

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
AUSTIN, TEXAS

Delivery of Water
From
Belton Reservoir to the Brazos River Gaging Station
at Richmond, Texas, by way of the Leon, Little
and Brazos River Channels
1956

by

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11/15/56

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AT RICHMOND, TEXAS, BY WAY OF THE LEON, LITTLE
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INTRODUCTION

Beginning November 1, 1956 and ending December 14, 1956, the Corps of Engineers, in cooperation with the Brazos River Authority, released 73,000 acre-feet of water (as measured at the gaging station on Leon River near Belton) from the Belton Reservoir for industrial use in the vicinity of Freeport, Tex. (see fig. 1). The need for this water at Freeport came as a result of the prolonged drought conditions causing flows in the Brazos River in the vicinity of Freeport to be insufficient to satisfy the industrial and other uses of vital importance.

PURPOSE

The purpose of this report is to show the quantity of water released from the Belton Reservoir, the time of its travel downstream to Richmond, and the quantity of released water reaching the gaging station on Brazos River at Richmond, Tex.

The reservoir water traversed 342 miles of river channel before it reached the Richmond gaging station. Analysis of the streamflow records shows that about 54,300 acre-feet of the released water reached Richmond. The quantity of water reaching the Juliff station and other points downstream from Richmond could not be determined because of the lack of records of diversion and other basic data between

between Richmond and Juliff, essential for a complete analysis.

The gaging stations, operated cooperatively by the Geological Survey, the Brazos River Authority, the Corps of Engineers, U. S. Army, and the Board of Water Engineers, recorded the flow as the water was released from Belton reservoir and also when it passed gaging stations on Little River at Cameron and on the Brazos River near Bryan, near San Felipe, at Richmond, and near Juliff. The study of this flow was complicated by rises resulting from rainfall occurring at the beginning and end of the period of release; consequently, records of discharge during periods of steady flow of the water released at Belton were used when possible as basic data in the study.

Records for the Brazos River gaging station near Juliff, which is 26 river miles downstream from the gaging station at Richmond, were omitted from this study because the amount of diversion was unknown between the Richmond and Juliff gaging stations. Streamflow data used in this study were analyzed to determine the following:

1. Quantity of water released from Belton Reservoir.
2. Quantity of water released from Belton Reservoir which reached the gaging station on the Brazos River at Richmond.
3. Travel time required for discharges occurring during the delivery.

SCOPE OF STUDY

The reaches of the river directly involved in this study, in downstream order, are: Leon River from the gaging station near Belton to its confluence with Little River; Little River from the mouth of Leon River to its confluence with the Brazos River; and the Brazos River from the mouth of Little River to the gaging station near Juliff. Indirectly involved are the reach of the Brazos River from Waco to the mouth of Little River, and all tributaries adding appreciable inflow to the streams named above during the period of delivery.

From a hydrologic standpoint, the losses and rates of travel determined in this study may be expected only for conditions such as those existing during the period under study, with emphasis placed on season of the year, climatic conditions, and channel conditions.

FIELD WORK

Frequent current-meter measurements of discharge were made at each gaging station to maintain an accurate stage-discharge relation for computing the flow. Miscellaneous discharge measurements were made on the Brazos River just upstream from the mouth of Little River, and on all Brazos River tributaries contributing appreciable inflow to the reach under study. The miscellaneous measurement sites are indicated on figure 1, and the location and results of the miscellaneous measurements are shown in table 1 below.

Table 1 - Miscellaneous discharge measurements on streams contributing appreciable inflow to the released water.

Measurement Site	Location	Date of measurement	Discharge (cfs)
Nolan Creek at Belton at E. Central Ave. crossing	Lat 31°03' Long 97°28'	Dec. 6, 1956	3.18
Lampasas River 30 feet below mouth of Salado Creek	Lat 29°59' Long 97°25'	Dec. 7, 1956	15.1
San Gabriel River 5 mi NW of Rockdale, at FR 487	Lat 30°44' Long 97°03'	Dec. 5, 1956	0.43
Elm Creek near Cameron at State Hwy 77 & US Hwy 190	Lat 30°54' Long 96°59'	Dec. 4, 1956	0.83
Brazos River above Hwy 190 above Little River nr. Hearne	Lat 30°52' Long 96°42'	Dec. 27, 1956	108
Brazos River nr. Hearne, at US Hwy 190 & above Little R.	Lat 30°52' Long 96°42'	Dec. 4, 1956	87
Yegua Creek near Clay, at FR 50	Lat 30°22' Long 96°21'	Dec. 3, 1956	No flow
Navasota River nr. Hwy 6 near Navasota	Lat 30°25' Long 96°06'	Dec. 3, 1956	6.76
DO	DO	Dec. 23, 1956	22.7
Walker Creek near Washington	Lat 30°17' Long 96°05'	Nov. 27, 1956	No flow
Doe Run near Washington	Lat 30°13' Long 96°09'	do	do
Jackson Creek near Hempstead	Lat 30°12' Long 96°10'	do	do
New Year Creek near Chapel Hill	Lat 30°08' Long 96°12'	do	do
Caney Creek near Hempstead	Lat 30°04' Long 96°09'	Nov. 28, 1956	do
Piney Creek near Sunnyside	Lat 29°57' Long 96°09'	do	do
Eight Mile Creek near Sealy	Lat 29°40' Long 96°03'	do	do
Big Creek near Lochridge	Lat 29°23' Long 95°35'	do	do

Other small creeks with no names shown on figure 1 were investigated and found to have no flow.

Weekly visits were made to each regular gaging station involved and water-stage recorder charts were removed for use in preparing weekly reports furnished to cooperating agencies.

In general, the field work was coordinated so as to obtain regular and miscellaneous discharge measurements at the same time the water-stage recorder charts were removed. After the water release was stopped and base-flow conditions were resumed, the water-stage recorder charts were removed and low-flow measurements were made at all gaging stations to determine base flow at each station. Local gage observers reported daily gage-heights at all stations.

RAINFALL

As mentioned above, the basic records used in this report were considerably complicated by inflow from rainfall at the beginning and end of the period of release. Table 2 on the next page shows the significant rainfall occurring during November and December 1956 on watersheds within the area of this report.

Table 2 - Rainfall in inches at selected stations from Climatological Data published by the U. S. Weather Bureau.

Precipitation Station	November 1956						December 1956					
	2	3	4	5	6	15	18	19	20	21	22	23
		Little River basin below Belton Reservoir										
Temple	0.24	0.29	1.22	0.53			0.41	1.29	0.51			
Davilla	1.42	0.40	0.65				0.37	1.79	0.45			
Troy	0.56	0.50	0.85				1.40	0.70		0.15		
Burlington		0.75	1.65	0.22				1.10	0.36			
Cameron	0.69	0.20	0.95	0.15			1.30	0.22				
Lake Victor							2.00	0.25		0.20		
Liberty Hill												
Taylor	0.10	0.50	0.24				0.16	1.98	0.44			
Jarrell	0.65	0.20	2.15	0.55	0.10		0.20	1.07	0.58			0.10
		Brazos River basin above Little River										
Waco, WB-AP	0.54	1.02	0.77				0.83	1.03				
		Brazos River basin below Little River										
Valley Junction		0.59	0.30	0.70			0.43	0.90	0.19			
Brenham		0.62	0.70	0.23			2.15	0.68	0.20		0.22	1.83
Hempstead		0.25	2.44	0.22			1.45	0.27			0.53	0.91
Sealy		0.52	0.23	0.10			2.92	0.16		0.88	0.43	
Richmond		0.37	0.17				1.92	0.74			1.09	
Sugarland		0.29				0.75	1.45	0.33			1.10	
Dime Box	0.20	0.52	0.48				1.90			0.35	0.38	0.13
Thornton		1.09	0.80	0.85	0.12			1.14	0.18			
College Station	1.03	0.38	0.30	0.12			1.15	0.11		0.15	0.30	
Anderson	0.43	1.58	0.48	0.12			1.73			0.22	2.23	
Brenham		0.62	0.70	0.23		0.15	2.15	0.68	0.20		0.22	1.83
Sealy		0.52	0.23	0.10			2.92	0.16		0.88	0.43	

The rises from rainfall shown in table 2 above unfortunately arrived at the gaging stations when water released from Belton Reservoir was passing with the exception of the Cameron station, where the release water preceded the rise resulting from rainfall by about one day (see fig. 3). This fact, combined with very good discharge measuring conditions at the Cameron station, greatly facilitated the separation of the released water from flood water, as well as the determination of

the time of travel for all types of flow involved.

DAILY AND WEEKLY REPORTS DURING PERIOD OF WATER RELEASE

A daily report of flow at each station was compiled from previously defined stage-discharge relation curves and from once-daily gage readings received from local observers by long-distance telephone. This information (subject to later revision) was furnished immediately to cooperating agencies. In addition, a summary of daily flow at all gaging stations was furnished to cooperating agencies at the end of each week. These data were used by the Corps of Engineers and the Brazos River Authority to regulate the amounts of water released to conform with water losses and variations in travel time of water.

After the release had been completed a final summary of daily discharge (USGS form 9-192a) was prepared for each gaging station covering the entire period of the release. These summaries, combined with actual current-meter measurements, were the basic data used in this study.

DISCUSSION

Very early in the study of this flow-routing investigation, it became obvious that this, and probably most other similar flow-routing investigations, must be treated as special cases with emphasis placed on the following prime factors:

1. Current season of the year
 - a. Regarding growth period of phreatophytes
 - b. Regarding ground-water conditions affecting base flow.
 - c. Regarding inflow from rainfall

2. Condition of river channels
 - a. Regarding the flow existing in the channels before and during the period of the routing.
 - b. Regarding existing river-bed characteristics.

This investigation was complicated by a considerable amount of flood inflow resulting from rains soon after release of water began, as well as at the end of the release period, and by some diversions between the stations near San Felipe and at Richmond. Also, during the time this release was in progress, other small intermittent releases were being made from Lake Whitney on the Brazos River upstream from Waco (fig. 4). It may be noted by inspecting the discharge hydrographs (figs. 2 - 7) that periods of low flow existed prior to and following the period of release, and that several long periods of steady flow existed at all gaging stations during the release. These steady-flow periods provided important data for determining water losses between Belton Reservoir and the gaging station on Brazos River at Richmond.

