Instructions for Running the Carrizo-Wilcox Ground-Water Model and Surface Water Models to Determine the Impacts of Carrizo-Wilcox Aquifer Pumpage On Surface Water Flows in the Nueces and Guadalupe-San Antonio River Basins

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Step 1

Run MODFLOW using the files included on the CD-ROM. These are standard MODFLOW files and can be used with any MODFLOW executable. Also included on the CD-ROM are the well package files for the 1994, 2050, and 2050 "Plus" runs described in the report.

Step 2

Run QBasic, and run the *monthstr.bas* program, which picks out the streamflow data from the monthly MODFLOW output file. Also included in the \Groundwater\QBasic Programs directory is the program *yearstrm.bas*, which is used to extract streamflow data from a yearly MODFLOW output file. The *monthstr.bas* program identifies the line directly above the stream data in the output file, and then writes each to a separate file titled "MON####.DAT", where #### is the number of the month, with leading zeros (ie. 1 is 0001 and represents the first month of the monthly transient model simulation).

The *monthstr.bas* program will need to be edited before being used. The following portions of the program need to be changed before being used.

1) Line 29- This needs to be changed such that the "INFILENAME" reflects the correct path and filename for the output file from the MODFLOW run from Step 1.
2) Line 43- This needs to be changed to the header immediately above the streamflow data in the output file, if it is different than the line included in the program. It is possible that this line is the same and therefore will not need to be changed. This is the line that the program looks for to indicate that the streamflow data will follow below it.
3) Lines 58-61- These lines need to be changed so that the path is correct to where the output needs to be written.
4) Line 70- This line skips a certain number of lines in the output file, such as column indicators. Change the second number in this "DO" statement to the number of lines that need to be skipped before the actual streamflow data starts. It is possible that the number of lines is the same, and therefore the line will not need to be changed.

The changes in the program are based on the format of the output file from the particular MODFLOW executable that was used in Step 1.

NOTE: If the format for the streamflow data in the output file for the MODFLOW executable version used in Step 1, the program extracting the data will need to be rewritten, or a separate program to reformat the data will need to be written, so that the streamflow data is in the correct format before being used in the surface water executable programs described in Step 3 below.

Step 3

After running the MODFLOW groundwater model and executing the data post processing file, *monthstr.bas*, there will be a large number of files with the following naming convention, MON####.DAT, where #### is a number from 1 to 732 with leading zeros (i.e. 1 is 0001). Each of these files contains information about the surface water flows into and out of each cell in the MODFLOW model. In order to trim this list of data into more manageable pieces, a series of programs were written to read the surface water flows from the groundwater model, at key locations, into surface water outflow summary files. This is done in a two step process with two FORTRAN utility programs.

Step 3-A Run the program, *flowcon.exe*, to group all the MON###.DAT files into one mega-flows file. The mega-flows file is called OUTPUT.DAT. Note that *flowcon.exe* needs the input file FILENAME.DAT (this file has the names of all the pertinent MON####.DAT files).

Step 3-B Rename or copy OUTPUT.DAT to a file called INPUT.DAT and run the program, *floworg.exe*. This program reads the mega-flows output file and creates flow files at control points at surface water model locations where impacts of carrizo-wilcox pumpage are determined in the surface water models. This program creates seven files with a *.flw* extension.

Step 4

The next step is to run the program *sprgflow.exe* to convert the model run *.flw* files into the format needed for the surface water models. Included in the \Surface Water\ Springs subdirectory are the executable conversion program (*sprgflow.exe*) and the baseline streamflow files used in computing the changes in surface water flows due to pumpage of the Carrizo-Wilcox (see the report for more explanation of how these changes in flow are modeled). There are seven baseline streamflow files with the same names at the *.flw* files but with the extension *.bas*. The output from *sprgflow.exe* will be two files, SPRING.NRA and SPRINGS.GSA. These will be used in Step 5.

Step 5

The next step is to run the surface water models. The instructions below are specific to each of the three surface water models: the Guadalupe-San Antonio River Basin Model (GSA Model), the Nueces River Basin Model (Nueces Model), and the Lower Nueces River Basin and Estuary Model (Nubay Model).

Step 5-A Run the GSA Model – In order to run the GSA Model, copy the SPRINGS.GSA file created Step 4 into a subdirectory with all the files in the \Surface Water\GSA subdirectory on the CD and run the batch file GSABAT.BAT. This file will copy the new Carrizo-Wilcox springflows in the SPRINGS.GSA file into the springflow file for the GSA Model, run the GSA Model with the basin assumptions detailed in the Carrizo-Wilcox Study Report, and write out some summary flow files.

Step 5-B Run the Nueces Model – In order to run the Nueces Model, copy the SPRING.NRA file created Step 4 into a subdirectory with all the files in the \Surface Water\Nueces subdirectory on the CD and run the batch file NRB-BAT.BAT. This file will run the Nueces Model with the basin assumptions detailed in the Carrizo-Wilcox Study Report, and write out some summary flow files.

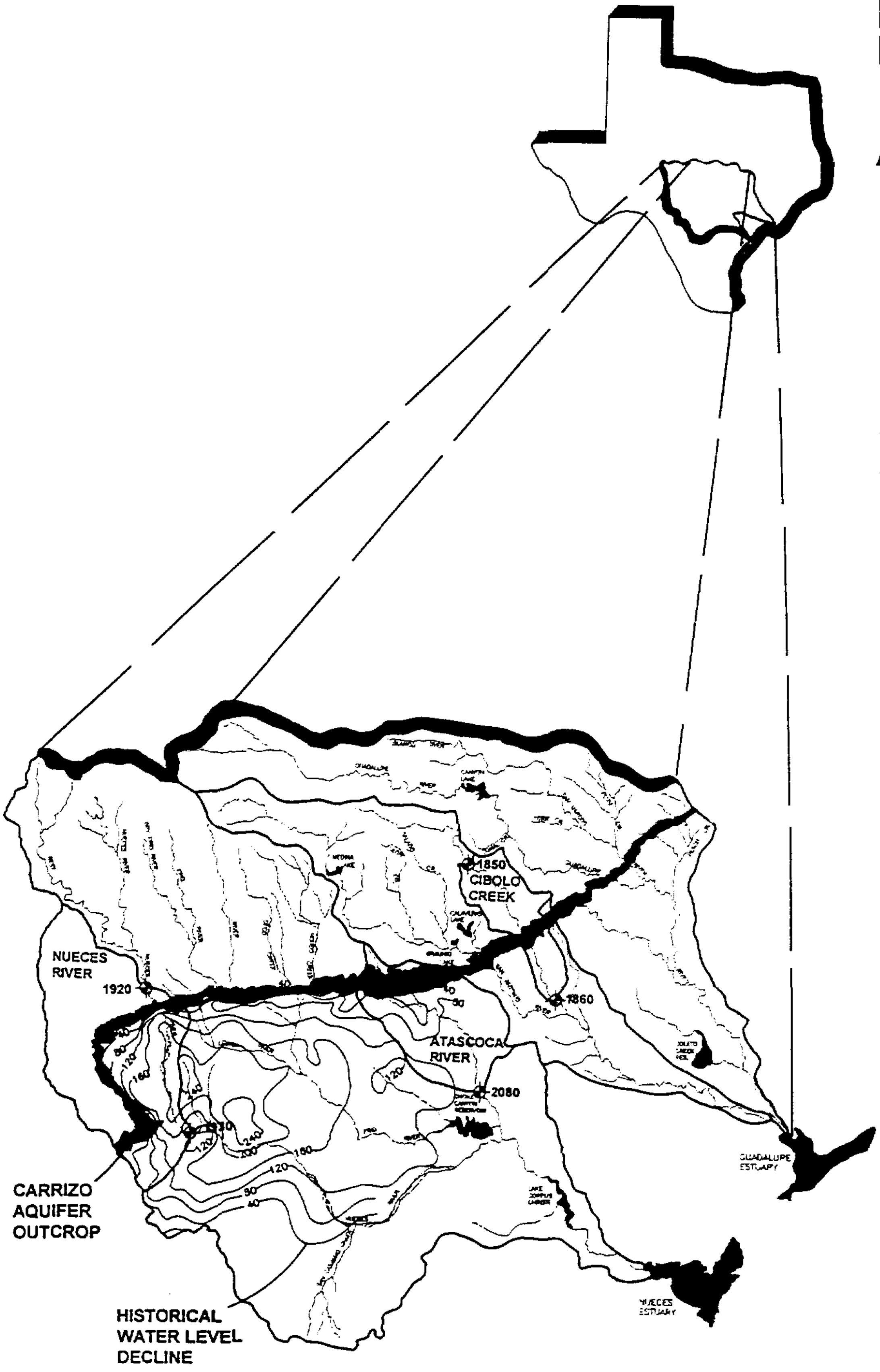
Step 5-C Run the Nubay Model – In order to run the Nubay Model, locate the following files created as part of Step 5-B: OQTLD., OQCHK., and QM2080.DAT. These three files may have different extensions depending on the batch file used in Step 5-B, but the files must be copied into the Nubay Model working directory with the extensions as they appear above (i.e. no extension for OQTLD. and OQCHK or .DAT extension for QM2080.) These three files should be copied into a subdirectory with all the files in the \Surface Water\Nubay subdirectory on the CD. Execute the batch file NUBAYBAT.BAT which will run the Nubay Model with the basin assumptions detailed in the Carrizo-Wilcox Study Report, and write out some summary output files.

These are the basic steps to run the Carrizo-Wilcox MODFLOW ground-water model and convert data from the groundwater model into data that can be used in the Guadalupe-San Antonio and Nueces River Basin surface water models. For additional information or questions regarding the model results or any other aspect of the models, please contact Mr. Andrew Donnelly at LBG-Guyton Associates for assistance with the ground-water programs, or Mr. Kelly D. Payne, P.E. at HDR Engineering, Inc. for assistance with the surface water programs. Mr. Donnelly can be reached at 512-327-9640 or *andyd@onr.com*. Mr. Payne can be reached at 512-912-5133 or *kpayne@hdrinc.com*.

Final Report

August 1998

Interaction between Ground Water and Surface Water in the Carrizo - Wilcox Aquifer



Texas Water Development Board

LBG-GUYTON ASSOCIATES

in association with

HDR Engineering, Inc.

INTERACTION BETWEEN GROUND WATER AND SURFACE WATER IN THE CARRIZO-WILCOX AQUIFER

Prepared for

TEXAS WATER DEVELOPMENT BOARD
Austin, Texas

August 1998

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I. EXECUTIVE SUMMARY

The Carrizo-Wilcox is one of the state's major aquifers and an important water resource in the Winter Garden Area of South Texas. The Winter Garden Area, as referred to in this study, lies southwest of the San Marcos River and within the Guadalupe, San Antonio, Nueces and Rio Grande River Basins. The Winter Garden Area consists of all or parts of Atascosa, Bexar, Caldwell, Dimmit, Frio, Gonzales, Guadalupe, Karnes, La Salle, Live Oak, McMullen, Maverick, Medina, Uvalde, Webb, Wilson and Zavala Counties.

The Carrizo aquifer is the most continuous, permeable and most developed (heavily pumped) water-bearing unit in the Winter Garden Area. In this area, the Carrizo is composed mainly of very permeable, massive, cross-bedded, medium-grained sands. In the outcrop, it unconformably overlies the sands, silts and clays of the Wilcox, but in the downdip subsurface, its sands are distinguished with difficulty from those of the Wilcox. Throughout most of the Winter Garden Area, the Carrizo aquifer yields ground water which is acceptable for most purposes. The largest use of Carrizo-Wilcox water is for irrigation.

The minor aquifers overlying the Carrizo-Wilcox aquifer in the Winter Garden Area include the Queen City-Bigford aquifer and the Sparta-Laredo aquifer above it. The strata of these aquifers are marine and continental in origin and consist mainly of beach sand, clay, cross-bedded river sand, silt and lignite.

Numerous ground-water investigations and engineering water-supply studies have been performed, primarily targeting individual and multiple counties in the Winter Garden Area. The results of these investigations have been published as reports or bulletins by the Texas Water Development Board (TWDB) and its predecessor agencies. The primary objective of one of these studies (Klemt and others, 1976) included the construction of a two-dimensional numerical ground-water flow model in order to simulate the Carrizo aquifer in the Winter Garden Area. In the early 1990's, LBG-Guyton and HDR Engineering looked at the feasibility of developing a large well field which would draw water from the Carrizo-Wilcox aquifer in Atascosa, Wilson, Gonzales and Bastrop

Counties. All of these studies, at least to some degree, recognized that the Carrizo-Wilcox aquifer and the major streams and rivers in the Guadalupe, San Antonio, Nueces and Rio Grande basins are interrelated in-stream aquifer systems where ground water is in hydraulic connection with the surface-water bodies.

The primary objectives of this investigation were as follows: (a) develop, calibrate and demonstrate the applicability of a numerical ground-water flow model (MODFLOW) to simulate hydrologic variations in the Carrizo-Wilcox aquifer in the Winter Garden Area, including ground-water/surface-water interaction; (b) use the calibrated model to simulate various pumping conditions in the aquifer; (c) use surface-water models to demonstrate how streamflows respond to these simulated changes in ground-water conditions; (d) demonstrate how water availability to water rights, in-stream flows and fresh-water inflows to estuaries are affected by these changes; and (e) use surface- and ground-water models to interpret and define the relationship between hydrologic stresses (such as pumpage and recharge) and changes in streamflows.

A three-dimensional numerical ground-water flow model of the Carrizo-Wilcox and associated younger aquifers was constructed using many of the data files of TWDB's Carrizo-Wilcox model described in Report 210. This model is capable of simulating changes in riverine discharge and aquifer water levels due to changes in pumpage and discharge. The USGS modular finite-difference ground-water model (MODFLOW) was used for the modeling effort (McDonald and Harbaugh, 1988). Construction and calibration of the model included steady-state simulations designed to replicate the estimated predevelopment head conditions of the aquifers and transient simulations which incorporated estimates of historical pumpage in order to replicate historical water levels and streamflows.

The surface-water models used include the latest versions of the Nueces River Basin, Lower Nueces River Basin and Estuary, and Guadalupe-San Antonio River Basin models developed by HDR Engineering, Inc. over the past several years with partial funding from the TWDB. The outputs from the ground-water model were used with surface-water models to demonstrate how streamflows respond to changes in ground-water levels, and also to demonstrate how water rights, streamflows and fresh-water inflows to the Nueces and Guadalupe Estuaries may be affected.

Several future pumpage scenarios were evaluated with the models to determine effects on water levels within the aquifer as well as impacts to significant surface-water streams which are hydraulically connected. The three future pumpage scenarios modeled were:

- 1994 Pumpage – Approximate current (1994) pumpage was used annually for the 61-year simulation.
- 2050 Pumpage – Estimated pumpage for 2050 was used annually for the 61-year simulation.
- "2050 Plus" Pumpage – 2050 pumpage plus additional pumpage in Atascosa, Dimmit, Gonzales and Wilson Counties was used annually for the 61-year simulation.

The following table summarizes total pumpage volumes for the three scenarios.

TABLE 1-1
Summary of Total Annual Pumpage for Future Scenarios

Scenario	Annual Pumpage (acft/year)
1994 Pumpage	249,890
2050 Pumpage	264,715
2050 Plus Pumpage	449,952

The model results indicate that if 1994 pumping levels continue, water levels over the next 60 years will generally be stable, with little or no decline in most areas. A steady decline that totals less than 100 feet over the 60-year period was found in Atascosa, Frio and La Salle Counties for two model runs. When the estimated 2050 pumpage is modeled, the results show similar results with two exceptions. In portions of Frio and La Salle Counties, water levels are actually higher using the 2050 pumpage, because pumping levels are projected to decrease between 1994 and 2050. The second exception is in Gonzales County, where Carrizo water levels are moderately lower (50 to 100 feet), compared to 1994, when using the 2050 pumping levels. This is due to pumpage from Gonzales County that is projected to be used for supplying municipal demands in the region.

With the additional pumpage proposed in the 2050 Plus scenario, the model results indicate that water levels will decline significantly (greater than 400 feet) around the hypothetical well field in Dimmit County, which would withdraw 40,000 acre-feet per year. Water levels will also decline moderately (100 to 200 feet) around the proposed line of wells in Atascosa, Gonzales and Wilson Counties.

Additionally, the results of the study indicate that average annual streamflows will be reduced in each of the two major river systems that drain the area, the Nueces River and the Guadalupe-San Antonio (GSA) River systems. Predicted reductions in average annual streamflows as compared to the historical period of record (1934-89) are shown in the following table for each scenario where each river system empties into its respective estuary.

TABLE 1-2
Reductions in Streamflows Resulting from Three Future Pumping Scenarios

Scenario	River System	Average Annual Reduction in Streamflow (acft/year)	Percent Reduction
1994 Pumpage	Nueces GSA	4,728 27,913	1.0% 1.7%
2050 Pumpage	Nueces GSA	4,738 40,461	1.0% 2.5%
2050 Plus Pumpage	Nueces GSA	13,040 76,131	2.7% 4.7%

II. INTRODUCTION

This report presents the results of a study that has been made to investigate the interaction between ground water and surface water with regard to the Carrizo-Wilcox aquifer in the Winter Garden Area of South Texas. The research contract was between LBG-Guyton Associates, HDR Engineering, Inc. and the Texas Water Development Board, TWDB Contract No. 96-483-173.

PURPOSE AND SCOPE

The purpose of this investigation was to develop, verify and demonstrate the applicability of a numerical ground-water flow model (MODFLOW) to simulate hydrologic conditions in the Carrizo-Wilcox, Queen City-Bigford, Sparta-Laredo and younger aquifers. The results from the ground-water model were used with surface-water models to demonstrate how streamflows respond to changes in ground-water levels, and also to demonstrate how water rights, streamflows and fresh-water inflows to estuaries are affected.

The area covered by the ground-water model is referred to as the Winter Garden Area (Figure 2-1). It consists of all or parts of Atascosa, Bexar, Dimmit, Frio, Gonzales, Guadalupe, Karnes, La Salle, Live Oak, McMullen, Maverick, Medina, Uvalde, Webb, Wilson and Zavala Counties, and covers an area approximately 213 miles (east to west) by 118 miles (north to south).

The ground-water flow model was constructed from the data files of the Texas Water Development Board's (TWDB) Carrizo-Wilcox model described in Report 210. The model input files were constructed from the data file for this model, irrigation inventory maps and records, water-level observation well records and other data gathered or generated for this study (streamflow, stream infiltration, and flowing wells data, etc.). The surface-water models used include the latest versions of the Nueces River Basin, Lower Nueces River Basin and Estuary, and Guadalupe-San Antonio River Basin models developed by HDR Engineering, Inc. over the past several years with partial funding from the TWDB.

SELECTION OF STUDY AREAS WITHIN THE WINTER GARDEN AREA

To accurately describe the interrelationship between the aquifers and streams in the Winter Garden Area, hydrologic analyses of selected watershed areas and stream segments were performed. Data for candidate watersheds were reviewed for selection based on the following criteria: (a) the availability of water-level, pumping and streamflow data; and (b) a significant portion of the watershed area being located over the outcrop of the Carrizo aquifer. Watersheds with long-term (greater than 40 years) availability of data and with a significant portion of the watershed area located over the Carrizo outcrop were selected for more intense study.

Three areas were selected for more intense study. These areas include the following: (a) Nueces River between Uvalde and Asherton where intensive ground-water pumpage started in the early 1900's and where water-level declines of more than 100 feet have occurred in the outcrop of the Carrizo-Wilcox aquifer; (b) Atascosa River above Whitsett where an upsurge in irrigation pumpage has more recently occurred and where moderate water-level declines of up to 60 feet have been observed; and (c) Cibolo Creek between Selma and Falls City where only minor pumpage and minor water-level declines have occurred.

PREVIOUS INVESTIGATIONS

To date, there have been numerous ground-water investigations primarily targeting individual and multiple counties in the study area, and one major report covering the entire Winter Garden Area. The results of these investigations have been published as reports or bulletins by the TWDB) and its predecessor agencies.

The most comprehensive ground-water study covering the study area was made by the TWDB and published in two volumes as Report 210 (Klemt and others, 1976; Marquardt and Rodriguez, 1977). This report covered the hydrogeology of the Winter Garden Area, particularly the extent of water-level declines in the Carrizo aquifer and availability and quality of its ground-water resources. In addition, later research work on the area by TWDB was published as separate reports (Duffin and Elder, 1979; Elder and others, 1980; McCoy, 1991) or as open-file reports (Opfel and Elder, 1977).

Smaller reports concerning some of the counties within the study area have also been published by the State water agencies. Among the counties covered by published ground-water investigations are Atascosa and Frio (Alexander and White, 1966), Dimmit (Mason, 1960), Gonzales (Shafer, 1965), La Salle and McMullen (Harris, 1965), and Wilson (Anders, 1957). In addition, historical well records, water levels and water-quality analyses collected by the State water agencies and U. S. Geological Survey (USGS) are available for all counties in the study area.

Other regional reports covering various major and minor aquifers in the study area include an investigation of ground-water availability from aquifers within the state by the Texas Department of Water Resources (TDWR) (Muller and Price, 1979), hydrogeologic studies by The University of Texas at Austin Bureau of Economic Geology (Fisher and McGowan, 1967; Guevara and Garcia, 1972; Ricoy and Brown, 1977; Hamlin, 1988).

Engineering water-supply studies detailing the potential for using some of the ground-water resources studied in this investigation have also been completed by HDR Engineering and others. The most detailed and most recent was published as the Trans-Texas Water Program, West Central Study Area report (HDR, 1994). A portion of this study looks at the feasibility of developing a large well field which would draw water from the Carrizo-Wilcox aquifer in Atascosa, Wilson, Gonzales and Bastrop Counties to meet future water demands in the San Antonio area. Other similar reports which detail water-supply studies involving the Carrizo-Wilcox aquifer include Barnes, 1956; CH2M Hill and Lee Wilson & Associates, 1991; and Getzendaner, 1953.

INVESTIGATION PROCEDURES

The various ground-water and surface-water tasks required to complete this research project include the following:

Task 1 - Data Collection/Development

Data collection and development for the modeling effort included: (a) collection and review of available reports on the Carrizo-Wilcox and younger aquifers in the study area; (b) review of TWDB and U. S. Army Corps of Engineers Carrizo-Wilcox modeling efforts; and (c) data collection, compilation and estimation of historical (1934-1994) water levels, recharge, pumpage, aquifer leakage and streamflows. A large portion of the data development work focused on the estimation of historical monthly ground-water recharge, baseflow gains and losses to rivers, and collection of data summarizing historical land use in selected watersheds.

Surface-water model databases were developed for the historical period of 1934 through 1994 for selected watersheds. Part of this task was accomplished by work performed for the City of Corpus Christi on the Atascosa River watershed. This work was expanded, for the purposes of this investigation, to cover other watersheds which have experienced significant water-level declines in the past and those expected to experience declines as development of the aquifer moves eastward. These watersheds include the following: (a) Nueces River between Uvalde and Asherton; (b) Frio River at Derby; (c) San Miguel Creek at Tilden; (d) San Antonio River at Falls City; (e) Cibolo Creek at Falls City; (f) Guadalupe River at Cuero; and (g) San Marcos River at Luling.

Task 2 - Development and Calibration of the Ground-Water Flow Model

A three-dimensional numerical ground-water flow model of the Carrizo-Wilcox and associated younger aquifers was constructed capable of simulating changes in riverine discharge and aquifer water levels due to changes in pumpage. The USGS modular finite-difference ground-water model (MODFLOW) was used for the modeling effort (McDonald and Harbaugh, 1988). Construction of the model included steady-state simulations designed to replicate the estimated predevelopment head condition of the aquifer and transient simulations which incorporated estimates of historical pumpage in order to replicate historical water levels and streamflows. Most of the model calibration was done using results from transient simulations.

Because ground-water development in the Winter Garden Area began around 1910, transient model runs were for the 1910-to-1994 time period. Prior to 1910 it was assumed that conditions were "predevelopment" and could be characterized with a predevelopment steady-state model run. Because data for recharge and streamflows were not available for 1910-34, an average value was used for each of these years in the transient simulation.

Task 3 - Modification of Surface-Water Models

Existing surface-water simulation models of both the Nueces and Guadalupe-San Antonio River Basins were adapted to accept changes in streamflows simulated in the MODFLOW model. The surface-water models were then used to calculate effects of increased or decreased ground-water pumpage on recharge and discharge to the rivers at control points located downstream of aquifer outcrops. These changes were then tracked through multiple downstream control points to obtain cumulative impacts from multiple watersheds on fresh-water inflows to the estuaries.

Task 4 - Simulation of Effects of Future Aquifer Pumpage

To determine the effects of additional pumping of the Carrizo-Wilcox aquifer on historical streamflows, long-term ground-water model simulations (1934-1994) were performed for three scenarios of future pumpage.

To model the effect of future pumpage on the aquifer, the following steps were completed: (a) ground-water model runs were made with future pumpage scenarios using the historical (1934-1994) recharge and streamflows; (b) the ground-water model outputs were tabulated and the surface/ground-water interaction differences between the simulated historical record and the simulation of future pumpage were tabulated; and finally, (c) these differences were used as inputs to the river basin models for the simulation of downstream effects in Task 5.

Task 5 - Simulation of Effects of Aquifer Pumpage on Surface-Water Availability and Existing Water Rights

Changes in ground-water discharges, as determined from the alternative ground-water pumping simulations, were input to the surface-water models to determine changes in monthly water availability to significant water rights within each basin for a 56-year period (1934-1989). This included the following water rights or groups of water rights within the Nueces and Guadalupe-San Antonio basins:

Nueces River Basin

(1) Water rights located on the Nueces River held by Zavala-Dimmit Co. WCID #1

(2) Yield of Choke Canyon Reservoir/Lake Corpus Christi System (water rights held by the City of Corpus Christi et al.)

Guadalupe-San Antonio River Basin

(1) Water rights located at or just upstream of the Saltwater Barrier at Tivoli.

For the Nueces basin, the above water rights represent about 90 percent of all water rights in the basin. For the Guadalupe-San Antonio basins, existing water rights at the Saltwater Barrier total about 40 percent of all consumptive water rights in the basin.

Task 6 - Simulation of Effects of Aquifer Pumpage on In-Stream Flows and Fresh-Water Inflows to the Nueces and Guadalupe Estuaries

The effects of the two future ground-water model pumping scenarios on in-stream flows and on fresh-water inflows to the affected estuaries were calculated using the methodologies described in Tasks 4 and 5. Relevant flow-frequency statistics were tabulated and are presented in graphical form. In addition, changes in flows for certain key control points in the Nueces and Guadalupe-San Antonio River Basins are also shown by illustrations in this report.

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III. HYDROGEOLOGY

The Wilcox and Claiborne Groups are important hydrogeologic units within the Winter Garden Area of South Texas. The strata of these units are marine and continental in origin and consist mainly of beach sand, clay, cross-bedded river sand, silt and lignite. Within the Wilcox and Claiborne Groups are one major aquifer (Carrizo-Wilcox) and two minor aquifers (Queen City-Bigford and Sparta-Laredo). Table 3-1 shows the position of each aquifer in the subsurface, along with its layer number in the ground-water flow model and approximate range in thickness.

WILCOX GROUP

For the purpose of this report, the Wilcox Group will be considered as an undifferentiated aquifer which overlies the impermeable shales, siltstones and fine-grained sandstones of the Midway Group. The Wilcox consists of interbedded sands, clays and silts with discontinuous beds of lignite. The shale and clay beds sometimes contain gypsum. The Wilcox yields small to moderate quantities (<100 to 1,000 gallons per minute (gpm)) of fresh to slightly saline water (<1,000 to 3,000 milligrams per liter (mg/l) dissolved solids).

South and west of the Frio River, the Wilcox Group is sometimes called the Indio Formation. In general, the Indio is composed of irregularly bedded sandstone and shale and yields only small amounts (<100 gpm) of usually highly mineralized water to stock and domestic wells.

CLAIBORNE GROUP

In the study area northeast of the Frio River, the Claiborne Group consists mostly of marine shales and clays and nonmarine blanket sands. In this area, each geologic unit is traceable for miles laterally along the outcrop and for several tens of miles downdip. In the study area west of the Frio River (Rio Grande embayment), the formations, except

TABLE 3-1

Geologic Formations and Aquifers of the Wilcox and Claiborne Groups, Including the Approximate Range in Thickness (Feet) and Ground-Water Flow Model Layer Number

SYSTEM	SERIES	GROUP	MODEL LAYER	WINTER GARDEN AREA	
				West of Frio River	East of Frio River
Tertiary	Eocene	Claiborne	1	Yegua Formation (700 - 1,000 feet)	
				Laredo Aquifer (600 - 700 feet)	Cook Mountain Formation (400 - 500 feet)
					Sparta Aquifer (40 - 200 feet)
					Weches Formation (50 - 200 feet)
			2	El Pico Clay (700 - 1,500 feet)	Queen City Aquifer (500 - 1,400 feet)
			3	Bigford Aquifer (200 - 900 feet)	Reklaw Formation (200 - 400 feet)
			4	Carrizo Aquifer (150 - 1,200 feet)	
		Wilcox	5	Wilcox Aquifer (0 - 2,800 feet)	

for the Carrizo Sand at the base of the Claiborne Group, differ in lithologic character from their equivalent formations to the northeast. In the Rio Grande embayment, the formations are generally composed of fresh- or brackish-water sediments which interfinger complexly with the marine and nonmarine formations to the northeast in the vicinity of the Frio River.

Carrizo Aquifer

Overlying the Wilcox Group is the Carrizo Sand, the lowermost geologic unit of the Claiborne Group. In the study area, the Carrizo is composed mainly of very permeable, massive, cross-bedded and medium-grained sands. On the surface it unconformably overlies the sands, silts and clays of the Wilcox, but in the downdip subsurface its sands are difficult to distinguish from those of the Wilcox.

The Carrizo is the principal and most heavily pumped aquifer in the Winter Garden Area of Texas. It yields moderate to large quantities (100 to over 1,000 gpm) of fresh to slightly saline (<1,000 to 3,000 mg/l dissolved solids) water to wells.

Reklaw Formation

The Reklaw overlies the Carrizo aquifer and consists of brown clay with thin beds of sand and lignite. The basal portion of the Reklaw is generally sandy and yields small quantities (<100 gpm) of slightly to moderately saline (1,000 to 10,000 mg/l dissolved solids) water to wells. It is a semipermeable, semiconfining geologic formation (aquitard) which partially restricts the vertical movement of ground water.

Bigford Aquifer

The Bigford overlies the Carrizo and is the equivalent of the Reklaw west of the Frio River in the Rio Grande embayment. The formation consists of sands, some very thin beds of silts and shales, and coal beds. The shales are gypsiferous and make up about 25 percent of the formation.

The basal sediments of the Bigford, near the contact with the underlying massive and highly permeable Carrizo aquifer, are reported to yield small to moderate quantities (generally on the order of < 100 to 200 gpm) of fresh to slightly saline (< 1,000 to 3,000 mg/l dissolved solids) water to wells. Wells completed in the middle and upper portions of the Bigford generally yield only small quantities of water which may be mineralized (3,000 to 35,000 mg/l).

In the Rio Grande embayment, the middle and upper sediments of the Bigford are generally semipermeable and semiconfining. Pumping-test data, hydraulic-head differences and water-quality differences indicate that there is very little vertical leakage between the Carrizo and the Bigford.

Queen City Aquifer and Weches Formation

The Queen City, lying conformably on the Reklaw formation, is a thick unit of sands and sandy clays that extends from the eastern study area southwestward to the eastern part of the Rio Grande embayment in the vicinity of the Frio River. Westward beyond the Frio River, the Queen City is indistinguishable from the overlying Weches as it and the Weches interfinger laterally with the clays of the El Pico Formation in the Rio Grande embayment.

The Weches Formation is a relatively thin marine formation consisting chiefly of clay with some marl and limestone. It is an aquitard that lies conformably on the Queen City aquifer in the northeastern portion of the study area.

The Queen City aquifer supplies small to moderate quantities (generally < 100 to 200 gpm) of ground water to wells in the vicinity of the Frio River and moderate to large quantities (about 100 to 500 gpm) of water to wells in the northeastern part of the study area. The aquifer generally yields fresh to slightly saline (< 1,000 to 3,000 mg/l dissolved solids) water to wells.

El Pico Clay

The El Pico lies conformably on the uppermost sandstone beds of the Bigford and is composed of clay with interbedded sandstones, claystones and coal lenses. There are only a few water wells which are known to be completed in the El Pico. However, it has been reported that the sandstone lenses in the lower part of the formation yield small amounts (generally <10 gpm) of highly mineralized water in the outcrop.

Younger Sediments

In the southwestern portion of the study area, the Sparta aquifer and Cook Mountain Formation merge southward into the Laredo aquifer which overlies the El Pico Clay in the Nueces River valley. More than half of the Laredo consists of sands and sandstones. Overlying the Laredo is the Yegua Formation.

Northeast of the Frio River, the Sparta aquifer and Cook Mountain Formation overlie the Weches Formation. The Sparta is composed of interbedded sands and clays, and the Cook Mountain consists chiefly of marine clays with a few beds of fine sand. Southwest of the Atascosa River, sands appear in the Cook Mountain, and the formation becomes less distinguishable from the Sparta aquifer below and the Yegua Formation above. The Sparta, Laredo and Yegua yield small to moderate quantities (<100 to 1,000 gpm) of fresh to moderately saline (<1,000 to 10,000 mg/l) water to wells in the study area.

GROUND-WATER FLOW MODEL STRATIGRAPHY

For the purpose of the ground-water flow model, the following model layer assignments were made in ascending order: Wilcox Group, Layer 5; Carrizo aquifer, Layer 4; above the Carrizo aquifer southwest of the Frio River, Layers 3, 2 and 1 of the model represent, respectively, the Bigford aquifer, El Pico Clay and younger sediments consisting of the Laredo aquifer and Yegua Formation; above the Carrizo aquifer northeast of the Frio River, Layers 3, 2 and 1 of the model represent, respectively, the Reklaw Formation, Queen City aquifer and younger sediments consisting of the Sparta aquifer, Cook Mountain Formation and Yegua Formation (Table 3-1).

IV. GROUND-WATER PUMPAGE

INTRODUCTION

Estimates of historical pumpage were calculated in order to calibrate the mathematical ground-water model. Historically, the primary use of pumpage from the Carrizo-Wilcox aquifer has been for irrigation. In the early 1930's, vegetable farms in Zavala and Dimmit Counties pumped large volumes of water from the aquifer leading to large declines in water-table elevations in these counties (Klemt and others, 1976). During the 1950's and 1960's, irrigation use of water from the Carrizo-Wilcox significantly increased in the central counties of the study area including Frio, Medina and Atascosa Counties (HDR, 1994). These counties have continued to experience high pumpage since the 1960's, while irrigation pumpage in Zavala and Dimmit Counties has declined.

HISTORICAL IRRIGATION PUMPAGE COMPUTATIONS

A search for the available data on historical ground-water pumpage revealed that the most complete set had been gathered by the Texas Water Development Board. The TWDB's data are based on surveys of ground-water use for irrigation compiled every five years. The data have been tabulated by county and are available on maps which indicate the general spatial distribution of the pumpage. These data were used as the basis of the pumpage information for this study.

The TWDB pumpage data are collected and summarized every five years, and data dating back to 1939 were used in this analysis. With the exception of data summarized in 1958 rather than 1959, the summaries were compiled for the fourth and ninth years in each decade from 1939 to 1994. For the period from 1954 to 1994, maps generated by the TWDB were used to distribute the pumpage spatially across the model region. Additional mapping from the U. S. Department of Commerce Census of Agriculture was used prior to 1954. The following discussion details the method used to estimate pumpage between each of the TWDB's five-year censuses.

Estimation of Missing Historical Pumpage

The method selected to estimate pumpage between the five-year census data sets takes into account factors which significantly affect pumpage for irrigation, namely acres irrigated and rainfall in the area irrigated.[1] Data for these two key variables were gathered and analyzed using statistical linear regression models (Draper and Smith, 1981). Areal precipitation records were developed in previous surface-water studies in the region for each month from 1934 to 1989 (HDR, 1991a; 1993c). These data were extended through 1994 and distributed by county as part of this study and were used as one of the potential independent variables in the regression. In order to take into account the timing of the rainfall within the growing season, monthly rainfall data were summed into four groups, and each group was tested for its ability to predict pumpage. The groups tested included annual precipitation, the sum of precipitation in January through March, the sum of precipitation in April through June, and the sum of precipitation in January through June.

Acreage irrigated was also assumed to be an indicator of irrigation pumpage. The data on acreage per county irrigated by ground water were rather limited, however. The only reliable information was from the five-year agricultural census data (TWDB, 1996). Therefore, it was assumed that between the agricultural censuses, large changes in acreage irrigated did not occur, and a straight-line increase or decrease was assumed to provide the best estimate of acreage irrigated for each of these four-year periods.

Regression analyses were performed by county to determine which combination of variables best predicted the pumpage. The results of these analyses are presented in Table 4-1. As shown in this table, the best-fit regression equations included some form of precipitation for two-thirds of the counties studied. For the other counties, rainfall was not found to be a significant indicator of pumpage (Bexar, Gonzales, Guadalupe and Wilson Counties). In these four counties, irrigation pumpage has not historically been

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[1] It should be noted that the type of crop plays a role in the volume of water needed for irrigation. However, due to the limited data available from the Agricultural Censuses regarding crops farmed, it was assumed in this analysis that the crops farmed in a region were approximately similar in water- need characteristics for the period of record.

TABLE 4-1
Summary of Regression Analyses for Estimating Pumpage by County

County	Pumpage Estimate Equation	Historical Average Pumpage (acft/yr)	Coefficient of Determination (R^2)
Atascosa	$\text{Pumpage} = 1{,}859 + 1.426*\text{Acres} - 294.84*P_{\text{JAN-MAR}}$	32,625	90.0 %
Bexar	$\text{Pumpage} = 568 + 1.122*\text{Acres}$	1,730	64.7 %
Dimmit	$\text{Pumpage} = 6{,}623 + 1.365*\text{Acres} - 269.08*P_{\text{ANNUAL}}$	19,635	93.9 %
Frio	$\text{Pumpage} = 5{,}168 + 1.410*\text{Acres} - 193.90*P_{\text{ANNUAL}}$	51,162	87.9 %
Gonzales	$\text{Pumpage} = 0.737*\text{Acres}$	1,892	52.8 %
Guadalupe	$\text{Pumpage} = 1.113*\text{Acres}$	293	59.3 %
Karnes	$\text{Pumpage} = 334 + 1.829*\text{Acres} - 94.42*P_{\text{JAN-MAR}}$	1,079	54.4 %
La Salle	$\text{Pumpage} = 4{,}167 + 0.943*\text{Acres} - 126.76*P_{\text{JAN-MAR}} - 336.65*P_{\text{APR-JUN}}$	6,961	82.4 %
Live Oak	$\text{Pumpage} = 362 + 0.712*\text{Acres} - 56.77*P_{\text{JAN-MAR}}$	878	65.6 %
Medina	$\text{Pumpage} = 2{,}715 + 2.286*\text{Acres} - 390.25*P_{\text{APR-JUN}}$	7,054	89.3 %
Wilson	$\text{Pumpage} = 648 + 0.819*\text{Acres}$	7,526	89.8 %
Zavala	$\text{Pumpage} = 31{,}918 + 1.936*\text{Acres} - 1{,}819.80*P_{\text{ANNUAL}}$	102,541	90.4 %
		Weighted Average:	≈89 %

Notes:

1. Pumpage = estimated annual pumpage (acre-feet); Acres = acres irrigated using ground water in a given year; and P = sum of the monthly areal precipitation for the county for the months indicated in the subscript (i.e. Annual = January through December, APR-JUN = April, May and June, etc.)
2. Unless otherwise noted, regressions are based on annual pumpage, areal precipitation and acreage irrigated with ground water for the following years: 1939, 1944, 1949, 1954, 1958, 1964, 1969, 1974, 1979, 1984, 1989 and 1994. Pumpage and irrigated acreage provided by TWDB.
3. Bexar County regression is based on data from the following years: 1964, 1969, 1974, 1979, 1984, 1989 and 1994.
4. Gonzales County regression is based on data from the following years: 1958, 1969, 1974, 1979, 1984, 1989 and 1994.
5. Guadalupe County regression is based on data from the following years: 1974, 1979, 1984 and 1989.
6. Karnes County regression is based on data from the following years: 1939, 1954, 1958, 1964, 1969, 1974, 1979, 1984, 1989 and 1994.
7. Live Oak County regression is based on data from the following years: 1949, 1954, 1958, 1964, 1969, 1974, 1979, 1984, 1989 and 1994.
8. Medina County regression is based on data from the following years: 1958, 1964, 1969, 1974, 1979, 1984, 1989 and 1994.
9. Historical average pumpage computed using reported pumpage data from TWDB.

high, and acreage irrigated generally describes the fluctuations in pumpage. For the counties in the western part of the region (Frio, Zavala and Dimmit) where crops are cultivated almost year-round, the annual precipitation was found to be the best indicator of pumpage. In the other five counties, one or both of the quarterly precipitation volumes resulted in the best pumpage estimate equations. Overall, the resulting regression equations explain most of the variation in pumpage with a composite weighted average coefficient of determination (R^2) of approximately 89 percent.

Figures 4-1, 4-2 and 4-3 show the annual historic pumpage volumes for three regions of the aquifer. The largest volume of pumpage has been withdrawn in the westernmost counties of the region (Zavala and Dimmit). However, in the latter half of the historical period, pumpage in the central counties (Frio and Atascosa) began to significantly increase, and by the end of the period (1994), pumpage in these two counties was two to three times greater than the pumpage in the west (see Figure 4-2). As shown in Figure 4-3, the other counties in the region currently have little pumpage from the Carrizo-Wilcox. However, data received from the TWDB on future pumpage projections indicate that municipal pumpage in the eastern region of the study area (Gonzales and Guadalupe Counties) could significantly increase in the future. In addition to the regional summaries of pumpage, summaries of the annual pumpage totals for each county which were used in calibrating the aquifer model are provided in Appendix A.

DISTRIBUTION OF HISTORICAL PUMPAGE

Pumpage in the model area consists of two main components: irrigation pumpage, which accounts for more than 95 percent of the total pumpage, and municipal and industrial pumpage, which accounts for the remainder. Domestic and stock pumpage was considered to be negligible and was not included in pumpage estimates.

Municipal and Industrial Pumpage

Annual municipal and industrial pumpage estimates were obtained by county from the Texas Natural Resources Information System database. Each user was identified, and its cell location in the model was identified. The pumpage estimates for municipal and industrial users were included in the final well package file.

Irrigation Pumpage

Irrigation pumpage estimates were based on irrigation surveys conducted every five years by the U. S. Department of Agriculture Soil Conservation Service. These irrigation surveys were then used to estimate annual irrigation pumpage by county, as described above.

Irrigation survey maps were included with each of the five-year irrigation surveys described above. Years for which irrigation surveys were completed will be referred to as "baseline" years, because they are used to estimate irrigation pumpage for the two years before and after. The irrigation survey maps were used to estimate irrigation pumpage amounts for each model cell of the entire model area for each "baseline" year. The unique array of irrigation pumpage that was obtained for each "baseline" year was then used to estimate irrigation pumpage arrays for the two years before and after the "baseline" year, for which surveys were not made. For example, the irrigation pumpage distribution array for 1969 was used as the basis to estimate irrigation pumpage arrays for 1967, 1968, 1970 and 1971.

Estimated county irrigation pumpage totals were then compared to the estimated county irrigation pumpage total in the "baseline" to obtain a ratio between the irrigation pumpage for the year being calculated and the irrigation pumpage for the "baseline" year. These ratios were then used to multiply the baseline years' arrays of irrigation pumpage to obtain a unique irrigation pumpage array for each year. For example, estimated irrigation pumpage in Frio County in 1968 was compared to estimated irrigation pumpage in 1969 (the "baseline" year) to obtain a ratio between the total pumpage for those two years. The 1969 irrigation pumpage values in Frio County were then multiplied by the 1968 Frio ratio to obtain an estimated irrigation pumpage for each cell in the array in Frio County in 1968.

Once both the irrigation and municipal and industrial pumpage estimates were completed, they were combined into a single well file for input into the MODFLOW model.

Monthly Pumpage Estimates

In order to run the model with monthly time steps, it was necessary to divide the annual pumpage estimates up on a monthly basis. To accomplish this, factors had to be calculated to multiply the average annual pumpage rates by in order to get approximate monthly pumpage estimates. The pumpage estimates needed to increase during the summer months when pumpage was high and decrease during the winter months when pumpage was low. This was the method developed, given the available data, for varying the pumpage stress to simulate pumping conditions throughout the year.

Because irrigation pumpage accounted for more than 95 percent of the historical pumpage, only the irrigation pumpage amounts were used to calculate factors for converting annual pumpage stress into monthly pumpage stress. These factors are given in the following table.

TABLE 4-2
Irrigation Pumpage Distribution Factors

Month	Irrigation Pumpage Distribution Factor	Month	Irrigation Pumpage Distribution Factor
January	0.589	July	1.479
February	0.631	August	1.284
March	0.980	September	0.864
April	1.289	October	0.660
May	1.463	November	0.606
June	1.660	December	0.496

These factors were based on work done in the Nueces River Basin and Guadalupe-San Antonio River Basin model developments (HDR, 1991a; 1993c). These values were derived from historical records of reported surface-water use. The use of these factors allowed the annual pumpage data sets to be converted into monthly estimates of pumpage stress.

CALCULATION OF FUTURE PUMPAGE ESTIMATES

Three future pumping scenarios were run as part of this investigation. The first scenario was a simulation of estimated 2050 pumpage, and the second was a simulation of estimated 2050 pumpage plus a line of wells in the eastern region of the model and additional Dimmit County pumpage. A third pumping scenario which was 1994 pumpage was also run as a comparison for the first two future scenarios. Each of these pumpage data sets are described below.

1994 Pumpage

As a comparison for the two future pumping scenarios, a simulation was run using only 1994 pumpage. This pumpage data set was the historic pumpage for 1994 repeated annually for the entire simulation.

2050 Pumpage

The second pumping scenario that was modeled was estimated pumpage for the year 2050. Details of the overall run are given later in Section VIII. This simulation models the situation where estimated pumpage for 2050 was repeated annually to determine what the effect of this amount of pumpage would be through the 1934-to-1994 time period.

The assumptions used for the creation of the 2050 pumpage data set were that the distribution of irrigation pumpage would be the same as in 1994 throughout the model area. Therefore, the 1994 irrigation pumpage array was used as a baseline to create the new 2050 irrigation pumpage array. The total estimated irrigation pumpage volumes for 2050 for Atascosa, Dimmit, Frio, Gonzales, Guadalupe, Karnes, La Salle, Live Oak, McMullen, Wilson and Zavala Counties were obtained from the TWDB based on their planning projections. These county totals were then compared to the total irrigation pumpage in each of those counties in the 1994 array, and a ratio was calculated for each county. The 1994 irrigation pumpage amounts for each cell were multiplied by the corresponding ratio to create a unique irrigation pumpage estimate for 2050. For the other counties in the model, pumpage in 1994 was used in the 2050 data set.

Municipal, industrial and mining pumpage estimates for the year 2050 were also obtained from the TWDB for each of the 10 counties. The municipal pumpage was identified by city or town, and the cell in which each individual city's or town's pumping was located was identified. The pumpage for that municipality was then assigned to that cell. Mining, power and industrial pumpage amounts were randomly distributed throughout each county.

Both irrigation and municipal/industrial/mining/power pumpage estimates for 2050 were on an annual basis, and therefore these had to be increased or decreased to create the monthly pumpage estimates, as did the historical monthly pumpage data sets described above. Because the percentage of pumpage accounted for by irrigation pumpage in 2050 is not as high as in the historical time period, two unique sets of monthly ratios were used to construct monthly data sets for 2050, one for irrigation and one for municipal/industrial/mining. Irrigation pumpage accounts for 70 percent of the total estimated pumpage in 2050, while municipal/industrial/mining pumpage accounts for the other 30 percent. Thus, each had a separate set of ratios to convert the annual pumpage to monthly pumpage. For irrigation, the factors were the same as those used for the historical time period and are given above. For municipal/mining/industrial pumpage, the following ratios were used.

TABLE 4-3
Municipal, Mining and Industrial Pumpage Distribution Factors

Month	Municipal/Mining/Industrial Pumpage Distribution Factors	Month	Municipal/Mining/Industrial Pumpage Distribution Factors
January	0.795	July	1.299
February	0.783	August	1.303
March	0.903	September	1.095
April	0.993	October	0.959
May	0.986	November	0.873
June	1.116	December	0.892

2050 Pumpage Plus Additional Pumpage

The second future pumping scenario that was run was a simulation of 2050 pumpage plus additional pumpage in the eastern portion of the model representing pumpage from a line of wells proposed in (HDR, 1994), and another large pumping center added in south-central Dimmit County in the western portion of the model. This pumpage data set included all of the estimated 2050 pumpage described above, plus an additional 185,237 acre-feet per year of municipal pumpage in cells shown in Figure 4-4. The additional pumpage was distributed in Atascosa County (26,500 acre-feet per year), Wilson County (64,400 acre-feet per year), Gonzales County (54,337 acre-feet per year) and Dimmit County (40,000 acre-feet per year). The pumpage was distributed among the cells within each county based on the size of the cells where the pumpage was to be included.

V. RECHARGE

INTRODUCTION

This section describes the procedure used to estimate recharge to the Carrizo-Wilcox aquifer in the Winter Garden Area. This region of the state has a wide variability in annual precipitation and runoff from west to east. In the west, in Zavala and Dimmit Counties, rainfall averages 22 inches per year (Larkin and Bomar, 1983), and streamflow for the Nueces River watershed between Uvalde and Asherton averages about 37,700 acre-feet per year or 0.32 inch per year (Dougherty, 1980). Conversely, the rainfall in the eastern part of the study area, in Gonzales and Guadalupe Counties, averages approximately 34 inches per year (Larkin and Bomar, 1983), and streamflow in the Guadalupe River, above the Comal River at New Braunfels, Texas, averages about 269,074 acre-feet per year or 3.32 inches per year (for the period of record prior to the completion of Canyon Dam) (Dougherty, 1980). In addition to being the most arid portion of the region, the westernmost counties have historically had the largest pumpage volumes from the aquifer for irrigation. As shown in the previous section, the peak annual pumpage in Zavala and Dimmit Counties is twice the maximum observed in Frio and Atascosa Counties combined and six times greater than the sum of maximum pumpage amounts for the remaining eight counties in the study area. The lack of rainfall in conjunction with the overwhelmingly large volume of historical pumpage has led to large declines in water levels in the western part of the aquifer in the Winter Garden Area. Likewise, the combination of wetter climatic conditions and significantly smaller pumpage volumes in the eastern part of the aquifer result in leakage into streams, indicating that portions of the aquifer in this area are at capacity.

Due to the highly variable climatic and hydrologic characteristics, a methodology was needed that was robust enough to estimate recharge in the semi-arid west equally as well as it estimates recharge in the east. The remainder of this section discusses the methodology developed for this study.

ESTIMATION METHODOLOGY

The model area was divided up into watersheds and subwatersheds (also referred to as basins and subbasins) as shown in Figure 5-1. Recharge calculations were performed on watersheds that intersect the Carrizo-Wilcox outcrop. These watersheds included the subwatersheds between the downstream end of the Edwards Aquifer Recharge Zone and the following USGS streamflow gaging stations:

- Nueces River near Asherton (USGS Gage No. 08193000),
- Frio River near Derby (USGS Gage No. 08205500),
- San Miguel Creek near Tilden (USGS Gage No. 08206700),
- Atascosa River at Whitsett (USGS Gage No. 08208000),
- San Antonio River near Falls City (USGS Gage No. 08183500),
- Cibolo Creek near Falls City (USGS Gage No. 08186000),
- Guadalupe River at Cuero (USGS Gage No. 08175800), and
- San Marcos River at Luling (USGS Gage No. 08172000).

In addition to the Carrizo-Wilcox outcrop in these watersheds, the Bigford, Queen City and Sparta aquifers also outcrop. Recharge between the downstream edge of the Edwards outcrop and the downstream gages listed above was computed and distributed to the aquifers outcropping in that subwatershed. The distribution of recharge was performed using a weighting procedure which considered the relative values of aquifer outcrop area and aquifer transmissivity. This is described in more detail below.

In general, the approach developed to compute recharge categorizes recharge into one of three components. The total recharge for each subbasin was computed by summing the following three components:

- Baseflow recharge (main channel),
- Flood-flow recharge (main channel), and
- Areal recharge (includes tributaries and outcrop areas outside main channel).

The first component, baseflow recharge, is the interaction that occurs with the aquifer outcrop as long as there is water flowing in the main channel. This component describes the direct interface between the wetted bottom of the streambed and the aquifer. Streamflow records during baseflow conditions (i.e. when little or no intervening runoff is occurring between stream gages) were analyzed to determine a unique average baseflow loss or gain due to interaction with the aquifer for each major stream reach. The results of this analysis showed seasonal variability which results from the effects of evaporation and transpiration. During the summer months, April through September, the apparent losses to the aquifer were larger than the losses observed in the winter months. Table 5-1 summarizes the streamflow losses/gains for each stream segment. In order to analyze losses and gains in the main channel across the outcrop, a stream segment needed a streamflow gage located above and below the Carrizo-Wilcox aquifer outcrop. San Miguel Creek and Atascosa River segments were not analyzed for baseflow gains or losses because the headwaters of each watershed is located in the recharge zone and so neither of these has an upstream gage. In addition, the analysis of the flows on the San Marcos River were inconclusive.

The second component of recharge is also related to streamflow and involves the recharge that occurs along the main channel during flood events. During a major storm event, the rivers and streams in the area tend to overflow their banks and lose water. Historical records indicate that large losses occur between the downstream edge of the Edwards outcrop and the lower reaches of the basin. For example, analysis of streamgage records during a major storm event in October 1996 indicate that losses for the 238-mile river segment between the Uvalde and Three Rivers streamflow gages on the Nueces River totaled 164,400 acre-feet. This resulted in 84 percent of the flow that passed Uvalde being lost prior to arriving at the Three Rivers gage. Likewise on the Frio River, 46,200 acre-feet or 87 percent of the flow that made it across the Edwards Recharge Zone was lost before reaching the Tilden gage. This loss includes recharge of temporary bank storage, evapotranspiration losses and other losses and indicates that flood-related recharge to the aquifer is significant. For this reason, a flood-flow recharge component was included in the methodology.

The remaining component of recharge is the recharge that occurs in the watershed through the tributaries and soils of the watershed, outside the main channel. In these areas, areal precipitation falling on the watershed infiltrates the soil and fills the soil matrix. In the days after the storm, water that is not lost to evaporation and transpiration through the bare soils and plants is contributed to the aquifer by deep percolation.

TABLE 5-1
Summary of Base Streamflow Gain/Loss Analyses

Stream	Winter Base Gain or Loss (-)[1] ($QLOSS_B$) (acft/mo)	Summer Base Gain or Loss (-) (acft/mo)	Estimated Maximum Seasonal ET[2] (ET_B) (acft/mo)	Aquifer Outcrop(s) Intersected
Nueces River between Uvalde and Asherton	-1,500	-4,000	2,500	Wilcox, Carrizo and Bigford
Frio River between downstream edge of Edwards outcrop and Derby	-1,000	-3,000	2,000	Wilcox, Carrizo, Reklaw and Queen City
San Miguel Creek at Tilden[3]	--	--	--	Wilcox, Carrizo, Reklaw and Queen City
Atascosa River at Whitsett[3]	--	--	--	Wilcox, Carrizo, Reklaw and Queen City
San Antonio River between downstream edge of Edwards outcrop and Falls City	1,075	-500	1,575	Wilcox, Carrizo, Reklaw and Queen City
Cibolo Creek between Selma and Falls City	900	475	425	Wilcox, Carrizo, Reklaw and Queen City
Guadalupe River between downstream edge of Edwards outcrop and Lake Wood	1,200	-700	1,900[4]	Wilcox, Carrizo, Reklaw and Queen City
San Marcos River between downstream edge of Edwards outcrop and Luling[5]	--	--	--	Wilcox

Footnotes:

[1] Winter base gain or loss assumed to represent the potential aquifer flux into or out of the stream.

[2] Difference between winter and summer base gain or loss assumed to be primarily evapotranspiration (ET).

[3] San Miguel Creek and Atascosa River are not gaged upstream of the outcrops.

[4] Guadalupe River above Lake Wood has a large seasonal ET component because 70 percent of the reach is in reservoirs.

[5] Analysis of flows above the San Marcos River at Luling were inconclusive.

In computing recharge for a given subwatershed, the following equation was used:

$$R_T = R_A + R_B + R_F \tag{5.1}$$

where

R_T = Total recharge;
R_A = Areal recharge;
R_B = Baseflow river recharge; and
R_F = Flood-flow river recharge.

In reviewing this conceptual equation, the first variable that can be computed directly is R_B. The baseflow recharge was computed by comparing the flow upstream of the Carrizo-Wilcox outcrop to the base winter stream losses and monthly evapotranspiration summarized in Table 5-1. If the stream has historically been a losing reach, the baseflow recharge to the aquifer was computed using the following equation:

$$R_B = \begin{cases} QLOSS_B & \text{if } QG \geq QLOSS_B + ET_B \\ QG - ET_B & \text{if } ET_B < QG < QLOSS_B + ET_B \\ 0 & \text{if } QG \leq ET_B \end{cases} \tag{5.2}$$

where

$QLOSS_B$ = Monthly winter baseflow loss rate (Table 5-1);
QG = Gaged river flow upstream of the aquifer recharge zone; and
ET_B = Monthly maximum baseflow evapotranspiration (Table 5-1).

Close inspection of Equation 5.2 shows that in the computation the upstream flow is incrementally reduced by first taking out evapotranspiration and then, if any flow remains, taking out baseflow recharge up to the maximum baseflow recharge rate. If any flow remains in the stream after taking out evapotranspiration and baseflow recharge, it is considered to be flood flow and is subjected to the methodology used to compute flood-flow recharge.

Flood-flow recharge and areal recharge are calculated using similar procedures. Due to the similarities in the wetting characteristics of these recharge components, (i.e., they both involve waters impacting soils that are normally dry before the rainfall event, and do not stay inundated long after the rainfall stops) the equations developed for both of these areas use the same percentage for the water impacting these regions which becomes recharge. For the flood-flow recharge (R_F), the volume of water that impacts the soils along the main river was assumed to be equal to the flow that passes the upstream gage which exceeds the volume needed to satisfy both baseflow recharge and/or baseflow evapotranspiration. Similarly, the volume of water available outside the main channel areas which contributes to areal recharge (R_A) was assumed to be the intervening potential runoff estimated for each subwatershed area crossed by the outcrop.

In estimating intervening potential runoff, the Soil Conservation Service's Curve Number Method (SCS, 1972) was used as applied in previous surface-water studies in the region (HDR, 1991a; 1993c) with one modification. For the most part, the soils in the Carrizo-Wilcox aquifer outcrop are sandy soils which have relatively low curve numbers. A low curve number produces less runoff for a given depth of precipitation than would be expected in a watershed with a higher curve number. In general, the other soils in the outcrop subwatersheds have more clay and loam characteristics and exhibit higher curve numbers and higher runoff rates. Since a portion of the loss computed using the lower curve number is recharge to the aquifer, it was decided that the potential runoff which is available to recharge would be generated assuming the watershed did not include the outcrop soils. For the selected procedure, an adjusted curve number was computed for each of the subwatersheds analyzed and a revised composite watershed curve number determined. This new curve number was then used with areal precipitation estimates region (HDR, 1991a; 1993c) to estimate potential runoff that might have occurred historically had the watershed not contained the aquifer outcrop. This intervening potential runoff estimate without the outcrop ($QI_{W/O}$) was then used in the computation of areal recharge.

Flood-flow recharge and areal recharge were calculated in an iterative fashion using the following equations:

$$R_F = P_Q * QG_F \tag{5.3}$$

$$R_A = P_Q * QI_{W/O} \tag{5.4}$$

where

P_Q = Percentage of flow that becomes recharge;
QG_F = Flood component of gaged upstream flow
= $QG - R_B - ET_B$ or 0 (whichever is greater); and
$QI_{W/O}$ = Intervening potential runoff estimate assuming no outcrop in the watershed.

In order to solve Equation 5.1 for total recharge, Equations 5.2, 5.3 and 5.4 must be solved simultaneously. To accomplish this, a long-term estimate of the recharge potential of the aquifer based on aquifer characteristics was used. For each watershed where this methodology was used, an estimate of the aquifer's potential to accept recharge and deliver it down into the deep aquifers was determined and used in conjunction with Equations 5.1 though 5.4 to estimate recharge month by month for the 1934-to-1994 period of record. Estimates of the aquifer recharge potential for each watershed are summarized in Table 5-2. In order to simultaneously solve all the equations, Equation 5.2 (baseflow recharge) was solved first for each month in the period of record and a long-term annual average recharge due to the baseflow component was calculated. Then a percentage (P_Q) of potential recharge flows (QG_F and $QI_{W/O}$) was assumed, applied to the flows, and the long-term annual average recharge was computed using Equation 5.1. The average recharge estimate was then compared to the long-term aquifer recharge potentials in Table 5-2. If the long-term annual average recharge estimate did not approximately match the long-term aquifer recharge potential, the percentage (P_Q) of flow that becomes recharge was adjusted, total recharge was recalculated, and the new long-term averages were compared. This process was performed in an iterative fashion until the long-term average annual recharge estimate approximately matched the long-term aquifer recharge potential.

TABLE 5-2
Summary of Aquifer Recharge Potential Based on Transmission Capacities[1]

County	Aquifer Recharge Potential Based on the Transmission Capacities			
	Carrizo-Wilcox (acft/year)	Queen City/ Bigford (acft/year)	Sparta and Younger (acft/year)	Recharge Sum (acft/year/county)
Atascosa	21,582	3,910	12,400	37,892
Bexar	10,552	0	0	10,552
Caldwell	3,063	109	0	3,172
Dimmit	6,095	1,000	0	7,095
Frio	5,677	3,550	4,440	13,667
Gonzales	9,840	4,883	9,212	23,935
Guadalupe	19,947	0	0	19,947
Maverick	1,803	0	0	1,803
Medina	18,265	0	0	18,265
Uvalde	1,614	0	0	1,614
Wilson	33,551	4,686	12,520	50,757
Zavala	11,058	3,000	500	14,558
Sum by Aquifer	143,047	21,138	39,072	203,257

Footnote:
[1] Transmission capacity estimates were developed based on unpublished TWDB records.

The procedure described above was used in the basins where channel loss/gain evaluations showed the reach to be a long-term losing reach (i.e. the Nueces and Frio Rivers). For the San Miguel Creek and Atascosa River watersheds, it was impossible to compute a baseflow recharge or a flood-flow recharge because neither basin has an upstream gage above the Carrizo-Wilcox outcrop. Therefore, for these basins, the percentage (P_Q) of potential intervening runoff ($QI_{W/O}$) was adjusted until the long-term average areal recharge estimate was approximately equal to the long-term aquifer recharge potential.

In the eastern watersheds, the streams are usually gaining reaches (see Table 5-1), and the baseflow recharge component is normally zero. In this region there are upstream streamflow gages on the reaches that can be used to compute gaged flood flows which are believed to recharge to the aquifers even though the streams gain from the aquifer during baseflow conditions. It was assumed that any upstream flow in excess of the long-term median gaged flow could be considered gaged flood flow. Therefore, for the streams in the east (San Antonio, Guadalupe and San Marcos Rivers and Cibolo Creek), the percentage (P_Q) of potential recharge flows (QG_F and $QI_{W/O}$) was adjusted until the long-term annual average recharge (R_F + R_A) approximately matched the long-term aquifer recharge potential for a given watershed (Table 5-2).

These recharge calculations were performed in each of the eight watersheds for the 1934-94 period of record. A summary of the long-term average annual recharge per watershed and by recharge component is shown in Table 5-3 and Figure 5-2. The total recharge from these three components is 207,694 acre-feet per year and is within 2 percent of the aquifer recharge based on transmission capabilities (Table 5-2). About 67 percent of the total recharge occurs as areal recharge in areas outside the main channel with the remaining 33 percent occurring in the main channels. A summary of the total annual recharge estimates, by county, is provided in Appendix B.

TABLE 5-3
Summary of Recharge Estimates

Stream	**Average Baseflow Recharge (acft/year)**	**Average Flood-Flow Recharge (acft/year)**	**Average Areal Recharge (acft/year)**	**Total Recharge (acft/year)**
Nueces River above Asherton	9,668	7,507	7,682	24,857
Frio River above Derby	7,932	5,303	8,964	22,199
Atascosa River and San Miguel Creek	0[1]	0[1]	52,198	52,198
San Antonio River above Falls City	0[2]	11,713	18,090	29,803
Cibolo Creek above Falls City	0[2]	3,265	28,724	31,989
Guadalupe River above Cuero	0[2]	22,060	18,307	40,367
San Marcos River above Luling	0[2]	1,676	4,605	6,281
Sum	17,600	51,524	138,570	207,694
Percent of Total	8.5%	24.8%	66.7%	

Footnotes:
[1] No upstream gage for these watersheds.
[2] Stream reaches have historically been gaining baseflow reaches.

DISTRIBUTION OF RECHARGE

Once the areal, flood and river recharge estimates were made, it was necessary to accurately distribute the recharge within the model. Areal and flood recharge were input into the model using the Recharge package. River recharge was handled by controlling the amount of leakage from the rivers and streams in the model, which was done using the Stream package, and was evaluated during calibration.

Recharge is input into the ground-water model as a flux, in units of feet per day. The flux is the rate of flow across a surface which, in the case of a recharge flux, is the surface area of each cell. Therefore, recharge values for each subbasin had to be converted from a recharge value in units of acre-feet per month (L^3/T) to a flux value in units of feet per day (L/T). Recharge was not distributed equally across each subbasin but was varied depending on what formation outcropped in each particular cell. For example, cells in which the Carrizo and the Wilcox outcropped had a much higher recharge rate than cells in which other formations outcropped.

Areal Recharge

The major component of recharge handled using the Recharge package was areal recharge. To obtain an areal recharge flux, the total areal recharge to all of the subbasins was first estimated. This estimate was then divided between the seven formations (in five layers) in the model based on the transmissivities of the formations and the estimated ability of each formation to accept water. Table 5-4 below shows the breakdown of the areal recharge to each formation in the model. As shown in the table, areal recharge to the Carrizo accounts for a majority of the recharge with approximately 50 percent of the total. The Wilcox and Queen City follow with 23 percent and 12 percent, respectively.

TABLE 5-4
Total and Areal Recharge to Each Formation

Formation	Areal Recharge (acft/yr)	Percent of Total	Formation	Areal Recharge (acft/yr)	Percent of Total
Wilcox	31,706	23%	Queen City	16,912	12%
Carrizo	69,135	50%	El Pico	743	0.5%
Reklaw	794	1%	Younger	13,198	9.5%
Bigford	6,082	4%	TOTAL	**138,570**	100%

Recharge totals for each formation within each subbasin were then converted to flux in units of feet per day based on the total area of the outcrop within each subbasin. Table 5-5 below gives the total areal recharge for each of the formations in each of the subbasins in the model.

TABLE 5-5
Total Areal Recharge to Each Formation within Each Subbasin

	Recharge (acft/yr)							Total
	Wilcox	Carrizo	Reklaw	Bigford	Queen City	El Pico	Younger	
Nueces1	2,305	1,152	0	3,841	0	384	0	7,682
Frio1	2,689	1,165	0	2,241	1,345	359	1,165	8,964
San Miguel/ Atascosa	5,220	27,665	522	0	11,484	0	7,308	52,199
Medina/ San Antonio 1&2	4,975	11,849	181	0	543	0	543	18,091
Cibolo	8,617	17,234	0	0	1,436	0	1,436	28,723
San Marcos	4,605	0	0	0	0	0	0	4,605
Guadalupe	3,295	10,069	92	0	2,105	0	2,746	18,307
Total	31,706	69,134	795	6,082	16,913	743	13,198	138,571

Recharge totals for each formation within each subbasin were then converted to a flux in units of feet per day based on the total area of the outcrop within each subbasin. Table 5-6 below gives the fluxes obtained for each of the formations in each of the subbasins in the model.

TABLE 5-6
Areal Recharge Flux for Each Formation within Each Subbasin

	Flux (feet/day)						
	Wilcox	**Carrizo**	**Reklaw**	**Bigford**	**Queen City**	**El Pico**	**Younger**
Nueces1	0.0000486	0.0000186	0	0.0000334	0	0.0000046	0.00002
Frio1	0.0000571	0.0000253	0	0.000144	0.0000375	0.0000047	0.0000229
San Miguel/ Atascosa	0.000276	0.000574	0.0000296	0	0.000115	0	0.0000292
Medina/ San Antonio 1&2	0.0000707	0.000379	0.0000178	0	0.000028	0	0.0000228
Cibolo	0.000278	0.00121	0	0	0.0000888	0	0.0000608
San Marcos	0.000328	0	0	0	0	0	0
Guadalupe	0.0000709	0.00041	0.000005	0	0.0000605	0	0.0000143

Flood Recharge

Flood recharge was handled in a similar manner to the areal recharge, except instead of using the total outcrop area within each subbasin to calculate the fluxes, only those cells that included a river or stream segment were included. This approach assumes that the flood recharge is evenly distributed across those cells that contain rivers or streams in the model. The same percentages used to calculate areal recharge were used to distribute the flood recharge.

Once the areal and flood recharge flux estimates were calculated, they were added together to obtain a total recharge flux for each cell in the model. This array was then converted into the format required for the Recharge package in MODFLOW and used in the model.

VI. COMPUTER MODELS

Computer models were used in this study to investigate the effects of future ground-water pumpage on both ground-water and surface-water systems. In general, the interaction of the models was performed in the following manner. The databases of channel losses, recharge estimates and streamflows from the surface-water models were used as input to the ground-water model. The ground-water model was then executed and streamflows from the MODFLOW simulations were tabulated at key points in the river basins downstream in the surface-water models, and the surface-water models were executed to simulate the impacts of changes in streamflows at a number of locations. Evaluations included tabulation of impacts on water rights, fresh-water flows to estuaries, and well levels across the study area. Each of the models used in this study are described below.

GROUND-WATER MODEL

Introduction

The USGS modular finite-difference ground-water model (MODFLOW) was used for the ground-water modeling on the project (McDonald and Harbaugh, 1988). MODFLOW is a three-dimensional finite-difference ground-water model, and is the most commonly used ground-water model. This model allows the incorporation of streams, recharge, drains and other stresses that were required for this model without altering other stresses that are already included in the model.

Model Description

The MODFLOW model uses separate modular packages that can be added or removed from the main program without affecting the rest of the model. This allows the independent addition of stresses such as wells, streams and recharge. Each of these stress packages can be changed separately to determine the effect of the change on the model. The packages used with this MODFLOW model include the following:

a. *Basic Package* - Provides the basic model data, number of layers, rows, columns and stress periods, packages that will be included in the model, active and inactive cells, and starting heads for all active cells. This package is required with all MODFLOW models.

b. *Block-Centered Flow Package* - Provides the basic aquifer parameters, layer types, size of rows and columns, steady-state/transient flag and aquifer characteristics (top and bottom elevations, hydraulic conductivity or transmissivity, storativity and specific yield, and leakage between layers). This package is required with all MODFLOW models.

c. *Output Control Package* - Controls the output from the model. This package is required with all MODFLOW models.

d. *Well Package* - Allows water to be injected or pumped from individual cells in the model. Data required for this package include layer, row and column for the pumping cell and the volume pumped (in units of cubic feet per day). The input data can vary from one stress period to the next.

e. *Recharge Package* - Allows water to be added as recharge in the model. Data required for this package include the recharge flux (in units of feet per day), which are included for all active cells in the model.

f. *Stream Package* - Allows streams to be modeled and interact with the aquifer. Flow to and from the streams is based on head differences between the stream stage and the water level in the model cell containing the stream. Streamflows are tracked as the stream flows through the model, allowing comparisons to actual streamflow gage data. Data required for this package include the layer, row and column of the cell containing the stream, the segment and reach number of the stream in that cell, the flow (only for the uppermost reach in each stream segment), the stage of the stream, the elevation of the top and bottom of the streambed, the conductance of the streambed, and information about the tributaries entering the streams. These will be described in detail below.

g. *Horizontal Flow Boundary Package* - Allows horizontal flow variations due to lower horizontal hydraulic conductivities to be modeled. These variations in hydraulic conductivity are due to impeded ground-water flow across growth faults in the area. Data required for this package include the layer, row and column of the two cells between which a horizontal flow boundary will be placed, and the hydraulic conductivity (in units of feet per day) across the horizontal flow boundary.

h. *Drain Package* - Allows drains to be added to model. The drains for this model represent flowing wells in the Carrizo aquifer. Data required for this package include the layer, row and column of the drain, the elevation of the drain and the hydraulic conductivity of the drain, which determines the rate at which water leaves the drain.

Model Design. The model was based on the CARIZO model (TWDB, 1973), which contained one layer, 35 rows and 69 columns. This design was changed to contain five layers instead of one. The only modification to the model grid was that the first row was doubled in width so that the Wilcox outcrop could be fully included at the top of the model. Otherwise, the basic grid setup for the model was not changed. The model grid is shown in Figure 6-1. A large number of inactive cells in the CARIZO model were changed to active cells because of the addition of the Wilcox aquifer to the model.

Model Layers. The model was developed as a five-layer model. Layer 5 represents the Wilcox Formation and Layer 4 represents the Carrizo Formation, which are the two main aquifers in the model. Layer 3 represents the Reklaw Formation in the northeastern half of the region and the Bigford Formation in the southwestern portion of the region. Layer 2 represents the Queen City in the northeastern half of the region and the El Pico Clay in the southwestern half of the region. Layer 1 represents all formations younger than the Queen City/El Pico, which include the Sparta Sand, etc. The layering convention is shown in Table 3-1.

Formations in the region dip to the east-southeast. Outcrops of each of the formations being modeled were mapped, and each cell was assigned an "outcrop formation," which represents the formation that outcrops for most of each particular cell. Figure 6-2 shows the outcrop cells for the entire model area.

Elevations for the top and bottom of the Carrizo Formation (Layer 4) were obtained from the CARIZO model input files. Average surface elevations for each of the cells in the model were also obtained from these input files and were assumed to represent the top of the layer that outcrops in each particular cell. Thicknesses of the other layers in the model were then estimated, and the tops and bottoms for all model layers were then calculated using these estimates.

Boundary Conditions. All boundaries of the ground-water model are simulated as no-flow boundaries. The western and northern boundaries represent the outcrop of the deepest formation included in the model, the Wilcox Formation. The southern and southeastern boundaries represent the downdip extent of slightly-saline (greater than 3,000 mg/l) water. Little flow is assumed to occur between the saline and slightly saline water sections, and so this was considered to also be a no-flow boundary. The eastern boundary represents a ground-water divide near the San Marcos River.

The bottom boundary of the model is the base of the Wilcox Formation. Beneath the Wilcox is the Midway Group, which mainly consists of impermeable shales, siltstones and fine-grained sandstones. Some water may flow between the Midway and the Wilcox. However, because the volume of this flow is probably very low and because the primary interest of this model is the Carrizo Formation which is located above the Wilcox, no significant error was considered to be introduced by modeling the bottom of the Wilcox as a no-flow boundary.

Model Runs. The ground-water model was run in two parts during calibration. First, a "predevelopment" steady-state model was run, which included all packages except the drain package and the well package. Average recharge and streamflow values were calculated for use in this simulation, and the results of this run were assumed to be the conditions prior to any development occurring in the area. Because development of ground-water in the Winter Garden Area began around 1910, the results of the steady-state predevelopment run were assumed to represent conditions at the beginning of 1910.

The second part of the model calibration run was a transient simulation from 1910 to 1994. Data for streamflows and recharge were only available for 1934 through 1994. The average of the values from 1934 through 1994 were used for each of the years between 1910 and 1933.

Once the model was calibrated, it was changed to run on a monthly basis. Input data files were converted to monthly data, but the basic structure of the model was not changed. Final runs of the model were done on a monthly basis.

Data Requirements

A significant amount of input data was required to set up the ground-water model, including physical and hydrologic aquifer characteristics, aquifer water levels, irrigation and municipal pumpage estimates, stream characteristics and recharge estimates. The collection of the data for the ground-water model is described below.

Aquifer Parameters. Data for the Carrizo aquifer were obtained primarily from TWDB Report 210 and the TWDB digital CARIZO aquifer model. Because the model design was taken from the CARIZO model, the Carrizo aquifer parameters were easily imported directly from that model into the MODFLOW model. Estimates of the aquifer parameters for the other four layers in the model (Wilcox, Reklaw/Bigford, Queen City/El Pico and younger formations) were generally taken from published water agency reports.

Pumpage. Development of input data sets for both historic and future pumpage are described above in Section IV.

Recharge. Development of input data sets for both historic and future recharge are described above in Section V.

Stream Characteristics. The streams and rivers included in the ground-water model are shown in Figure 6-3. This figure shows each stream or river (which will all be referred to as streams in this discussion) and the cells that the streams are located in. The streams modeled include the Rio Grande, Nueces River, Frio River, Leona River, Sabinal River, Seco Creek, Hondo Creek, San Miguel River, Atascosa River, Medina River, Leon Creek, San Antonio River, Calaveras Creek, Cibolo Creek, Guadalupe River and San Marcos River.

Each stream was divided up into segments, based on the location of USGS stream gages and confluences with other streams. Each segment was then divided up into reaches, with one reach per cell within the segment. Segment and reach numbers are also included in Figure 6-3. Physical characteristics for each reach of each stream were input into the ground-water model.

The physical characteristics of each of the reaches were estimated using topographic maps of the area. Estimates of the width and the average depth of each stream were then made to obtain estimates of stream stage. The thickness of the streambed was assumed to be 1 foot for the purposes of calculating the streambed conductivity. Streambed conductivities were determined during calibration.

Streamflows. The input into the ground-water model also includes streamflows at the top of each major stream segment as it enters the model. Streamflows were actual flows measured at USGS streamflow-gaging stations or estimated streamflows. These streamflows were converted into units of cubic feet per day and input into the stream package.

Drain Package. Numerous wells were completed in the Carrizo in the 1940's through the 1960's (one was installed in 1914). These were artesian wells which flowed uncontrolled for many years. Originally oil test wells, these wells had been subsequently perforated in the Carrizo and left for the landowners to use, generally without caps placed on them. These wells were modeled as drains in the MODFLOW model. Data on the wells, including wellhead elevation, location and estimated flow in 1960, were obtained for each well from published well records. Where multiple wells were located in a single cell, they were combined into a single drain. Cells containing drains are shown in Figure 6-4. During the calibration runs, varying hydraulic conductivities were tested for each of the drains (wells) to determine what conductivity gave the best approximation of flow in the 1960 stress period.

Horizontal Flow Boundaries. Horizontal flow within the Carrizo aquifer is somewhat impeded by the numerous faults that run through the area. These faults were mapped and included as horizontal flow boundaries in the MODFLOW model. The locations of the horizontal flow boundaries are shown in Figure 6-5. Hydraulic conductivities across these boundaries were determined during the calibration process but are generally 1/100 of the normal horizontal hydraulic conductivity.

Leakage Values. Leakage values were determined during calibration runs. In general, because of the large thicknesses of the modeled formations, leakage values were several orders of magnitude lower than the hydraulic conductivity of the layers. Leakage values between most of the sandy units ranged from 10^{-5} to 10^{-7}. Leakage in certain areas was lower than this.

SURFACE-WATER MODELS

Introduction

As part of the investigation of the interaction between surface water and ground water, a number of surface-water computer models previously developed by HDR Engineering, Inc. (HDR) were used. The following is a brief discussion of the basic features of each surface-water model followed by a discussion of the enhancements made to the models in order to simulate the ground-water/surface-water interaction in the study area.

Description of Existing Surface-Water Models

Descriptions of the three existing surface-water models, the Nueces River Basin Model, the Lower Nueces River Basin and Estuary Model, and the Guadalupe-San Antonio River Basin Model, are given below.

Nueces River Basin Model. As part of several previous water-supply planning studies for the Nueces River Basin (HDR, 1991a; 1991b; 1993b), a customized computer model has been developed for the basin. The model employs a monthly time step proceeding with flow calculations in an upstream to downstream order simulating Edwards aquifer recharge, channel losses, water rights and reservoir operations at 30 control points for a 56-year (1934-89) period of record. The original model was capable of simulating the Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System subject to a maximum firm yield policy, with limited consideration of release programs for maintenance of fresh-water inflows to Nueces Estuary. The model includes the capabilities for daily simulation of recharge dams to estimate recharge enhancement potential for up to four recharge dams operating simultaneously.

Lower Nueces River Basin and Estuary Model. HDR was retained by the City of Corpus Christi and other sponsors to develop a Lower Nueces River Basin and Estuary model which focuses on the operations of the CCR/LCC System (HDR, 1991b; 1993a; 1993b). As a result of these studies, the Lower Nueces River Basin and Estuary Model was developed and is capable of simulating the CCR/LCC System under the City's Phased Operation Plans and the 1995 Agreed Order issued by the TNRCC which governs system operations with respect to fresh-water inflows for the Nueces Estuary. This model operates on a monthly time step over a 56-year period of record (1934-89), and computations in the model reflect alternative reservoir operating policies as well as channel losses in the rivers associated with water delivery from CCR to LCC and from LCC to the City's water-supply intake at Calallen diversion dam. The model also calculates salinity in the Upper Nueces Bay using relationships developed by the TWDB (Powell, 1990) and reduces or suspends reservoir inflows passage to the bays and estuaries when certain salinity criteria are satisfied, in accordance with the 1995 Agreed Order.

