depicted as a horizontal line in the plotted flood profiles.

Although the principal flood threat for the PGDP reservation is from the three streams mentioned above, there are smaller streams and other drainage systems on the site that can overflow and cause flooding. A formula to estimate flood heights for streams with drainage areas between one-half and one square mile has been included to obtain flood information in these areas when it is required.

AN IDENTIFICATION OF FLOODPLAINS WITHIN THE PADUCAH GASEOUS DIFFUSION PLANT STUDY AREA McCRACKEN COUNTY, KENTUCKY

SECTION 1 - INTRODUCTION

1.1 Authority. The work in this report was conducted by the U.S. Army Corps of Engineers, Nashville District, during the period January 1992 through May 1993 for the U.S. Department of Energy (DOE). The study was performed under Interagency Agreement No. DE-A105-920R22026 - Environmental Assessments Paducah Gaseous Diffusion Plant, dated 2 February 1992.

1.2 Purpose and Scope.

1.2.1 Purpose. The purpose of this study is to identify and delineate the floodplains corresponding to the 100 and 500 year frequency events on select streams near the Department of Energy (DOE) Paducah Gaseous Diffusion Plant (PGDP). This request was made by the DOE to the U.S. Army Corps of Engineers, Nashville District, in support of the Paducah Gaseous Diffusion Plant's (PGDP's) National Environmental Policy Act (NEPA) compliance program. This assessment is intended to be used in upcoming Environmental Impact Statements (EIS's) for the site. It will also be used in support of the current DOE regulation (10 CFR 1022) which implements Executive Order 11988 (Floodplain Management).

1.2.2 Initial Scope. The initial Interagency Agreement between DOE and the Corps stipulated that the Corps conduct a detailed hydrologic and hydraulic analyses of selected streams within the PGDP study limits. These analyses were to ultimately provide a delineation of floodplain boundaries for the flood of record, Probable Maximum Flood (PMF), and the 100 year and 500 year frequency events. Mapping was to be in an electronic format (Computer Aided Drafting and Design files) suitable for future use by DOE.

1.2.3 Final Scope. The initial scope of work was modified during a November 3, 1992 meeting between DOE, Martin Marietta Energy Systems, Inc. (MMES) and Corps representatives. The final scope calls for the determination of only the 100 and 500-year frequency profiles, and placement of the corresponding boundaries on the maps provided by the DOE. The frequency profiles will be computed for all streams with drainage areas greater than one square mile. The one square mile drainage area limit is based on guidance from the Federal Emergency Management Agency publication, Guidelines and Specifications for Study Contractors, (Reference 1). In addition to a report containing copies of the maps, CADD files are to be provided to DOE for future incorporation into a Geographic Information System (GIS) of the PGDP study area. Computer data files used to calculate water surface profiles of the selected streams will be provided.

Regression equations for the approximation of frequency flood depths for streams with less than one (1) square mile of drainage area will also be provided.

1.3 Study Coordination. Nashville District Corps Hydrology and Hydraulics Branch personnel coordinated the determination and mapping of the floodplain boundaries of streams located within the PGDP study area with various federal and private contractors involved with the study. These agencies and private contractors include the Tennessee Valley Authority (TVA), Louisville District Corps of Engineers, United States Geological Survey (USGS), Oak Ridge National Laboratory (ORNL), and MMES.

1.4 Related Studies and Reports. During the search for previous floodplain information at the PGDP site, it was determined that no detailed flood analysis had been performed for streams within the study limits, with the exception of the Ohio River. The Louisville District has developed flood frequency profiles for the Ohio River. ORNL has prepared two (2) flood reports of the PGDP site. The first report, PROBABLE MAXIMUM FLOOD CALCULATION FOR THE PADUCAH GASEOUS DIFFUSION PLANT PADUCAH, KENTUCKY, dated August 1992, is a report on the effects of a Probable Maximum Flood (PMF) of the Ohio River for the PGDP site. The second report, LOCAL DRAINAGE ANALYSIS OF THE PADUCAH GASEOUS DIFFUSSION PLANT, PADUCAH, KENTUCKY, DURING AN EXTREME STORM, dated May 1993, is an analysis of the plant drainage system during an extreme storm. Both of these reports were done in support of the Gaseous Diffusion Plant (GDP) Final Safety Analysis Report (FSAR) Upgrade Program.