The typical discharge recession curve for Richmond (fig. 9) was based partly on rises following the release and partly on previous rises of a comparable magnitude for the same season of the year, and was used to define the flood-flow recession hydrograph comprising the upper limits of base flow for rises which were partly obscured by the release water. The lower limits of base flow for each station were determined from a study of low-flow records for each station prior to and following the release.

An account of inflow from Brazos River tributaries contributing appreciable amounts of water was obtained by miscellaneous discharge measurements shown in table 1.

Although no seepage investigation has been made on the Brazos River reach considered in this report, the following statement from the Austin, Texas office of the Ground Water Branch of the U. S. Geological Survey is an indication of the inflow from ground water affecting base flow for this reach of the Brazos River.

"We have made no detailed studies along the Brazos River, but based on general knowledge of hydrologic conditions in the area, we can make the following general statements:

Area between Waco and Falls County line.-- Geologic formations can be expected to make extremely small contribution to base flow of the Brazos River. River crosses outcrop of Taylor marl and Navarro group.

"Area between Falls County line and Bryan.-- Geologic formations can be expected to make large contribution to base flow of the Brazos River. River crosses outcrop of Midway group, Wilcox group, Carizzo sand, Mount Selman formation, Sparta sand, and Cook Mountain formation.

"Area between Bryan and Hempstead.-- Geologic formations can be expected to make small contribution to base flow of the Brazos River. River crosses outcrop of Yegua formation, Jackson group, Catahoula sandstone, Oakville sandstone, and Logarto clay.

"Area between Hempstead and Richmond.-- Geologic formations can be expected to make moderate contribution to base flow of the Brazos River. River crosses outcrop of Willis sand, Lissie formation, and Beaumont clay.

"Area between Richmond and Gulf Coast.-- Geologic formations can be expected to make small contribution to base flow of the Brazos River. River crosses outcrop of the Beaumont clay."

Periods of diversions by pumping between San Felipe and Juliff for period Nov. 1, 1956 to Jan. 30, 1957, were obtained from the American, the Richmond and the South Texas Canal companies. These

pumping periods, fortunately, occurred during periods of steady flow of the release water and, therefore, could be defined on the Richmond hydrograph.

The time of arrival of the first water released from Belton Reservoir could be accurately determined at the Belton and Cameron gaging stations from the water-stage recorder chart for those stations. The arrival of this released water at the gaging stations near Bryan and below was obscured by what appeared to be the coincidental arrival of flood runoff. Therefore, the time-of-travel curve (fig. 8) is based on the travel of the released water from Belton to Cameron and on the travel of the initial portion of the flood wave from Bryan to Richmond.

Twice during the time water was being released from Belton Reservoir the gates at the dam were partly closed, reducing the flow by about 100 cfs each time. The time of arrival of the "influence-wave" caused by this reduction in flow could be accurately determined at the Belton, Cameron and Bryan gaging stations. The expression "influence-wave" as used in this report is used to identify a wave caused in the release flow as a result of changing the gate openings at the Belton Dam. The time of travel of this wave from Belton to Cameron was 1.25 days, whereas the time of travel for first water released was 2.00 days. The influence-waves do not seem to move according to the empirical laws governing the movement of a rise resulting from rainfall runoff, but instead seem to behave more like the "sloping waves" as described by King 1/.

1/ King, H.W., Handbook of Hydraulics, 3d ed., p. 424, 1939.

An effort has been made in the discussion of the various phases of this investigation to explain the problems involved in determining water losses connected with delivering water through the reaches of the above-named river channels. The results of each phase of the water-separation study were combined to form a simple graphic analysis of the flow involved. The net accumulated losses from Belton to the Richmond station were obtained by separating the basic types of flow, namely, release, base flow, pumpage, and rainfall-runoff, into their proper category by comparing their respective ordinates on the hydrograph for each day throughout the period of release.

CONCLUSIONS

Upon the completion of this study of the water released from Belton Reservoir from Nov. 1 to De. 14, 1956, the following conclusions were drawn:

1. Each flow-routing investigation must be treated as a special case with emphasis placed on the prime factors as mentioned on pages 7 and 8.
2. The time of travel of the first portion of a flood wave is considerably more in many cases than that required for an influence wave as defined in this report.
3. The quantity of water released from Belton Reservoir and reaching the gaging station on Little River and on the Brazos River near Richmond is shown in the table below:

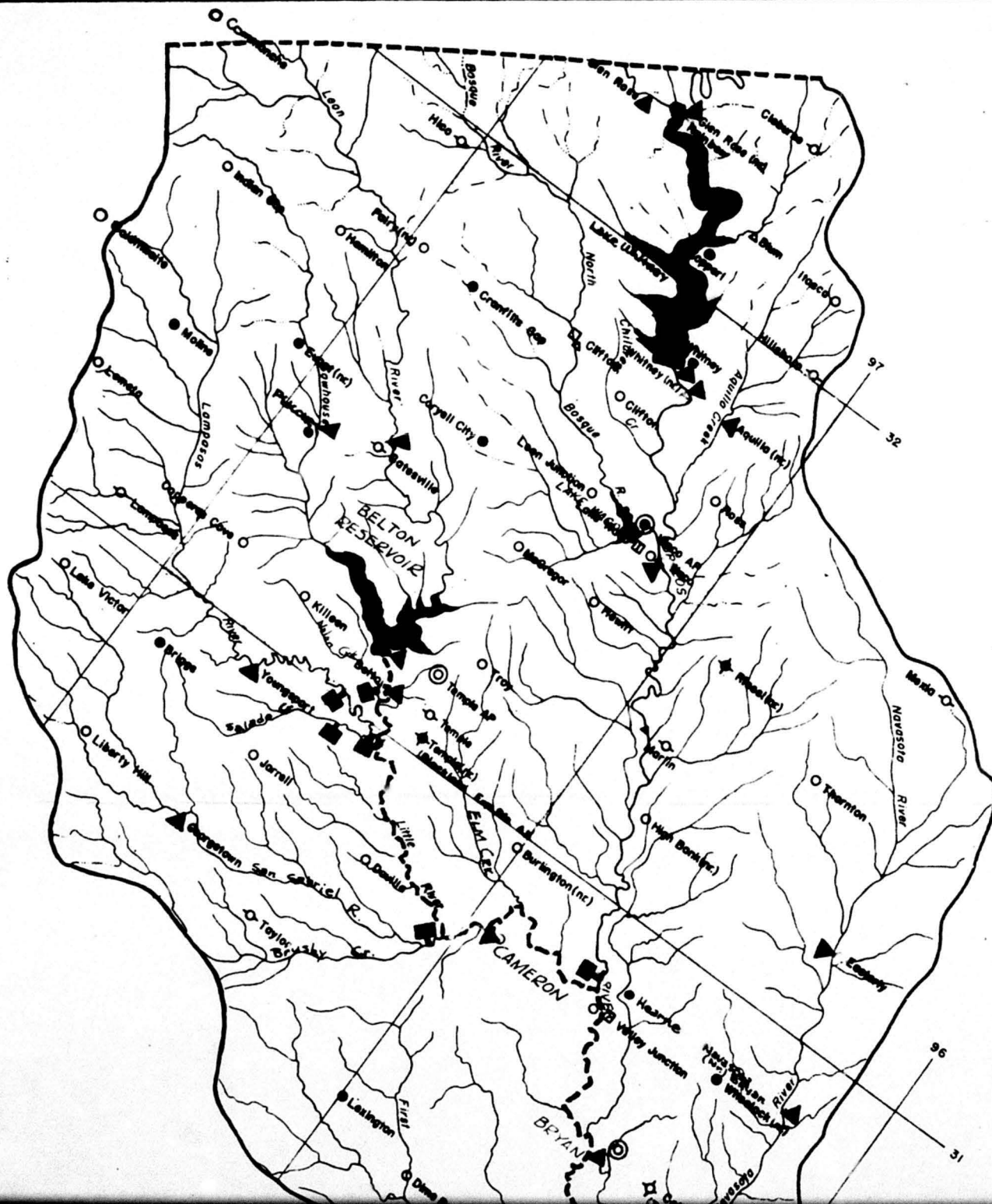
Table 3 - Quantity of water released from Belton Reservoir
reaching streamflow stations as indicated

Station	Period of flow 1956	Belton Res.re- lease water reaching indi- cated station	Percent of re- lease water reaching indi- cated station
Leon River nr.Belton	Nov.1 to Dec.15	72,800 acre-ft.	100
Little River nr.Cameron	Nov.3 to Dec.19	69,900 do	96
Brazos River nr.Richmond	Nov.19 to Dec.30	54,300 do	74

ACCURACY OF FIELD DATA AND COMPUTED RESULTS

Application of records - The computation of quantities of released water reaching the Richmond gaging station was made complex because an estimate of base flow and flood inflow had to be made. The accuracy of these estimates is classified as "fair", or they are subject to errors of 15 percent or more.

Basic records - The basic records or total flow at all gaging stations and the miscellaneous measurements of flow of tributaries have an accuracy rating of "excellent", or the error in the total runoff past each gaging station is believed to be within 5 percent.