Guadalupe-San Antonio (GSA) River Basin Model. As part of a study to evaluate the potential for recharge enhancement projects in the GSA River Basin, HDR developed a customized computer model of the basin (HDR, 1993c). The model's capabilities include accurate reproduction of historical streamflows at approximately 38 control points as well as historical recharge to the Edwards aquifer. A unique aspect of the model is the incorporation of channel-loss equations for each stream derived for gaged upstream and downstream flows and calibrated estimates of intervening runoff. Changes in upstream flow from the natural flow at each control point due to diversions and/or impoundments are translated downstream to the next control point using these equations. The model operates on a monthly time step and simulates several existing and proposed reservoirs in the basins in accordance with specific operation policies and constraints. These constraints include net evaporation, recharge, leakage, direct diversions, water-rights releases, and spills. Another unique feature of this model is the simulation of changes in springflows at five springflow control points within the basin. This feature adjusts springflows in the surface-water model based on various aquifer pumpage scenarios using the TWDB's Edwards Aquifer Model. The same technique for adjusting historical springflow sequences based on future Edwards pumpage scenarios was applied in this study to incorporate into the surface-water models the flow changes simulated by the Carrizo-Wilcox aquifer model. A detailed discussion of this application follows.

Modifications to Existing Surface-Water Models

The surface-water models used to evaluate the ground-water/surface-water interaction in this study are complex simulation models. These models compute streamflows from upstream to downstream accounting for changes along the way. Output from the ground-water computer models developed in this study includes simulated streamflows at a number of control points downstream of the Carrizo-Wilcox outcrop. The resulting streamflows predicted by the ground-water model account for changes in water levels in the aquifers (resulting from changes in pumpage of the aquifers) which in turn change the volume of water that enters the aquifer through the streambed and vice versa. The changes in interactions between the surface-water and ground-water media were applied to the streamflows in the surface-water model to evaluate the impacts on downstream water rights and streamflows.

A baseline historical sequence of pumpage volumes and streamflows was simulated in the ground-water model with simulated streamflows downstream of the Carrizo-Wilcox outcrop being tabulated. This is referred to as the baseline aquifer model flow set. After tabulating these baseline data, the ground-water model was run with an alternative future aquifer pumpage scenario. Resulting streamflows downstream of the Carrizo-Wilcox outcrop were then tabulated and differences from the baseline flows calculated. These differences were then brought into the surface-water model by use of the following relationship:

$$QN_{FUT} = QN_{HIST} - \Delta_{BRR} \tag{6.1}$$

where

QN_{FUT} = Natural flow taking into account future pumpage effects on streamflow;
QN_{HIST} = Natural flow based on historical pumpage effects on streamflow; and
Δ_{BRR} = Baseflow river recharge.

The following relationship was used to compute the change in flow (Δ_{BRR}):

$$\Delta_{BRR} = \begin{cases} QGW_B - QGW_F & \text{if } QGW_B - QGW_F < QN_{HIST} \\ QN_{HIST} & \text{if } QGW_B - QGW_F \geq QN_{HIST} \end{cases} \qquad 6.2$$

where

QGW_B = Baseline aquifer model flows; and
QGW_F = Future aquifer model flows.

Changes in river recharge are incorporated into the Nueces River Basin and GSA River Basin Models at the control points immediately downstream of the Carrizo-Wilcox outcrop (i.e., Nueces River at Asherton, Frio River at Derby, Frio River at Choke Canyon Reservoir (incorporating changes on San Miguel Creek), Atascosa River at Whitsett, San Antonio River at Falls City, Cibolo Creek at Falls City and Guadalupe River at Cuero). At these control points, the results of the application of Equations 6.1 and 6.2 are applied in the surface-water model, and the modified flows are simulated downstream through the remainder of the basin. Impacts of these changes as a result of ground-water pumpage volumes are discussed in a subsequent section of this report.

VII. GROUND-WATER MODEL CALIBRATION

The adjustment of model input values to produce the best possible match between simulated and actual water levels was accomplished during calibration. During the calibration process for this model, both steady-state simulations and 85-year (1910-94) transient simulations were run to complete the calibration.

DESCRIPTION OF CALIBRATION PROCESS

The first step necessary in the calibration process was to use the estimated average recharge, streamflows, etc. in a steady-state model run to determine how well the model-calculated water levels matched estimates of predevelopment water levels. Predevelopment conditions were considered to exist prior to 1910. However, very little water-level data were available prior to 1910 for comparison with the model results. Therefore, the main purpose of the steady-state simulations was to determine if the model ran properly and to provide starting water levels for the transient simulations. A regionwide evaluation of water levels was made on a cursory basis only to determine if the general ground-water flow matched what we thought it should be.

Transient simulations were run for the 1910-to-1994 time period using annual stress-period lengths. Hydrographs for wells throughout the model area were obtained and plotted for comparison to transient simulation results. Figure 7-1 shows the locations of the wells used for comparison in the calibration process. A majority of these wells were completed in the Carrizo aquifer, with lesser numbers in the Bigford, Queen City, Sparta and Wilcox. Table 7-1 below gives a summary of the number of monitoring wells in each of these formations.

TABLE 7-1
Summary of Monitoring Wells

Aquifer	**Number of Monitoring Wells**
Sparta	1
Bigford	5
Queen City	6
Carrizo	95
Wilcox	3

These hydrographs provided the main method for model calibration. Very little solid regional ground-water elevation data were available, so comparison of regional maps to model results in plan view was not considered to be a valid method of calibration. Actual calibration changes were made based on the hydrographs, and how well hydrographs from different regions within the model area matched the transient simulation results.

CALIBRATION RESULTS

Ground-Water Calibration

The final results of the model calibration are shown in the hydrographs included in Appendix C. Several changes had to be made to achieve reasonable calibration, including changing basic aquifer characteristics, the incorporation of the drain package to simulate flowing wells, the inclusion of the horizontal flow boundary package to simulate restricted flow across faults and revision of the stream characteristics.

The results of the calibration gave fairly good model-wide correspondence between the actual measured water levels and those predicted by the model, as shown in Figures 7-2 through 7-5. The predicted water levels show a general agreement with measured water levels, and the slopes of a majority of the hydrographs are similar. Because the model is of such a regional scale and the elevations predicted by the model are an average for the entire cell, differences between the actual water levels and the model-predicted water levels are expected and cannot be avoided.

Once the model was calibrated, it was converted to run using monthly stress-period lengths. As described in Section IV above, the average annual pumpage totals were converted to estimated monthly pumpage volumes based on factors to increase or decrease the average pumpage. Because the factors used to increase or decrease the pumpage for each month were consistent and did not vary from year to year, the hydrograph resulting from a monthly run showed a significant, continuous variation in water levels reflecting the annual increase and decrease in pumpage from summer to winter. An example of a monthly hydrograph is shown in Figure 7-6. This is an extreme example and is probably the result of significant pumpage occurring in the cell containing the monitoring well. Also shown on this figure are the results for this well from an annual run.

One area of the model consistently showed problems during calibration, specifically an area around the Zavala-Dimmit County border. This area has a significant amount of historic drawdown, and the model has been unable to provide accurate historic estimates of water levels for this area. When the model was adjusted during calibration to attempt to correct the problem, water-level estimates in adjacent areas, which previously had shown reasonable correspondence to actual water levels, were changed such that they no longer matched actual water levels. Horizontal flow boundaries were added to simulate the impedence of horizontal ground-water flow due to faulting in the area, but this did not eliminate the problem. It was concluded that the differences between actual and modeled water levels could be due to one of two reasons: (a) there is a component of the hydrogeology of this area that is not being correctly modeled or (b) there is an error in the historic pumpage estimates for this area. The conversion of annual pumpage estimates to monthly estimates may also have had a significant effect on the results, but probably could not account for all of the differences observed in this problem area.

Surface-Water Calibration

It was necessary to confirm the model's ability to simulate the historical interaction between the aquifer and surface streamflow. For each river segment crossing the outcrop, the ground-water model uses streambed transmissivities, monthly surface-water volumes entering each segment and monthly ground-water levels throughout each segment to determine the monthly volume of gain or loss. Because the aquifer model does not take into account runoff generated within the surface watershed between the upstream and downstream limits of the model, agreement between observed gaged flows and simulated streamflow is not practical. However, it is reasonable to use the results from alternative ground-water model pumpage scenarios to evaluate impacts on streamflows provided the following two conditions are satisfied: (1) the ground-water model reasonably simulates the observed characteristics of the streamflow interaction, and (2) only changes in recharge and leakance between the historical ground-water pumpage run (baseline) and future pumpage scenarios are used in evaluating impacts on surface water. Item (1) involves reviewing the results of the ground-water simulations for historical conditions and checking the trends in streamflows for reasonableness. Item (2) is addressed by incorporating the changes in streamflows predicted by the ground-water models into the surface-water models to determine impacts.

As part of the calibration process, riverbed transmissivities were varied until comparisons of streamflow changes generated by the ground-water model for each stream segment were determined to be reasonable. Simulated streambed losses or gains, per mile of outcrop intersected, for the 1934-to-1994 period of record were plotted for numerous ground-water model runs to determine consistency and reasonableness. The results for the final calibration run are shown in Figure 7-7. The curves shown in this figure represent the 10-year moving average of simulated losses or gains. In general, the streams with the largest losses are in the west (Nueces and Frio Rivers) with loss rates generally declining from west to east. The streams in the Guadalupe-San Antonio River Basin are all gaining reaches in the early part of the period analyzed, with only the Guadalupe and San Marcos Rivers gaining throughout the period. Three streams begin the period as gaining reaches but end the period as losing reaches – the Atascosa River, San Antonio River and Cibolo Creek. The reason for the change in these reaches is explained by the increase in pumpage in the 1960's. As pumpage increased during the 1960's, water levels in the central region of the study area began to decline, and by the end of the period of record, water levels were low enough to cause these streams to more consistently lose water to the aquifer.

The steepness of the decline of the San Antonio River was of concern, so a second characteristic of the channel losses and gains was evaluated. A plot of the 20-year moving average of simulated streamflow losses as a percentage of upstream flow was prepared and is shown in Figure 7-8. Review of this figure shows that the western region streams (Nueces and Frio Rivers) have the largest percentage of upstream flow lost to the aquifer (20 to 30 percent). The figure also demonstrates that the magnitude of losses on the San Antonio River expressed as a percentage of streamflow are small (less than 10 percent) compared to the Nueces and Frio Rivers and are reasonable considering there is significantly more water available to lose in the San Antonio River compared to the Nueces and Frio Rivers.

CONCLUSIONS

As seen in the hydrographs from around the model area, calibration was fairly good for most areas in the model. However, an additional comparison was made to determine the effect of varying monthly pumpage on model results. Figures 7-9, 7-10 and 7-11 show some hydrographs of the results of a model run on a monthly basis (water levels after each December stress period) compared to the results of the same model simulation run on an annual basis. As shown in Figure 7-9, the difference between these two runs can be minimal. However, as shown in Figures 7-10 and 7-11, the difference between running the model on monthly versus annual stress-period lengths can have significantly different results in water levels. This difference is a result of the variation in water levels due to the variation in monthly pumpage. This analysis emphasizes the extreme importance of pumpage to the results of the model; the variation in pumpage far outweighs any changes made during the calibration process. This could prove to be a limiting factor in how well the model can be calibrated using historical input data, because the historical pumpage volumes include a significant degree of uncertainty. With respect to surface water, the results shown in Figures 7-7 and 7-8 indicate that the aquifer model is reasonably simulating the interaction between ground water and surface water.

It is also important to note that actual measured water levels used for calibration are discrete points which are being compared to a result from the model for a particular cell, which represents an average value for a large area. This will also limit the ability to use these water levels for calibration. In addition, most of the available water levels were measured during the nonirrigation season. While this will provide a good tool for calibration of long-term effects of pumpage, these data cannot be used to calibrate the short-term effects of irrigation pumpage by the model.

VIII. IMPACTS OF FUTURE GROUND-WATER PUMPAGE SCENARIOS

INTRODUCTION

Three future pumping scenarios were run with the calibrated model to evaluate the impacts of these scenarios on ground-water levels in the model area and on the surface-water flows.

Pumping Scenarios

The first future pumping scenario run included pumpage based on 1994 withdrawals. The second future pumping scenario run included estimated 2050 pumping conditions. The third future scenario included the estimated 2050 pumpage plus additional pumpage in the eastern and southwestern portion of the model area. A summary of total pumpage volumes for each of these scenarios is given in Table 1-1. Each of these pumping scenarios is described below.

1994 Pumpage. The pumpage data set for the year 1994 was used annually for the historic time period. This run provides a baseline for comparison with the two future runs and shows what the effects of current pumpage on the aquifers would be if these pumping levels remained constant.

2050 Pumpage. This run included estimated pumpage for 2050 from the TWDB used annually for the historic time period. Other than different pumpage amounts for each county, the 2050 pumpage run was identical to the 1994 pumpage runs. Table 8-1 provides the differences between the 1994 and 2050 pumpage data sets for the major water-use categories (irrigation and municipal).

TABLE 8-1
Differences between 1994 and 2050 Pumpage Data Sets

County	1994 Pumpage			2050 Pumpage		
	Irrigation	Municipal*	Total	Irrigation	Municipal*	Total
Atascosa	45,175	4,858	50,033	35,208	33,652	68,860
Dimmit	4,678	2,373	7,051	3,924	6,259	10,183
Frio	105,165	2,597	107,762	63,849	4,785	68,634
Gonzales	93	1,238	1,331	855	5,198	6,053
Guadalupe	28	5,094	5,122	255	18,996	19,251
Karnes	623	2,039	2,662	389	3,398	3,787
La Salle	5,411	1,298	6,709	3,438	1,600	5,038
Live Oak	7	1,067	1,074	2,090	5,544	7,634
Wilson	10,163	3,319	13,482	3,548	7,311	10,859
Zavala	52,361	2,303	54,664	59,301	5,115	64,416

*Municipal totals for 1994 are actually 1992 values. 1994 values were not readily available.

"2050 Plus" Pumpage. This scenario was identical to the 2050 Pumpage Scenario, but an additional 180,237 acre-feet per year of pumpage was added in Atascosa, Gonzales, Wilson and Dimmit Counties. The additional pumpage in Atascosa, Gonzales, and Wilson Counties totals 145,237 acre-feet per year and is based on scenarios identified in previous studies (HDR, 1994). The pumpage in Dimmit County represents a hypothetical well field placed in south-central Dimmit County with an additional demand of 40,000 acre-feet pear year. Other than the addition of this pumpage, the 2050 Plus pumpage runs used the same assumptions and initial conditions as the 1994 and 2050 pumpage runs.

Ground-Water Model Assumptions

For all three of the pumping scenarios described above, the same input data sets were used for the other stresses on the aquifers. The future runs were based on the assumption that future pumpage would be run with historical recharge, streamflows, etc. to determine what the effect of the future pumpage would be if the 1934-to-1994 period of record were repeated. Recharge values for 1934 to 1994, calculated as described in Section V, were used for the recharge input data set. Historical gaged streamflows upstream of the Carrizo-Wilcox recharge zone for 1934 to 1994 were used to create the stream input data set for the ground-water model. The starting heads for the future runs were the heads at the end of the final, calibrated monthly model, which represent water levels at the end of 1994. The pumpage data sets were constructed as described in Section IV.

Surface-Water Model Assumptions

A description of the baseline assumptions used in each surface-water model to evaluate the impacts of changing pumpage from the Carrizo-Wilcox aquifer on surface-water flows are described below. The surface-water model runs were simulated using the 1934-to-1989 period of record. The hydrologic, water rights, and reservoir operations databases were developed for the surface-water models used in this analysis under previous contracts, and updating the input databases for the surface-water models was not part of this study.

Nueces River Basin Models. One baseline assumption made regarding the operation of the Nueces River Basin Model was that all existing water rights be exercised to the fullest extent possible (i.e. to the extent that water is available for diversion). In0 the Lower Nueces River Basin and Estuary Model, the following assumptions were made regarding the operation of the Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System:

- Firm yield demands;
- Phase IV Water Supply Operations Plan;
- 1995 Agreed Order;
- 2050 sediment accumulation in the lakes; and
- 1934-1989 period of record.

In addition, for the 1994 Carrizo-Wilcox Pumpage Scenario, the firm yield was computed assuming 1990 sediment accumulation in the lakes. This additional evaluation was performed in order to show the current status of the CCR/LCC System with adjustments made to the historical flows based on current conditions within the aquifers.

Guadalupe-San Antonio (GSA) River Basin Model. In the GSA River Basin Model the following assumptions were used:

- 400,000 acre-feet per year Edwards aquifer pumpage;
- Full water rights use;
- 47,000 acre-feet per year yield from Canyon Lake (600 cfs hydro);
- CP&L 300 cfs water right at Victoria honored; and
- 1934-1989 period of record.

These assumptions are consistent with some previous studies performed in the region. The following scenarios include comparisons of modeled historical pumpage sequences with future pumpage sequences, under the above listed baseline assumptions.

SCENARIO 1 - 1994 PUMPAGE

Introduction

This run used 1994 pumpage from the historic transient run repeated annually through the historic time period. 1994 water levels from the final calibrated transient run were used as starting water levels. Historical recharge and streamflows were used.

Ground-Water Results

Hydrographs for 28 monitoring wells that provide an accurate representation of all of the areas within the model area are shown in Appendix D. These hydrographs reflect the pumpage that occurs in or near the cell where the monitoring well is located. In some areas, such as Wilson and Gonzales Counties, pumpage in 1994 is less than estimated pumpage in 2050, and therefore water levels in the 1994 plot are higher than in 2050. In other areas, such as Frio, La Salle and Atascosa Counties, estimated pumpage in 1994 is higher than in 2050, and therefore water levels in the 1994 plot are lower than those for 2050. Where the differences in pumpage are small, the curves are very close to one another. Water levels in aquifers other than the Carrizo showed very little difference between the 1994 plot and the 2050 plot, indicating that the change in pumpage has a significant effect only on the aquifer that is being pumped, i.e. the Carrizo.

Surface-Water Results

To evaluate the 1994 Pumpage Scenario, changes in streamflow were extracted from the ground-water model runs and incorporated into the Nueces and GSA River Basin Models based on a comparison with historical streamflow. The flow changes were tabulated at appropriate streamflow locations and are summarized in Figures 8-1 through 8-12. These figures include an annual streamflow decile comparison for the surface-water model period of record (1934-89) and an annual 10-year drought (1947-56) comparison for the six streamflow locations evaluated. Annual streamflow decile averages are computed by ranking the annual streamflows and averaging the annual values within successive 10-percentile groups. For example, to compute the 0 to 10 percent decile average, the lowest 10 percent of the annual streamflows are averaged. Likewise, to compute the 91 to 100 percent decile average, the highest 10 percent of the annual values are averaged. This statistic creates an approximate bar graph representation of a flow frequency plot and was commonly used in the Trans-Texas Water Program. Table 8-2 summarizes the average annual changes in streamflow for all six locations.

TABLE 8-2
Impacts on Average Annual Streamflow
Scenario 1 - 1994 Pumpage

Stream	Average Annual Streamflow (acft)			Percent Change
	Historical	With 1994 Carrizo-Wilcox Pumpage	Change	
Nueces R. @ Asherton	135,692	132,819	-2,873	-2.1%
Frio R. @ Derby	98,123	93,563	-4,560	-4.7%
Atascosa R. @ Whitsett	93,248	87,203	-6,045	-6.5%
San Antonio R. @ Falls City	287,571	260,517	-27,054	-9.4%
Cibolo Cr. @ Falls City	92,550	88,399	-4,151	-4.5%
Guadalupe R. @ Cuero	1,130,009	1,123,357	-6,652	-0.6%

As shown in Table 8-2, the greatest impact on average annual streamflows occurs in the Atascosa and San Antonio River Basins. This is a result of the large increase in pumpage from the aquifer in this region since the 1950's. In fact, these streams have changed through the historical period from normally gaining reaches to normally losing reaches. The changes in the Guadalupe River Basin are small, indicating that pumpage is still relatively low in this region and aquifer levels have not been significantly drawn down.

It is worth noting that these comparisons of annual changes in streamflow tend to smooth out the seasonal or monthly variations that can occur due to increased pumpage. In some instances the monthly variations could be more significant than the annual changes indicate. Therefore, a series of tables showing the monthly flow changes at the six stream locations and the two estuary fresh-water inflow locations analyzed in this study are presented in Appendix E, Potential Impacts on Monthly Streamflows.

As shown in the previous table, the flows in the Nueces River Basin are impacted by roughly two to six percent immediately downstream of the Carrizo-Wilcox outcrop. By the time these flows reach the CCR/LCC System, these impacts are further reduced because of the large channel losses in the reaches below Asherton and Derby. Table 8-3 shows the changes in the yield of the CCR/LCC System for both 1990 and 2050 sediment accumulation. The 1990 sediment accumulation firm yield represents the effects of historical pumpage on the reservoir system today, and the 2050 sediment accumulation firm yield reflects what the impact could be in 2050 if current pumpage levels of the aquifers are maintained.

TABLE 8-3
Impacts on CCR/LCC System Yield
Scenario 1 - 1994 Pumpage

Sedimentation Year	Reservoir System Yield			Percent Change in System Yield
	With Historical Carrizo-Wilcox Pumpage	**With 1994 Carrizo-Wilcox Pumpage**	**Change in Yield**	
1990	203,300	199,100	-4,200	-2.1%
2050	189,600	186,500	-3,100	-1.6%

Note:
CCR/LCC System Operations include the City of Corpus Christi's Phase IV Operations Plan and the 1995 Agreed Order.

The impacts of Carrizo-Wilcox aquifer pumpage on two regions with large run-of-the-river water rights were also evaluated. The rights analyzed were the Zavala-Dimmit WCID #1 water rights on the Nueces River near the model's Asherton control point and the combined water rights at the Saltwater Barrier control point in the GSA River Basin Model. Table 8-4 shows a summary of the impacts on the availability for these water rights assuming 1994 pumpage of the Carrizo-Wilcox aquifer. As demonstrated in the table, the impact on water-right availability at these two locations is generally minor (a decrease of less than five percent). However, on the average, there are 17 more months under 1994 pumpage conditions when streamflows are not available to meet the full monthly diversion at the Asherton control point (Zavala-Dimmit plus others). At the Saltwater Barrier, water-right shortages occur in 8 additional months.

TABLE 8-4
Impacts on Selected Run-of-the-River Water Rights
Scenario 1 - 1994 Pumpage

Water Right	With Historical Carrizo-Wilcox Pumpage	With 1994 Carrizo-Wilcox Pumpage	Change in Availability	Increase in Number of Months Experiencing a Shortage
Average Annual Water-Right Availability (1934-89)				
Zavala-Dimmit WCID #1	70%	66%	-4%	17
Saltwater Barrier Water Rights	95%	94%	-1%	8
Drought Average Annual Water-Right Availability (1947-56)				
Zavala-Dimmit WCID #1	51%	48%	-3%	0
Saltwater Barrier Water Rights	82%	78%	-4%	4

Notes:

1. Zavala-Dimmit water-right availability was estimated using the availability of all water rights (36,590 acft/yr) at the Asherton control point in the Nueces River Basin Model. This is a worst-case estimate because it includes water-right shortages to rights at this control point which are junior to Zavala-Dimmit. Zavala-Dimmit holds 28,000 acft/yr in water rights at this location.
2. This represents the total (220,433 acft/yr) of all water rights on the Guadalupe and San Antonio Rivers between Cuero, Goliad and the Saltwater Barrier. The majority of these rights are at the Saltwater Barrier (Guadalupe River @ Tivoli).

Availability of unappropriated flows for diversion was evaluated, subject to environmental criteria, at the Saltwater Barrier on the Guadalupe River near Tivoli. In order to provide a basis for assessment of potential changes in water availability at the Saltwater Barrier, the following monthly environmental criteria for fresh-water inflows to bays and estuaries were applied. Due to the proximity of the Saltwater Barrier to the Guadalupe Estuary, environmental criteria for in-stream flows were not included. The Texas Parks and Wildlife Department (TPWD) and the TWDB established a set of monthly fresh-water inflows to the Guadalupe Estuary that provide for the Maximum Harvest of selected species in the estuary. These monthly fresh-water inflow targets are presented in Table 8-5. In order to estimate unappropriated streamflow available for diversion at the Saltwater Barrier in a given month, the sum of the unappropriated streamflow in the Guadalupe River immediately below the Saltwater Barrier plus the estimated ungaged fresh-water inflow to the estuary originating downstream of the

Saltwater Barrier was compared to the appropriate monthly Fresh-Water Inflow Target for Maximum Harvest. If there was sufficient water to satisfy the Fresh-Water Inflow Target, the remaining unappropriated streamflow upstream of the Saltwater Barrier was assumed available for diversion. Although other environmental criteria may or may not be applicable at this location, differences in estimates of water availability reported herein should be indicative of the potential effects of simulated pumpage stresses.

TABLE 8-5
Guadalupe Estuary Fresh-Water Inflow Targets

Month	Fresh-Water Inflow Target (acft/month)
January	111,200
February	124,200
March	52,420
April	52,420
May	222,600
June	162,700
July	95,200
August	81,700
September	52,420
October	52,420
November	52,420
December	87,620
Annual	1,147,320

Note:
Fresh-Water Inflow Targets based on TPWD/TWDB Maximum Harvest values.

The potential impacts of Carrizo-Wilcox aquifer pumpage on water availability at the Saltwater Barrier assuming 1994 pumpage of the aquifer are shown in Table 8-6. As shown in this table, the potential impact on water availability at the Saltwater Barrier is relatively minor (less than five percent), both on the long-term average and during drought.

TABLE 8-6
Impacts on Water Availability at the Saltwater Barrier
Scenario 1 - 1994 Pumpage

Average Annual Water Available, 1934-89 (acft/yr)			
Historical	**With Carrizo-Wilcox Pumpage**	**Change**	**Percent Change**
948,236	933,321	-14,915	-1.6%
Drought Average Annual Water Available, 1947-56 (acft/yr)			
161,274	155,377	-5,897	-3.7%
Minimum Year Water Available (acft/yr)			
0	0	0	0%

Note:
Water available for diversion subject to upstream water rights and full monthly TPWD/TWDB Maximum Harvest Fresh-Water Inflow Targets for Guadalupe Estuary.

In addition to streamflows and reservoir yields, the effects of the 1994 pumpage on fresh-water inflows to the bays and estuaries of the Nueces and GSA River Basins were tabulated (Table 8-7). Changes in long-term inflows were minor (i.e. one percent) in the Nueces River Basin due to the operation of the CCR/LCC System under the terms of the 1995 Agreed Order. In the GSA River Basin, long-term changes in fresh-water inflows at the Saltwater Barrier (Guadalupe River @ Tivoli) were also minor (i.e. 1.7 percent). However, changes during the 10-year drought period from 1947 to 1956 are more significant, with inflows reduced by 4.9 percent. Summaries of the changes in annual flows, median monthly flows and annual decile flows are shown for each river basin in Figures 8-13 through 8-18.

TABLE 8-7
Impacts on Average Annual Fresh-Water Bay and Estuary Inflows
Scenario 1 - 1994 Pumpage

River Basin	With Historical Carrizo-Wilcox Pumpage	With 1994 Carrizo-Wilcox Pumpage	Change	Percent Change
Average Annual Streamflow for 1934-89 (acft)				
Nueces Estuary Fresh-Water Inflows [1]	487,795	483,067	-4,728	-1.0%
Guadalupe River at Saltwater Barrier [2]	1,625,115	1,597,202	-27,913	-1.7%
Drought Average Annual Streamflow for 1947-56 (acft)				
Nueces Estuary Fresh-Water Inflows [1]	241,932	237,729	-4,203	-1.7%
Guadalupe River at Saltwater Barrier [2]	537,239	510,918	-26,321	-4.9%

Footnotes:

[1] Total fresh-water inflows to the Nueces Estuary including releases from the CCR/LCC System and ungaged runoff below LCC.

[2] Does not include ungaged runoff to the estuary below the Saltwater Barrier at Tivoli.

SCENARIO 2 - 2050 PUMPAGE

Introduction

As described above, the second pumping scenario run was a simulation using the estimated 2050 pumpage annually for the historic time period.

Ground-Water Results

As noted above in the discussion on ground-water results from the 1994 runs, the results of the 2050 estimated pumpage reflect the pumpage in and around the cells containing the monitoring wells. Higher pumpage resulted in lower water levels, and lower pumpage resulted in higher water levels. As with the 1994 results, little variation over time was observed in the slope of the water-level changes. This indicates that pumpage is affecting water levels the most, and other stresses (recharge, streamflows, etc.) do not play a major role in controlling water levels in the model.

Surface-Water Results

To evaluate the 2050 Pumpage Scenario, changes in streamflow were extracted from the ground-water model runs and incorporated once again into the Nueces and GSA River Basin Models. The flow changes were tabulated at appropriate streamflow locations and are summarized in Figures 8-1 through 8-12. These figures include a decile comparison for the surface-water model period of record (1934-89) and an annual 10-year drought (1947-56) comparison for the six streamflow locations evaluated. Table 8-8 summarizes the average annual changes in streamflow for all six locations.

TABLE 8-8
Impacts on Average Annual Streamflow
Scenario 2 - 2050 Pumpage

Stream	Average Annual Streamflow (acft)			Percent Change
	Historical	With 2050 Carrizo-Wilcox Pumpage	Change	
Nueces R. @ Asherton	135,692	132,649	-3,043	-2.2%
Frio R. @ Derby	98,123	93,815	-4,308	-4.4%
Atascosa R. @ Whitsett	93,248	87,216	-6,032	-6.5%
San Antonio R. @ Falls City	287,571	258,973	-28,598	-9.9%
Cibolo Cr. @ Falls City	92,550	88,356	-4,194	-4.5%
Guadalupe R. @ Cuero	1,130,009	1,109,429	-20,580	-1.8%

As shown in Table 8-8, the greatest impact on average annual streamflows (on a percentage basis) occurs once again in the Atascosa and San Antonio River Basins. However, compared to the impacts under 1994 pumpage, the impacts on streamflows of the Frio and Atascosa Rivers are slightly less. This is due to the large decrease in the projected 2050 pumpage in Atascosa and Frio Counties as compared to existing pumpage in these counties. The changes in the Guadalupe River Basin are becoming more significant under this scenario (as compared to the impacts of 1994 pumpage). This increase in impact is due to a significant increase in municipal pumpage for Gonzales County as predicted in the TWDB's planning projections.

As noted earlier, these comparisons of annual changes in streamflow tend to smooth out the seasonal or monthly variations that can occur due to increased pumpage. In some instances the monthly variations could be more significant than the annual changes indicate. Therefore, a series of tables showing the monthly flow changes at the six stream locations and the two estuary fresh-water inflow locations analyzed in this study is presented in Appendix E, Potential Impacts on Monthly Streamflows.

As shown in the previous table, the flows in the Nueces River Basin are once again impacted by roughly two to six percent immediately downstream of the Carrizo-Wilcox outcrop. Table 8-9 shows the changes in the yield of the CCR/LCC System for 2050 sediment accumulation. This firm yield reflects what the impact could be in 2050 if pumpage levels increase as projected by the TWDB. As discussed previously, the impacts on flows upstream of the CCR/LCC System are reduced because of the large channel losses in the reaches below Asherton and Derby.

TABLE 8-9
Impacts on CCR/LCC System Yield
Scenario 2 - 2050 Pumpage

Sedimentation Year	Reservoir System Yield			Percent Change in System Yield
	With Historical Carrizo-Wilcox Pumpage	With 2050 Carrizo-Wilcox Pumpage	Change in Yield	
2050	189,600	186,700	-2,900	-1.5%

Note:
CCR/LCC System Operations include the City of Corpus Christi's Phase IV Operations Plan and the 1995 Agreed Order.

In addition to these CCR/LCC System water rights, the impacts of Carrizo-Wilcox aquifer pumpage on two regions with large run-of-the-river water rights were evaluated. Table 8-10 shows a summary of impacts on the availability for the Zavala-Dimmit and Saltwater Barrier water rights assuming projected 2050 pumpage of the Carrizo-Wilcox aquifer. The impact on water-right availability at these two locations is about the same as for the 1994 Pumpage Scenario.

TABLE 8-10
Impacts on Selected Run-of-the-River Water Rights
Scenario 2 - 2050 Pumpage

Average Annual Water-Right Availability (1934-89)				
Water Right	**With Historical Carrizo-Wilcox Pumpage**	**With 2050 Carrizo-Wilcox Pumpage**	**Change in Availability**	**Increase in Number of Months Experiencing a Shortage**
Zavala-Dimmit WCID #1	70%	66%	-4%	19
Saltwater Barrier Water Rights	95%	93%	-2%	9
Drought Average Annual Water-Right Availability (1947-56)				
Zavala-Dimmit WCID #1	51%	48%	-3%	0
Saltwater Barrier Water Rights	82%	77%	-5%	5

Notes:

1. Zavala-Dimmit water-right availability was estimated using the availability of all water rights (36,590 acft/yr) at the Asherton control point in the Nueces River Basin Model. This is a worst-case estimate because it includes water-right shortages to rights at this control point which are junior to Zavala-Dimmit. Zavala-Dimmit holds 28,000 acft/yr in water rights at this location.
2. This represents the total (220,433 acft/yr) of all water rights on the Guadalupe and San Antonio Rivers between Cuero, Goliad and the Saltwater Barrier. The majority of these rights are at the Saltwater Barrier (Guadalupe River @ Tivoli).

The potential impacts of Carrizo-Wilcox Aquifer pumpage on water availability at the Saltwater Barrier, subject to environmental criteria (see section on Scenario 1 - 1994 Pumpage), assuming 2050 pumpage of the aquifer are shown in Table 8-11. As shown in this table, the potential impact on water availability at the Saltwater Barrier is relatively minor (less than five percent), both on the long-term average and during the drought.

TABLE 8-11
Impacts on Water Availability at the Saltwater Barrier
Scenario 2 - 2050 Pumpage

Average Annual Water Available, 1934-89 (acft/yr)			
Historical	**With Carrizo-Wilcox Pumpage**	**Change**	**Percent Change**
948,236	926,423	-21,813	-2.3%
Drought Average Annual Water Available, 1947-56 (acft/yr)			
161,274	153,693	-7,581	-4.7%
Minimum Year Water Available (acft/yr)			
0	0	0	0%

Note:

Water available for diversion subject to upstream water rights and full monthly TPWD/TWDB Maximum Harvest Fresh-Water Inflow Targets for Guadalupe Estuary.

In addition to streamflows and reservoir yields, the effects of the potential 2050 pumpage on fresh-water inflows to the bays and estuaries of the Nueces and GSA River Basins were tabulated (Table 8-12). Changes in long-term and drought inflows were minor (i.e. 1 and 1.7 percent) in the Nueces River Basin due to the operation of the CCR/LCC System under the terms of the 1995 Agreed Order. In the GSA River Basin, changes in long-term fresh-water inflows at the Saltwater Barrier (Guadalupe River @ Tivoli) were generally minor (i.e. 1.7 percent) but became more significant in the drought (i.e. 6.4 percent) due to the effects of the increased municipal pumpage from the Carrizo-Wilcox aquifer projected in 2050. Summaries of the changes in annual flows, median monthly flows and annual decile flows for each river basin are shown in Figures 8-13 through 8-18.

TABLE 8-12
Impacts on Average Annual Fresh-Water Bay and Estuary Inflows
Scenario 2 - 2050 Pumpage

Average Annual Streamflow for 1934-89 (acft)				
River Basin	**With Historical Carrizo-Wilcox Pumpage**	**With 2050 Carrizo-Wilcox Pumpage**	**Change**	**Percent Change**
Nueces Estuary Fresh-Water Inflows [1]	487,795	483,057	-4,738	-1.0%
Guadalupe River at Saltwater Barrier [2]	1,625,115	1,584,654	-40,461	-2.5%
Drought Average Annual Streamflow for 1947-56 (acft)				
Nueces Estuary Fresh-Water Inflows [1]	241,932	237,740	-4,192	-1.7%
Guadalupe River at Saltwater Barrier [2]	537,239	502,712	-34,527	-6.4%

Footnotes:

[1] Total fresh-water inflows to the Nueces Estuary including releases from the CCR/LCC System and ungaged runoff below LCC.

[2] Does not include ungaged runoff to the estuary below the Saltwater Barrier at Tivoli.

SCENARIO 3 - 2050 PLUS ADDITIONAL PUMPAGE

Introduction

As described above, the 2050 Plus Pumpage Scenario was identical to the 2050 Pumpage Scenario, except an additional 185,237 acre-feet per year was added to the pumpage data set to represent new well fields in Atascosa, Gonzales and Wilson Counties and an additional well field in south-central Dimmit County.

Ground-Water Results

Water levels in the Carrizo aquifer in the 2050 Plus run were equal to or lower than the 2050 water levels. Water levels in or near the additional pumping centers were significantly lower than the water levels in the previous 2050 scenario. Near the new well fields, water levels could be as much as 150 to 200 feet lower with the additional pumpage included compared to the water levels without this pumpage. The larger differences in water levels were in those areas located closer to the additional pumping wells. Water-level differences downdip, away from the pumping wells, were generally around 100 feet.

In the vicinity of the hypothetical well field in south-central Dimmit County, water levels for the run using the 2050 Plus pumpage were up to 600 feet lower than when using just the 2050 pumpage. This dramatic decline in water levels in a hypothetical well field is due to the inability of the aquifer to produce this amount of pumpage in that area. The Carrizo aquifer is too tight and storativities are too low to allow the pumpage stress used in the model to be possible. This area appears to only be suitable for smaller, lower-producing well fields, based on the aquifer model that currently exists.

Surface-Water Results

To evaluate this scenario, changes in streamflow were extracted from the ground-water model runs assuming projected 2050 pumpage from the TWDB plus additional municipal pumpage volumes (2050 Plus) in the east and west parts of the study area. These changes were incorporated into the Nueces and GSA River Basin Models, and the flow changes for the appropriate streamflow locations are tabulated and summarized in Figures 8-1 through 8-12. These figures include a decile comparison for the surface-water model period of record (1934-89) and an annual 10-year drought (1947-56) comparison for the six streamflow locations evaluated. Table 8-13 summarizes the average annual changes in streamflow for all six locations.

TABLE 8-13
Impacts on Average Annual Streamflow
Scenario 3 - 2050 Plus Pumpage

Stream	Average Annual Streamflow (acft)			Percent Change
	Historical	With 2050 Plus Carrizo-Wilcox Pumpage	Change	
Nueces R. @ Asherton	135,692	99,453	-36,239	-26.7%
Frio R. @ Derby	98,123	93,534	-4,589	-4.7%
Atascosa R. @ Whitsett	93,248	87,196	-6,052	-6.5%
San Antonio R. @ Falls City	287,571	233,214	-54,357	-18.9%
Cibolo Cr. @ Falls City	92,550	88,261	-4,289	-4.6%
Guadalupe R. @ Cuero	1,130,009	1,088,837	-41,172	-3.6%

As shown in Table 8-13, the additional municipal pumpage (40,000 acre-feet per year) in northern Dimmit County and 145,237 acre-feet per year in Atascosa, Wilson and Gonzales Counties) has a large effect on streams in the areas near the pumpage. For example, the Nueces River, because of the large municipal pumpage placed in Dimmit County, begins to show drastic decreases (over 26 percent) in annual average streamflows at Asherton. Likewise, the line of wells through Atascosa, Wilson and Gonzales Counties causes average annual losses on the San Antonio River that are double the losses under the 1994 Pumpage Scenario. Similarly, this line of wells increases the average annual losses on the Guadalupe River to more than six times the losses computed for the 1994 pumpage.

As noted earlier, these comparisons of annual changes in streamflow tend to smooth out the seasonal or monthly variations that can occur due to increased pumpage. In some instances the monthly variations could be more significant than the annual changes indicate. Therefore, a series of tables showing the monthly flow changes at the six stream locations and the two estuary fresh-water inflow locations analyzed in this study is presented in Appendix E, Potential Impacts on Monthly Streamflows.

As shown in the previous table, the flow in the Nueces River under this pumpage scenario is reduced by 26 percent from historical conditions immediately downstream of the Carrizo-Wilcox outcrop. By the time these flows reach the CCR/LCC System, these impacts are reduced because of the large channel losses in the reaches below Asherton and Derby. Table 8-14 shows the changes in the yield of the CCR/LCC System for 2050 sediment accumulation. Surprisingly, the large decreases in flow at the Asherton control point do not greatly impact the firm yield of the CCR/LCC System. This result becomes more obvious when one considers that the natural losses between Asherton and LCC are so large that the net effect of large changes in upstream flow are minor at the lake. The combination of large losses between Asherton and LCC and the fact that flows are lowest during drought even without the effects of ground-water pumpage tend to limit inflows to LCC during the drought anyway. Therefore, decreasing the flows at Asherton through increased pumpage of the aquifer has little net effect on the CCR/LCC system yield.

TABLE 8-14
Impacts on CCR/LCC System Yield
Scenario 3 - 2050 Plus Pumpage

Reservoir System Yield				
Sedimentation Year	**With Historical Carrizo-Wilcox Pumpage**	**With 2050 Plus Carrizo-Wilcox Pumpage**	**Change in Yield**	**Percent Change in System Yield**
2050	189,600	186,400	-3,200	-1.6%
Note: CCR/LCC System Operations include the City of Corpus Christi's Phase IV Operations Plan and the 1995 Agreed Order.				

In addition to these CCR/LCC System water rights, the impacts of Carrizo-Wilcox aquifer pumpage on two regions with large run-of-the-river water rights were evaluated, and the additional municipal pumpage produced a noticeable effect. Table 8-15 presents a summary of the impacts on availability for the Zavala-Dimmit and Saltwater Barrier water rights. As demonstrated in the table, the impacts on water-right availability on the Guadalupe River are more significant than with 2050 pumpage alone. Average availability is reduced by three percent over the long term and by seven percent for drought conditions. The Zavala-Dimmit availability drops to 55 percent during average conditions (a 15-percent decrease), and the additional number of months (compared to baseline historical pumpage conditions) in which some shortage occurs increases by 85 months (or over 7 years).

TABLE 8-15
Impacts on Selected Run-of-the-River Water Rights
Scenario 3 - 2050 Plus Pumpage

Water Right	With Historical Carrizo-Wilcox Pumpage	With 2050 Plus Carrizo-Wilcox Pumpage	Change in Availability	Increase in Number of Months Experiencing a Shortage
Average Annual Water-Right Availability (1934-89)				
Zavala-Dimmit WCID #1	70%	55%	-15%	85
Saltwater Barrier Water Rights	95%	92%	-3%	21
Drought Average Annual Water-Right Availability (1947-56)				
Zavala-Dimmit WCID #1	51%	48%	-3%	0
Saltwater Barrier Water Rights	82%	75%	-7%	10

Notes:

1. Zavala-Dimmit water-right availability estimated using the availability of all water rights (36,590 acft/yr) at the Asherton control point in the Nueces River Basin Model. This is a worst-case estimate because it includes water-right shortages to rights at this control point which are junior to Zavala-Dimmit. Zavala-Dimmit holds 28,000 acft/yr in water rights at this location.
2. This represents the total (220,433 acft/yr) of all water rights on the Guadalupe and San Antonio Rivers between Cuero, Goliad and the Saltwater Barrier. The majority of these rights are at the Saltwater Barrier (Guadalupe River @ Tivoli).

The potential impacts of Carrizo-Wilcox aquifer pumpage on water availability at the Saltwater Barrier, subject to environmental criteria (see section on Scenario 1 - 1994 Pumpage), assuming 2050 Plus pumpage of the aquifer, are shown in Table 8-16. As shown in this table, the potential impact on water availability at the Saltwater Barrier is relatively minor (less than five percent) on the long-term average, but the impact on water availability during the 10-year drought is more significant at 7.8 percent.

TABLE 8-16
Impacts on Water Availability at the Saltwater Barrier
Scenario 3 - 2050 Plus Pumpage

Average Annual Water Available, 1934-89 (acft/yr)			
Historical	**With Carrizo-Wilcox Pumpage**	**Change**	**Percent Change**
948,236	907,112	-41,124	-4.3%
Drought Average Annual Water Available, 1947-56 (acft/yr)			
161,274	148,661	-12,613	-7.8%
Minimum Year Water Available (acft/yr)			
0	0	0	0%

Note:
Water available for diversion subject to upstream water rights and full monthly TPWD/TWDB Maximum Harvest Fresh-Water Inflow Targets for Guadalupe Estuary.

In addition to streamflows and reservoir yields, the effects of the projected 2050 Plus pumpage on fresh-water inflows to the bays and estuaries of the Nueces and GSA River Basins are tabulated in Table 8-17. Changes in long-term inflows as a result of the additional pumpage in the Nueces River Basin showed a more significant decrease in average annual inflow to the estuary (i.e. a 2.7-percent decrease) than with projected 2050 pumpage alone. In the GSA River Basin, changes in fresh-water inflows at the Saltwater Barrier (Guadalupe River @ Tivoli) showed a significant decrease, with long-term and drought annual average streamflows at the Saltwater Barrier decreasing by 76,000 and 59,000 acre-feet per year, respectively. For the long-term average, this represents an additional 35,670 acre-feet per year reduction in flows over the 2050 Pumpage Scenario, and for the drought annual average, an additional reduction of 24,589 acre-feet per year. Summaries of the changes in annual flows, median monthly flows and annual decile flows are shown for each river basin in Figures 8-13 through 8-18.

TABLE 8-17
Impacts on Average Annual Fresh-Water Bay and Estuary Inflows
Scenario 3 - 2050 Plus Pumpage

<table>
<tr><th colspan="5">Average Annual Streamflow for 1934-89 (acft)</th></tr>
<tr><th>River Basin</th><th>With Historical Carrizo-Wilcox Pumpage</th><th>With 2050 Plus Carrizo-Wilcox Pumpage</th><th>Change</th><th>Percent Change</th></tr>
<tr><td>Nueces Estuary Fresh-Water Inflows [1]</td><td>487,795</td><td>474,755</td><td>-13,040</td><td>-2.7%</td></tr>
<tr><td>Guadalupe River at Saltwater Barrier [2]</td><td>1,625,115</td><td>1,548,984</td><td>-76,131</td><td>-4.7%</td></tr>
<tr><th colspan="5">Drought Average Annual Streamflow for 1947-56 (acft)</th></tr>
<tr><td>Nueces Estuary Fresh-Water Inflows [1]</td><td>241,932</td><td>237,625</td><td>-4,307</td><td>-1.8%</td></tr>
<tr><td>Guadalupe River at Saltwater Barrier [2]</td><td>537,239</td><td>478,123</td><td>-59,116</td><td>-11.0%</td></tr>
<tr><td colspan="5">Footnotes:
[1] Total fresh-water inflows to the Nueces Estuary including releases from the CCR/LCC System and ungaged runoff below LCC.
[2] Does not include ungaged runoff to the estuary below the Saltwater Barrier at Tivoli.</td></tr>
</table>

IX. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The Carrizo-Wilcox is one of the state's major aquifers and an important water resource in the Winter Garden Area of South Texas. The Winter Garden Area lies southwest of the San Marcos River and within the Guadalupe, San Antonio, Nueces and Rio Grande River Basins. The Winter Garden Area consist of all or parts of Atascosa, Bexar, Caldwell, Dimmit, Frio, Gonzales, Guadalupe, Karnes, La Salle, Live Oak, McMullen, Maverick, Medina, Uvalde, Webb, Wilson and Zavala Counties.

Within the Wilcox and Claiborne Groups, are one major aquifer (Carrizo-Wilcox) and two minor aquifers (Queen City-Bigford and Sparta-Laredo). The strata of these units are marine and continental in origin and consist mainly of beach sand, clay, cross-bedded river sand, silt and lignite.

Overlying the Wilcox Group, the Carrizo Sand is the principal and most heavily pumped aquifer in the study area. This aquifer supplies water for many uses, the largest of which is for irrigation. Historical withdrawals of ground water in the Winter Garden Area have exceeded recharge (primarily in Dimmit and Zavala Counties), resulting in significant water-level declines (greater than 200 feet). However, water-level declines have been minimal in Gonzales and Wilson Counties which indicates the aquifer can continue to support irrigation and the development of additional ground-water supplies in these counties.

A three-dimensional numerical ground-water flow model (MODFLOW) was constructed to simulate hydrologic conditions that occur in the Carrizo-Wilcox, Queen City-Bigford and Sparta-Laredo aquifers (including also younger water-bearing strata) under various pumping scenarios. Calibration of the model included steady-state simulations designed to replicate the estimated predevelopment head conditions of the aquifers and transient simulations which incorporated estimates of historical pumpage in order to replicate historical water levels and streamflows.

The ground-water model was calibrated by adjusting permeability, aquifer storage and streambed characteristics. Once calibrated, the ground-water model was applied to predict the effects of additional pumping from the aquifer. The results of these model runs were used with surface-water models to demonstrate how streamflows respond to changes in ground-water levels, and also to demonstrate how water rights, reservoir yields, streamflows and fresh-water inflows to estuaries are affected.

Several future pumpage scenarios were evaluated with the models to determine effects on water levels within the aquifer as well as impacts on significant surface-water streams which are hydraulically connected. The three future pumpage scenarios modeled were a 1994 Pumpage Scenario where the approximate current (1994) pumpage was used annually for the 61-year simulation; a 2050 Pumpage Scenario where the estimated pumpage for 2050 was used annually for the 61-year simulation; and a "2050 Plus" Pumpage Scenario where the 2050 pumpage plus additional pumpage in Atascosa, Dimmit, Gonzales and Wilson Counties was modeled. Total annual pumpage amounts for these scenarios were 249,890 acre-feet per year, 264,715 acre-feet per year and 449,952 acre-feet per year. Water-level maps for these three scenarios in the year 2050 are shown in Figures 9-1, 9-2 and 9-3.

The model results indicate that, if 1994 pumping levels continue, water levels over the next 60 years will generally be stable, with little or no decline in most areas and only a steady decline that totals less than 100 feet over the 60-year period in central portions of the study area (Frio, Atascosa and La Salle Counties). When the estimated 2050 pumpage is modeled, the results are similar with two exceptions. In Frio and La Salle Counties, water levels are actually higher using the 2050 pumpage because pumping levels are projected to decrease between 1994 and 2050. The second exception is with the results in Gonzales County, where Carrizo water levels, compared to 1994, are significantly lower (50 to 100 feet) using the 2050 pumping levels. This is due to the 40,000 acre-feet per year of pumpage from Gonzales County that is projected to be used to supply municipal demands in the region.

With the additional pumpage proposed in the 2050 Plus scenario, the model results indicate that water levels will decline significantly (greater than 400 feet) around the hypothetical well field in Dimmit County, which withdraws 40,000 acre-feet annually. Water levels will also decline moderately (100 to 200 feet) around the proposed line of wells in Atascosa, Gonzales and Wilson Counties.

Additionally, the results of the study indicate that average annual streamflows will be reduced in each of the two major river systems that drain the area, the Nueces River and the Guadalupe-San Antonio (GSA) River systems. Predicted reductions in average annual streamflows as compared to the historical period of record (1934-89) are shown in the following table for each scenario where each river system empties into its respective estuary.

TABLE 9-1
Reductions in Streamflows

Scenario	River System	Average Annual Reduction in Streamflow (acft/year)	Percent Reduction
1994 Pumpage	Nueces GSA	4,728 27,913	1.0% 1.7%
2050 Pumpage	Nueces GSA	4,738 40,461	1.0% 2.5%
2050 Plus Pumpage	Nueces GSA	13,040 76,131	2.7% 4.7%

The models indicate an interaction between ground water and surface water. As ground-water levels change, surface-water discharge also changes, but we currently lack the data to accurately define the magnitude of these changes. As additional basic data become available in the future, many of the details presented in this report may need to be updated, and a better understanding of the hydrogeology of the Carrizo aquifer and its interaction with the rivers that cross its outcrop will emerge. Additional water-level data from new observation wells located near stream segments which directly recharge the Carrizo, operated in conjunction with stream gages (some new) located above and below these segments, could result in significant improvements in the model's ability to simulate this surface-water/ground-water interaction. Additionally, estimates of areal recharge can be significantly improved with the installation of additional rain gages and streamflow gages located throughout the recharge areas as well as in adjacent partner watersheds (which are not affected by recharge). However, it is believed that this work provides the foundation for future refinement and revision.

RECOMMENDATIONS

It is recommended that the TWDB observation well program be reviewed and modified to include the following: (a) intensive water-level-measuring efforts in all of the counties within the Winter Garden Area of Texas, with emphasis on the Carrizo, Queen City and Sparta aquifers and especially on stream segments which cross outcrop areas; (b) evaluation of observation well completion data to insure that measured water-level data reflect the proper aquifer; and (c) expansion of the number of Carrizo water-level observation wells in northern Webb, southern La Salle and southwestern McMullen Counties.

In many of the irrigated districts within the Winter Garden Area, estimates of the location of irrigated tracts and associated irrigation pumpage are not very accurate. During the calibration phase of model development, it was noted that model-simulated water-level declines using the irrigation inventory pumpage estimates in some cases did not agree well with measured observation well water-level declines. The possible reasons for the discrepancy are many, one of which may be the methodology which is used to estimate the irrigation pumpage. Therefore, it is recommended that methods be researched and implemented which can be used to more accurately estimate irrigation pumpage from areas containing both electric- and nonelectric-powered pumping plants.

The collection of basic hydrogeologic data pertaining to the Carrizo-Wilcox aquifer should be continued and expanded in order to better understand the following: (a) recharge (areal and stream); (b) movement and occurrence of ground waters; (c) depositional framework; (d) leakage to or from the Carrizo aquifer across confining beds in the Wilcox Group and Reklaw Formation; (e) evapotranspiration; and (f) degree of hydraulic connection between the Carrizo aquifer and streams, rivers and other surface-water bodies on the outcrop.

Because of sparse and limited streamflow loss and/or gain data in the Carrizo-Wilcox outcrop, we recommend that TWDB's surface-water seepage measurement and water-level observation well programs in the outcrop be expanded. This increased data collection effort will provide a better indication than we presently have of the amount of water lost or gained from the rivers in the outcrop. Additionally, an expanded network of rain gages and streamflow gages located throughout the recharge areas and in adjacent watersheds will significantly improve areal recharge estimates. Additional water-level data in areas where stream segments directly recharge the Carrizo, with new gages located above and below these segments, will significantly improve the understanding of the Carrizo's ability to accept stream recharge and the ability to accurately model this process. The would provide a wealth of additional data regarding the interaction of ground-water and surface-water bodies. New streamflow-gaging stations are recommended for the following locations:

- Nueces River downstream of the Bigford outcrop intersection with the river (between the USGS Gages at Uvalde (08192000) and Asherton (08193000));
- San Miguel Creek upstream of the Wilcox outcrop;
- San Miguel Creek below the Queen City and Sparta outcrops;
- Atascosa River below the Queen City and Sparta outcrops;
- San Antonio River below the Queen City and Sparta outcrops (upstream of the USGS Gages at Elmendorf (08181800) and Falls City (08183500); and
- San Marcos River below the Queen City and Sparta outcrops (upstream of the confluence with the Guadalupe River).

In addition, rainfall gages should be placed at appropriate locations in the watersheds located on and adjacent to the recharge areas to insure more accurate estimation of losses to the aquifer in the associated watersheds.

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APPENDIX A

GROUND-WATER PUMPAGE BY COUNTY

APPENDIX A

GROUND-WATER PUMPAGE BY COUNTY

TABLE A-1

Annual Pumpage Estimate Summary - Atascosa County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	1,105	1955	15,476	1976	48,630
1935	1,970	1956	22,474	1977	46,923
1936	3,183	1957	27,347	1978	46,498
1937	3,363	1958	30,915	1979	55,665
1938	3,333	1959	35,269	1980	45,713
1939	2,835	1960	36,296	1981	45,406
1940	3,919	1961	37,765	1982	45,439
1941	2,850	1962	39,363	1983	45,383
1942	4,557	1963	40,166	1984	35,039
1943	4,844	1964	43,278	1985	47,193
1944	3,556	1965	41,329	1986	49,534
1945	4,571	1966	43,577	1987	49,761
1946	4,821	1967	45,442	1988	52,528
1947	5,347	1968	44,159	1989	50,914
1948	5,938	1969	51,977	1990	53,109
1949	5,813	1970	47,332	1991	52,104
1950	7,429	1971	49,431	1992	51,235
1951	7,693	1972	49,565	1993	54,078
1952	8,340	1973	48,491	1994	44,790
1953	9,346	1974	56,962	Average	30,827
1954	9,756	1975	49,314	(acft/yr)	

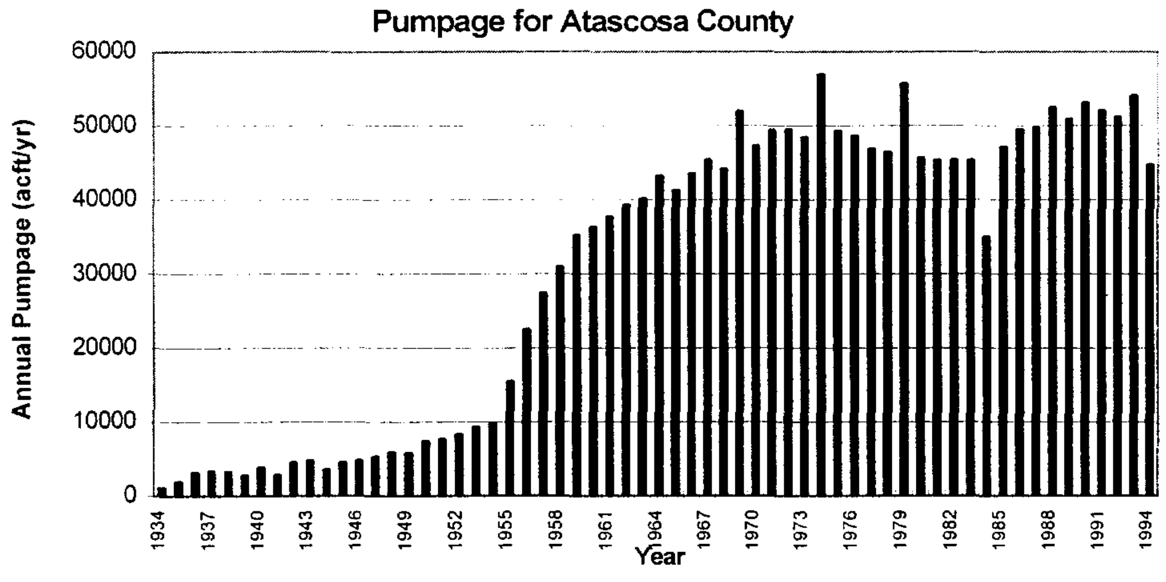


TABLE A-2

Annual Pumpage Estimate Summary - Bexar County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	0	1955	0	1976	2,154
1935	0	1956	0	1977	2,087
1936	0	1957	0	1978	2,019
1937	0	1958	0	1979	1,854
1938	0	1959	0	1980	1,767
1939	0	1960	0	1981	1,583
1940	0	1961	0	1982	1,399
1941	0	1962	0	1983	1,214
1942	0	1963	0	1984	918
1943	0	1964	3,047	1985	1,030
1944	0	1965	2,263	1986	1,030
1945	0	1966	2,347	1987	1,030
1946	0	1967	2,431	1988	1,030
1947	0	1968	2,515	1989	900
1948	0	1969	2,481	1990	1,030
1949	0	1970	2,537	1991	1,030
1950	0	1971	2,475	1992	1,030
1951	0	1972	2,413	1993	1,030
1952	0	1973	2,351	1994	1,192
1953	0	1974	1,715	**Average**	887
1954	0	1975	2,221	(acft/yr)	

Pumpage for Bexar County

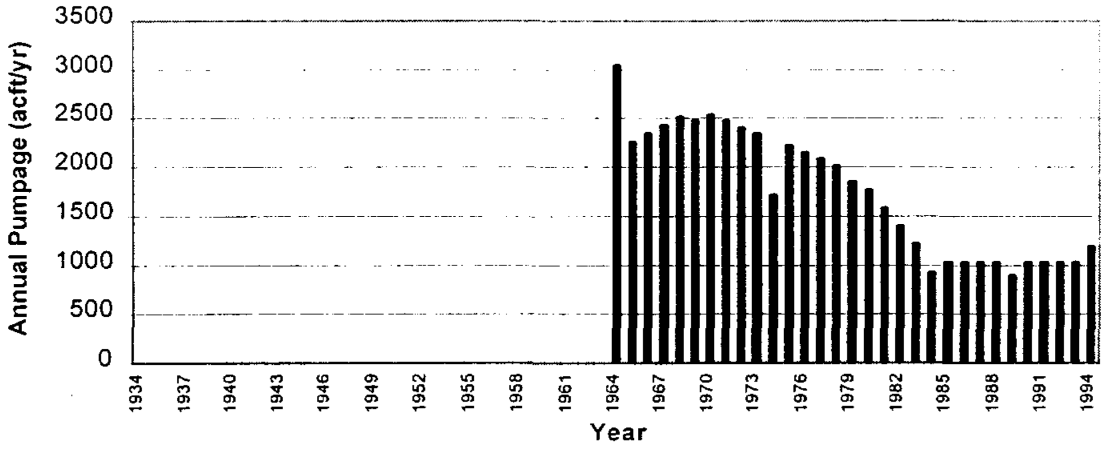


TABLE A-3

Annual Pumpage Estimate Summary - Dimmit County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	16,537	1955	27,138	1976	18,092
1935	15,355	1956	28,897	1977	19,903
1936	16,343	1957	22,716	1978	14,563
1937	18,635	1958	22,258	1979	11,839
1938	19,532	1959	23,122	1980	12,201
1939	16,573	1960	23,217	1981	10,862
1940	16,446	1961	25,701	1982	13,418
1941	17,450	1962	26,320	1983	14,780
1942	17,945	1963	24,954	1984	17,679
1943	19,516	1964	23,161	1985	11,963
1944	16,949	1965	25,455	1986	8,626
1945	21,426	1966	27,826	1987	7,982
1946	22,144	1967	27,854	1988	10,757
1947	26,496	1968	29,951	1989	7,383
1948	28,998	1969	27,356	1990	4,174
1949	31,098	1970	32,046	1991	5,607
1950	30,523	1971	26,486	1992	3,829
1951	30,447	1972	30,036	1993	7,198
1952	30,411	1973	26,022	1994	4,507
1953	29,091	1974	26,671	**Average**	**22,479**
1954	30,143	1975	22,837	(acft/yr)	

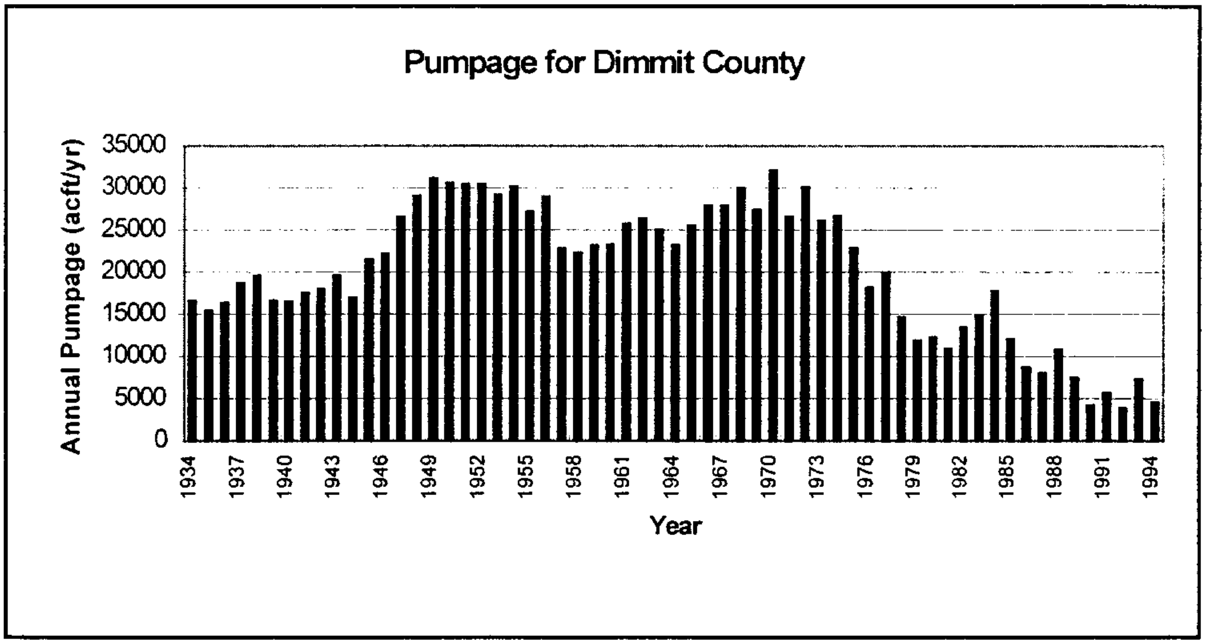


TABLE A-4

Annual Pumpage Estimate Summary - Frio County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	1,262	1955	16,637	1976	87,977
1935	0	1956	24,665	1977	93,672
1936	740	1957	26,131	1978	94,610
1937	1,999	1958	30,373	1979	76,013
1938	2,872	1959	38,351	1980	93,678
1939	784	1960	42,936	1981	90,372
1940	787	1961	49,278	1982	89,833
1941	0	1962	55,542	1983	87,361
1942	619	1963	59,547	1984	89,283
1943	2,166	1964	56,300	1985	82,800
1944	950	1965	65,299	1986	80,880
1945	2,113	1966	69,192	1987	80,279
1946	819	1967	70,836	1988	82,246
1947	3,576	1968	72,571	1989	96,369
1948	3,575	1969	74,300	1990	78,583
1949	2,369	1970	79,331	1991	77,569
1950	5,329	1971	79,798	1992	76,786
1951	6,593	1972	83,785	1993	79,448
1952	7,786	1973	82,876	1994	106,657
1953	8,606	1974	72,767	**Average**	**48,263**
1954	7,777	1975	88,404	**(acft/yr)**	

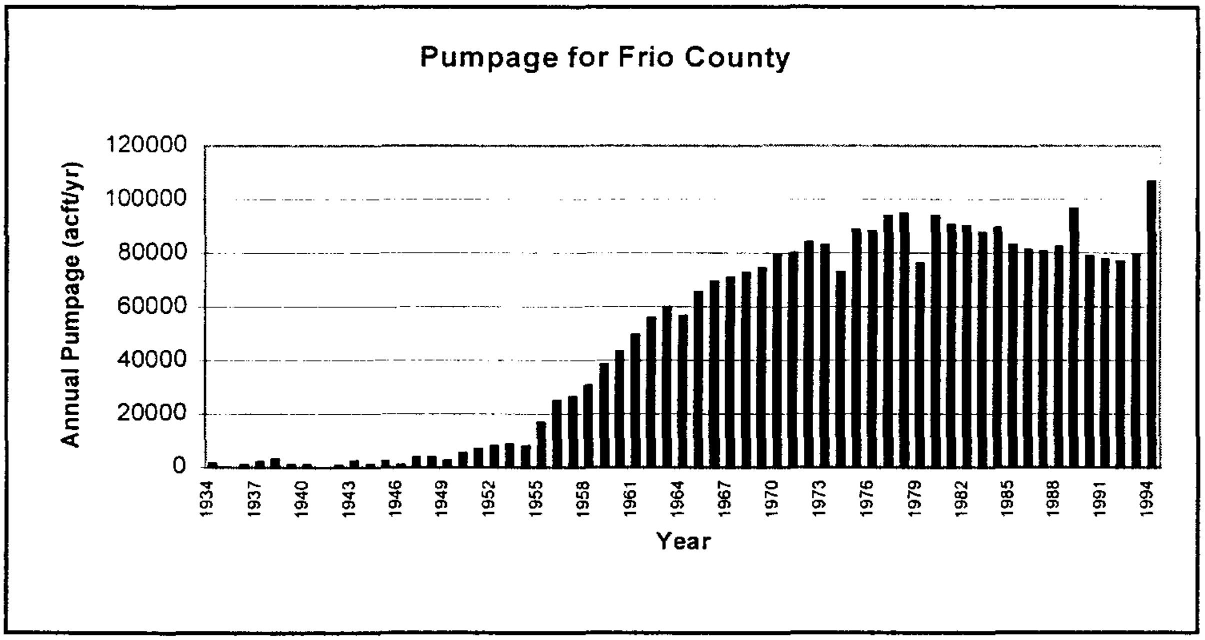


TABLE A-5

Annual Pumpage Estimate Summary - Gonzales County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	0	1955	261	1976	1,024
1935	0	1956	268	1977	1,002
1936	0	1957	275	1978	980
1937	0	1958	274	1979	422
1938	0	1959	1,360	1980	959
1939	0	1960	2,438	1981	960
1940	0	1961	3,516	1982	960
1941	0	1962	4,594	1983	961
1942	0	1963	5,673	1984	939
1943	0	1964	9,892	1985	937
1944	8	1965	5,619	1986	912
1945	26	1966	4,486	1987	887
1946	43	1967	3,354	1988	863
1947	61	1968	2,222	1989	796
1948	78	1969	1,448	1990	716
1949	96	1970	1,085	1991	594
1950	127	1971	1,081	1992	472
1951	159	1972	1,077	1993	350
1952	190	1973	1,073	1994	93
1953	222	1974	1,268	**Average**	**1,121**
1954	254	1975	1,047	**(acft/yr)**	

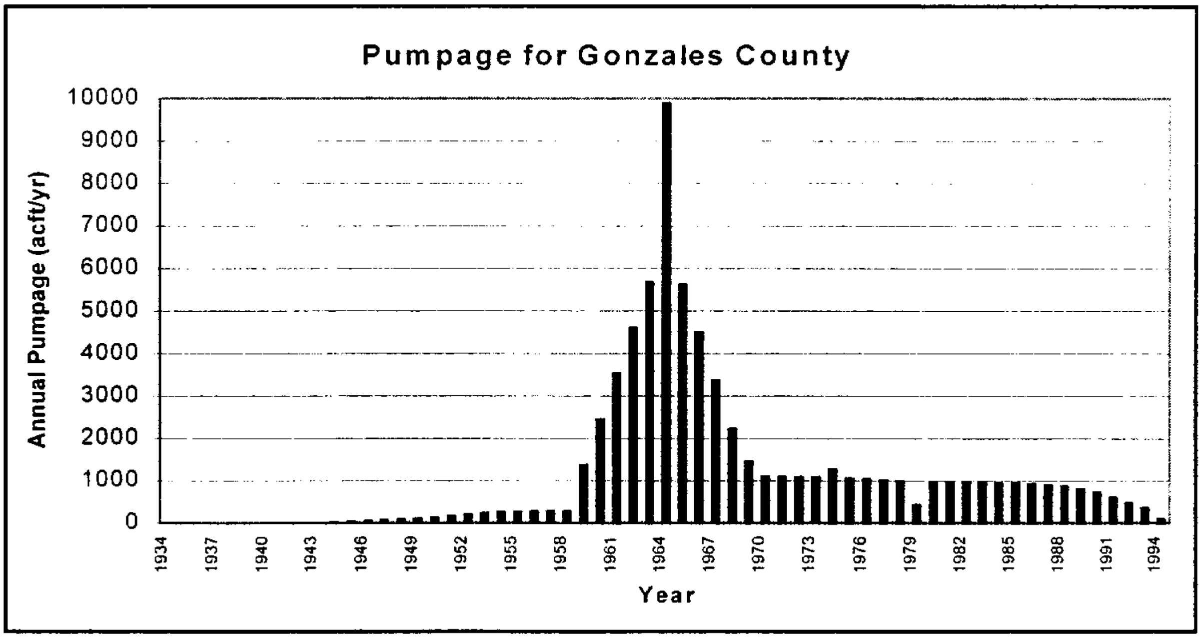


TABLE A-6

Annual Pumpage Estimate Summary - Guadalupe County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	0	1955	0	1976	193
1935	0	1956	0	1977	180
1936	0	1957	0	1978	168
1937	0	1958	0	1979	98
1938	0	1959	0	1980	244
1939	0	1960	0	1981	332
1940	0	1961	0	1982	420
1941	0	1962	0	1983	508
1942	0	1963	0	1984	660
1943	0	1964	0	1985	539
1944	0	1965	0	1986	482
1945	0	1966	0	1987	425
1946	0	1967	0	1988	368
1947	0	1968	0	1989	265
1948	0	1969	0	1990	255
1949	0	1970	0	1991	198
1950	0	1971	0	1992	141
1951	0	1972	0	1993	85
1952	0	1973	0	1994	28
1953	0	1974	149	**Average**	**97**
1954	0	1975	205	**(acft/yr)**	

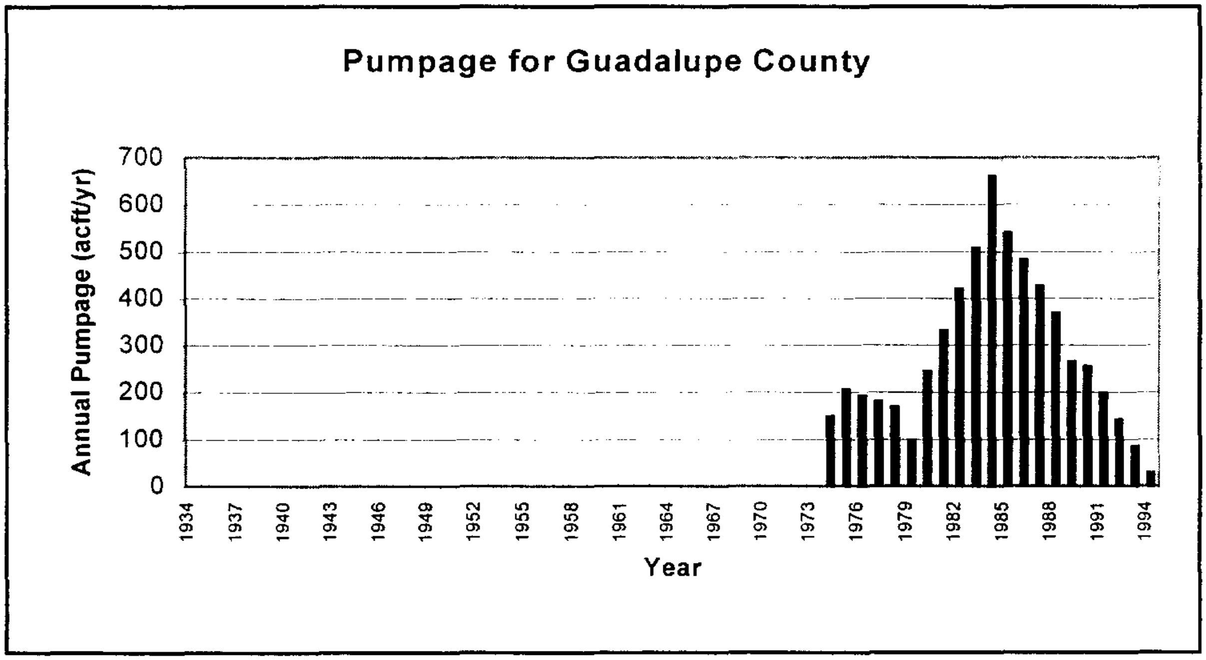


TABLE A-7

Annual Pumpage Estimate Summary - Karnes County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	0	1955	1,010	1976	1,514
1935	0	1956	1,394	1977	1,069
1936	0	1957	1,001	1978	1,088
1937	0	1958	454	1979	1,210
1938	0	1959	1,587	1980	1,082
1939	23	1960	1,819	1981	1,213
1940	5	1961	2,119	1982	1,235
1941	0	1962	2,537	1983	1,186
1942	275	1963	2,725	1984	1,631
1943	190	1964	2,339	1985	1,190
1944	0	1965	1,932	1986	1,362
1945	296	1966	2,213	1987	809
1946	127	1967	2,172	1988	1,078
1947	456	1968	1,462	1989	281
1948	485	1969	849	1990	459
1949	424	1970	1,198	1991	396
1950	852	1971	1,782	1992	0
1951	758	1972	1,530	1993	629
1952	832	1973	1,200	1994	623
1953	1,031	1974	2,673	Average	982
1954	550	1975	1,549	(acft/yr)	

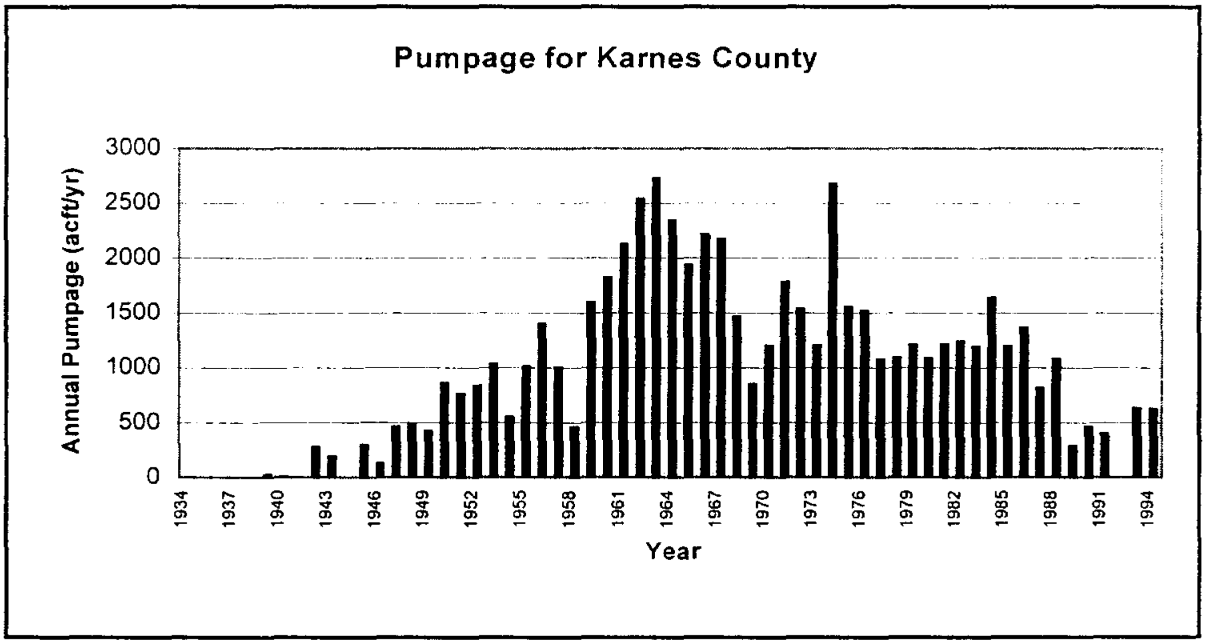


TABLE A-8

Annual Pumpage Estimate Summary - La Salle County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	2,691	1955	5,026	1976	11,633
1935	0	1956	6,136	1977	11,935
1936	1,164	1957	3,115	1978	12,154
1937	4,185	1958	4,142	1979	8,974
1938	3,704	1959	5,861	1980	11,263
1939	2,251	1960	7,073	1981	6,917
1940	1,071	1961	8,109	1982	9,101
1941	295	1962	9,343	1983	8,390
1942	4,131	1963	9,878	1984	8,657
1943	3,845	1964	15,886	1985	5,093
1944	3,881	1965	10,825	1986	5,892
1945	4,134	1966	8,595	1987	5,013
1946	2,122	1967	12,336	1988	7,697
1947	2,469	1968	10,493	1989	5,980
1948	3,747	1969	11,850	1990	7,266
1949	1,347	1970	10,838	1991	6,300
1950	2,124	1971	11,102	1992	5,081
1951	3,389	1972	11,556	1993	6,261
1952	3,959	1973	11,360	1994	5,411
1953	4,536	1974	11,876	**Average**	**6,622**
1954	3,272	1975	11,210	(acft/yr)	

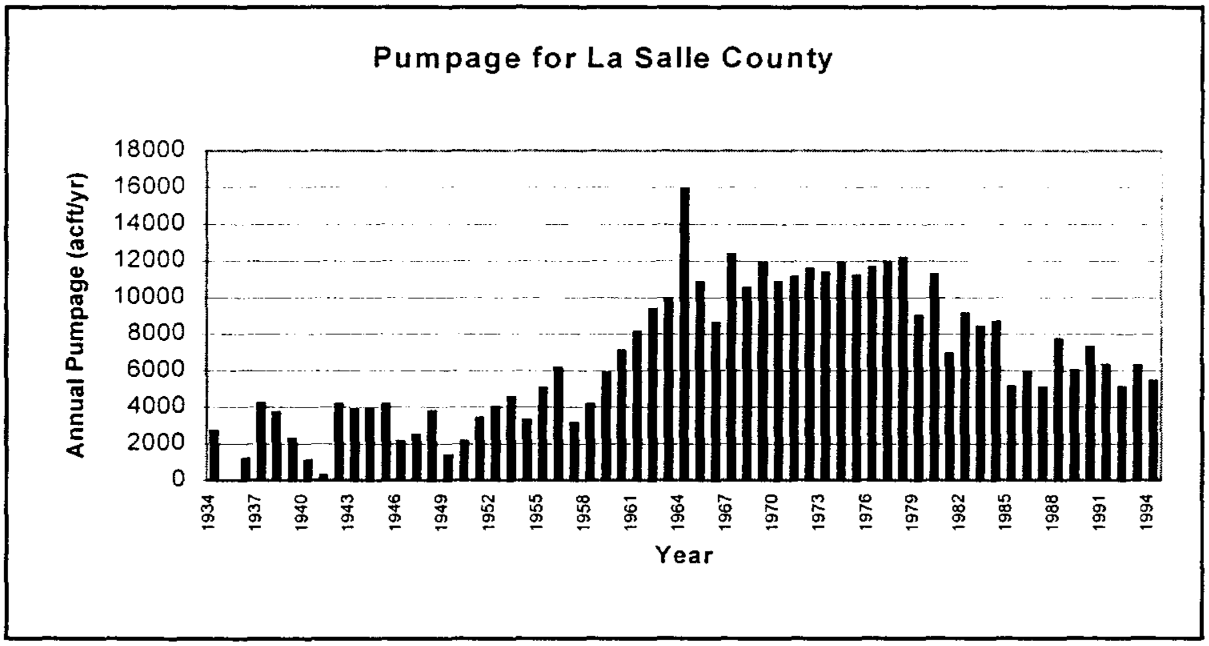


TABLE A-9

Annual Pumpage Estimate Summary - Live Oak County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	0	1955	1,573	1976	1,117
1935	0	1956	1,496	1977	778
1936	0	1957	1,125	1978	722
1937	0	1958	931	1979	280
1938	0	1959	1,106	1980	523
1939	0	1960	1,330	1981	549
1940	0	1961	1,547	1982	680
1941	0	1962	1,865	1983	655
1942	0	1963	1,983	1984	1,043
1943	0	1964	1,741	1985	565
1944	0	1965	1,847	1986	639
1945	0	1966	1,809	1987	330
1946	0	1967	1,837	1988	394
1947	0	1968	1,376	1989	24
1948	0	1969	829	1990	39
1949	75	1970	1,409	1991	91
1950	633	1971	1,621	1992	0
1951	1,452	1972	1,433	1993	70
1952	1,581	1973	1,210	1994	7
1953	1,777	1974	892	Average	773
1954	2,936	1975	1,238	(acft/yr)	

