APPENDIX C

DEVELOPMENT
OF
PUMP STATION DESIGN CRITERIA

INTRODUCTION

To prevent flooding within leveed areas, pumps are recommended (instead of only providing storage) to handle interior drainage when the exterior river stage impedes gravity outflow. To determine the required pumping capacity and, therefore, the pump size needed for the pump station, design criteria were developed. One of the major components of the design criteria centers around the rainfall amount to be used in sizing the pump station that would be required to remove interior drainage during high water levels outside of the leveed area that submerge the gravity outlet.

The normal design criteria for large-scale drainage facilities (e.g. open channels, detention facilities) is based on the rainfall for the 100-year storm event. Large-scale interior drainage facilities for leveed areas should also be designed to the same standard (i.e. a condition that will be equaled or exceeded on the average only once in 100 years). For leveed areas providing flood protection from creeks and bayous (excluding the Brazos River), the drainage facilities (pumping and storage capacities) would need to be designed to handle the excess rainfall from a 100-year storm within the interior area, since the exterior creek/bayou would probably be at its 100-year flood stage as a result of the same storm event and thereby restrict any gravity outflow from the leveed area. For leveed areas providing flood protection from the Brazos River, however, the 100-year flood stage on the Brazos does not result from the same storm event as the 100-year rainfall over the leveed area. Thus, there are two different circumstances that would produce a critical design condition for interior drainage facilities. The first condition would be a 100-year storm event over the leveed area when the Brazos River water surface elevation is low, and the second condition would be a storm event over the leveed area when a large flood on the Brazos River is occurring that would restrict gravity outflow from the leveed area. Since these two conditions would occur from different storm events, the drainage facilities for the leveed area need to be designed so that the overall design capacities are equaled or exceeded on the average only once in 100 years. Thus, the pumping and storage facilities need to be designed for one storm event, and the channels under gravity flow conditions need to be designed for another storm event, so that together, the design would only be exceeded on the average once in 100 years. It was determined that a good combination for the pump

station and gravity outlet designs would provide for exceedance frequencies of once in 1,000 years during high river states and nine times in 1,000 years during other periods, thus yielding a combined exceedance frequency of once in 100 years. This meant that the pump station and storage facilities would be designed to handle a coincidental probability of occurrence between high river stages and an event having local rainfall of once in 1,000 years. Also, the gravity outlet and internal channel system should be designed to handle the storm event with an exceedance frequency of nine times in 1,000 years; however, it was decided that a comparable design would be to design the gravity system for the 100-year storm event with one foot of freeboard.

DESIGN CRITERIA

The development of the pump station design criteria centers around establishing the percentage of time that a critical flood level on the Brazos River at the leveed area and a particular rainfall event over the leveed area occurring coincidentally will produce a frequency of occurrence that, together with the gravity outlet design criteria, would result in the entire design of the leveed area's drainage facilities being exceeded on the average once in 100 years. To establish this coincidental probability, the percent of time that a flood level on the Brazos River is equaled or exceeded needs to be related to the chance of occurrence of a storm event at the same time over the leveed area.

A flow-duration analysis for the Brazos River was performed using the flow records from the U.S.G.S. gauging station at Richmond in Fort Bend County. This analysis produced a curve showing the percent of time that a particular flow on the Brazos River has been equaled or exceeded based on the period of recorded data (approximately 67 years). Unfortunately, since the recorded data does not have any daily flow values greater than 125,000 cfs, this analysis indicates this value is never exceeded. However, the 100-year computed discharge value for the Brazos River is 181,000 cfs at Richmond. Therefore, the 10-, 50- and 100-year flood hydrographs generated at Richmond for the Fort Bend County Flood Insurance Study (dated 1986) were analyzed to produce some data at these higher flow values. Since such floods last almost a week at a flow within about five percent of the peak flow, a percent of time was determined that showed these flows would be equaled or exceeded during one week every 10-, 50- and 100-years, respectively. These percentages were used for adjusting the flow –duration curve to better represent the higher flow values. (See Figure 1).