SECTION 2 - STUDY AREA DESCRIPTION

2.1 General. The Paducah Gaseous Diffusion Plant (PGDP) is a DOE uranium enrichment facility located in western McCracken County, Kentucky approximately ten (10) miles west of the city of Paducah, Kentucky and three (3) miles south of the Ohio River. The Shawnee Steam Plant, which is owned and operated by the TVA, is located between the PGDP and the Ohio River. The study area encompasses approximately 7,000 acres and is comprised of property owned by DOE, TVA, the State of Kentucky, and private land owners (Exhibit 1). A majority of the acreage is a part of the West Kentucky State Wildlife Management Area. The entire study area is drained by Bayou Creek and its tributaries, which flow northeasterly to the Ohio River.

2.2 Basin Description. The drainage area of Bayou Creek is oblong in shape and extends about 6.8 miles northeast by southwest and 4.8 miles northwest by southeast. The basin is comprised of two major drainages. The larger portion of the basin extends from the mouth southwest past PGDP and encompasses 18.2 square miles of the 27.2 square mile total drainage.

The smaller portion is the Little Bayou Creek basin which drains into Bayou Creek from its right bank at mile 0.2 and extends southwest, paralleling the main drainage basin of Bayou Creek.

2.3 Principal Flood Problems. No knowledge of major floods on streams within the study area is available with the exception of the Ohio River. The flood of record for the Ohio River occurred in 1937 and the elevation at the mouth of Bayou Creek (Ohio River Mile 947.5) was 342.5 feet National Geodetic Vertical Datum (NGVD). It should be noted that this elevation does not take into account flood control measures that have been implemented in the Ohio Basin since the 1937 Flood.

SECTION 3 - ENGINEERING METHODS

3.1 Hydrologic Analyses. Peak discharges in the PGDP study area for the 100- and 500-year recurrence floods are indicated in the "Summary of Discharges," Table 1. The peak discharge is the discharge that is used to produce the maximum flood elevation for a given historic flood event or a hypothetical flood event (ie. 100-year flood). Bayou and Little Bayou Creeks were previously gaged by the USGS for a nine (9) month period and then discontinued. Due to this limited period of record, no usable gage information is available for streams located in the study area. Frequency discharges for the selected streams were calculated by using the procedures outlined in, Regionalization Of Peak Discharges For Streams In Kentucky, (Reference 2). A copy of the regression equations used in this study are shown in Exhibit 2. This is a regression method developed to estimate peak flood frequency discharges for different hydrologic regions of Kentucky. These regression equations were developed using data from 266 continuous-record and partial-record streamflow-gaging stations in and adjacent to Kentucky that had at least seven (7) years of gaged record through water year 1985. The regression relations developed were limited to natural flow streams in Kentucky that are not significantly affected by regulation or urbanization. Peak discharges of future floods with recurrence intervals of as much as 100 years for streams with upstream drainage areas less than 1,000 $mi.^2$ are estimated. The 500-year peak discharges in this study were determined by extrapolating the resulting regression based discharge-frequency curve computed for each basin using log-probability paper.

3.2 Hydraulic Analyses. The hydraulic characteristics of the streams within the study area were determined to compute flood elevations for the 100- and 500-year recurrence intervals along Bayou Creek, Little Bayou Creek, and a tributary of Bayou Creek. The tributary to Bayou Creek drains from the south and and empties into Bayou Creek at Bayou Creek river mile 7.85. Water-surface profiles of the floods were computed using the Computer Program HEC-2, Water Surface Profiles (Reference 3). Cross sections used in the backwater analysis of the three (3) streams were obtained by both field surveys and one-foot or two-foot contour interval mapping provided by the DOE. All data necessary to define the hydraulic characteristics for the bridges was obtained through field surveys. Channel roughness factors (Mannings "n" values) were determine during site visits and based on experienced values for similar streams. Due to the low probability of coincident flood peaks between the Ohio River and Bayou and Little Bayou Creeks, starting water surface elevations were developed by the slope area method for these streams rather than Ohio River backwater. The starting water surface elevations for the tributary to Bayou Creek assumes coincident peaks and was taken from the backwater profiles of Bayou Creek.