Pumpage for Live Oak County

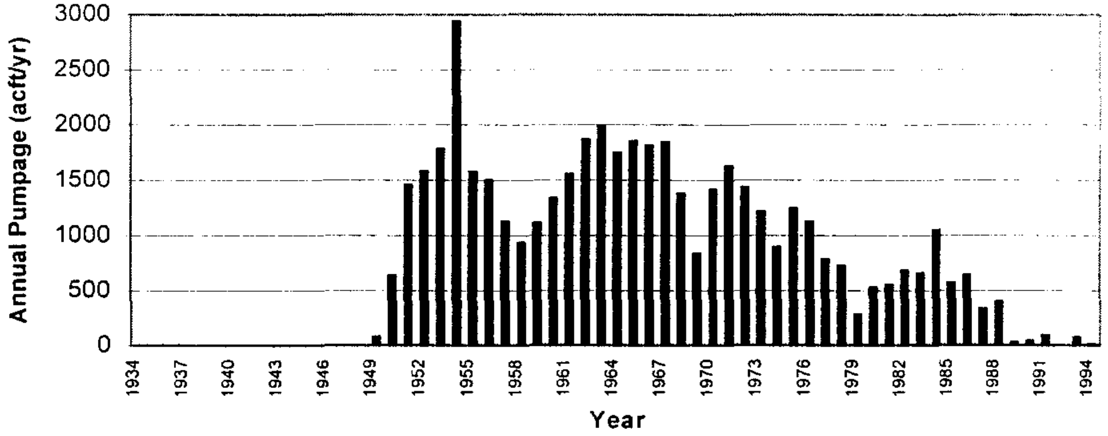


TABLE A-10

Annual Pumpage Estimate Summary - Medina County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	0	1955	0	1976	6,266
1935	0	1956	0	1977	6,522
1936	0	1957	0	1978	7,676
1937	0	1958	719	1979	6,211
1938	0	1959	1,024	1980	8,027
1939	0	1960	414	1981	4,722
1940	0	1961	721	1982	8,935
1941	0	1962	1,671	1983	9,808
1942	0	1963	2,439	1984	10,667
1943	0	1964	1,810	1985	7,787
1944	0	1965	2,548	1986	8,483
1945	0	1966	825	1987	7,707
1946	0	1967	4,917	1988	10,264
1947	0	1968	2,376	1989	11,732
1948	0	1969	4,759	1990	10,263
1949	0	1970	4,058	1991	8,405
1950	0	1971	6,051	1992	7,633
1951	0	1972	5,669	1993	8,738
1952	0	1973	5,052	1994	7,970
1953	0	1974	6,227	Average	3,532
1954	0	1975	6,388	(acft/yr)	

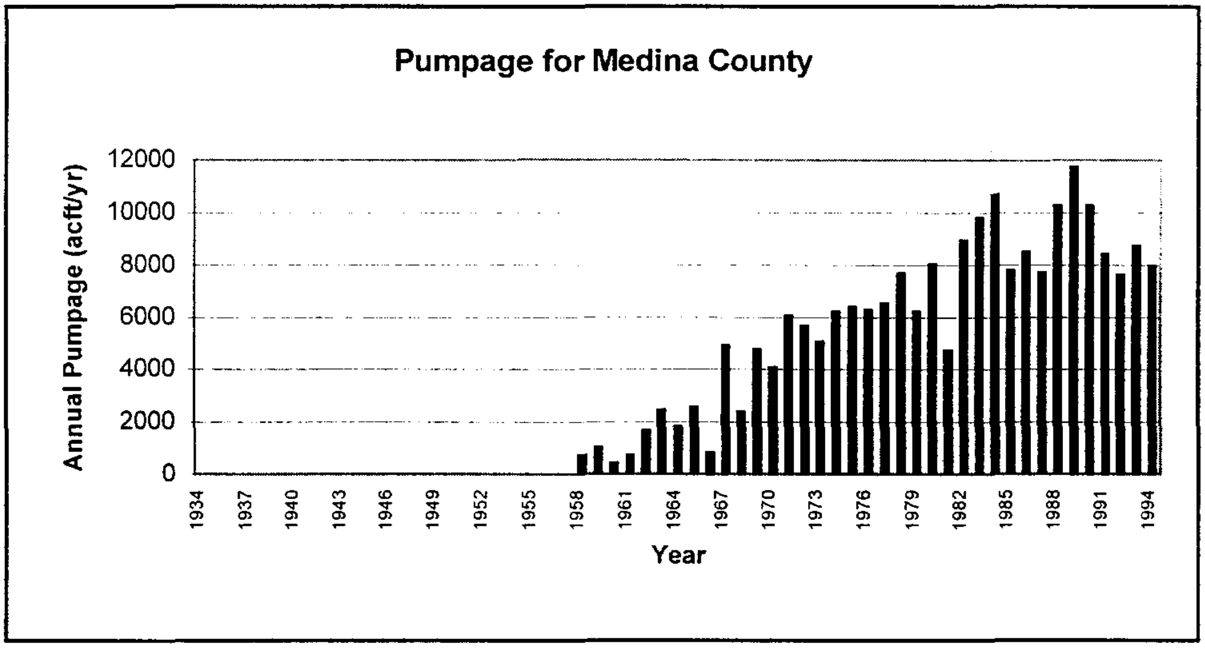


TABLE A-11

Annual Pumpage Estimate Summary - Wilson County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	857	1955	3,871	1976	11,569
1935	870	1956	4,926	1977	10,112
1936	883	1957	5,981	1978	8,655
1937	895	1958	11,856	1979	6,318
1938	908	1959	8,204	1980	7,582
1939	427	1960	9,372	1981	7,967
1940	874	1961	10,540	1982	8,351
1941	828	1962	11,708	1983	8,736
1942	782	1963	12,876	1984	7,242
1943	736	1964	13,738	1985	9,227
1944	67	1965	13,761	1986	9,333
1945	761	1966	13,478	1987	9,440
1946	833	1967	13,195	1988	9,547
1947	904	1968	12,912	1989	9,068
1948	975	1969	12,514	1990	9,858
1949	624	1970	13,000	1991	10,063
1950	1,400	1971	13,371	1992	10,268
1951	1,754	1972	13,741	1993	10,472
1952	2,108	1973	14,112	1994	10,163
1953	2,462	1974	14,908	**Average**	**7,187**
1954	3,389	1975	13,026	**(acft/yr)**	

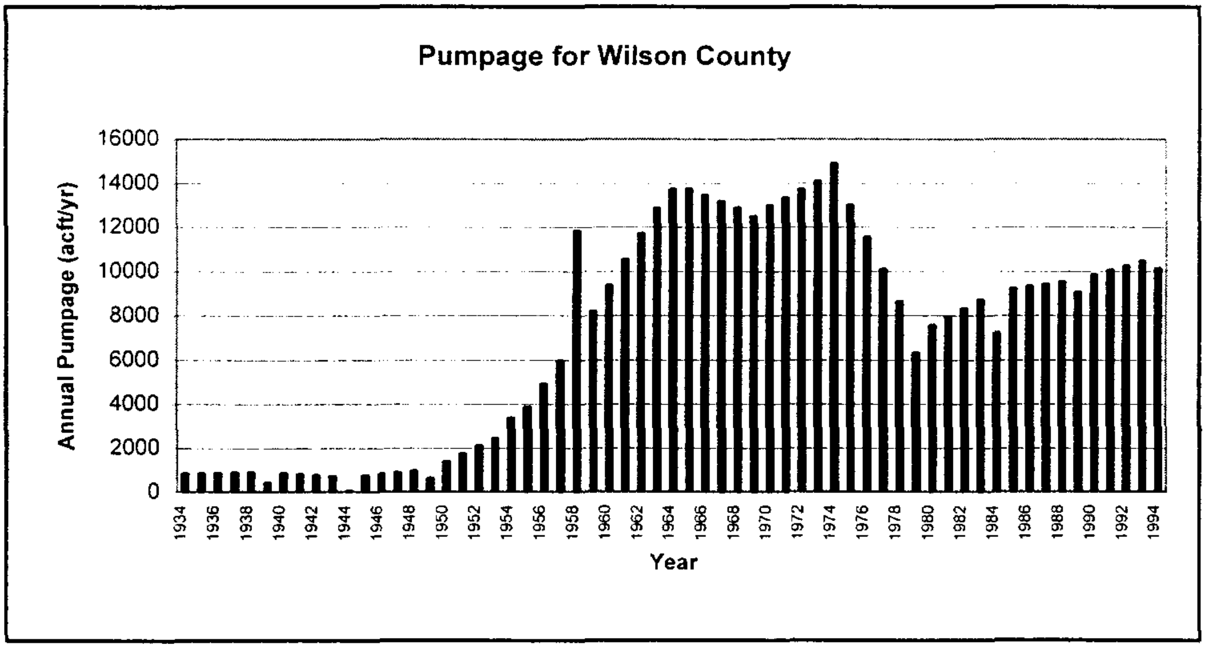
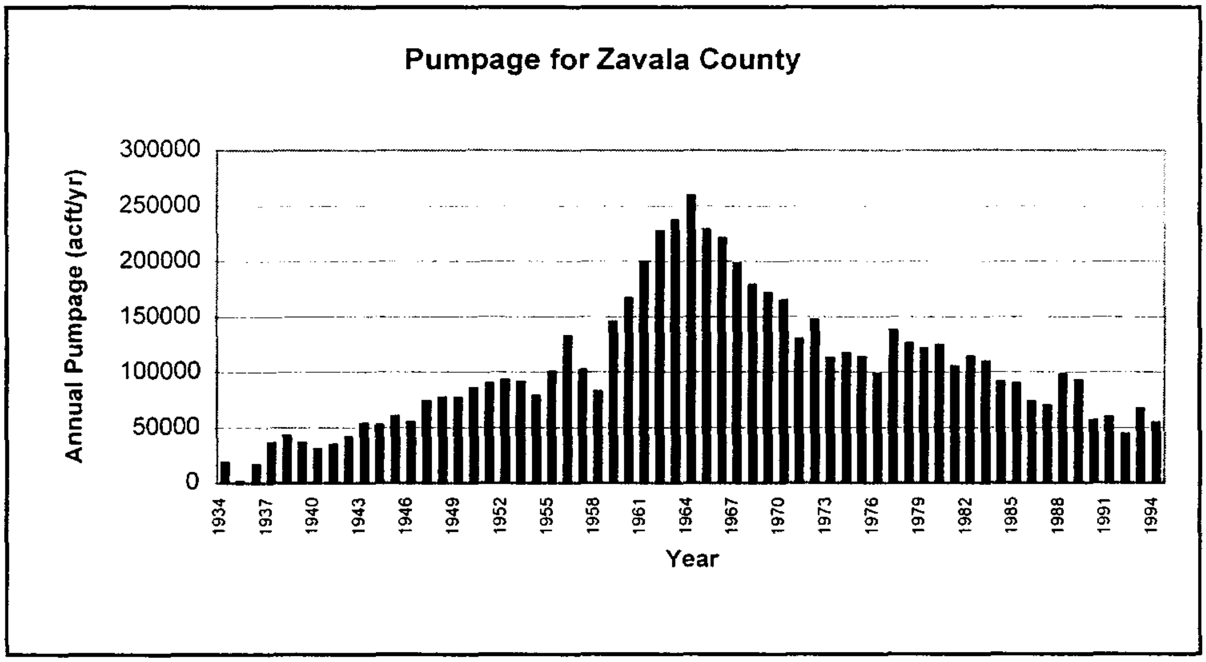


TABLE A-12

Annual Pumpage Estimate Summary - Zavala County in Acre-Feet/Year

Year	Pumpage	Year	Pumpage	Year	Pumpage
1934	18,473	1955	99,547	1976	97,739
1935	607	1956	132,190	1977	137,370
1936	16,144	1957	101,710	1978	125,558
1937	35,556	1958	81,868	1979	120,547
1938	42,567	1959	145,008	1980	123,638
1939	35,896	1960	166,147	1981	104,832
1940	30,107	1961	198,681	1982	113,378
1941	33,973	1962	226,634	1983	109,043
1942	40,956	1963	236,714	1984	90,673
1943	52,989	1964	258,498	1985	89,423
1944	51,789	1965	228,450	1986	72,994
1945	59,542	1966	220,164	1987	69,231
1946	53,993	1967	197,374	1988	97,371
1947	73,459	1968	178,464	1989	92,370
1948	76,687	1969	170,849	1990	55,882
1949	76,335	1970	164,142	1991	58,959
1950	85,137	1971	129,607	1992	43,695
1951	89,488	1972	146,537	1993	66,440
1952	92,663	1973	112,366	1994	54,095
1953	90,747	1974	116,530	**Average**	**102,996**
1954	77,930	1975	112,986	(acft/yr)	



APPENDIX B

ESTIMATES OF ANNUAL RECHARGE BY COUNTY

APPENDIX B

ESTIMATES OF ANNUAL RECHARGE BY COUNTY

TABLE B-1

Annual Recharge Summary - Nueces River above Asherton in Acre-Feet/Year

Year	Recharge	Year	Recharge	Year	Recharge
1934	1,743	1955	17,935	1976	68,241
1935	89,722	1956	183	1977	30,317
1936	41,262	1957	38,232	1978	16,057
1937	14,266	1958	69,356	1979	29,841
1938	12,505	1959	43,448	1980	12,555
1939	16,625	1960	26,321	1981	56,244
1940	11,508	1961	28,349	1982	17,844
1941	11,205	1962	7,278	1983	8,240
1942	18,549	1963	5,626	1984	10,426
1943	6,195	1964	47,095	1985	24,185
1944	19,867	1965	14,829	1986	32,192
1945	4,352	1966	16,803	1987	70,293
1946	11,512	1967	18,156	1988	15,098
1947	6,567	1968	18,422	1989	5,585
1948	7,903	1969	27,437	1990	44,965
1949	34,841	1970	25,469	1991	29,225
1950	5,143	1971	100,717	1992	40,821
1951	2,619	1972	26,182	1993	16,583
1952	3,481	1973	53,159	1994	11,538
1953	3,629	1974	27,106	**Average**	**24,858**
1954	10,731	1975	29,737	**(acft/yr)**	

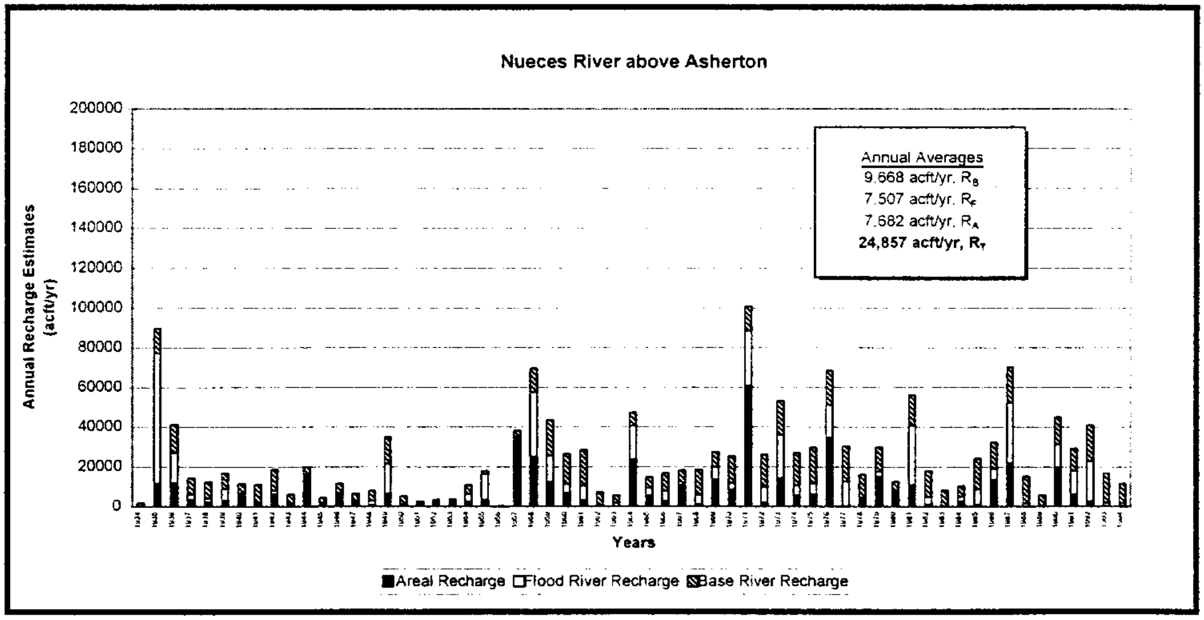


TABLE B-2

Annual Recharge Summary - Frio River above Derby in Acre-Feet/Year

Year	Recharge	Year	Recharge	Year	Recharge
1934	5,786	1955	5,330	1976	43,957
1935	107,256	1956	892	1977	20,184
1936	37,853	1957	39,739	1978	16,246
1937	15,463	1958	58,496	1979	33,573
1938	13,582	1959	24,817	1980	27,355
1939	11,666	1960	20,555	1981	43,273
1940	13,900	1961	21,981	1982	13,187
1941	24,802	1962	6,369	1983	10,607
1942	18,678	1963	1,754	1984	12,347
1943	7,262	1964	6,461	1985	17,847
1944	16,086	1965	8,682	1986	30,703
1945	11,174	1966	12,313	1987	72,541
1946	11,282	1967	31,039	1988	13,725
1947	7,865	1968	27,058	1989	8,955
1948	6,507	1969	23,281	1990	22,353
1949	22,272	1970	21,323	1991	26,240
1950	5,084	1971	72,030	1992	39,551
1951	8,159	1972	18,017	1993	16,130
1952	1,042	1973	46,402	1994	13,122
1953	8,119	1974	45,246	**Average**	**22,199**
1954	2,736	1975	23,887	**(acft/yr)**	

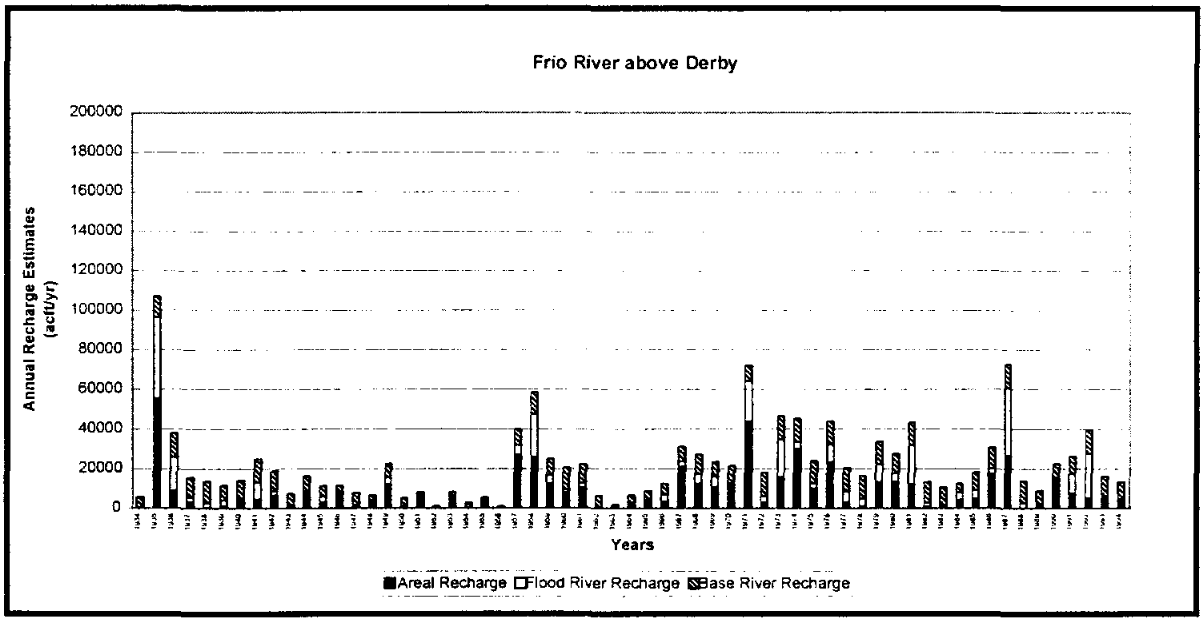


TABLE B-3

Annual Recharge Summary - Atascosa River/ San Miguel Creek Watersheds in Acre-Feet/Year

Year	Recharge	Year	Recharge	Year	Recharge
1934	44,994	1955	9,260	1976	107,209
1935	181,466	1956	3	1977	60,245
1936	71,327	1957	128,307	1978	27,907
1937	34,294	1958	147,236	1979	28,264
1938	8,055	1959	29,918	1980	106,665
1939	7,960	1960	63,542	1981	71,636
1940	56,601	1961	32,394	1982	15,604
1941	101,169	1962	4,110	1983	7,794
1942	89,030	1963	1,330	1984	31,008
1943	20,915	1964	6,191	1985	38,113
1944	38,466	1965	65,519	1986	87,190
1945	17,909	1966	15,839	1987	80,922
1946	126,658	1967	148,895	1988	-
1947	9,497	1968	101,639	1989	4,497
1948	5,149	1969	34,830	1990	40,565
1949	109,875	1970	65,694	1991	56,380
1950	12,407	1971	74,689	1992	59,863
1951	35,773	1972	48,156	1993	54,247
1952	4,529	1973	168,859	1994	20,802
1953	17,519	1974	87,153	**Average**	**52,198**
1954	454	1975	57,582	**(acft/yr)**	

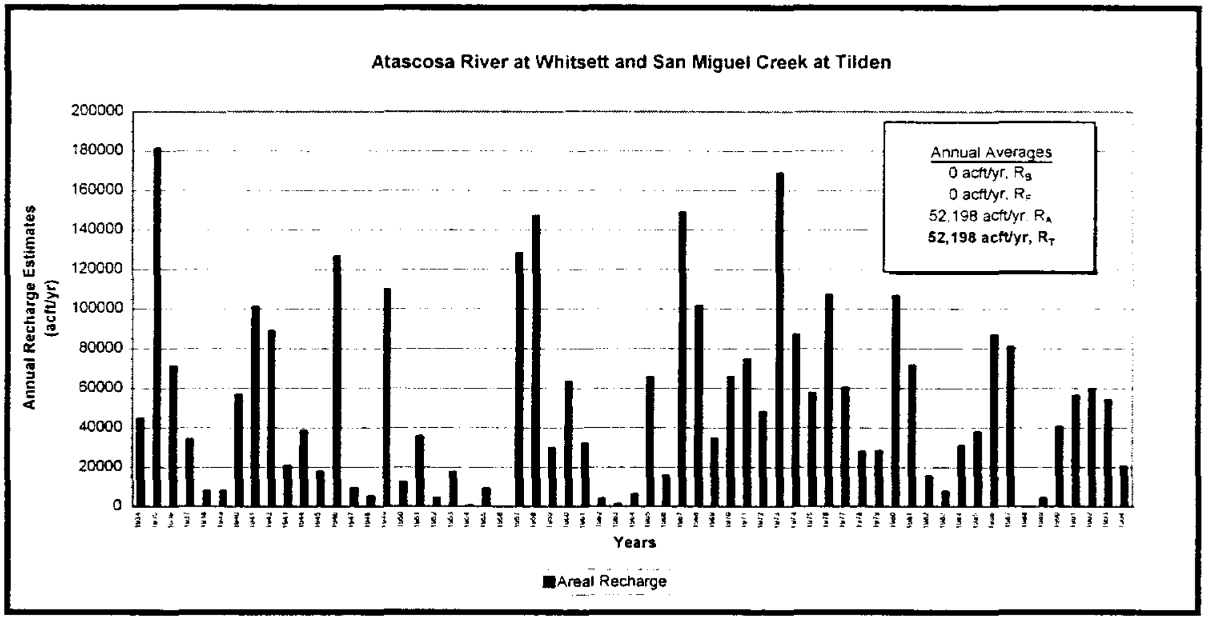


TABLE B-4

Annual Recharge Summary - San Antonio River above Falls City in Acre-Feet/Year

Year	Recharge	Year	Recharge	Year	Recharge
1934	12,936	1955	10,703	1976	47,413
1935	67,013	1956	19,844	1977	58,269
1936	55,578	1957	34,721	1978	42,766
1937	21,439	1958	42,138	1979	47,431
1938	20,465	1959	14,531	1980	13,497
1939	10,173	1960	21,807	1981	44,533
1940	26,081	1961	28,863	1982	10,530
1941	35,342	1962	11,023	1983	17,278
1942	62,298	1963	6,027	1984	11,570
1943	9,857	1964	15,652	1985	29,437
1944	15,403	1965	23,177	1986	43,409
1945	16,650	1966	11,709	1987	87,300
1946	58,256	1967	35,805	1988	10,749
1947	9,403	1968	36,980	1989	6,653
1948	14,438	1969	21,698	1990	26,591
1949	31,139	1970	10,937	1991	37,424
1950	10,326	1971	21,502	1992	126,820
1951	11,156	1972	25,488	1993	38,073
1952	20,202	1973	96,740	1994	26,673
1953	19,080	1974	32,149	**Average**	**29,803**
1954	7,546	1975	35,274	**(acft/yr)**	

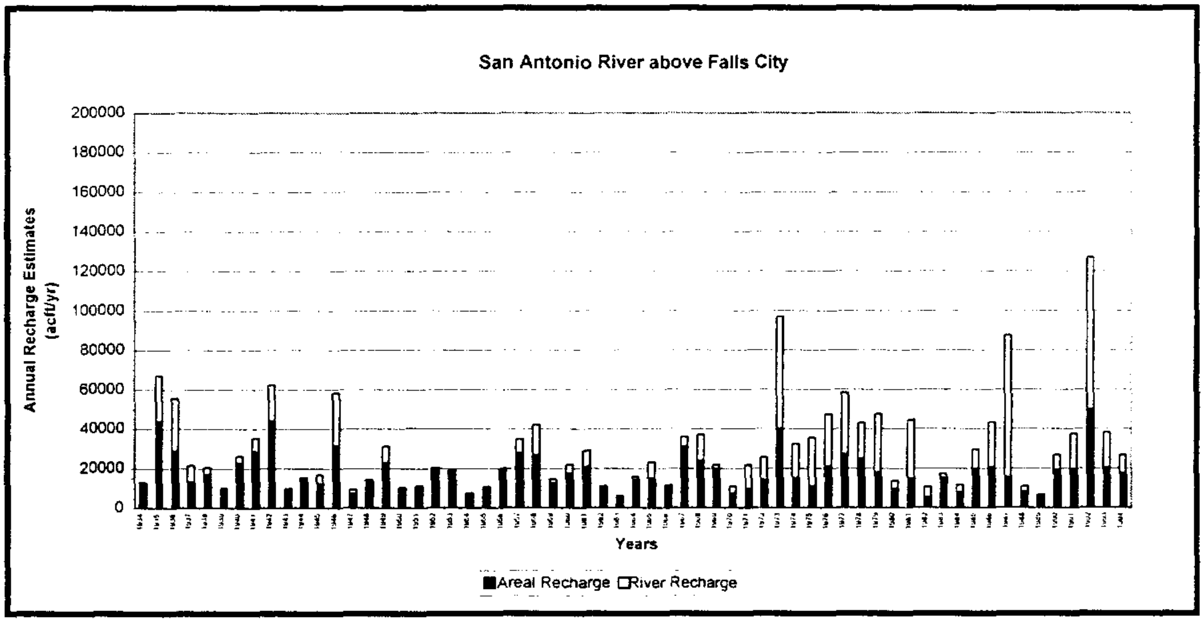


TABLE B-5

Annual Recharge Summary - Cibolo Creek above Falls City in Acre-Feet/Year

Year	Recharge	Year	Recharge	Year	Recharge
1934	14,302	1955	12,655	1976	43,575
1935	60,110	1956	8,415	1977	47,182
1936	28,726	1957	68,445	1978	27,513
1937	40,690	1958	54,613	1979	41,786
1938	39,105	1959	23,155	1980	12,496
1939	5,660	1960	29,955	1981	51,968
1940	36,846	1961	29,408	1982	23,610
1941	62,905	1962	3,759	1983	11,497
1942	85,457	1963	9,032	1984	9,545
1943	31,955	1964	13,943	1985	36,533
1944	35,109	1965	39,815	1986	31,725
1945	21,686	1966	6,463	1987	64,893
1946	59,851	1967	50,618	1988	3,343
1947	13,341	1968	60,043	1989	2,868
1948	10,194	1969	28,056	1990	8,234
1949	43,394	1970	6,249	1991	75,869
1950	8,154	1971	5,662	1992	118,740
1951	19,388	1972	30,432	1993	43,659
1952	26,520	1973	76,723	1994	15,259
1953	23,969	1974	20,700	**Average**	**31,989**
1954	4,542	1975	30,964	**(acft/yr)**	

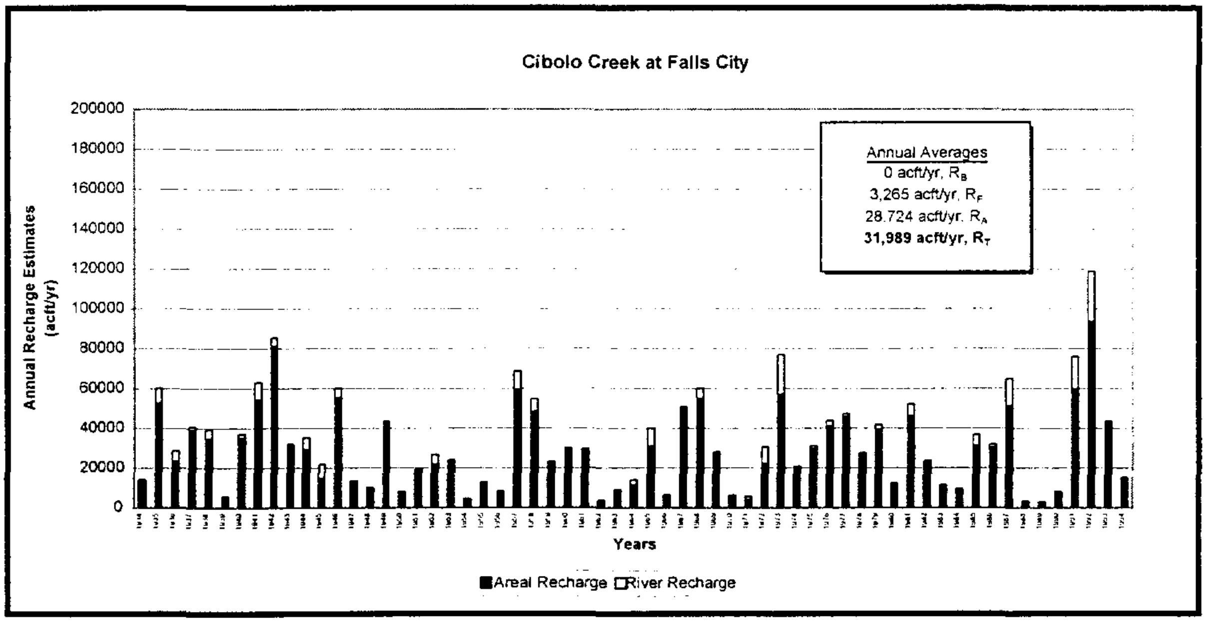


TABLE B-6

Annual Recharge Summary - Guadalupe River above Cuero in Acre-Feet/Year

Year	Recharge	Year	Recharge	Year	Recharge
1934	14,390	1955	10,863	1976	74,777
1935	58,048	1956	5,877	1977	69,664
1936	72,276	1957	81,781	1978	24,915
1937	31,702	1958	68,152	1979	75,743
1938	42,766	1959	26,050	1980	9,284
1939	7,620	1960	64,266	1981	90,157
1940	47,894	1961	51,942	1982	13,736
1941	87,921	1962	4,300	1983	17,526
1942	61,974	1963	2,028	1984	4,855
1943	14,651	1964	6,749	1985	54,895
1944	47,506	1965	41,235	1986	46,529
1945	39,869	1966	10,325	1987	132,971
1946	62,384	1967	29,740	1988	2,724
1947	31,176	1968	60,621	1989	5,263
1948	8,186	1969	30,764	1990	6,127
1949	36,195	1970	28,703	1991	58,823
1950	8,008	1971	13,879	1992	179,964
1951	15,430	1972	39,946	1993	48,244
1952	37,036	1973	85,061	1994	10,810
1953	18,301	1974	50,369	**Average**	**40,366**
1954	3,659	1975	75,702	**(acft/yr)**	

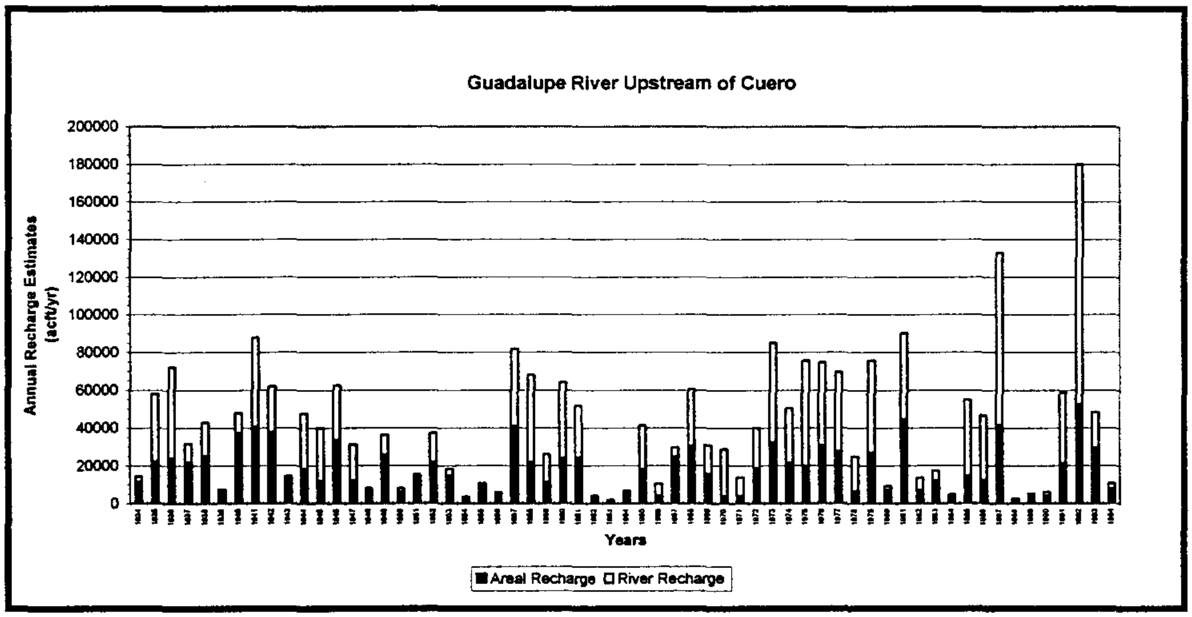
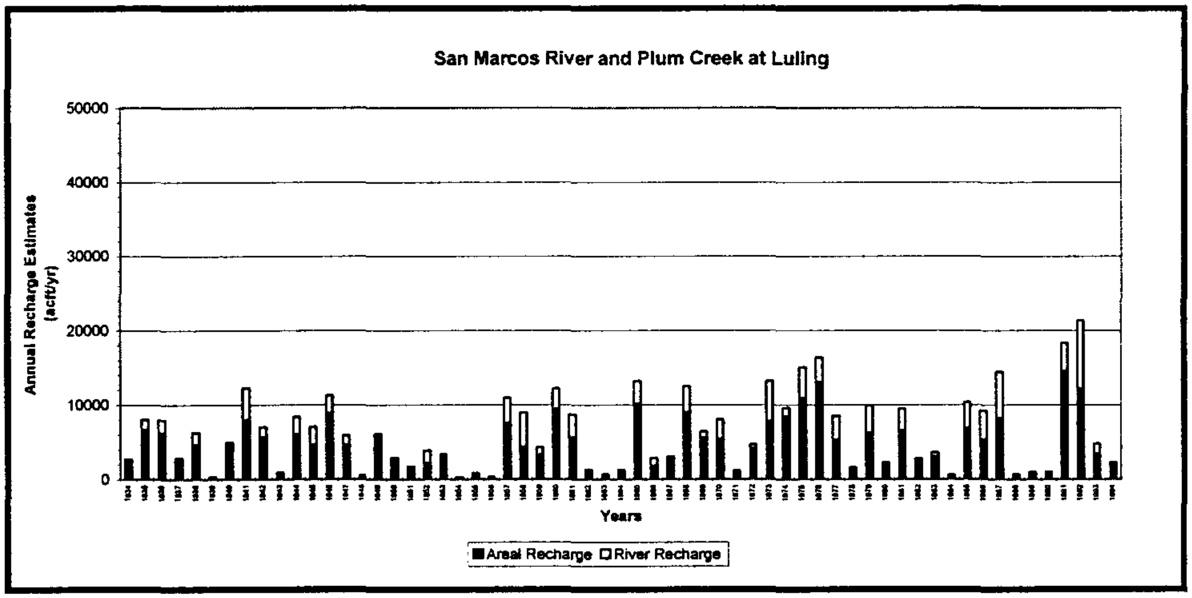


TABLE B-7

Annual Recharge Summary - San Marcos River above Luling in Acre-Feet/Year

Year	Recharge	Year	Recharge	Year	Recharge
1934	2,754	1955	885	1976	16,395
1935	8,076	1956	329	1977	8,535
1936	7,941	1957	10,940	1978	1,587
1937	2,857	1958	8,966	1979	9,938
1938	6,293	1959	4,305	1980	2,224
1939	353	1960	12,211	1981	9,479
1940	4,973	1961	8,671	1982	2,784
1941	12,264	1962	1,350	1983	3,582
1942	6,998	1963	705	1984	626
1943	933	1964	1,289	1985	10,376
1944	8,410	1965	13,203	1986	9,195
1945	7,031	1966	2,882	1987	14,442
1946	11,259	1967	3,079	1988	717
1947	5,903	1968	12,537	1989	1,014
1948	524	1969	6,444	1990	1,057
1949	6,085	1970	8,056	1991	18,341
1950	2,919	1971	1,197	1992	21,334
1951	1,705	1972	4,694	1993	4,776
1952	3,850	1973	13,228	1994	2,313
1953	3,391	1974	9,574	**Average**	**6,281**
1954	298	1975	15,038	**(acft/yr)**	