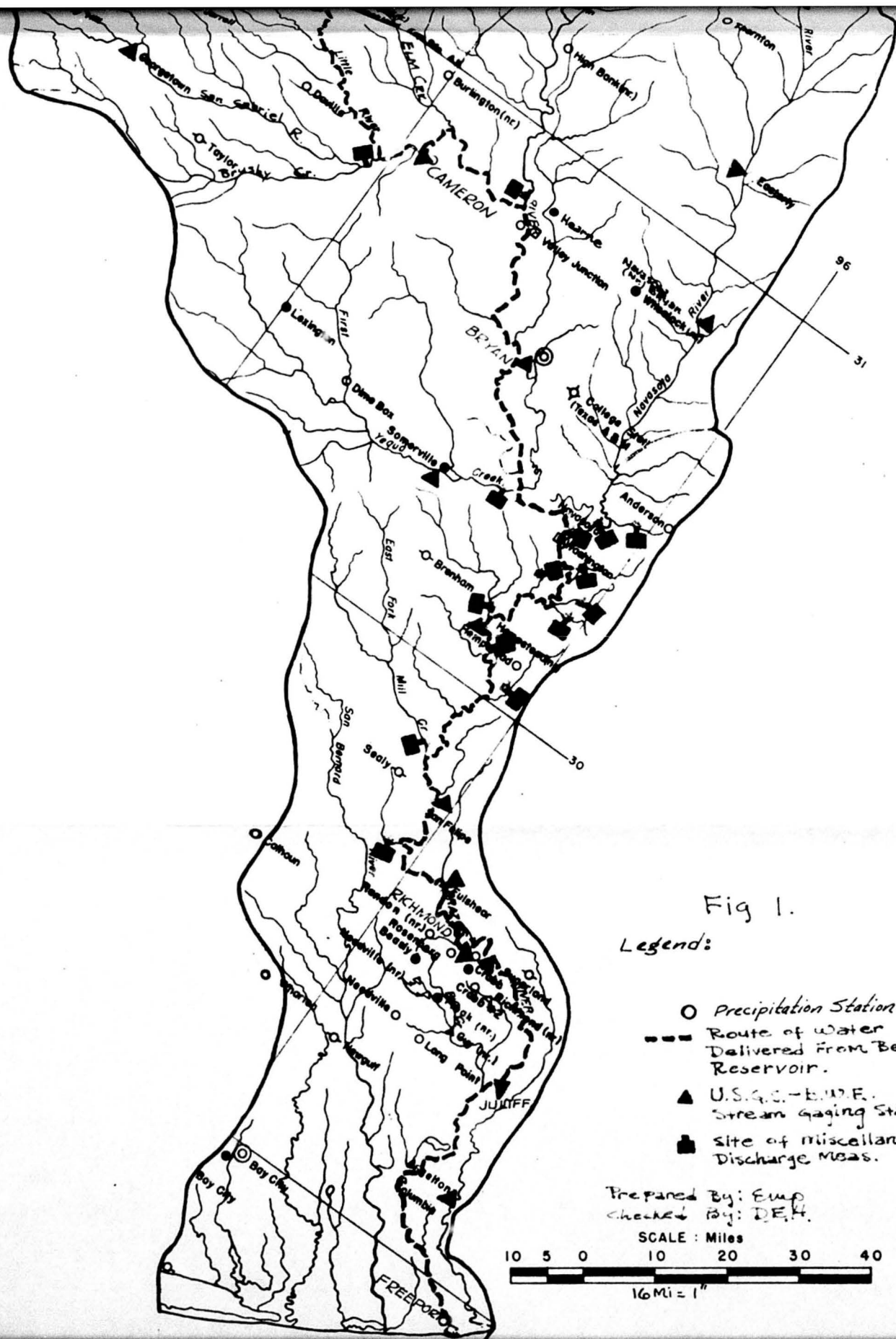


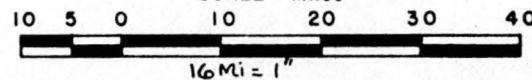
Fig 1.

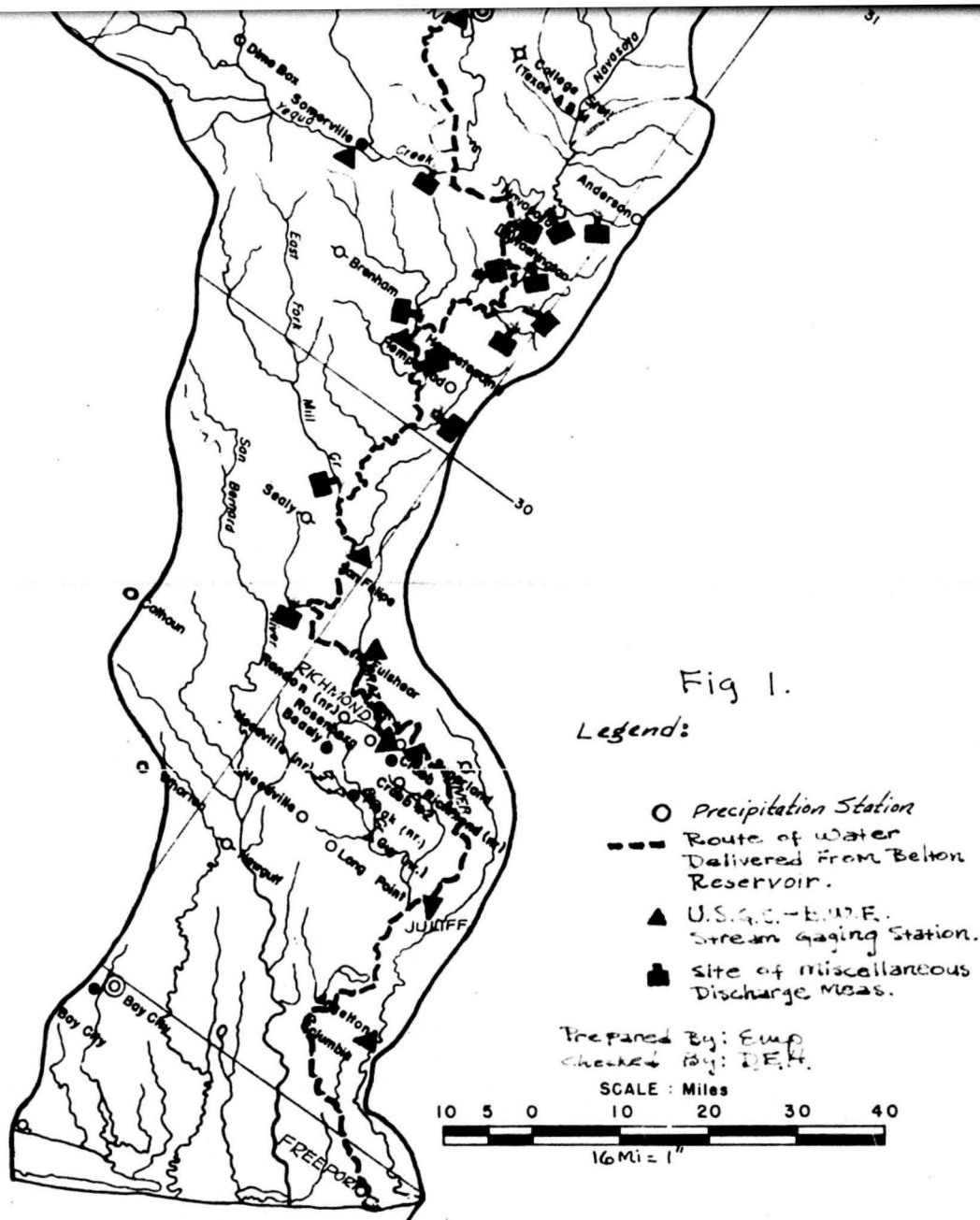
Legend:

- Precipitation Station
- Route of water Delivered from Belton Reservoir.
- ▲ U.S.G.C.-B.M.F. Stream Gaging Station.
- Site of miscellaneous Discharge Meas.

Prepared By: EMP
Checked By: DEH.

SCALE: Miles

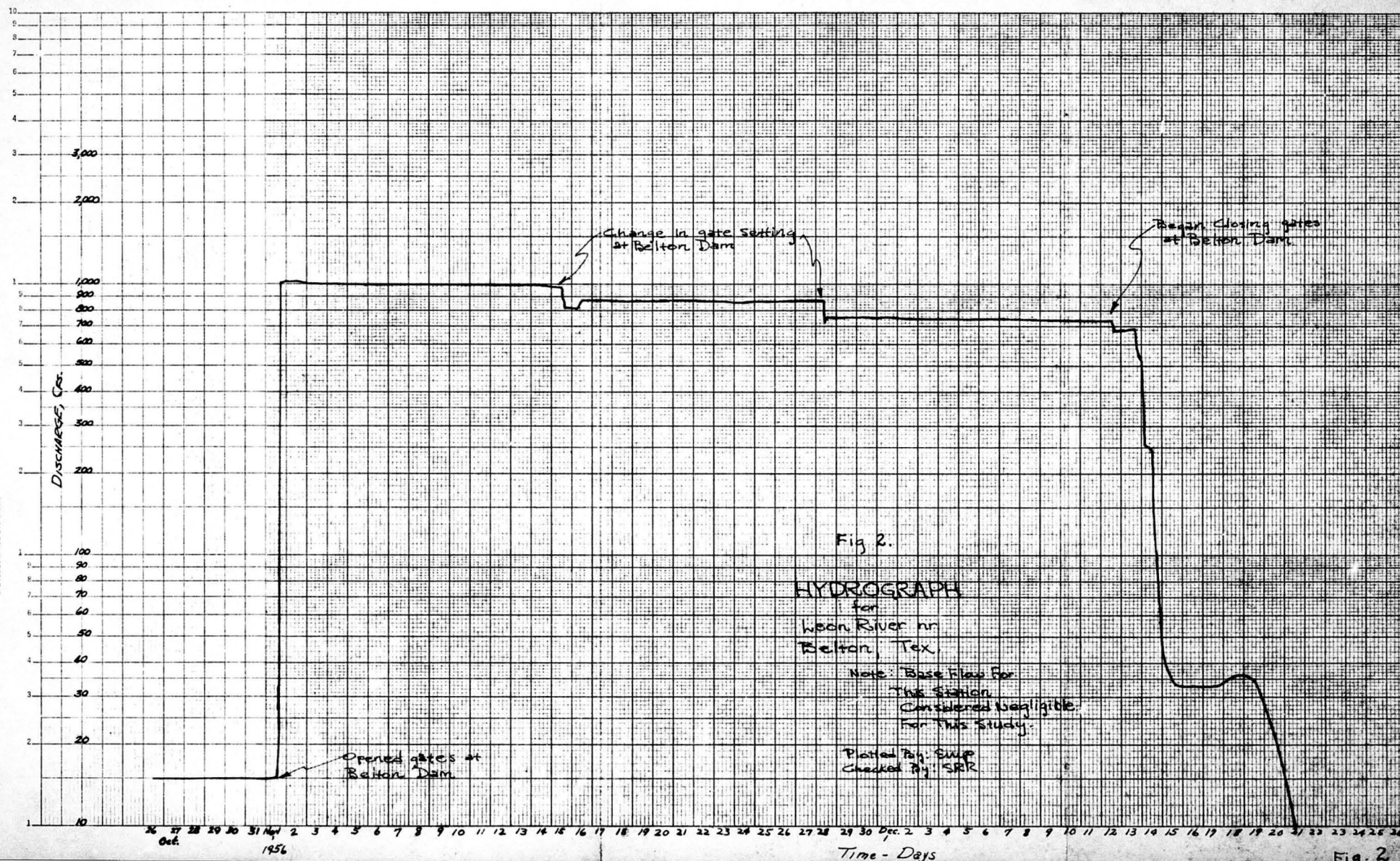




LOWER BRAZOS RIVER BASIN

Showing Streamflow Stations, Precipitation Stations,
Sites of Miscellaneous Measurements, and Route of Water
Delivered From Belton Reservoir.