The lower flow values from this curve also presented some concern, since the assumption of independency between the two events (i.e. Brazos River flooding and rainfall over leveed area) may not hold true for low flows on the Brazos River. Therefore, an analysis was made of actual recorded rainfall amounts at rain gages located in and around Fort Bend County during days when the Brazos River was flooding at or above 70,000 cfs (selected as approximately bankfill conditions). Discharge records for the USGS gage at Richmond (1923 to 1984) were used in the study along with three National Weather Service Cooperative rainfall gages. These rain gages included: Angleton (1923 to 1984), Sealy (1923 to 1984), and Thompson (1958 to 1984).

The discharge records were reviewed and the data and magnitude of all instances of flow above 70,000 cfs were documented. Daily rainfall totals were noted for the same dates and were tabulated, along with a 5-day antecedent period prior to each extreme flow event, in order to establish the correlation between Fort Bend County rainfall and Brazos River discharges. The total rainfall for the period of record was determined for each rain gage along with a total amount occurring simultaneous with Brazos River discharges above 70,000 cfs. Incomplete or mission data were replaced with estimates of rainfall using the other gages, as appropriate. From this, a daily percent of occurrence was found for each rain gage: Angleton 1.2%, Sealy 0.9%, and Thompson 1.05%. The TP-40 rainfall frequency could then be adjusted by these percentages of occurrence (exceedance) for each gage. Thus, the 1.2% exceedance for Angleton equates to a 1.2-year rainfall frequency to represent the 100-year coincidental event while the Brazos River flow is above 70,000 cfs. The corresponding rainfall amount for a 1.2-year storm event would be determined from the rainfall frequency curves developed from TP-40. Similarly, any coincidental frequency event could be computed. (For example, the 1,000-year event would be a 12-year rainfall event using the Angleton gage.) Similar TP-40 adjustment analyses were conducted for the same 3 rain gages based on discharges in the Brazos River exceeding 80,000 cfs, 90,000 cfs, and 100,000 cfs. The following table shows the percentages of occurrence for each gage for each discharge category:

Rain Gage	Percentage of Rainfall Occurring With Discharge (cfs) above: 70,000	80,000	90,000	100,000
Angleton	1.2	0.36	.05	.01
Sealy	0.9	0.25	.06	.02
Thompsons	1.05	0.38	.02	0

The results of this analysis indicated the percent of rainfall that would occur during the time that the Brazos River had a flow of 70,000 cfs or greater in Fort Bend County. This analysis does not assume that the occurrence of rainfall in Fort Bend County is independent of river stage, since it is based on rainfall percentages actually observed during high river stages. It does assume, however, that the percentage of total rainfall observed is essentially the same as the percentage of high-intensity rainfall that would occur during high river stages. In order to check this assumption, a further study of the three rainfall records was made to determine the percentage of large storms (daily rainfalls exceeding one inch) that occurred historically during high river stages. Results from this further analysis confirmed this assumption.

The results of this percent of rainfall analysis were used along with the flow-duration curve, to develop a curve finally adopted for use in the pump station design criteria as shown on Figure 1, and was based upon the most conservative of the data available from the analyses discussed above. This adopted curve provided the means for generating the coincidental probability relationship between Brazos River flows and the rainfall event over a leveed area to be used in designing the pump station, having an exceedance frequency of once in 1,000 years. In order to simplify the use of these criteria, the curve adopted above was combined with the coincidental frequency curve to produce the curve as shown on Figure 2. It was determined however, that a 1-year frequency storm event should be set as the minimum allowable for designing the pump/storage facilities. Also, the curve should not be extended much below 70,000 cfs since such data were not utilized in deriving these coincidental relationships.

Although these criteria are considered to provide a conservative design, it is not an unacceptable over-design. Previous pump stations in Fort Bend County have used a fixed design rainfall of 7.55 inches

in 24 hours, which equates to approximately a 7-year storm event. This compares to the 1-year storm event for highly protected areas through the 11-year storm event for low lying areas located along the Brazos River.

REFERENCES

Federal Emergency Management Agency, "Flood Insurance Study, Fort Bend County, Texas", 1986.

Haan, Charles T., "Statistical Methods in Hydrology). The Iowa State University Press, 1977.

Hershfield, D.M., "Rainfall Frequency Atlas of the United States, Technical Paper No. 40", U.S. Weather Bureau, 1961.

Texas Natural Resources Information Services," Data Retrieval System", 1986.

U.S. Geological Survey, "National Water Data Storage and Retrieval System (WATSTOR)", 1986.

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