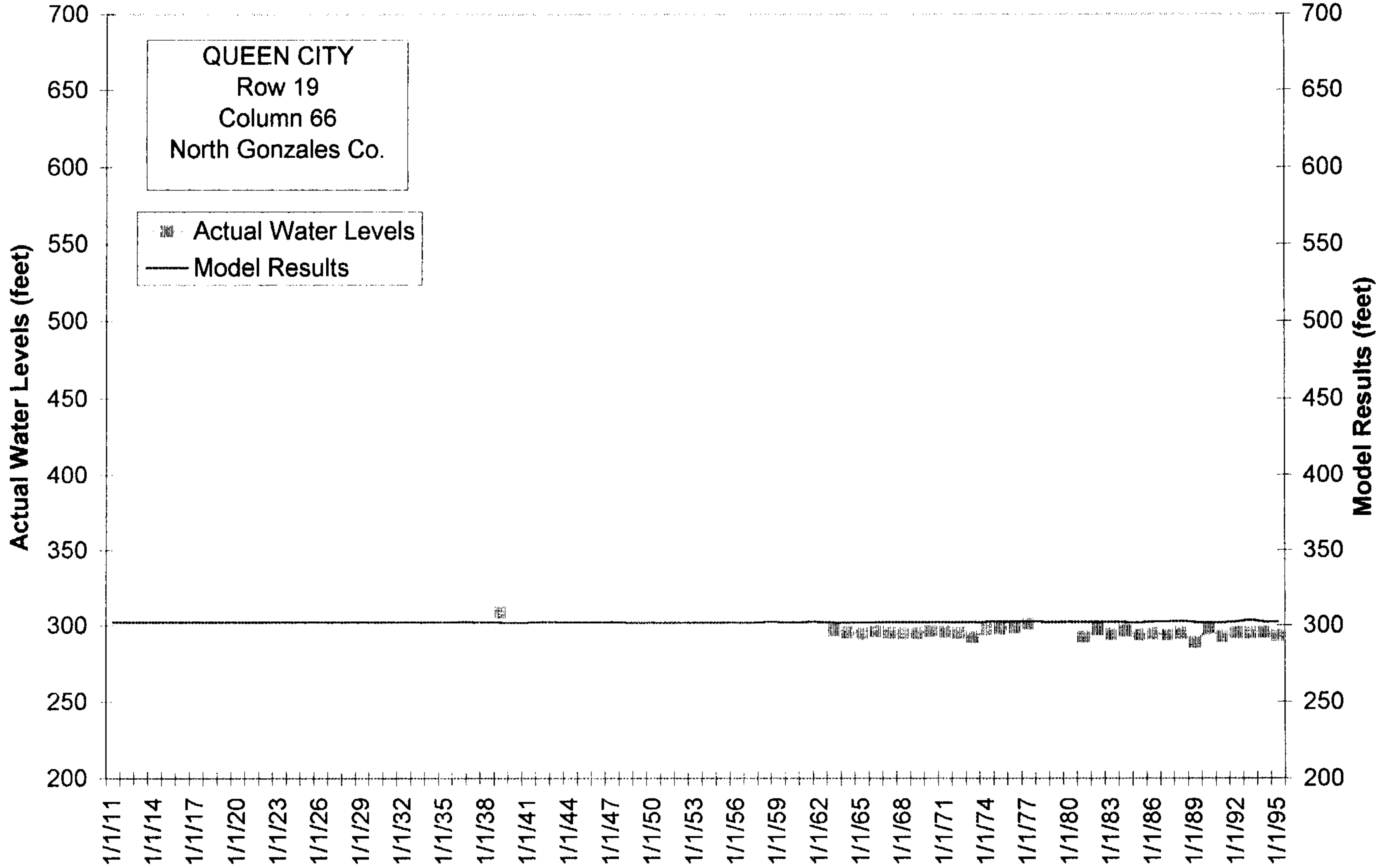
APPENDIX C

HYDROGRAPHS USED FOR MODEL CALIBRATION

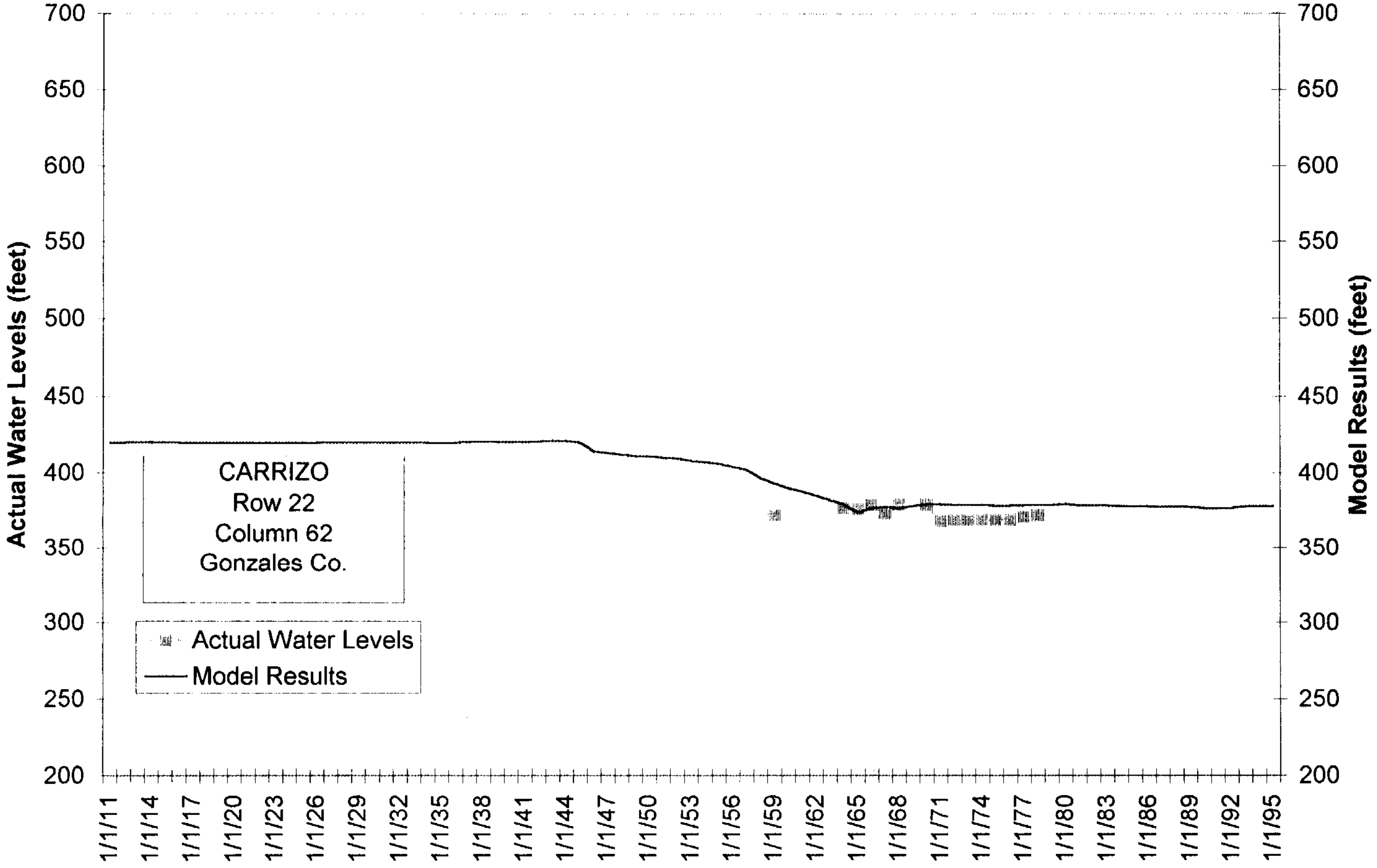
APPENDIX C

HYDROGRAPHS USED FOR MODEL CALIBRATION

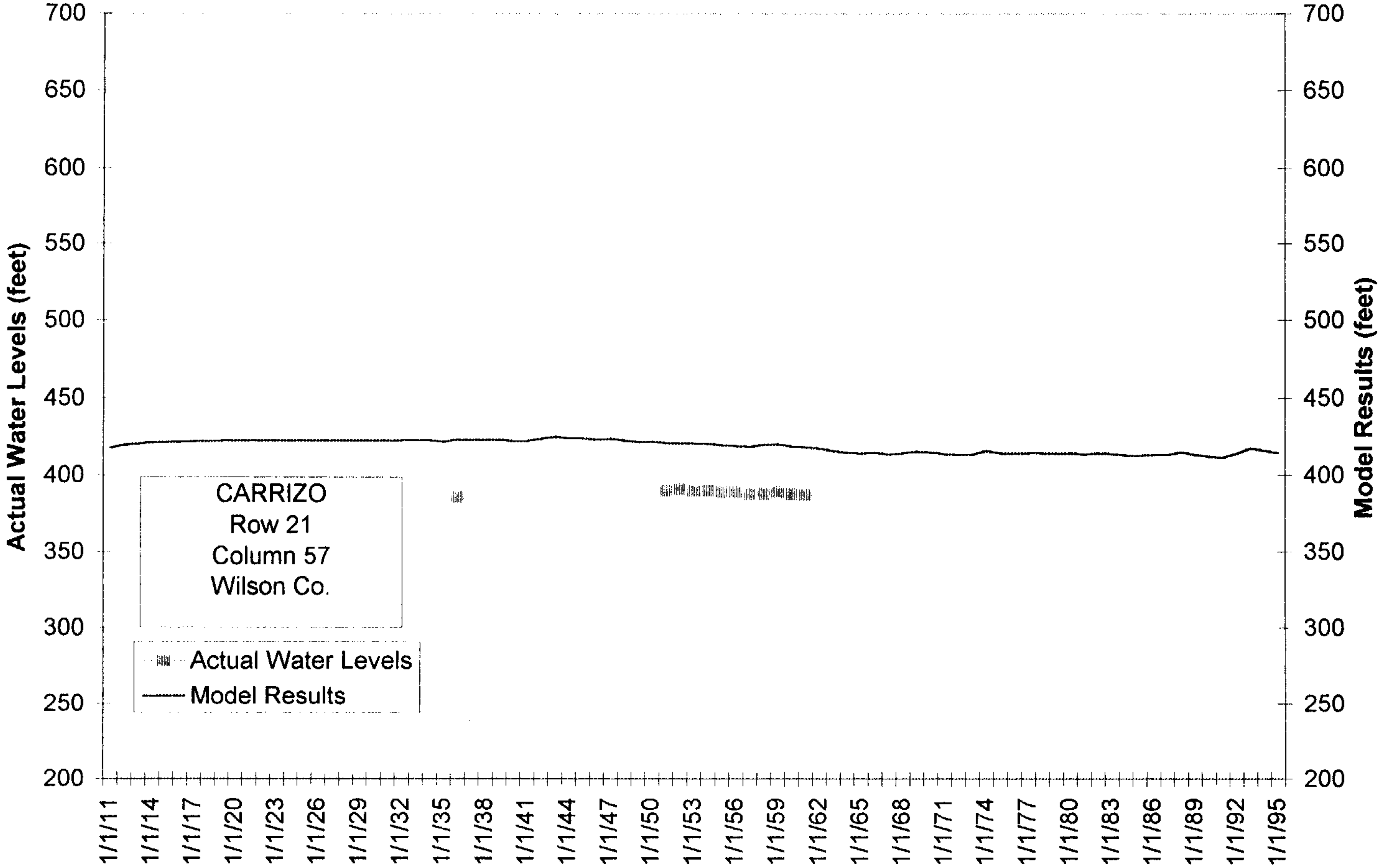
67-28-303 Hydrograph



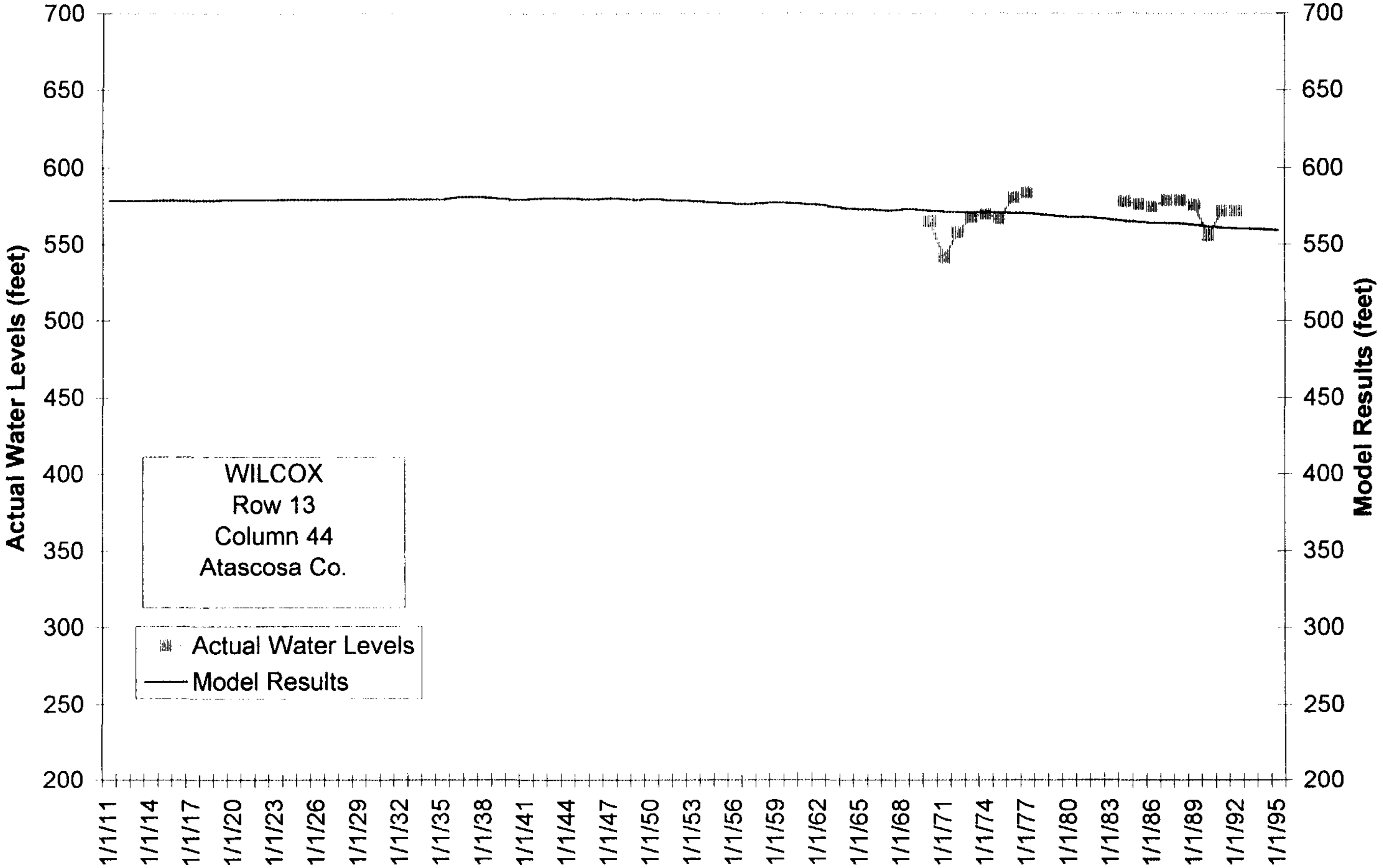
67-35-701 Hydrograph



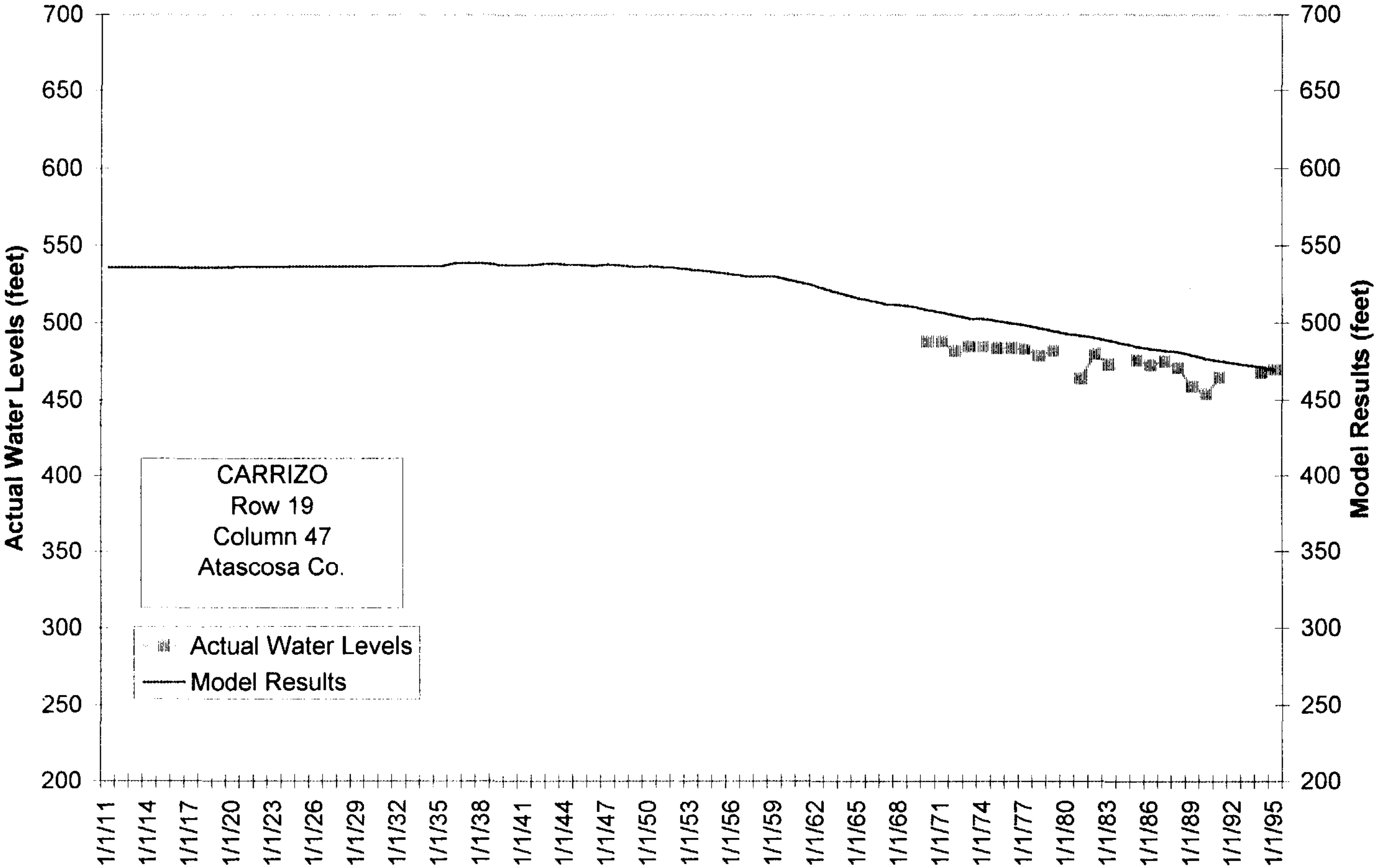
68-48-801 Hydrograph



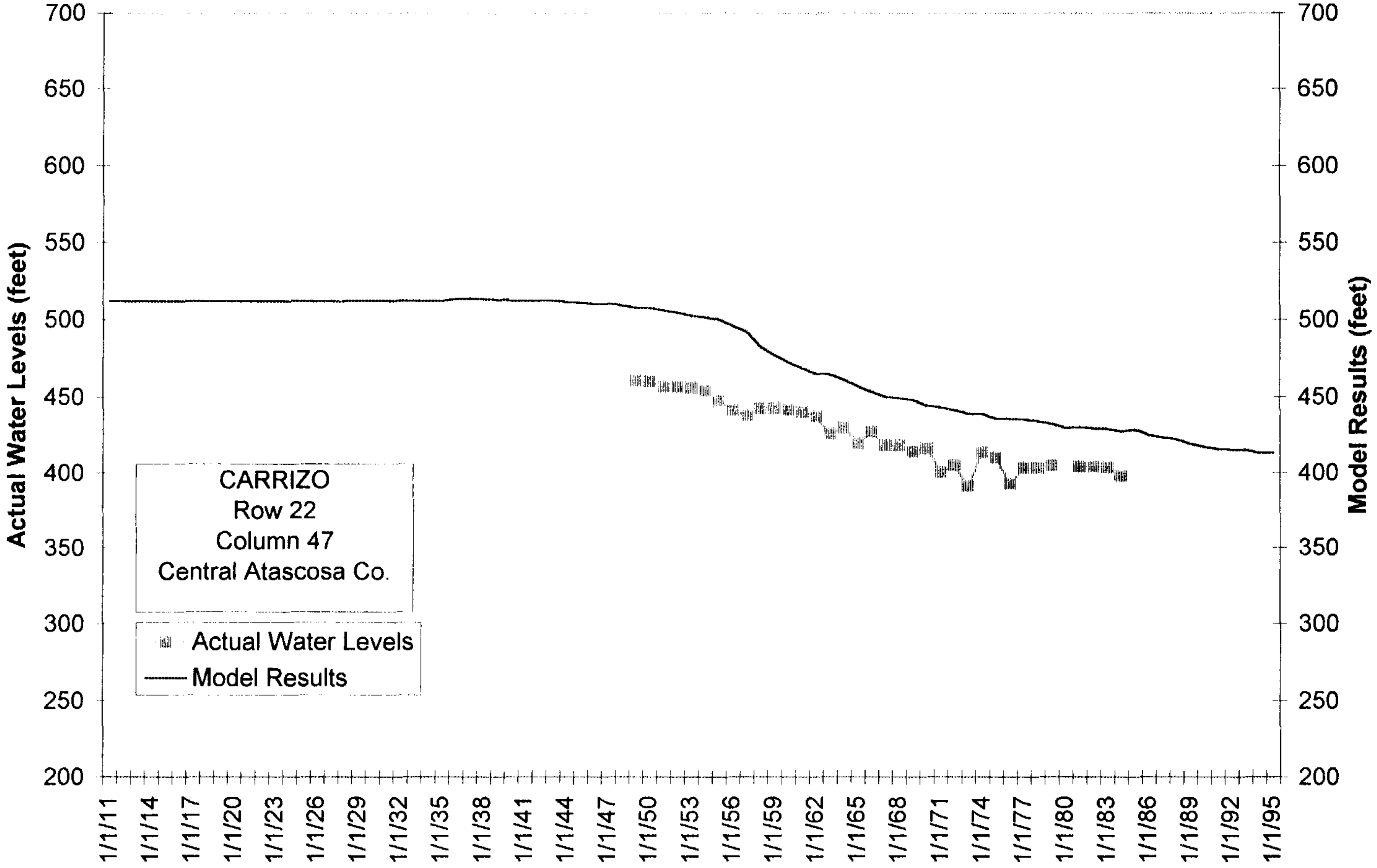
68-50-603 Hydrograph



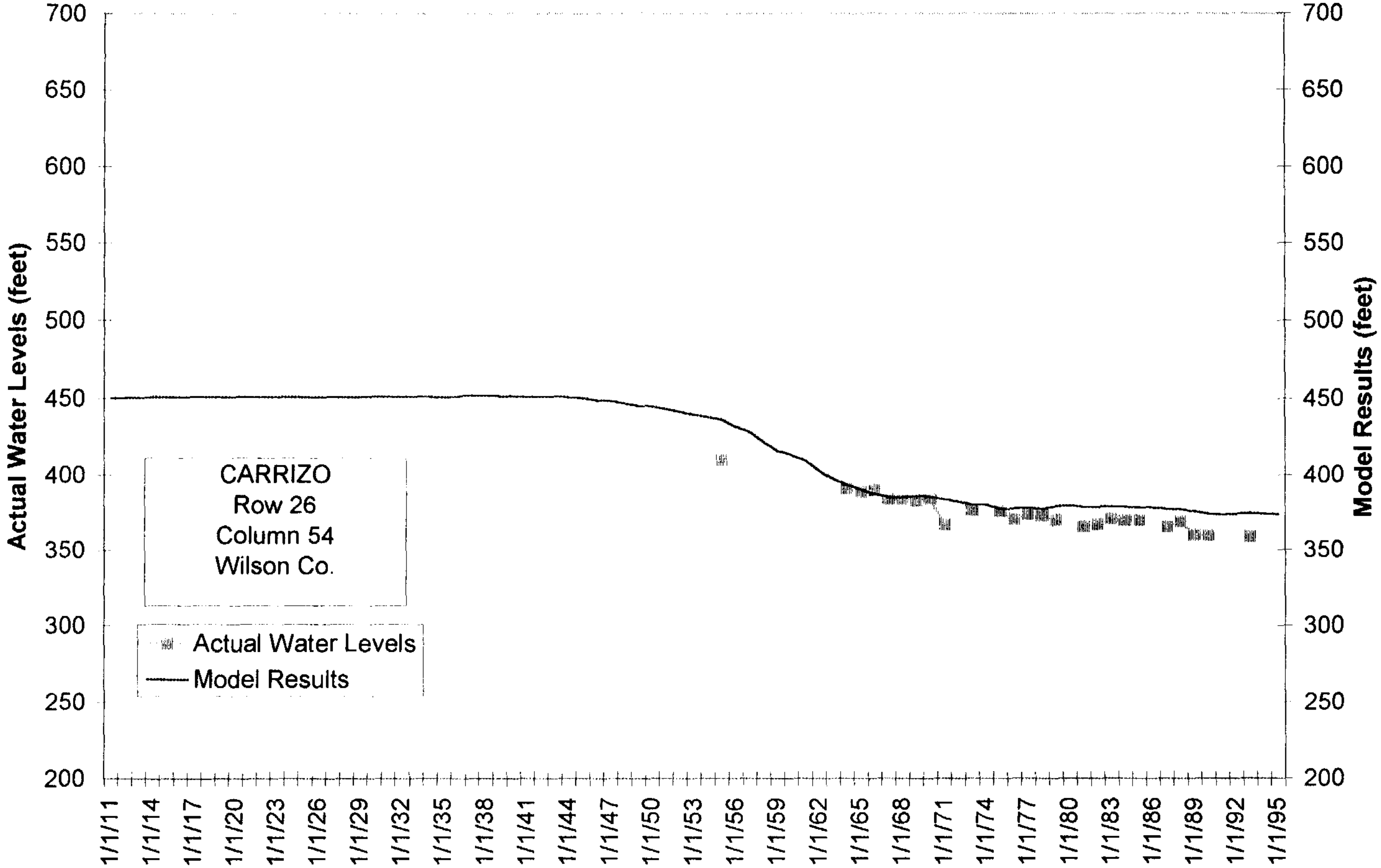
68-52-718 Hydrograph



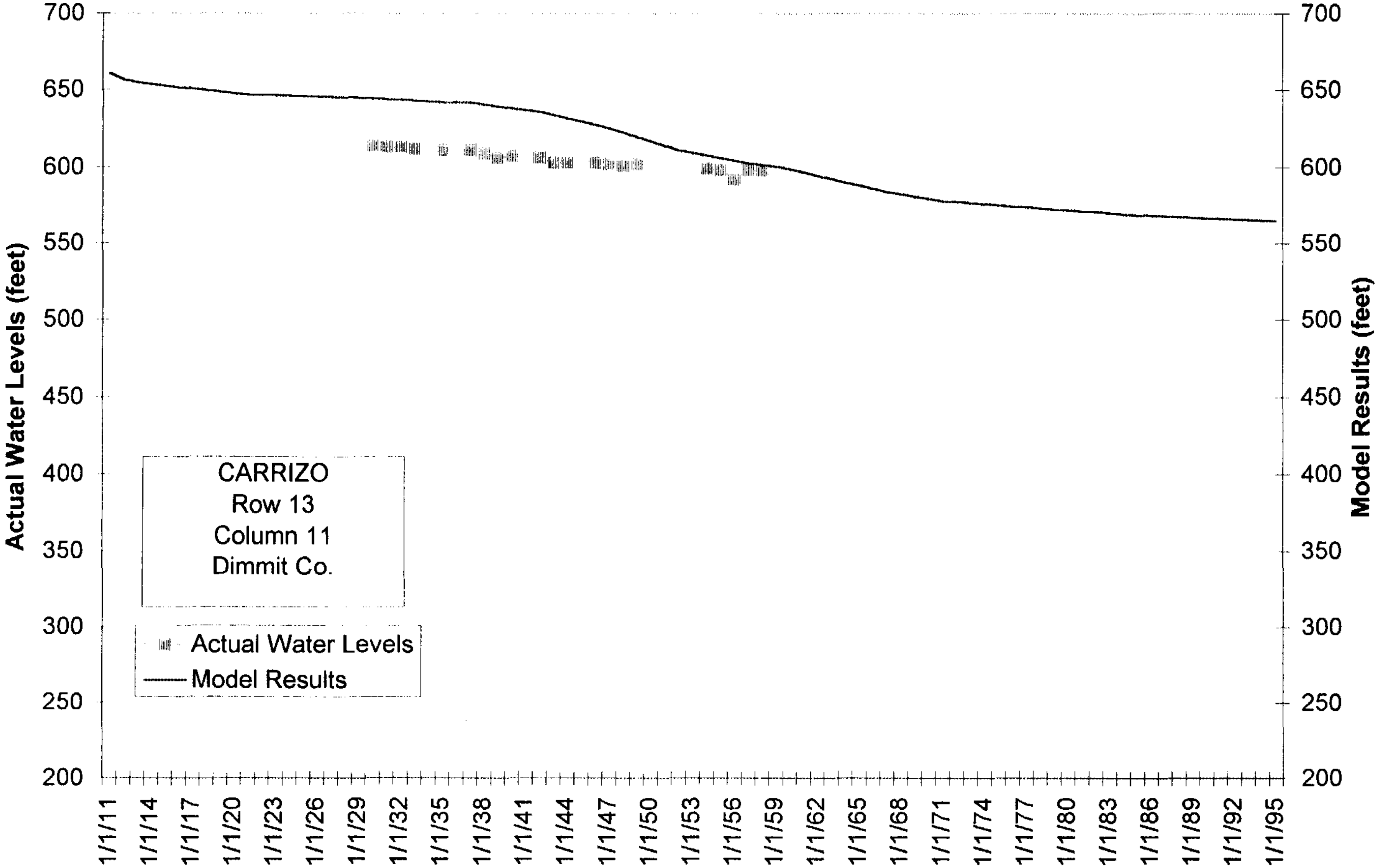
68-60-610 Hydrograph



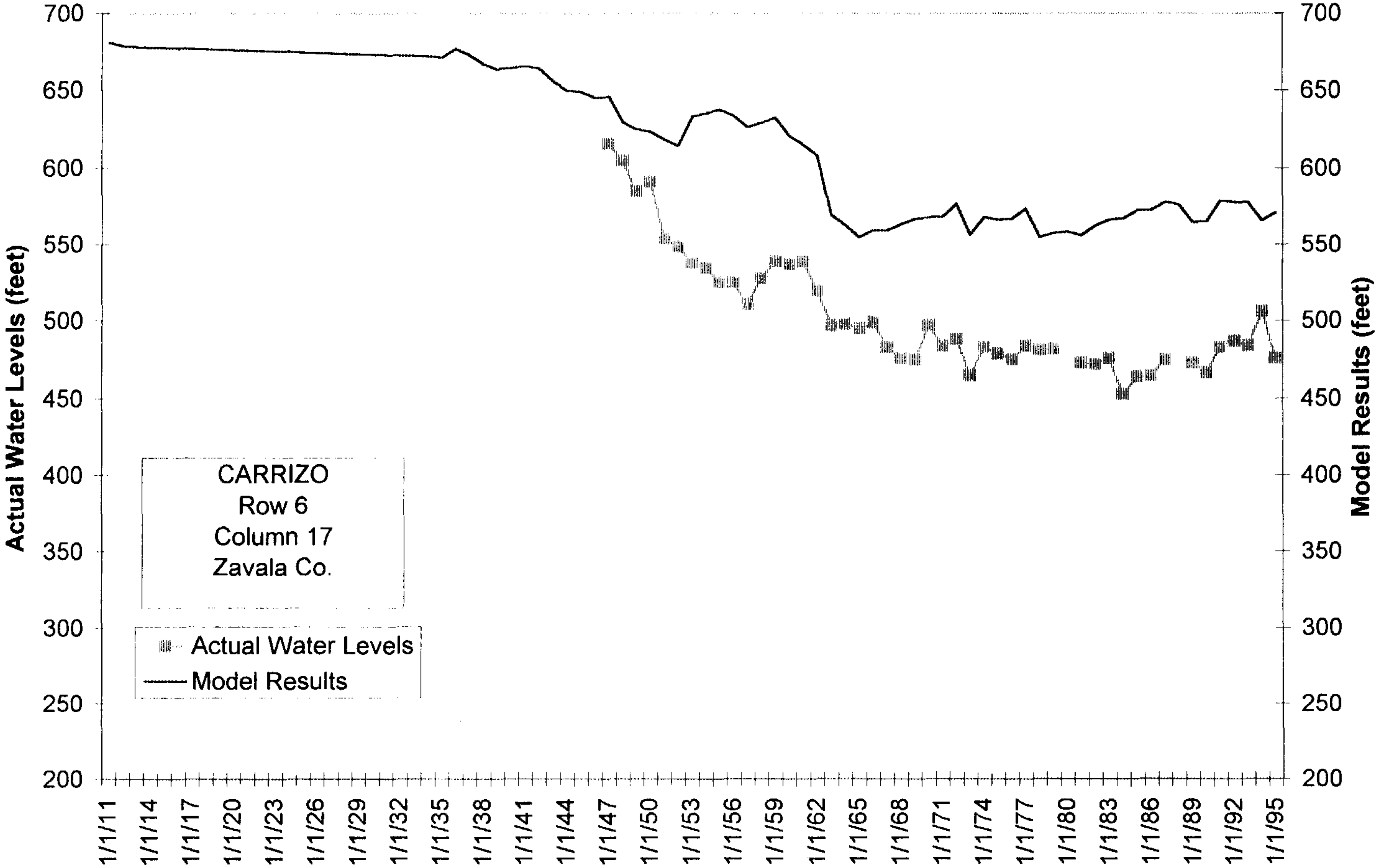
68-64-401 Hydrograph



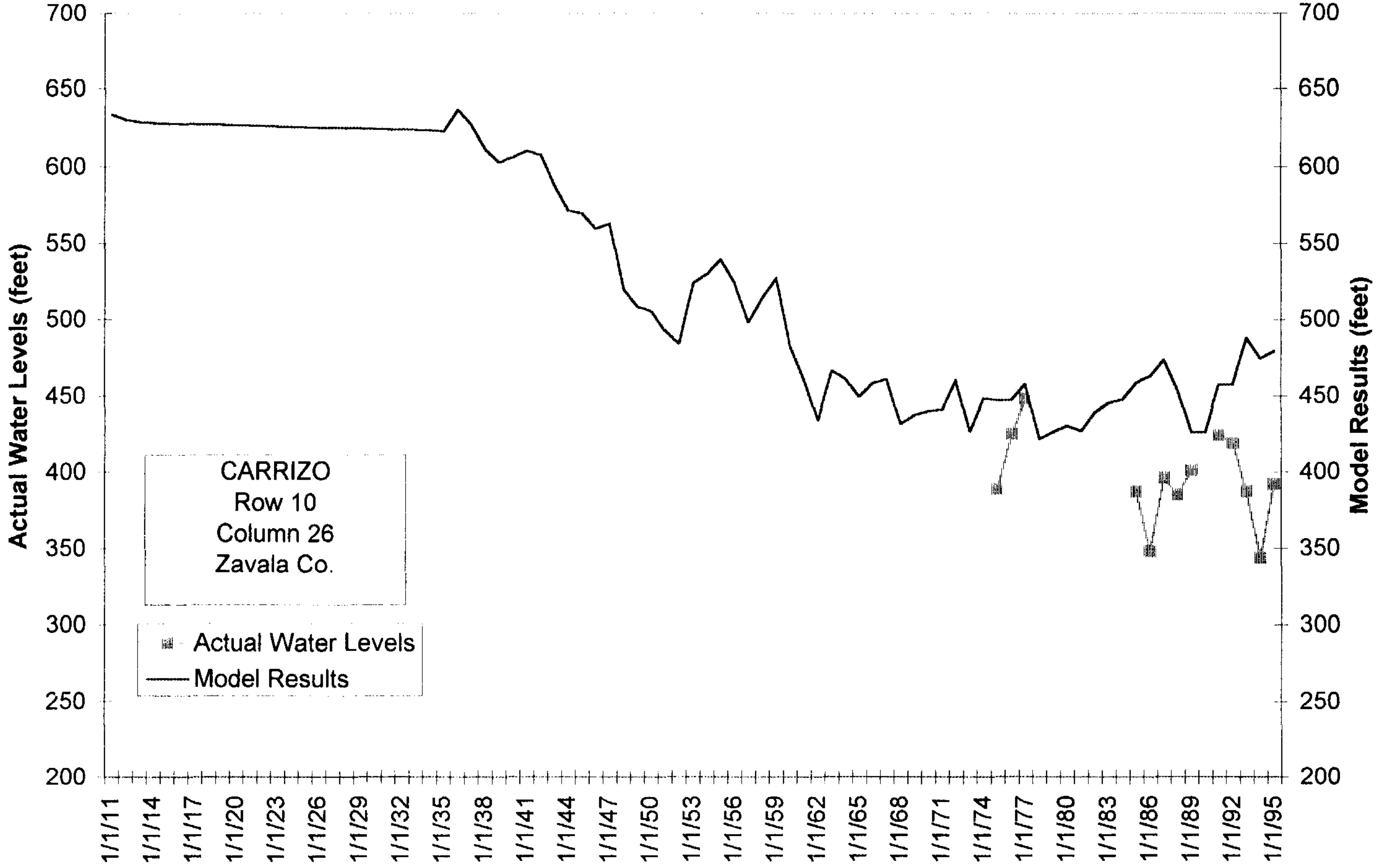
76-24-903 Hydrograph



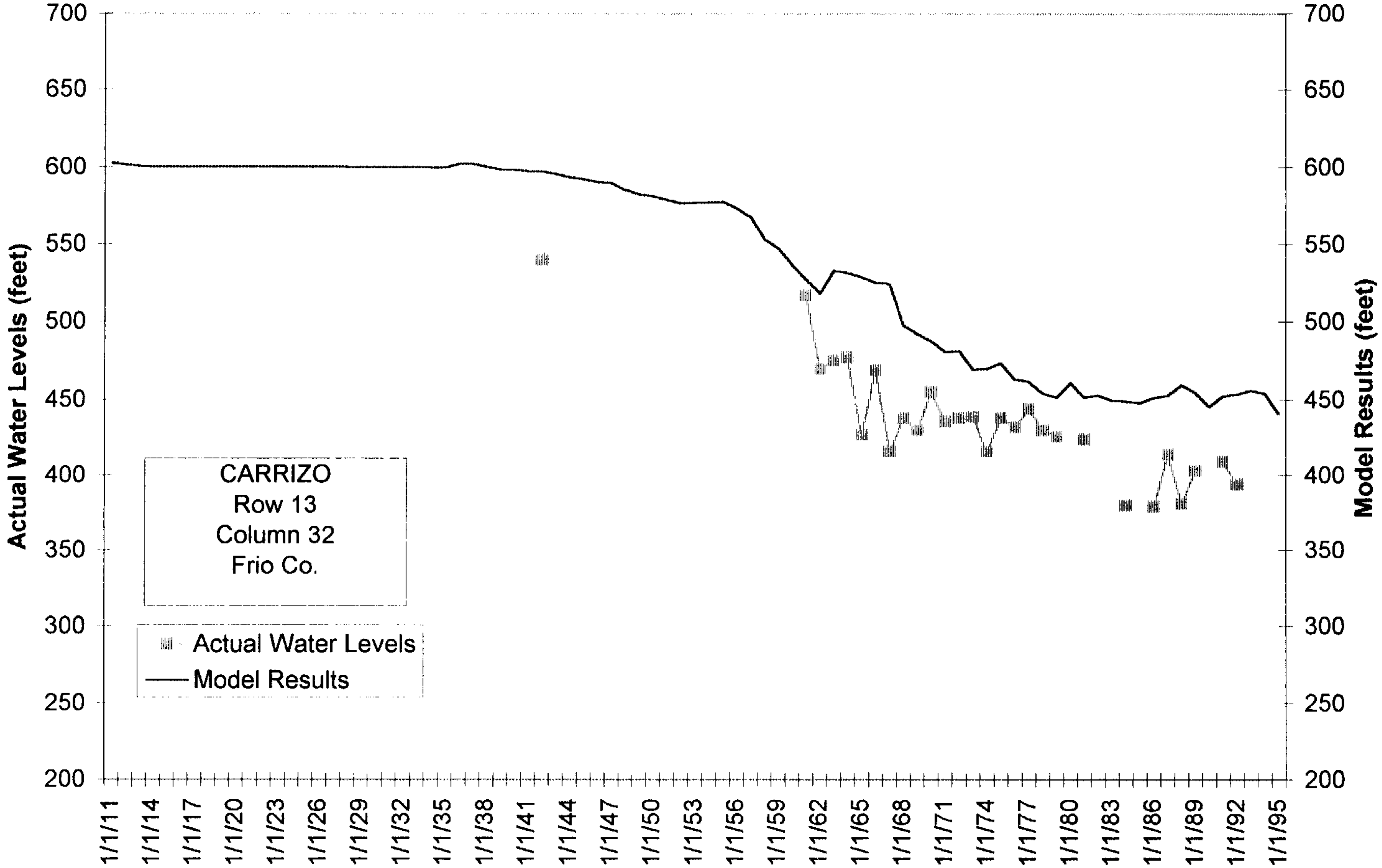
77-01-501 Hydrograph



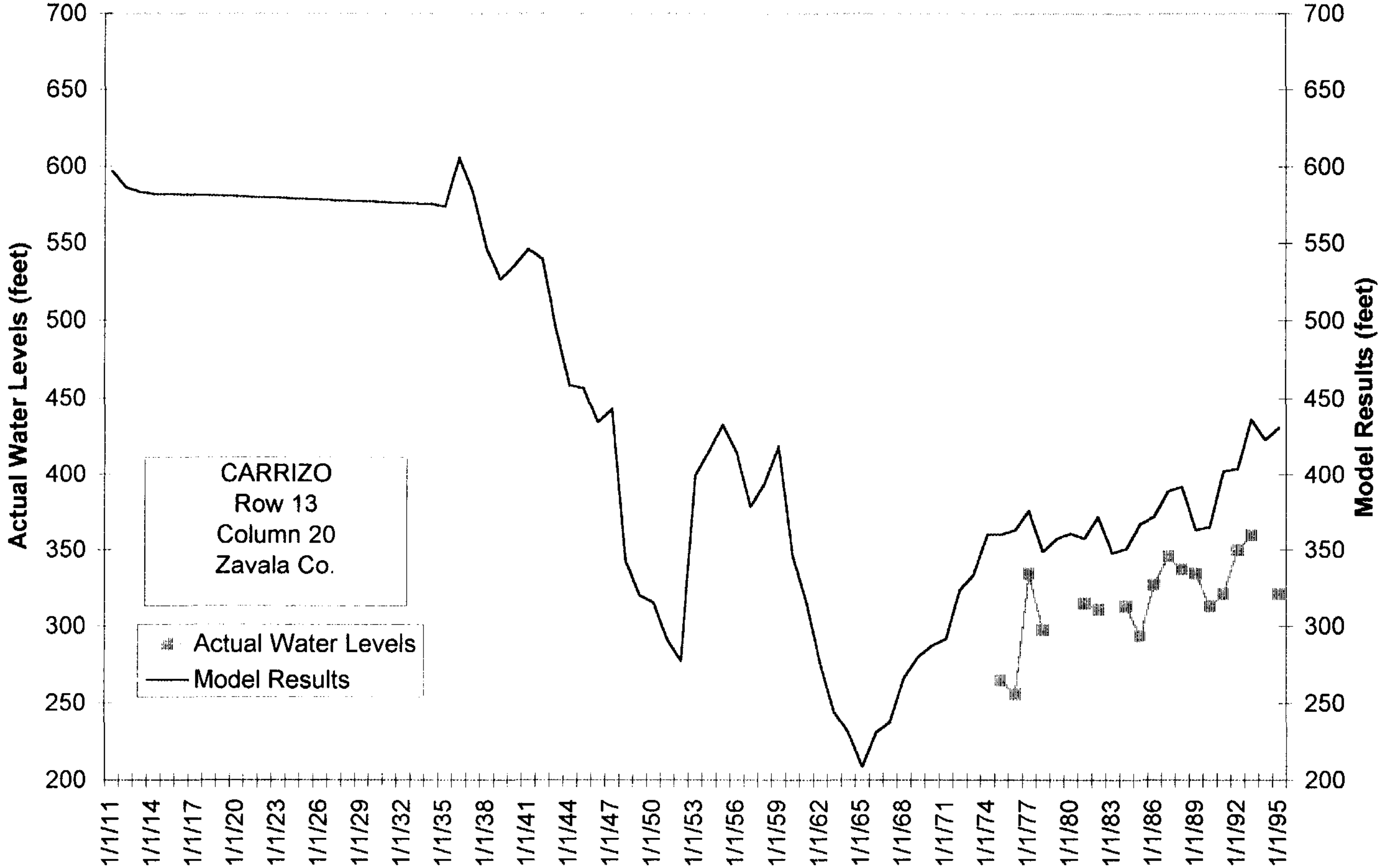
77-04-603 Hydrograph



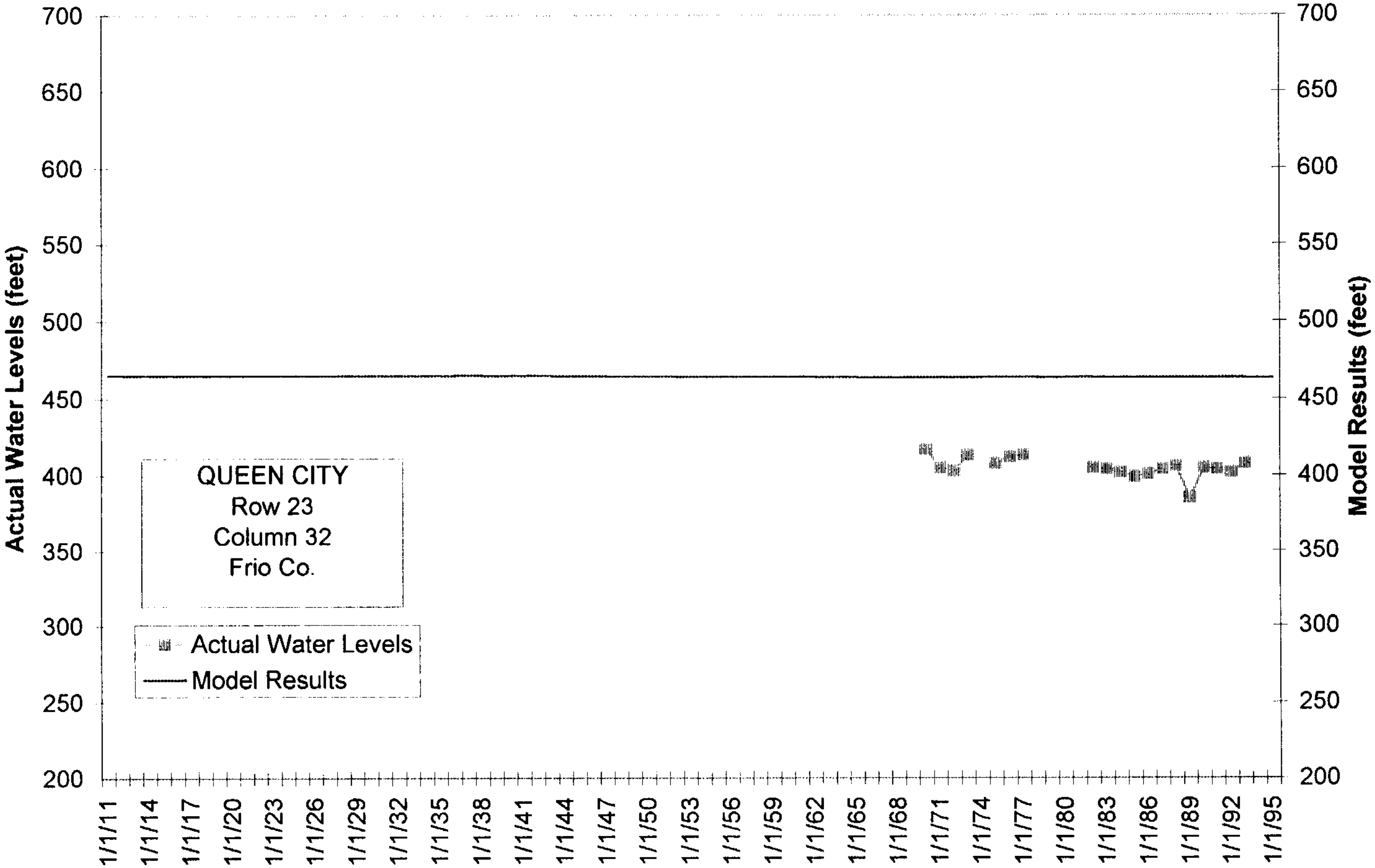
77-06-301 Hydrograph



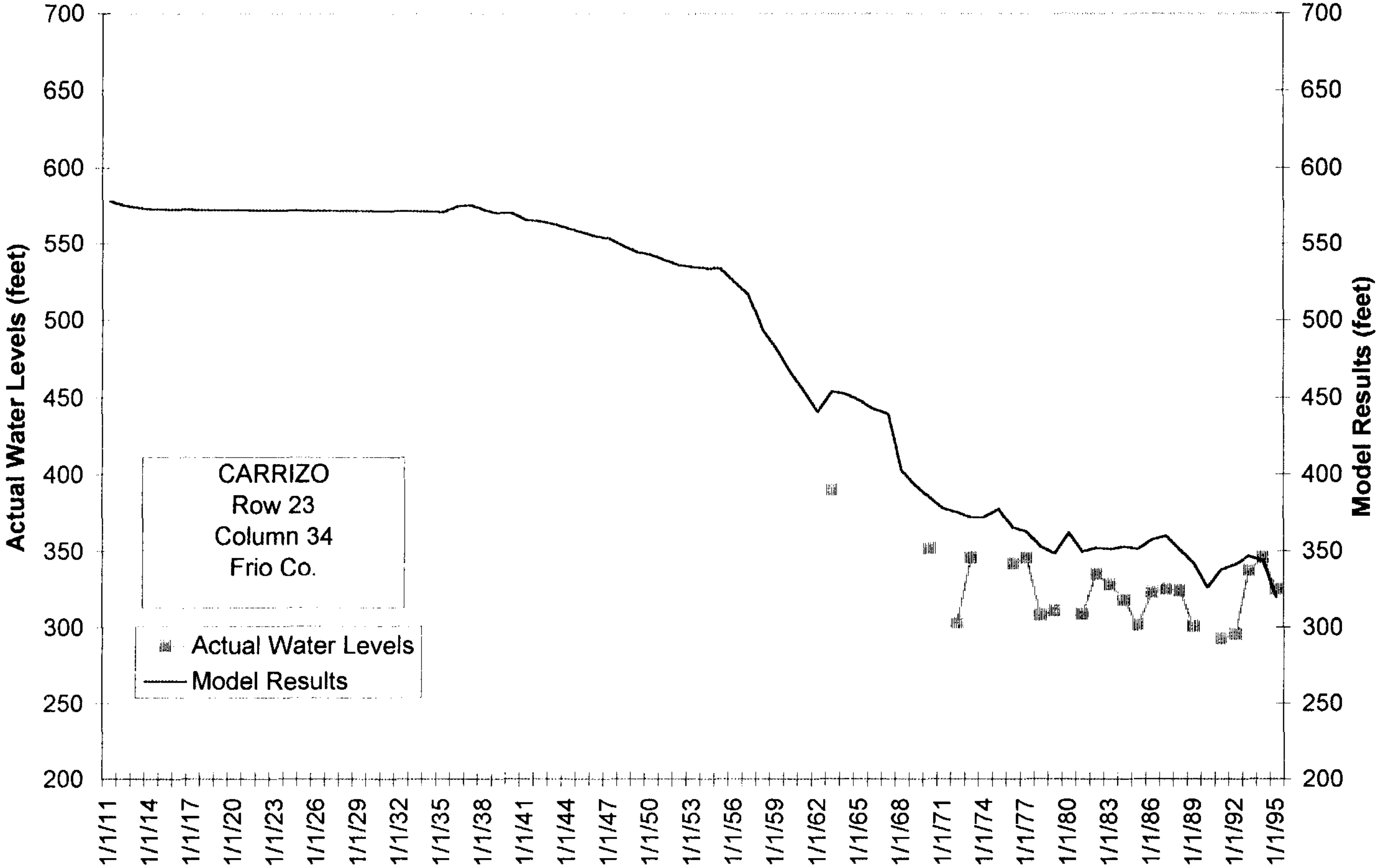
77-11-718 Hydrograph



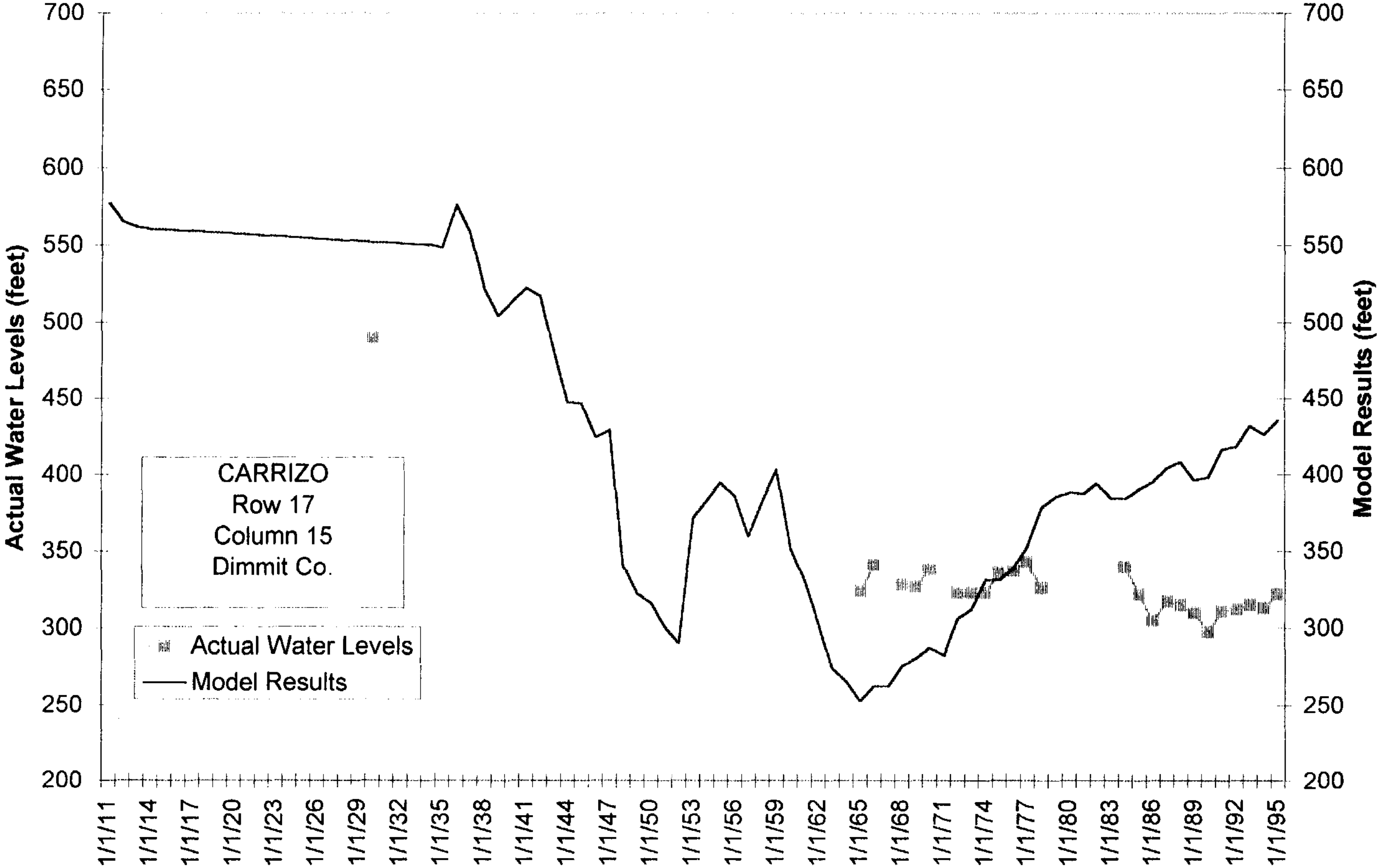
77-15-903 Hydrograph



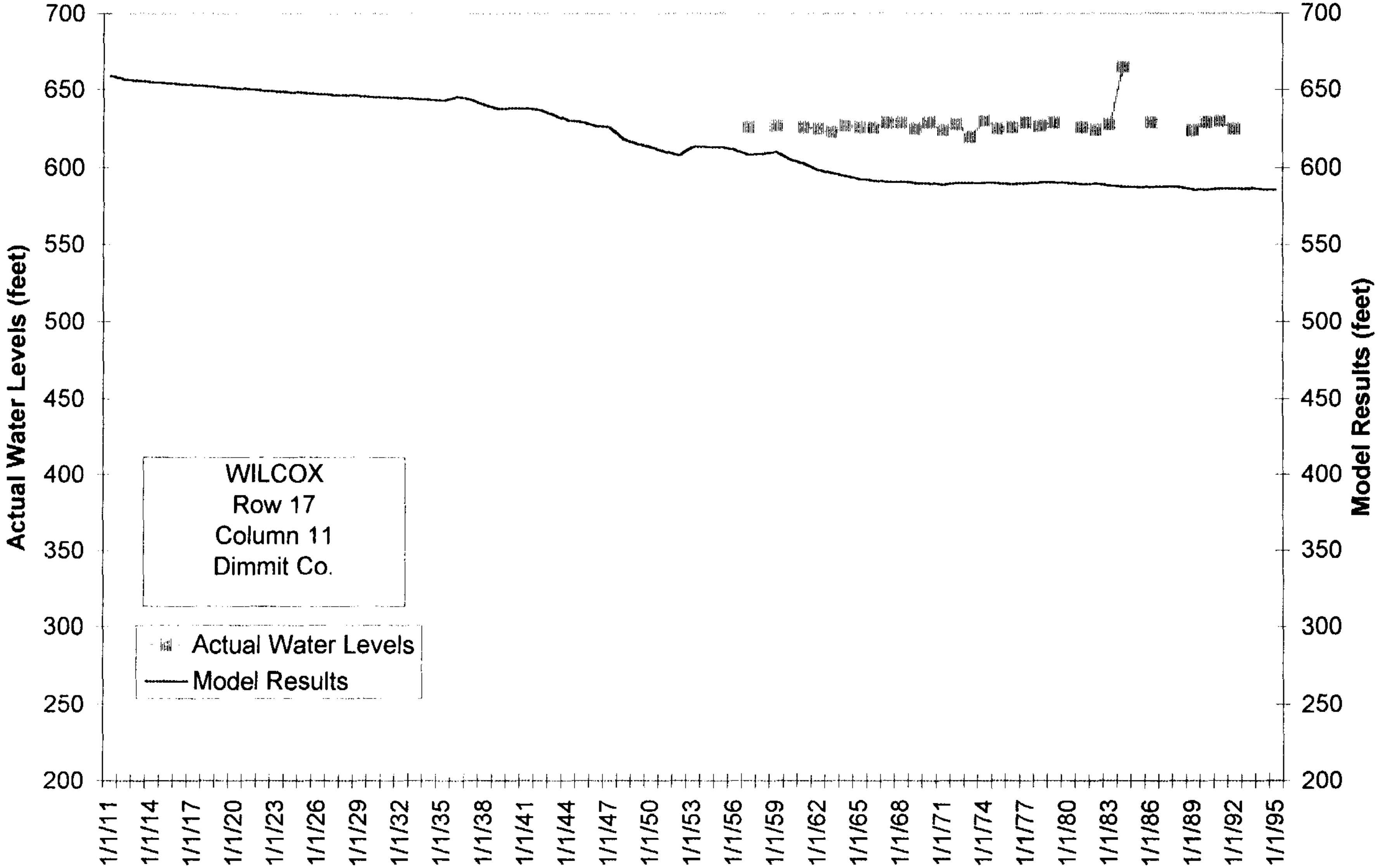
77-16-603 Hydrograph



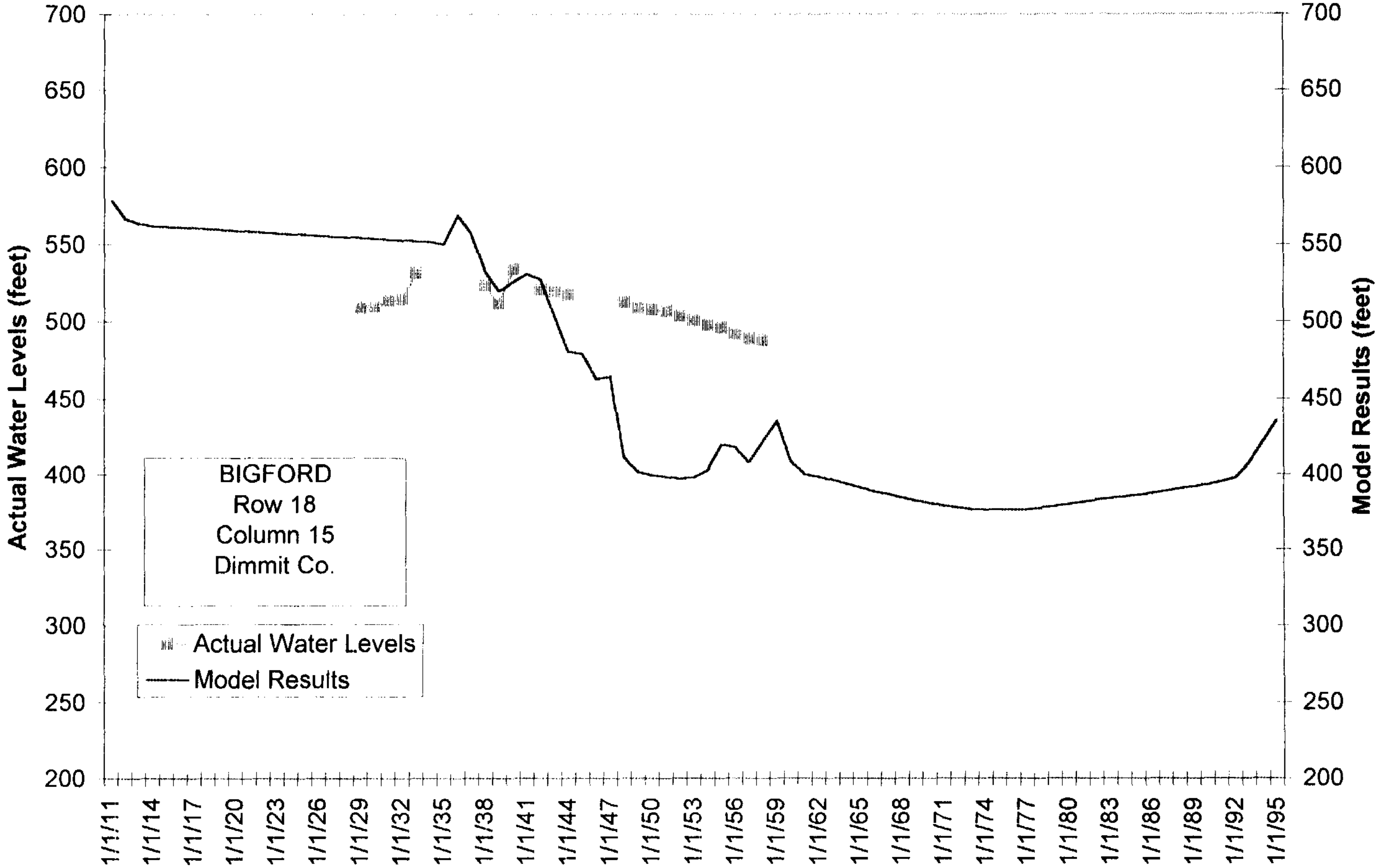
77-18-704 Hydrograph



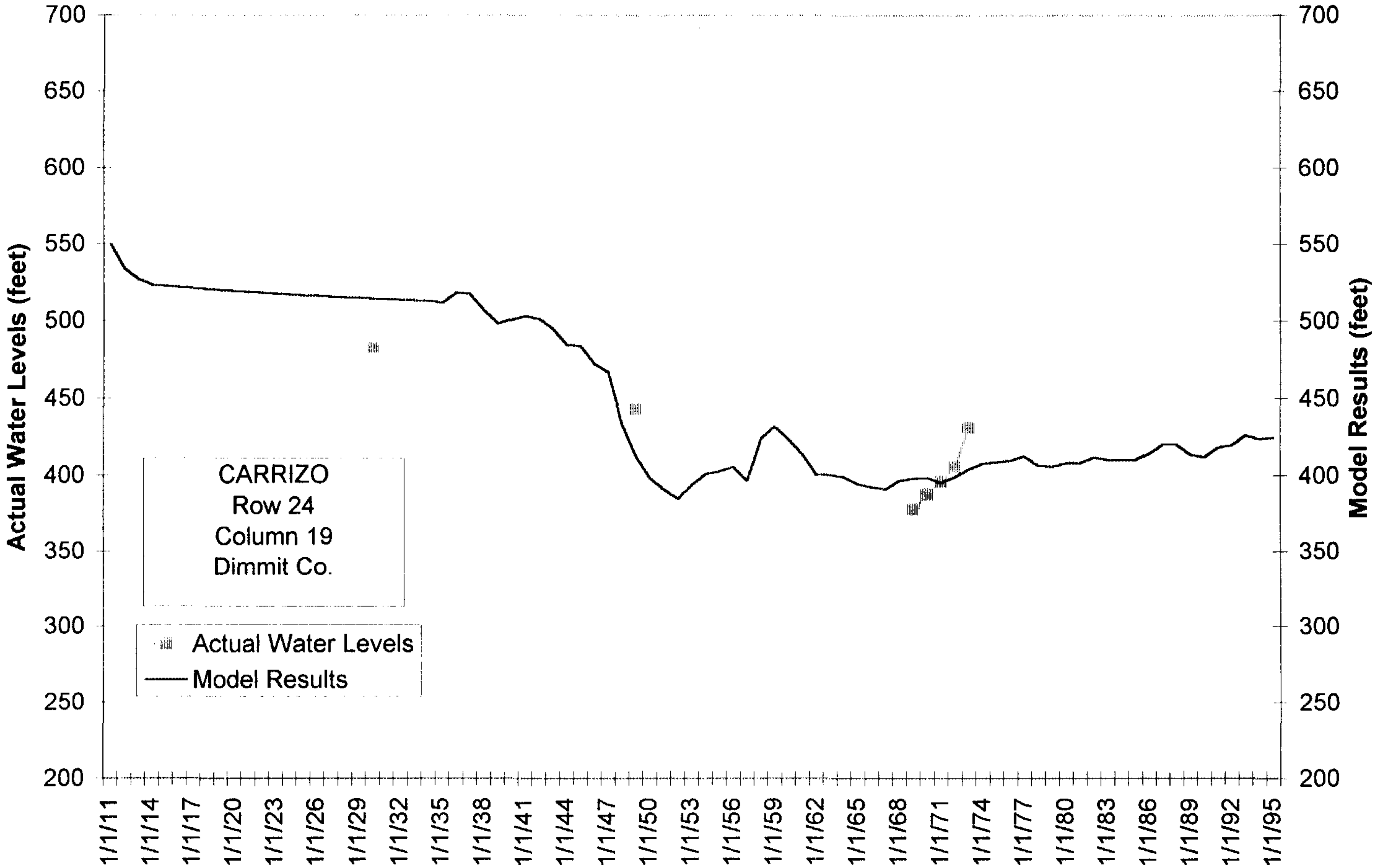
77-25-401 Hydrograph



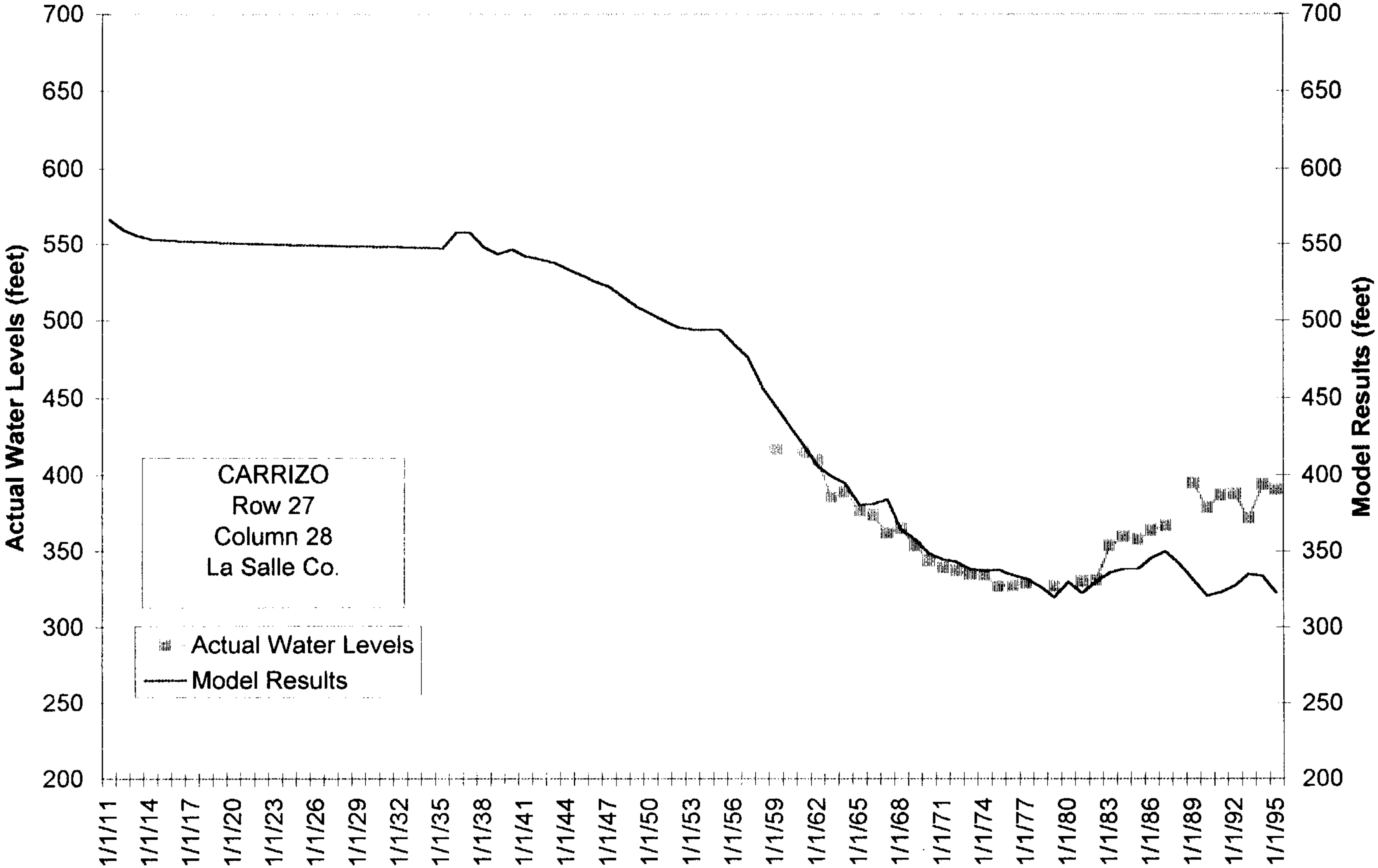
77-26-114 Hydrograph



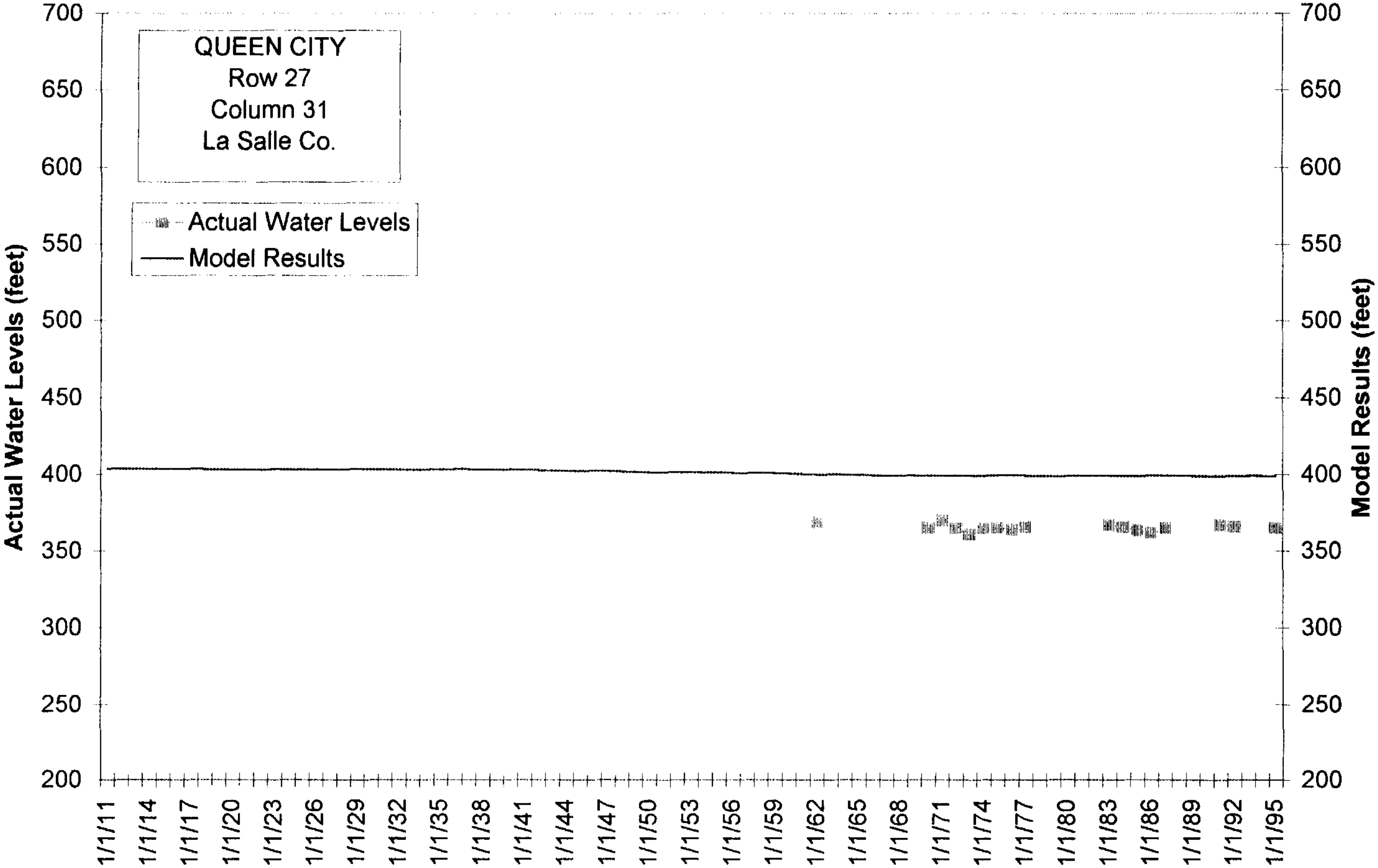
77-27-901 Hydrograph



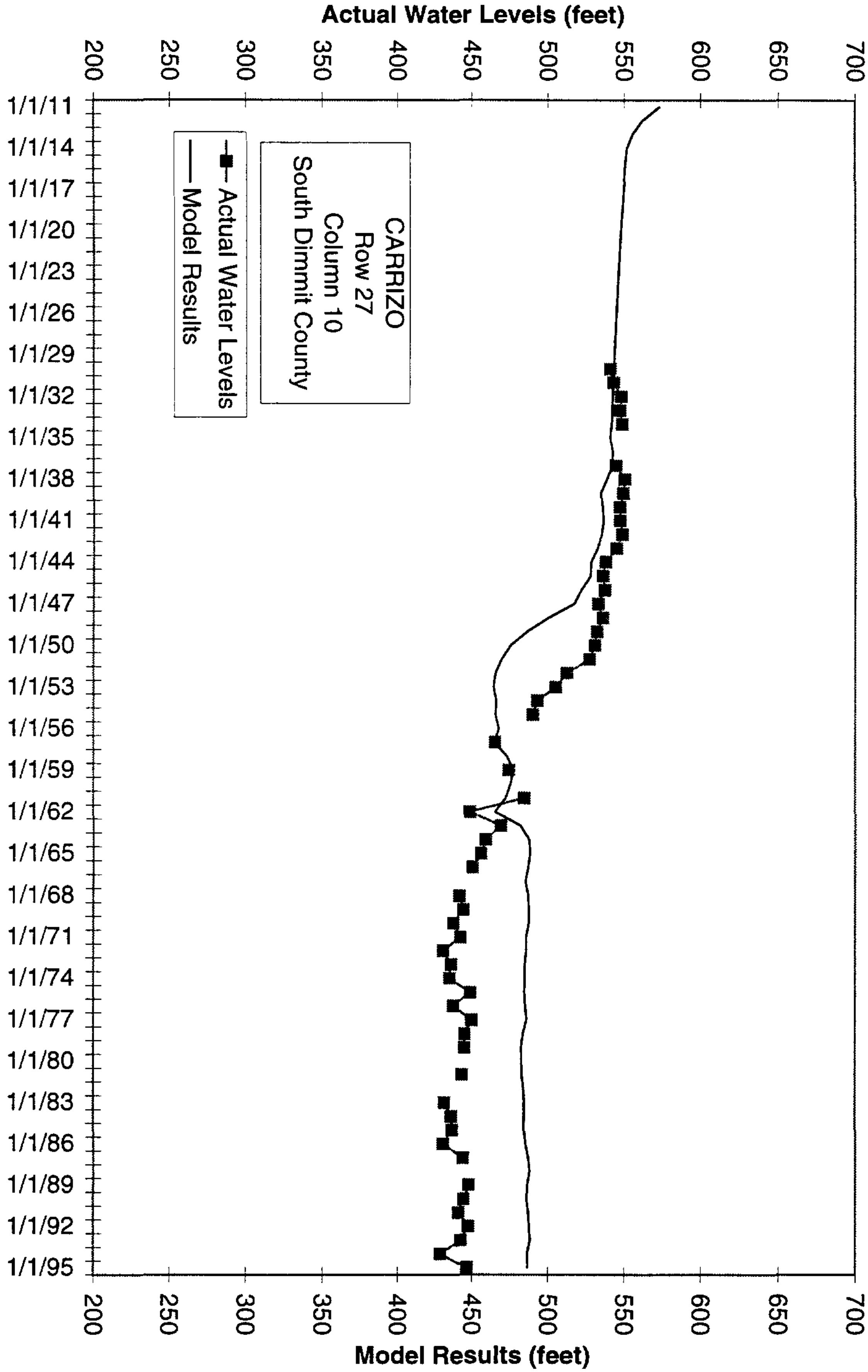
77-31-703 Hydrograph



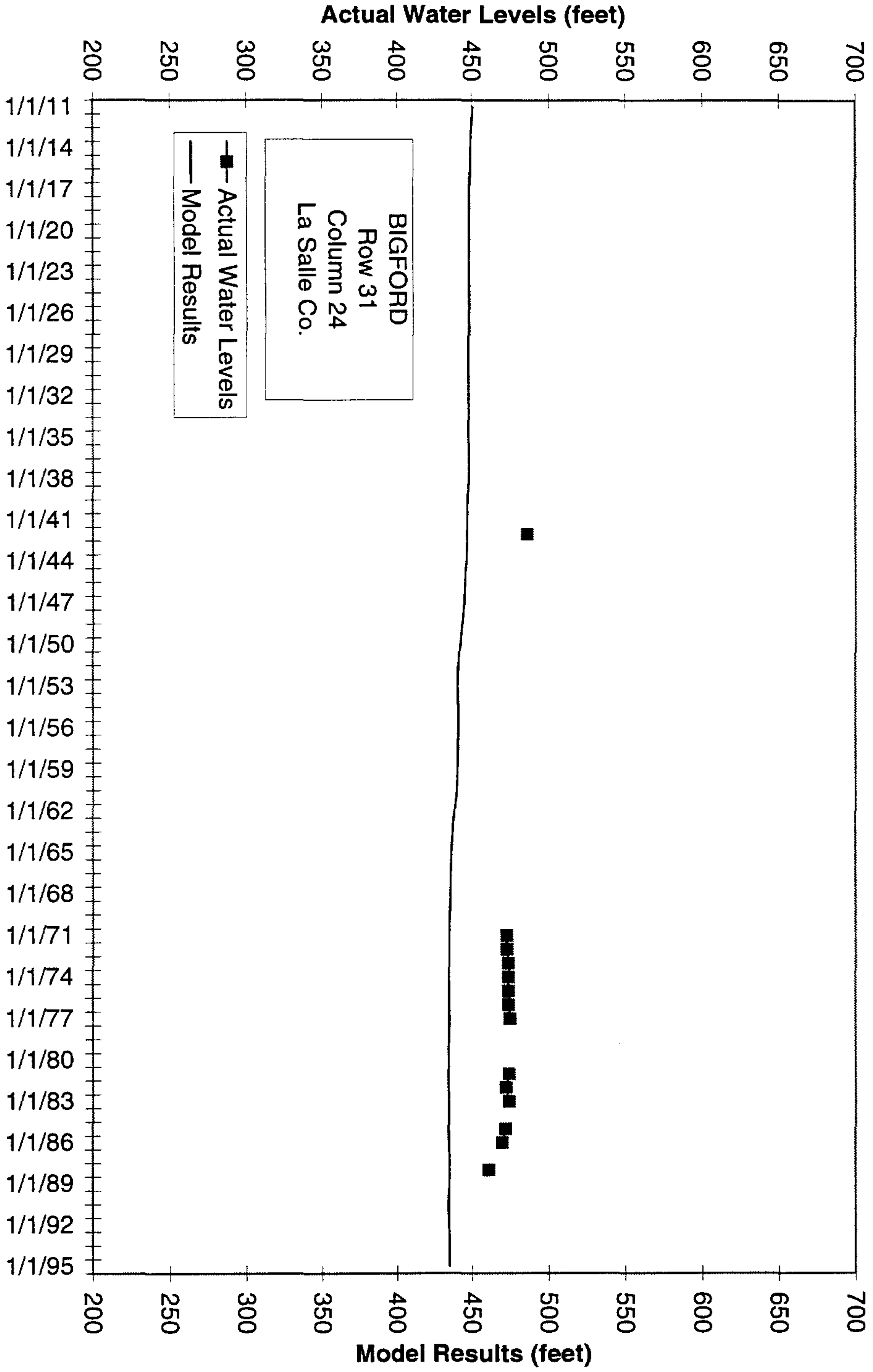
77-32-501 Hydrograph



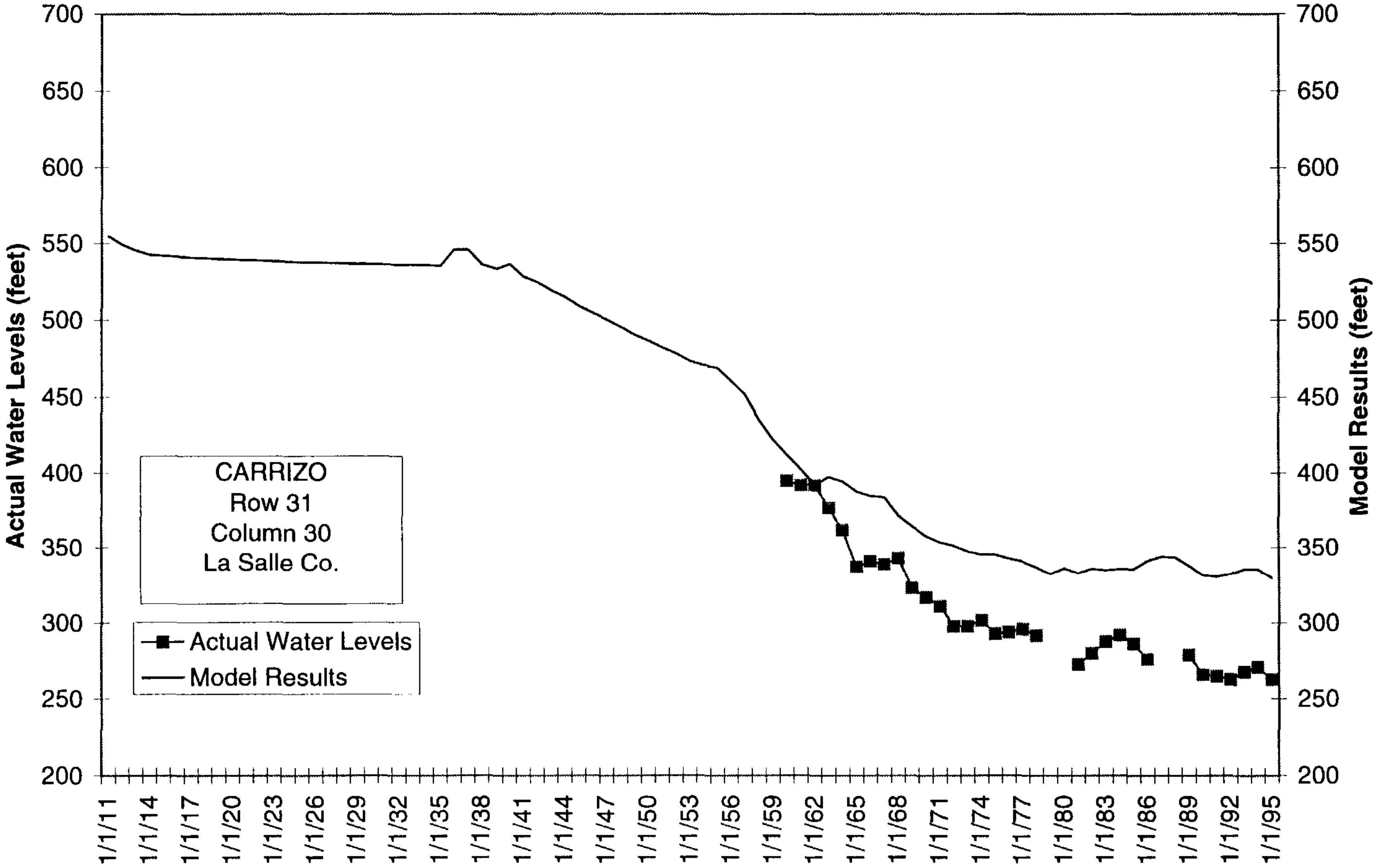
77-42-801 Hydrograph



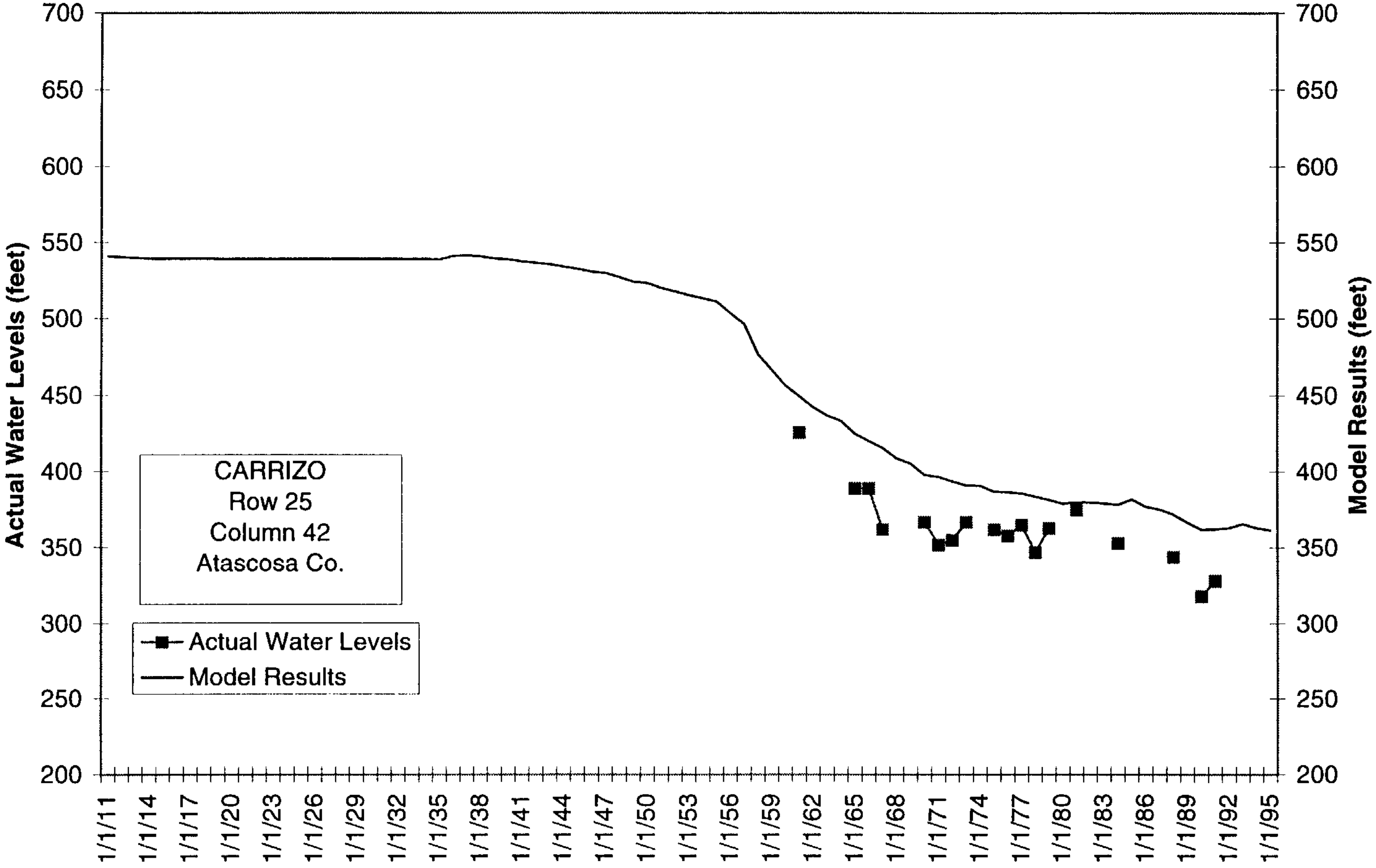
77-46-804 Hydrograph



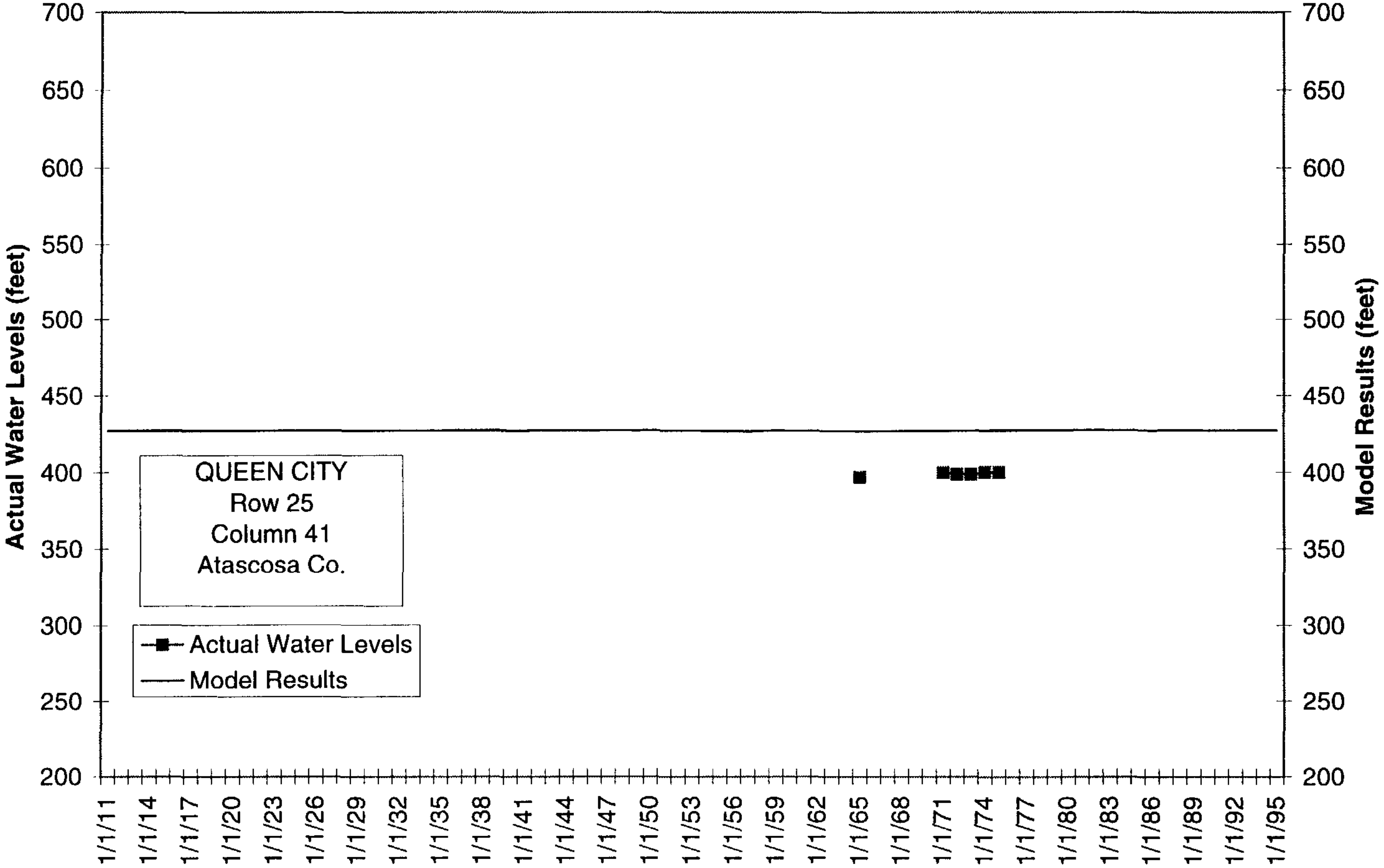
77-48-301 Hydrograph



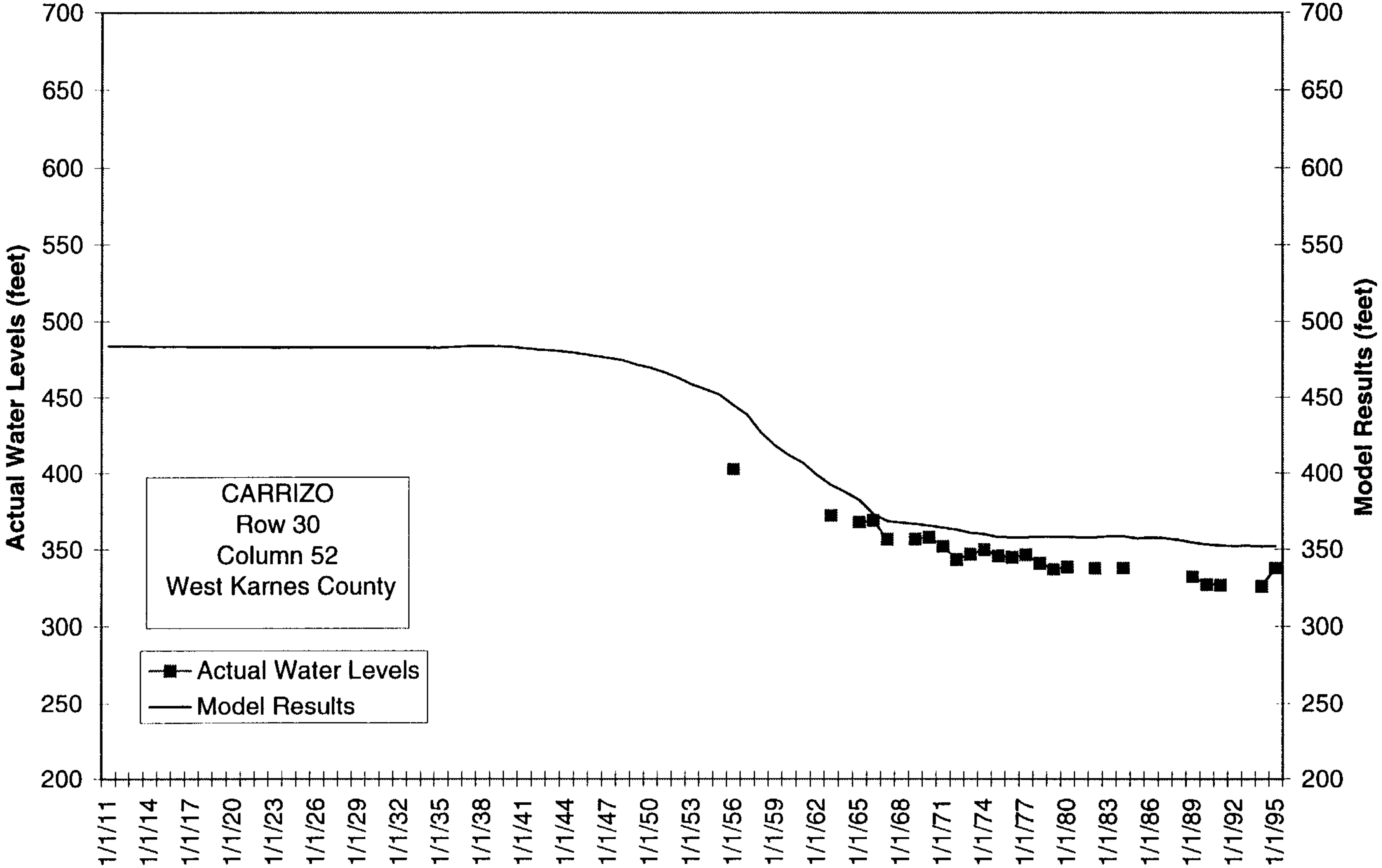
78-11-301 Hydrograph



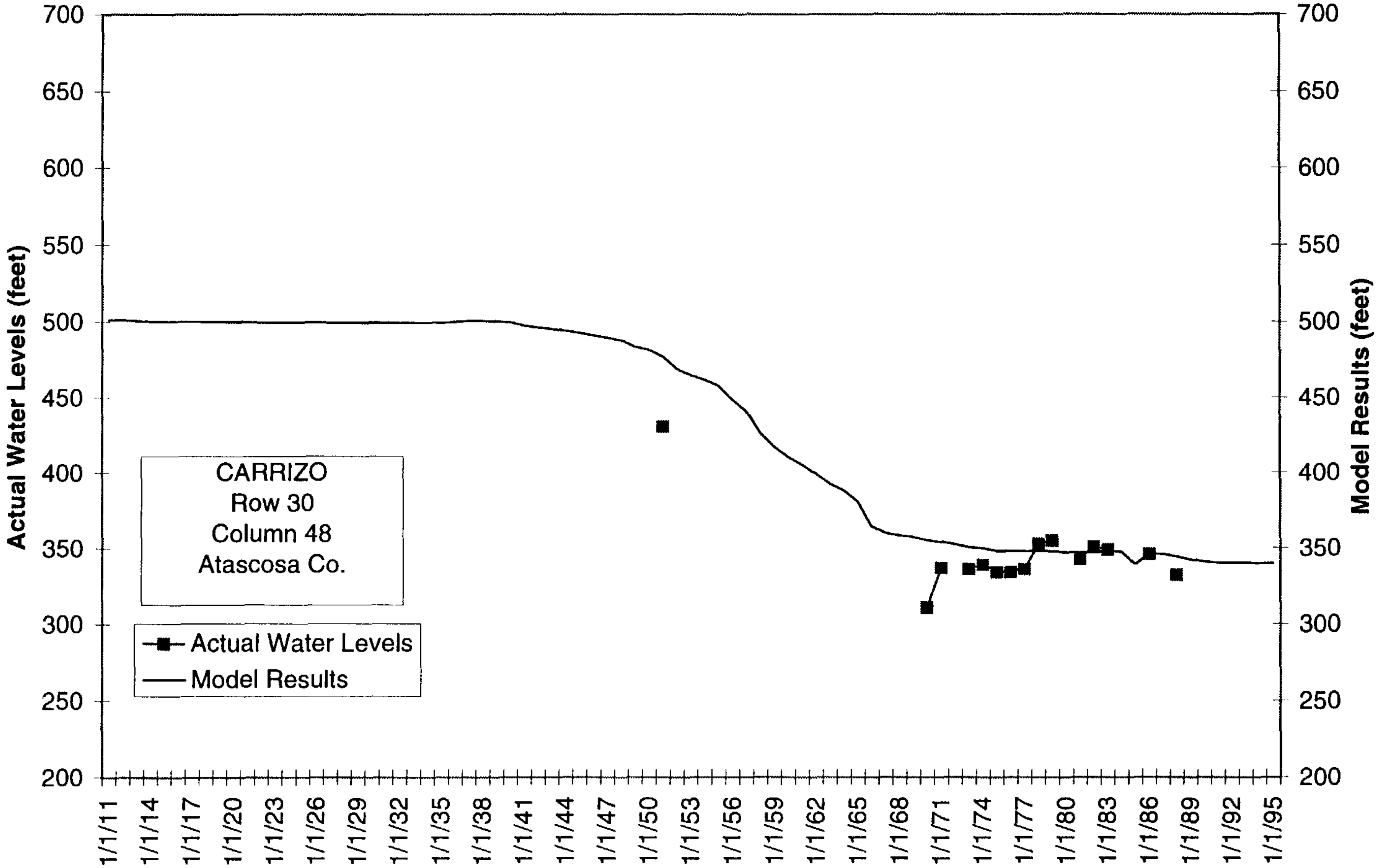
78-11-305 Hydrograph



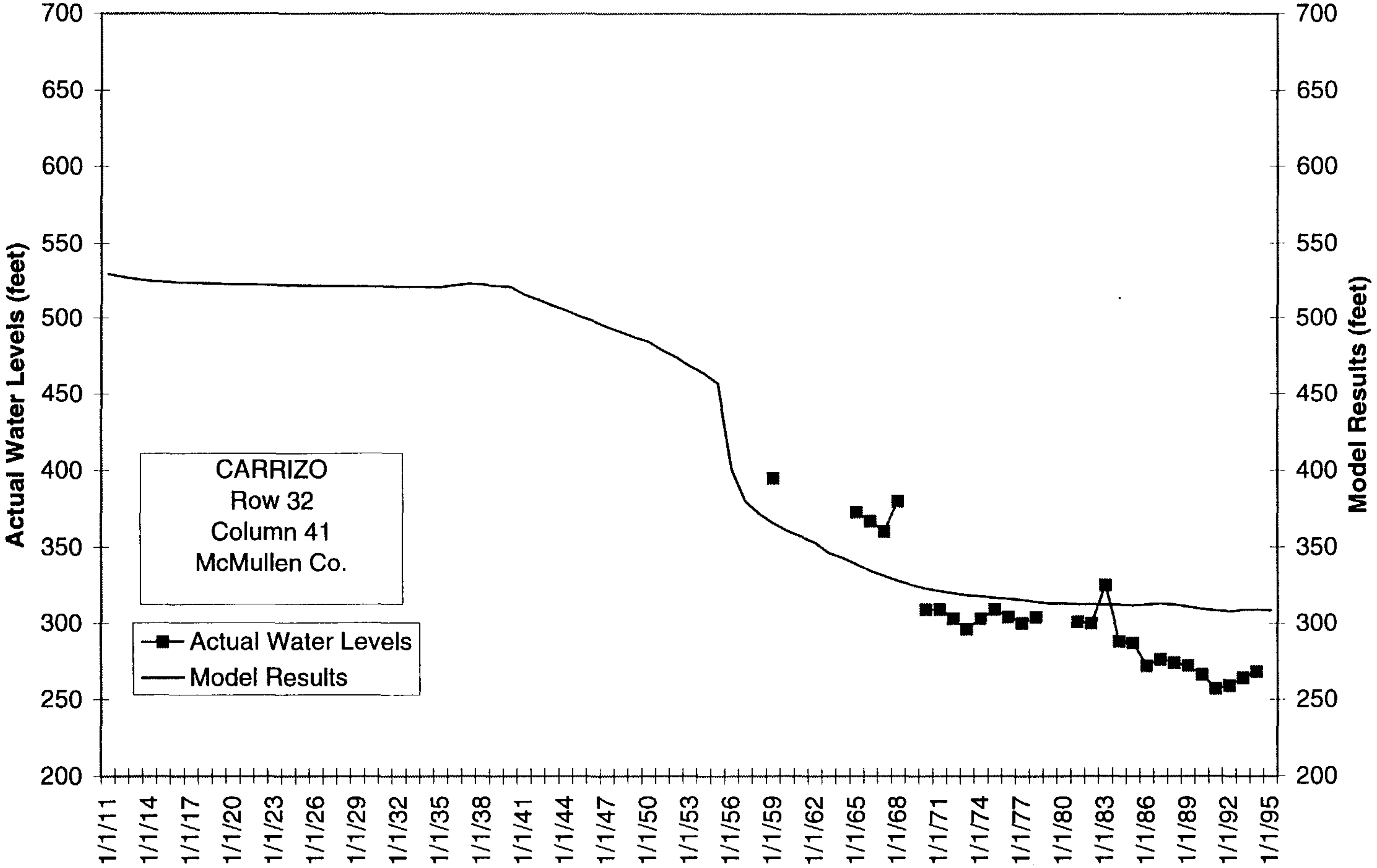
78-16-601 Hydrograph



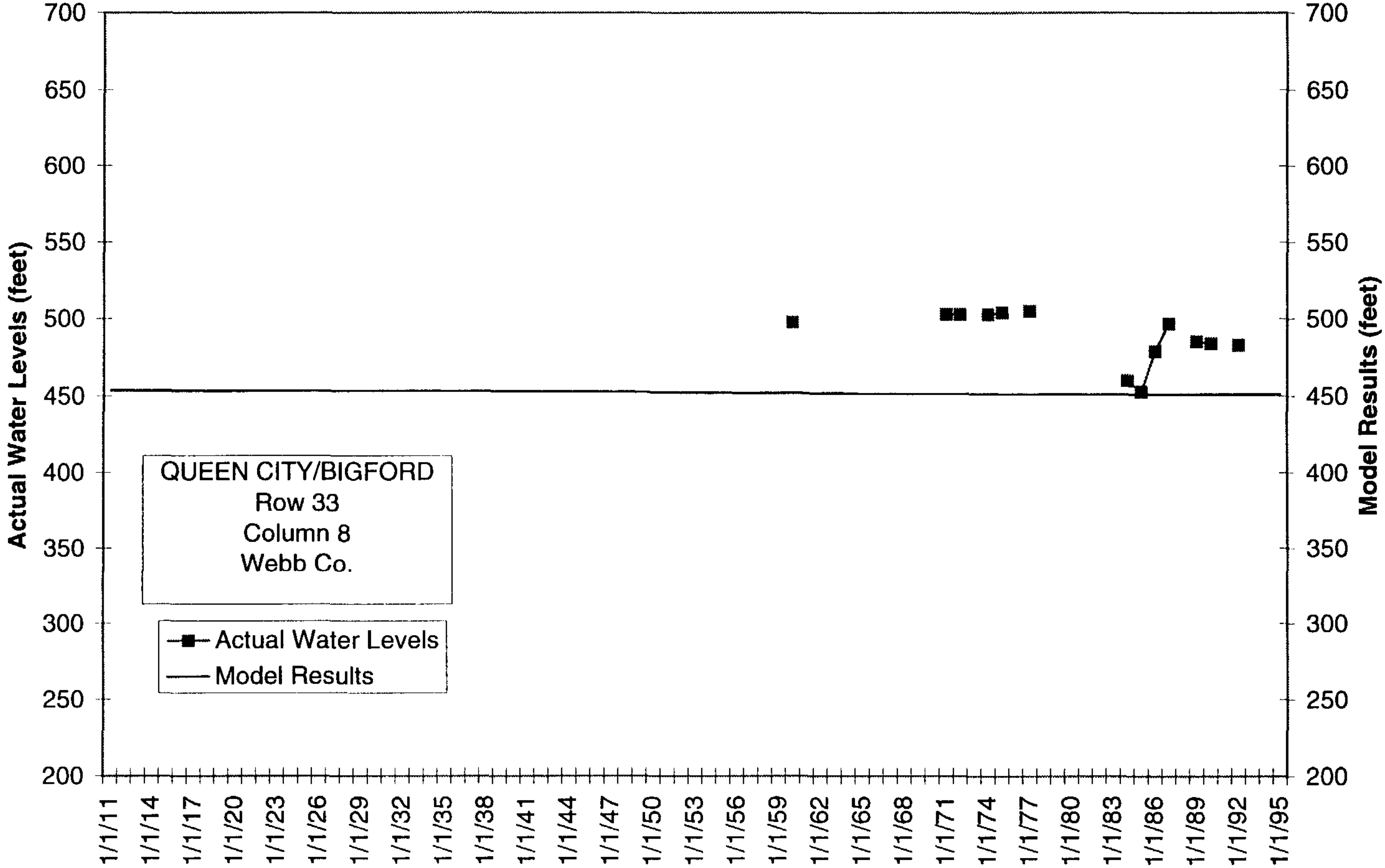
78-22-202 Hydrograph



78-37-103 Hydrograph



85-19-201 Hydrograph



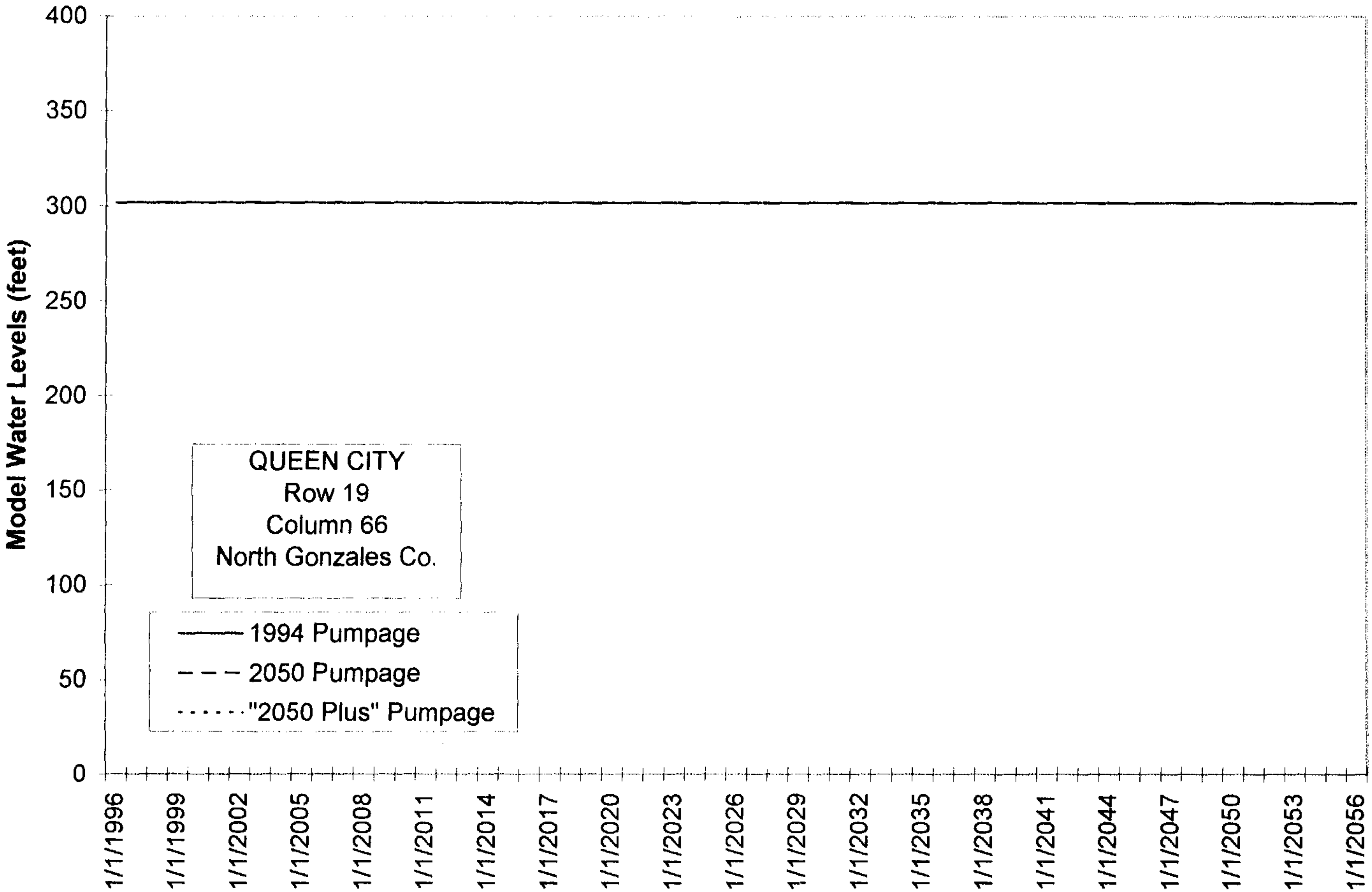
APPENDIX D

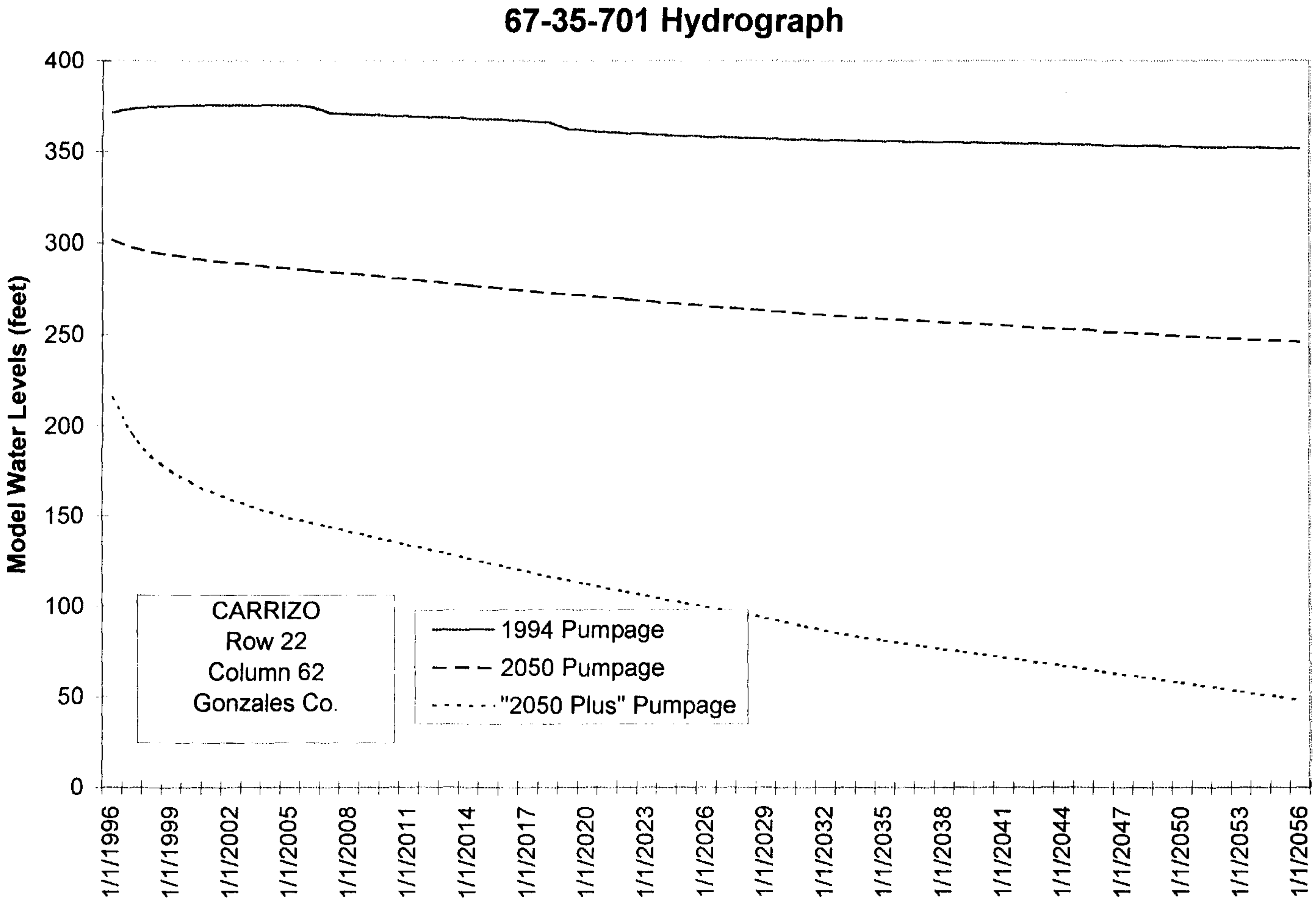
HYDROGRAPHS GENERATED FOR FUTURE GROUND-WATER PUMPAGE SCENARIOS

APPENDIX D

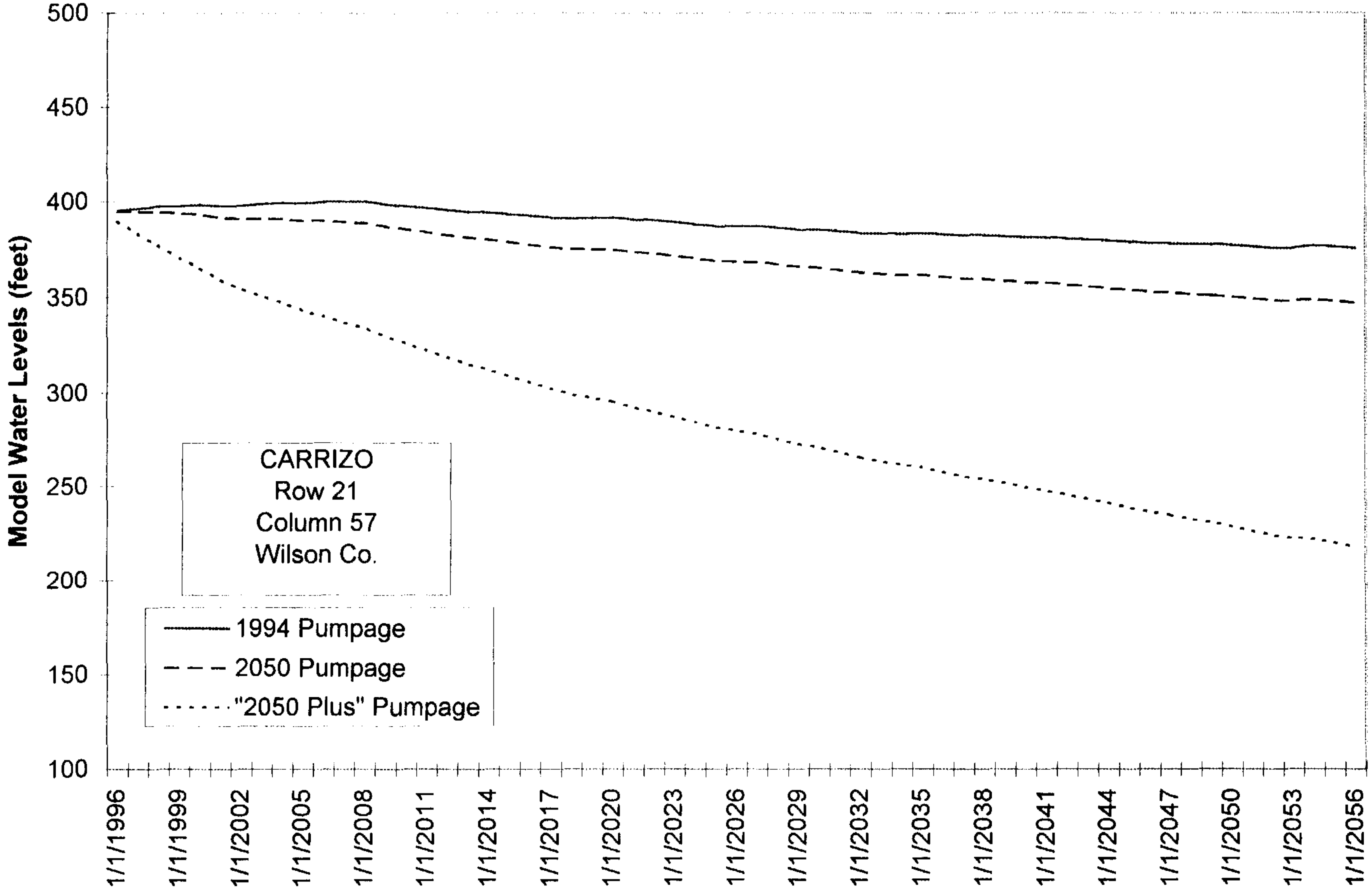
HYDROGRAPHS GENERATED FOR FUTURE GROUND-WATER PUMPAGE SCENARIOS

67-28-303 Hydrograph

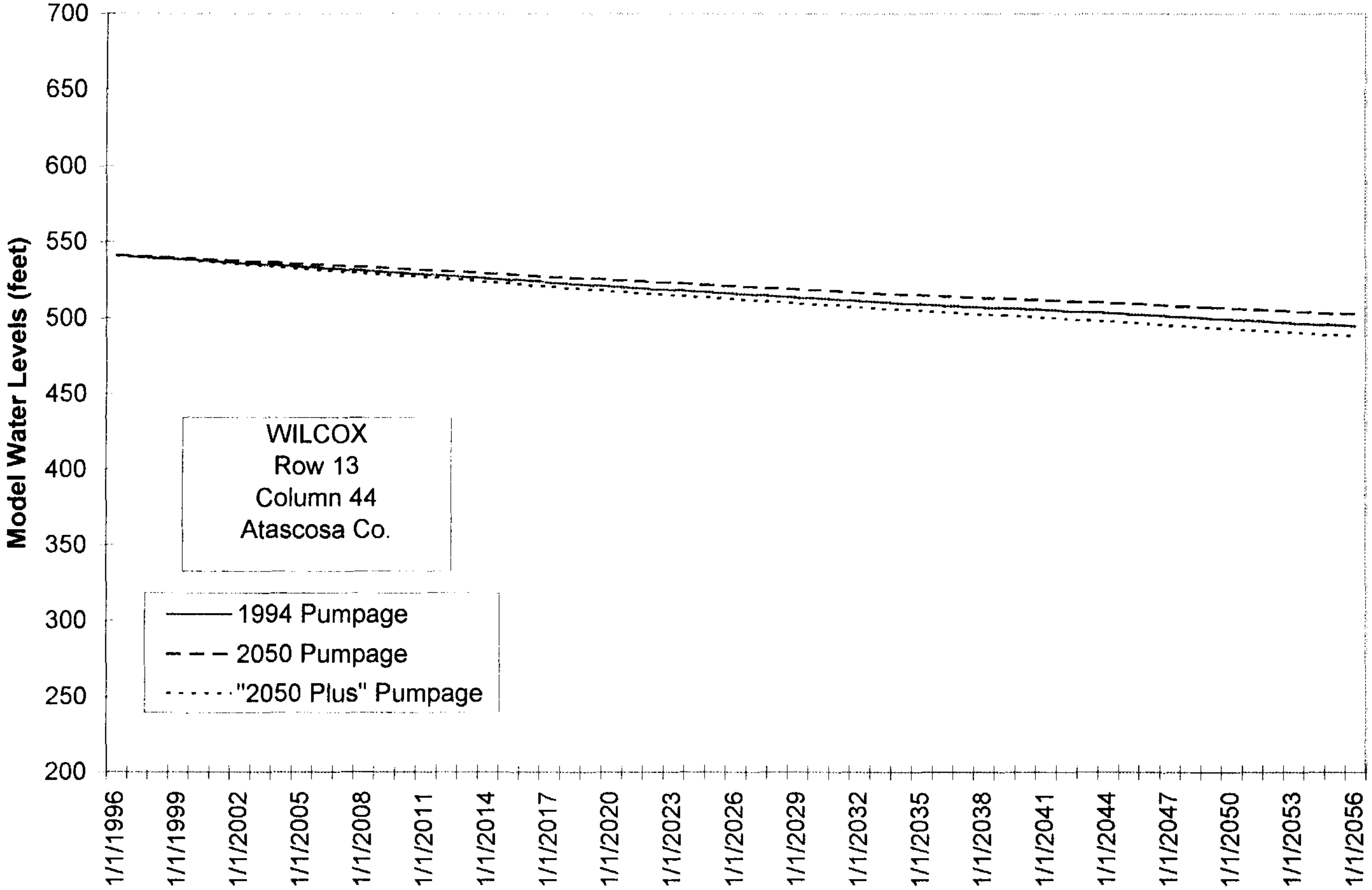


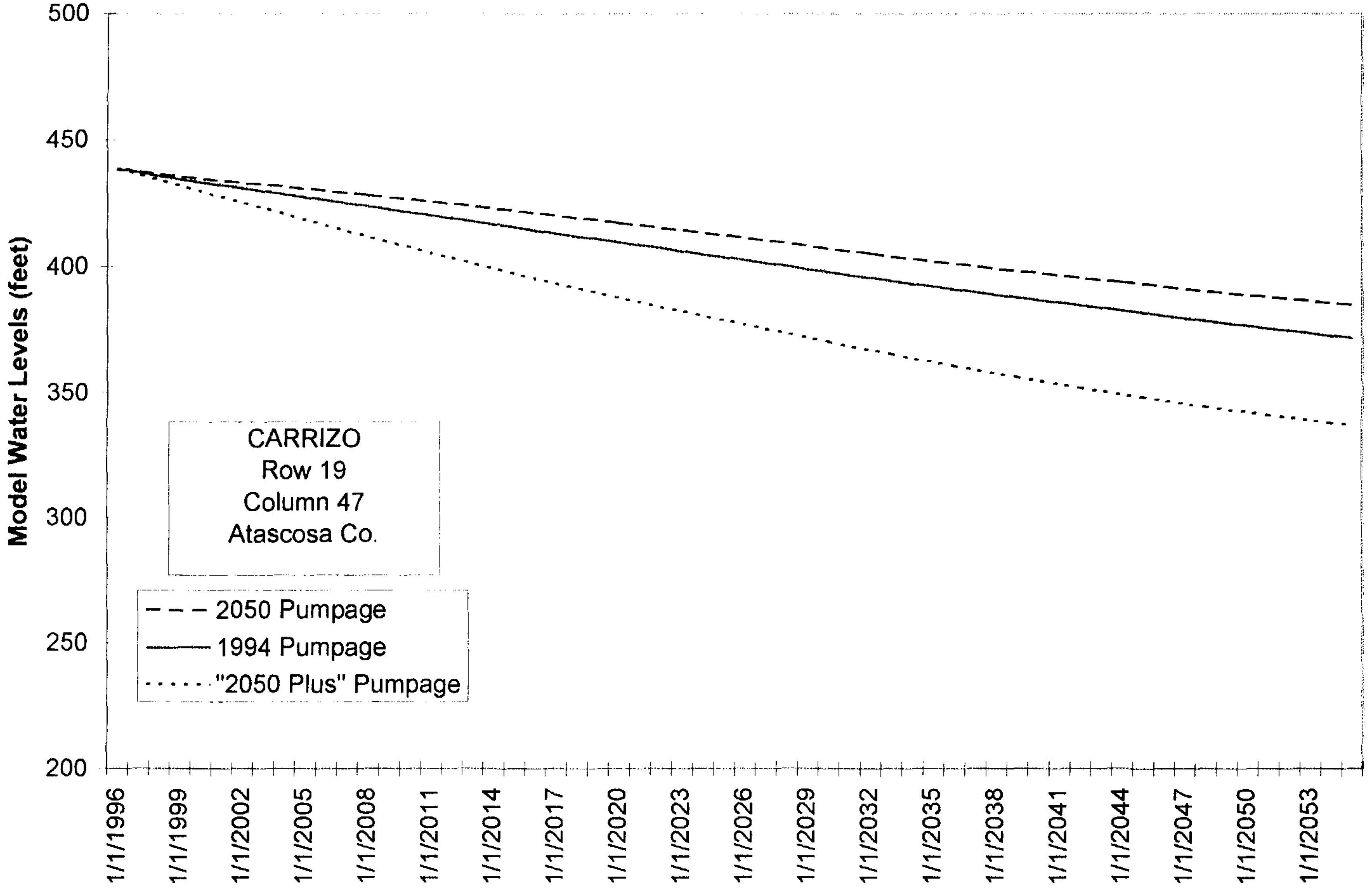
67-35-701 Hydrograph
Model Water Levels (feet)
400
350
300
250
200
150
100
50
0
CARRIZO
Row 22
Column 62
Gonzales Co.
1994 Pumpage
2050 Pumpage
"2050 Plus" Pumpage
1/1/1996
1/1/1999
1/1/2002
1/1/2005
1/1/2008
1/1/2011
1/1/2014
1/1/2017
1/1/2020
1/1/2023
1/1/2026
1/1/2029
1/1/2032
1/1/2035
1/1/2038
1/1/2041
1/1/2044
1/1/2047
1/1/2050
1/1/2053
1/1/2056