From U.S. Weather Bureau Maps No 52453



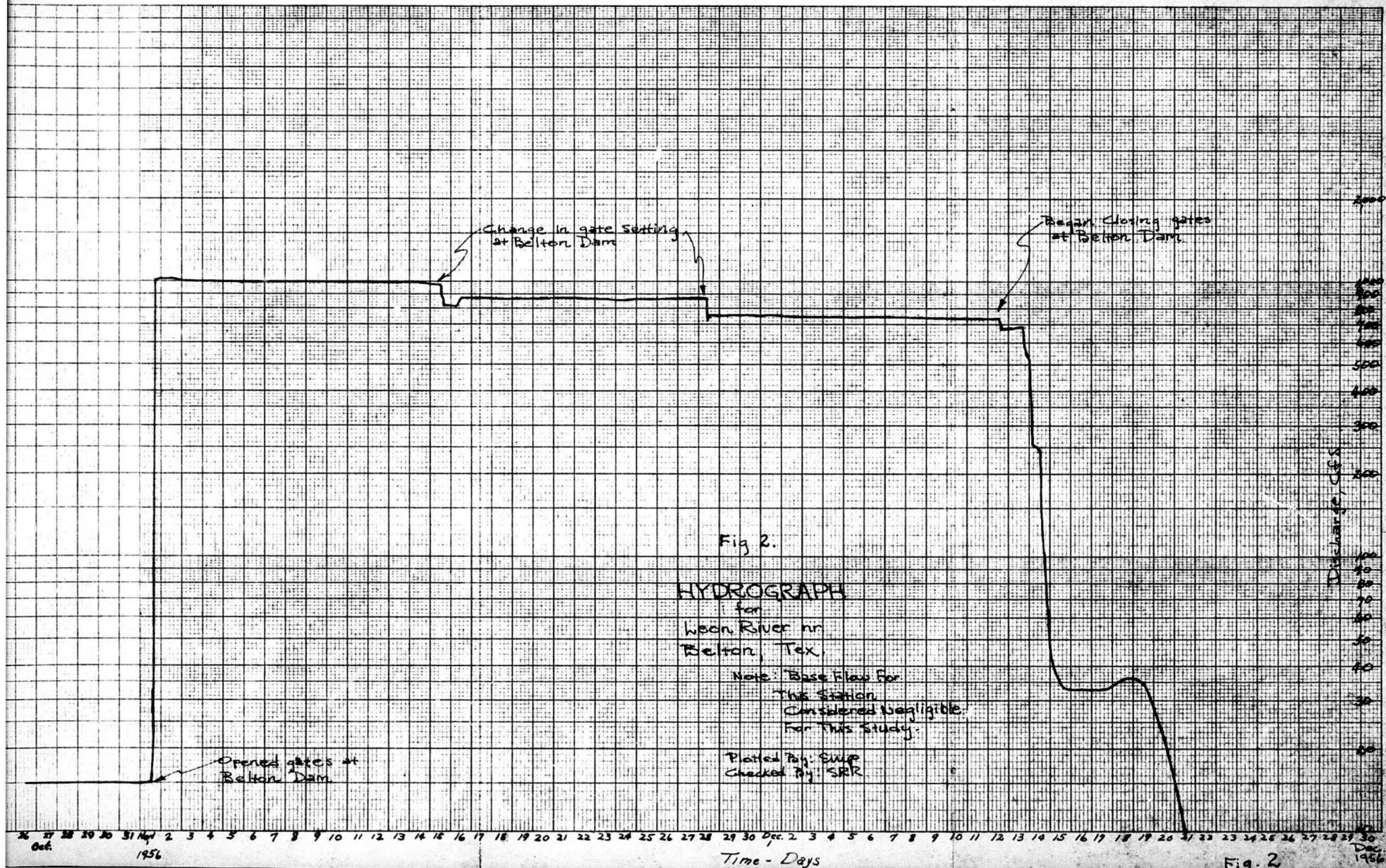
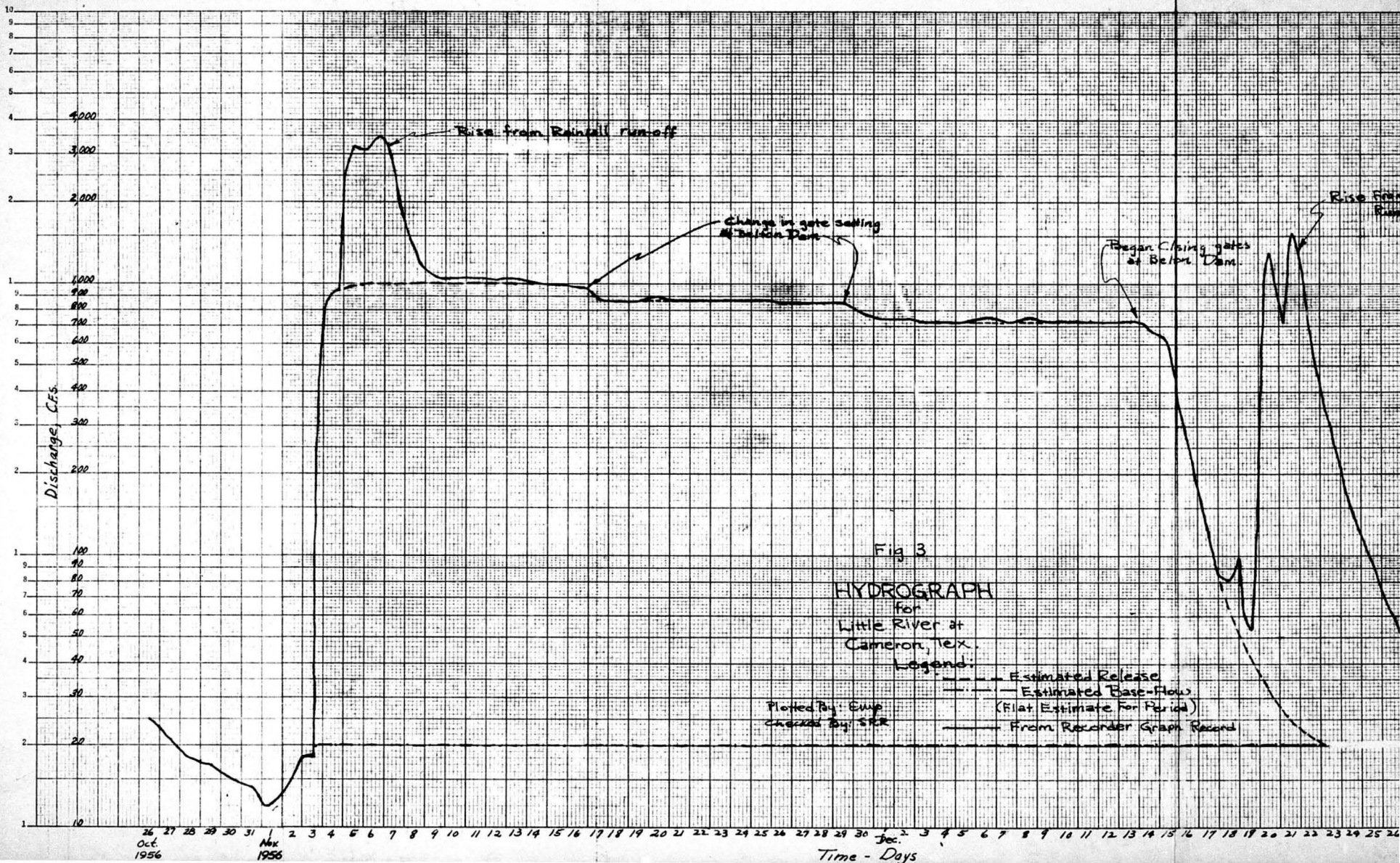
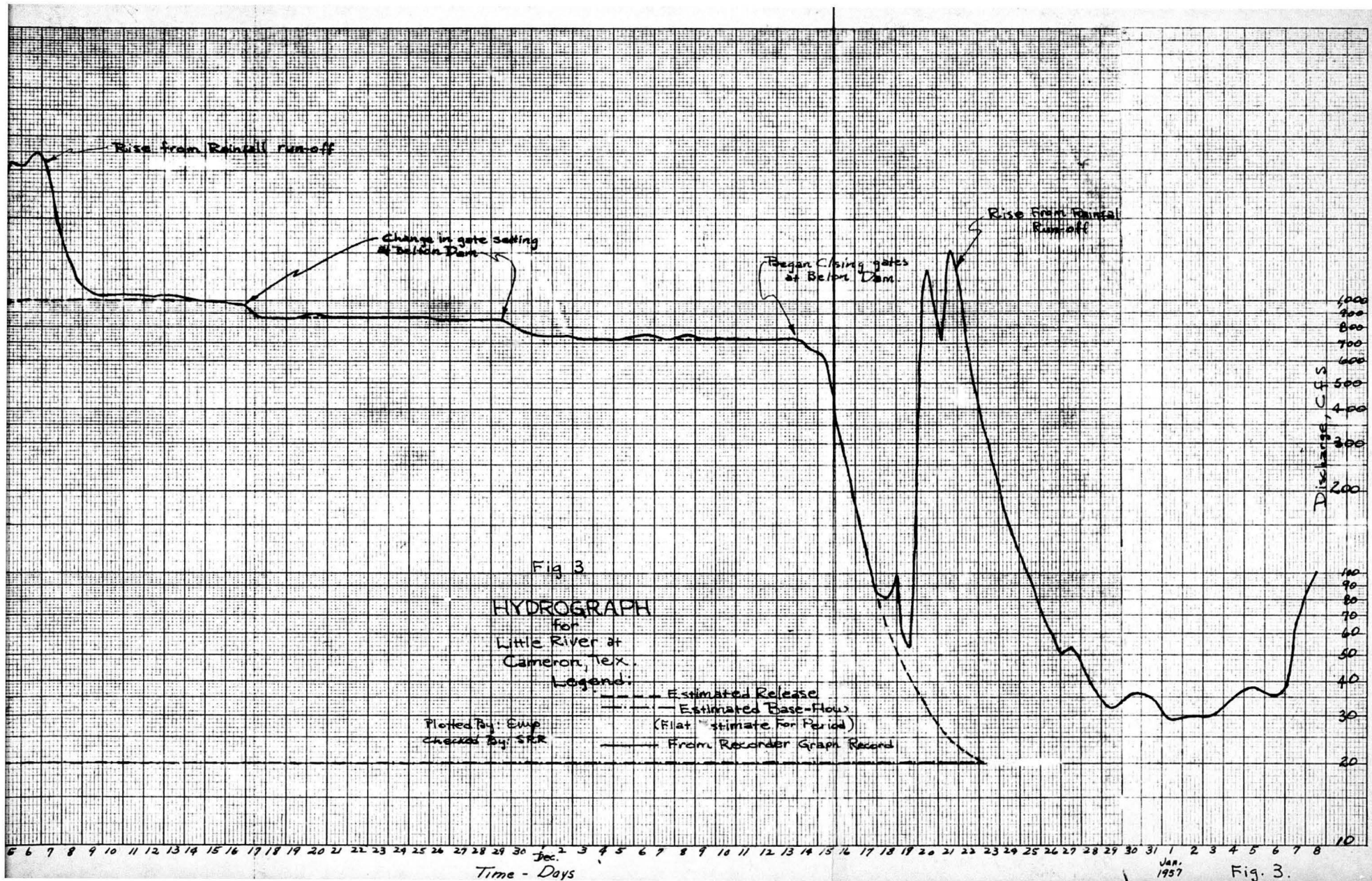