TABLE 1 - SUMMARY OF DISCHARGES

Flooding Source And Location	**Drainage Area MI^2**	**Peak Discharges (cfs)* 100-Year**	**500-year**
BAYOU CREEK Above mi. 3.48	17.70	6535	8600
BAYOU CREEK Above Brushy Cr.	12.61	5698	7400
BAYOU CREEK Above trib @ mi. 7.85	7.59	4934	6210
LITTLE BAYOU CREEK Above mi. 2.42	5.89	3446	4580
LITTLE BAYOU CREEK Above mi. 2.77	5.08	3317	4360
LITTLE BAYOU CREEK Above mi. 4.90	2.99	2768	3620
LITTLE BAYOU CREEK Above mi. 5.33	2.02	1485	2000
BAYOU CREEK TRIB. Above mouth	2.48	1751	2320

*** CUBIC FEET PER SECOND**

3.2.1 Flood profiles showing computed water surface elevations for the 100- and 500-year floods and a profile of the streambed elevations at cross-section locations for each stream studied are included as Plates 1-8. The profiles for Bayou and Little Bayou Creeks include backwater flooding from the Ohio River at the lower end of each stream with headwater flooding in the upper reaches. These profiles can be used to determine flood elevations for specific sites along the streams studied.

By locating the stream mile adjacent to a desired location the profiles can be read to determine the water surface elevation at that location. These stream miles are depicted on the flooded area maps provided in Volume V, Floodplain Investigation, Part B, Floodplain Maps.

3.2.2 Drainage ditches located within the plant area were not studied in detail. However, carrying capacity calculations performed by ORNL indicate that all drainage ditches within the plant area will contain the 500-year and 100-year flood discharges. These calculations can be found in the report, LOCAL DRAINAGE ANALYSIS OF THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, DURING AN EXTREME STORM, (Reference 4).

3.2.3 The hydraulic analyses for this study are based only on the effects of unobstructed, debris free flow. Thus, the flood elevations as shown on the profiles are representative only if hydraulic structures remain unobstructed.

3.2.4 Elevations for drainages with less than one (1) square mile area can be calculated using the procedure outlined in the USGS publication, Technique for Estimating Depth of Floods in Tennessee, (Reference 5). No depth/area relationships have been derived for this specific area, so we are providing relationships derived for similar basins and hydrologic areas.
A depth/drainage area curve for the hydrologic area of West Tennessee and instructions for its use are provided in Exhibits 3-1 and 3-2. This technique is only valid for drainage areas within the range of 0.51 to 936.0 square miles.

3.3 Floodplain Mapping Procedures. Flood boundaries for the 100- and 500-year frequency events were delineated on digital mapping provided by DOE through MMES. This mapping was provided by MMES in an AUTOCAD format. CADD files containing these boundaries are supplied on magnetic media in a digital format. These files can be referenced to DOE's existing digital files.

3.3.1 The HEC-2 computed water surface profiles were used to delineate the elevation of the flood boundaries along each stream studied. Since the maps provided by DOE did not show river miles, mileage along the streams studied were determined and placed on the mapping. These mileages were determined by assigning a starting mileage of 0.0 at the most downstream point of each stream and measuring upstream along the centerline of the channel. Mileages are shown on the maps at 0.10 mile intervals. This procedure is mentioned to eliminate confusion between the river miles used in this study and the river miles on the Ohio River (which proceed from upstream to downstream). The flood boundaries were delineated on work maps by interpolating a line between contours at the elevation corresponding to the river mile as shown on the flood profiles. These flood boundaries were then digitized into CADD files that are referenced to the mapping provided by DOE.

3.3.2 A final set of maps were plotted at a graphic scale and are provided in Volume V, Floodplain Investigation, Part B, Floodplain Maps. A legend and an index sheet is provided showing the location of each map sheet in relation to the other sheets in the set. The maps are divided into two (2) areas, those within the plant area and those outside the plant area.

Section 4 - References.