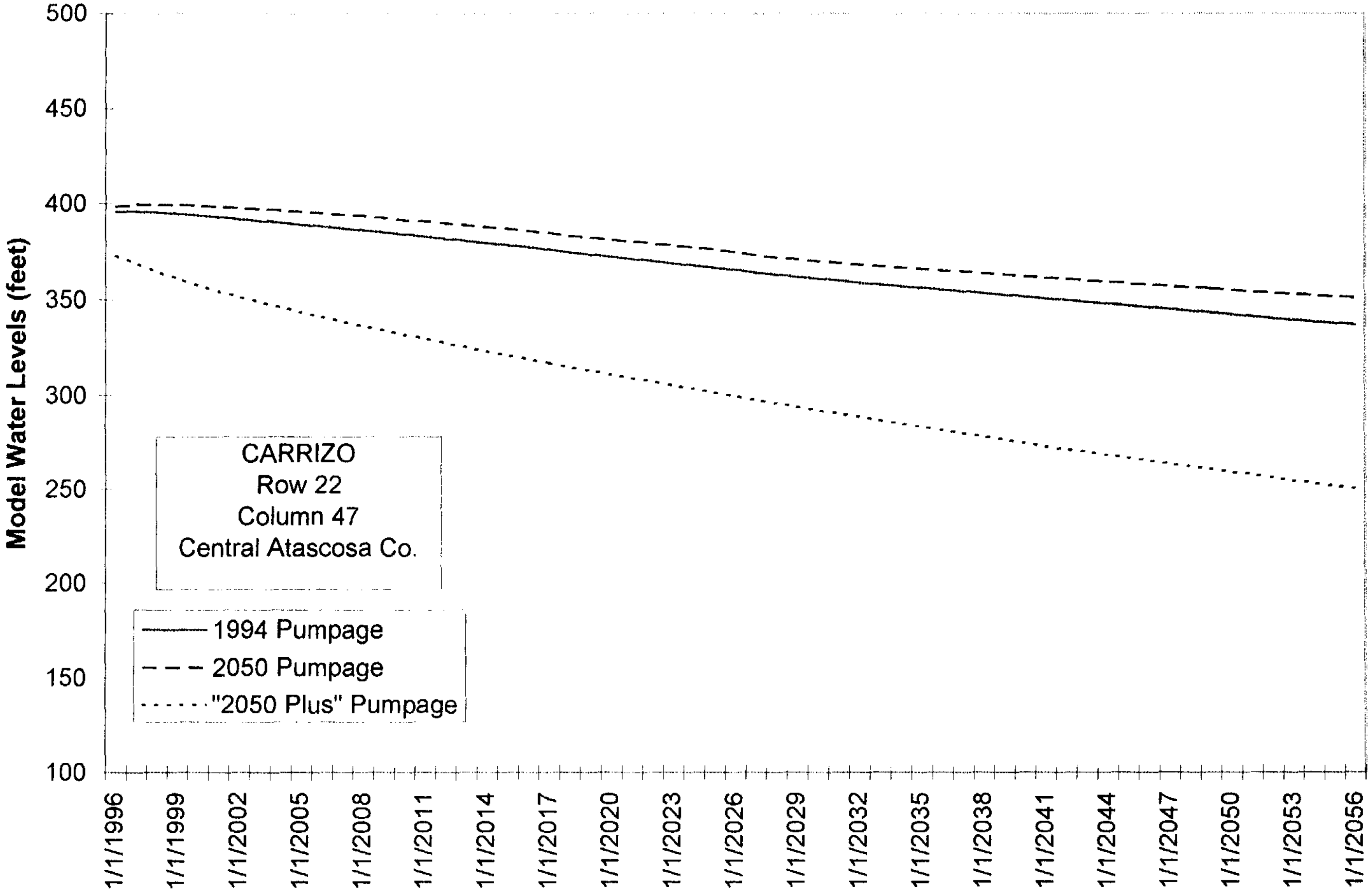
68-48-801 Hydrograph



68-50-603 Hydrograph

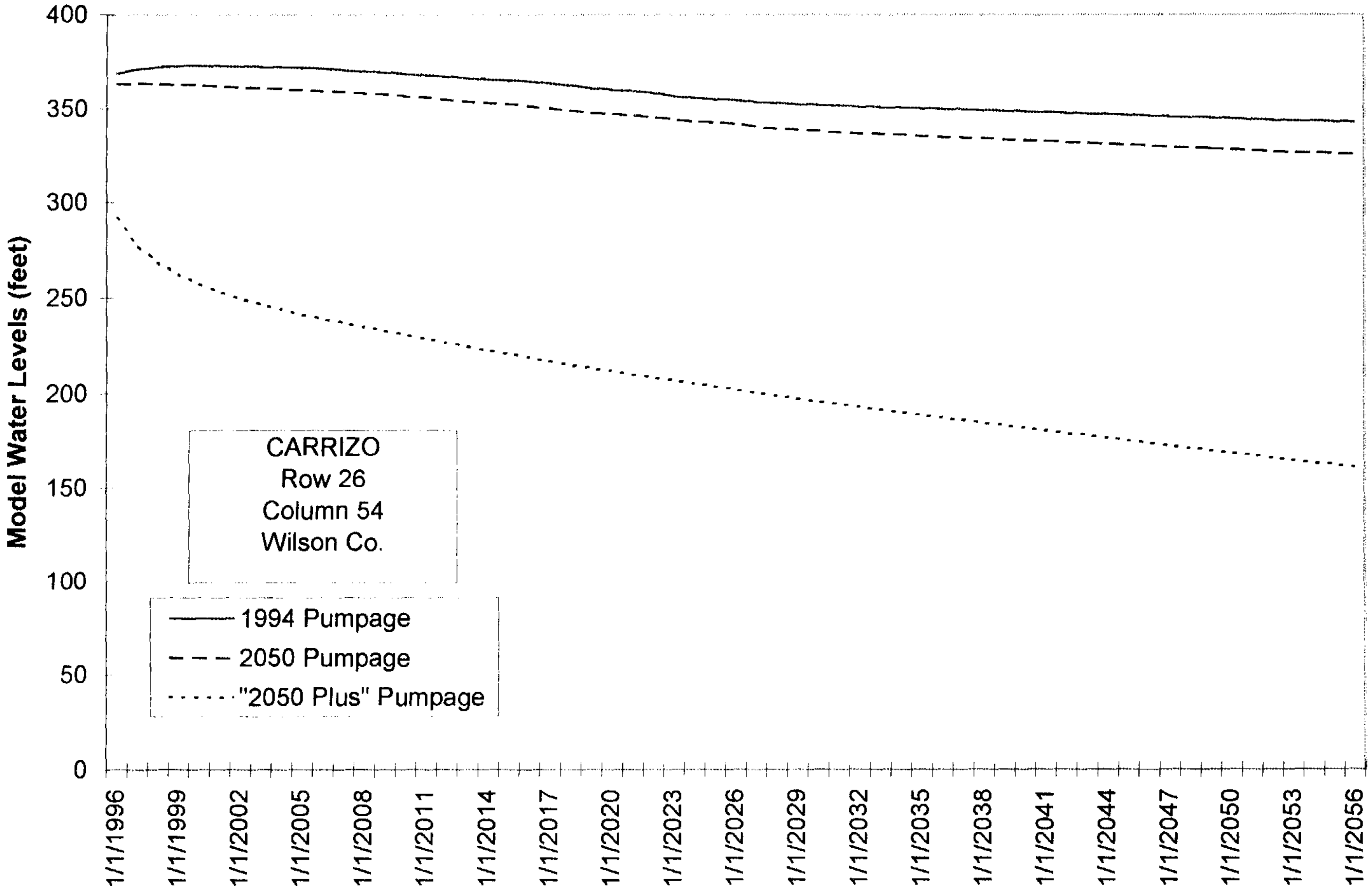



68-52-718 Hydrograph

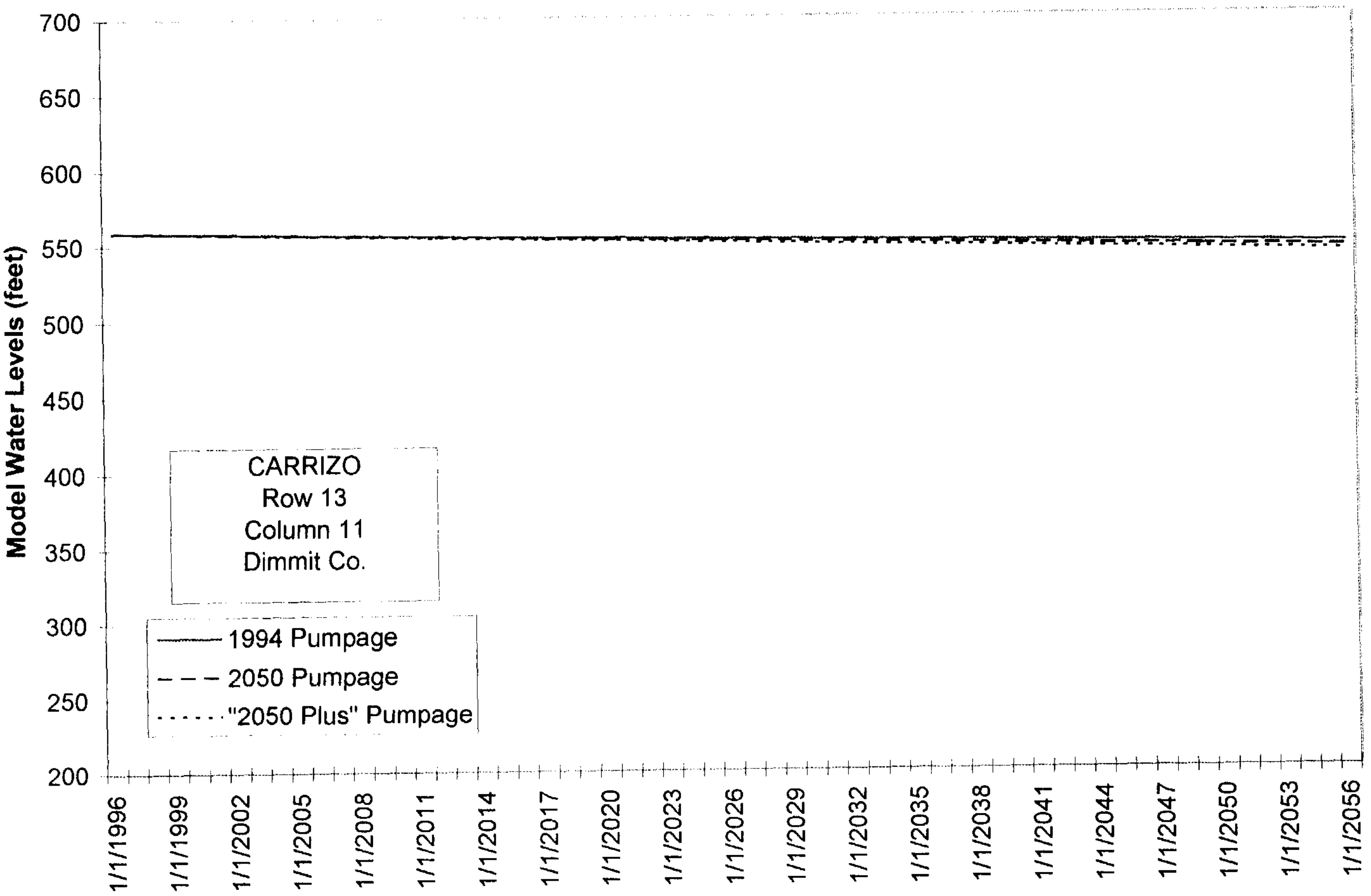


68-60-610 Hydrograph

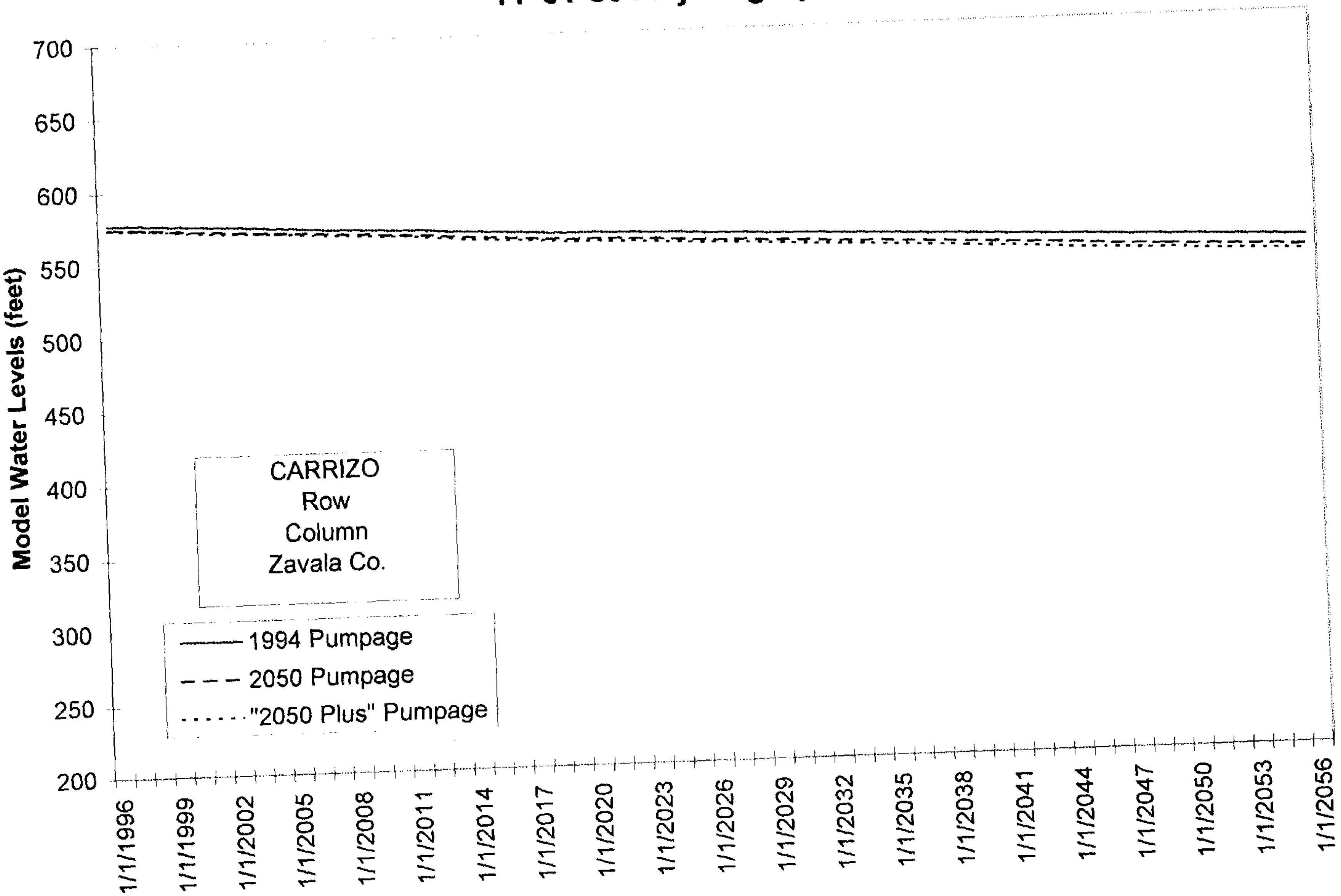
68-64-401 Hydrograph

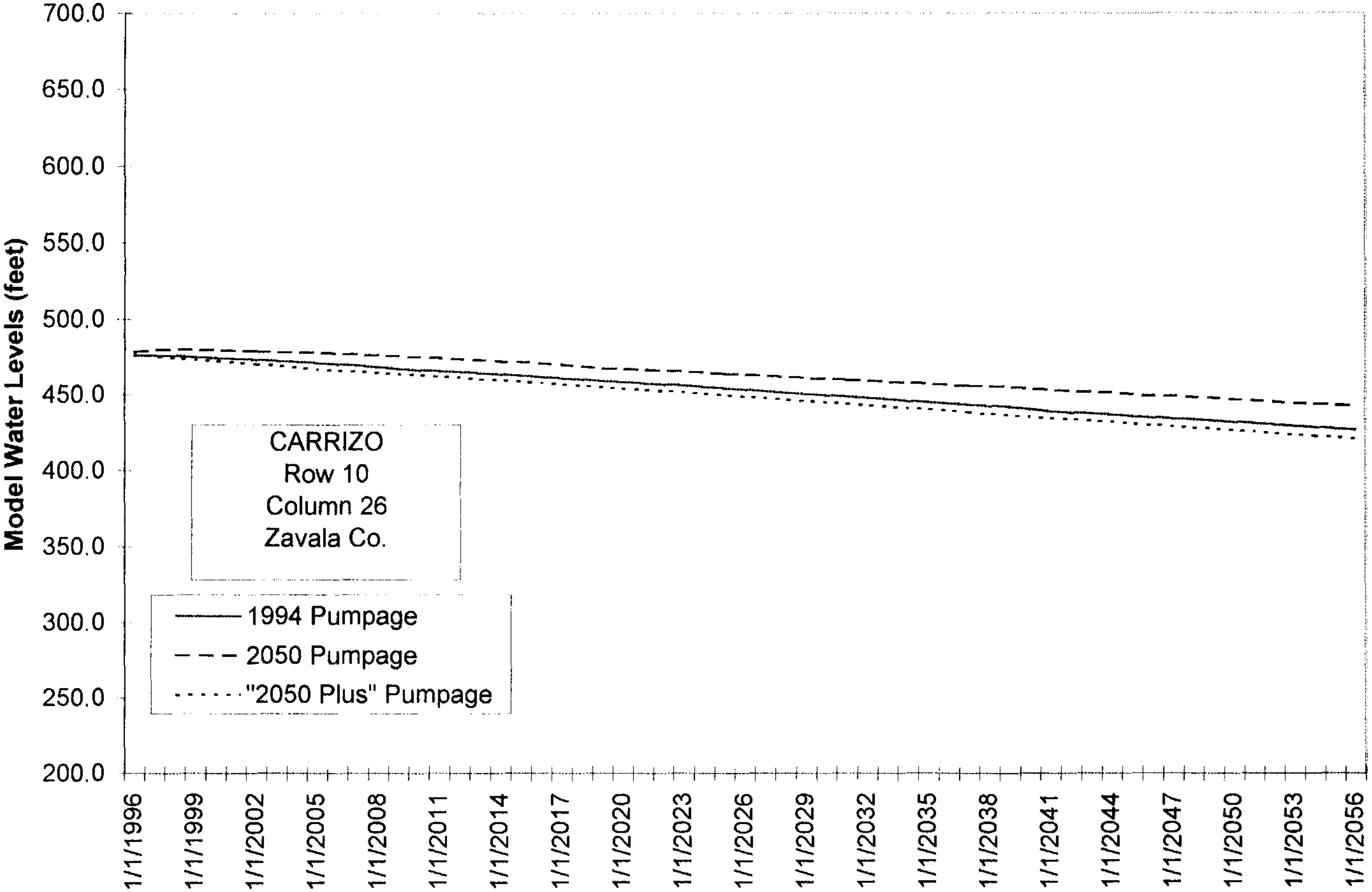


76-24-903 Hydrograph

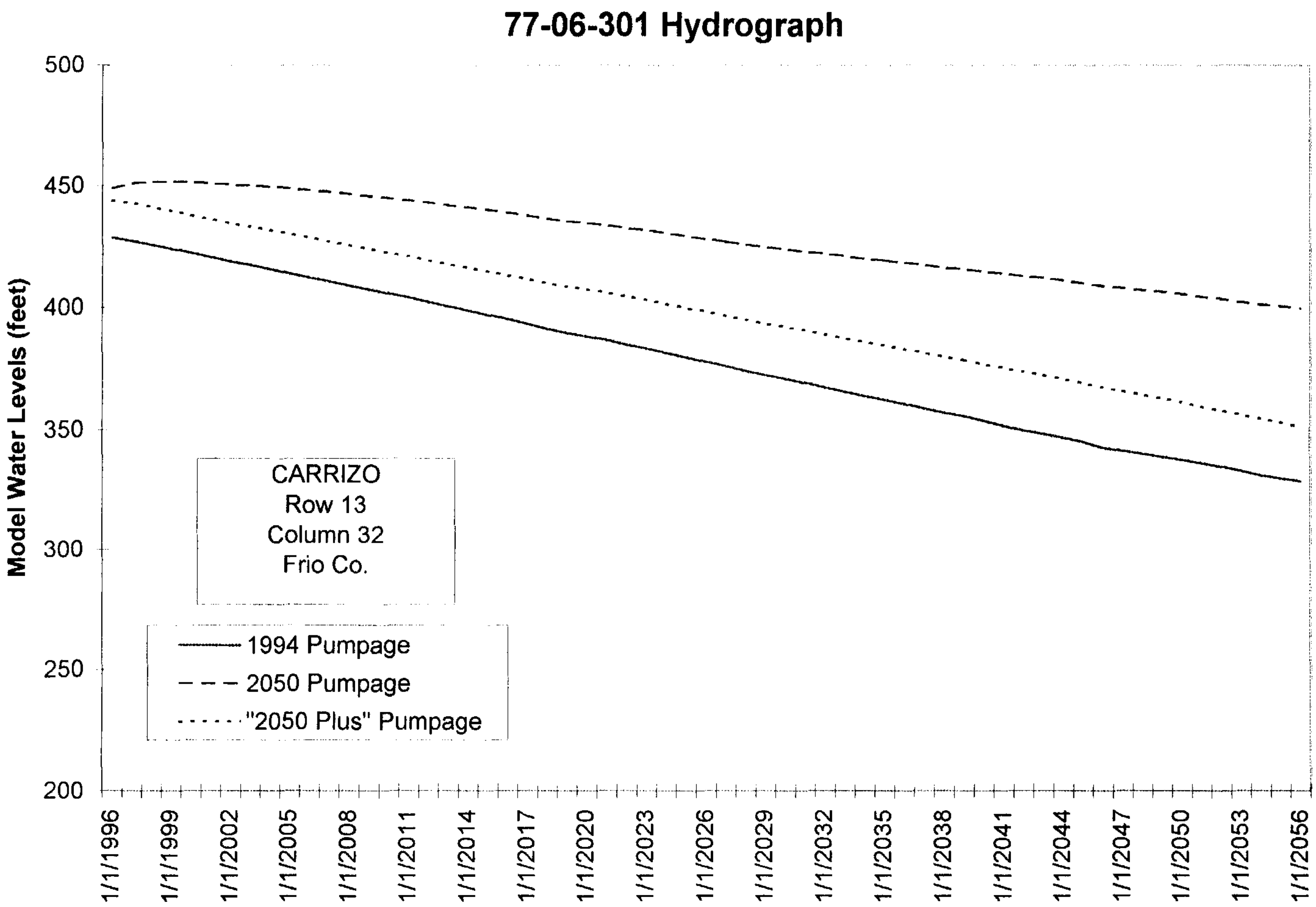


77-01-501 Hydrograph

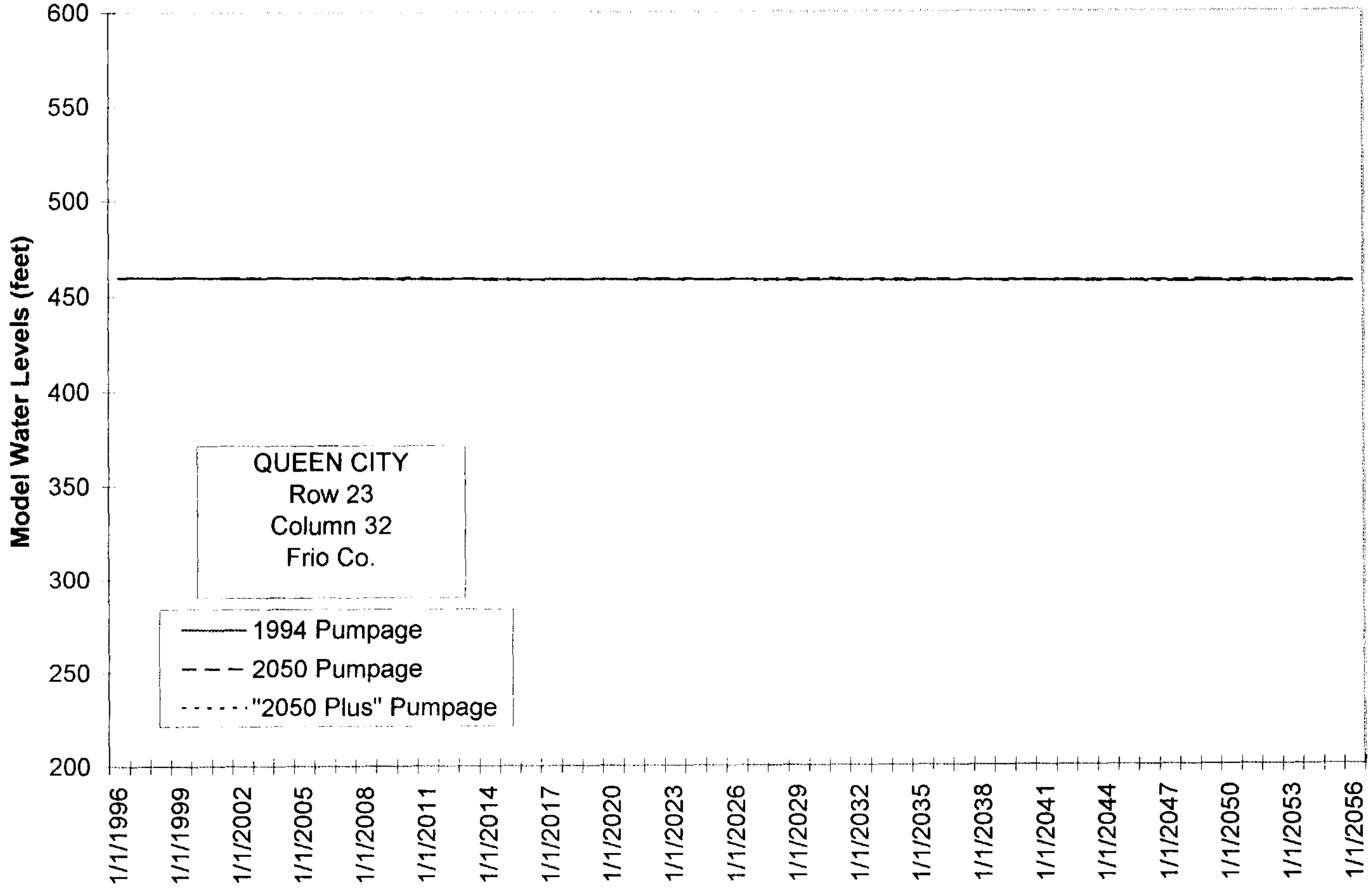




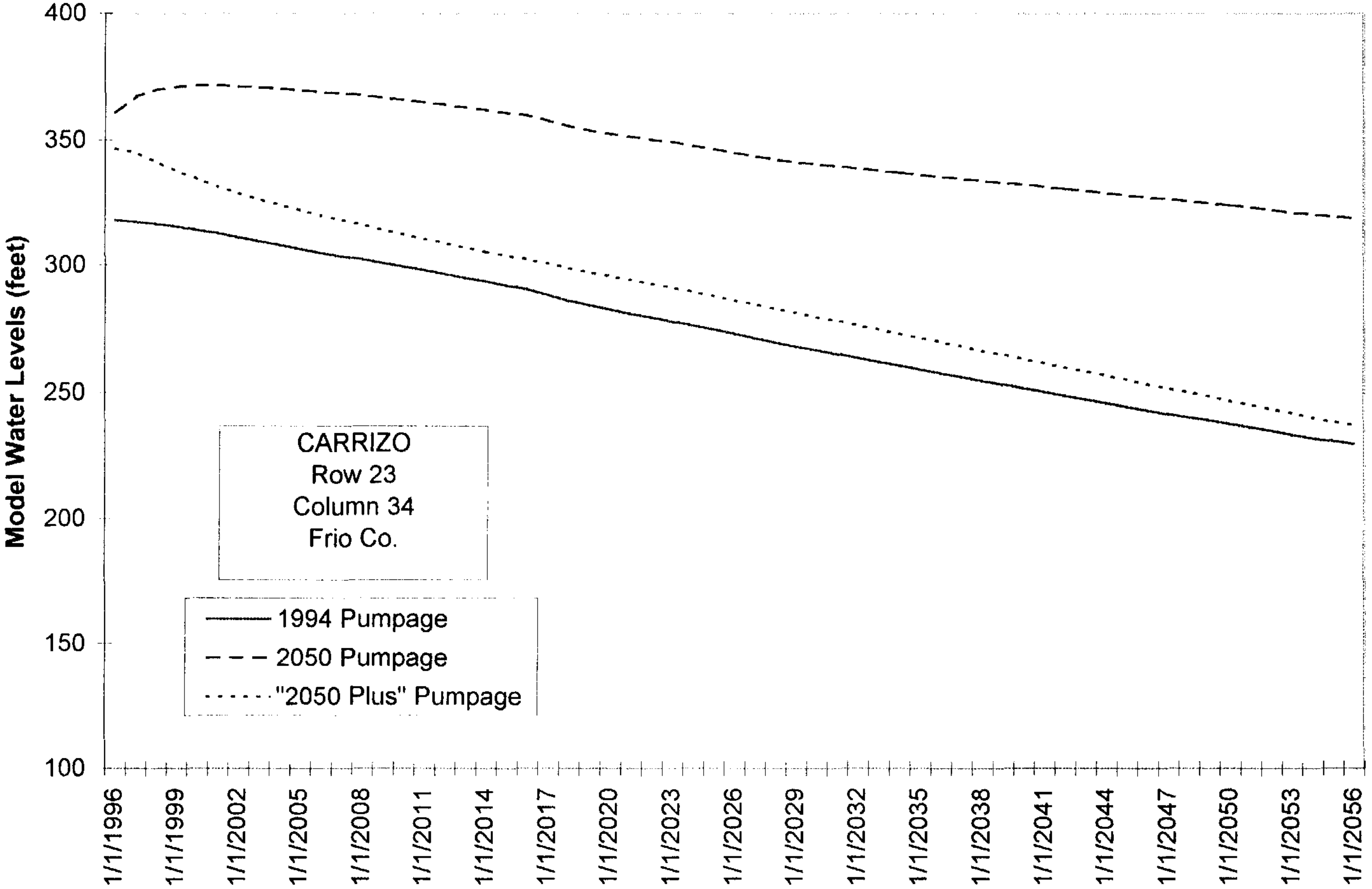
77-04-603 Hydrograph


77-06-301 Hydrograph
Model Water Levels (feet)
500
450
400
350
300
250
200
CARRIZO
Row 13
Column 32
Frio Co.
1994 Pumpage
2050 Pumpage
"2050 Plus" Pumpage
1/1/1996
1/1/1999
1/1/2002
1/1/2005
1/1/2008
1/1/2011
1/1/2014
1/1/2017
1/1/2020
1/1/2023
1/1/2026
1/1/2029
1/1/2032
1/1/2035
1/1/2038
1/1/2041
1/1/2044
1/1/2047
1/1/2050
1/1/2053
1/1/2056

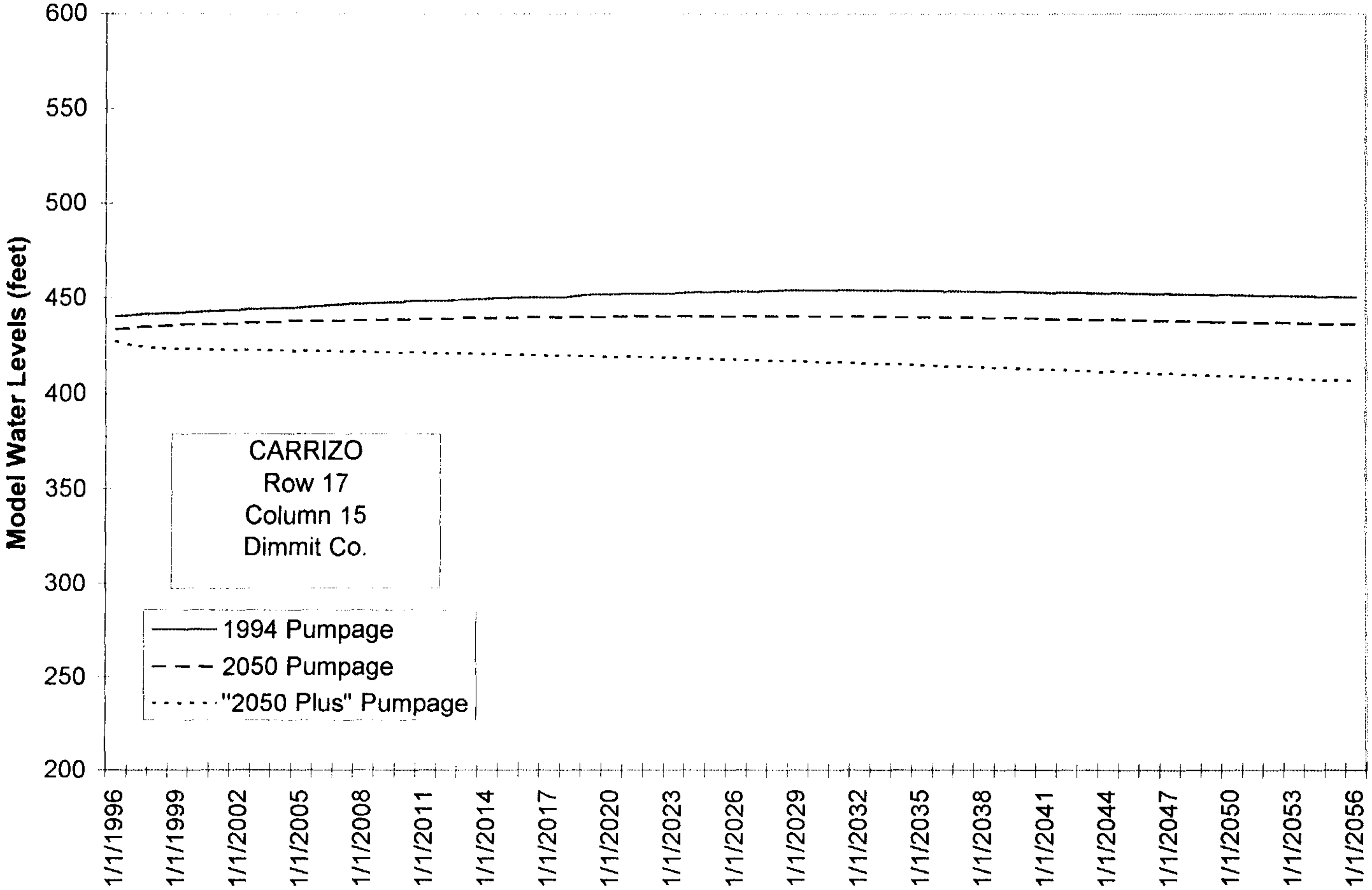
77-15-903 Hydrograph



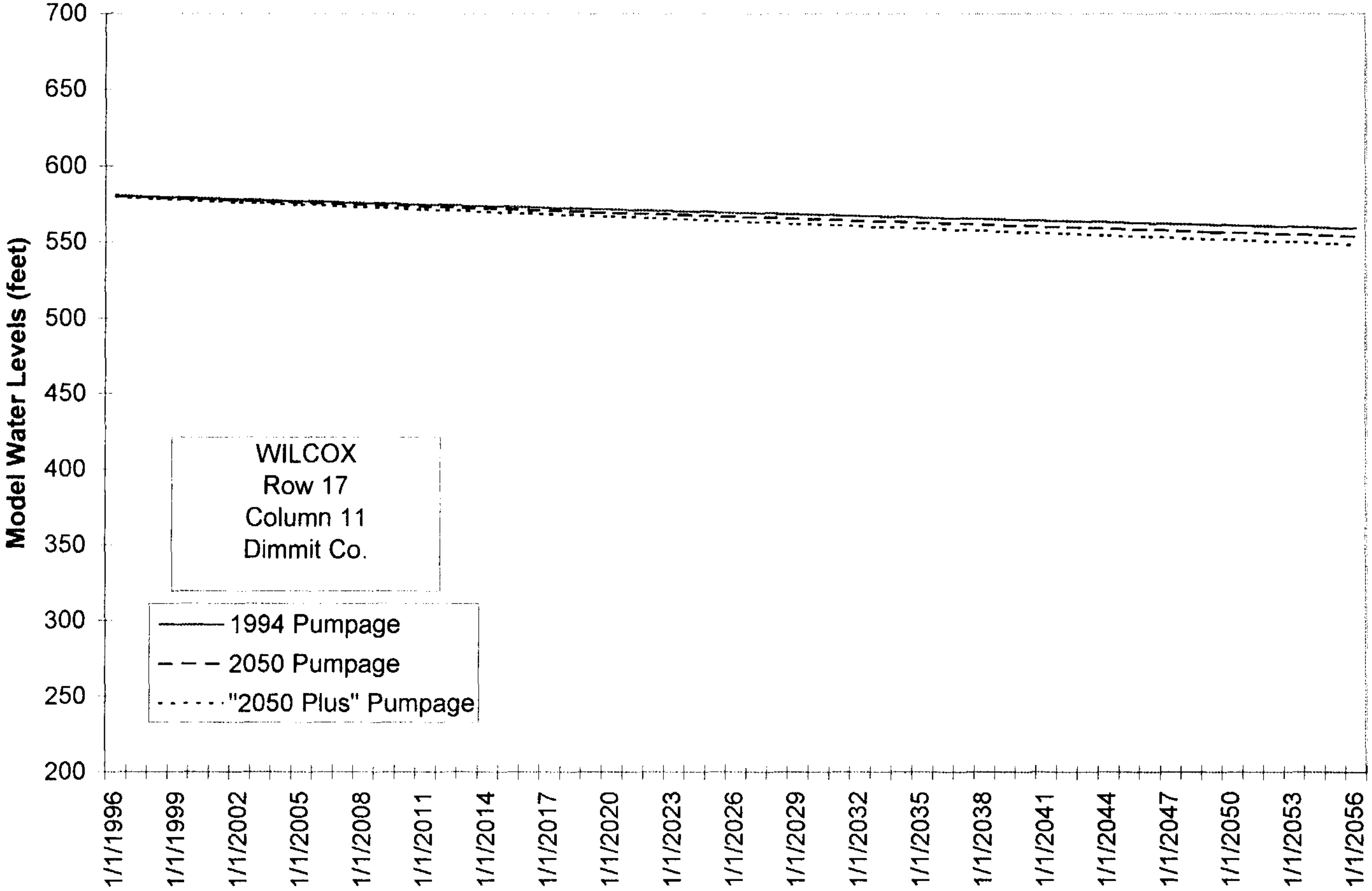
77-16-603 Hydrograph



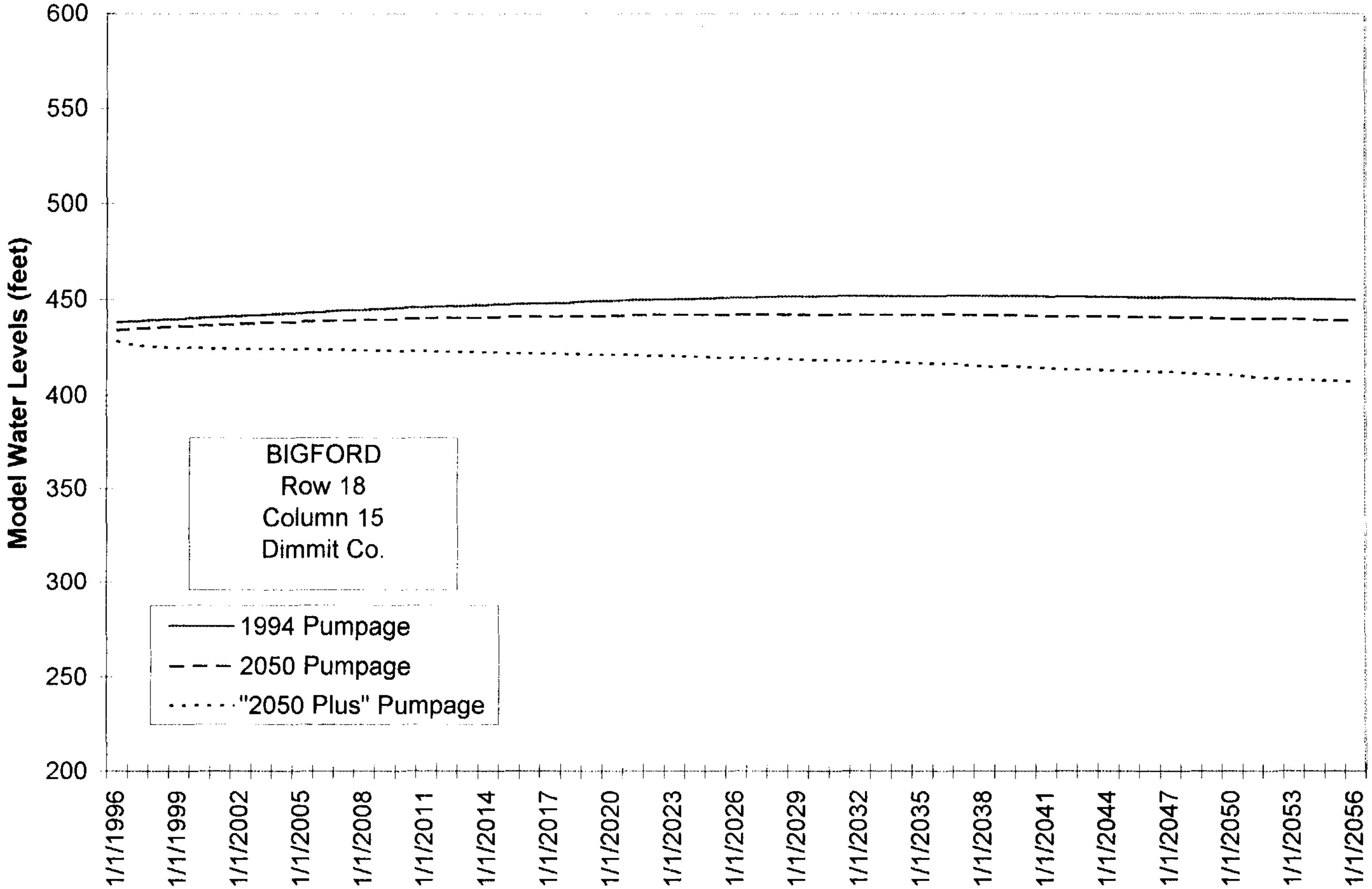
77-18-704 Hydrograph



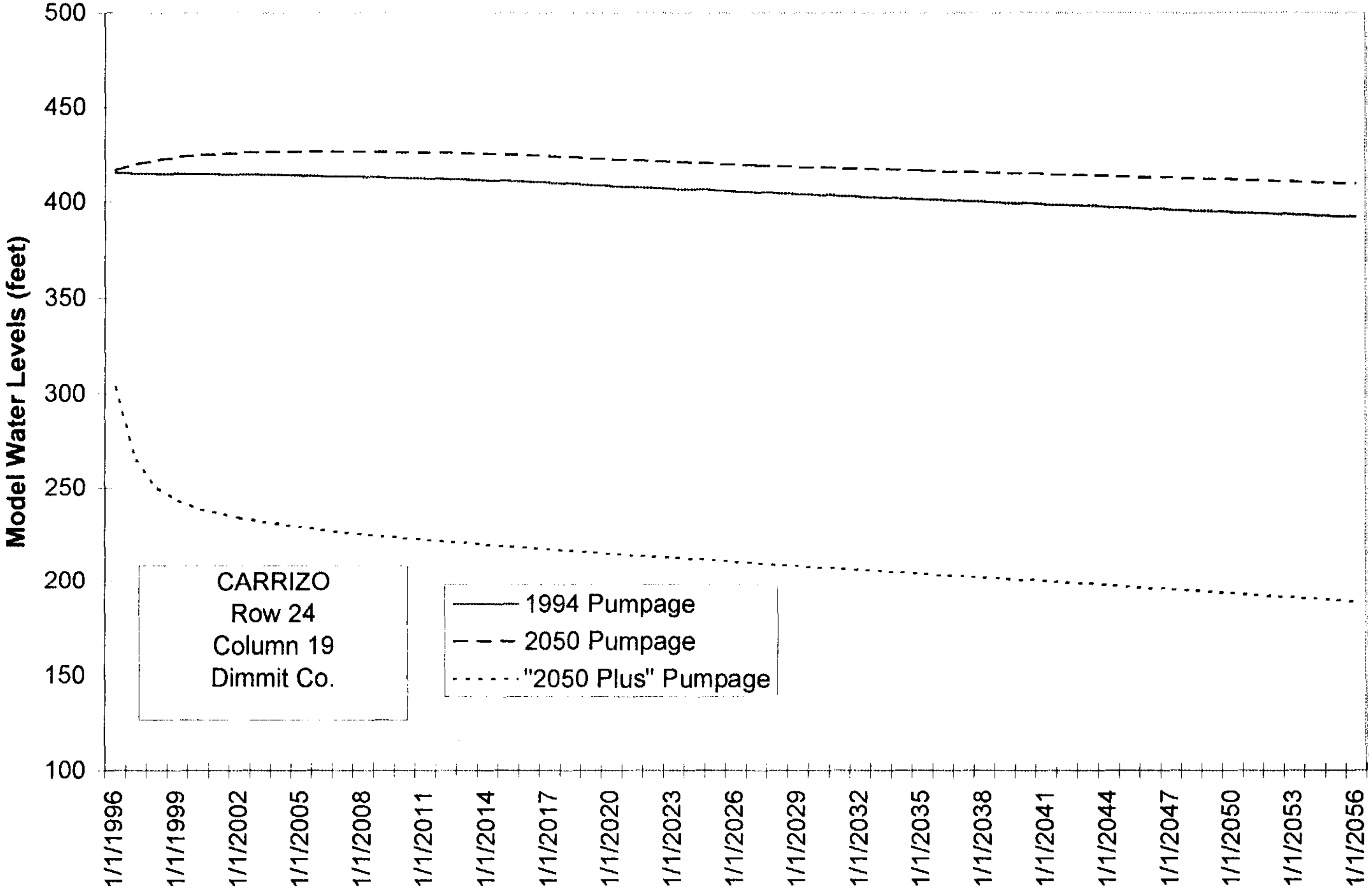
77-25-401 Hydrograph



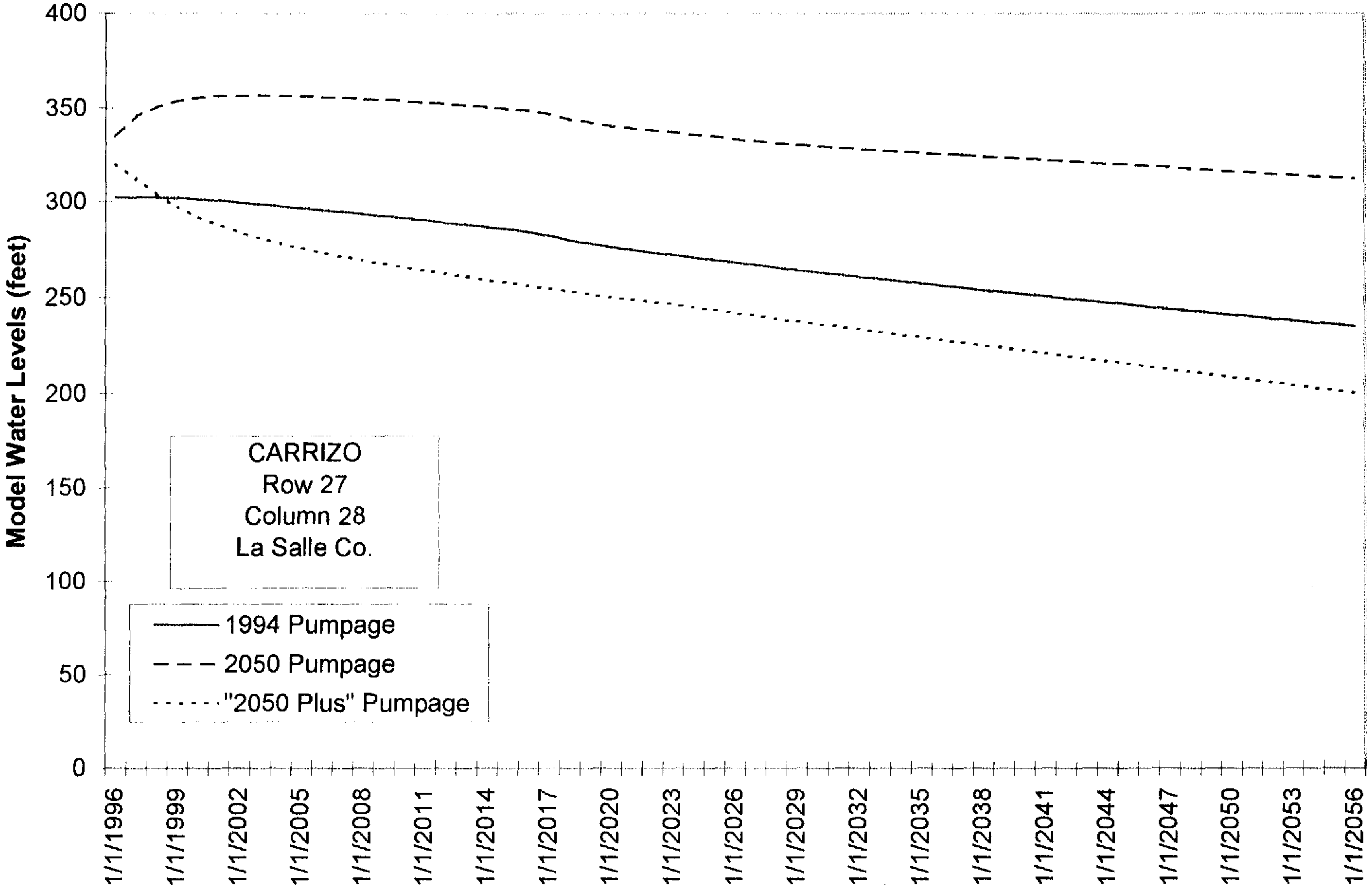
77-26-114 Hydrograph



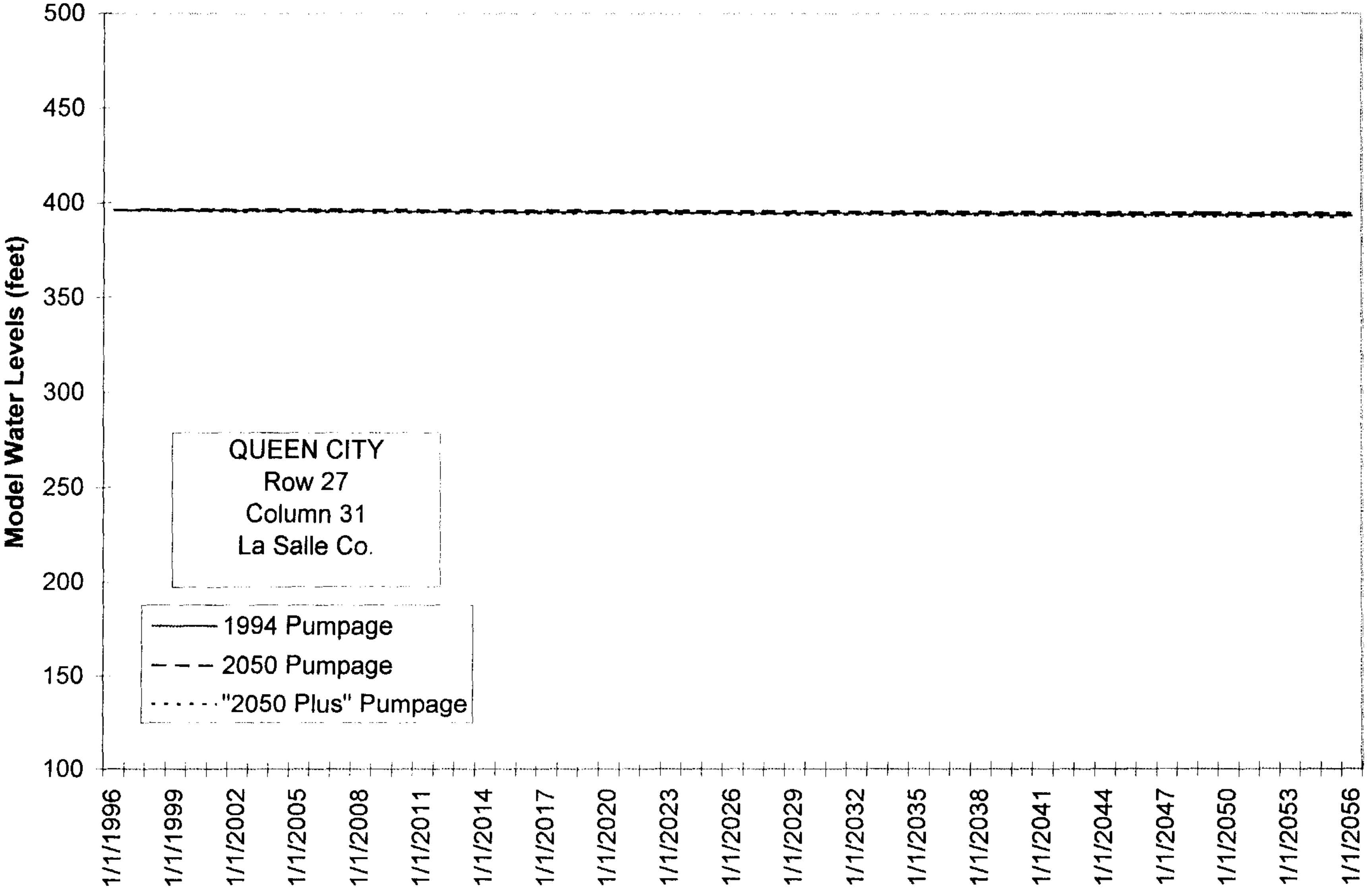
77-27-901 Hydrograph



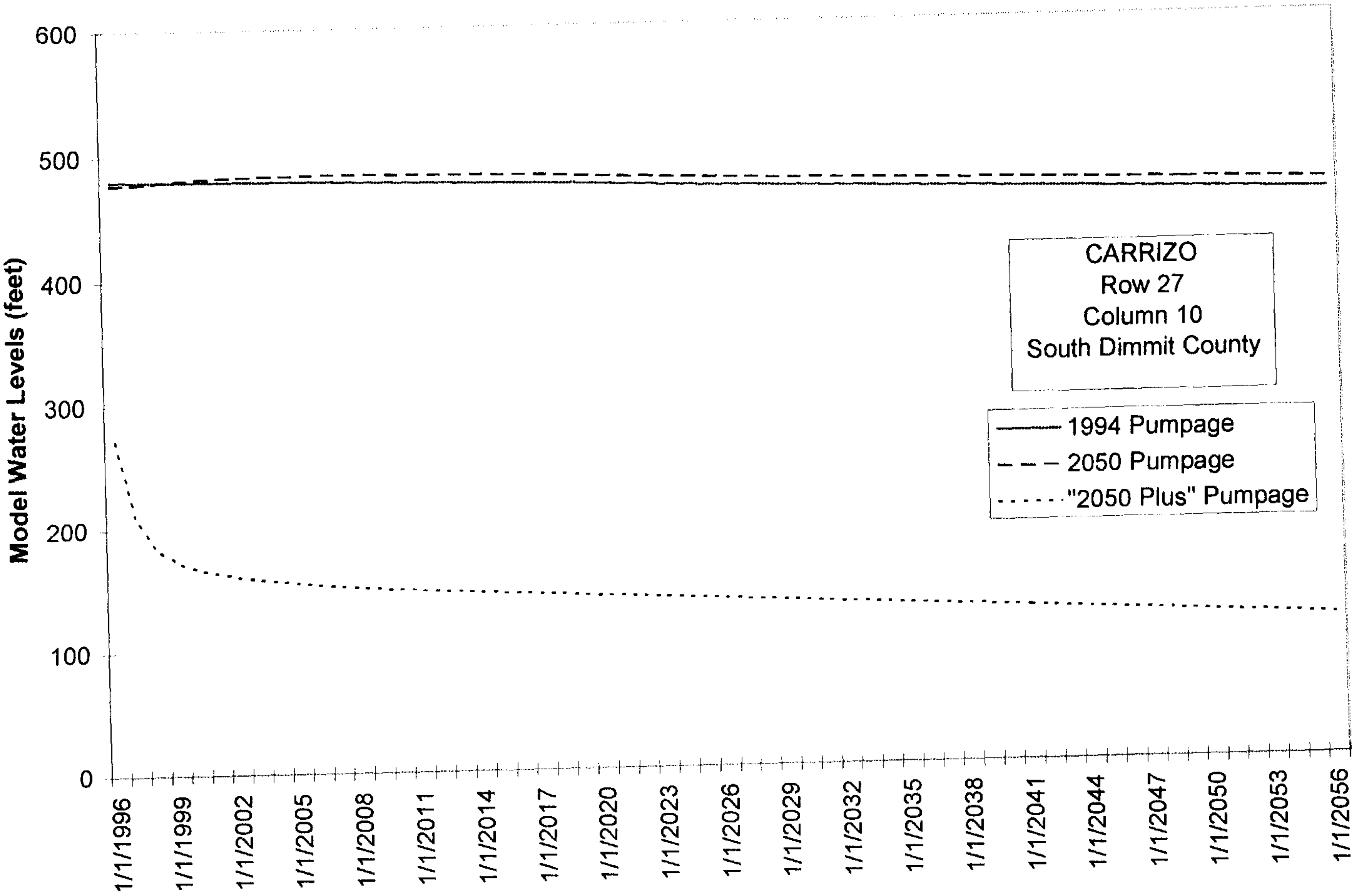
77-31-703 Hydrograph



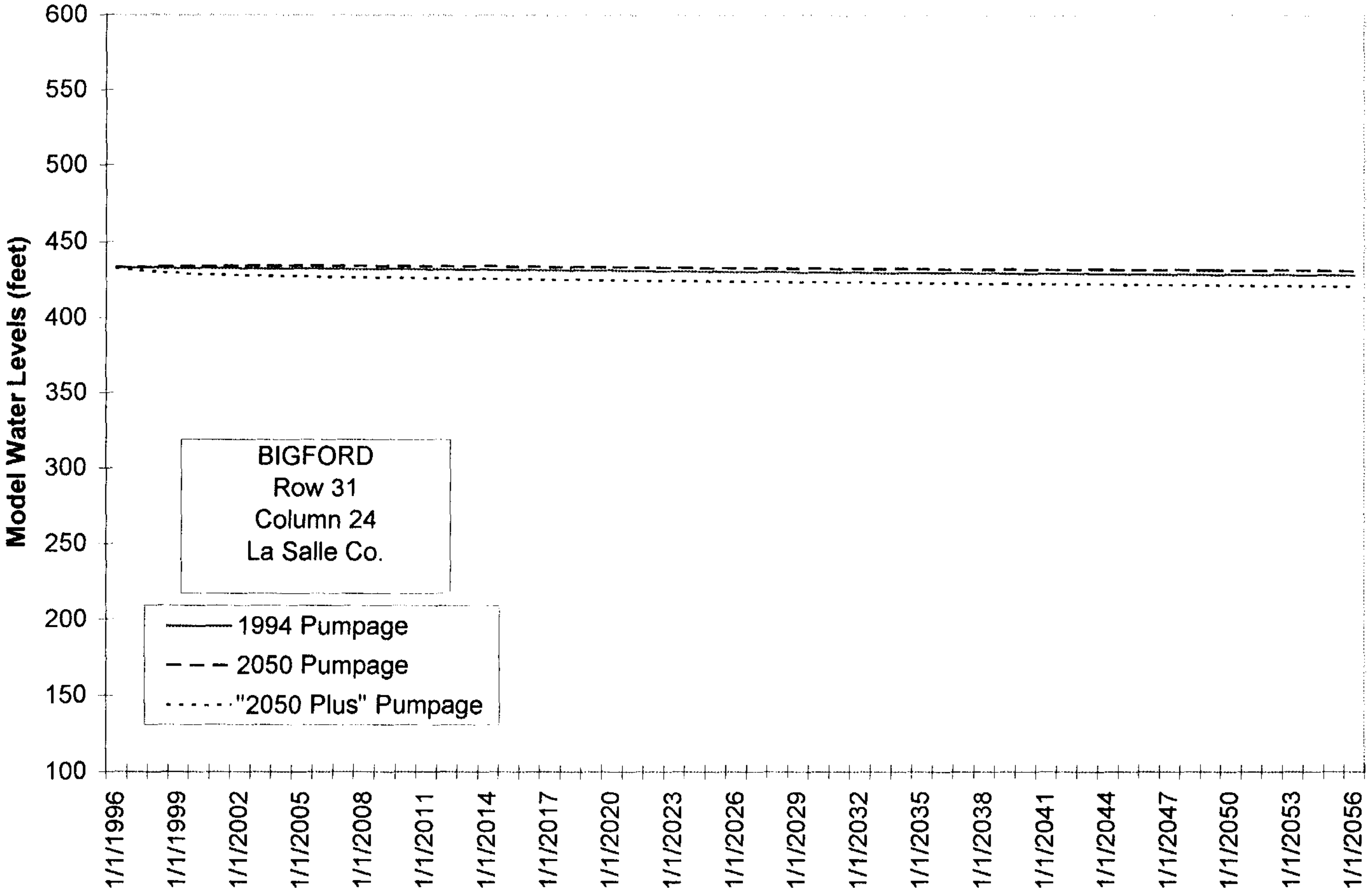
77-32-501 Hydrograph



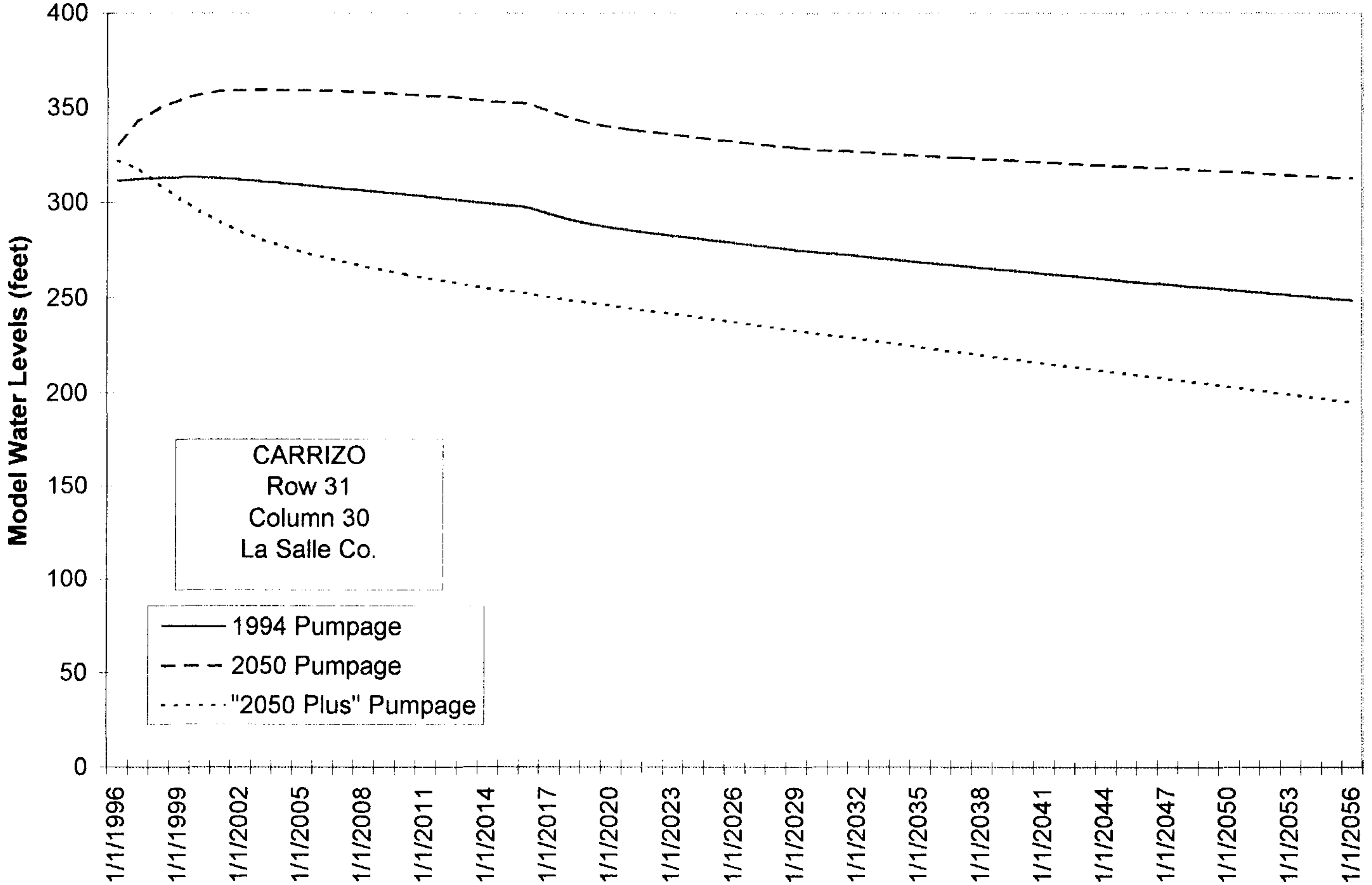
77-42-801 Hydrograph



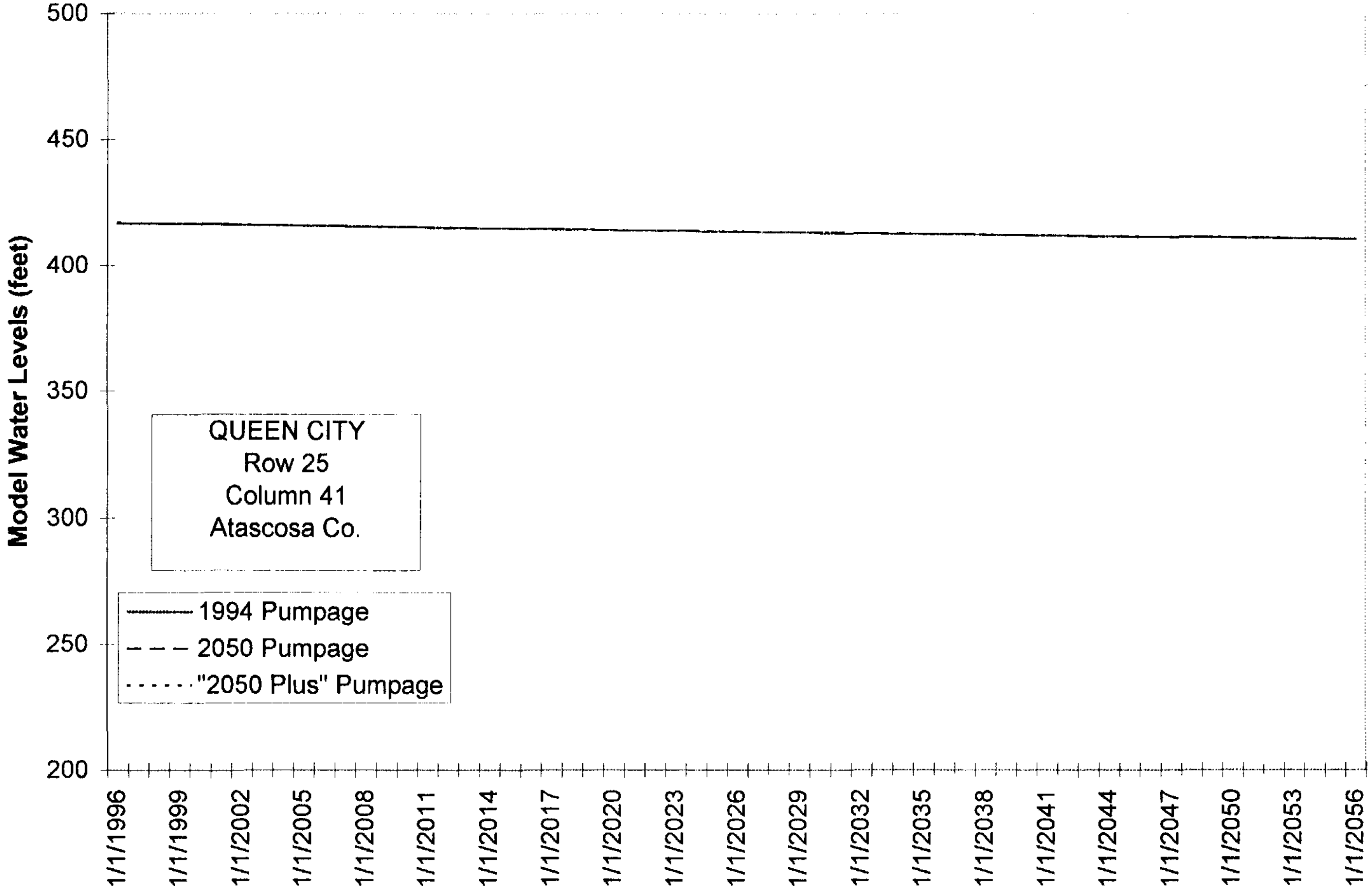
77-46-804 Hydrograph

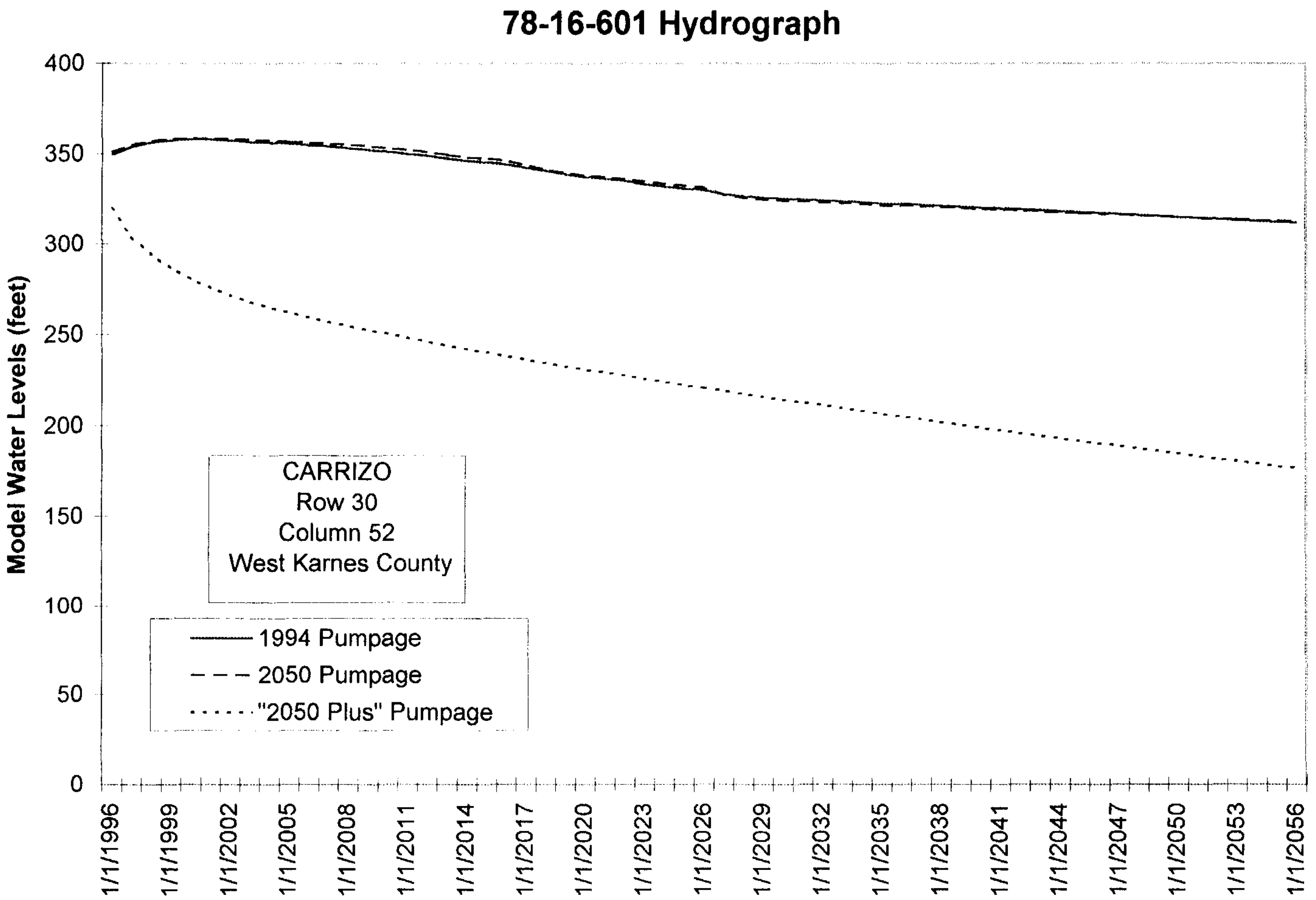


77-48-301 Hydrograph

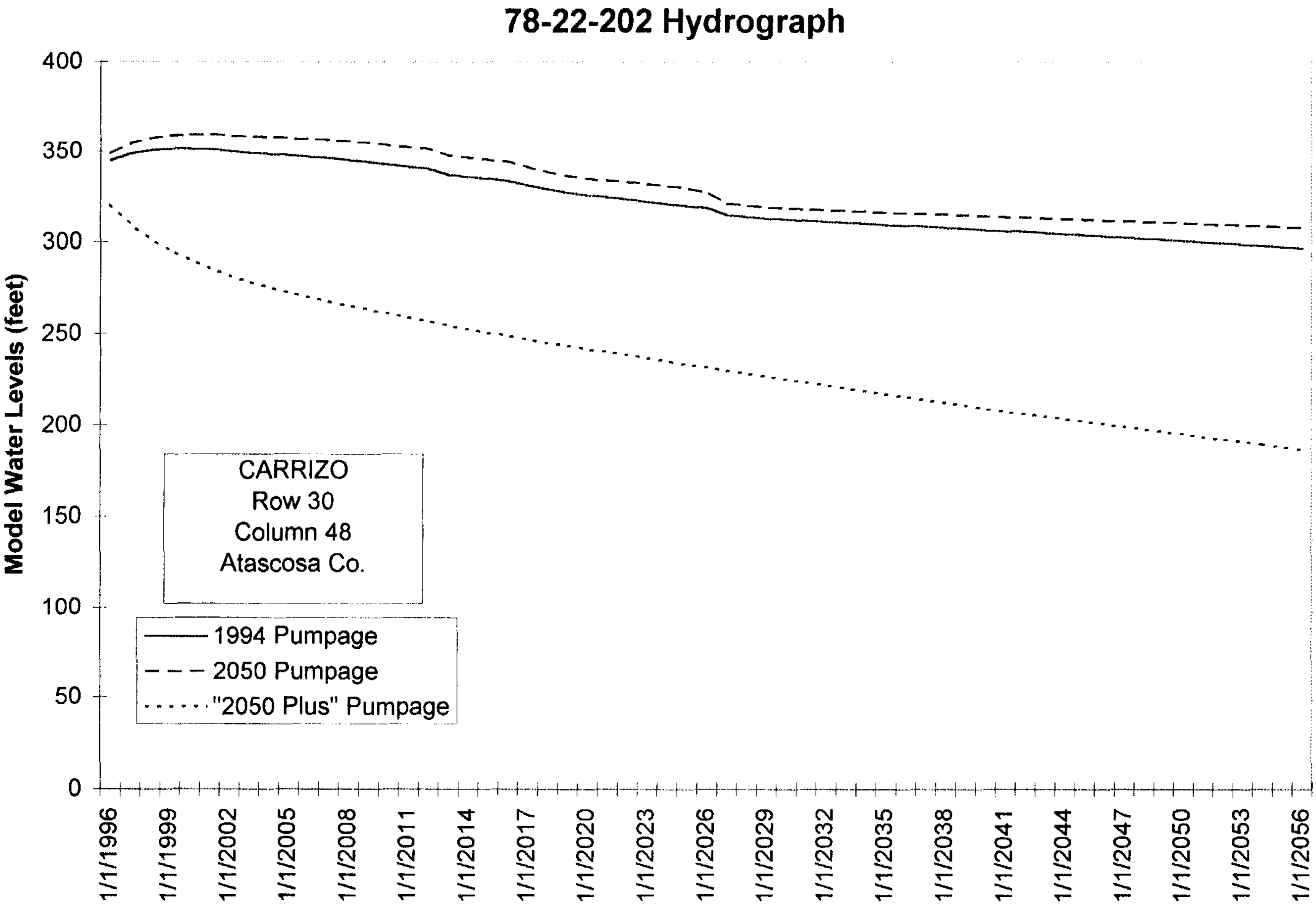


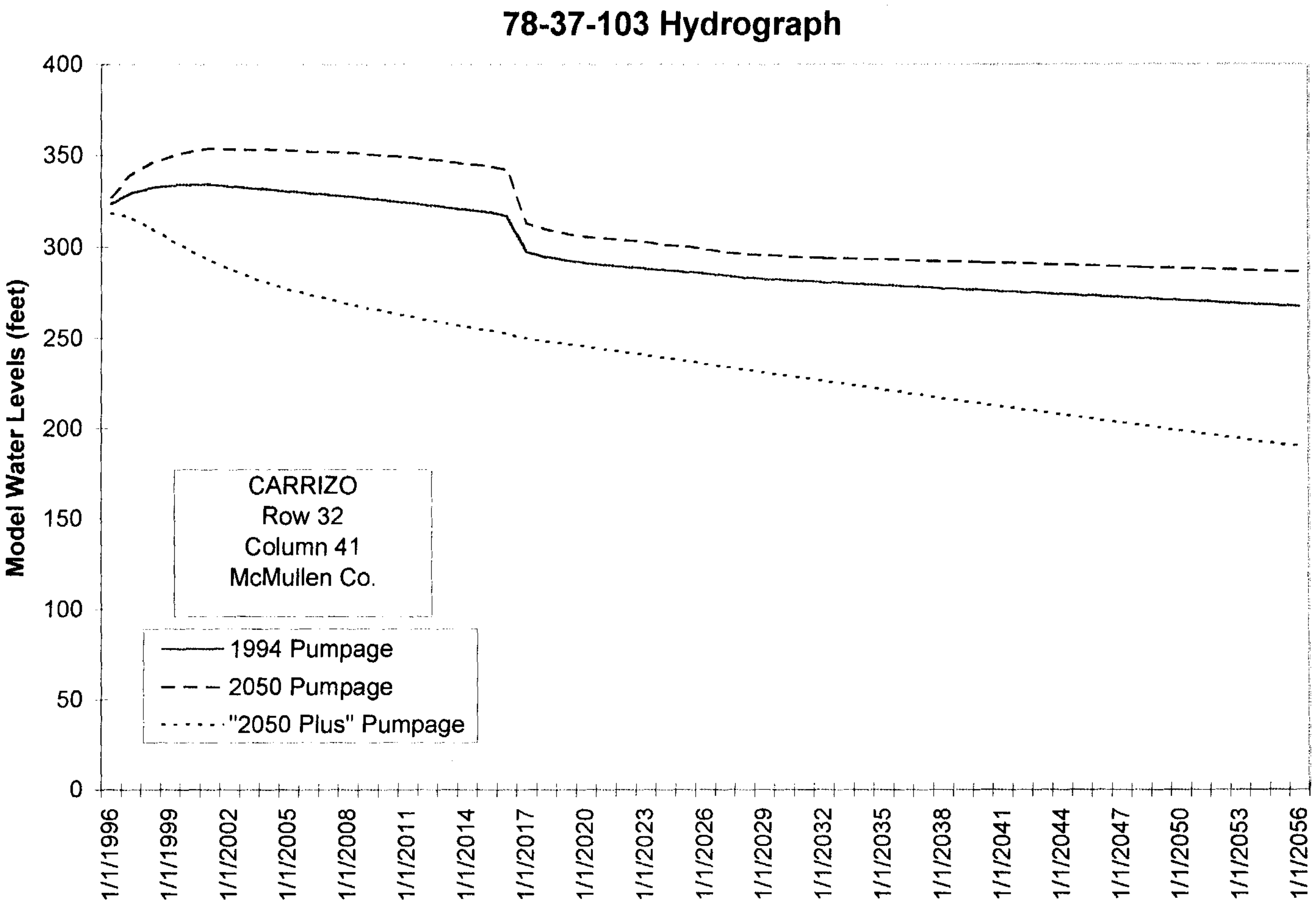
78-11-305 Hydrograph

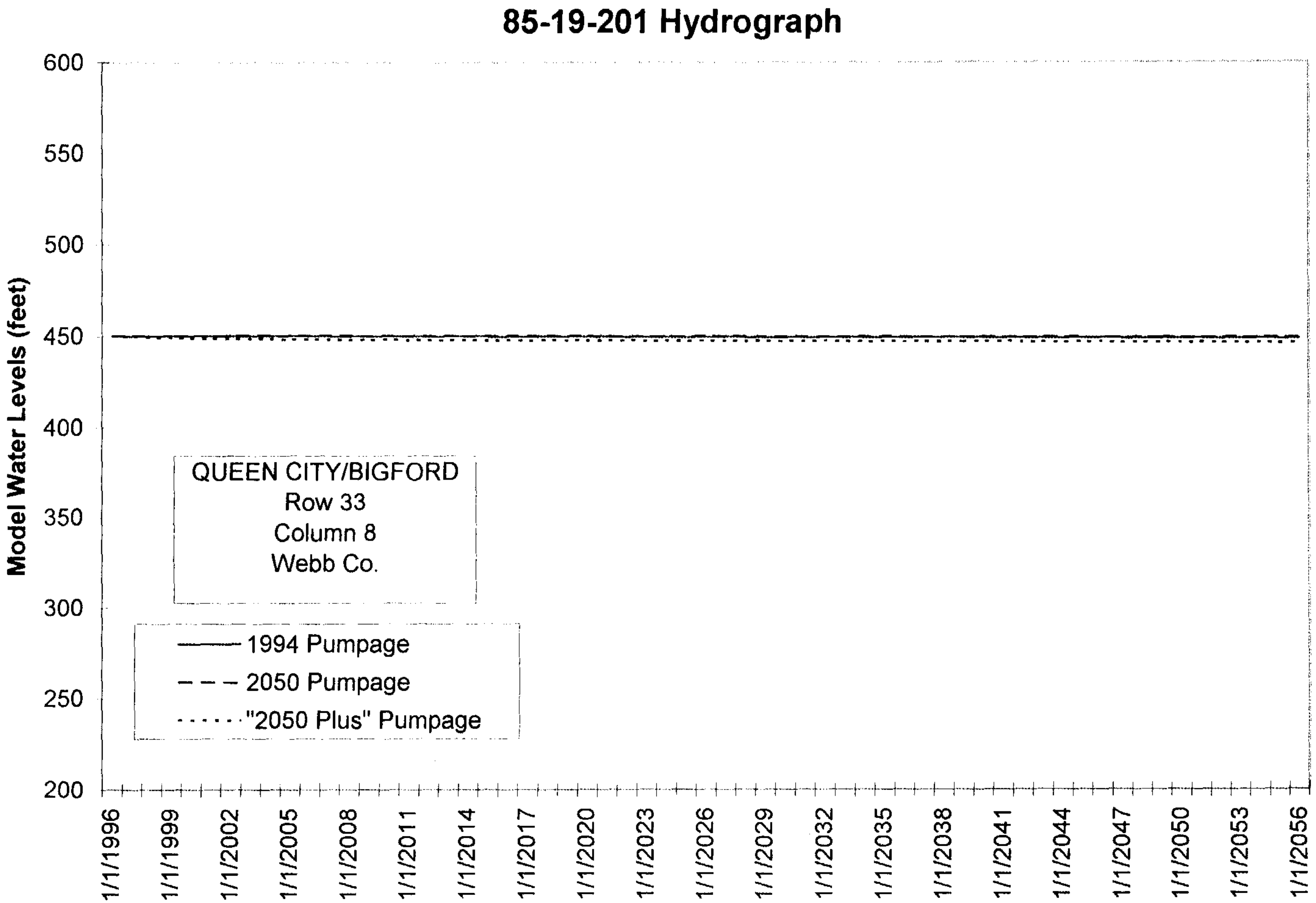




78-16-601 Hydrograph


78-22-202 Hydrograph


78-37-103 Hydrograph
Model Water Levels (feet)
400
350
300
250
200
150
100
50
0
1/1/1996
1/1/1999
1/1/2002
1/1/2005
1/1/2008
1/1/2011
1/1/2014
1/1/2017
1/1/2020
1/1/2023
1/1/2026
1/1/2029
1/1/2032
1/1/2035
1/1/2038
1/1/2041
1/1/2044
1/1/2047
1/1/2050
1/1/2053
1/1/2056
CARRIZO
Row 32
Column 41
McMullen Co.
1994 Pumpage
2050 Pumpage
"2050 Plus" Pumpage