Fig. 2





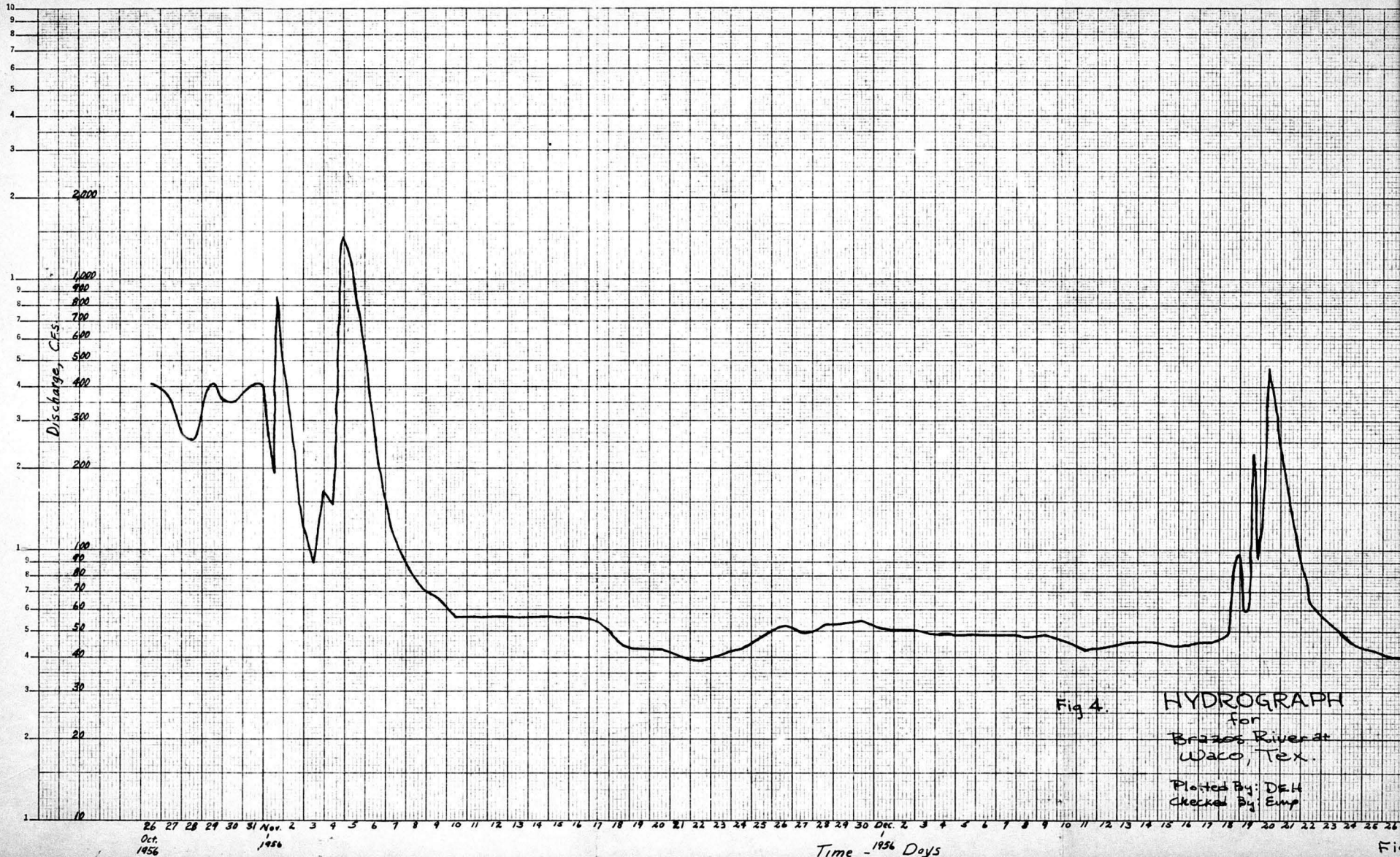
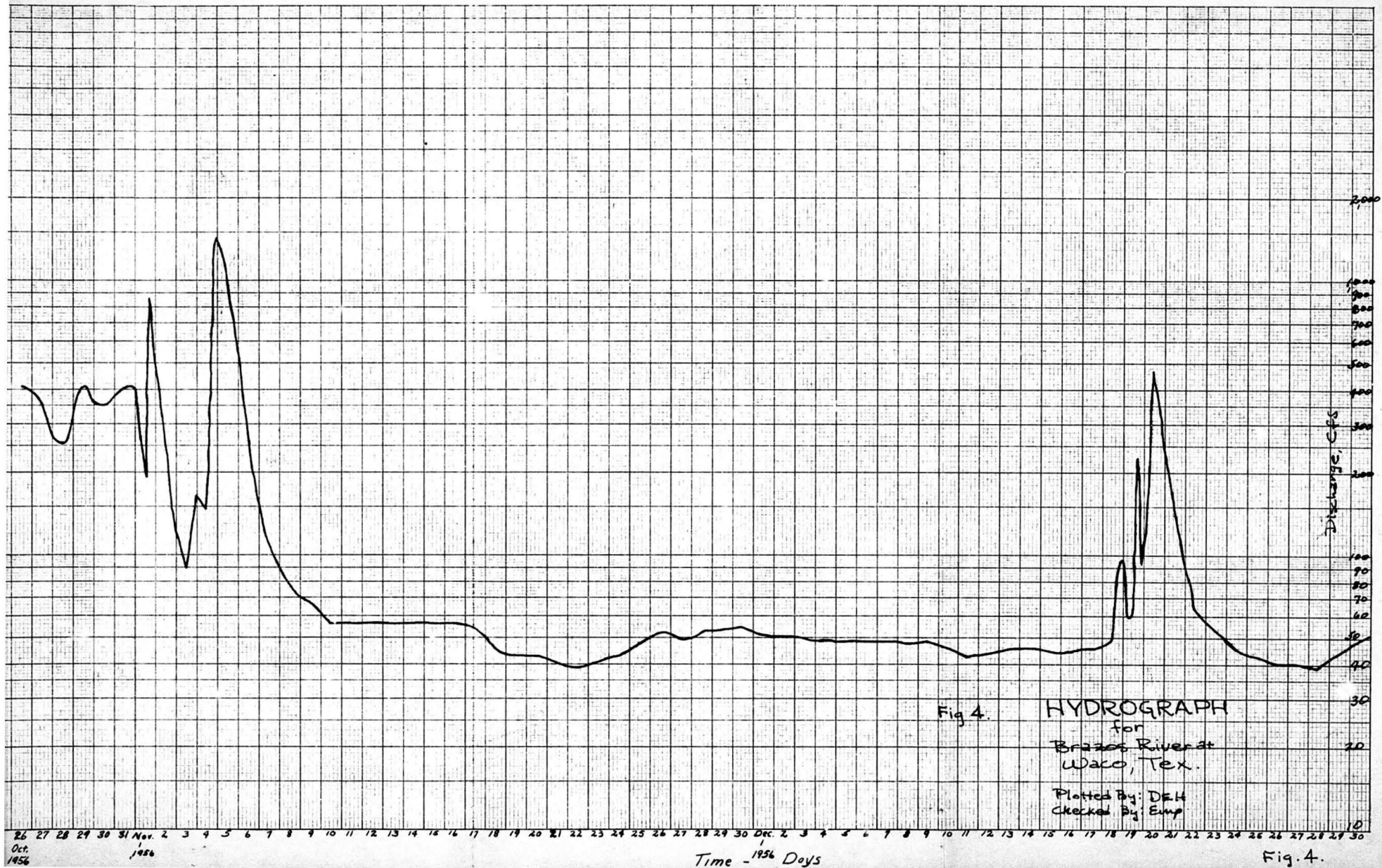
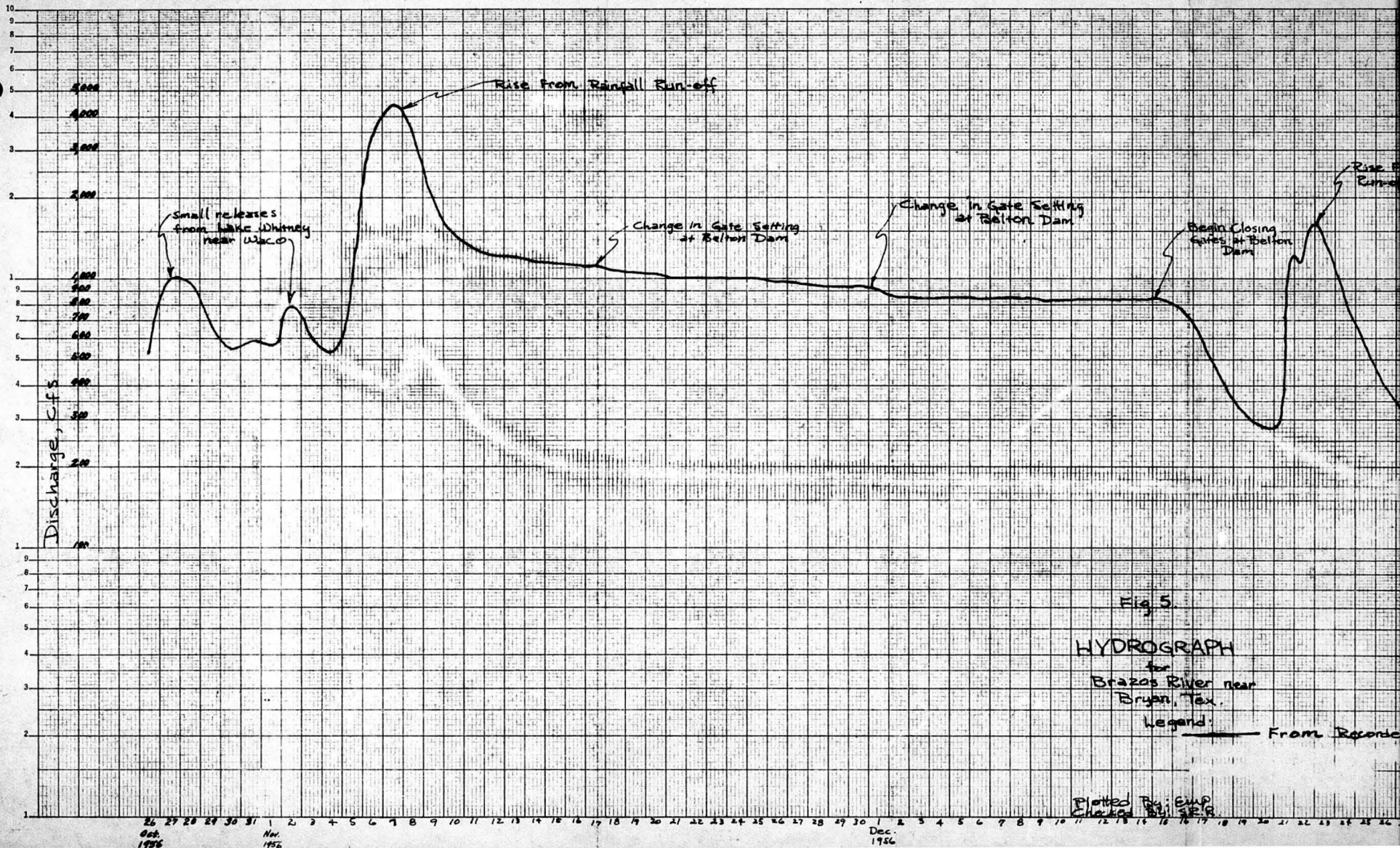