1 Federal Emergency Management Agency, FEMA 37, Guidelines and Specifications for Study Contractors, 1993.

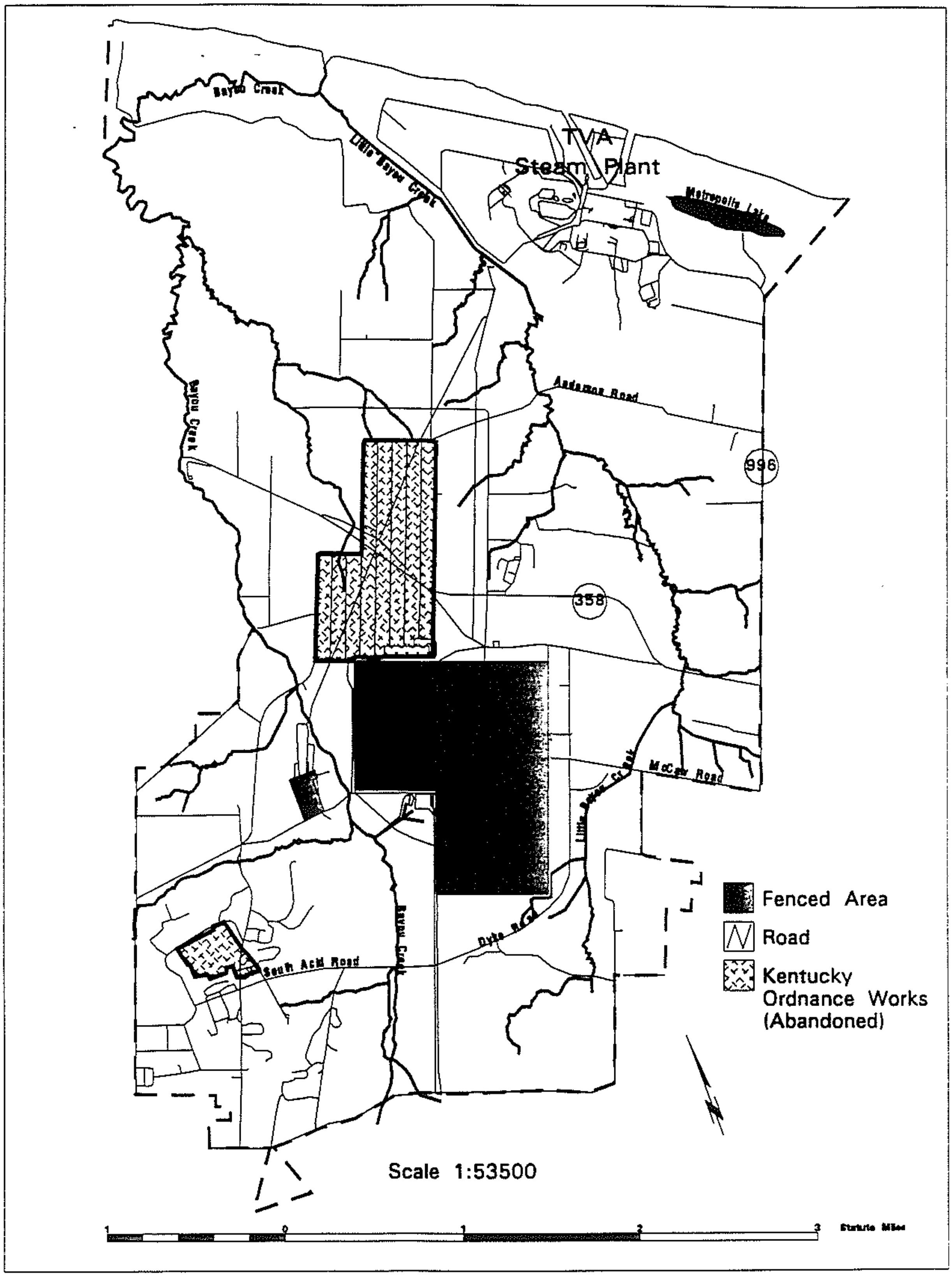
2 U.S. Geological Survey, Water-Resources Investigations Report 87-4209, Regionalization of Peak Discharges for Streams in Kentucky, 1988.

3 U. S. Army Corps of Engineers, Hydrologic Engineering Center, Computer Program HEC-2, Water Surface Profiles, September 1990.