85-19-201 Hydrograph
Model Water Levels (feet)
600
550
500
450
400
350
300
250
200
QUEEN CITY/BIGFORD
Row 33
Column 8
Webb Co.
1994 Pumpage
2050 Pumpage
"2050 Plus" Pumpage
1/1/1996
1/1/1999
1/1/2002
1/1/2005
1/1/2008
1/1/2011
1/1/2014
1/1/2017
1/1/2020
1/1/2023
1/1/2026
1/1/2029
1/1/2032
1/1/2035
1/1/2038
1/1/2041
1/1/2044
1/1/2047
1/1/2050
1/1/2053
1/1/2056

APPENDIX E

POTENTIAL IMPACTS ON MONTHLY STREAMFLOWS

APPENDIX E

POTENTIAL IMPACTS ON MONTHLY STREAMFLOWS

Nueces River @ Asherton Flow Statistics

Baseline Historical Modified Flows at Asherton in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	0	0	0	1652	1838	3470	0	0	6186	0	8670	787	22603
1935	0	0	0	9550	107411	533419	82926	22121	74850	4908	1133	416	836734
1936	0	0	0	0	3526	0	108251	0	170497	44339	10253	5889	342755
1937	1326	0	0	0	0	5561	0	0	0	0	0	0	6887
1938	34585	1130	0	8799	174	0	30341	44216	0	0	0	0	119245
1939	0	0	0	0	83885	7125	19898	5442	0	37688	0	0	154038
1940	0	0	0	15531	20759	25892	7458	3303	284	0	0	0	73227
1941	3110	21792	0	6052	20566	0	0	0	2126	0	0	0	53646
1942	0	0	0	1437	11445	0	4328	0	62461	8167	0	0	87838
1943	0	0	0	0	0	25048	0	0	0	1537	57	0	26642
1944	0	0	0	0	25488	9789	0	101673	146195	2246	0	0	285391
1945	0	0	6019	28393	1332	0	0	0	21243	47625	0	0	104612
1946	0	0	0	35145	16255	3941	0	358	5525	7647	0	0	68871
1947	0	0	0	0	1212	27034	0	0	0	0	0	0	28246
1948	0	0	0	0	0	29086	9193	0	10670	1420	0	0	50369
1949	0	81298	80218	14238	3803	15500	0	17800	0	4221	0	0	217078
1950	0	0	0	0	0	14011	721	7919	5306	0	0	0	27957
1951	0	0	0	0	23808	0	0	0	0	0	0	0	23808
1952	109	104	137	136	20661	1419	146	122	109	121	108	91	23263
1953	0	0	0	0	0	0	0	0	63857	6563	0	0	70420
1954	0	0	0	0	38500	11747	28282	0	0	7779	0	0	86308
1955	0	0	0	0	0	0	20594	0	90597	857	0	0	112048
1956	0	0	0	0	0	0	778	0	0	1769	0	0	2547
1957	0	0	0	71083	103216	83406	0	0	0	21192	0	0	278897
1958	2119	7099	0	0	0	181111	13034	0	125177	44409	36598	10194	419741
1959	3791	1529	0	0	7013	26110	25384	4949	10591	197325	6915	3273	286880
1960	3904	2709	574	0	0	0	23597	7878	6418	13694	15952	6684	81410
1961	6157	8506	3443	0	0	17250	44901	9121	1232	0	752	1054	92416
1962	0	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	8542	0	0	0	0	0	0	0	8542
1964	0	0	0	0	1047	0	0	10681	217662	63742	0	0	293132
1965	0	0	0	0	48226	26001	477	0	0	0	0	0	74704
1966	471	316	456	5626	50115	759	355	23038	14829	764	581	437	97747
1967	712	644	940	1250	895	931	770	894	34551	13167	332	410	55496
1968	10799	6709	3993	4072	90538	0	0	0	0	8602	0	0	124713
1969	0	0	0	0	4546	678	0	591	2752	91272	19864	18129	137832
1970	5399	1226	2772	0	0	0	0	0	12235	4835	0	0	26467
1971	0	0	1240	1161	1215	42723	110763	320349	20081	82825	19338	12129	611824
1972	7039	4409	468	0	365	0	0	36888	4841	31	0	0	54041
1973	0	0	0	0	0	0	9560	1468	758	131914	21541	10447	175688
1974	5706	2040	3859	0	8039	0	0	4301	13513	814	13009	3728	55009
1975	2780	3838	0	2702	4229	114697	23660	6191	2078	565	561	0	161301
1976	116	0	0	0	2356	0	82067	23109	20321	25918	29102	17289	200278
1977	13983	12270	9789	36594	30650	9307	3252	57	0	0	1563	2279	119744
1978	0	9	0	0	9792	9889	0	0	4777	0	0	46	24513
1979	0	0	0	11456	6453	126896	0	0	0	0	0	0	144805
1980	0	0	0	0	41694	1715	0	1451	0	0	0	0	44860
1981	0	0	0	36747	24859	125473	18052	1869	5075	111265	17208	6463	347011
1982	3983	1549	5419	847	18453	3156	517	0	140	59	0	0	34123
1983	0	0	0	0	0	0	0	0	28840	408	745	0	29993
1984	0	0	0	0	0	0	0	0	0	62331	0	0	62331
1985	44076	5525	9329	6509	7421	0	0	0	0	62035	8787	1349	145031
1986	0	0	0	0	5015	42599	0	0	6586	55183	14232	10288	133903
1987	12581	6895	8763	5175	33719	257603	36051	15387	32116	14890	9477	7990	440647
1988	6277	3512	1332	0	0	0	0	0	0	0	0	0	11121
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	3018	3091	2478	5431	15876	31845	12596	11985	21866	21145	4228	2132	135692
Max	44076	81298	80218	71083	107411	533419	110763	320349	217662	197325	36598	18129	836734
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
median	0	0	0	0	4016	1567	0	0	2439	1653	0	0	83859
drt avg	11	8140	8036	1437	8798	9880	5971	2584	17054	2273	11	9	64204

Nueces River @ Asherton Flow Statistics
1994 Pumpage
Pumpage Affected Modified Flows at Asherton in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	0	0	0	1222	1288	3045	0	0	5825	0	8346	447	20173
1935	0	0	0	9162	104618	529927	80273	19747	72685	2876	0	0	819288
1936	0	0	0	0	2054	0	106756	0	169101	42872	8857	4521	334161
1937	0	0	0	0	0	4293	0	0	0	0	0	0	4293
1938	33105	0	0	7479	0	0	29084	42994	0	0	0	0	112662
1939	0	0	0	0	83083	6483	17942	3673	0	36082	0	0	147263
1940	0	0	0	14442	19593	24767	6419	2435	0	0	0	0	67656
1941	2379	21094	0	5060	18541	0	0	0	742	0	0	0	47816
1942	0	0	0	431	10251	0	3609	0	61113	6840	0	0	82244
1943	0	0	0	0	0	24369	0	0	0	978	0	0	25347
1944	0	0	0	0	25061	8178	0	100086	144379	1194	0	0	278898
1945	0	0	5514	28033	1060	0	0	0	21121	47626	0	0	103354
1946	0	0	0	34996	16106	2991	0	302	4464	4714	0	0	63573
1947	0	0	0	0	849	25114	0	0	0	0	0	0	25963
1948	0	0	0	0	0	26781	7056	0	10605	1375	0	0	45817
1949	0	79203	78193	12513	2295	14271	0	16682	0	3244	0	0	206401
1950	0	0	0	0	0	13983	694	7892	5280	0	0	0	27849
1951	0	0	0	0	23808	0	0	0	0	0	0	0	23808
1952	55	46	91	102	19837	1401	121	106	99	116	88	75	22137
1953	0	0	0	0	0	0	0	0	62411	6563	0	0	68974
1954	0	0	0	0	37026	10141	26620	0	0	7779	0	0	81566
1955	0	0	0	0	0	0	20594	0	89200	857	0	0	110651
1956	0	0	0	0	0	0	778	0	0	1769	0	0	2547
1957	0	0	0	71083	101903	81939	0	0	0	21192	0	0	276117
1958	2119	7099	0	0	0	179016	11149	0	123082	42244	34503	8029	407241
1959	1752	0	0	0	5770	24993	24407	4042	9753	196487	6077	2463	275744
1960	3136	1969	0	0	0	0	23087	7390	5957	13206	15464	6196	76405
1961	5710	8087	3038	0	0	16894	44552	8842	918	0	431	719	89191
1962	0	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	7983	0	0	0	0	0	0	0	7983
1964	0	0	0	0	1047	0	0	10702	217662	63323	0	0	292734
1965	0	0	0	0	48226	25512	0	0	0	0	0	0	73738
1966	471	316	456	5626	50115	759	367	22758	14410	282	512	437	96509
1967	712	643	939	1250	917	942	770	894	34551	12728	0	12	54358
1968	10450	6360	3741	3821	90328	0	0	0	0	8477	0	0	123177
1969	0	0	0	0	4542	674	0	591	2748	90923	19584	17919	136981
1970	5190	1037	2604	0	0	0	0	0	12095	4744	0	0	25670
1971	0	0	1239	1161	1207	42584	110617	319650	19942	82686	19199	12060	610345
1972	6900	4283	335	0	246	0	0	36818	4736	0	0	0	53318
1973	0	0	0	0	0	0	9420	1349	639	131914	21401	10377	175100
1974	5580	1914	3734	0	7969	0	0	4182	13401	695	12939	3609	54023
1975	2654	3719	0	2576	4089	114627	23520	6052	1960	447	442	0	160086
1976	0	0	0	0	2224	0	81369	22970	20181	25779	28962	17149	198634
1977	13913	12130	9649	36524	30511	9167	3161	0	0	0	1472	2181	118708
1978	0	0	0	0	9694	9793	0	0	4686	0	0	0	24173
1979	0	0	0	11316	6355	126756	0	0	0	0	0	0	144427
1980	0	0	0	0	41694	1724	0	1497	0	0	0	0	44915
1981	0	0	0	36397	24510	124775	17773	1667	4893	111265	16998	6324	344602
1982	3843	1416	5293	721	18313	3016	398	0	30	0	0	0	33030
1983	0	0	0	0	0	0	0	0	28829	408	568	0	29805
1984	0	0	0	0	0	0	0	0	0	62323	0	0	62323
1985	43727	5316	9049	6299	7226	0	0	0	0	61895	8648	1196	143356
1986	0	0	0	0	4872	42453	0	0	6439	54974	14092	10148	132978
1987	12441	6742	8623	5036	33579	257603	35912	15248	31977	14751	9338	7781	439031
1988	6138	3380	1199	0	0	0	0	0	0	0	0	0	10717
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	2862	2942	2387	5272	15514	31410	12258	11760	21534	20815	4070	1994	132819
Max	43727	79203	78193	71083	104618	529927	110617	319650	217662	196487	34503	17919	819288
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
median	0	0	0	0	3192	1563	0	0	2354	1285	0	0	78986
drt avg	6	7925	7828	1262	8382	9169	5586	2468	16760	2170	9	8	61571

Nueces River @ Asherton Flow Statistics
2050 Pumpage
Pumpage Affected Modified Flows at Asherton in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	0	0	0	1243	1300	3028	0	0	5827	0	8347	447	20192
1935	0	0	0	9165	104618	529927	80273	19677	72616	2855	0	0	819131
1936	0	0	0	0	2054	0	106749	0	169101	42872	8857	4514	334147
1937	0	0	0	0	0	4283	0	0	0	0	0	0	4283
1938	33091	0	0	7467	0	0	29084	42987	0	0	0	0	112629
1939	0	0	0	0	83099	6438	17873	3650	0	36082	0	0	147142
1940	0	0	0	14499	19639	24719	6396	2409	0	0	0	0	67662
1941	2392	21105	0	5063	18513	0	0	0	739	0	0	0	47812
1942	0	0	0	464	10263	0	3619	0	61057	6840	0	0	82243
1943	0	0	0	0	0	24391	0	0	0	984	0	0	25375
1944	0	0	0	0	25059	8176	0	100088	144272	1199	0	0	278794
1945	0	0	5520	28033	1060	0	0	0	21123	47610	0	0	103346
1946	0	0	0	34996	16106	2991	0	302	4464	4574	0	0	63433
1947	0	0	0	0	849	25114	0	0	0	0	0	0	25963
1948	0	0	0	0	0	26642	6979	0	10605	1375	0	0	45601
1949	0	79203	78123	12513	2162	14271	0	16543	0	3160	0	0	205975
1950	0	0	0	0	0	13983	694	7892	5280	0	0	0	27849
1951	0	0	0	0	23808	0	0	0	0	0	0	0	23808
1952	48	46	91	102	19837	1401	121	106	99	116	88	75	22130
1953	0	0	0	0	0	0	0	0	62355	6563	0	0	68918
1954	0	0	0	0	36964	10001	26508	0	0	7779	0	0	81252
1955	0	0	0	0	0	0	20594	0	88502	857	0	0	109953
1956	0	0	0	0	0	0	778	0	0	1769	0	0	2547
1957	0	0	0	71083	101819	81848	0	0	0	21192	0	0	275942
1958	2119	7099	0	0	0	179016	11079	0	123082	42174	34434	8029	407032
1959	1661	0	0	0	5616	24923	24267	3972	9683	196417	6007	2414	274960
1960	3094	1934	0	0	0	0	23038	7320	5908	13206	15394	6126	76020
1961	5668	8017	3004	0	0	16859	44552	8772	883	0	403	691	88849
1962	0	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	7843	0	0	0	0	0	0	0	7843
1964	0	0	0	0	1047	0	0	10681	217662	63254	0	0	292644
1965	0	0	0	0	48226	25442	0	0	0	0	0	0	73668
1966	473	318	458	5656	50135	769	357	22689	14340	212	516	437	96360
1967	712	643	939	1263	899	931	770	894	34551	12602	0	0	54204
1968	10310	6290	3637	3730	90258	0	0	0	0	8433	0	0	122658
1969	0	0	0	0	4583	678	0	591	2748	90783	19514	17850	136747
1970	5120	974	2548	0	0	0	0	0	12025	4695	0	0	25362
1971	0	0	1245	1161	1154	42514	110568	319650	19942	82686	19129	11990	610039
1972	6900	4248	307	0	218	0	0	36748	4708	0	0	0	53129
1973	0	0	0	0	0	0	9420	1314	604	131914	21331	10307	174890
1974	5552	1886	3706	0	7899	0	0	4154	13366	667	12869	3581	53680
1975	2626	3684	0	2548	4089	114557	23451	6052	1932	419	407	0	159765
1976	0	0	0	0	2196	0	81369	22970	20181	25779	28892	17080	198467
1977	13843	12061	9580	36455	30511	9167	3127	0	0	0	1437	2153	118334
1978	0	0	0	0	9659	9763	0	0	4651	0	0	0	24073
1979	0	0	0	11316	6320	126756	0	0	0	0	0	0	144392
1980	0	0	0	0	41765	1719	0	1454	0	0	0	0	44938
1981	0	0	0	36328	24440	124775	17773	1618	4851	111265	16998	6254	344302
1982	3801	1381	5252	686	18243	3016	363	0	0	0	0	0	32742
1983	0	0	0	0	0	0	0	0	28829	408	568	0	29805
1984	0	0	0	0	0	0	0	0	0	62328	0	0	62328
1985	43657	5176	8979	6216	7149	0	0	0	0	61826	8599	1154	142756
1986	0	0	0	0	4835	42418	0	0	6404	54974	14092	10078	132801
1987	12441	6714	8553	5015	33579	257603	35912	15178	31907	14751	9338	7781	438772
1988	6138	3345	1171	0	0	0	0	0	0	0	0	0	10654
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	2851	2931	2377	5268	15497	31395	12245	11745	21505	20797	4058	1981	132649
Max	43657	79203	78123	71083	104618	529927	110568	319650	217662	196417	34434	17850	819131
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
median	0	0	0	0	3143	1560	0	0	2340	1287	0	0	78636
drt avg	5	7925	7821	1262	8362	9141	5567	2454	16684	2162	9	8	61400

Nueces River @ Asherton Flow Statistics
2050 + TTexas Pumpage
Pumpage Affected Modified Flows at Asherton in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	0	0	0	1240	1297	3024	0	0	5820	0	8340	439	20160
1935	0	0	0	9153	104618	529927	80273	19677	72616	2834	0	0	819098
1936	0	0	0	0	2039	0	106708	0	169101	42872	8787	4472	333979
1937	0	0	0	0	0	4245	0	0	0	0	0	0	4245
1938	33042	0	0	7437	0	0	29014	42938	0	0	0	0	112431
1939	0	0	0	0	83026	6438	17873	3588	0	36012	0	0	146937
1940	0	0	0	14455	19595	24719	6383	2409	0	0	0	0	67561
1941	2377	21094	0	5060	18401	0	0	0	729	0	0	0	47661
1942	0	0	0	443	10254	0	3609	0	60959	6701	0	0	81966
1943	0	0	0	0	0	24369	0	0	0	973	0	0	25342
1944	0	0	0	0	25059	8176	0	100081	144130	1192	0	0	278638
1945	0	0	5514	28033	1060	0	0	0	21121	47610	0	0	103338
1946	0	0	0	34996	16106	2991	0	302	4464	4365	0	0	63224
1947	0	0	0	0	849	25114	0	0	0	0	0	0	25963
1948	0	0	0	0	0	26502	6818	0	10605	1375	0	0	45300
1949	0	79203	77983	12513	1983	14271	0	16403	0	3048	0	0	205404
1950	0	0	0	0	0	13983	694	7892	5280	0	0	0	27849
1951	0	0	0	0	23808	0	0	0	0	0	0	0	23808
1952	48	46	91	102	19837	1401	121	106	99	116	88	75	22130
1953	0	0	0	0	0	0	0	0	62104	6563	0	0	68667
1954	0	0	0	0	36719	9862	26355	0	0	7779	0	0	80715
1955	0	0	0	0	0	0	20594	0	88502	857	0	0	109953
1956	0	0	0	0	0	0	778	0	0	1769	0	0	2547
1957	0	0	0	71083	101722	81709	0	0	0	21192	0	0	275706
1958	2119	7099	0	0	0	179016	10869	0	123082	42034	34294	7890	406403
1959	1535	0	0	0	5400	24714	24127	3832	9543	196277	5938	2330	273696
1960	3017	1858	0	0	0	0	22961	7250	5831	13136	15324	6077	75454
1961	5599	7947	2934	0	0	16789	44482	8702	820	0	333	621	88227
1962	0	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	7773	0	0	0	0	0	0	0	7773
1964	0	0	0	0	1047	0	0	10681	216964	63114	0	0	291806
1965	0	0	0	0	48226	25233	0	0	0	0	0	0	73459
1966	471	316	456	5626	50115	759	355	22479	14130	59	512	437	95715
1967	712	643	939	1250	895	931	770	894	34551	12385	0	0	53970
1968	10101	6011	3448	3570	90119	0	0	0	0	8332	0	0	121581
1969	0	0	0	0	4542	674	0	591	2748	43999	9599	4373	66526
1970	0	0	0	0	0	0	0	0	0	3	0	0	3
1971	0	0	1239	1161	1154	31132	109751	96902	1577	48680	1253	957	293806
1972	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	2827	322	3149
1974	0	0	710	0	0	0	0	1424	7801	0	0	0	9935
1975	0	0	0	0	0	105689	0	0	0	0	0	0	105689
1976	0	0	0	0	0	0	0	276	0	7484	9969	740	18469
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	8612	9290	0	0	3925	0	0	0	21827
1979	0	0	0	3286	1858	111813	0	0	0	0	0	0	116957
1980	0	0	0	0	41694	1712	0	1451	0	0	0	0	44857
1981	0	0	0	7908	15223	27715	1852	0	0	0	2893	0	55591
1982	0	0	238	0	0	0	0	0	0	0	0	0	238
1983	0	0	0	0	0	0	0	0	28829	408	568	0	29805
1984	0	0	0	0	0	0	0	0	0	62323	0	0	62323
1985	5741	0	1508	3597	5117	0	0	0	0	41087	4870	0	61920
1986	0	0	0	0	4741	37837	0	0	4100	23482	0	0	70160
1987	501	87	0	0	0	124233	2604	0	0	0	0	0	127425
1988	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	1165	2220	1698	3766	13444	26326	9232	6212	19633	13358	1886	513	99453
Max	33042	79203	77983	71083	104618	529927	109751	100081	216964	196277	34294	7890	819098
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
median	0	0	0	0	1054	845	0	0	0	262	0	0	62774
drt avg	5	7925	7807	1262	8320	9113	5536	2440	16659	2151	9	8	61234

Frio River @ Derby Flow Statistics

Baseline Historical Modified Flows at Derby in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	1261	730	539	3927	466	0	0	0	0	864	1012	790	9589
1935	0	0	0	1657	141167	478888	110670	9296	36383	5292	1361	2679	787393
1936	2518	1809	1297	3400	5542	2067	37163	656	70364	25893	6759	4387	161855
1937	3224	2669	2696	2050	1445	4029	896	616	755	804	780	5005	24969
1938	5782	1312	1909	4446	1885	520	618	224	223	225	363	653	18160
1939	915	833	959	438	1511	423	33155	4654	367	13100	891	992	58238
1940	1133	1086	882	1611	1191	4438	570	26	0	0	1556	3416	15909
1941	1131	48174	8741	21873	36602	5475	1806	6848	5980	10735	1050	935	149350
1942	1146	1515	1302	2058	878	270	9990	1168	33879	13629	599	715	67149
1943	1162	1115	1142	1083	807	15981	444	0	322	320	1705	376	24457
1944	318	213	1956	14	3612	2365	0	12085	8213	15175	0	341	44292
1945	6747	512	368	4062	0	1029	0	0	8206	18089	0	0	39013
1946	0	0	0	3092	970	68	0	16124	28661	7655	0	0	56570
1947	0	0	0	0	0	19553	0	34	0	0	0	0	19587
1948	0	0	0	0	0	24298	1981	13	215	5201	3	9	31720
1949	24	23637	5408	14641	1436	4748	0	3903	0	13513	0	0	67310
1950	0	0	0	0	1900	0	64	0	0	0	0	0	1964
1951	0	0	0	0	60323	672	0	0	0	77	0	0	61072
1952	0	0	0	0	273	108	0	0	654	0	0	0	1035
1953	0	0	0	0	0	0	0	592	78985	7668	51	0	87296
1954	0	0	0	0	18722	0	0	74	0	0	0	0	18796
1955	0	0	0	0	6858	0	0	17	1226	0	0	0	8101
1956	0	0	0	404	0	0	6856	1418	0	1192	0	0	9870
1957	0	0	416	63146	73681	47918	0	0	9387	28730	874	0	224152
1958	9500	10262	18266	1642	8910	97175	7332	0	56926	22424	29479	3432	265348
1959	922	176	0	0	281	21585	6412	0	412	48826	0	32	78646
1960	0	0	0	0	0	0	0	1434	0	375	194	171	2174
1961	47	4637	1148	0	0	62981	3906	574	32	852	661	795	75633
1962	911	574	304	1733	50	0	0	0	0	0	0	0	3572
1963	0	0	0	0	3040	0	0	0	0	0	0	0	3040
1964	0	0	515	65	0	5379	0	0	6495	2833	1970	0	17257
1965	0	30	0	3207	4246	0	0	0	0	1203	0	540	9226
1966	0	0	0	1137	557	100	0	23260	3314	0	0	0	28368
1967	0	0	0	1825	0	0	0	0	24652	14426	7241	970	49114
1968	9596	4679	6489	3075	30793	2186	1568	41	334	0	0	0	58761
1969	0	0	0	0	1221	147	245	36	0	49162	2052	1557	54420
1970	967	688	876	783	10724	2343	129	0	5708	1381	733	749	25081
1971	845	237	96	111	116	0	4017	345237	6587	56531	12640	4778	431195
1972	3207	2517	1650	983	22987	643	243	12815	2939	1347	1145	1744	52220
1973	2406	2595	2576	5021	1588	15699	157569	17651	29333	45331	14845	8341	302955
1974	7221	5499	5202	3369	11178	2654	713	7572	83848	7515	7842	6861	149474
1975	6977	26808	7880	8465	16247	8727	7937	4771	4760	4353	4714	4483	106122
1976	4418	3051	2414	23583	35054	5025	58102	13681	9030	14858	13645	14148	197009
1977	13421	15058	12782	26721	27642	11096	5542	3469	2892	14669	7355	6486	147133
1978	5488	3806	3199	2522	1464	5031	276	23280	1739	1284	2375	2394	52858
1979	4095	2951	14992	24478	9645	90385	7181	2718	1896	1538	1934	3137	164950
1980	3185	1612	954	634	32723	1160	0	9901	21711	11457	293	354	83984
1981	848	715	266	43627	24862	135978	27722	3646	2752	32248	5051	4448	282163
1982	4126	2740	4070	3053	15360	2713	1642	493	509	560	1165	1672	38103
1983	2286	1983	2073	1687	644	6292	446	731	693	596	761	1029	19221
1984	1310	695	135	107	41	0	56	33	26	29698	62	0	32163
1985	32800	1645	4697	675	3200	107	250	0	0	15576	2107	1730	62787
1986	1413	1118	319	694	807	34210	891	0	2879	31738	5650	9234	88953
1987	10389	5589	8605	5766	49264	382654	38950	12236	15683	9429	8692	9498	556755
1988	9544	7320	6207	4921	3405	4793	8940	1145	1707	2182	2943	2512	55619
1989	3327	3599	2992	1652	1142	0	0	0	0	0	0	0	12712
Average	2939	3468	2434	5347	12080	26998	9719	9687	10191	10546	2724	1989	98123
Max	32800	48174	18266	63146	141167	478888	157569	345237	83848	56531	29479	14148	787393
Min	0	0	0	0	0	0	0	0	0	0	0	0	1035
median	1049	782	879	1647	1550	2265	360	534	1467	3593	771	732	53639
drt avg	2	2364	541	1505	8951	4938	890	605	8108	2765	5	1	30675

Frio River @ Derby Flow Statistics
1994 Pumpage
Pumpage Affected Modified Flows at Derby in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	0	0	0	2790	0	0	0	0	0	0	94	0	2884
1935	0	0	0	938	136978	475397	107249	6015	33101	2115	0	0	761793
1936	0	196	0	2158	3825	503	35746	0	66873	22751	3687	1384	137123
1937	340	958	0	605	454	2863	0	0	0	0	33	3189	8442
1938	2738	0	170	2708	0	0	0	0	0	0	0	3	5619
1939	287	211	351	0	924	0	30223	2650	0	12458	214	98	47416
1940	246	346	114	829	0	3460	0	0	0	0	787	2682	8464
1941	377	47420	7929	18870	33809	2787	186	4194	3466	8221	0	0	127259
1942	329	851	624	494	0	0	9327	533	31337	11129	0	59	54683
1943	499	458	695	504	262	15248	0	0	0	0	1116	0	18782
1944	0	0	31	0	2965	308	0	11497	7563	14531	0	0	36895
1945	4156	0	0	1653	0	410	0	0	7676	17593	0	0	31488
1946	0	0	0	2768	611	0	0	15711	28232	5490	0	0	52812
1947	0	0	0	0	0	17130	0	0	0	0	0	0	17130
1948	0	0	0	0	0	24137	1642	0	0	4891	0	0	30670
1949	0	21682	3607	12924	0	4422	0	3589	0	12993	0	0	59217
1950	0	0	0	0	1499	0	0	0	0	0	0	0	1499
1951	0	0	0	0	58591	415	0	0	0	0	0	0	59006
1952	0	0	0	0	27	0	0	0	402	0	0	0	429
1953	0	0	0	0	0	0	0	382	78775	7464	0	0	86621
1954	0	0	0	0	16697	0	0	0	0	0	0	0	16697
1955	0	0	0	0	6666	0	0	0	0	0	0	0	6666
1956	0	0	0	237	0	0	6766	1336	0	1076	0	0	9415
1957	0	19	192	61331	72151	46591	0	0	8339	27612	539	0	216774
1958	8732	9355	17498	972	8597	96477	6836	0	56227	21656	28711	2832	257893
1959	723	1	0	0	113	21166	6175	0	184	47988	0	0	76350
1960	0	0	0	0	0	0	0	1260	0	116	0	0	1376
1961	0	3952	603	0	0	62422	3634	364	0	677	473	599	72724
1962	722	378	130	1572	0	0	0	0	0	0	0	0	2802
1963	0	0	0	0	3035	0	0	0	0	0	0	0	3035
1964	0	0	517	64	0	5354	0	0	5810	2544	1949	0	16238
1965	0	0	0	3117	4162	0	0	0	0	1008	0	499	8786
1966	0	0	0	1072	488	54	0	22631	2727	0	0	0	26972
1967	0	0	0	1821	0	0	0	0	24100	13937	6899	943	47700
1968	9184	4142	6280	2573	30234	1732	1156	0	5	0	0	0	55306
1969	0	0	0	0	1000	0	43	0	0	48743	1857	1348	52991
1970	750	464	659	678	10556	2169	0	0	5517	1167	622	651	23233
1971	719	88	0	0	0	0	3959	344539	6266	55903	12173	4541	428188
1972	3088	2140	1336	843	22827	531	131	12256	2842	1207	1005	1612	49818
1973	2281	2455	2618	5021	1553	15071	156871	17093	29145	44703	14468	8034	299313
1974	7040	5352	5034	3258	10648	2479	545	7084	83659	7347	7702	6721	146869
1975	6872	26669	7761	8213	16073	8594	7832	4603	4558	4136	4483	4260	104054
1976	4209	2848	2225	23331	34705	4872	57753	13430	8876	14705	13463	13981	194398
1977	13268	14807	12601	26372	27432	10865	5360	3316	2871	14320	7243	6284	144739
1978	5328	3716	3158	2515	1269	4787	95	23001	1613	1158	2243	2282	51165
1979	3998	3000	14643	24198	9394	90036	7139	2473	1679	1503	1830	3081	162974
1980	3094	1563	731	481	32548	979	0	9714	21432	11156	333	167	82198
1981	629	530	124	43278	24513	135978	27372	3471	2591	31899	4897	4295	279577
1982	4167	2712	4063	2864	14941	2664	1565	416	341	371	1018	1491	36613
1983	2104	1802	1892	1505	476	6082	278	577	553	464	635	910	17278
1984	1296	702	34	26	0	0	210	50	66	29727	0	0	32111
1985	32450	1335	4355	450	2941	0	284	0	0	15226	1926	1625	60592
1986	1337	1055	270	714	583	33882	1003	0	2823	31193	5531	8822	87213
1987	10040	5268	8319	5648	49264	381956	38600	12006	15313	9234	8504	9330	553482
1988	9551	7271	6186	4718	3168	4416	8521	1131	1637	2098	2866	2351	53914
1989	3139	3453	2817	1470	960	0	0	0	0	0	0	0	11839
Average	2566	3164	2099	4921	11552	26540	9402	9381	9761	10045	2452	1680	93563
Max	32450	47420	17498	61331	136978	475397	156871	344539	83659	55903	28711	13981	761793
Min	0	0	0	0	0	0	0	0	0	0	0	0	429
median	359	362	150	891	1135	1356	69	25	1083	2330	154	31	50492
drt avg	0	2168	361	1316	8348	4610	841	531	7918	2642	0	0	28735

Frio River @ Derby Flow Statistics
2050 Pumpage
Pumpage Affected Modified Flows at Derby in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	0	0	0	2790	0	0	0	0	0	0	97	0	2887
1935	0	0	0	905	137676	475397	107249	6015	33101	2129	0	0	762472
1936	0	210	0	2151	3825	510	35746	0	66873	22751	3757	1384	137207
1937	354	972	0	619	468	2877	0	0	22	15	54	3203	8584
1938	2752	0	177	2715	6	0	0	0	0	0	0	17	5667
1939	301	225	365	0	938	0	30223	2664	0	12472	235	112	47535
1940	260	360	127	843	0	3481	0	0	0	0	802	2673	8546
1941	427	47447	7759	18940	33809	2835	221	4236	3466	8291	0	0	127431
1942	357	879	652	362	0	0	9368	554	31379	11164	0	87	54802
1943	527	486	528	560	318	15297	0	0	0	0	1149	0	18865
1944	0	0	58	0	2962	332	0	11521	7587	14555	0	0	37015
1945	4226	0	0	1702	0	443	0	0	7695	17590	0	0	31656
1946	0	0	0	2779	614	0	0	15727	28209	5420	0	0	52749
1947	0	0	0	0	0	17276	0	0	0	0	0	0	17276
1948	0	0	0	0	0	23991	1684	0	0	4911	0	0	30586
1949	0	21822	3719	13014	0	4452	0	3647	0	13043	0	0	59697
1950	0	0	0	0	1537	0	0	0	0	0	0	0	1537
1951	0	0	0	0	58640	436	0	0	0	0	0	0	59076
1952	0	0	0	0	57	0	0	0	453	0	0	0	510
1953	0	141	0	0	0	0	0	382	78238	7935	201	0	86897
1954	0	0	0	0	15998	0	0	0	0	0	0	0	15998
1955	0	0	0	0	6644	0	0	0	0	0	0	0	6644
1956	0	0	0	492	0	0	7183	1566	549	1460	60	0	11310
1957	0	0	85	60353	71586	46270	0	68	7921	27333	386	0	214002
1958	8732	9355	17498	986	8611	96477	6850	0	56227	21656	28711	2860	257963
1959	748	26	0	0	138	21166	6084	0	196	48197	0	0	76555
1960	0	0	0	0	0	0	0	1323	0	165	0	0	1488
1961	0	4001	645	0	0	62492	3669	406	0	719	515	634	73081
1962	743	399	130	1586	0	0	0	0	0	0	0	0	2858
1963	0	0	0	0	2887	0	0	18	0	0	0	0	2905
1964	0	0	545	80	0	5386	7	0	6055	2867	2010	0	16950
1965	56	39	0	3288	4315	0	33	0	0	959	0	455	9145
1966	0	0	0	1159	583	119	0	22701	2811	0	0	0	27373
1967	0	0	0	1863	0	0	0	0	24177	14007	6829	847	47723
1968	9149	4183	6203	2628	30304	1781	1218	0	58	0	0	0	55524
1969	0	0	0	0	1044	35	100	0	0	48813	1905	1397	53294
1970	799	513	694	608	10647	2239	0	0	5612	1241	566	574	23493
1971	670	53	0	0	0	0	3962	344539	6211	56112	12326	4764	428637
1972	3179	2217	1385	752	22897	587	208	12396	2660	1396	1068	1668	50413
1973	2344	2665	2527	4916	1484	15210	156871	17232	29194	44773	14551	8111	299878
1974	7012	5457	5097	3383	10752	2619	622	7154	83778	7473	7709	6770	147826
1975	6879	26669	7810	8227	16059	8573	7811	4624	4600	4192	4546	4323	104313
1976	4258	2897	2260	23401	34775	4913	57823	13500	8883	14754	13512	14030	195006
1977	13303	14877	12649	26442	27502	10928	5416	3350	2794	14390	7208	6374	145233
1978	5376	3709	3283	2536	1359	4856	123	23001	1648	1193	2277	2303	51664
1979	4228	2965	14712	24198	9450	90036	7167	2536	1735	1398	1823	3116	163364
1980	3191	1591	829	564	32625	1049	0	9773	21502	11219	316	232	82891
1981	688	581	150	43348	24582	135978	27442	3527	2647	31969	4946	4344	280202
1982	4028	2782	4070	2948	15080	2685	1628	458	362	420	1039	1540	37040
1983	2160	1865	1948	1568	532	6152	341	626	595	498	663	938	17886
1984	1219	611	57	150	103	0	82	27	24	29668	39	0	31980
1985	32520	1434	4469	519	3025	0	129	0	0	15366	1926	1639	61027
1986	1330	1041	403	652	611	34203	787	0	2768	31521	5678	9032	88026
1987	10250	5407	8431	5620	49264	381956	38670	12090	15390	9310	8574	9379	554341
1988	9439	7404	6221	4816	3231	4499	8661	1033	1749	2140	2943	2386	54522
1989	3195	3481	2866	1526	1023	0	0	0	0	0	0	0	12091
Average	2584	3192	2113	4928	11571	26563	9417	9405	9771	10098	2472	1700	93815
Max	32520	47447	17498	60353	137676	475397	156871	344539	83778	56112	28711	14030	762472
Min	0	0	0	0	0	0	0	0	0	0	0	0	510
median	392	380	140	874	1202	1415	91	48	1122	2504	218	52	51039
drt avg	0	2196	372	1351	8288	4616	887	560	7924	2735	26	0	28953

Frio River @ Derby Flow Statistics
2050 + TTexas Pumpage
Pumpage Affected Modified Flows at Derby in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	0	0	0	2790	0	0	0	0	0	0	95	0	2885
1935	0	0	0	903	136978	475397	107249	6015	33101	2122	0	0	761765
1936	0	203	0	2144	3818	503	35739	0	66873	22751	3687	1384	137102
1937	340	965	0	605	454	2863	0	0	0	22	54	3203	8506
1938	2745	0	177	2708	0	0	0	0	0	0	0	3	5633
1939	287	211	351	0	924	0	30223	2650	0	12458	214	98	47416
1940	246	346	114	829	0	3460	0	0	0	0	787	2658	8440
1941	406	47428	7748	18940	33809	2814	207	4215	3466	8291	0	0	127324
1942	336	858	631	341	0	0	9347	533	31358	11143	0	73	54620
1943	506	465	702	511	269	15255	0	0	0	0	1120	0	18828
1944	0	0	33	0	2966	308	0	11500	7563	14532	0	0	36902
1945	4170	0	0	1660	0	412	0	0	7681	17596	0	0	31519
1946	0	0	0	2763	598	0	0	15770	28285	5420	0	0	52836
1947	0	0	0	0	0	17130	0	0	0	0	0	0	17130
1948	0	0	0	0	0	23972	1667	0	0	4895	0	0	30534
1949	0	21752	3663	12966	0	4436	0	3603	0	13001	0	0	59421
1950	0	0	0	0	1631	0	0	0	0	0	0	0	1631
1951	0	0	0	0	58577	395	0	0	0	0	0	0	58972
1952	0	0	0	0	141	0	0	0	558	0	0	0	699
1953	0	0	132	0	0	0	0	359	78203	7921	188	0	86803
1954	0	0	0	0	15789	17	0	0	0	0	0	0	15806
1955	0	0	0	0	6629	0	0	0	0	0	0	0	6629
1956	0	0	0	223	0	0	6723	1291	0	1053	0	0	9290
1957	0	0	206	61331	72165	46661	0	0	8339	27543	525	0	216770
1958	8802	9355	17498	972	8596	96477	6836	0	56227	21656	28711	2839	257969
1959	725	3	0	0	115	21166	6182	0	187	47988	0	0	76366
1960	0	0	0	0	0	0	0	1267	0	123	0	0	1390
1961	0	3959	603	0	0	62422	3627	357	0	677	473	599	72717
1962	715	378	130	1572	0	0	0	0	0	0	0	0	2795
1963	0	0	0	0	2885	0	0	43	0	0	0	0	2928
1964	0	12	548	74	0	5384	0	0	5838	2743	1811	0	16410
1965	0	0	0	3177	4164	0	22	6	0	840	65	897	9171
1966	135	0	430	1467	724	163	0	21584	2127	0	0	0	26630
1967	0	0	0	1782	0	0	0	0	24017	13867	6843	875	47384
1968	9149	4107	6252	2545	30234	1711	1135	0	0	0	0	0	55133
1969	0	0	0	0	996	0	181	0	0	48743	1841	1334	53095
1970	736	450	645	664	10542	2155	0	0	5505	1157	754	539	23147
1971	621	4	0	25	6	0	4014	344539	6245	55903	12173	4527	428057
1972	3081	2133	1322	913	22792	517	110	12256	2730	1235	1033	1633	49755
1973	2281	2644	2492	4965	1532	15071	156871	17093	29138	44703	14475	8027	299292
1974	6970	5401	5048	3258	10641	2466	531	7014	83638	7326	7674	6714	146681
1975	6872	26669	7740	8185	16178	8657	7769	4547	4516	4108	4462	4246	103949
1976	4195	2841	2211	23331	34705	4858	57753	13430	8828	14698	13456	13974	194280
1977	13261	14814	12594	26372	27432	10872	5367	3309	2822	14320	7334	6284	144781
1978	5328	3792	3144	2501	1255	4780	88	23001	1599	1151	2236	2275	51150
1979	3991	2958	14643	24198	9401	90036	7139	2473	1679	1370	1844	3095	162827
1980	3108	1577	738	487	32555	986	0	9718	21432	11163	276	182	82222
1981	641	534	118	43278	24513	135978	27372	3478	2598	31899	4897	4295	279601
1982	4126	2719	4070	2871	14941	2664	1565	409	334	364	1011	1477	36551
1983	2083	1795	1885	1512	476	6089	285	577	549	459	635	903	17248
1984	1192	583	159	101	0	0	28	9	128	29755	0	0	31955
1985	32450	1353	4379	461	2948	0	91	30	0	15226	1863	1646	60447
1986	1316	1048	270	596	520	34000	738	0	2733	31395	5517	8941	87074
1987	10180	5337	8368	5571	49264	381956	38600	12027	15334	9255	8518	9323	553733
1988	9411	7299	6214	4739	3168	4437	8591	998	1672	2119	2866	2344	53858
1989	3132	3453	2810	1470	967	0	0	0	0	0	0	0	11832
Average	2563	3169	2108	4925	11541	26544	9394	9359	9738	10053	2454	1686	93534
Max	32450	47428	17498	61331	136978	475397	156871	344539	83638	55903	28711	13974	761765
Min	0	0	0	0	0	0	0	0	0	0	0	0	699
median	373	362	192	908	1126	1349	58	37	1079	2433	201	38	50453
drt avg	0	2175	380	1319	8277	4595	839	525	7876	2687	19	0	28692

Atascosa River @ Whitsett Flow Statistics

Baseline Historical Modified Flows at Whitsett in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	16189	5878	4226	9320	364	70	2022	125	917	2171	6559	7009	54850
1935	855	8868	2826	10440	33847	204979	3262	746	60079	4451	1309	2569	334231
1936	1479	960	5026	817	48837	10029	45702	2684	4099	2291	840	943	123707
1937	945	646	786	508	831	3159	1332	60	0	965	186	24509	33927
1938	12349	1268	1216	15970	2777	626	407	70	671	9	505	1779	37647
1939	765	550	441	75	1837	6199	8092	2724	5729	217	55	207	26891
1940	341	1195	758	7983	7322	19792	9144	8694	1046	4627	23726	17106	101734
1941	5998	8378	5667	69787	72256	26176	3587	6767	83818	10199	1098	1068	294799
1942	974	1368	934	6867	3267	528	176998	11578	116498	7269	1839	1389	329509
1943	1531	1291	2151	1093	2494	3483	1963	167	7552	692	1512	1032	24961
1944	6132	1281	5620	817	26564	1405	1257	1669	732	200	2382	2542	50601
1945	1315	4675	1904	23832	646	8741	941	125	1385	21186	550	552	65852
1946	1288	1528	8678	8397	15467	23087	538	74238	70398	48449	3339	2419	257826
1947	4378	1658	3538	1897	15027	937	679	7278	427	255	2209	892	39175
1948	688	1086	801	672	315	2744	11825	5216	418	2548	404	485	27202
1949	659	4978	1037	58537	3177	18447	62467	4887	1668	5579	1148	4049	166633
1950	1017	851	754	1754	6054	6814	11035	122	362	26	32	163	28984
1951	295	350	609	407	11540	14201	90	392	26455	1226	1225	847	57637
1952	1075	2785	909	3881	2400	393	6992	408	14605	462	969	1505	36384
1953	1378	954	1067	3537	33347	1797	1967	3097	35168	4689	826	616	88443
1954	603	854	923	3691	2678	2350	450	0	186	1321	1610	560	15226
1955	1169	7068	982	705	7977	3589	1162	2404	1149	39	299	710	27253
1956	705	637	638	1880	3837	1269	871	4164	10519	12551	397	3599	41067
1957	889	1028	6596	71850	83877	19059	827	532	41819	6161	14319	1429	248386
1958	57789	83218	3966	1810	12747	1389	2902	174	6999	23741	17029	5389	217153
1959	1759	2048	1196	1000	5107	1409	508	155	423	12291	1849	721	28466
1960	1019	978	1926	1300	596	11949	8692	8314	833	23131	12239	18059	89036
1961	5899	14278	1156	2470	472	46919	2732	893	308	16301	4389	1229	97046
1962	1189	1158	789	886	466	11169	132	114	452	50	243	1269	17917
1963	477	2761	317	131	2133	1195	329	192	167	205	1853	2773	12533
1964	420	1260	832	508	538	229	468	6287	180	1293	1023	269	13307
1965	438	5302	386	1897	33337	1138	606	120	218	2035	590	4084	50151
1966	479	597	367	11648	5753	3590	720	767	2733	563	120	257	27594
1967	329	378	341	213	3188	314	195	5831	297931	5716	9379	1519	325334
1968	126191	8270	2589	3284	76922	6263	5476	684	4891	609	656	2571	238406
1969	639	11027	1296	3531	21456	3042	295	1381	621	9152	544	881	53865
1970	1850	1618	15367	951	52283	48460	1854	1044	1961	524	294	455	126661
1971	433	408	408	283	142	940	54	18161	4043	20353	1071	1220	47516
1972	812	702	566	308	54128	4065	475	2520	6102	555	356	346	70935
1973	553	2898	752	10212	1198	171494	4041	1643	26012	34873	2890	1390	257956
1974	1269	970	869	749	2727	1192	141	8584	11049	817	1609	664	30640
1975	571	576	529	1470	40394	13961	3353	786	893	680	423	399	64035
1976	473	383	399	7230	19587	772	5274	145	5049	45671	16169	8939	110091
1977	6539	2108	1188	136780	15827	2411	645	215	1679	573	1699	419	170083
1978	455	504	415	364	646	7251	4134	28586	23789	1001	3079	1019	71243
1979	7249	1510	865	14650	3959	20870	1446	588	705	102	185	1339	53468
1980	499	405	377	185	78858	859	322	55058	3969	933	2649	1109	145223
1981	1419	887	1946	2560	2627	5819	1742	1289	13569	2811	1289	832	36790
1982	691	7068	1416	786	7927	3279	119	10	1119	4551	560	413	27939
1983	438	1238	3406	392	1077	2419	1542	2524	45589	4431	488	487	64031
1984	2359	438	399	273	344	282	104	0	217	12911	2109	1419	20855
1985	2369	716	2896	14610	2307	2469	5912	13	4069	28271	14249	1559	79440
1986	745	605	350	100	881	8139	50	26	695	18641	1189	26759	58180
1987	2979	11128	5076	836	1817	71159	1092	377	976	103	178	542	96263
1988	267	294	187	138	688	349	1192	39	533	0	1	0	3688
1989	306	274	446	141	195	0	136	16	0	211	1189	231	3145
Average	5213	4038	1984	9400	14948	14905	7327	5084	17026	7334	3017	2974	93248
Max	126191	83218	15367	136780	83877	204979	176998	74238	297931	48449	23726	26759	334231
Min	267	274	187	75	142	0	50	0	0	0	1	0	3145
median	960	1217	929	1612	3228	3219	1225	777	1674	2103	1169	1089	56244
drt avg	1197	2122	1126	7696	8635	5254	9754	2797	9096	2870	912	1343	52800

Atascosa River @ Whitsett Flow Statistics
1994 Pumpage
Pumpage Affected Modified Flows at Whitsett in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	15002	4663	3011	8064	0	0	800	0	0	956	5337	5822	43655
1935	0	7681	1639	9253	32660	203582	2061	0	58892	3256	115	1382	320521
1936	292	0	3839	0	47650	8842	44445	1490	2905	1097	0	0	110560
1937	0	0	0	0	0	1972	145	0	0	0	0	23322	25439
1938	11162	80	43	14783	1604	0	0	0	0	0	0	592	28264
1939	0	0	0	0	643	5005	6905	1558	4569	0	0	0	18680
1940	0	8	0	6796	6205	18605	8027	7577	0	3496	22609	15988	89311
1941	4867	7261	4550	68740	70860	25059	2470	5671	83119	9081	0	0	281678
1942	0	257	0	5799	2164	0	175601	10461	115102	6152	722	279	316537
1943	421	187	1054	0	1397	2387	874	0	6435	0	423	0	13178
1944	5049	198	4545	0	25517	337	189	600	0	0	1307	1473	39215
1945	246	3607	843	22715	0	7624	0	0	330	20138	0	0	55503
1946	220	467	7630	7350	14419	22109	0	73540	69001	47402	2277	1365	245780
1947	3331	611	2491	857	13980	0	0	6231	0	0	1168	0	28669
1948	0	67	0	0	0	1725	10777	4204	0	1535	0	0	18308
1949	0	3965	31	57560	2179	17469	61489	3903	684	4602	171	3079	155132
1950	46	0	0	783	5091	5872	10057	0	0	0	0	0	21849
1951	0	0	0	0	10492	13154	0	0	25407	221	234	0	49508
1952	104	1814	0	2924	1457	0	6043	0	13628	0	21	569	26560
1953	442	32	152	2622	32439	889	1066	2203	34261	3795	0	0	77901
1954	0	0	26	2798	1784	1463	0	0	0	407	702	0	7180
1955	268	6181	92	0	7139	2716	303	1545	290	0	0	0	18534
1956	0	0	0	1021	2985	431	31	3333	9681	11713	0	2775	31970
1957	67	218	5813	70454	83178	18290	47	0	41051	5393	13550	675	238736
1958	57091	82520	3226	1077	11979	676	2197	0	6279	23043	16331	4697	209116
1959	1081	1371	526	343	4458	773	28	25	135	11662	1220	105	21727
1960	411	375	1332	714	135	11320	8133	7755	295	22573	11750	17570	82363
1961	5375	13789	639	1968	158	46431	2243	416	194	15882	3914	761	91770
1962	728	704	344	448	218	10680	17	108	357	38	235	829	14706
1963	385	2321	291	110	1707	776	303	170	148	188	1448	2368	10215
1964	302	855	435	416	410	181	417	5854	131	881	619	225	10726
1965	315	4897	345	1506	32988	754	432	73	179	1651	441	3686	47267
1966	449	444	309	11299	5362	3206	474	394	2370	456	64	210	25037
1967	289	342	309	76	2824	286	63	5482	297931	5374	9030	1183	323189
1968	125493	7920	2268	2970	76922	5948	5168	379	4591	377	467	2264	234767
1969	473	10678	996	3231	21177	2748	171	1095	400	8802	499	578	50848
1970	1549	1325	15088	669	52004	48181	1581	778	1696	443	172	449	123935
1971	432	410	411	179	41	661	0	17951	3778	20074	808	955	45700
1972	552	445	427	291	53849	3800	354	2269	5851	437	343	338	68956
1973	547	2619	480	10003	940	171494	3783	1385	25733	34594	2632	1138	255348
1974	1025	724	627	508	2490	962	37	8375	10770	592	1386	439	27935
1975	451	438	425	1218	40115	13681	3122	558	671	459	322	299	61759
1976	483	395	412	7013	19377	545	5051	36	4832	45462	15890	8730	108226
1977	6316	1892	972	136082	15618	2195	430	117	1470	466	1476	313	167347
1978	457	510	422	373	523	6986	3904	28376	23510	777	2855	800	69493
1979	7019	1286	651	14441	3743	20660	1229	459	482	0	181	1123	51274
1980	496	406	381	189	78159	632	315	54849	3745	712	2432	892	143208
1981	1202	676	1743	2351	2424	5609	1533	1080	13359	2616	1087	635	34315
1982	496	6872	1220	594	7787	3091	23	0	937	4363	489	417	26289
1983	447	1029	3204	395	874	2217	1346	2329	45379	4243	385	494	62342
1984	2163	443	407	178	251	191	14	0	129	12701	1914	1224	19615
1985	2180	523	2708	14401	2125	2281	5730	0	3888	28062	14040	1377	77315
1986	566	494	351	108	683	7930	50	31	597	18432	986	26550	56778
1987	2777	10918	4880	643	1628	70460	896	275	780	3	80	475	93815
1988	273	303	93	47	599	254	982	51	458	0	0	0	3060
1989	212	182	356	52	107	0	52	0	0	130	998	151	2240
Average	4706	3489	1465	8865	14384	14342	6811	4696	16543	6870	2556	2475	87203
Max	125493	82520	15088	136082	83178	203582	175601	73540	297931	47402	22609	26550	323189
Min	0	0	0	0	0	0	0	0	0	0	0	0	2240
median	448	502	426	820	2657	2552	637	438	1204	1027	494	585	51061
drt avg	419	1267	279	6857	7755	4372	8977	2142	8395	2227	230	642	43561

Atascosa River @ Whitsett Flow Statistics
2050 Pumpage
Pumpage Affected Modified Flows at Whitsett in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	15002	4663	3011	8064	0	0	800	0	0	956	5337	5822	43655
1935	0	7681	1639	9253	32660	203582	2061	0	58892	3256	115	1382	320521
1936	292	0	3839	0	47650	8842	44445	1490	2905	1097	0	0	110560
1937	0	0	0	0	0	1972	145	0	0	0	0	23322	25439
1938	11162	80	43	14783	1604	0	0	0	0	0	0	592	28264
1939	0	0	0	0	643	5005	6905	1558	4569	0	0	0	18680
1940	0	8	0	6796	6205	18605	8027	7577	0	3496	22609	15988	89311
1941	4874	7261	4550	68740	70860	25059	2470	5671	83119	9081	0	0	281685
1942	0	264	0	5799	2164	0	175601	10461	115102	6152	722	279	316544
1943	421	187	1054	0	1397	2387	874	0	6435	0	430	0	13185
1944	5049	198	4545	0	25517	337	195	600	0	0	1314	1473	39228
1945	246	3614	843	22715	0	7624	0	0	330	20138	0	0	55510
1946	220	467	7630	7350	14419	22109	0	73540	69001	47402	2277	1372	245787
1947	3331	618	2491	857	13980	0	0	6231	0	0	1168	0	28676
1948	0	67	0	0	0	1725	10777	4211	0	1535	0	0	18315
1949	0	3965	31	57560	2179	17469	61489	3903	684	4602	171	3079	155132
1950	46	0	0	790	5091	5879	10057	0	0	0	0	0	21863
1951	0	0	0	0	10492	13154	0	0	25407	221	241	0	49515
1952	104	1821	0	2931	1457	0	6043	0	13628	0	24	569	26577
1953	449	35	152	2622	32439	896	1066	2203	34261	3795	0	0	77918
1954	0	0	30	2798	1791	1470	0	0	0	407	709	0	7205
1955	275	6188	97	0	7139	2723	303	1552	297	0	0	0	18574
1956	0	0	0	1028	2992	438	37	3333	9681	11713	0	2775	31997
1957	72	218	5820	70454	83178	18290	52	0	41051	5400	13620	675	238830
1958	57091	82520	3233	1084	11979	683	2204	0	6279	23043	16331	4704	209151
1959	1081	1378	533	350	4465	773	28	25	135	11662	1220	110	21760
1960	416	379	1339	721	168	11390	8133	7755	299	22642	11750	17570	82562
1961	5382	13789	646	1975	157	46431	2250	421	193	15882	3921	768	91815
1962	735	711	350	453	218	10680	17	107	357	36	234	836	14734
1963	384	2321	290	109	1707	776	303	170	148	188	1448	2368	10212
1964	302	855	437	415	410	181	417	5854	131	881	620	225	10728
1965	315	4904	345	1506	32988	754	432	73	179	1651	441	3686	47274
1966	449	444	309	11299	5362	3213	474	395	2370	486	63	209	25073
1967	288	341	308	75	2824	285	62	5482	297931	5374	9030	1190	323190
1968	125493	7920	2268	2970	76922	5948	5168	379	4591	377	467	2264	234767
1969	473	10678	996	3231	21177	2748	171	1095	400	8802	499	579	50849
1970	1549	1325	15088	671	52004	48181	1581	780	1703	443	172	449	123946
1971	432	410	411	179	40	661	0	17951	3778	20074	809	955	45700
1972	553	446	427	291	53849	3800	354	2269	5851	437	343	338	68958
1973	547	2619	480	10003	940	171494	3783	1385	25733	34594	2639	1138	255355
1974	1025	725	628	510	2490	962	37	8375	10770	594	1386	441	27943
1975	451	438	426	1218	40115	13681	3122	559	672	460	322	300	61764
1976	483	395	412	7013	19377	545	5051	36	4832	45462	15890	8730	108226
1977	6316	1892	972	136082	15618	2195	430	117	1470	466	1476	313	167347
1978	457	510	422	373	523	6986	3904	28376	23510	777	2855	800	69493
1979	7019	1286	651	14441	3743	20660	1229	459	482	0	181	1123	51274
1980	497	406	381	189	78159	632	315	54849	3745	712	2432	892	143209
1981	1202	676	1743	2351	2424	5609	1533	1080	13359	2616	1087	635	34315
1982	496	6872	1220	594	7787	3091	23	0	937	4363	489	417	26289
1983	447	1029	3204	395	874	2217	1346	2329	45379	4243	385	494	62342
1984	2163	443	407	178	251	192	14	0	129	12701	1914	1224	19616
1985	2180	524	2708	14401	2125	2281	5730	0	3888	28062	14040	1377	77316
1986	567	494	351	108	684	7930	50	31	616	18432	986	26550	56799
1987	2777	10918	4880	642	1628	70460	896	275	779	3	79	475	93812
1988	273	302	93	46	599	254	982	50	458	0	0	0	3057
1989	212	181	355	52	107	0	52	0	0	130	998	151	2238
Average	4707	3490	1466	8865	14385	14344	6811	4697	16544	6872	2558	2476	87216
Max	125493	82520	15088	136082	83178	203582	175601	73540	297931	47402	22609	26550	323190
Min	0	0	0	0	0	0	0	0	0	0	0	0	2238
median	449	502	427	824	2657	2555	637	440	1204	1027	494	586	51062
drt avg	421	1269	280	6859	7756	4375	8977	2143	8396	2227	231	642	43577

Atascosa River @ Whitsett Flow Statistics
2050 + TTexas Pumpage
Pumpage Affected Modified Flows at Whitsett in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	15002	4663	3011	8064	0	0	800	0	0	956	5337	5822	43655
1935	0	7681	1639	9253	32660	203582	2061	0	58892	3256	115	1382	320521
1936	292	0	3839	0	47650	8842	44445	1490	2905	1097	0	0	110560
1937	0	0	0	0	0	1972	145	0	0	0	0	23322	25439
1938	11162	80	43	14783	1604	0	0	0	0	0	0	592	28264
1939	0	0	0	0	636	5005	6905	1558	4569	0	0	0	18673
1940	0	8	0	6796	6205	18605	8027	7577	0	3496	22609	15988	89311
1941	4867	7261	4550	68740	70860	25059	2470	5671	83119	9081	0	0	281678
1942	0	257	0	5792	2164	0	175601	10461	115102	6152	722	272	316523
1943	421	187	1047	0	1397	2387	874	0	6435	0	423	0	13171
1944	5049	198	4545	0	25517	337	189	600	0	0	1307	1466	39208
1945	246	3607	843	22715	0	7624	0	0	330	20138	0	0	55503
1946	220	467	7630	7350	14419	22109	0	73540	69001	47402	2277	1365	245780
1947	3331	611	2491	857	13980	0	0	6231	0	0	1168	0	28669
1948	0	60	0	0	0	1725	10777	4204	0	1528	0	0	18294
1949	0	3965	31	57560	2179	17469	61489	3903	684	4602	164	3072	155118
1950	46	0	0	783	5091	5872	10057	0	0	0	0	0	21849
1951	0	0	0	0	10492	13154	0	0	25407	221	234	0	49508
1952	104	1814	0	2924	1450	0	6036	0	13628	0	19	569	26544
1953	442	30	145	2615	32439	889	1059	2196	34261	3795	0	0	77871
1954	0	0	24	2791	1784	1463	0	0	0	400	702	0	7164
1955	268	6181	90	0	7139	2716	296	1545	290	0	0	0	18525
1956	0	0	0	1021	2985	431	29	3326	9681	11713	0	2768	31954
1957	65	211	5813	70454	83178	18290	45	0	41051	5393	13550	668	238718
1958	57091	82520	3226	1077	11979	669	2197	0	6272	23043	16331	4697	209102
1959	1074	1371	526	343	4458	766	28	24	135	11662	1213	102	21702
1960	408	372	1332	714	135	11320	8133	7755	292	22573	11750	17570	82354
1961	5375	13789	639	1968	157	46431	2243	415	193	15882	3914	761	91767
1962	728	704	343	447	217	10680	17	108	357	37	234	829	14701
1963	384	2321	291	109	1707	776	303	170	148	188	1441	2368	10206
1964	302	855	435	415	410	181	417	5854	131	881	618	224	10723
1965	314	4897	345	1499	32988	754	432	73	179	1644	441	3686	47252
1966	449	444	309	11299	5362	3206	473	393	2370	455	64	209	25033
1967	289	342	308	76	2824	286	63	5482	297931	5374	9030	1183	323188
1968	125493	7920	2268	2970	76922	5948	5161	378	4584	377	467	2257	234745
1969	473	10678	989	3224	21177	2741	171	1095	399	8802	499	577	50825
1970	1549	1325	15088	669	52004	48181	1581	778	1696	442	172	449	123934
1971	431	409	410	178	40	660	0	17951	3778	20074	808	955	45694
1972	551	445	427	290	53849	3800	353	2269	5851	437	343	338	68953
1973	547	2619	480	10003	940	171494	3783	1385	25733	34594	2632	1131	255341
1974	1025	723	627	508	2490	955	37	8375	10770	592	1386	439	27927
1975	450	437	425	1218	40115	13681	3122	557	670	459	321	299	61754
1976	482	395	412	7013	19377	545	5051	35	4832	45462	15890	8730	108224
1977	6316	1892	972	136082	15618	2195	533	110	1463	460	1469	307	167417
1978	452	505	418	368	519	6986	3904	28376	23510	773	2855	797	69463
1979	7012	1286	648	14441	3736	20660	1229	457	480	0	179	1123	51251
1980	495	405	379	188	78159	630	314	54849	3745	712	2432	892	143200
1981	1202	675	1736	2351	2417	5609	1533	1080	13359	2616	1087	633	34298
1982	495	6872	1220	594	7787	3091	22	0	930	4363	488	417	26279
1983	446	1029	3204	395	874	2217	1346	2329	45379	4243	384	493	62339
1984	2163	442	407	178	250	191	13	0	129	12701	1914	1224	19612
1985	2173	523	2708	14401	2125	2281	5723	0	3888	28062	14040	1377	77301
1986	565	493	350	108	683	7930	49	31	596	18432	986	26550	56773
1987	2777	10918	4880	642	1621	70460	896	275	779	2	79	475	93804
1988	273	302	92	46	599	253	982	50	457	0	0	0	3054
1989	211	181	355	51	107	0	51	0	0	129	996	151	2232
Average	4706	3489	1464	8864	14383	14341	6812	4696	16543	6870	2555	2474	87196
Max	125493	82520	15088	136082	83178	203582	175601	73540	297931	47402	22609	26550	323188
Min	0	0	0	0	0	0	0	0	0	0	0	0	2232
median	448	499	426	820	2657	2552	667	436	1197	1027	494	585	51038
drt avg	419	1266	278	6855	7754	4372	8974	2141	8395	2226	229	641	43550

Nueces Estuary Inflow Flow Statistics

2050 Sediment Conditions, Phase IV and 1995 Agreed Order Operating Policies
Baseline Historical Flows into the Nueces Estuary

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	101291	7672	8825	12123	12090	10330	32141	8553	30552	12049	55419	7432	298477
1935	10180	8213	12198	17975	182718	1457323	90179	99057	390415	95302	7533	24045	2395138
1936	7553	8178	25593	8133	55585	53188	307520	8098	112978	157854	10791	9180	764651
1937	8178	8178	8776	8678	11703	25501	8556	11977	11178	10199	16464	74226	203614
1938	58738	10510	8678	37777	25707	7891	7427	24988	9850	7427	8520	48512	256025
1939	7647	7427	7435	9440	31472	39125	8094	10682	18469	9394	7427	10674	167286
1940	7427	8440	8678	8678	34268	174111	220515	27476	25811	15081	9269	9204	548958
1941	8178	43046	8465	165869	570492	132892	100758	8553	179848	12103	9188	9918	1249310
1942	7950	14699	7851	8678	30683	15121	448626	66271	420017	32216	9350	8899	1070361
1943	14047	9642	12081	7803	22503	26081	8553	7427	40170	11928	20546	24535	205316
1944	9690	7470	9406	8101	42447	57787	8553	50378	286843	7427	9961	9994	508057
1945	8178	8604	19096	43020	31181	34119	11117	30874	7683	123573	7427	7656	332528
1946	8582	7456	8689	15696	76079	111320	9469	23986	174945	484330	7427	9133	937112
1947	8323	7644	8700	8864	75926	14904	21232	16846	7519	7583	43614	12210	233365
1948	7427	7427	13005	7427	7985	8171	10320	19013	58494	8751	8928	7684	164632
1949	7603	8809	8870	120038	185036	57816	83916	13752	18485	26686	9178	10163	550352
1950	8178	10314	8281	9813	30441	24765	9026	7427	23396	9178	7427	7427	155673
1951	7427	7653	10357	8364	30428	37517	7427	7427	139136	7806	8928	7756	280226
1952	8178	8178	8506	10236	30911	24178	14411	7611	40916	7427	9764	8807	179123
1953	7528	7528	7528	7528	8128	7427	7577	98823	119165	49579	20254	7738	348803
1954	8178	8178	8602	9471	14811	32910	8053	8471	14155	22675	7928	7679	151111
1955	7916	8178	8163	7522	9143	23577	7427	7828	106685	7549	7916	7613	209517
1956	7427	7427	7427	57686	13368	7427	7427	7601	7427	8445	7427	7427	146516
1957	7427	7427	7680	7749	392852	369834	7427	7894	30020	59842	40453	8053	946658
1958	295433	287414	145448	7427	32432	26053	8580	8384	45136	191207	168486	19865	1235865
1959	13396	8231	8678	7739	23662	46242	14481	16275	10598	132249	7427	9374	298352
1960	8181	8303	9367	8798	7652	50071	8553	20961	29448	131119	67920	103771	454144
1961	38159	58522	7427	16249	7427	36462	50198	10419	23323	11928	11428	7793	279335
1962	7427	7427	7427	7427	7427	30647	7427	7429	20564	7427	8035	10015	128679
1963	8178	8251	8678	7427	8128	10689	7427	9275	7491	7455	8749	7528	99276
1964	7907	7427	7427	7427	13604	7427	11464	7427	16750	191670	7427	8074	294031
1965	7427	15372	8093	7427	65521	22171	7528	7615	8826	7522	7532	8048	173082
1966	7736	7427	7427	34041	96717	25032	8026	11009	8448	7828	7528	7427	228646
1967	10193	13437	7427	7427	7833	7427	7428	8323	1443492	166652	7427	9287	1696353
1968	134986	22796	7803	8678	216902	52932	13136	10178	31299	13558	9179	9178	530625
1969	8178	24975	7803	17064	32681	14849	9178	8684	16780	12542	18716	8761	180211
1970	8212	8236	8737	8678	32377	131416	8553	62605	22402	9406	9090	9178	318890
1971	8178	8019	7456	8679	14434	8796	132443	492355	747313	794216	62241	16705	2300835
1972	9347	24063	8792	14495	101232	21165	10178	25588	44614	11928	7512	7427	286341
1973	7658	7617	8827	8960	12768	178495	16145	11070	76777	509706	46800	8153	892976
1974	8305	7509	14120	7887	34745	18950	9136	11870	98976	7882	13531	8152	241063
1975	9862	8250	8756	8741	53574	80706	44555	16478	43026	13251	10068	9028	306295
1976	8288	7513	7510	17326	44934	12839	57404	8676	51656	160116	252750	103584	732596
1977	40577	17868	8008	262014	72498	16778	10245	10533	10534	20079	9432	9287	487853
1978	8313	8294	8778	9203	14987	82953	19762	9636	78675	13710	9333	9463	273107
1979	11267	8512	9334	18649	45695	33817	12831	10591	83896	7693	7564	9310	259159
1980	17453	7590	7559	7527	31606	26129	9152	317926	28123	13774	13771	8244	488854
1981	11276	9508	9407	8978	75146	328733	142280	14496	39239	105491	35985	8296	788835
1982	8350	36994	8311	8859	37936	24878	8686	12297	15704	12214	10036	9334	193599
1983	8344	9263	9968	8811	12340	25570	37601	8871	32524	15342	8651	7573	184858
1984	25446	7948	8944	7628	14857	8252	8123	7972	9236	27597	12495	9374	147872
1985	7920	8747	8730	42076	51475	37810	23713	9296	49476	73150	107302	7963	427658
1986	9621	8448	7603	8620	11273	31747	8276	13310	13765	12804	11595	15150	152212
1987	8669	16061	8221	8812	31321	408897	98709	9714	35616	12783	9385	9307	657495
1988	8311	8272	8732	8757	14127	16592	10732	12072	33631	10823	9014	9268	150331
1989	8476	8317	8766	9352	18246	17423	9270	10782	8613	7914	8084	9034	124277
Average	20077	16695	11651	21926	56634	82058	40660	31842	97502	69919	23851	14981	487795
Max	295433	287414	145448	262014	570492	1457323	448626	492355	1443492	794216	252750	103771	2395138
Min	7427	7427	7427	7427	7427	7427	7427	7427	7427	7427	7427	7427	99276
median	8250	8251	8678	8805	31046	26067	9824	10637	30926	12794	9301	9156	290186
drt avg	7819	8134	8944	24695	40618	23869	17682	19480	53538	15568	13136	8450	241932

Nueces Estuary Inflow Flow Statistics
1994 Pumpage
2050 Sediment Conditions, Phase IV and 1995 Agreed Order Operating Policies
Pumpage Affected Flows into the Nueces Estuary

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	100051	7412	8701	11999	11567	10104	32017	8429	30272	11925	55296	7309	295082
1935	10056	8089	12074	12272	177432	1454114	87376	96732	387742	92771	7410	23921	2369989
1936	7429	7831	25470	8009	46363	51891	305875	7975	109677	155434	8650	9056	743660
1937	8054	8054	8652	8028	11069	24452	8432	11853	10648	9655	16341	74103	199341
1938	56934	10387	8554	35552	25084	7501	7304	24864	9581	7304	8246	48389	249700
1939	7401	7304	7312	9317	31348	39001	7970	10558	18345	9270	7304	10551	165681
1940	7304	8316	8554	8554	34144	168037	219740	26983	26057	14957	9145	9080	540871
1941	8054	39626	8341	145430	566478	131154	100266	8429	175859	10398	9509	9399	1212943
1942	7481	14575	7728	8554	29810	14894	442376	66148	417080	30144	9226	8500	1056516
1943	13923	9518	11957	7530	22094	32332	8429	7304	40046	11804	20422	24412	209771
1944	9566	7304	9282	7924	42323	56092	8429	50255	284964	7304	9784	9870	503097
1945	8054	8480	18972	40048	30858	33995	10993	30751	7560	122749	7304	7533	327297
1946	8458	7340	8565	15572	73669	110617	9345	23862	173814	463213	7304	9016	910775
1947	8199	7528	8576	8740	72926	14780	20232	16722	7396	7460	43490	12087	228136
1948	7304	7304	12882	7304	7862	7926	10196	18889	58360	8628	8804	7564	163023
1949	7435	8685	8746	117927	184159	57037	83510	13037	18368	26562	9054	10039	544559
1950	8054	10198	8166	9689	30317	24641	8902	7304	23272	9054	7304	7304	154205
1951	7304	7537	10242	8253	30304	37393	7304	7304	138084	7683	8804	7640	277852
1952	8054	8054	8323	10112	30787	24054	14287	7498	40793	7304	9647	8691	177604
1953	7404	7404	7404	7404	8004	7304	7465	98700	117807	49158	19854	7622	345530
1954	8054	8054	8487	9347	13355	32786	7929	8357	14039	22552	7804	7563	148327
1955	7800	8054	8048	7411	9019	8004	7704	7704	106562	7426	7792	7489	193013
1956	7304	7304	7304	57563	13245	7304	7304	7478	7304	8322	7304	7304	145040
1957	7304	7304	7557	7626	391316	369119	7304	7781	29526	59500	40088	7929	942354
1958	294870	287067	145120	7304	32308	25929	8456	8261	45012	179331	167196	19412	1220266
1959	11792	8732	8554	7616	23065	46118	14357	16151	10095	128778	7304	9250	291812
1960	8057	8179	9243	8674	7489	49947	8429	20837	29206	128941	67595	102703	449300
1961	37646	57842	7304	16125	7304	36338	50075	10295	23117	11804	11304	7587	276741
1962	7304	7304	7304	7304	7304	30523	7304	7306	20440	7304	7912	9898	127207
1963	8054	8127	8554	7304	8004	10565	7304	9152	7368	7332	8625	7404	97793
1964	7784	7304	7304	7304	13481	7304	11341	7304	16627	192426	7304	7951	293434
1965	7304	15249	7970	7304	66235	21961	7404	7492	8703	7399	7409	7925	172355
1966	7613	7304	7304	33918	96404	24955	7903	10885	8324	7704	7404	7304	227022
1967	10070	13314	7304	7304	7710	7304	7305	8200	1444884	166454	7304	9054	1696207
1968	134558	22570	7679	8554	216985	52808	13013	10054	30983	13434	9055	9054	528747
1969	8054	24852	7679	16941	32558	14674	9054	8489	16662	12418	18593	8637	178611
1970	8088	8112	8613	8554	32253	131426	8429	62482	22279	9282	8939	9054	317511
1971	8054	7838	7333	8555	14323	8538	132252	492234	747251	793291	61919	16529	2298117
1972	9201	23940	8668	14372	101586	21041	10054	25464	44490	11804	7389	7304	285313
1973	7535	7494	8703	8836	12644	178365	16147	10946	76558	509310	46551	8029	891118
1974	8181	7386	13996	7763	34303	18682	8951	11746	99177	7759	13407	8028	239379
1975	9738	8126	8632	8617	53450	80681	44573	16354	42729	13127	9944	8816	304787
1976	8164	7390	7387	17202	44810	12662	57281	8552	52116	159877	252509	103393	731343
1977	40400	17616	7884	261506	72338	16654	10121	10342	10353	19811	9308	9163	485496
1978	8189	8170	8654	9079	14767	82829	19638	9512	78551	13587	9209	9339	271524
1979	11143	8388	9210	18525	45571	33693	12708	10467	83686	7570	7441	9186	257588
1980	17330	7467	7436	7404	31482	26005	9028	318074	28124	13650	13647	8120	487767
1981	11152	9384	9283	8854	75942	329820	142095	14373	39333	104994	35914	8172	789316
1982	8226	36870	8187	8735	37694	24658	8562	12150	15515	12090	9912	9210	191809
1983	8220	9139	9844	8687	12158	25316	37477	8747	32400	15218	8527	7450	183183
1984	25322	7824	8820	7505	14730	8128	7999	7848	9112	27474	12372	9251	146385
1985	7796	8623	8606	41953	51752	37856	23801	9172	49352	73561	107246	7840	427558
1986	9497	8324	7480	8509	10985	31623	8152	13197	13511	12681	11471	15026	150456
1987	8545	15938	8097	8688	31197	410749	98549	9590	35492	12659	9261	9183	657948
1988	8187	8148	8608	8633	13916	16260	10608	11948	33507	10699	8890	9144	148548
1989	8352	8193	8642	9228	18058	17312	9146	10658	8489	7790	7960	8910	122738
Average	19847	16498	11523	21197	56006	81522	40325	31664	97082	68931	23655	14816	483067
Max	294870	287067	145120	261506	566478	1454114	442376	492234	1444884	793291	252509	103393	2369989
Min	7304	7304	7304	7304	7304	7304	7304	7304	7304	7304	7304	7304	97793
median	8126	8138	8554	8681	30823	25967	9700	10513	30628	12670	9177	9035	288563
drt avg	7691	8012	8818	24375	39998	22123	17483	19299	53199	15415	12986	8330	237729