Fig 4. HYDROGRAPH
 for
 Brazos River at
 Waco, Tex.
 Plotted By: D&H
 Checked By: Emp

Time - 1956 Days

Fig





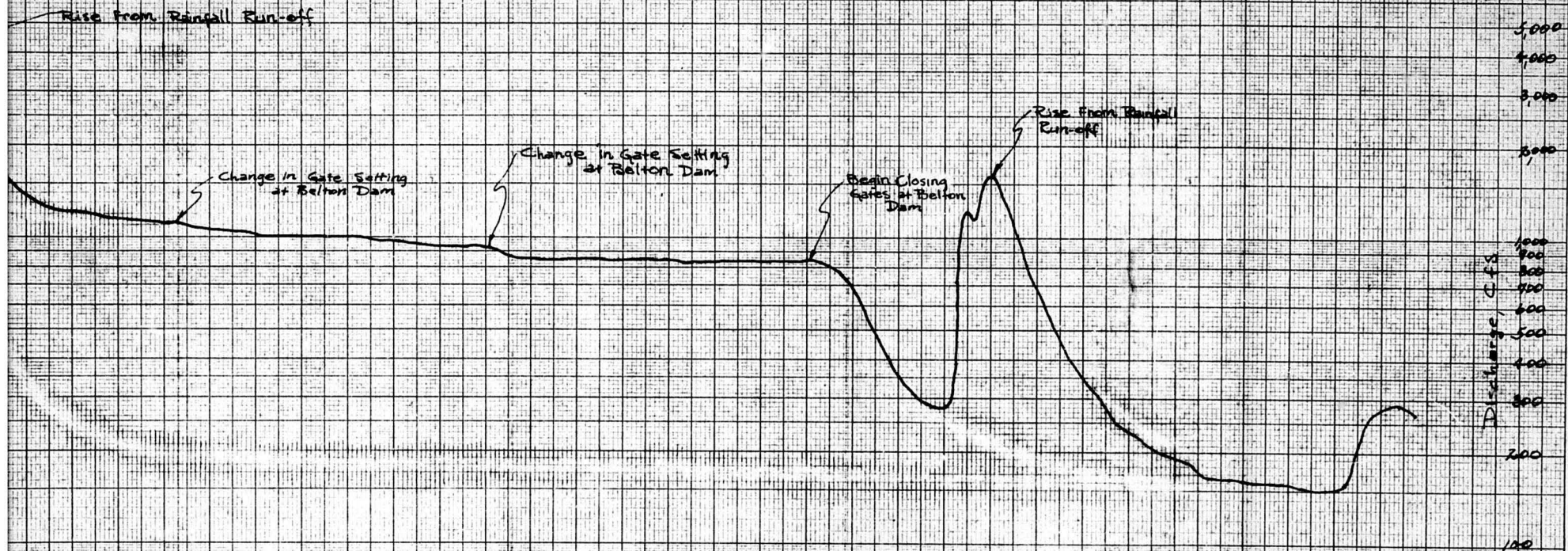


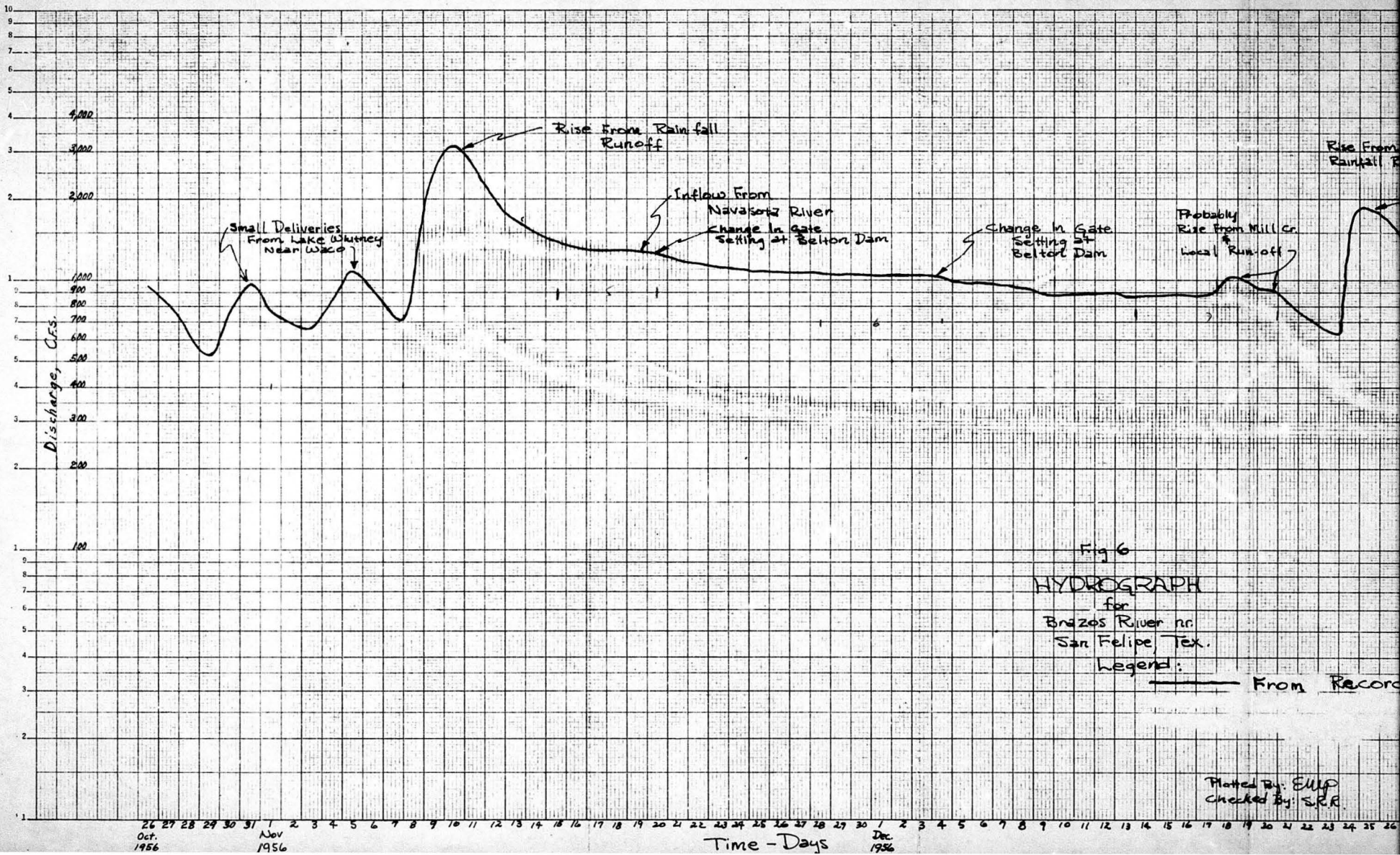
Fig. 5.