4 U.S. Department of Energy, Energy Division, Oak Ridge National Laboratory, Local Drainage Analysis Of The Paducah Gaseous Diffusion Plant, Paducah, Kentucky, During An Extreme Storm, 1993.

5 U. S. Geological Survey, Water Resources Investigations 83-4050, Technique for Estimating Depth of Floods in Tennessee, 1983.

Exhibits



FLOOD PLAIN INVESTIGATION STUDY AREA

Exhibit 1

Table 13.--Regression models for estimating flood quantiles for streams in the West Region

[Q_t, peak discharge in cubic feet per second where t indicates average recurrence interval in years; A_c, contributing drainage area in square miles; B_s, basin shape index = ratio of (basin length in miles) / (average basin width in miles); S_s, main channel sinuosity = ratio of (main channel length in miles) / (basin length in miles)]

Regression equation	Standard error of the estimate (percent)	Estimated standard error of prediction (percent)	Equivalent years of record
$Q_2 = 601. (A_c^{0.659})(B_s^{-0.569})(S_s^{-0.964})(1.069)^a$	37.9	43.5	2
$Q_5 = 893. (A_c^{0.647})(B_s^{-0.523})(S_s^{-0.809})(1.059)$	34.9	40.3	3
$Q_{10} = 1{,}090. (A_c^{0.642})(B_s^{-0.501})(S_s^{-0.725})(1.059)$	34.4	40.5	4
$Q_{25} = 1{,}340. (A_c^{0.640})(B_s^{-0.482})(S_s^{-0.635})(1.063)$	36.1	42.3	5
$Q_{50} = 1{,}530. (A_c^{0.639})(B_s^{-0.472})(S_s^{-0.579})(1.069)$	37.6	44.3	6
$Q_{100} = 1{,}710. (A_c^{0.639})(B_s^{-0.466})(S_s^{-0.528})(1.075)$	39.4	46.6	7

[a] Bias correction factor

Table 14.--Summary of the regression models for estimating flood quantiles in Kentucky. The summary is based on information from the regression models for estimating the 2-, 5-, 10-, 25-, 50-, and 100-year peak discharge (tables 6 through 12)

[A_c, contributing drainage area in square miles; S_c, main channel slope in feet per mile; B_s, basin shape index = ratio of (basin length in miles) / (average basin width in miles); S_s, main channel sinuosity = ratio of (stream length in miles) / (basin length in miles)]

Hydrologic region	Independent variables	Standard error of the estimate	Estimated standard error of prediction (percent)	Number of gaging stations
North	A_c, S_c	39 - 48	42 - 53	33
Upper East	A_c, B_s, S_s	33 - 40	35 - 43	77
Lower East	A_c, S_s	21 - 25	24 - 30	26
Southeast	A_c	23 - 29	26 - 33	20
East-Central	A_c	35 - 52	37 - 55	40
West-Central	A_c, S_c	34 - 38	38 - 42	32
West	A_c, B_s, S_s	34 - 39	40 - 47	38

Exhibit 2

APPLICATION OF RELATION

To determine the elevation of the 100-year flood at a given point on a stream, proceed as follows:

1. Determine the drainage area of the stream above the location desired, in square miles, from 7.5-minute topographic maps.

2. Compute the depth of the 100-year flood for this location by using the graph on Exhibit 3-2. This is accomplished by locating the drainage area determined in step 1 on the x-axis and reading the corresponding depth on the y-axis at the point of intersection for the 100-year frequency flood.

3. Add this depth to the median discharge elevation represented by contour crossings on the 7.5 minute topographic maps to obtain the elevation of the 100-year flood. If a contour does not cross at the location of interest then you should determine the median discharge elevation by applying the slope between upstream and downstream crossings to your location. This will give you the 100-year flood elevation at the desired location.