Nueces Estuary Inflow Flow Statistics
2050 Pumpage
2050 Sediment Conditions, Phase IV and 1995 Agreed Order Operating Policies
Pumpage Affected Flows into the Nueces Estuary

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	100044	7420	8709	12007	11579	10108	32025	8437	30280	11933	55304	7317	295163
1935	10064	8097	12082	12053	177711	1454104	87363	96700	387714	92763	7418	23929	2369998
1936	7437	7845	25478	8017	46257	51883	305860	7983	109647	155425	8643	9064	743539
1937	8062	8062	8660	8042	11083	24464	8440	11861	10666	9669	16349	74111	199469
1938	56923	10395	8562	35510	25075	7509	7312	24872	9590	7312	8254	48397	249711
1939	7415	7312	7320	9325	31356	39009	7978	10566	18353	9278	7312	10559	165783
1940	7312	8324	8562	8562	34152	167832	219720	26970	26087	14965	9153	9088	540727
1941	8062	39528	8349	145404	566267	131164	100253	8437	175860	10422	9517	9407	1212670
1942	7501	14583	7736	8562	29821	14902	442238	66156	417061	30150	9234	8520	1056464
1943	13931	9526	11965	7563	22126	32340	8437	7312	40054	11812	20430	24420	209916
1944	9574	7312	9290	7933	42331	56080	8437	50263	284889	7312	9792	9878	503091
1945	8062	8488	18980	39960	30848	34003	11001	30759	7568	122663	7312	7541	327185
1946	8466	7349	8573	15580	73568	110606	9353	23870	173764	463008	7312	9024	910473
1947	8207	7536	8584	8748	72833	14788	20201	16730	7404	7468	43498	12095	228092
1948	7312	7312	12890	7312	7870	7874	10204	18897	58368	8636	8812	7572	163059
1949	7443	8693	8754	117899	184113	57026	83497	12986	18377	26570	9062	10047	544467
1950	8062	10206	8174	9697	30325	24649	8910	7312	23281	9062	7312	7312	154302
1951	7312	7545	10250	8261	30312	37401	7312	7312	138018	7691	8812	7648	277874
1952	8062	8062	8332	10120	30795	24062	14295	7506	40801	7312	9656	8699	177702
1953	7412	7412	7412	7412	8012	7312	7473	98708	117783	49149	19846	7630	345561
1954	8062	8062	8495	9355	13044	32794	7937	8365	14047	22560	7812	7571	148104
1955	7808	8062	8056	7412	9027	8012	7712	7712	106570	7434	7800	7497	193102
1956	7312	7312	7312	57571	13253	7312	7312	7486	7312	8330	7312	7312	145136
1957	7312	7312	7565	7634	391283	369084	7312	7812	29459	59495	40124	7937	942329
1958	294848	287062	145115	7312	32316	25937	8464	8269	45020	178101	167170	19420	1219034
1959	11762	8740	8562	7624	23043	46126	14365	16159	10089	128650	7312	9258	291690
1960	8065	8187	9251	8682	7497	49955	8437	20845	29200	128798	67569	102678	449164
1961	37684	57838	7312	16133	7312	36346	50083	10303	23115	11812	11312	7610	276860
1962	7312	7312	7312	7312	7312	30531	7312	7314	20448	7312	7920	9907	127304
1963	8062	8135	8562	7312	8012	10573	7312	9160	7376	7340	8633	7412	97889
1964	7792	7312	7312	7312	13489	7312	11349	7312	16635	192133	7312	7959	293229
1965	7312	15257	7978	7312	66135	21932	7412	7500	8711	7407	7417	7933	172306
1966	7621	7312	7312	33926	96408	24952	7911	10893	8332	7712	7412	7312	227103
1967	10078	13322	7312	7312	7718	7312	7313	8208	1444826	166411	7312	9062	1696186
1968	134487	22545	7687	8562	216870	52816	13021	10062	31014	13442	9063	9062	528631
1969	8062	24860	7687	16949	32566	14699	9062	8497	16670	12426	18601	8645	178724
1970	8096	8120	8621	8562	32261	131188	8437	62490	22287	9290	8923	9062	317337
1971	8062	7831	7343	8563	14316	8527	132247	492221	747242	793094	61959	16599	2298004
1972	9234	23948	8676	14380	101506	21049	10062	25472	44498	11812	7397	7312	285346
1973	7543	7502	8711	8844	12622	178373	16134	10954	76671	509334	46564	8037	891289
1974	8189	7394	14004	7771	34337	18751	8992	11754	99195	7767	13415	8036	239605
1975	9746	8134	8640	8625	53458	80566	44542	16362	42745	13135	9952	8851	304756
1976	8172	7398	7395	17210	44818	12688	57289	8560	52098	159893	252504	103388	731413
1977	40388	17623	7892	261494	72359	16662	10129	10364	10329	19849	9316	9171	485576
1978	8197	8178	8662	9087	14804	82837	19646	9520	78559	13595	9217	9347	271649
1979	11151	8396	9218	18533	45579	33701	12716	10475	83718	7578	7449	9194	257708
1980	17338	7475	7444	7412	31490	26013	9036	318027	28115	13658	13655	8128	487791
1981	11160	9392	9291	8862	75805	329999	142112	14381	39279	105063	35906	8180	789430
1982	8234	36878	8195	8743	37642	24675	8570	12176	15532	12098	9920	9218	191881
1983	8228	9147	9852	8695	12191	25354	37485	8755	32408	15226	8535	7458	183334
1984	25330	7832	8828	7513	14783	8136	8007	7856	9120	27482	12380	9259	146526
1985	7804	8631	8614	41961	51522	37845	23787	9180	49360	73496	107225	7848	427273
1986	9505	8332	7488	8517	11006	31631	8160	13205	13461	12689	11479	15034	150507
1987	8553	15946	8105	8696	31205	410864	98564	9598	35500	12667	9269	9191	658158
1988	8195	8156	8616	8641	13951	16305	10616	11956	33515	10707	8898	9152	148708
1989	8360	8201	8650	9236	18093	17321	9154	10666	8497	7798	7968	8918	122862
Average	19852	16503	11531	21197	55990	81523	40327	31670	97081	68896	23661	14825	483057
Max	294848	287062	145115	261494	566267	1454104	442238	492221	1444826	793094	252504	103388	2369998
Min	7312	7312	7312	7312	7312	7312	7312	7312	7312	7312	7312	7312	97889
median	8134	8146	8562	8689	30822	25975	9708	10521	30647	12678	9185	9043	288518
drt avg	7699	8020	8826	24379	39958	22123	17485	19301	53196	15421	12992	8338	237740

Nueces Estuary Inflow Flow Statistics
2050 + TTexas Pumpage
2050 Sediment Conditions, Phase IV and 1995 Agreed Order Operating Policies
Pumpage Affected Flows into the Nueces Estuary

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	100053	7409	8699	11997	11568	10096	32015	8427	30268	11923	55293	7306	295054
1935	10054	8087	12072	12341	177421	1454118	87380	96717	387727	92766	7407	23919	2370009
1936	7427	7831	25467	8007	46382	51895	305863	7972	109687	155437	8633	9054	743655
1937	8052	8052	8650	8025	11066	24436	8430	11851	10646	9661	16338	74100	199307
1938	56920	10384	8552	35553	25088	7498	7301	24862	9579	7301	8244	48386	249668
1939	7398	7301	7309	9314	31346	38999	7968	10556	18343	9268	7301	10548	165651
1940	7301	8314	8552	8552	34142	168014	219734	26987	26048	14955	9143	9078	540820
1941	8052	39659	8339	145438	566490	131169	100270	8427	175881	10430	9507	9396	1213058
1942	7482	14573	7725	8552	29808	14892	442363	66145	417057	30115	9224	8504	1056440
1943	13921	9516	11955	7530	22095	32330	8427	7301	40044	11802	20420	24409	209750
1944	9564	7301	9280	7921	42321	56094	8427	50252	284910	7301	9781	9868	503020
1945	8052	8478	18970	40075	30861	33993	10991	30748	7557	122770	7301	7530	327326
1946	8456	7338	8563	15570	73700	110620	9343	23860	173830	463222	7301	9014	910817
1947	8197	7525	8574	8738	72957	14778	20241	16720	7393	7457	43488	12084	228152
1948	7301	7301	12879	7301	7859	7853	10194	18887	58358	8625	8802	7561	162921
1949	7432	8683	8744	117873	184077	57040	83514	12965	18366	26560	9052	10037	544343
1950	8052	10196	8163	9687	30315	24639	8900	7301	23270	9052	7301	7301	154177
1951	7301	7535	10239	8251	30302	37391	7301	7301	138105	7680	8802	7637	277845
1952	8052	8052	8321	10110	30785	24052	14285	7495	40790	7301	9645	8688	177576
1953	7402	7402	7402	7402	8002	7301	7462	98697	117723	49161	19856	7619	345429
1954	8052	8052	8484	9345	12876	32784	7927	8355	14036	22549	7802	7560	147822
1955	7797	8052	8045	7408	9017	8002	7702	7702	106559	7423	7790	7487	192984
1956	7301	7301	7301	57560	13242	7301	7301	7475	7301	8319	7301	7301	145004
1957	7301	7301	7554	7623	391270	369060	7301	7778	29540	59502	40090	7927	942247
1958	294873	287069	145122	7301	32306	25927	8454	8258	45010	179269	167141	19409	1220139
1959	11702	8730	8552	7613	22964	46116	14355	16149	10037	128581	7301	9248	291348
1960	8055	8177	9241	8672	7486	49945	8427	20835	29169	128784	67559	102674	449024
1961	37598	57809	7301	16123	7301	36336	50072	10293	23087	11802	11302	7585	276609
1962	7301	7301	7301	7301	7301	30521	7301	7303	20438	7301	7909	9896	127174
1963	8052	8125	8552	7301	8002	10563	7301	9149	7365	7329	8623	7402	97764
1964	7781	7301	7301	7301	13478	7301	11338	7301	16624	192216	7301	7948	293191
1965	7301	15246	7967	7301	66261	21889	7402	7489	8700	7396	7406	7922	172280
1966	7610	7301	7301	33915	96407	24959	7900	10883	8322	7702	7402	7301	227003
1967	10067	13311	7301	7301	7707	7301	7302	8197	1444795	166363	7301	9055	1696001
1968	134471	22477	7677	8552	216796	52806	13010	10052	30978	13432	9053	9052	528356
1969	8052	24849	7677	16938	32555	14671	9052	8485	16659	12416	18590	8635	178579
1970	8086	8110	8611	8552	32251	111576	8427	62479	22276	9280	8964	9052	297664
1971	8052	7800	7330	8553	14305	7301	132079	431611	742256	781099	57037	13503	2210926
1972	7583	23937	8666	14369	100077	21039	10052	25462	44488	11802	7386	7301	282162
1973	7532	7491	8701	8834	12632	178362	13587	10944	66469	473410	41500	8027	837489
1974	8179	7383	13994	7761	32129	18674	8943	11744	92541	7756	13405	8026	230535
1975	9736	8124	8630	8615	53448	70969	38176	16352	42172	13125	9942	8807	288096
1976	8162	7387	7384	17200	44808	12653	57278	8550	38234	134161	247339	98926	682082
1977	36612	14320	7882	248995	64037	16652	10119	10336	10329	19808	9306	9161	457557
1978	8187	8168	8652	9077	14464	82827	19136	9510	78549	13584	9207	9337	270698
1979	11141	8386	9208	18523	45569	33691	12705	10465	83683	7567	7438	9184	257560
1980	17327	7464	7433	7401	31480	26003	9026	318073	28127	13648	13645	8118	487745
1981	11150	9382	9281	8852	73443	302160	131063	15171	36798	74718	32077	8170	712265
1982	8224	36868	8185	8733	35022	23835	8560	12144	15509	12088	9910	9208	188286
1983	8218	9137	9842	8685	12156	25316	37475	8745	32398	15216	8525	7447	183160
1984	25320	7822	8818	7502	14727	8126	7997	7846	9110	27471	12369	9248	146356
1985	7794	8621	8604	41950	36103	37859	23800	9170	49350	67912	106220	7837	405220
1986	9495	8322	7477	8506	10956	31621	8150	13194	12808	12678	11469	15024	149700
1987	8543	15935	8095	8686	31195	337226	89485	9588	30009	12657	9259	9181	569859
1988	8185	8146	8606	8631	13914	16267	10606	11946	33505	10697	8888	9142	148533
1989	8350	8191	8640	9226	18058	17310	9144	7806	8487	7788	7958	8908	119866
Average	19744	16435	11521	20972	55399	79146	39792	30541	96273	66958	23296	14679	474755
Max	294873	287069	145122	248995	566490	1454118	442363	431611	1444795	781099	247339	102674	2370009
Min	7301	7301	7301	7301	7301	7301	7301	7301	7301	7301	7301	7301	97764
median	8071	8136	8552	8679	30823	25965	9698	10401	30139	12668	9175	9033	285129
drt avg	7689	8010	8815	24368	39943	22114	17483	19290	53190	15413	12984	8328	237625

San Antonio River @ Falls City Flow Statistics

Baseline Historical Modified Flows at Falls City in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	33890	27038	26762	30577	16710	9431	12719	9721	12136	14925	22226	28482	244617
1935	21363	22624	17897	21339	57182	93924	23472	16504	41564	31249	25537	28640	401295
1936	26738	22992	22747	18567	49671	25995	104247	21571	173230	86036	46535	39970	638299
1937	36748	26919	27522	19053	14960	51985	16853	14915	14276	19435	18763	32516	293945
1938	30498	21059	22039	28148	21573	13809	12244	10457	12383	12807	15537	17998	218552
1939	20616	17086	15362	10945	9698	10115	10600	7289	5900	6814	8277	11303	134005
1940	11393	12267	8785	16988	10361	20209	21683	8565	4927	15039	50151	31736	212104
1941	22006	38717	22006	41467	52408	28299	10829	8692	22204	20233	13313	15985	296159
1942	15621	14128	11183	22346	17022	8472	90437	12022	113415	92553	26355	20116	443670
1943	22851	16343	17532	12924	13147	12533	16380	7299	15579	12630	15325	15102	177645
1944	25597	14787	20366	11651	29420	10466	6767	10227	13712	12463	14027	23292	192775
1945	33992	35327	26885	29251	13467	16897	9574	9087	8891	21604	13386	14267	232628
1946	21102	16220	19576	22834	29911	30251	6766	49554	240254	62413	33983	26686	559550
1947	33678	21135	23884	16413	17249	9542	6757	15611	8050	10467	14219	16230	193235
1948	15359	15338	12033	8942	7200	3329	12588	17251	8557	13787	9040	8800	132224
1949	12166	18024	9541	58294	18299	71830	14677	10676	6090	37155	13327	18331	288410
1950	16603	10972	12296	12224	10089	10920	4858	6662	7501	6662	7587	8519	114893
1951	7521	10290	10514	5802	18520	15854	2555	2517	8458	5412	8595	8566	104604
1952	8987	12052	8253	12299	5897	2271	7519	2418	7770	3596	9048	12517	92627
1953	11711	8011	8272	5995	7433	1824	2388	4939	35515	7758	8168	9887	111901
1954	10331	5950	4832	6002	9777	1969	2160	2196	2612	3811	4390	4394	58424
1955	8698	14055	7234	2904	9430	4502	3602	4921	4376	4064	3927	5928	73641
1956	8931	6457	4976	3300	3678	3101	4478	3994	10130	7438	4022	16522	77027
1957	7980	8381	9433	75174	75589	49774	3804	3804	47407	28487	21927	14420	346180
1958	48299	63435	20937	13231	54997	16884	18240	4300	37286	61203	68595	33101	440508
1959	25101	23599	18181	21445	24264	7478	7826	6550	7931	32089	17967	16808	209239
1960	20060	17939	21279	11796	10250	7753	8896	18807	5437	54289	30422	31249	238177
1961	29390	36144	32722	17694	6983	28026	34583	9925	12752	26135	22611	16730	273695
1962	16993	13543	10443	14341	7684	11263	3901	4212	5657	4095	11763	14343	118238
1963	13110	16863	8924	8346	4427	2521	3444	2899	3911	16371	11913	10095	102824
1964	12445	18822	17935	6880	3961	8601	2522	2643	3628	11028	26581	11508	126554
1965	12156	39044	11291	17403	78579	16641	3685	2969	5144	12620	9326	23981	232839
1966	15082	15190	11893	15403	17347	6678	3300	7813	11892	7872	8506	10197	131173
1967	11698	8020	8845	6220	4586	2057	4939	3728	116875	18873	30721	15771	232333
1968	162208	32486	22592	19909	48810	18246	15839	4909	26514	10522	14141	20795	396971
1969	16718	22824	15794	11474	42922	12361	2866	9003	5334	14334	8519	13801	175950
1970	20895	21344	20432	12069	45166	16293	2882	2646	7417	10310	8052	8297	175803
1971	11596	7478	6199	4649	4290	6673	3783	46303	16080	37387	35911	35406	215755
1972	23201	18810	12783	9592	107951	27808	13063	17782	12211	13335	17194	17256	290986
1973	22509	26351	20088	48149	19293	98264	157211	50258	166611	169192	70936	41102	889964
1974	38643	26982	24265	19091	31603	12742	6068	55761	63102	31513	39741	28963	378474
1975	34667	101469	43298	28602	107465	78320	27037	19573	16531	19418	15181	18953	510514
1976	24689	13765	16459	50092	96549	21941	33853	20416	28950	64927	77408	61687	510736
1977	60343	60828	44762	130517	89089	44490	24463	11726	23569	20455	45794	25134	581170
1978	21595	23281	22164	25969	15733	21819	1536	49573	58875	20088	33493	22826	316952
1979	54929	42382	61280	95563	53924	109096	35076	23264	13504	11314	14655	21718	536705
1980	23693	18701	11234	11153	45750	5312	2713	17482	17966	8422	17210	15525	195161
1981	20447	14267	14395	10620	20157	170033	54921	17501	19963	45633	22783	18539	429259
1982	18583	18739	16719	10819	38915	11327	3996	3796	3883	19694	29423	29557	205451
1983	28815	26570	34129	15431	22024	19949	12089	16561	30883	19215	22772	20403	268841
1984	23995	20199	22950	12969	12155	6990	7398	8608	9018	43197	18956	22551	208986
1985	30131	17133	31342	24412	13818	30747	31924	4040	17662	43906	40982	20682	306779
1986	19728	15597	10954	9121	22865	153821	12594	4631	25061	53194	24659	78629	430854
1987	56225	54017	49364	27702	74472	573438	69926	29330	29436	18086	28951	30388	1041335
1988	28560	22416	22081	15167	10354	10463	11912	3478	10166	8178	10435	12033	165243
1989	22990	10951	12784	13766	8734	11850	3134	3469	3261	8079	14458	14626	128102
Average	25454	22879	18940	21863	29947	37596	18561	13366	29624	26489	22464	21171	287571
Max	162208	101469	61280	130517	107951	573438	157211	55761	240254	169192	77408	78629	1041335
Min	7521	5950	4832	2904	3678	1824	1536	2196	2612	3596	3927	4394	58424
median	21479	18720	17715	15285	17823	13276	9235	8848	12568	17229	17202	18165	232481
drt avg	13399	12228	10184	13218	10757	12514	6158	7119	9906	10015	8232	10969	124699

San Antonio River @ Falls City Flow Statistics
1994 Pumpage
Pumpage Affected Modified Flows at Falls City in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	31096	24315	23968	27784	13917	6638	9926	6858	9343	12132	19433	25759	211169
1935	18640	19831	15174	18615	54388	91131	20679	13711	38841	28456	22744	25916	368126
1936	23945	20199	20024	15843	46878	23272	101454	18848	170437	83312	43742	37247	605201
1937	34025	24125	24798	16329	12237	49262	14129	12122	11483	16712	16040	29723	260985
1938	27774	18335	19316	25425	18850	11086	9450	7664	9659	10083	12813	15205	185660
1939	17892	14363	12639	8222	6905	7322	7877	4510	3142	4042	5644	8545	101103
1940	8642	9502	6062	14265	7568	17416	18890	5807	2140	12246	47428	28943	178909
1941	19282	35924	19283	38674	49685	25575	8036	5899	19411	17440	10520	13192	262921
1942	12828	11405	8460	19623	14299	5748	87644	9229	110622	89760	23562	17393	410573
1943	20127	13550	14739	10131	10424	9740	13587	4492	12786	9837	12532	12309	144254
1944	22804	12029	17573	8928	26626	7673	3939	7364	10919	9670	11234	20499	159258
1945	31199	32534	24162	26458	10674	14104	6781	6294	6098	18811	10593	11543	199251
1946	18309	13427	16783	20041	27118	27458	3972	46761	237461	59620	31190	23893	526033
1947	30955	18342	21091	13620	14526	6749	3963	12748	5257	7673	11426	13437	159787
1948	12566	12545	9310	6148	4456	556	9795	14444	5750	11022	6212	6014	98818
1949	9408	15231	6803	55571	15506	69037	11877	7869	3297	34362	10562	15538	255061
1950	13880	8235	9573	9501	7295	8127	2065	3868	4708	3841	4773	5768	81634
1951	4748	7504	7784	3036	15726	13040	0	0	5657	2731	5928	5906	72060
1952	6334	9231	5467	9666	2943	0	4929	0	5159	977	6436	9731	60873
1953	9113	5344	5507	3202	4836	0	0	2111	32722	5056	5479	7080	80450
1954	8047	3604	2430	3042	6837	0	0	0	56	1165	1820	1810	28811
1955	5821	11017	4225	293	6435	1883	970	1967	1744	1551	1420	3533	40859
1956	6117	3566	2114	451	850	280	1671	1313	7462	4659	1250	13946	43679
1957	5229	5818	6702	72451	72866	47051	1241	1101	44683	25799	19273	11732	313946
1958	45645	60781	18284	10633	52414	14300	15657	1744	34702	58689	66081	30587	409517
1959	22588	21085	15667	18931	21750	4964	5312	4085	5474	29645	15453	14364	179318
1960	17616	15495	18835	9352	7848	5337	6522	16363	3021	51845	28047	28875	209156
1961	27016	33769	30348	15320	4630	25652	32209	7621	10447	23761	20307	14425	245505
1962	14689	11267	8167	12037	5373	9001	1618	1936	3387	2007	9507	12067	91056
1963	10869	14607	6697	6105	2206	301	1230	867	1733	14206	9693	7924	76438
1964	10231	16665	15771	4702	1804	6437	365	499	1485	8863	24416	9365	100603
1965	10054	36949	9196	15239	76484	14546	1597	882	3077	10532	7287	21956	207799
1966	12995	13165	9820	13308	15253	4667	1261	5962	9888	5812	6474	8172	106777
1967	9680	6009	6841	4216	2771	46	2935	1724	114850	16848	28766	13809	208495
1968	160253	30461	20637	17953	46855	16221	13884	2940	24489	8581	12200	18840	373314
1969	14783	20868	13839	9491	40967	10406	904	7048	3393	12379	6599	11846	152523
1970	18940	19389	18477	10184	43281	14407	990	726	5532	8411	6146	6412	152895
1971	9675	5579	4306	2757	2405	4760	1898	44418	14194	35501	34025	33521	193039
1972	21386	16924	10968	7707	106066	25922	11248	15966	10395	11519	15378	15441	268920
1973	20694	24536	18272	46334	17478	96448	155116	48442	165214	167097	69120	39287	868038
1974	36897	25166	22450	17275	29787	10996	4302	54015	61357	29767	38065	27217	357294
1975	32921	100072	41552	26856	105789	76574	25292	17827	14855	17672	13435	17208	490053
1976	22944	12041	14783	48416	94803	20196	32177	18740	27205	63251	75663	59941	490160
1977	58597	59082	43086	128771	87344	42744	22787	10050	21893	18780	44118	23459	560711
1978	19919	21605	20488	24224	14037	20122	0	48177	57200	18412	31817	21150	297151
1979	53253	40706	59604	93887	52248	107700	33400	21588	11828	9568	12979	19973	516734
1980	22017	17025	9558	9449	44074	3629	1037	15806	16290	6753	15576	13891	175105
1981	18771	12598	12740	8979	18481	168637	53315	15826	18357	43957	21107	16863	409631
1982	16977	17133	15043	9213	37308	9652	2341	2100	2215	17997	27747	27951	185677
1983	27181	24936	32453	13790	20370	18253	10385	14913	29186	17553	21124	18762	248906
1984	22305	18537	21295	11308	10493	5328	5729	6932	7342	41521	17287	20883	188960
1985	28455	15478	29666	22792	12142	29071	30248	2385	15980	42231	39306	19075	286829
1986	18053	13991	9341	7487	21189	152215	10918	2976	23455	51588	22983	77023	411219
1987	54619	52411	47758	26096	73076	572041	68320	27724	27830	16480	27345	28781	1022481
1988	26954	20810	20475	13561	8748	8878	10306	1879	8539	6586	8850	10448	146034
1989	21453	9352	11185	12167	7163	10293	1556	1898	1697	6508	12873	13069	109214
Average	23343	20687	16814	19747	27437	34873	16210	11054	27060	24023	20211	19058	260517
Max	160253	100072	59604	128771	106066	572041	155116	54015	237461	167097	75663	77023	1022481
Min	4748	3566	2114	293	850	0	0	0	56	977	1250	1810	28811
median	19111	16795	15109	13435	15380	11041	6652	6576	10421	15343	15416	15490	203525
drt avg	10699	9462	7430	10453	7941	9967	3527	4432	7181	7304	5531	8276	92203

San Antonio River @ Falls City Flow Statistics
2050 Pumpage
Pumpage Affected Modified Flows at Falls City in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	31096	24315	23968	27784	13917	6708	9996	6928	9413	12132	19433	25759	211449
1935	18640	19831	15174	18615	54388	91131	20679	13711	38841	28456	22744	25916	368126
1936	23945	20199	20024	15843	46878	23272	101454	18848	170437	83312	43742	37247	605201
1937	33955	24125	24798	16260	12167	49262	14059	12122	11483	16642	16040	29723	260636
1938	27705	18266	19246	25355	18850	11016	9450	7664	9590	10014	12743	15205	185104
1939	17823	14293	12569	8152	6905	7322	7807	4482	3114	4007	5602	8496	100572
1940	8586	9439	5999	14195	7568	17416	18890	5765	2106	12176	47358	28943	178441
1941	19212	35854	19213	38674	49615	25506	8036	5830	19341	17370	10450	13122	262223
1942	12758	11335	8390	19553	14229	5679	87644	9159	110552	89760	23492	17323	409874
1943	20058	13481	14669	10061	10354	9670	13517	4437	12716	9767	12463	12239	143432
1944	22734	11945	17503	8858	26557	7603	3877	7364	10849	9601	11164	20429	158484
1945	31129	32464	24022	26388	10604	14034	6711	6224	6028	18741	10523	11404	198272
1946	18239	13357	16713	19971	27048	27388	3903	46691	237391	59550	31051	23753	525055
1947	30816	18273	21021	13550	14386	6680	3894	12678	5187	7604	11356	13367	158812
1948	12496	12475	9170	6079	4365	480	9683	14374	5673	10938	6128	5916	97777
1949	9310	15161	6699	55431	15436	68967	11793	7785	3220	34292	10471	15398	253963
1950	13741	8130	9433	9361	7156	8057	1981	3799	4569	3750	4682	5663	80322
1951	4644	7393	7672	2932	15657	12942	0	0	5573	2633	5823	5801	71070
1952	6222	9126	5362	9554	2845	0	4831	0	5061	880	6331	9626	59838
1953	8995	5302	5388	3083	4717	0	0	2013	32583	5028	5361	6961	79431
1954	7922	3471	2304	2916	6718	0	0	0	0	1060	1701	1685	27777
1955	5696	10892	4092	167	6309	1771	865	1862	1632	1320	1190	3415	39211
1956	5879	3448	1995	339	738	175	1566	1096	7358	4561	1145	13715	42015
1957	5110	5581	6584	72311	72796	46981	1130	1004	44614	25687	19162	11620	312580
1958	45505	60642	18214	10508	52274	14161	15587	1640	34633	58549	65942	30448	408103
1959	22518	20946	15528	18791	21611	4894	5242	3973	5355	29505	15383	14224	177970
1960	17476	15356	18695	9212	7715	5211	6382	16244	2902	51706	27908	28736	207543
1961	26876	33630	30209	15180	4497	25582	32070	7481	10308	23691	20167	14286	243977
1962	14549	11120	8027	11897	5233	8875	1499	1817	3262	1868	9375	11927	89449
1963	10722	14461	6550	5958	2066	168	1104	734	1607	14067	9553	7784	74774
1964	10085	16518	15631	4555	1664	6297	239	373	1359	8723	24276	9218	98938
1965	9900	36810	9029	15099	76344	14406	1465	749	2944	10392	7141	21747	206026
1966	12834	13005	9659	13169	15120	4520	1121	5809	9748	5665	6320	8019	104989
1967	9519	5842	6673	4048	2603	0	2788	1577	114710	16694	28627	13641	206722
1968	160043	30322	20427	17744	46715	16082	13744	2794	24350	8420	12039	18631	371311
1969	14609	20659	13699	9317	40828	10266	750	6839	3239	12239	6432	11637	150514
1970	18772	19249	18267	9974	43071	14198	836	572	5371	8251	5978	6237	150776
1971	9501	5397	4118	2575	2230	4592	1737	44278	14055	35362	33886	33312	191043
1972	21176	16715	10758	7497	105926	25783	11038	15757	10186	11310	15169	15231	266546
1973	20554	24326	18133	46124	17268	96239	155116	48302	164516	167097	68911	39147	865733
1974	36687	25027	22310	17136	29648	10787	4134	53876	61217	29557	37856	27007	355242
1975	32781	100072	41343	26647	105579	76434	25152	17688	14646	17462	13226	17068	488098
1976	22734	11838	14560	48207	94594	19986	31968	18531	27065	63042	75523	59732	487780
1977	58458	58873	42876	128562	87134	42605	22578	9841	21684	18570	43979	23319	558479
1978	19709	21395	20279	24084	13848	19934	0	48177	57060	18202	31607	20941	295236
1979	53044	40497	59395	93678	52039	107002	33260	21448	11619	9428	12770	19833	514013
1980	21808	16816	9349	9246	43865	3441	856	15666	16151	6565	15381	13689	172833
1981	18562	12389	12531	8777	18271	167939	53105	15686	18148	43747	20897	16654	406706
1982	16768	16924	14833	9003	37099	9442	2152	1911	2026	17809	27537	27714	183218
1983	26971	24727	32244	13581	20167	18057	10196	14725	28997	17357	20929	18559	246510
1984	22096	18328	21078	11098	10290	5125	5540	6744	7154	41312	17085	20673	186523
1985	28239	15262	29456	22576	11932	28861	30109	2190	15784	42021	39096	18866	284392
1986	17871	13712	9124	7271	20979	152006	10708	2788	23246	51379	22774	76813	408671
1987	54339	52201	47549	25886	73076	572041	68110	27585	27620	16341	27135	28572	1020455
1988	26745	20600	20265	13352	8539	8675	10097	1683	8343	6383	8641	10231	143554
1989	21244	9128	10961	11951	6946	10090	1361	1695	1494	6299	12664	12853	106686
Average	23204	20553	16675	19610	27310	34746	16104	10947	26931	23898	20078	18919	258973
Max	160043	100072	59395	128562	105926	572041	155116	53876	237391	167097	75523	76813	1020455
Min	4644	3448	1995	167	738	0	0	0	0	880	1145	1685	27777
median	18992	16617	15004	13261	15278	10902	6547	6484	10247	15204	15275	15315	202149
drt avg	10572	9367	7314	10341	7833	9907	3461	4361	7086	7207	5419	8155	91022

San Antonio River @ Falls City Flow Statistics
2050 + TTexas Pumpage
Pumpage Affected Modified Flows at Falls City in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	31096	24245	23899	27644	13777	6429	9716	6579	8994	11713	19014	25270	208376
1935	18151	19342	14615	17987	53830	90503	20050	13013	38142	27757	22046	25148	360584
1936	23177	19431	19256	15005	46040	22434	100756	17940	169040	82405	42834	36339	594657
1937	33048	23218	23821	15282	11189	48284	13082	11144	10435	15665	14993	28675	248836
1938	26657	17218	18199	24307	17732	9899	8333	6547	8472	8896	11556	14018	171834
1939	16635	13106	11382	6965	5648	6058	6550	3226	1843	2729	4331	7204	85677
1940	7287	8133	4686	12890	6207	16020	17493	4410	737	10807	45961	27546	162177
1941	17816	34458	17817	37207	48149	24039	6570	4363	17910	15904	8984	11655	244872
1942	11292	9798	6854	18017	12693	4135	86108	7630	109016	88154	21956	15717	391370
1943	18452	11875	13133	8525	8748	8134	11911	2824	11110	8147	10857	10626	124342
1944	21128	10290	15897	7182	24881	5927	2194	5619	9173	7855	9418	18753	138317
1945	29453	30718	22346	24642	8858	12289	4965	4437	4290	16996	8777	9658	177429
1946	16423	11541	14898	18155	25232	25573	2080	44876	235576	57734	29235	21938	503261
1947	29000	16387	19136	11665	12571	4794	2001	10828	3274	5711	9471	11482	136320
1948	10576	10590	7271	4165	2445	0	7756	12440	3732	8997	4180	3968	76120
1949	7355	13178	4737	53476	13432	67012	9810	5802	1230	32267	8467	13443	230209
1950	11716	6119	7429	7364	5166	6032	0	1732	2558	1704	2629	3610	56059
1951	2591	5333	5605	864	13562	10869	0	0	3471	580	3763	3741	50379
1952	4155	7003	3240	7480	715	0	2652	0	2882	0	4243	7475	39845
1953	6907	3200	3231	918	2615	0	0	0	30418	2898	3308	4754	58249
1954	5708	1257	83	695	4498	0	0	0	0	0	0	0	12241
1955	3580	8622	1823	0	4033	0	0	0	0	0	0	1093	19151
1956	3733	1113	0	0	0	0	0	0	5069	2201	0	11530	23646
1957	2869	3388	4328	69937	70422	44537	0	0	42191	23299	16767	9225	286963
1958	43131	58268	15791	8113	49900	11786	13143	0	32189	56105	63568	28073	380067
1959	20074	18571	13153	16417	19237	2443	2784	1550	2932	27131	12925	11773	148990
1960	15011	12912	16251	6775	5278	2767	3924	13800	451	49262	25464	26292	178187
1961	24432	31186	27765	12736	2032	23068	29626	4996	7815	21177	17724	11772	214329
1962	12035	8635	5534	9432	2740	6382	0	0	762	0	7015	9413	61948
1963	8201	11940	4029	3437	0	0	0	0	0	11553	7018	5242	51420
1964	7550	13969	13089	2013	0	3728	0	0	0	6189	21763	6655	74956
1965	7338	34226	6459	12543	73761	11823	0	0	367	7809	4564	19163	178053
1966	10250	10421	7068	10585	12529	1930	0	3281	7151	3067	3723	5414	75419
1967	6915	3237	4062	1437	57	0	177	0	112127	14069	25973	11016	179070
1968	157460	27668	17774	15139	44062	13442	11091	147	21724	5774	9386	15998	339665
1969	11955	18033	11039	6656	38174	7606	0	4185	572	9544	3764	8990	120518
1970	16098	16540	15614	7293	40418	11531	0	0	2683	5555	3283	3542	122557
1971	6798	2702	1422	0	0	1890	0	41555	11331	32639	31162	30588	160087
1972	18453	13991	8049	4802	103203	23059	8315	13034	7463	8608	12446	12494	233917
1973	17761	21603	15339	43401	14545	93516	152323	45509	161932	164304	66188	36354	832775
1974	33894	22234	19517	14342	26855	8028	1355	51083	58424	26764	35063	24214	321773
1975	29988	97279	38550	23854	102786	73641	22289	14894	11853	14683	10433	14226	454476
1976	19927	9024	11739	45414	91801	17193	29174	15738	24202	60249	72660	56939	454060
1977	55595	56080	40013	125769	84341	39742	19715	6978	18821	15707	41116	20456	524333
1978	16846	18532	17416	21221	10971	17064	0	45384	54197	15339	28744	18078	263792
1979	50181	37634	56532	90815	49176	104209	30328	18516	8756	6502	9886	16900	479435
1980	18875	13932	6465	6335	40932	529	0	12727	13204	3639	12455	10763	139856
1981	15664	9463	9598	5844	15339	165146	50172	12753	15215	40815	17965	13721	371695
1982	13765	13949	11880	6015	34096	6481	0	0	0	14841	24570	24746	150343
1983	24004	21752	29269	10606	17185	15082	7215	11743	26009	14369	17940	15564	210738
1984	19100	15332	18083	8103	7295	2130	2536	3741	4149	38316	14075	17664	150524
1985	25229	12245	26426	19559	8923	25845	27064	0	12761	39019	36073	15829	248973
1986	14834	10709	6087	4233	17949	148933	7685	0	20194	48307	19771	73741	372443
1987	51337	49129	44476	22814	69584	568550	65038	24442	24548	13198	24063	25500	982679
1988	23603	17528	17193	10286	5446	5582	7010	0	5250	3290	5547	7131	107866
1989	18109	6028	7854	8843	3839	6976	0	0	0	3184	9550	9731	74114
Average	20950	18291	14415	17414	25087	32733	14339	9098	24762	21668	17833	16622	233214
Max	157460	97279	56532	125769	103203	568550	152323	51083	235576	164304	72660	73741	982679
Min	2591	1113	0	0	0	0	0	0	0	0	0	0	12241
median	17304	13941	13111	10436	13497	9017	4445	4387	8614	12456	12451	13582	177741
drt avg	8532	7280	5256	8663	5904	8871	2222	3080	5263	5436	3606	6110	70222

Cibolo Creek @ Falls City Flow Statistics

Baseline Historical Modified Flows at Falls City in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	6411	2929	5782	12664	1395	607	16982	1238	1343	1417	9546	10048	70362
1935	2151	7319	1922	12134	69635	87904	4732	2434	16111	3329	2136	4818	214625
1936	2161	1869	2852	1964	24465	2264	55232	2124	5011	3819	2426	2418	106605
1937	2411	1919	3072	1974	1195	42834	1652	1464	2461	2109	1470	23598	86159
1938	17111	2499	10442	46044	7555	3114	1792	1444	1441	1469	1676	1938	96525
1939	1791	1529	1502	1141	1625	1007	1192	2154	949	1120	1027	1275	16312
1940	1360	1316	1211	6634	1715	22574	6912	810	888	4849	34106	31508	113883
1941	10821	16679	9852	46524	44635	18424	3262	2294	10821	11299	2156	2198	178965
1942	2011	1739	1742	5404	3155	1174	83632	3864	88161	35159	5176	3818	235035
1943	3671	2759	3402	2064	4725	4314	4582	1304	2681	1679	3006	2008	36195
1944	8001	2539	5522	3834	39705	3454	1862	1994	2781	1739	2046	4678	78155
1945	12101	14919	11312	13124	1855	4454	1322	1324	1052	4389	1616	1788	69256
1946	2531	2619	5642	16364	38225	14204	1482	56144	50151	15949	7516	4228	215055
1947	11351	2679	5362	3254	15645	2184	1642	2054	1461	1467	1696	1948	50743
1948	1901	1979	1692	1354	4145	1254	2862	10184	2021	2919	1377	1508	33196
1949	1711	3399	1603	46465	5757	16306	2304	2535	1432	32089	2576	4398	120575
1950	2172	2271	1796	3349	1382	16002	1368	1449	1535	1236	1258	1491	35309
1951	1530	1443	1618	1297	2660	10590	824	784	2517	1174	1327	1457	27221
1952	1477	2103	1357	3033	3806	1143	1013	685	49240	1714	2099	4986	72656
1953	2142	1554	1442	3325	4469	911	770	6248	17271	2215	1579	4257	46183
1954	1682	1377	1308	1276	2723	1022	686	594	764	1460	1260	1201	15353
1955	1318	2754	3562	1058	3129	4177	681	1349	1881	1190	1030	1450	23579
1956	1215	1015	834	790	1350	189	709	434	1933	3230	1176	9249	22124
1957	1249	1829	6422	63194	39635	29486	1740	1161	33871	11009	8996	2618	201210
1958	21671	49149	4102	2834	31959	2422	2172	1229	6221	11429	5176	2108	140472
1959	2191	2209	1812	9134	4756	1324	1682	1098	1165	12369	2476	2008	42224
1960	2931	1809	1913	1825	1726	8125	2453	4105	1193	48549	8626	9178	92433
1961	4701	7299	2592	2244	1785	40854	17914	2444	2041	5409	19286	3048	109617
1962	2706	2379	2292	3234	1629	2409	1292	706	1326	1273	2276	2428	23950
1963	1750	3913	1545	1663	1099	575	616	594	837	1400	8038	1524	23554
1964	3697	6158	6127	1337	884	3616	670	1177	6438	2903	7893	1597	42497
1965	2362	22191	2482	5246	53135	9915	1574	1418	1126	15068	3197	16684	134398
1966	2375	3371	4219	5566	6792	1592	1257	1338	2458	1507	1382	1404	33261
1967	1701	1252	1184	949	703	393	831	3238	86703	4532	19802	3264	124552
1968	100564	7903	4321	11496	17770	9982	2837	1617	9490	1974	3670	9141	180765
1969	3132	21061	5396	5757	12720	5401	1401	1326	2051	3420	2068	3440	67173
1970	2879	2758	5354	1929	28912	4652	1648	1374	1238	1708	1612	1893	55957
1971	1677	1523	1378	888	691	593	504	24847	6399	8346	2376	7410	56632
1972	2366	1909	1816	1264	137199	9297	3330	2514	1967	1832	2283	2265	168042
1973	2906	4771	4445	25168	3293	63814	59225	6595	94165	61581	10386	5444	341793
1974	6661	3650	3578	2796	6801	1876	1418	13272	13605	2482	16667	4604	77410
1975	3719	16249	3216	4944	37850	16004	4328	3396	2108	2196	2243	2725	98978
1976	2314	1774	2380	16486	41820	3505	6616	2077	4767	38643	19704	15187	155273
1977	12521	13273	4852	88701	16529	4548	2930	1993	14460	2850	30094	3293	196044
1978	3095	3240	2971	7018	2791	16997	1582	9927	14936	2262	21481	3649	89949
1979	21537	11634	11955	50526	15502	21955	6112	3677	2666	2136	2181	2586	152467
1980	2641	2326	2091	1539	18844	1283	812	2182	20479	1755	2400	2082	58434
1981	2314	1807	1872	3363	6036	6126	1190	5585	6198	4547	5774	2121	46933
1982	2012	3957	2220	1570	5593	1340	587	478	898	3774	1130	1562	25121
1983	2038	2982	4062	1389	2134	753	887	785	2527	999	5177	1248	24981
1984	1538	1091	2318	737	483	251	182	254	361	7699	2760	1687	19361
1985	4047	1153	7348	4417	714	13631	14685	575	2195	7177	14280	2949	73171
1986	2136	1808	1511	944	1996	26261	1285	672	1560	4890	2802	35793	81658
1987	6576	17185	6693	2540	27910	166736	6574	3743	2889	2154	2198	2951	248149
1988	2543	2273	2193	1617	1182	1339	1397	697	737	705	829	1429	16941
1989	2260	1699	1438	1622	1504	1572	579	672	361	877	1226	1503	15313
Average	6026	5561	3584	10115	14835	13420	6051	3826	11127	7547	5822	5037	92550
Max	100564	49149	11955	88701	137199	166736	83632	56144	94165	61581	34106	35793	341793
Min	1215	1015	834	737	483	189	182	254	361	705	829	1201	15313
median	2371	2519	2537	3134	4307	3897	1612	1457	2327	2666	2388	2602	72914
drt avg	2650	2057	2057	6520	4507	5378	1286	2632	8006	4869	1538	3195	44694

Cibolo Creek @ Falls City Flow Statistics
1994 Pumpage
Pumpage Affected Modified Flows at Falls City in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	5875	2397	5254	12137	873	91	16472	732	842	921	9055	9559	64208
1935	1667	6837	1444	11837	67052	85321	2484	2071	14540	2284	1728	4389	201654
1936	1007	1401	2368	1203	22691	0	54740	0	2497	1384	785	1933	90009
1937	1931	1444	761	501	526	40488	1169	983	1985	1638	1004	23129	75559
1938	14743	183	8169	43809	5390	2632	1316	973	975	1006	1218	1486	81900
1939	1343	1085	1062	705	1194	580	770	1736	535	710	621	873	11214
1940	925	884	782	6206	1288	20302	5523	388	467	2607	33620	29944	102936
1941	10521	14402	7624	44359	42470	16329	1173	1979	10480	10938	1775	1331	163381
1942	1596	0	1333	3798	2748	0	81468	3439	86046	33050	4721	3370	221569
1943	3229	2323	2971	1296	4301	3891	2997	882	900	122	2591	1597	27100
1944	7595	2080	3532	1879	37763	1527	1454	1592	889	1337	496	2807	62951
1945	10251	13117	9497	11316	1225	3866	930	939	673	2776	1246	1398	57234
1946	1155	1195	3855	16010	36439	13815	1131	55798	48364	15561	5728	3682	202733
1947	10965	2320	5009	2907	15299	1845	1308	1726	1137	1149	1384	1641	46690
1948	1599	1682	1363	1029	3825	938	2733	10024	1834	2705	1141	1252	30125
1949	1436	3110	1317	44489	5503	16012	2013	2247	1148	31795	2287	4112	115469
1950	1891	1992	1522	3079	1115	15739	1109	1192	1282	985	1011	1247	32164
1951	1290	1206	1384	1067	2430	10195	597	561	2289	949	1106	1238	24312
1952	1262	1891	1148	2826	3601	942	815	491	47215	1506	1895	4786	68378
1953	1944	1360	1251	3137	4284	725	589	6070	16997	2041	1407	4087	43892
1954	1515	1214	1149	1121	2571	874	542	454	628	1327	1131	1075	13601
1955	1194	2631	3441	941	3017	4068	577	1248	1782	1094	936	1359	22288
1956	1128	1102	892	714	1277	121	646	374	1877	3178	1125	9200	21634
1957	1203	1786	5416	60960	37471	27413	1734	1135	33761	8893	9111	2705	191588
1958	21729	46998	3155	2852	29795	2429	2161	1207	5146	10628	4261	2101	132462
1959	2190	2209	1812	9134	4756	1324	1682	1098	1165	12369	2476	2008	42223
1960	2931	1809	1913	1825	1726	8125	2453	1890	1193	46608	8626	9178	88277
1961	4701	7299	2592	2244	1785	40854	17914	2444	2041	5409	19286	3048	109617
1962	2706	2379	2166	3126	1540	2338	1238	668	1302	1260	2273	2428	23424
1963	1750	3913	1545	1663	1099	575	616	594	837	1400	8038	1524	23554
1964	3697	6158	6127	1144	884	1789	662	1177	4693	2903	7893	1597	38724
1965	2362	22191	2482	3675	51599	8449	1574	1418	1126	13700	3197	15371	127144
1966	2375	3371	4219	5566	6792	1592	1257	1338	2458	1507	1382	1404	33261
1967	1701	1252	1184	949	703	393	831	3238	86703	4532	19802	3264	124552
1968	99377	8070	4455	11600	17786	10034	2865	1624	9490	1974	3670	9141	180086
1969	3132	21061	5396	5757	12720	5401	1401	1326	2051	3420	2068	3250	66983
1970	2879	2758	5354	1929	28912	4652	1648	1374	1238	1708	1612	1893	55957
1971	1677	1523	1378	888	691	593	503	23542	6399	8223	2376	7410	55203
1972	2366	1909	1816	1264	135942	9297	3330	2514	1967	1832	2283	2265	166785
1973	2906	4771	4445	25168	3293	62747	58178	6595	93160	60604	10386	5422	337675
1974	6659	3650	3578	2796	6801	1876	1418	12494	13605	2482	16667	4604	76630
1975	3719	15550	3216	4944	37850	16004	4328	3396	2108	2196	2243	2725	98279
1976	2314	1774	2287	15885	41829	3555	6643	2083	4767	37980	19704	15187	154008
1977	12521	13273	4852	88058	16453	4548	2930	1993	14460	2850	30032	3259	195229
1978	2908	3084	2847	6922	2722	16952	1559	9924	14936	2262	21481	3649	89246
1979	21537	11634	11508	50526	15502	21955	6236	3771	2733	2179	2201	2586	152368
1980	2641	2326	2091	1539	18844	1283	812	2182	20479	1755	2400	2082	58434
1981	2314	1807	1707	3231	5933	5497	1104	5524	6160	4531	5774	2121	45703
1982	2012	3957	2220	1570	5090	1340	587	478	898	3774	1130	1562	24618
1983	2038	2982	4062	1389	2134	753	887	785	2527	999	5177	1248	24981
1984	1538	1091	2318	737	483	251	182	254	361	7699	2760	1687	19361
1985	4047	1153	7348	4417	714	13072	14150	575	2195	7177	14280	2949	72077
1986	2136	1808	1511	944	1996	26261	1285	672	1560	4890	2802	35242	81107
1987	6576	17185	6693	2540	27837	166178	6574	3743	2889	2154	2198	2951	247518
1988	2543	2273	2193	1617	1182	1339	1397	697	737	705	829	1429	16941
1989	2260	1699	1438	1622	1504	1572	579	672	361	877	1226	1503	15313
Average	5777	5189	3258	9729	14129	12692	5951	3542	10552	7010	5672	4898	88399
Max	99377	46998	11508	88058	135942	166178	81468	55798	93160	60604	33620	35242	337675
Min	925	0	761	501	483	0	182	0	361	122	496	873	11214
median	2338	2297	2343	2839	4055	3711	1399	1356	2046	2273	2285	2646	67681
drt avg	2422	1851	1848	6131	4292	5146	1093	2439	7619	4673	1342	3000	41855

Cibolo Creek @ Falls City Flow Statistics
2050 Pumpage
Pumpage Affected Modified Flows at Falls City in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	5875	2397	5254	12137	873	91	16472	732	842	921	9055	9559	64208
1935	1667	6837	1444	11837	67052	85321	2484	2071	14540	2284	1727	4388	201652
1936	1007	1401	2368	1203	22691	0	54740	0	2497	1375	785	1933	90000
1937	1931	1444	761	501	526	40474	1169	983	1985	1638	1004	23129	75545
1938	14729	169	8155	43795	5376	2632	1316	973	975	1006	1218	1486	81830
1939	1343	1085	1062	705	1194	580	770	1736	535	710	621	873	11214
1940	925	884	782	6206	1288	20298	5523	388	467	2586	33620	29818	102785
1941	10556	14402	7617	44359	42470	16329	1167	1997	10497	10953	1789	1343	163479
1942	1607	0	1335	3798	2748	0	81468	3439	86039	33050	4721	3370	221575
1943	3229	2323	2971	1296	4301	3891	2997	882	900	122	2591	1597	27100
1944	7595	2080	3511	1879	37736	1506	1454	1592	889	1337	496	2786	62861
1945	10223	13089	9427	11288	1225	3866	930	939	673	2776	1246	1398	57080
1946	1155	1195	3820	16010	36408	13815	1131	55798	48336	15561	5693	3682	202604
1947	10965	2320	5009	2907	15299	1845	1308	1726	1137	1149	1384	1641	46690
1948	1599	1682	1363	1029	3825	938	2733	10024	1834	2705	1141	1252	30125
1949	1436	3110	1317	44442	5460	16012	2013	2247	1148	31795	2287	4112	115379
1950	1891	1992	1522	3079	1115	15739	1109	1192	1282	985	1011	1247	32164
1951	1290	1206	1384	1067	2430	10195	597	561	2289	949	1106	1238	24312
1952	1262	1891	1148	2826	3601	942	815	491	47215	1506	1895	4786	68378
1953	1944	1360	1251	3137	4284	725	589	6070	16997	2041	1407	4087	43892
1954	1515	1214	1149	1121	2571	874	542	454	628	1327	1131	1075	13601
1955	1194	2631	3441	941	3017	4068	577	1248	1782	1094	936	1359	22288
1956	1300	1069	862	714	1277	121	646	374	1877	3178	1125	9200	21743
1957	1203	1786	5416	60890	37401	27336	1727	1128	33754	8817	9106	2701	191265
1958	21725	46921	3151	2849	29725	2427	2159	1205	5146	10626	4261	2101	132296
1959	2190	2209	1812	9134	4756	1324	1682	1098	1165	12369	2476	2008	42223
1960	2931	1809	1913	1825	1726	8125	2453	1818	1193	46608	8626	9178	88205
1961	4701	7299	2592	2244	1785	40854	17914	2444	2041	5409	19286	3048	109617
1962	2706	2379	2166	3126	1540	2338	1238	668	1302	1260	2273	2428	23424
1963	1750	3913	1545	1663	1099	575	616	594	837	1400	8038	1524	23554
1964	3697	6158	6127	1144	884	1740	662	1177	4644	2903	7893	1597	38626
1965	2362	22191	2482	3675	51529	8386	1574	1418	1126	13644	3197	15308	126892
1966	2375	3371	4219	5566	6792	1592	1257	1338	2458	1507	1382	1404	33261
1967	1701	1252	1184	949	703	393	831	3238	86703	4532	19802	3264	124552
1968	99308	7903	4321	11666	17847	10089	2916	1670	9520	1982	3670	9141	180033
1969	3132	21061	5396	5757	12720	5401	1401	1326	2051	3420	2068	3250	66983
1970	2879	2758	5354	1929	28912	4652	1648	1374	1238	1708	1612	1893	55957
1971	1677	1523	1378	888	691	593	503	23493	6399	8223	2376	7410	55154
1972	2366	1909	1816	1264	135942	9297	3330	2514	1967	1832	2283	2265	166785
1973	2906	4771	4445	25168	3293	62709	58178	6595	93111	60534	10386	5422	337518
1974	6659	3650	3578	2796	6801	1876	1418	12446	13605	2482	16667	4604	76582
1975	3719	15501	3216	4944	37850	16004	4328	3396	2108	2196	2243	2725	98230
1976	2314	1774	2287	15830	41836	3562	6649	2088	4767	37924	19704	15187	153922
1977	12521	13273	4852	87926	16453	4548	2930	1993	14460	2850	30032	3259	195097
1978	2904	3084	2847	6922	2722	16952	1559	9924	14936	2262	21481	3649	89242
1979	21537	11634	11417	50526	15502	21955	6112	3767	2729	2175	2198	2586	152138
1980	2641	2326	2091	1539	18844	1283	812	2182	20479	1755	2400	2082	58434
1981	2314	1807	1707	3231	5933	5428	1104	5524	6160	4531	5774	2121	45634
1982	2012	3957	2220	1570	5090	1340	587	478	898	3774	1130	1562	24618
1983	2038	2982	4062	1389	2134	753	887	785	2527	999	5177	1248	24981
1984	1538	1091	2318	737	483	251	182	254	361	7699	2760	1687	19361
1985	4047	1153	7348	4417	714	13072	14120	575	2195	7177	14280	2949	72047
1986	2136	1808	1511	944	1996	26261	1285	672	1560	4890	2802	35214	81079
1987	6576	17185	6693	2540	27837	166108	6574	3743	2889	2154	2198	2951	247448
1988	2543	2273	2193	1617	1182	1339	1397	697	737	705	829	1429	16941
1989	2260	1699	1438	1622	1504	1572	579	672	361	877	1226	1503	15313
Average	5779	5182	3251	9724	14125	12686	5949	3539	10550	7005	5672	4894	88356
Max	99308	46921	11417	87926	135942	166108	81468	55798	93111	60534	33620	35214	337518
Min	925	0	761	501	483	0	182	0	361	122	496	873	11214
median	2338	2297	2343	2838	4055	3714	1399	1356	2046	2273	2285	2644	67681
drt avg	2440	1848	1845	6126	4288	5146	1093	2439	7619	4673	1342	3000	41857

Cibolo Creek @ Falls City Flow Statistics
2050 + TTexas Pumpage
Pumpage Affected Modified Flows at Falls City in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	5875	2397	5254	12137	873	91	16472	732	842	921	9055	9559	64208
1935	1667	6837	1444	11837	66982	85321	2638	2040	14540	2258	1704	4367	201635
1936	987	1383	2364	1203	22691	0	54740	0	2427	1322	785	1933	89835
1937	1931	1444	761	501	526	40432	1169	983	1985	1638	1004	23129	75503
1938	14667	106	8092	43733	5314	2632	1316	973	975	1006	1218	1486	81518
1939	1343	1085	1062	705	1194	580	770	1736	535	710	621	873	11214
1940	925	884	782	6206	1288	20298	5523	388	467	2475	33462	29978	102676
1941	10425	14312	7533	44220	42401	16189	1072	2016	10514	10969	1803	1356	162810
1942	1619	0	1336	3798	2748	0	81335	3439	85892	32897	4721	3370	221155
1943	3229	2323	2971	1296	4301	3891	2997	882	930	122	2591	1597	27130
1944	7595	2080	3322	1669	37561	1331	1454	1592	889	1337	496	2618	61944
1945	10062	12936	9287	11141	1225	3866	930	939	673	2776	1246	1398	56479
1946	1155	1195	3687	16010	36361	13815	1131	55798	48210	15561	5568	3682	202173
1947	10965	2320	5009	2907	15299	1845	1308	1726	1137	1149	1384	1641	46690
1948	1599	1682	1363	1029	3825	1120	2697	9991	1803	2677	1115	1212	30113
1949	1418	3110	1317	44391	5460	16012	2013	2247	1148	31795	2287	4112	115310
1950	1891	1992	1522	3079	1115	15739	1109	1192	1282	985	1011	1247	32164
1951	1290	1206	1384	1067	2430	10195	597	561	2289	949	1106	1238	24312
1952	1262	1891	1148	2826	3601	942	815	491	47146	1506	1895	4786	68309
1953	1944	1360	1251	3137	4284	725	589	6070	16997	2041	1407	4087	43892
1954	1515	1214	1149	1121	2571	874	542	454	628	1327	1131	1075	13601
1955	1194	2631	3441	941	3017	4068	577	1248	1782	1094	1108	1497	22598
1956	1236	1011	754	714	1277	121	646	374	1877	3178	1125	9200	21513
1957	1203	1786	5416	60820	37331	27259	1723	1124	33751	8743	8936	2732	190824
1958	21754	46854	3176	2871	29655	2445	2176	1220	5150	10626	4261	2101	132289
1959	2190	2209	1812	9134	4756	1324	1682	1098	1165	12369	2476	2008	42223
1960	2931	1809	1913	1825	1726	8125	2453	1739	1193	46608	8626	9178	88126
1961	4701	7299	2592	2244	1785	40854	17914	2444	2041	5409	19286	3048	109617
1962	2706	2379	2166	3126	1540	2338	1238	668	1302	1260	2273	2428	23424
1963	1750	3913	1545	1663	1099	575	616	594	837	1400	8038	1524	23554
1964	3697	6158	6127	1144	884	1679	662	1177	4588	2903	7893	1597	38509
1965	2362	22191	2482	3675	51459	8309	1574	1418	1126	13567	3197	15232	126592
1966	2375	3371	4219	5566	6792	1592	1257	1338	2458	1507	1382	1404	33261
1967	1701	1252	1184	949	703	393	831	3238	86703	4532	19802	3264	124552
1968	99238	7903	4321	11496	17877	10117	2941	1693	9541	2002	3676	9141	179946
1969	3132	21061	5396	5757	12720	5401	1401	1326	2051	3420	2068	3250	66983
1970	2879	2758	5354	1929	28912	4652	1648	1374	1238	1708	1612	1893	55957
1971	1677	1523	1378	888	691	593	503	23465	6399	8223	2376	7410	55126
1972	2366	1909	1816	1264	135872	9297	3330	2514	1967	1832	2283	2265	166715
1973	2906	4771	4445	25168	3293	62676	58108	6595	93076	60464	10386	5422	337310
1974	6659	3650	3578	2796	6801	1876	1418	12414	13605	2482	16667	4604	76550
1975	3719	15466	3216	4944	37850	16004	4328	3396	2108	2196	2243	2725	98195
1976	2314	1774	2287	15802	41833	3559	6647	2086	4767	37896	19704	15187	153856
1977	12521	13273	4852	87898	16453	4548	2930	1993	14460	2850	30032	3259	195069
1978	2904	3084	2847	6922	2722	16952	1559	9924	14936	2262	21481	3649	89242
1979	21537	11634	11375	50578	15502	21955	6112	3677	2666	2136	2181	2586	151939
1980	2641	2326	2091	1539	18844	1283	812	2182	20573	1822	2442	2102	58657
1981	2314	1807	1707	3231	5933	5428	1104	5524	6160	4531	5774	2121	45634
1982	2012	3957	2220	1570	5090	1340	587	478	898	3774	1130	1562	24618
1983	2038	2982	4062	1389	2134	753	887	785	2527	999	5177	1248	24981
1984	1538	1091	2318	737	483	251	182	254	361	7699	2760	1687	19361
1985	4047	1153	7348	4417	714	13002	14120	575	2195	7177	14280	2949	71977
1986	2136	1808	1511	944	1996	26261	1285	672	1560	4890	2802	35165	81030
1987	6576	17185	6693	2540	27837	166108	6574	3743	2889	2154	2198	2951	247448
1988	2543	2273	2193	1617	1182	1339	1397	697	737	705	829	1429	16941
1989	2260	1699	1438	1622	1504	1572	579	672	361	877	1226	1503	15313
Average	5770	5173	3238	9710	14113	12678	5947	3535	10542	6995	5667	4894	88261
Max	99238	46854	11375	87898	135872	166108	81335	55798	93076	60464	33462	35165	337310
Min	925	0	754	501	483	0	182	0	361	122	496	873	11214
median	2338	2297	2341	2849	4055	3713	1399	1356	2046	2260	2285	2602	67646
drt avg	2431	1842	1834	6121	4288	5164	1089	2435	7609	4670	1357	3010	41850

Guadalupe River @ Cuero Flow Statistics

Baseline Historical Modified Flows at Cuero in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	85234	78055	137445	103101	48631	32719	41498	30396	26838	28798	63807	107438	783960
1935	42938	103955	41339	62467	463090	575538	101335	62985	307184	85940	55738	117266	2019775
1936	78710	54134	58526	42331	269317	120914	1069454	67205	170433	246905	94150	85148	2357227
1937	77562	65542	160633	67911	48551	137614	45247	30000	28881	40705	31802	57085	791533
1938	127474	84798	78288	285712	277525	68018	45748	34449	31103	27846	29951	33179	1124091
1939	36148	29394	29351	26086	32454	31154	30485	12458	13661	16031	17759	21612	296593
1940	23270	33199	28124	38411	32148	43436	376743	17891	15254	26442	351888	295946	1282752
1941	143090	158185	219904	253679	746979	256047	128480	68913	52020	59649	59216	46726	2192888
1942	43178	35242	38283	117263	79773	40025	353947	41032	213156	147211	88201	74258	1271569
1943	74978	51477	57793	48148	42259	60917	40468	25310	30664	27980	27550	34024	521568
1944	68479	75223	138557	69260	171354	154680	56561	30002	83866	36762	61946	103729	1050419
1945	178029	161520	148666	301900	72847	63229	39080	26341	16725	57704	36028	45520	1147589
1946	65458	85644	161145	76778	97132	113575	33356	46338	249734	220169	194007	120069	1463405
1947	200081	102352	114923	110225	110031	47003	39192	64270	26911	23097	26193	32535	896813
1948	30197	35794	35406	20524	71256	14960	29294	17505	9691	15586	11724	14718	306655
1949	18784	31744	80610	208769	146880	50197	37708	23705	19061	146289	37376	47452	848575
1950	31408	37827	29121	61321	38930	117608	19925	8054	8754	9116	9261	13470	384795
1951	13101	12923	14502	14749	19773	115247	7170	871	9722	2735	7167	8858	226818
1952	9835	12268	9469	21909	56903	63178	14835	2540	79126	29787	43095	97865	440810
1953	86909	34473	27938	27552	138023	9143	9717	17730	80380	87000	28744	40634	588243
1954	24388	17461	14454	17289	28184	6755	2214	1163	2279	600	3660	6113	124560
1955	6757	41637	10582	8483	35684	36466	7393	7984	5006	3486	847	4583	168908
1956	5194	7803	3535	6075	9729	1435	1764	0	0	7446	850	24109	67940
1957	2655	17281	53202	146600	363536	259466	27252	12185	197480	393197	207359	98926	1779139
1958	202390	400314	181824	99590	236664	82454	57550	29161	83416	94148	111981	72662	1652154
1959	64173	93377	65654	172118	85579	35345	62382	35099	29360	114123	62484	54532	874226
1960	71971	69904	60145	62116	129702	150016	144552	64634	51904	517637	429813	183325	1935719
1961	214860	236469	132774	78500	58367	371542	141469	58521	98108	52528	118249	51296	1612683
1962	46399	40739	38604	45354	35126	38489	21575	13195	33592	31033	32449	40457	417012
1963	35037	49154	33232	33896	22808	14874	13839	6603	7456	6487	38379	22097	283862
1964	22447	41719	70046	35700	19434	28736	12127	7806	43151	33625	46569	23628	384988
1965	93896	265926	65668	67809	259288	243196	56419	34806	27545	71010	113887	144625	1444075
1966	71916	92899	93108	116308	148723	61813	43327	31389	49027	46738	35591	31160	821999
1967	32304	25972	28462	22756	16894	11677	11168	12306	514563	97528	115203	53818	942651
1968	451874	138643	111285	163127	235526	316324	75747	45357	85453	42416	51641	120074	1837467
1969	48704	181076	172198	177291	165228	76017	42923	34041	40243	75638	56254	93048	1162661
1970	83268	95102	162942	92589	209884	126694	64177	42241	38554	61488	36352	36993	1050284
1971	34546	28426	30462	20993	18138	19947	13649	62776	123087	87639	71164	113449	624276
1972	72505	62556	54545	35859	766448	131526	65503	57772	42379	44564	47357	45984	1426998
1973	62550	77165	129368	281187	106495	407830	260000	117628	118103	623749	153513	105918	2443506
1974	208846	83517	74139	60741	114348	78976	38608	67255	214550	70797	264323	147757	1423857
1975	107910	249220	119979	126071	620210	310308	163202	85020	69263	62560	56209	55025	2024977
1976	51595	46086	50488	271896	376698	155503	131078	70426	73205	262179	298245	380164	2167563
1977	156397	241380	112718	684734	247812	118820	72830	57967	55873	50084	84765	52612	1935992
1978	51960	52370	53279	51536	34757	71091	27662	213299	147493	60443	97824	68483	930197
1979	277290	202937	239158	321553	403409	338695	123036	85046	66189	54788	50147	55108	2217356
1980	60630	50871	49283	45147	144732	47080	28132	24145	66211	48622	45582	50908	661343
1981	51009	47252	61567	91531	92277	580707	176693	116754	654826	151492	225149	82038	2331295
1982	71389	75856	58569	50220	301735	65090	40936	27606	24738	28440	41935	40049	826563
1983	43779	67855	113282	65813	87836	72631	50095	33471	42822	35592	46058	33035	692269
1984	40433	31199	39056	24731	17418	13154	5789	6142	7198	36218	27230	43455	292023
1985	86478	62853	90951	95053	85339	200889	129560	50140	38051	100060	220801	158965	1319140
1986	89711	89073	62626	48635	91620	176871	57926	38697	71547	147322	135538	365799	1375365
1987	203238	189030	240328	106036	170031	1464737	260893	146833	93777	79393	77988	76744	3109028
1988	63172	53512	65383	47288	46452	54826	63661	45942	35188	31255	28382	32304	567365
1989	39657	36261	39280	36067	76346	33814	17544	9804	9647	13671	20743	22125	354959
Average	83654	86702	80996	103012	159594	150660	90753	42742	85593	89908	84842	77845	1130009
Max	451874	400314	240328	684734	766448	1464737	1069454	213299	654826	623749	429813	380164	3109028
Min	2655	7803	3535	6075	9729	1435	1764	0	0	600	847	4583	67940
median	63673	62705	62097	64140	91949	71861	43125	33756	42987	51306	50894	53215	996468
drt avg	42665	33428	34054	49690	65539	46199	16921	14382	24093	32514	16892	29034	405412

Guadalupe River @ Cuero Flow Statistics
1994 Pumpage
Pumpage Affected Modified Flows at Cuero in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	84257	77078	136468	102193	47723	31741	40591	29488	25930	27890	62899	106531	772789
1935	42030	103048	40501	61559	462392	574840	100497	62078	306486	85032	54830	116428	2009721
1936	77802	53226	57619	41493	268409	120216	1068756	66368	169735	246207	93312	84310	2347453
1937	76724	64704	159795	67073	47713	136777	44409	29162	28043	39867	30964	56247	781478
1938	126776	83960	77519	285013	276129	67180	44910	33611	30265	27008	29113	32341	1113825
1939	35310	28556	28513	25318	31686	30316	29647	11690	12893	15193	16921	20844	286887
1940	22432	32431	27286	37643	31380	42598	375906	17053	14486	25604	351050	295248	1273117
1941	142252	157487	219206	252981	746281	255349	127712	68145	51252	58881	58448	45958	2183952
1942	42410	34474	37515	116495	78935	39257	353179	40264	212458	146513	87363	73490	1262353
1943	74140	50709	57025	47310	41421	60149	39630	24542	29826	27212	26782	33186	511932
1944	67711	74455	137858	68422	170656	153982	55793	29234	83097	35994	61178	102961	1041341
1945	177331	160822	147968	301202	72149	62460	38382	25573	15956	56936	35260	44822	1138861
1946	64690	84946	160377	76010	96434	112807	32657	45640	248966	219401	193309	119370	1454607
1947	199383	101654	114155	109527	109332	46305	38424	63572	26143	22328	25425	31766	888014
1948	29498	35096	34708	19825	70488	14192	28596	16807	8923	14887	11026	13949	297995
1949	18085	31046	79912	208070	146182	49499	37009	23007	18363	145590	36608	46754	840125
1950	30710	37129	28422	60622	38232	116909	19227	7356	8055	8418	8562	12772	376414
1951	12403	12225	13803	14051	19074	114549	6471	173	9024	2009	6468	8160	218410
1952	9137	11570	8770	21211	56205	62480	14137	1856	78428	29089	42397	97167	432447
1953	86211	33775	27240	26854	137325	8514	9019	17032	79681	86302	28045	39936	579934
1954	23690	16763	13826	16591	27556	6057	1585	492	1609	0	2962	5485	116616
1955	6129	41009	9953	7840	35056	35837	6695	7286	4343	2829	190	3934	161101
1956	4552	7161	2879	5426	9080	1407	982	0	0	6727	180	23411	61805
1957	1985	16583	52503	145902	362838	258767	26624	11487	196851	393197	206661	98228	1771626
1958	201692	399616	181824	98892	235965	81755	56921	28533	82717	93520	111282	72034	1644751
1959	63544	92749	65025	171560	84951	34717	61754	34471	28731	113425	61856	53903	866686
1960	71412	69276	59587	61558	129143	149457	143993	64634	51346	516938	429115	183325	1929784
1961	214162	235771	132076	77941	57878	370843	140980	58032	97550	52039	117761	50808	1605841
1962	45911	40180	38115	44865	34637	37931	21087	12637	33033	30474	31891	39968	410729
1963	34548	48665	32743	33338	22319	14315	13351	6115	6940	5998	37820	21608	277760
1964	21889	41230	69557	35211	18946	28247	11638	7318	42663	33137	46080	23209	379125
1965	93407	265437	65179	67320	258590	242498	55930	34387	27056	70521	113399	144136	1437860
1966	71427	92411	92689	115889	148234	61324	42838	30901	48538	46319	35102	30741	816413
1967	31816	25483	28043	22268	16405	11188	10749	11817	514144	97039	114784	53329	937065
1968	451874	138225	110796	162429	234828	315835	75258	44938	85034	41998	51222	119655	1832092
1969	48215	180657	171709	176872	165228	75528	42504	33552	39754	75219	55835	92629	1157702
1970	83268	94613	162243	92589	209186	125996	63689	41752	38135	61069	35933	36574	1045047
1971	34127	27937	30043	20574	17649	19528	13230	62078	122668	87220	70676	112751	618481
1972	72086	62137	54126	35440	765750	130828	65015	57353	41960	44145	46938	45565	1421343
1973	62131	76746	128949	280768	106076	407132	259302	116930	117684	623051	152814	105918	2437501
1974	208427	83098	73720	60322	113929	78557	38189	66906	214201	70378	264323	147338	1419388
1975	107910	248522	119281	125722	620210	310308	163202	84321	68914	62141	55859	54606	2020996
1976	51246	45737	50138	271547	376698	154805	131078	70426	72856	261760	298245	379465	2164001
1977	156397	240682	112718	684734	247812	118820	72481	57548	55524	49734	84416	52263	1933129
1978	51611	52020	52860	51187	34408	70672	27312	213299	147493	60094	97475	68134	926565
1979	277290	202937	238460	320855	402711	337996	122337	84697	65840	54439	49728	54759	2212049
1980	60281	50522	48864	44798	144382	46731	27783	23796	65862	48273	45232	50559	657083
1981	50660	46903	61218	91112	91928	580707	175995	116754	654477	150794	225149	81689	2327386
1982	71040	75507	58220	49871	301037	64741	40587	27257	24388	28091	41586	39700	822025
1983	43430	67506	112863	65463	87486	72282	49746	33122	42473	35243	45709	32686	688009
1984	40084	30850	38707	24382	17069	12805	5440	5793	6849	35868	26881	43106	287834
1985	85780	62504	90951	95053	84990	200889	128861	49791	37701	100060	220103	158965	1315648
1986	89362	88724	62276	48285	91271	176871	57577	38347	71198	147322	135538	365101	1371872
1987	202540	189030	240328	106036	170031	1464737	260893	146135	93777	79044	77639	76465	3106655
1988	62823	53233	65034	46938	46103	54477	63312	45663	34839	30906	28033	31955	563316
1989	39308	35912	38931	35718	76067	33534	17195	9524	9298	13322	20464	21776	351049
Average	83131	85977	81448	102467	157046	148004	89305	41978	84008	88262	83908	77822	1123357
Max	451874	399616	240328	684734	765750	1464737	1068756	213299	654477	623051	429115	379465	3106655
Min	1985	7161	2879	5426	9080	1407	982	0	0	0	180	3934	61805
median	63184	62321	61747	63511	91600	71477	42671	33337	42568	50887	50475	52796	989203
drt avg	41980	32743	33367	49002	64853	45575	16215	13758	23457	31818	16186	28333	397286

Guadalupe River @ Cuero Flow Statistics
2050 Pumpage
Pumpage Affected Modified Flows at Cuero in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	84257	77008	136398	102053	47583	31601	40381	29279	25651	27611	62550	106251	770623
1935	41751	102768	40152	61210	461694	574142	100078	61659	305788	84613	54412	115939	2004206
1936	77313	52807	57130	41004	267921	119518	1068058	65809	169037	245508	92753	83752	2340610
1937	76166	64146	159236	66514	47154	136218	43781	28604	27414	39308	30405	55619	774565
1938	126078	83332	76891	284315	276129	66552	44281	32983	29637	26310	28485	31713	1106706
1939	34681	27858	27885	24620	30988	29687	29019	10991	12195	14494	16223	20146	278787
1940	21734	31732	26588	36944	30682	41900	375207	16354	13717	24836	350352	294550	1264596
1941	141554	156788	218507	252283	744885	254651	126944	67377	50484	58043	57610	45120	2174246
1942	41642	33706	36747	115727	78167	38419	352341	39426	211760	145814	86595	72652	1252996
1943	73372	49871	56187	46542	40653	59311	38862	23704	28988	26304	25944	32348	502086
1944	66873	73547	136462	67584	169957	152585	54885	28326	82190	35086	60271	102053	1029819
1945	176632	160124	147270	299806	71241	61553	37474	24666	15049	56028	34352	43914	1128109
1946	63783	84038	159469	75102	95526	111899	31750	44732	248059	218493	192611	118672	1444134
1947	197986	100955	113247	108619	108425	45327	37516	62595	25235	21421	24448	30859	876633
1948	28521	34118	33730	18918	69580	13284	27618	15830	7945	13910	10048	12972	286474
1949	17108	30068	78934	207093	145205	48521	35962	22029	17385	144543	35630	45777	828255
1950	29663	36082	27375	59645	37184	115932	18179	6378	7008	7370	7515	11725	364056
1951	11425	11247	12756	13073	18027	113572	5424	34	8605	1695	4890	6833	207581
1952	7873	10383	7583	20094	55087	61363	13019	815	77031	27902	41210	96050	418410
1953	85094	32727	26122	25806	136208	7397	7902	15914	78564	85185	26928	38819	566666
1954	22573	15645	12709	15473	26438	5009	1369	0	1002	0	1090	3956	105264
1955	4732	39752	8697	6646	33869	34650	5508	6113	3233	1600	0	2698	147498
1956	3358	5988	1720	6243	9589	360	1666	0	0	6476	0	22936	58336
1957	1650	14970	49152	143108	360743	256673	24668	9741	195176	391102	205264	96901	1749148
1958	200296	398220	180427	97495	234569	80359	55664	27276	81460	92263	110584	70777	1629390
1959	62357	91562	63838	170373	83764	33530	60567	33284	27544	112029	60669	52716	852233
1960	70225	68089	58400	60371	127886	148270	142736	63238	50089	515542	427718	181928	1914492
1961	212765	235073	130680	76754	56621	369866	139723	56775	96293	50782	116504	49551	1591387
1962	44654	38993	36858	43608	33380	36744	19830	11380	31776	29217	30634	38711	395785
1963	33291	47408	31486	32151	21062	13128	12094	4844	5676	4713	36563	20351	262767
1964	20632	39973	68300	33954	17689	26991	10382	6061	41336	31880	44823	21882	363903
1965	92150	264180	63922	66063	257193	241101	54673	33060	25799	69195	112072	142810	1422218
1966	70170	91154	91363	114562	146977	60067	41581	29574	47211	44993	33775	29414	800841
1967	30489	24226	26717	20941	15148	9861	9423	10491	512817	95712	113457	52003	921285
1968	450477	136898	109540	161731	233432	314578	73932	43611	83708	40671	49896	118328	1816802
1969	46888	179330	170382	175545	163692	74201	41177	32225	38428	73823	54508	91302	1141501
1970	81731	93286	160847	91192	207789	124599	62362	40426	36739	59672	34537	35247	1028427
1971	32730	26611	28717	19177	16323	18201	11833	60681	121271	85824	69349	111354	602071
1972	70689	60811	52799	34113	764353	129431	63688	55957	40564	42748	45542	44169	1404864
1973	60734	75349	127622	279441	104749	405735	257906	115533	116287	621654	151418	104522	2420950
1974	207031	81702	72324	58995	112532	77160	36793	65440	212734	68981	262926	145941	1402559
1975	106234	247126	117885	124326	618813	308912	161805	83134	67447	60745	54393	53210	2004030
1976	49780	44340	48742	270150	375302	153408	129682	68820	71390	260364	296499	378069	2146546
1977	155001	239285	111321	682639	246415	117423	71015	56152	54058	48268	82950	50797	1915324
1978	50145	50554	51464	49791	32942	69275	25846	211902	145398	58628	96008	66668	908621
1979	275894	201540	237064	319458	401314	336600	120941	83231	64374	52903	48261	53292	2194872
1980	58814	49056	47398	43332	142916	45265	26317	22330	64396	46806	43766	49022	639418
1981	49193	45437	59752	89645	90462	579310	174598	115357	653011	149397	223543	80223	2309928
1982	69574	74041	56684	48404	299640	63205	39120	25791	22922	26625	40050	38234	804290
1983	41894	65970	111396	63997	86020	70745	48280	31656	40937	33707	44173	31150	669925
1984	38548	29313	37171	22915	15533	11268	3931	4250	5299	34332	25344	41570	269474
1985	84383	60967	89554	92959	83454	199493	127465	48255	36165	98663	218706	156870	1296934
1986	87825	87188	60740	46819	89804	175475	56041	36811	69662	145926	134141	363704	1354136
1987	201143	186935	238234	104640	168495	1463341	258798	144738	91682	77507	76033	74859	3086405
1988	61287	51627	63498	45402	44567	52941	61776	44057	33303	29300	26497	30418	544673
1989	37771	34376	37395	34182	74461	31998	15659	7918	7692	11716	18858	20170	332196
Average	81975	84826	80240	101313	155897	146832	88170	40850	82833	87111	82746	76634	1109429
Max	450477	398220	238234	682639	764353	1463341	1068058	211902	653011	621654	427718	378069	3086405
Min	1650	5988	1720	6243	9589	360	1369	0	0	0	0	2698	58336
median	61822	60889	60246	62604	90133	70010	41379	31941	41137	49525	49079	51400	974856
drt avg	40833	31697	32287	48161	63961	44542	15416	12971	22601	31010	15176	27263	385917