HYDROGRAPH for Brazos River near Bruhan, Tex.

Legend: ——— From Recorder Graph Record

Plotted by EMP
Checked by JER

Fig. 5.



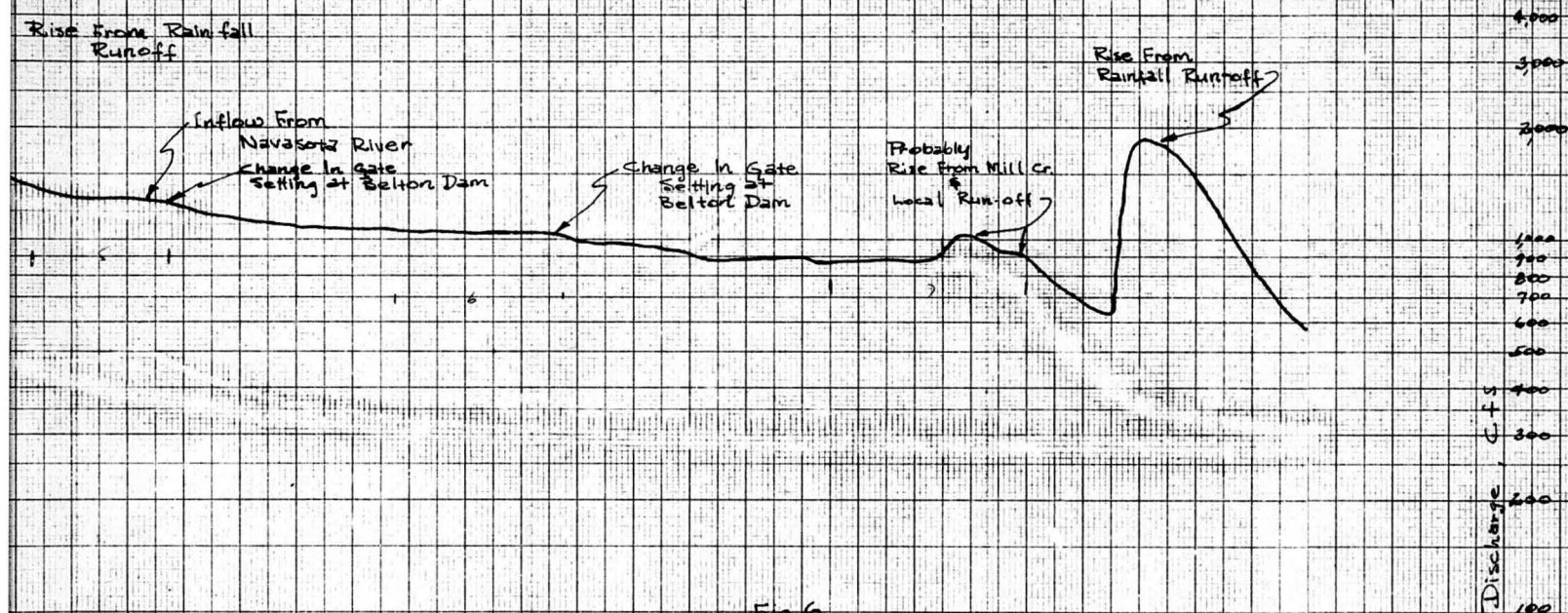


Fig 6
HYDROGRAPH
for
Brazos River nr
San Felipe, Tex.
Legend:

— From Recorder Graph Record

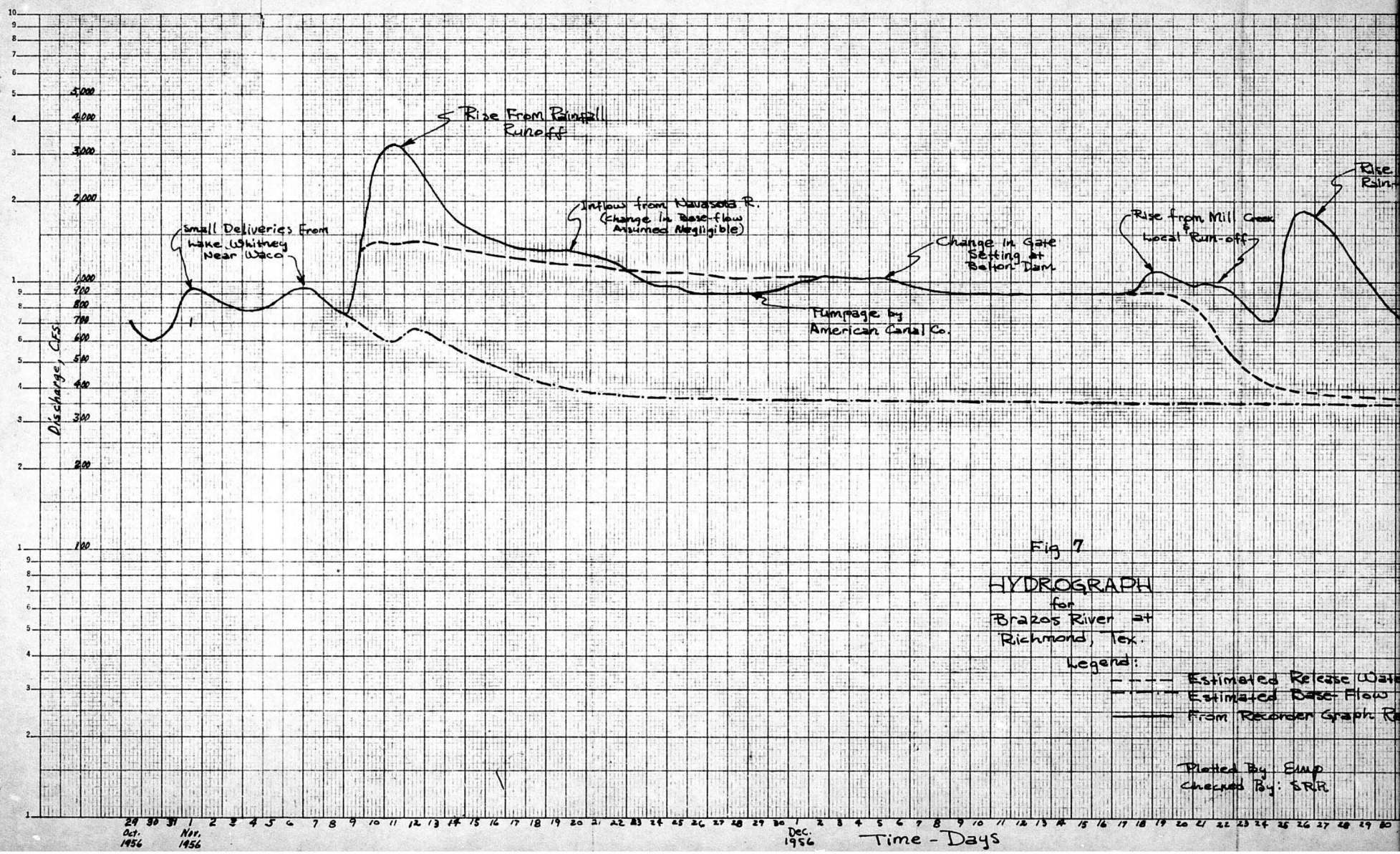
Plotted By: ELP
Checked By: SRR

Time - Days

Dec.
1956

Dec.
1956

Fig. 6.



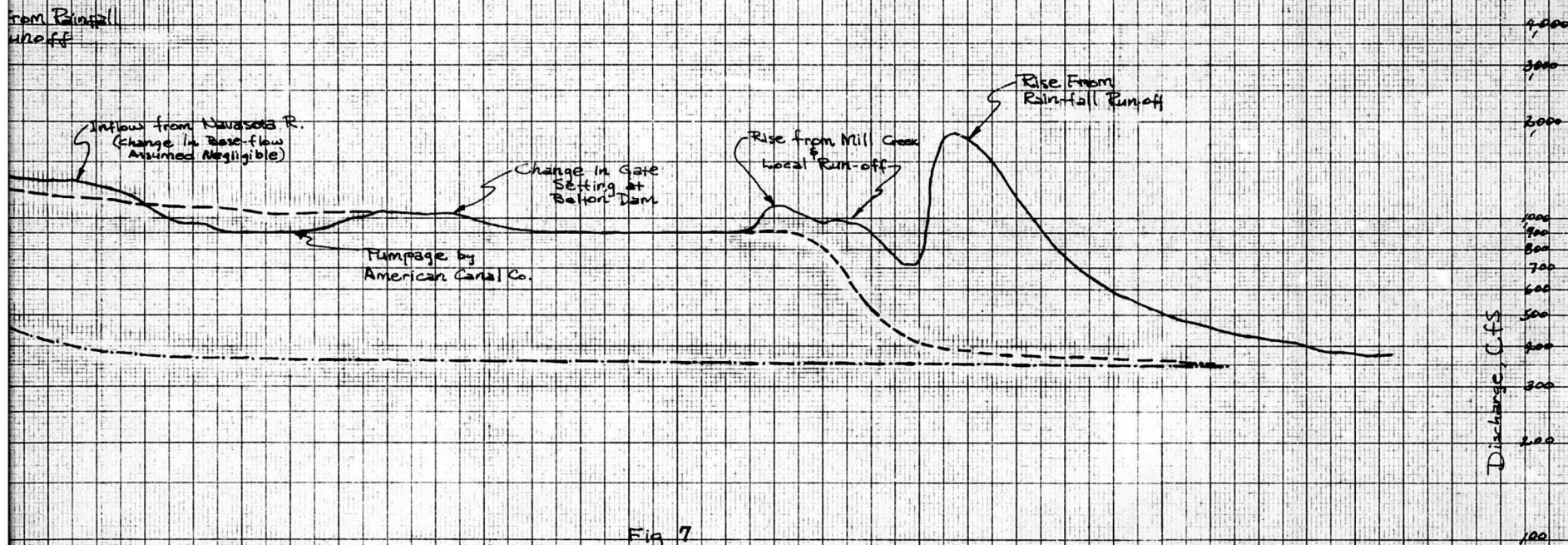


Fig 7
HYDROGRAPH
for
Brazos River at
Richmond, Tex.