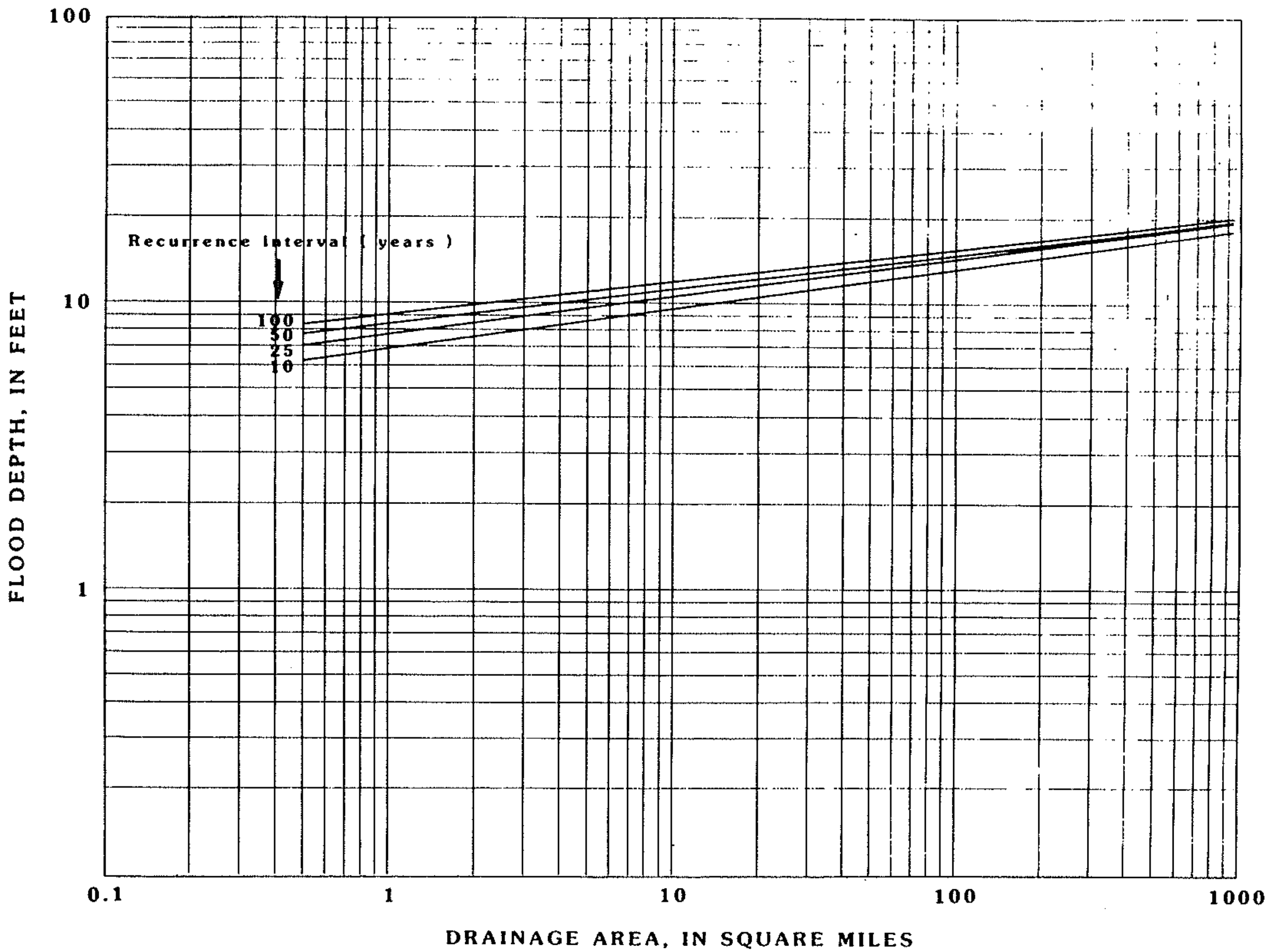
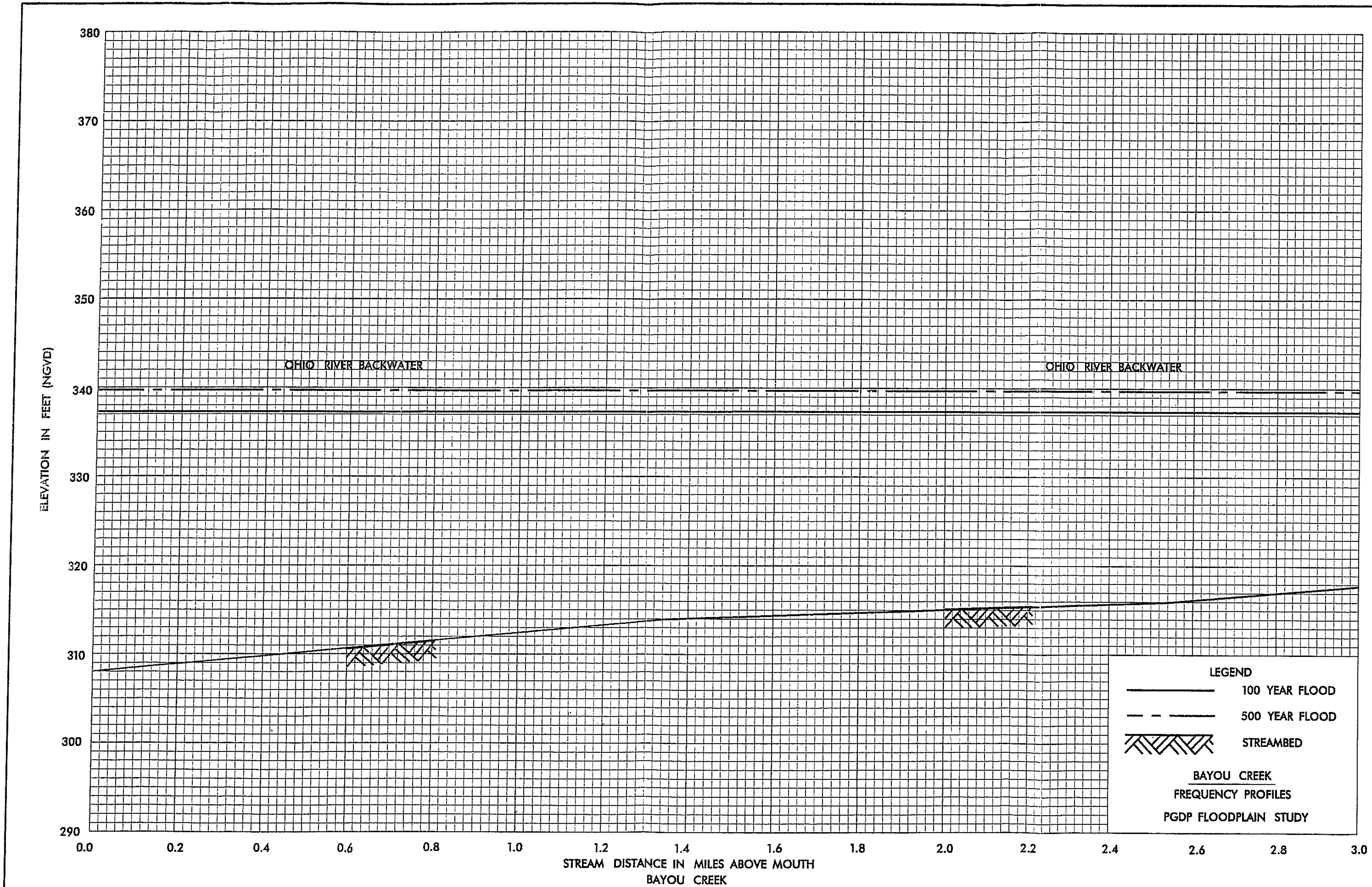