Legend:

- Estimated Release Water
- .-.- Estimated Base Flow
- From Recorder Graph Record.

Plotted By: EUMP
Checked By: SRR

Dec.
1956

Time - Days

Jan
1957

Fig. 7.

Legend

- Travel Time of First Released Water.
- - - Travel Time of Influence Wave Induced By Partially Closing Gates at Belton.

NOTE: — Time of arrival of released water at Bryan, San Felipe, and Richmond was obscured by the presence of flood runoff. The time of travel from Bryan to Richmond shown on this sheet was based on the travel of the beginning portion of the flood wave which obscured the time of travel of the released water.

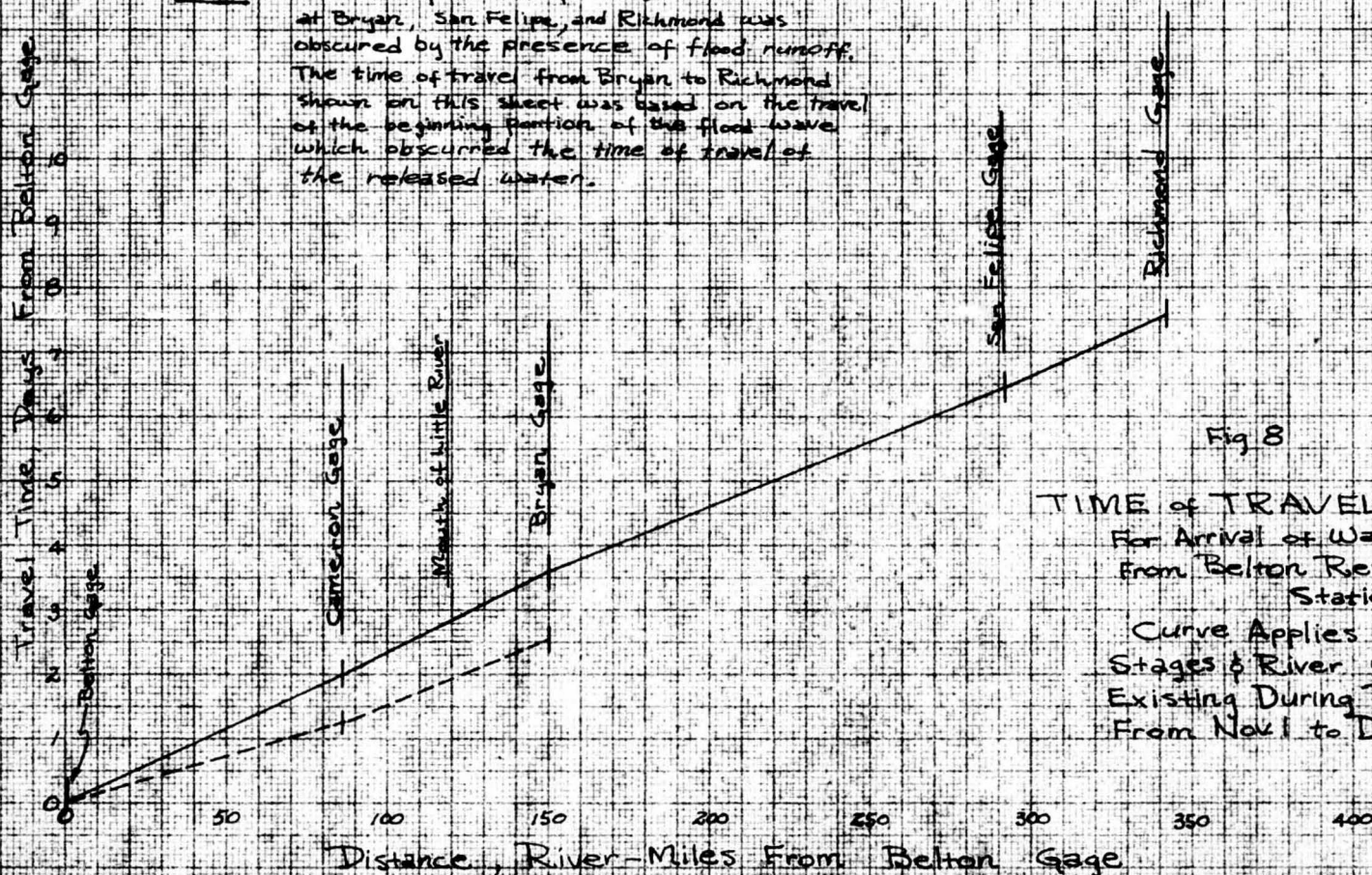


Fig 8

TIME of TRAVEL CURVE
For Arrival of Water Delivered
From Belton Res. To Indicated
Stations

Curve Applies Only to
Stages & River Conditions
Existing During Period of Release,
From Nov 1 to Dec 14, 1956

Discharge, cfs

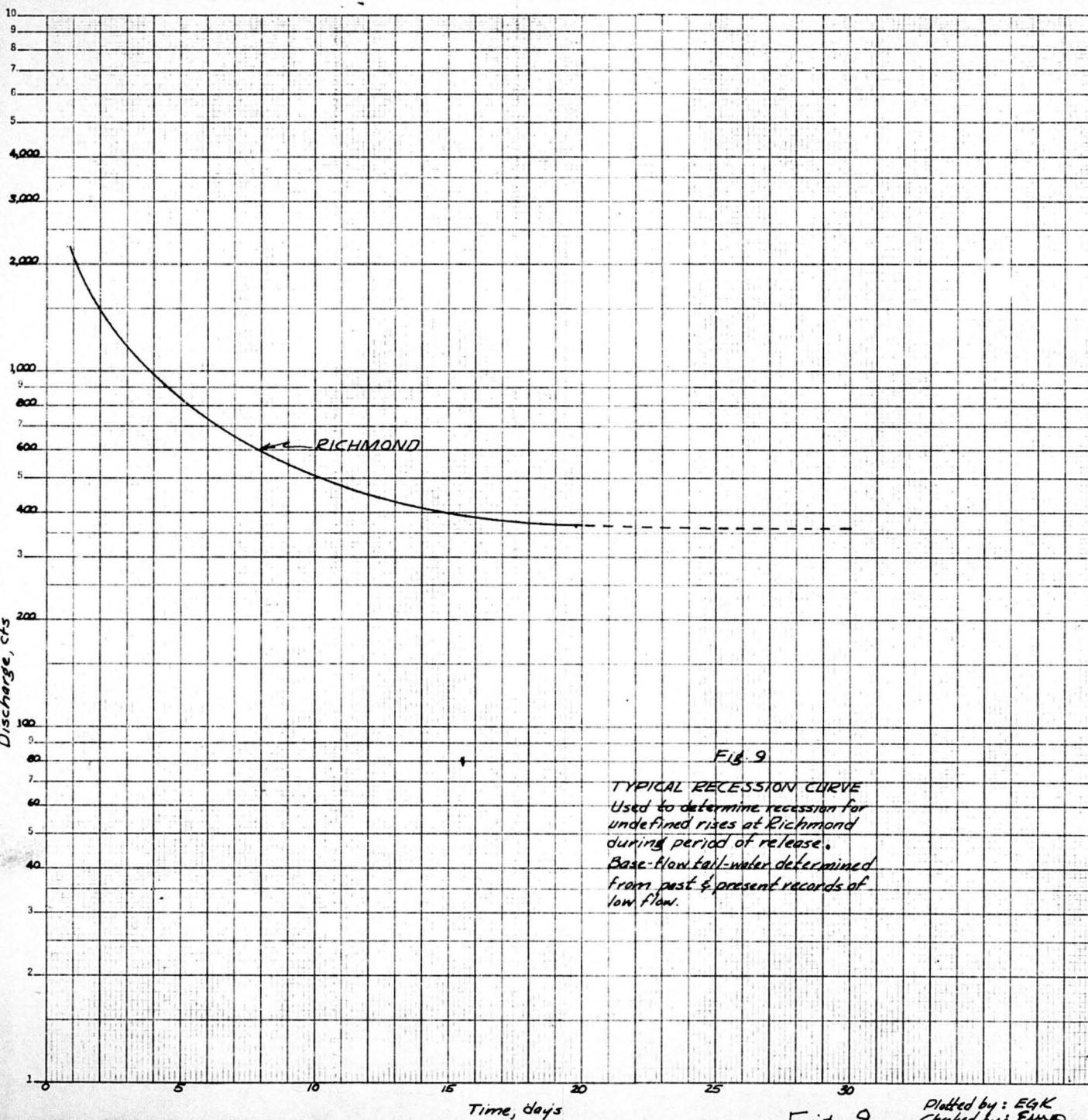


Fig. 9

TYPICAL RECESSION CURVE
Used to determine recession for
undefined rises at Richmond
during period of release.
Base flow tail-water determined
from past & present records of
low flow.

Fig. 9

Plotted by: EGK
Checked by: EMP