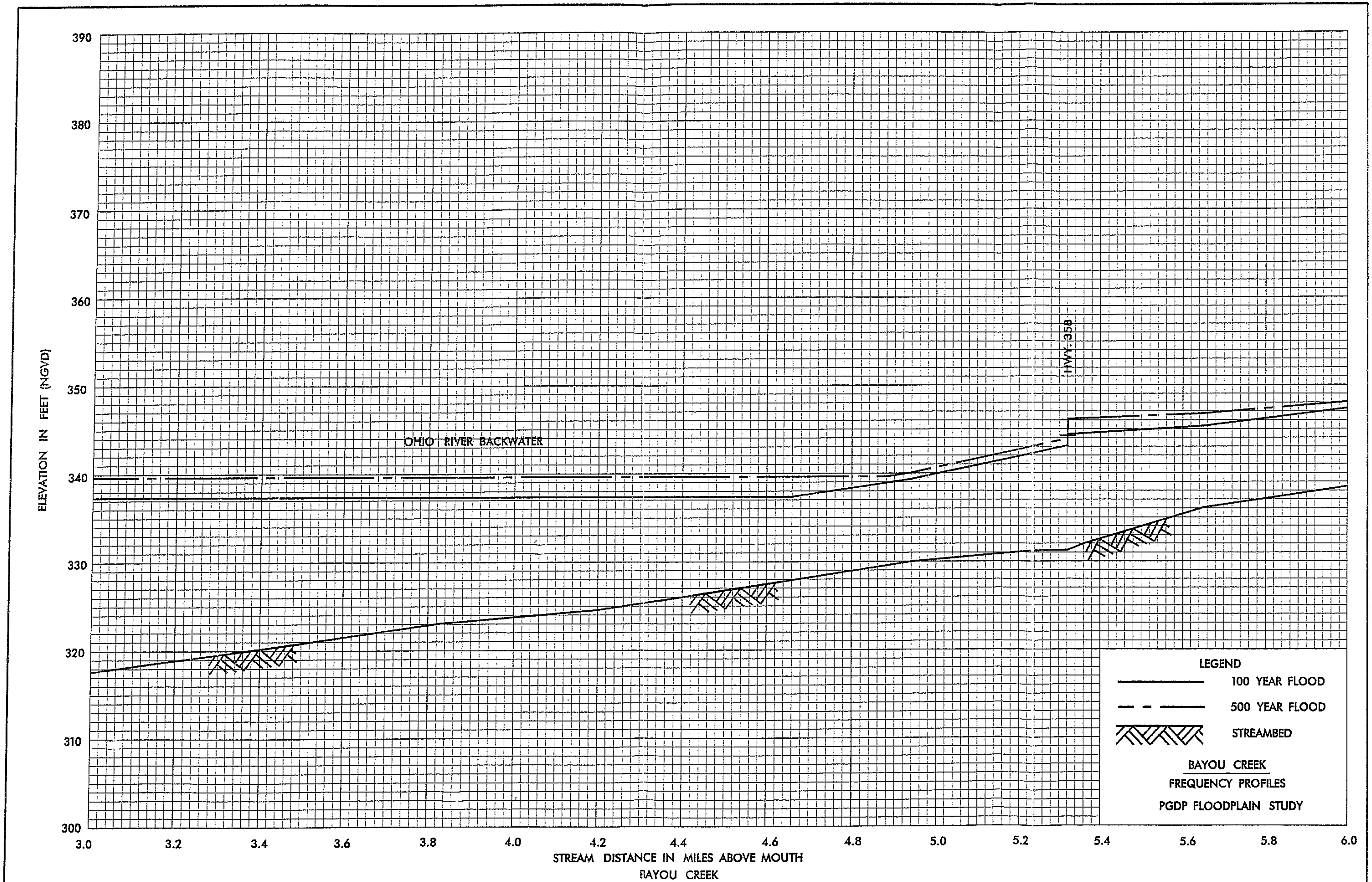
Figure 6.--Relation of flood depth to drainage area for hydrologic area 4.

Exhibit 3-2

Plates



380
370
360
350
340
330
320
310
300
290
ELEVATION IN FEET (NGVD)
OHIO RIVER BACKWATER
OHIO RIVER BACKWATER
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
STREAM DISTANCE IN MILES ABOVE MOUTH
BAYOU CREEK
LEGEND
100 YEAR FLOOD
500 YEAR FLOOD
STREAMBED
BAYOU CREEK
FREQUENCY PROFILES
PGDP FLOODPLAIN STUDY


390
380
370
360
350
340
330
320
310
300
ELEVATION IN FEET (NGVD)
HWY. 358
OHIO RIVER BACKWATER
LEGEND
100 YEAR FLOOD
500 YEAR FLOOD
STREAMBED
BAYOU CREEK
FREQUENCY PROFILES
PGDP FLOODPLAIN STUDY
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
STREAM DISTANCE IN MILES ABOVE MOUTH
BAYOU CREEK