Guadalupe River @ Cuero Flow Statistics
2050 + TTexas Pumpage
Pumpage Affected Modified Flows at Cuero in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	84257	77008	136328	101914	47374	31392	40102	28930	25302	27192	62131	105763	767693
1935	41192	102210	39594	60652	460996	573444	99380	60960	305090	83915	53643	115171	1996247
1936	76615	51970	56362	40236	267152	118819	1067359	64971	168339	244810	91845	82844	2331322
1937	75258	63238	158328	65537	46177	135240	42803	27556	26437	38261	29358	54571	762764
1938	125379	82284	75844	283617	274732	65504	43164	31866	28520	25193	27367	30595	1094065
1939	33494	26741	26698	23502	29871	28486	27832	9804	10973	13307	15036	18889	264633
1940	20477	30476	25331	35688	29425	40643	373950	15097	12461	23579	349025	293153	1249305
1941	140227	155392	217111	250886	744186	253254	125617	66050	49087	56716	56283	43793	2158602
1942	40245	32309	35350	114330	76770	37022	350944	38030	210363	144418	85128	71255	1236164
1943	71906	48405	54720	45076	39186	57845	37326	22237	27522	24837	24478	30881	484419
1944	65337	72081	135065	66117	168561	151189	53349	26860	80654	33550	58734	100517	1012014
1945	175236	158727	145873	298409	69705	60016	35868	23129	13513	54492	32746	42308	1110022
1946	62246	82432	157863	73496	93920	110363	30144	43126	246522	216887	191214	117275	1425488
1947	196589	98861	111641	106943	106749	43721	35910	60989	23629	19815	22911	29253	857011
1948	26985	32512	32124	17312	67974	11678	26012	14224	6395	12304	8442	11366	267328
1949	15502	28462	77328	205417	143599	46915	34356	20423	15779	142937	34024	44101	808843
1950	28057	34476	25769	57969	35578	114256	16573	4702	5388	5736	5895	10126	344525
1951	9749	9578	11150	11397	16351	111896	3867	0	7425	187	4346	4620	190566
1952	5932	8553	5810	18348	53342	59617	11343	271	74936	26017	39394	94304	397867
1953	83348	30912	24377	24060	134462	5651	6205	14239	76818	83439	25252	37073	545836
1954	20827	13900	10963	13728	24693	3243	0	0	373	0	196	2678	90601
1955	2372	37518	6706	5606	31844	32695	3622	4235	2604	267	0	764	128233
1956	1410	6177	1748	4581	8165	464	144	0	0	5281	0	20953	48923
1957	23	14796	45451	139617	357252	253879	21875	7088	192662	389008	203169	94597	1719417
1958	198201	396125	177634	95400	232474	78264	53639	25251	79505	90308	108489	68822	1604112
1959	60402	89606	61883	168418	81878	31645	58681	31399	25659	109934	58783	50831	829119
1960	68340	66203	56514	58415	126001	146315	140851	61143	48204	513447	425623	179833	1890889
1961	211369	232978	128585	74799	54666	367911	137768	54820	94408	48897	114618	47665	1568484
1962	42768	37108	34973	41723	31495	34858	17944	10542	29472	27122	28679	36756	373440
1963	31406	45523	29601	30265	19177	11243	10222	3091	4950	2339	34468	18368	240653
1964	18746	38018	66345	32069	15803	25105	8482	4154	39520	29994	42938	20067	341241
1965	90265	262225	62037	64178	255797	239425	52718	31175	23844	67309	110187	140924	1400084
1966	68215	89199	89477	112677	145022	58182	39626	27689	45326	43107	31890	27529	777939
1967	28604	22341	24831	19056	13193	7983	7523	8605	510932	93827	111572	50117	898584
1968	448383	134943	107584	159636	231337	312553	71977	41656	81752	38716	47941	116373	1792851
1969	44933	177375	168427	173590	161737	72246	39222	30270	36472	71938	52553	89347	1118110
1970	79776	91331	158752	89098	206393	123203	60407	38471	34784	57717	32651	33292	1005875
1971	30775	24655	26762	17222	14368	16246	9948	58587	119316	83869	67394	109958	579100
1972	68734	58855	50844	32158	762957	127406	61663	54002	38609	40793	43587	42213	1381821
1973	58779	73394	125597	277416	102724	403640	255811	113438	114262	619559	149323	102427	2396370
1974	205006	79607	70299	56970	110507	75135	34768	63484	210779	67026	260831	143916	1378328
1975	104209	245031	115790	122231	616718	306119	159710	81039	65422	58650	52368	51115	1978402
1976	47755	42315	46717	268055	373207	151313	127587	66795	69365	258269	294474	375974	2121826
1977	152906	237190	109226	680544	244321	115328	68920	54057	51963	46243	80925	48772	1890395
1978	48120	48529	49439	47766	30917	67250	23891	209807	144002	56603	93983	64643	884950
1979	273799	199445	234969	317363	399219	334505	118846	81136	62279	50878	46236	51267	2169942
1980	56720	47031	45373	41307	140891	43240	24292	20305	62371	44781	41741	47067	615119
1981	47168	43412	57727	87690	88437	577215	172503	113262	650916	147303	221448	78128	2285209
1982	67479	71946	54659	46309	297545	61180	37095	23766	20897	24600	38025	36209	779710
1983	39869	63945	109371	61972	83925	68720	46255	29631	38912	31752	42218	29125	645695
1984	36523	27288	35146	20890	13508	9285	2891	1799	3099	32307	23319	39545	245600
1985	82288	58942	87460	91143	81429	197398	125370	46230	34140	96569	216612	154775	1272356
1986	85731	85093	58645	44724	87710	173380	54016	34716	67567	143831	132046	361610	1329069
1987	199048	184840	236139	102545	166330	1460548	256704	142643	89587	75273	73868	72694	3060219
1988	59122	49532	61403	43238	42472	50846	59681	42032	31208	27275	24402	28393	519604
1989	35746	32281	35300	32157	72436	29903	13634	5914	5695	9761	16833	18214	307874
Average	80247	83131	78483	99562	154155	145086	86436	39209	81179	85395	81083	74872	1088837
Max	448383	396125	236139	680544	762957	1460548	1067359	209807	650916	619559	425623	375974	3060219
Min	23	6177	1748	4581	8165	464	0	0	0	0	0	764	48923
median	59762	58899	58186	61312	88074	67985	39864	29951	39216	47570	47089	49445	952230
drt avg	39077	30095	30762	46536	62276	43014	13803	11908	21335	29598	14046	25524	367973

Guadalupe River @ Saltwater Barrier Flow Statistics

Baseline Historical Modified Flows at Tivoli (SWB) in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	232553	107502	179478	159024	50128	18612	99315	21406	39967	34611	140296	154040	1236932
1935	70267	146514	75659	105672	596001	756305	111228	57485	395298	138299	82921	173968	2709617
1936	104648	73012	82976	59976	461212	154499	1299988	82828	336389	331531	139365	125041	3251465
1937	120462	88843	196812	75359	48605	254419	47866	34117	38430	64651	53879	161552	1184995
1938	187845	109492	108070	414403	344783	71639	34810	38043	38153	33147	47609	66114	1494108
1939	63991	44654	37002	22088	36640	23754	41582	0	5480	8705	13530	22148	319574
1940	69039	76828	40543	52531	25996	112325	449482	19644	686	38322	565036	483659	1934091
1941	222105	271643	307498	392522	1027354	351363	175322	69250	80503	78720	76690	68129	3121099
1942	58284	95702	64657	140739	86147	26519	699389	88739	479517	263029	119807	95048	2217577
1943	109893	73106	94762	57139	51249	81949	35258	7864	23979	25441	35259	70050	665949
1944	168669	124310	193661	75387	303357	167083	43743	30289	93799	35705	67664	123373	1427040
1945	211825	195530	165092	360828	71904	59151	18622	29170	12217	71042	40380	54237	1289998
1946	123089	148999	203381	107261	176499	155563	12901	69353	461259	652235	276786	158935	2546261
1947	277769	135873	141298	121404	195963	49961	25793	55324	15592	19140	29927	40970	1109014
1948	68615	86895	60336	23063	72232	0	17089	28303	4786	20560	11085	13224	406188
1949	29235	65683	96983	386705	203601	92196	57636	13088	6245	245651	64017	88629	1349669
1950	50690	46981	31796	56136	27573	118004	0	0	0	0	4926	9104	345210
1951	11058	12926	10987	2133	43655	156470	0	0	97641	23115	21118	13802	392905
1952	12791	23362	15203	27691	92967	48283	0	0	269358	20802	96479	145096	752032
1953	114115	55892	36607	22016	179558	0	0	36268	137962	89099	28854	47111	747482
1954	30071	15058	7493	4324	17913	0	0	0	0	0	3501	532	78892
1955	6067	70339	14217	0	33021	15060	0	0	0	0	0	0	138704
1956	2814	2784	0	0	0	0	0	0	0	7887	0	38805	52290
1957	2093	20530	170424	426766	596290	405327	19409	0	284550	461979	347858	140575	2875801
1958	390633	754297	277699	131562	361287	82110	51439	8872	158564	229619	224923	146993	2817998
1959	108302	212256	118595	229899	112023	26412	45320	17675	15846	152912	85531	98600	1223371
1960	105931	121451	97720	72020	127755	155890	141317	74525	38194	855506	622155	350593	2763057
1961	341241	373953	199975	103051	56360	433957	167680	47642	91479	64945	167406	64359	2112048
1962	58694	47649	36771	44879	22181	48423	0	0	23301	18082	32251	66020	398251
1963	50295	80572	39505	26226	6790	0	0	0	0	1506	48726	48754	302374
1964	62210	97846	93491	28658	6966	7555	0	7196	19866	35051	63936	27765	450540
1965	127122	404579	99888	112075	389860	253339	36054	13102	9603	88673	120099	231997	1886391
1966	133330	147889	115661	126709	191561	52775	25384	12148	38317	35108	29060	26659	934601
1967	34546	27736	24133	9126	4043	0	0	47880	1674891	333064	204760	89267	2449446
1968	724661	240194	163064	183350	474380	458919	121148	49100	140684	47038	59322	139691	2801551
1969	60911	257832	229648	327976	290792	108422	25178	13960	33024	75055	74567	134567	1631932
1970	152514	133340	244182	109424	300450	192842	43877	23749	35429	69403	41608	38140	1384958
1971	38338	26684	24569	5143	0	961	0	89928	316706	218285	135649	172826	1029089
1972	130605	92619	69567	60877	1045166	197228	79855	64852	51396	95312	87962	69138	2044577
1973	121176	157121	176505	429609	130588	801518	473984	187129	218729	1214126	271861	158804	4341150
1974	265954	118317	97262	67032	174137	83474	24202	87474	276353	94001	309149	205927	1803282
1975	156472	333608	155078	134654	668440	408398	190098	86767	67313	70129	62385	165661	2499003
1976	105810	67682	62338	474827	546958	196926	172349	74409	116855	443509	472825	599575	3334063
1977	323091	382797	187989	862057	373448	219589	103285	78300	75181	61095	153932	73118	2893882
1978	94104	116001	86342	73388	41858	96586	4199	234158	353365	107938	157319	85862	1451120
1979	464061	310018	305110	454724	590790	467072	136172	95802	116547	65363	61433	62810	3129902
1980	133872	86078	65604	42091	237971	44270	8095	36450	99733	46768	61760	64477	927169
1981	82944	63909	69262	89472	337693	924089	276927	117547	757520	344571	339568	122901	3526403
1982	96840	193284	105455	63648	389038	58725	16358	4325	5822	37439	151964	74447	1197345
1983	52228	109488	163519	55634	73624	48559	105673	32559	55261	79411	66951	30934	873841
1984	57013	36471	63851	9638	17358	0	0	0	0	92348	61249	61793	399721
1985	119405	76972	181149	180407	88875	215794	158516	30922	28824	138229	242219	203148	1664460
1986	107525	97465	68726	37650	93848	318543	49052	11272	61445	199394	152657	511884	1709461
1987	298579	253589	326729	115788	219469	2464544	350770	186775	103315	81409	101342	96206	4598515
1988	80721	65767	77116	42090	32102	32545	38633	24095	17290	20532	22751	33856	487498
1989	50276	41445	43842	33664	65610	14672	0	0	0	0	21699	21312	292520
Average	131724	136616	113196	139482	221163	209346	107922	43971	141504	146271	124286	116694	1625115
Max	724661	754297	326729	862057	1045166	2464544	1299988	234158	1674891	1214126	622155	599575	4598515
Min	2093	2784	0	0	0	0	0	0	0	0	0	0	52290
median	105871	96584	95873	74374	119889	87835	37344	29730	45682	69766	71116	80155	1405999
drt avg	60323	51579	41492	64347	86648	47997	10052	13298	53158	42625	25991	39727	537239

Guadalupe River @ Saltwater Barrier Flow Statistics
1994 Pumpage
Pumpage Affected Modified Flows at Tivoli (SWB) in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	229102	104095	176014	155651	46714	15116	95957	17932	36568	31226	136940	150744	1196059
1935	66957	143152	72406	102527	591341	751683	106545	54198	391373	134507	79621	170765	2665075
1936	100760	69658	79667	56502	456911	149979	1296892	78286	331801	326981	135199	121814	3204450
1937	117235	85550	192129	71316	45185	249845	44605	30804	35125	61410	50643	158317	1142164
1938	183304	104792	103508	410007	339698	68367	31482	34717	34896	29897	44372	62832	1447872
1939	60772	41433	33773	18906	33397	20456	38359	0	2268	5431	10379	18972	284146
1940	65782	73627	37292	49386	22759	107658	445498	16411	0	33630	561851	479711	1893605
1941	219003	267124	303023	388121	1023055	347047	170825	66114	77407	75589	73519	64571	3075398
1942	55082	91503	61497	136668	82942	22733	695015	85532	475264	258717	116536	91889	2173378
1943	106677	69890	91557	53591	48043	78767	31091	4618	19643	21326	32068	66793	624064
1944	165498	121093	189288	70928	299135	162731	40474	27035	89436	32503	63548	119042	1380711
1945	207607	191357	160932	356651	68578	55816	15467	25964	9024	66916	37203	51161	1246676
1946	119135	145055	199104	104142	172394	152425	9772	66347	457188	649175	272618	155707	2503062
1947	274737	132779	138155	118309	192964	46855	22612	52184	12440	16002	26808	37856	1071701
1948	65565	83847	57306	19974	69116	0	14178	25408	1768	17621	8052	10145	372980
1949	26231	62649	93958	382535	200599	89227	54617	10031	3179	242666	60936	85606	1312234
1950	47715	43973	28810	53144	24520	114993	0	0	0	0	1888	6118	321161
1951	8056	9930	8032	0	40689	153365	0	0	94687	20211	18235	10924	364129
1952	9919	20366	12227	24845	89859	45651	0	0	265252	17917	93627	142113	721776
1953	111279	52994	33637	19025	176764	0	0	33279	134994	86187	25961	44137	718257
1954	27518	12443	4890	1218	14908	0	0	0	0	0	776	0	61753
1955	3155	67296	11192	0	30009	12321	0	0	0	0	0	0	123973
1956	0	0	0	0	0	0	0	0	0	5060	0	36154	41214
1957	0	17853	166872	422423	591990	401067	16789	0	281834	458278	345259	137897	2840262
1958	388027	750052	274895	128899	357065	79458	48845	6244	155112	226526	221689	144477	2781289
1959	105781	209728	116061	227437	109504	23857	42758	15146	13331	150395	83000	96120	1193118
1960	103519	118970	95308	69590	125342	153488	138938	70876	35762	851567	619698	348763	2731821
1961	338767	371488	197503	100689	54045	431503	165414	45383	89155	62666	165190	62117	2083920
1962	56453	45360	34433	42543	19832	46103	0	0	20978	15891	29972	63801	375366
1963	48092	78368	37299	23945	4568	0	0	0	0	0	46489	46608	285369
1964	59977	95733	91363	26324	4793	3940	0	5069	16307	32911	61824	25702	423943
1965	125041	402539	97794	108708	386501	249926	33932	11037	7507	85554	118039	228972	1855550
1966	131249	145857	113647	124689	189485	50730	23297	10243	36304	33092	27008	24681	910282
1967	32518	25705	22168	7096	2162	0	0	45874	1673033	331053	202880	87292	2429781
1968	722351	238384	161205	181278	472272	456937	119197	47155	138742	45131	57420	137793	2777865
1969	58960	255946	227678	326048	289299	106453	23216	11962	31044	73141	72666	132501	1608914
1970	150985	131371	242027	107930	298374	190747	41910	21759	33550	67523	39720	36270	1362166
1971	36448	24741	22685	3251	0	0	0	86874	314861	216363	133755	170742	1009720
1972	128814	90767	67761	59021	1042199	195141	77992	63055	49595	93516	86166	67342	2021369
1973	119384	155334	174706	427847	128790	798737	471021	185110	216566	1211224	269848	157390	4315957
1974	264224	116530	95474	65237	172354	81723	22417	85234	274709	92273	307862	204192	1782229
1975	155119	331390	153103	132985	667188	407081	188747	84776	65686	68388	60700	163924	2479087
1976	104140	66013	60637	472772	545660	194970	171076	73100	115192	441361	471510	597607	3314038
1977	321761	380829	186699	860295	372078	218248	101667	76603	73576	59476	152297	71477	2875006
1978	92340	114261	84566	71650	40165	94867	2622	233087	352093	106318	155719	84243	1431931
1979	462789	308731	302852	452832	588877	465383	134345	94256	114967	63705	59758	61136	3109631
1980	132254	84455	63907	40433	236375	42611	6426	34838	98131	45131	60167	62883	907611
1981	81323	62285	67517	87696	335997	922587	274998	116210	755941	342643	338270	121277	3506744
1982	95270	191722	103831	62067	386771	57087	14711	2649	4170	35810	150349	72887	1177324
1983	50646	107900	161842	54022	72011	46909	104008	30950	53641	77798	65357	29336	854420
1984	55382	34857	62246	8012	15732	0	0	0	0	90754	59642	60180	386805
1985	117480	75358	179854	179148	87236	214068	156181	29269	27194	136943	240306	201891	1644928
1986	105898	95886	67132	36033	92220	317347	47419	9626	59879	198162	151350	509619	1690571
1987	296715	252365	325501	114538	218356	2463155	349549	184897	102066	79836	99780	94709	4581467
1988	79162	64264	75549	40514	30518	30976	37049	22552	15689	18954	21185	32293	468705
1989	48766	39873	42269	32096	64109	13190	0	0	0	0	20209	19781	280293
Average	131084	133563	111871	137348	215562	203631	105856	41655	137481	141881	122248	115023	1597202
Max	722351	750052	325501	860295	1042199	2463155	1296892	233087	1673033	1211224	619698	597607	4581467
Min	0	0	0	0	0	0	0	0	0	0	0	0	41214
median	103830	93618	92758	71122	117423	85475	35491	26500	43082	67220	69012	78565	1371439
drt avg	57418	48628	38821	61905	83943	46241	9141	12090	51232	40566	23628	37305	510918

Guadalupe River @ Saltwater Barrier Flow Statistics
2050 Pumpage
Pumpage Affected Modified Flows at Tivoli (SWB) in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	229102	104032	175951	155526	46591	15050	95827	17808	36383	30985	136630	150493	1194378
1935	66712	142901	72100	102218	590695	751035	106170	53827	390732	134131	79251	170324	2660096
1936	100324	69289	79235	56074	456464	149350	1296237	77790	331167	326335	134699	121316	3198280
1937	116684	85055	191623	70766	44639	249329	43999	30322	34581	60866	50158	157761	1135783
1938	182611	104166	102884	409303	339687	67755	30931	34171	34297	29240	43773	62287	1441105
1939	60170	40774	33174	18249	32792	19911	37758	0	1660	4812	9754	18336	277390
1940	65139	72969	36639	48721	22153	107039	444854	15784	0	32895	561155	478974	1886322
1941	218345	266436	302325	387481	1021700	346355	170127	65392	76689	74805	72735	63789	3066179
1942	54363	90779	60773	135922	82203	21946	694242	84745	474571	258085	115796	91089	2164514
1943	105940	69099	90762	52861	47316	77970	30365	3854	18863	20487	31290	66010	614817
1944	164699	120219	187955	70129	298428	161394	39623	26248	88571	31657	62689	118156	1369768
1945	206896	190649	160137	355293	67716	54957	14619	25127	8200	66059	36357	50254	1236264
1946	118276	144188	198198	103279	171503	151554	8930	65496	456286	648291	271848	154969	2492818
1947	273357	132098	137283	117438	192039	45942	21765	51263	11602	15170	25911	37014	1060882
1948	64664	82940	56343	19145	68237	0	13245	24527	902	16731	7171	9245	363150
1949	25322	61745	93003	381503	199628	88313	53638	9126	2285	241665	60011	84637	1300876
1950	46698	42976	27794	52169	23494	114060	0	0	0	0	954	5157	313302
1951	7154	9023	7061	0	39742	152410	0	0	94270	19893	16870	9751	356174
1952	8785	19291	11164	23799	88791	44662	0	0	263928	16812	92502	141029	710763
1953	110188	52049	32576	18026	175661	0	0	32243	133891	85167	24902	43067	707770
1954	26459	11389	3849	169	13848	0	0	0	0	0	0	0	55714
1955	1930	66097	10046	0	28875	11197	0	0	0	0	0	0	118145
1956	0	0	0	0	0	0	0	0	0	4779	0	35565	40344
1957	0	16297	163823	419732	589954	399038	15010	0	280251	456199	343895	136616	2820815
1958	386644	748599	273567	127545	355629	78102	47679	5072	153936	225292	220955	143252	2766272
1959	104675	208556	114899	226249	108335	22768	41652	14024	12209	149031	81894	94963	1179255
1960	102354	117806	94149	68429	124102	152314	137691	69488	34559	850167	618300	347385	2716744
1961	337384	370743	196136	99522	52828	430549	164171	44162	87919	61505	163950	60901	2069770
1962	55240	44206	33225	41330	18627	44967	0	0	19786	14690	28777	62591	363439
1963	46882	77148	36090	22796	3379	0	0	0	0	0	45283	45421	276999
1964	58785	94518	90139	25114	3608	2706	0	3929	15006	31707	60613	24445	410570
1965	123795	401282	96547	107482	385065	248490	32716	9775	6315	84224	116730	227562	1839983
1966	130006	144608	112335	123387	188243	49501	22081	8973	35029	31812	25732	23410	895117
1967	31240	24490	20890	5826	964	0	0	44660	1671697	329737	201580	85990	2417074
1968	720853	236948	159808	180534	470933	455715	117945	45911	137470	43848	56127	136436	2762528
1969	57657	254580	226364	324704	287797	105159	21930	10642	29762	71789	71362	131148	1592894
1970	149481	130074	240597	106513	296940	189324	40611	20474	32203	66161	38370	34975	1345723
1971	35096	23450	21386	1911	0	0	0	85495	313489	215006	132469	169325	997627
1972	127407	89428	66423	57700	1040792	193772	76649	61656	48206	92127	84776	65952	2004888
1973	118037	153926	173399	426469	127434	797261	469743	183745	214753	1209872	268424	156028	4299091
1974	262789	115176	94122	63954	170988	80313	21062	83793	273264	90868	306423	202763	1765515
1975	153505	330076	151685	131566	665733	405693	187371	83608	64220	66987	59241	162578	2462263
1976	102686	64627	59234	471289	544222	193545	169659	71514	113779	439882	469802	596160	3296399
1977	320389	379391	185280	858093	370642	216882	100201	75204	72121	58022	150882	70076	2857183
1978	90882	112806	83173	70312	38740	93480	1357	231813	350084	104856	154243	82780	1414526
1979	461349	307298	301348	451392	587428	463576	132885	92834	113495	62237	58301	59735	3091878
1980	130789	83001	62454	38990	234889	41173	5014	33475	96725	43693	58729	61372	890304
1981	79869	60834	66056	86225	334518	920719	273567	114847	754417	341216	336640	119806	3488714
1982	93803	190251	102308	60610	385326	55559	13277	1234	2759	34396	148830	71422	1159775
1983	49138	106371	160360	52556	70543	45389	102562	29531	52152	76303	63857	27846	836608
1984	53874	33359	60730	6586	14266	0	0	0	0	89256	58157	58670	374898
1985	116064	73826	178439	177099	85698	212634	154791	27760	25701	135529	238873	199827	1626241
1986	104380	94293	65598	34571	90744	315923	45897	8137	58353	196739	149927	508152	1672714
1987	295226	250299	323425	113121	216963	2461790	347470	183524	100029	78357	98186	93116	4561506
1988	77640	62685	74024	39001	29005	29462	35525	20985	14199	17402	19694	30789	450411
1989	47259	38357	40750	30587	62507	11696	0	0	0	0	18677	18238	268071
Average	129982	132455	110708	136237	214447	202638	105015	40786	136478	140853	121146	113910	1584654
Max	720853	748599	323425	858093	1040792	2461790	1296237	231813	1671697	1209872	618300	596160	4561506
Min	0	0	0	0	0	0	0	0	0	0	0	0	40344
median	102520	92536	91883	70221	116219	84313	34121	25688	42295	66110	67610	77101	1357746
drt avg	56456	47761	37912	61225	83032	45658	8865	11716	50688	40022	22832	36547	502712

Guadalupe River @ Saltwater Barrier Flow Statistics
2050 + TTexas Pumpage
Pumpage Affected Modified Flows at Tivoli (SWB) in acft

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1934	229102	103978	175834	155293	46297	14645	95365	17226	35749	30291	135933	149676	1189389
1935	65838	142019	71171	101237	589581	749923	105173	52634	389556	132943	78009	169019	2647103
1936	99087	67935	77953	54742	455121	148065	1295063	76333	329440	324968	133186	119803	3181696
1937	115172	83541	190037	69128	43005	247678	42371	28641	32909	59183	48426	156032	1116123
1938	181127	102357	101088	407821	337485	65942	29063	32309	32441	27387	41867	60380	1419267
1939	58203	38871	31205	16336	30813	17857	35727	0	0	2774	7723	16228	255737
1940	63023	70839	34496	46599	19972	104846	442620	13640	0	30638	558762	476751	1862186
1941	215960	264030	299901	384982	1019902	343848	167710	63067	74367	72503	70420	61476	3038166
1942	51990	88342	58330	133463	79750	19485	691720	82317	472057	255501	113291	88591	2134837
1943	103381	66542	88260	50358	44768	75476	27761	1297	16347	17932	28758	63459	584339
1944	162084	117608	185284	67320	295756	158664	36912	23590	85881	28931	59942	115335	1337307
1945	204207	187917	157457	352553	64966	52224	11815	22367	5503	63334	33571	47460	1203374
1946	115485	141319	195215	100443	168647	148775	6066	62701	453452	645475	269077	152296	2458951
1947	270683	128740	134367	114446	189128	43025	18835	48374	8683	12282	23093	34130	1025786
1948	61813	80049	53433	16240	65278	0	10304	21642	0	13825	4254	6301	333139
1949	22385	58786	90006	378466	196613	85408	50690	6170	0	238667	57025	81632	1265848
1950	43705	39970	24808	49097	20496	110971	0	0	0	0	0	2167	291214
1951	4099	5980	4056	0	36671	149300	0	0	91635	17138	14774	6299	329952
1952	5533	16075	8004	20659	85562	43117	0	0	260366	14470	89242	137760	680788
1953	106971	48779	29333	14775	172445	0	0	29203	130678	81906	21804	39783	675677
1954	23190	8114	567	0	10567	0	0	0	0	0	0	0	42438
1955	0	62346	6586	0	25299	8066	0	0	0	0	0	0	102297
1956	0	0	0	0	0	0	0	0	0	1939	0	32155	34094
1957	0	14384	158787	414738	584906	394575	11688	0	276127	452366	339999	132681	2780251
1958	382954	744832	269155	123788	351867	74374	43980	2000	150301	221674	217267	139668	2721860
1959	101032	204943	111294	222623	104799	19160	38011	10423	8625	145310	78290	91366	1135876
1960	98742	114203	90558	64760	120457	148621	134040	65647	30916	846388	614498	343593	2672423
1961	334216	366946	192347	95858	49117	426828	160525	40458	84251	57886	160366	57259	2026057
1962	51603	40588	29589	37722	14978	41358	0	0	15772	11343	25201	58899	327053
1963	43237	73505	32428	19127	71	0	0	0	0	0	41456	41696	251520
1964	55158	90814	86411	21415	633	0	0	2069	12268	28055	57005	20844	374672
1965	120101	397525	92831	103796	381798	244879	29795	7523	2519	80479	112979	223795	1798020
1966	126225	140819	108594	119661	184448	45745	19449	5309	31316	28070	22003	19694	851333
1967	27530	20772	17165	2099	0	0	0	41850	1668070	325999	197843	82257	2383585
1968	716965	233132	155979	176474	467026	451821	114133	42071	133701	40046	52312	132625	2716285
1969	53849	250781	222510	320844	283992	101325	19607	6793	25907	67984	67501	127306	1548399
1970	145641	126199	236630	102507	293639	185990	38200	18299	28326	62281	34564	31111	1303387
1971	31245	19593	17514	0	0	0	0	81542	309599	211158	128621	165963	965235
1972	123536	85552	62547	53860	1037429	189838	72702	57785	44338	88283	80914	62078	1958862
1973	114116	150061	169381	422543	123478	793281	465706	179718	210982	1205822	264456	151995	4251539
1974	258787	111129	90140	59967	166999	76327	17045	79898	269356	86960	302358	198757	1717723
1975	149520	326028	147645	127510	661697	401019	183250	79547	60223	62948	55247	158493	2413127
1976	98709	60621	55225	467217	540200	189459	165606	67522	109756	435833	465784	592109	3248041
1977	316307	375347	181190	854062	366623	212794	96103	71081	68054	53996	146894	66057	2808508
1978	86856	108783	79148	66302	34707	89459	0	227765	346641	100820	150228	78745	1369454
1979	457252	303189	297216	447368	583326	459556	128735	88603	109316	58094	54228	55651	3042534
1980	126639	78951	58380	34901	230816	37036	2566	29441	92729	39626	54681	57358	843124
1981	75811	56742	61943	82151	330418	916700	269418	110704	750228	337072	332452	115635	3439274
1982	89581	186060	98194	56390	381085	51407	9746	0	0	30323	144727	67331	1114844
1983	45045	102241	156227	48392	66323	41232	98389	25406	48065	72239	59803	23724	787086
1984	49747	29236	56603	2448	10144	0	0	0	0	85190	54053	54535	341956
1985	111853	69648	174217	173119	81499	208340	150550	24177	21549	131345	234659	195546	1576502
1986	100116	90045	61314	30281	86489	311729	41712	4028	54103	192485	145690	503875	1621867
1987	291020	246051	319156	108846	212355	2456678	343216	179185	95764	73891	93861	88797	4508820
1988	73274	58431	69758	34675	24696	25145	31214	17831	9902	13160	15410	26562	400058
1989	43027	34065	36448	26359	58217	7393	0	0	0	0	14492	14092	234093
Average	126835	129203	107391	133139	211292	199810	102725	38360	133710	137843	118018	110658	1548984
Max	716965	744832	319156	854062	1037429	2456678	1295063	227765	1668070	1205822	614498	592109	4508820
Min	0	0	0	0	0	0	0	0	0	0	0	0	34094
median	98915	89194	89133	66811	112628	80868	30505	22979	40044	62615	63722	73038	1320347
drt avg	53838	44884	35116	59368	80206	43989	7983	10539	49136	38023	21019	34023	478123

APPENDIX F

COMMENTS AND RESPONSES ON DRAFT REPORT

APPENDIX F

COMMENTS AND RESPONSES ON DRAFT REPORT

TEXAS WATER DEVELOPMENT BOARD

William B. Madden, *Chairman*
Elaine M. Barrón, M.D., *Member*
Charles L. Geren, *Member*

Craig D. Pedersen
Executive Administrator

Noé Fernández, *Vice-Chairman*
Jack Hunt, *Member*
Wales H. Madden, Jr., *Member*

April 2, 1998

Mr. Charles W. Kreitler
Senior Associate
LBG-Guyton Associates
1101 S. Capital of Texas Highway, Suite B-220
Austin, Texas 78746-6437

Re: Review Comments for Draft Report Submitted by LBG-Guyton Associates (Consultants), TWDB Contract No. 96-483-163

Dear Mr. Kreitler:

Staff members of the Texas Water Development Board have completed a review of the draft report under TWDB Contract No. 96-483-163. As stated in the above referenced contract, the Consultants will consider incorporating comments from the EXECUTIVE ADMINISTRATOR shown in Attachment 1 and other commentors on the draft final report into a final report. The Consultants must include a copy of the EXECUTIVE ADMINISTRATOR's comments in the final report.

The Board looks forward to receiving one (1) unbound camera-ready original and nine (9) bound double-sided copies of the Final Report on this planning project. Please contact Mr. Gordon Thorn , Division Director, at (512) 463-7979 if you have any questions about the Board's comments.

Sincerely,

Tommy Knowles

Tommy Knowles
Deputy Executive Administrator
for Planning

cc: Gordon Thorn, Division Director

Our Mission
Exercise leadership in the conservation and responsible development of water resources for the benefit of the citizens, economy, and environment of Texas.

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ATTACHMENT 1
TEXAS WATER DEVELOPMENT BOARD

COMMENTS ON LBG-GUYTON ASSOCIATES
Contract No. 96-483-163

1. Page 24: A reference refers to a report from the TDWB, should read TWDB.

2. Page 38: There is a reference to the CARIZO model published by the TWDB in 1973. This is not listed in the Selected References Section of the report.

3. TABLE OF CONTENTS: The section on Impacts of Future Ground-Water Pumpage Scenarios should be numbered VIII.

4. LIST OF APPENDICES: The four appendices should be given names or titles. Suggestions: A - Ground Water Pumpage by County, B - Estimates of Annual Recharge by County, C - Hydrographs Used for Model Calibration, and D- Hydrographs Generated for Future Ground-Water Pumpage Scenarios.

5. Pg. 1 - EXECUTIVE SUMMARY: Reference is made to "TWDB Report 210". There are two volumes of TWDB Report, and it isn't clear if reference is being made to both volumes or a specific volume. The volumes should be referred to as Klemt and others, 1976 and Marquardt and Rodriguez, 1977 as was done on page 7.

6. Pg. 5 – INTRODUCTION: The third paragraph refers to Figure 1. Please include Figures 1.

7. Pg. 7 – INTRODUCTION: Reference is made to a report "Elder and others, 1980". This report should be added to the Selected References.

8. Pg. 20 - Third Paragraph: Reference to the 1910-1994 time period on this and subsequent pages is confusing until the explanation given on page 40. The explanation for using data for 1910 and for the time period 1910-1994 needs to be included on page 20.

9. Pg. 21 - 1994 Pumpage: "as" should be "was".

10. Pgs. 25 and 26: The bullets near the top of page 25 include "Guadalupe River at Cuero", whereas "Guadalupe River at Lake Wood" appears in Table 5-1 on page 26. Are these the same gage?.

11. Pgs. 26 and 28: Unless there is a difference, monthly baseflow evapotranspiration should be presented and labeled the same in Table 5-1 on page 26 and in Equation 5.2 on page 28.

12. Pg. 28 - Equation 5.2: Which column in Table 5-1 represents $QMAX_B$?

13. Pg. 28 - Equation 5.2 and Pg. 29 Equations 5.3 and 5.4: The same font should be used for the equation and for the definition of terms. The Q in $QMAX_B$, QG and $QI_{W/O}$ is a particular problem.

14. Pg. 33 - Area Recharge: Reference should be made to Tables 5-5 and 5-6.

15. Pg. 39 - Model Layers: There is no Figure 3-1.

16. Pg. 42 - Drain Package: Was the drain package held constant for all model runs?

17. Pg. 44 - Lower Nueces River Basin and Estuary Model: Please identify the 1994 Agreed Bay and Estuary Release Order.

18. Pgs 45 and 46 - Equations 6.1 and 6.2: Please use the same font for the main equation and for the definition of terms in the report. The letter Q is a particular problem. Also the report should be consistent between QN_{FUT} and QN_{FU} and between QN_{HIST} and QN_{HIS}.

19. Pgs. 47 and 48 - Introduction of Calibration Process: The third paragraph on page 47 refers to 112 wells, whereas Table 7-1 on page 48 lists 110 wells.

20. Pg. 51 CONCLUSIONS: The report comments specifically on the difference between running the model on monthly versus annual stress-period lengths and on the importance of having accurate pumpage values. The discussion might be expanded as appropriate to state that the water levels used for calibration were for discreet points, whereas each cell in the model represents a rather large area which has an averaging effect. Another consideration may be the use of ground water measurements which were taken predominantly during the non-irrigation season. Equal numbers of measurements during irrigation and non-irrigation seasons or continuously monitored ground water levels may have provided a better basis for calibration.

21. Pg. 52 - Pumping Scenarios: Table 4-2 contains pumpage factors not volumes.

22. Pg. 55 - Surface-Water Results: The third sentence, which states "These figures include an annual streamflow decile ..." is not clear.

23. Pg. 70 - RECOMMENDATIONS: The report should relate the recommendations to the work done as part of the study. For example, this is the only place where the report refers to observation well completion data. In order to recommend that observation well completion data be evaluated in order to insure that measured water-level data reflect the correct aquifer, information should be presented on why this was a problem for the modeling effort. Was a large amount of data omitted because of uncertainties as to the aquifer being monitored? Are aquifers erroneously identified in the TWDB data? Why didn't the contractor as part of their quality control, review the observation well completion data?

24. Pg. 73 - SELECTED REFERENCES: The two reports listed for HDR Engineering, Inc. 1991 should be identified as 1991a and 1991b, and the three reports listed for HDR Engineering, Inc. 1993 should be identified as 1993a, 1993b and 1993c. This convention then should be used throughout the text where appropriate.

25. Table 4-1: First paragraph, page 17 states that the sum of precipitation in January through June was tested. The pumpage estimation equation for La Salle includes $P_{JAN-MAR}$ and $P_{APR-JUN}$, rather than $P_{JAN-JUN}$. Did separate coefficients for $P_{JAN-MAR}$ and $P_{APR-JUN}$ provide a better correlation than the six-month block of $P_{JAN-JUN}$?

26. OVERALL COMMENT ON THE TABLES: Tables 3-1 and 4-1 should be moved to the main body of the text. The tables are only one-page in size. Having them in the text, where the other tables are located, would make it easier for the reader to locate a table appearing in one section of the report but referenced in another.

27. OVERALL COMMENT ON THE FIGURES: The figures are good. The use of colors was excellent. An additional figure is recommended to show the rivers, outcrops and the locations of the gages selected for the analysis. The rivers also should be labeled in Figure 6-3.

28. Task 1, Scope of Work, specifies that hydrologic data bases will be developed through 1994. The draft report shows that this is done for groundwater data; but the surface water data goes through only the year 1989. The report should either state why this is or the study should comply strictly with the scope and expand the surface water data to include data through 1994.

29. Task 5, Scope of Work, speaks to the period of study 1934 -1989 regarding effects of groundwater on surface water, giving an impression that inaccessibility of surface water data for years 1990-1994 is the factor which limits the

groundwater - surface water analysis. If this is so, the report should state so. Please state why surface water data for recent years is not used.

30. Task 5, Scope of Work, addresses changes in groundwater flows and their effects on monthly water availability to significant surface water rights. Task 5 states " At a mininum, this will include the following water rights or groups of water rights . . ." and goes on to specifically list those water rights, including "water rights located at or just upstream of the Salt-Water Barrier at Tivoli" and "Unappropriated water at the Salt-Water Barrier subject to environmental criteria". Although environmental criteria is specifically mentioned by the Scope in this manner, the draft report's discussion in text of page 10 fails to mention environmental criteria. Table 8-3 and Table 8-7 and all textual discussion located between these two tables give results for water rights located at or just upstream of the Salt-Water Barrier at Tivoli, but do not address unappropriated water at that Salt-Water Barrier location subject to environmental criteria.

    It is recommended that the consultant use 1997 Consensus Water Plan environmental criteria, confer with pertinent TWDB staff or TNRCC staff for alternate criteria, or show why (if such is the case) an environmental criteria scheme has no effect.

31. Section II, Introduction, Purpose and Scope, p. 5: Figure 1 showing the area covered by the ground water model has not been included in the Report. In order to convey up-front the study objectives, Figure 1 should show both the aquifer outcrops and the streams of the study area, along with the county delineations (Fig. 6-3 superimposed on Fig. 6-2, without the stream cell numbers). Stream gauging stations used in this Report (p. 8), along with the drainage areas delineation (as shown on Fig. 5-1), should also be displayed on this figure.

32. Section V, Recharge, Estimation Methodology, p. 25: A detailed procedure was undertaken by the Consultants to compute the recharge for each of the counties of the study area. However, the following comments/concerns need further clarification/ evaluation:

    i) Table 5-1 (p. 26) showing the “Summary of Base Streamflow Gain/Loss Analyses” should include information on the upstream gages used to compute such values.

    ii) Table 5-2 (p. 30) showing the “Summary of Aquifer Recharge Potential based on Transmission Capacities” lists some numbers which appear to be contradictory to other parts of the Report. For example, Table 3-1 and Figure 6-2 show that Queen City outcrop is absent on the west side of Frio River, in Dimmit and Zavala counties. However, Table 5-2 shows that the Queen City aquifer recharge potential exists in these two counties.

iii) Table 5-3 (p. 32), "Summary of Recharge Estimates", lists the recharge estimates for several river subbasins, as three components and the total recharge. The Report's estimate of the total recharge for Atascosa River & San Miguel Creek (52,198 acft/yr) is significantly higher than the total recharge estimates for Nueces River above Asherton (24,857 acft/yr) and Frio River above Derby (22,199 acft/yr) on the west, and San Antonio River above Falls City (29,803 acft/yr) on the east. Table 5-5, "Total Areal Recharge to Each Formation within Each Subbasin", presenting one of the components of Table 5-3, have similar differences; for Nueces1 and Frio1 (Figure 5-1), the areal recharge estimates for the Carrizo formation are 1152 and 1165 acft/yr, respectively, and for San Antonio 1&2 is 11,849 acft/yr, whereas for San Miguel/Atascosa it is 27,665 acft/yr. Evaluation of Figures 5-1 and 6-2 show that the areal extent of Carrizo formation outcrops for both Nueces1 and Frio1 are probably more, if not equal to, than that for San Miguel/Atascosa segment, given the variation in the average annual precipitation value (increasing towards the east). Some adjustments are probably needed to these recharge estimates. It would be worthwhile to find out the impact of changes in the input values of recharge to the model on it's performance (see Comment #3 below).

The Report should present the total recharge for each formation within each subbasin (similar to Table 5-5). In addition, a comparison of the total recharge estimated in this Report for various formations with those from other available sources would probably validate these estimates.

33. Section VII, Ground Water Model Calibration, Calibration results, p. 48: Ground water model calibration results, as presented in Figs. 7-2 through 7-5, show a general good agreement between the measured water levels and those predicted by the model. However, these figures also indicate a general trend of overestimation at lower flows and underestimation at higher flows. Moreover, the model predicted water levels for several wells in Dimmit and Zavala counties present some concerns due to a significant difference (close to or more than 100 feet) with the measured water levels (some variation is expected since the measured water level is at a point and the predicted water level is the average for the entire cell, and due to other assumptions made for the model). These wells are: Fig. 7-9 for well 77-29-201, Fig. 7-11 for well 77-19-102, and hydrographs presented in Appendix C for wells 77-01-501, 77-18-704 and 77-26-114. This significant difference between the simulated and measured results raises the question of whether or not the model responses are reasonably accurate for both the historical and future simulations for the area encompassed by the above listed wells. The Report briefly pointed out (p. 51) that the variation in pumpage data (monthly distributions) impacts the model results significantly. The Report, however, did not elaborate on the possible reasons for the disagreements discussed above and whether any steps were taken to improve the model response for the above listed wells.

34. Section VIII, Impacts of Future Ground Water Pumpage Scenarios:

i) The information on estimates of aquifer leakage values were not presented in the Report (Task 4 of the Scope of Work).

ii) For the 2050 pumpage scenario, the Report should provide the numeric figures and it's difference with the 1994 pumpage scenario (Task 4).

iii) The Report did not include any map of simulated water levels for the three scenarios of future pumpage, as discussed on p. 68 (Task 7).

LBG-GUYTON ASSOCIATES

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May 12, 1998

Mr. Gordon Thorn
Division Director
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711-3231

Dear Mr. Thorn:

Enclosed is a revised version of our response to the comments on the draft report for the Carrizo-Wilcox Research Project that we sent you last week. We discovered a problem with the numbering of the responses on the second page. This has now been corrected, and we apologize for any confusion it may have caused.

Sincerely,

LBG-GUYTON ASSOCIATES

William B. Klemt
Senior Consultant

WBK:klm

Enclosure

RESPONSE TO COMMENTS ON DRAFT REPORT

Under TWDB Contract No. 96-483-163
Dated April 2, 1998

1. This reference should actually read TDWR; this will be corrected in the final report.
2. Agree. The reference will be included in the final report.
3. Agree. This change will be made in the final report.
4. Agree. This change will be made in the final report.
5. Agree. This will be clarified in the final report.
6. Agree. This reference was incorrectly made to "Figure 1." The actual figure that should be referenced is Figure 2-1 and it will be included in the final report.
7. Agree. The reference will be included in the final report.
8. Agree. However, page 20 is not the appropriate place for this explanation, which will be included in the description of the ground-water model in the Introduction. The reference to "1910-1994" on page 20 will be changed to "historic" to eliminate any confusion on page 20.
9. Agree. This change will be made in the final report.
10. These are not the same gage. The Guadalupe River at Cuero is a USGS streamflow measurement station downstream of the confluence of the Guadalupe River and the San Marcos River. It is our belief that this is the best location for applying changes in streamflow caused by aquifer interactions because it is the first surface-water model control point downstream of the outcrops for both the San Marcos and Guadalupe Rivers. The Guadalupe River at Lake Wood is a control point in the GSA River Basin Model and streamflows at this location were derived by analyzing hydropower records. This control point is closer to the downstream reaches of the Carrizo-Wilcox outcrop and should provide better information regarding losses/gains to the Carrizo than would a gage significantly downstream that includes the effects of another stream over the outcrop.
11. Agree. The references will be made compatible.
12. Winter Base Gain/Loss is the maximum gain/loss to the aquifer. As with Item 11, efforts will be made to make the table and equation terms more compatible.
13. Agree. This change will be made in the final report.
14. Agree. This change will be made in the final report.
15. Agree. This reference should be to Table 3-1, not Figure 3-1. This correction will be made in the final report.

16. As indicated in the text of the report, the drain package was varied during the calibration runs. Once the best numeric approximation of the drains was obtained, they were not changed for the rest of the runs.

17. Should be the 1995 Agreed Order (as in the text). Will clarify with a footnote.

18. Agree. This change will be made in the final report.

19. Agree. This will be corrected in the final report.

20. Agree. This discussion will be expanded in the final report to include the points made in this comment.

21. Agree. This reference should be to Table 1-1.

22. Annual streamflow deciles are a typical statistic that has been used in recent surface-water hydrology analyses (especially those under the Trans-Texas Program). An attempt will be made to better define the statistic in the report.

23. A cursory review of the observation well data was made during this project, and this showed that many wells were screened across multiple aquifers, or showed some inconsistencies in the well data. The questionable data were not used or were evaluated further as needed. However, a review of all of the observation well data in the model area would take a very large effort and is beyond the scope of work for this project. We can remove these recommendations from the report if desired.

24. Agree. These references will be clarified in the final report.

25. Yes. The separation of Jan - Mar precipitation and Apr - Jun precipitation was found to provide a slightly better fit than with Jan - Jun precipitation combined.

26. Agree. This change will be made in the final report.

27. Agree. Two additional figures will be created; the first an outline of the model area, including rivers, streams and locations of gages, and the second with the geology of the model area.

28. The hydrologic databases referred to in Task 1 include the hydrologic data needed to run the ground-water model for the period of record 1934 - 1994. Surface-water data, in the form of gaged streamflows for the USGS streamflow gages upstream of the Carrizo-Wilcox Aquifer outcrop, were obtained and used in the ground-water model. As stated in Task Item 4 of the Scope of Work, the effects of future pumpage on surface waters in the region (the step which includes the use of the surface-water models) will be performed for the period of record 1934-89. It was never a part of this scope to include development natural flows, water rights records, and other necessary data to extend the surface-water model databases through 1994. Section VI - Computer Models, Surface-Water Models contains a discussion of the surface-water models including the period of record of their databases. However, a reminder of the limits of the surface-water model databases can be included in the beginning of Section VII - Impacts of Future Ground-Water Pumpage Scenarios.

29. See response to Item 28.

30. Agree. We will compute the impacts to unappropriated flow at the Saltwater Barrier using the TWDB Max Harvest Freshwater inflow targets for the Guadalupe Estuary.

31. Agree. See response to Item 27 above.

32.(i) Agree. Will include in description of stream, i.e. Nueces River between Uvalde and Asherton.....

32.(ii) Table 5-2 erroneously labeled the second column as "Queen City." This column should be titled "Queen City/Bigford," which includes all aquifers between the Carrizo/Wilcox and the Sparta and younger units.

32.(iii) The recharge estimates for these basins were made based on an assessment of precipitation and hydrogeologic conditions in these areas. While precipitation is much higher in the eastern portion of the model area, and the formations tend to be much more transmissive, very little drawdown has occurred, and therefore the estimated recharge is lower than it would be if the aquifer had been developed more as it has been in the west. In the western portion of the model area. while the aquifer has been extensively developed, resulting in very large drawdowns and thus the potential for significant recharge. the precipitation is much lower and the formations are much less transmissive, thus limiting the recharge estimates. In the middle portion of the model area, where the San Miguel and Atascosa subbasins are located, the formations are more transmissive than to the west, there is higher precipitation than in the west, but there is more development of the aquifer than in the east. This resulted in the higher estimate of recharge in the central portion of the model than either to the west or to the east.

33. The area in question was examined in great detail to try and correct the predictions for the wells in this particular area. However, the model was unable to be changed to correct the water levels in this area without drastically changing water levels in areas adjacent to this problem area that were producing fairly good results. The reason for the problems in this particular area are not known and can only be speculated upon, but may include inaccuracies in pumpage estimates, very localized aquifer characteristics that cannot be modeled and poor well completions (see Item 23), etc. We can include a discussion of this area if desired.

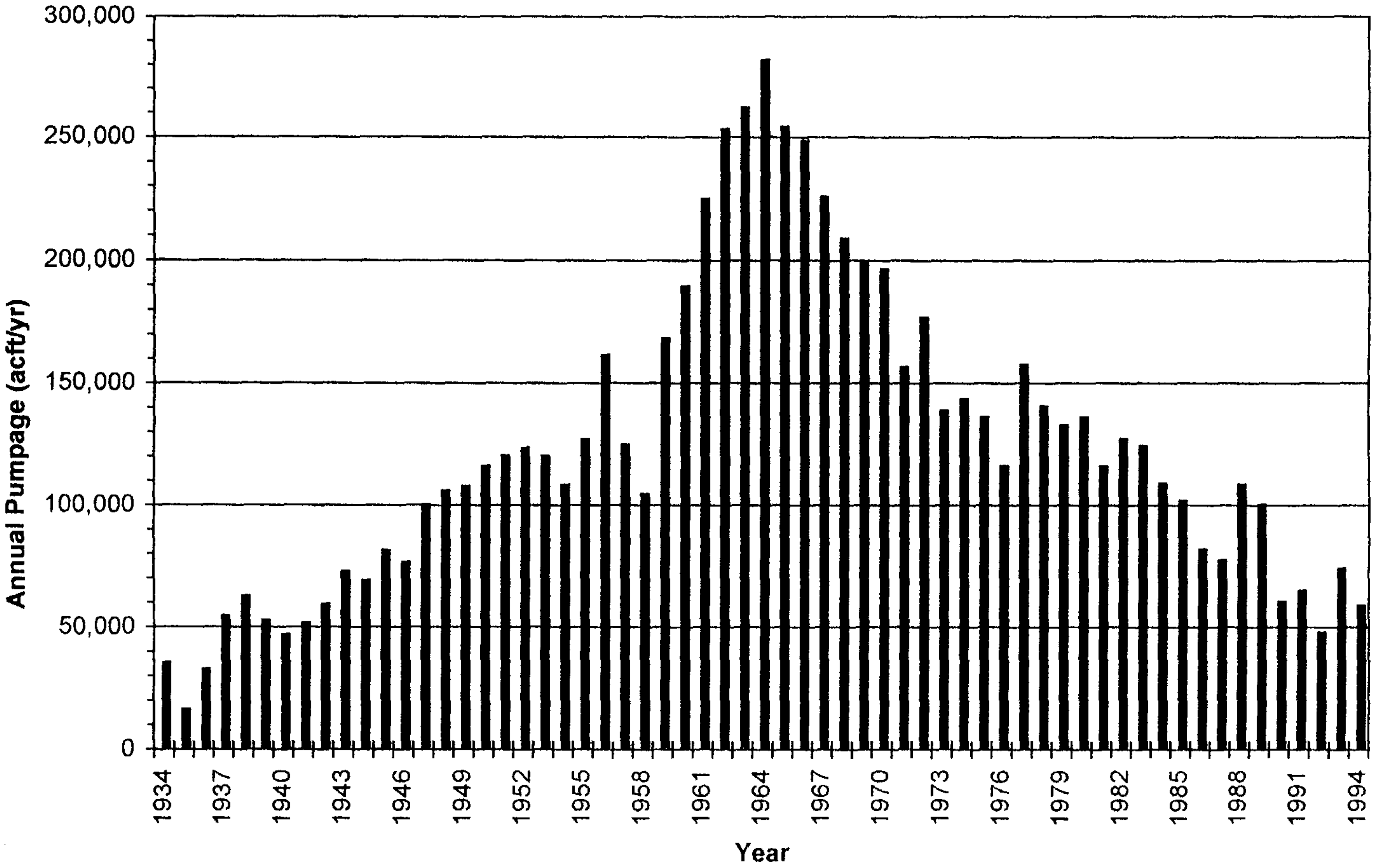
34.(i) Estimates of aquifer leakage will be included in the report.

34.(ii) Agree. This will be included in Section IV in the discussion of the creation of the future pumpage scenario input files.

34.(iii) Agree. Simulated water-level maps for the three future scenarios will be included in the final report.

FIGURES

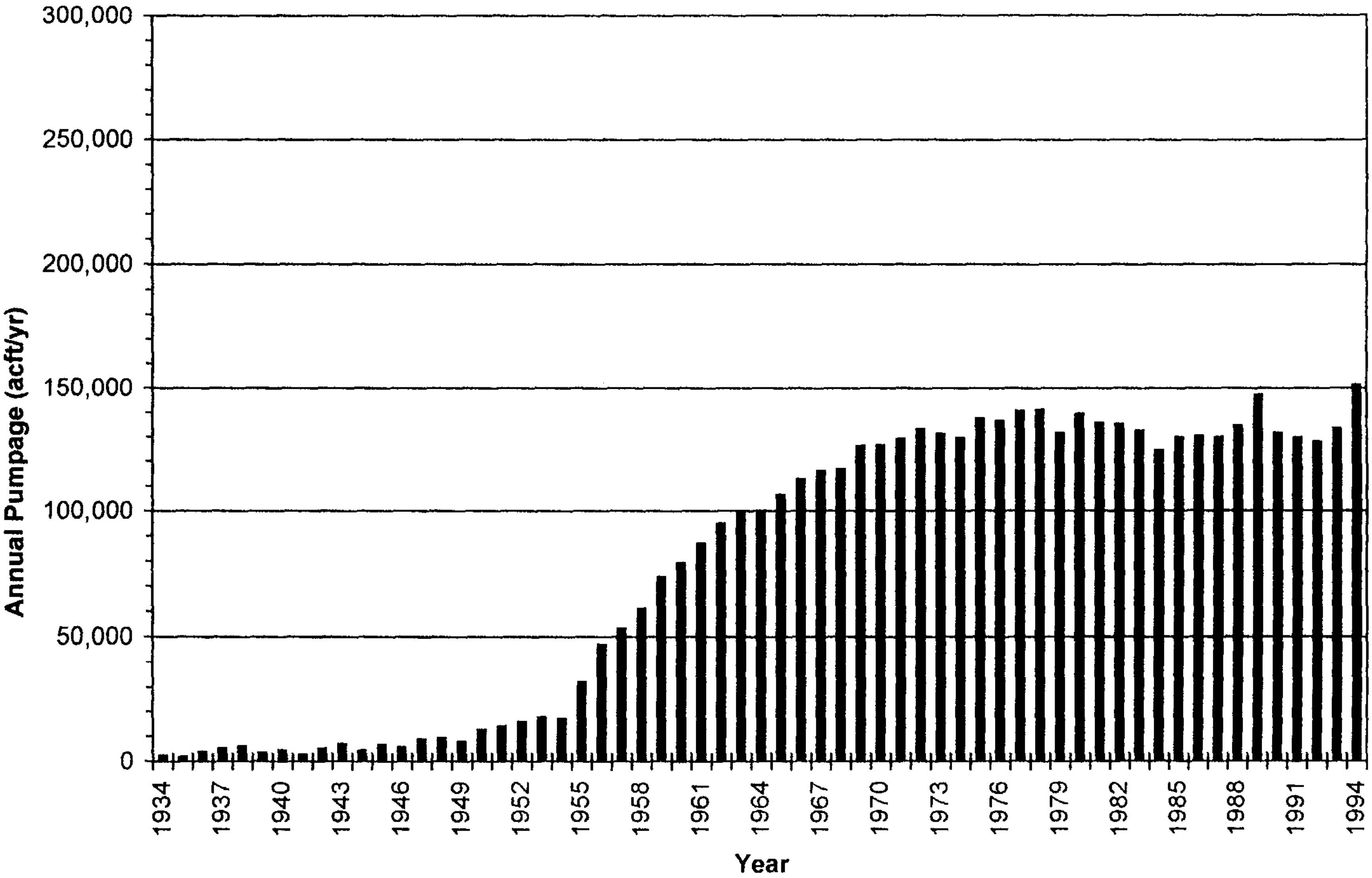
FIGURES



GROUND-WATER PUMPAGE FOR WESTERN STUDY AREA

FIGURE 4-1

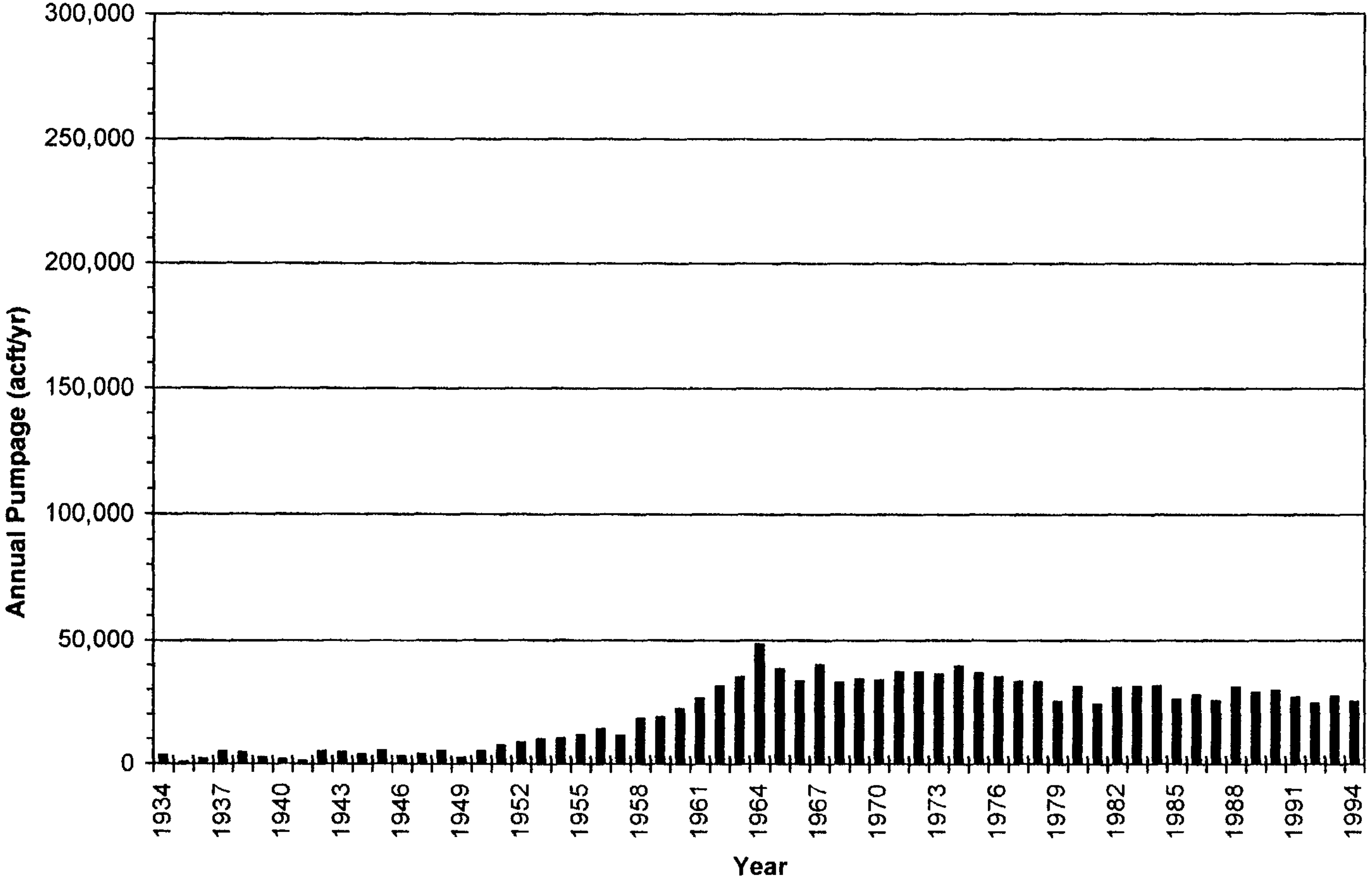
LBG-GUYTON ASSOCIATES



GROUND-WATER PUMPAGE FOR CENTRAL STUDY AREA

FIGURE 4-2

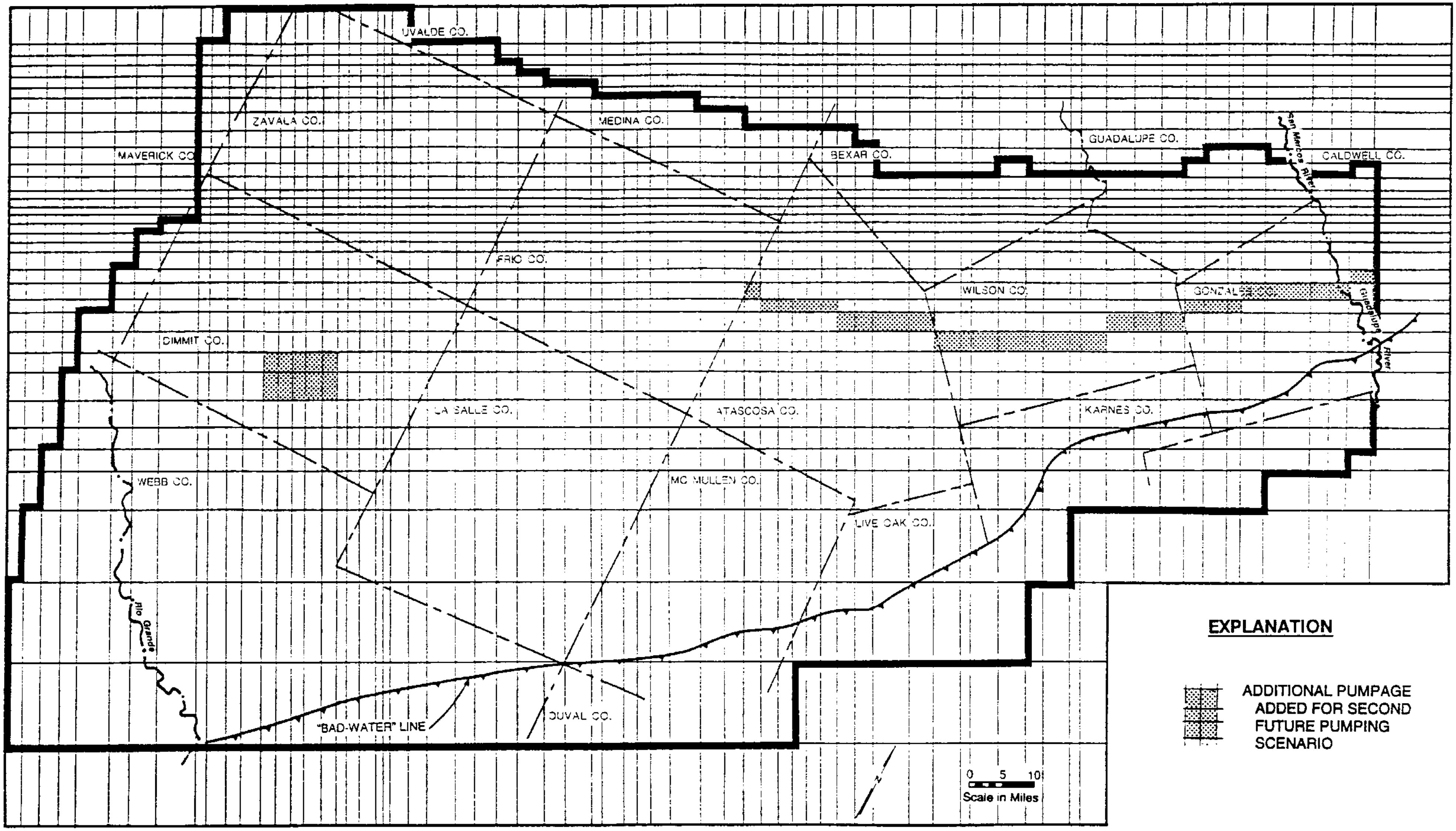
LBG-GUYTON ASSOCIATES



GROUND-WATER PUMPAGE FOR EASTERN STUDY AREA

FIGURE 4-3

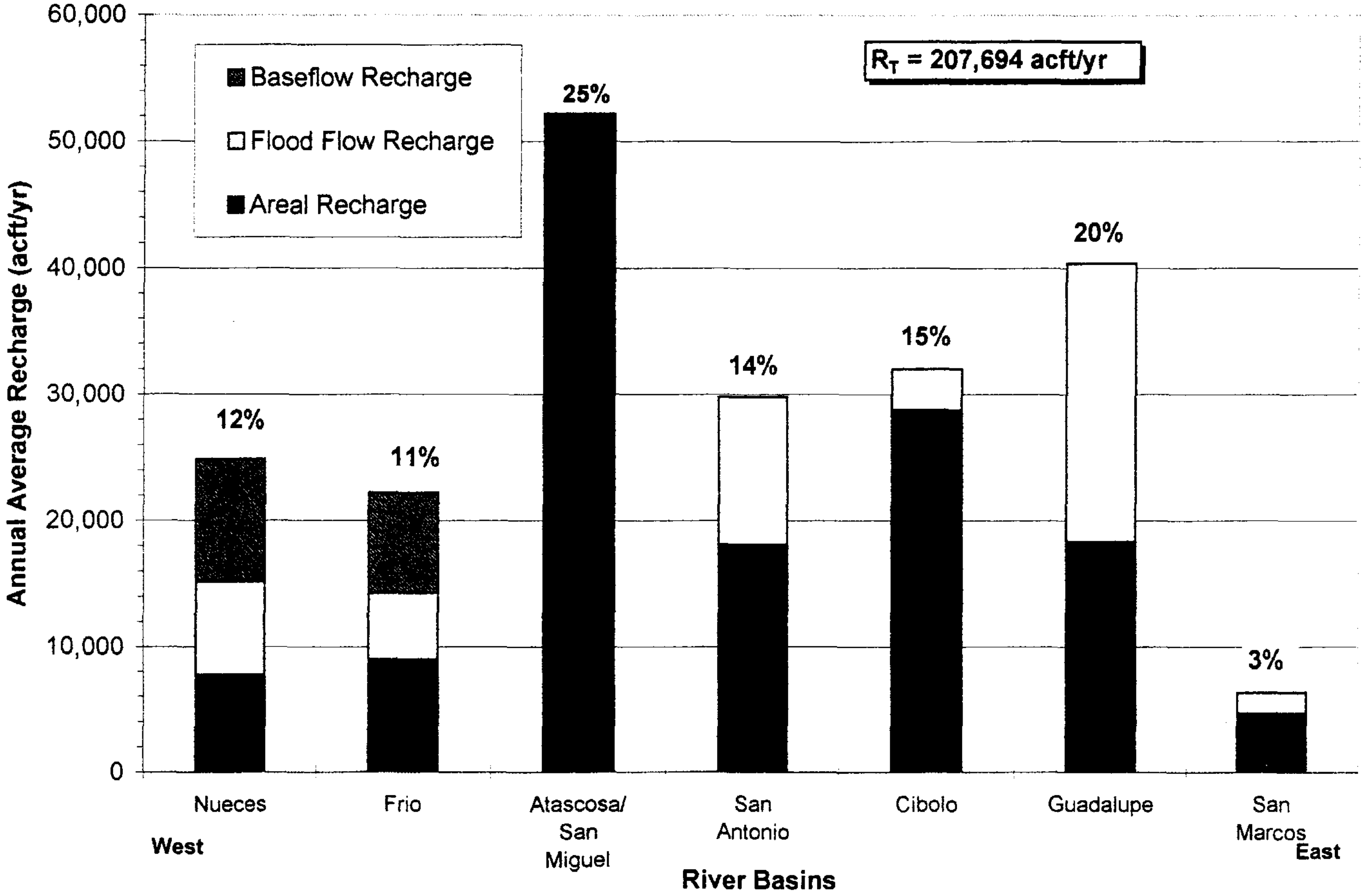
LBG-GUYTON ASSOCIATES



LOCATION OF ADDITIONAL PUMPAGE FOR "2050 PLUS" SIMULATION

FIGURE 4-4

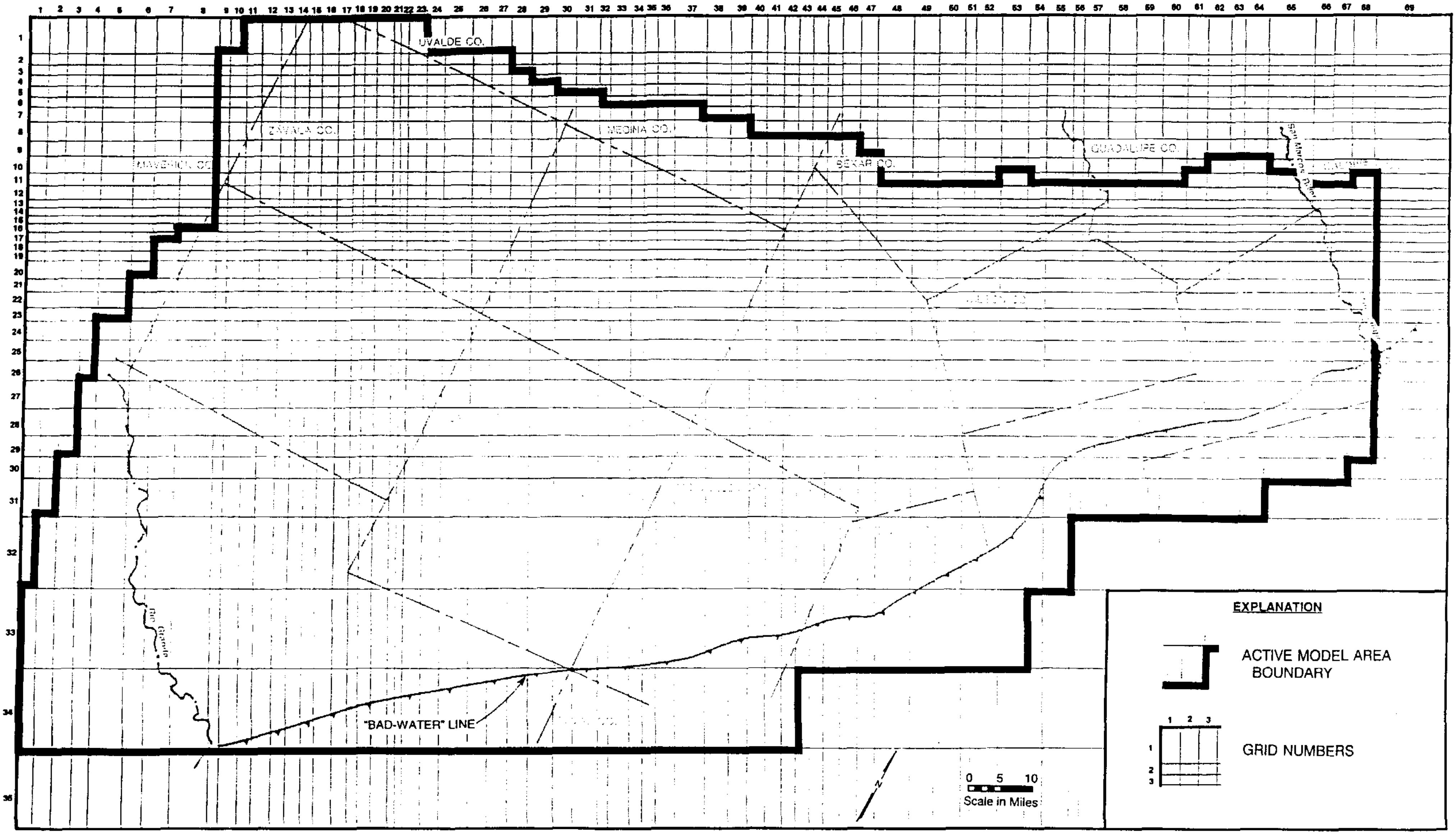
LBG-GUYTON ASSOCIATES



SUMMARY OF HISTORICAL ANNUAL AVERAGE RECHARGE ESTIMATES

FIGURE 5-2

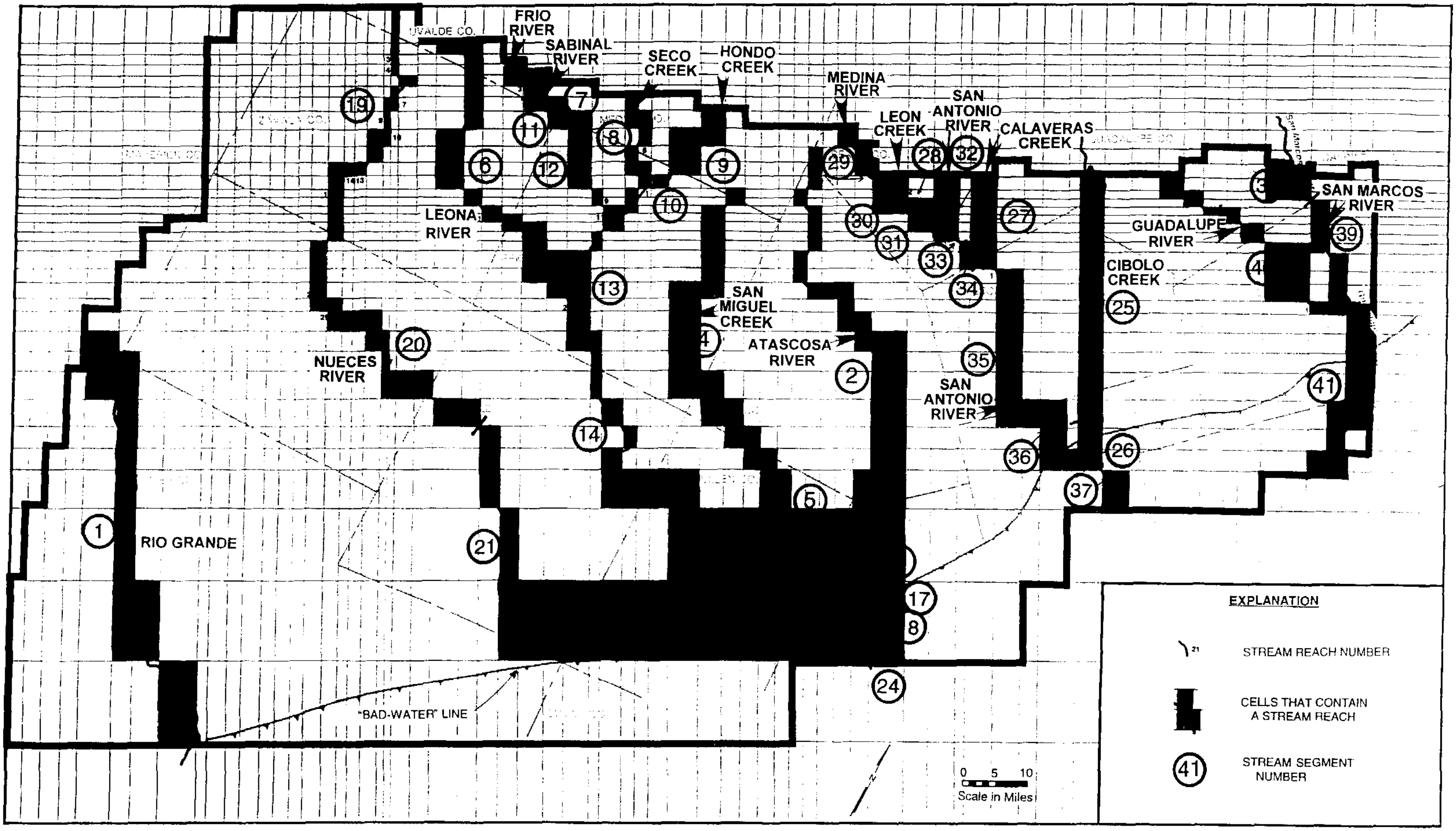
LBG-GUYTON ASSOCIATES



MODEL OUTLINE AND GRID NUMBERING SYSTEM

FIGURE 6-1

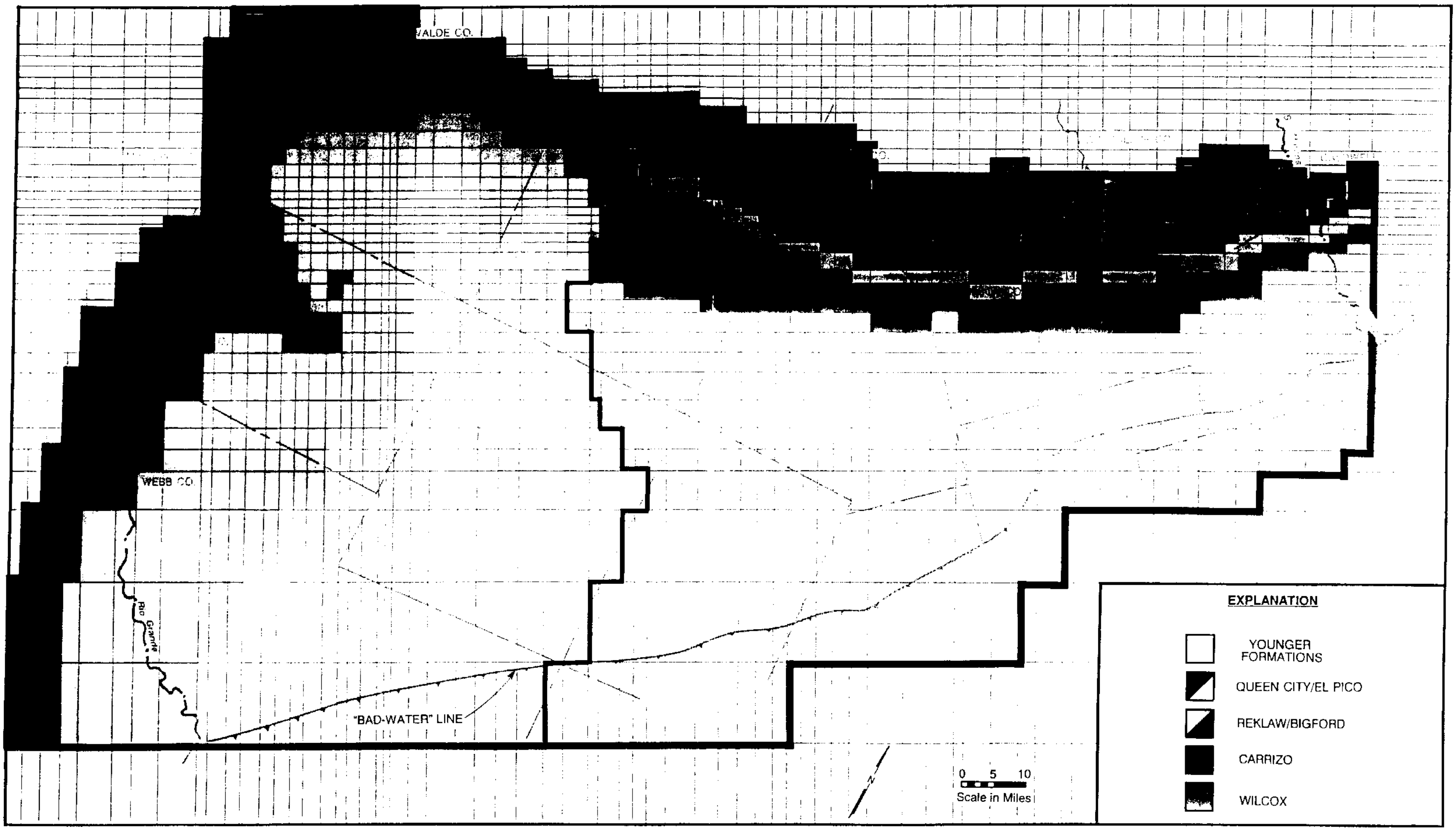
LBG-GUYTON ASSOCIATES



SEGMENT AND REACH NUMBERING SYSTEM FOR STREAM PACKAGE

FIGURE 6-3

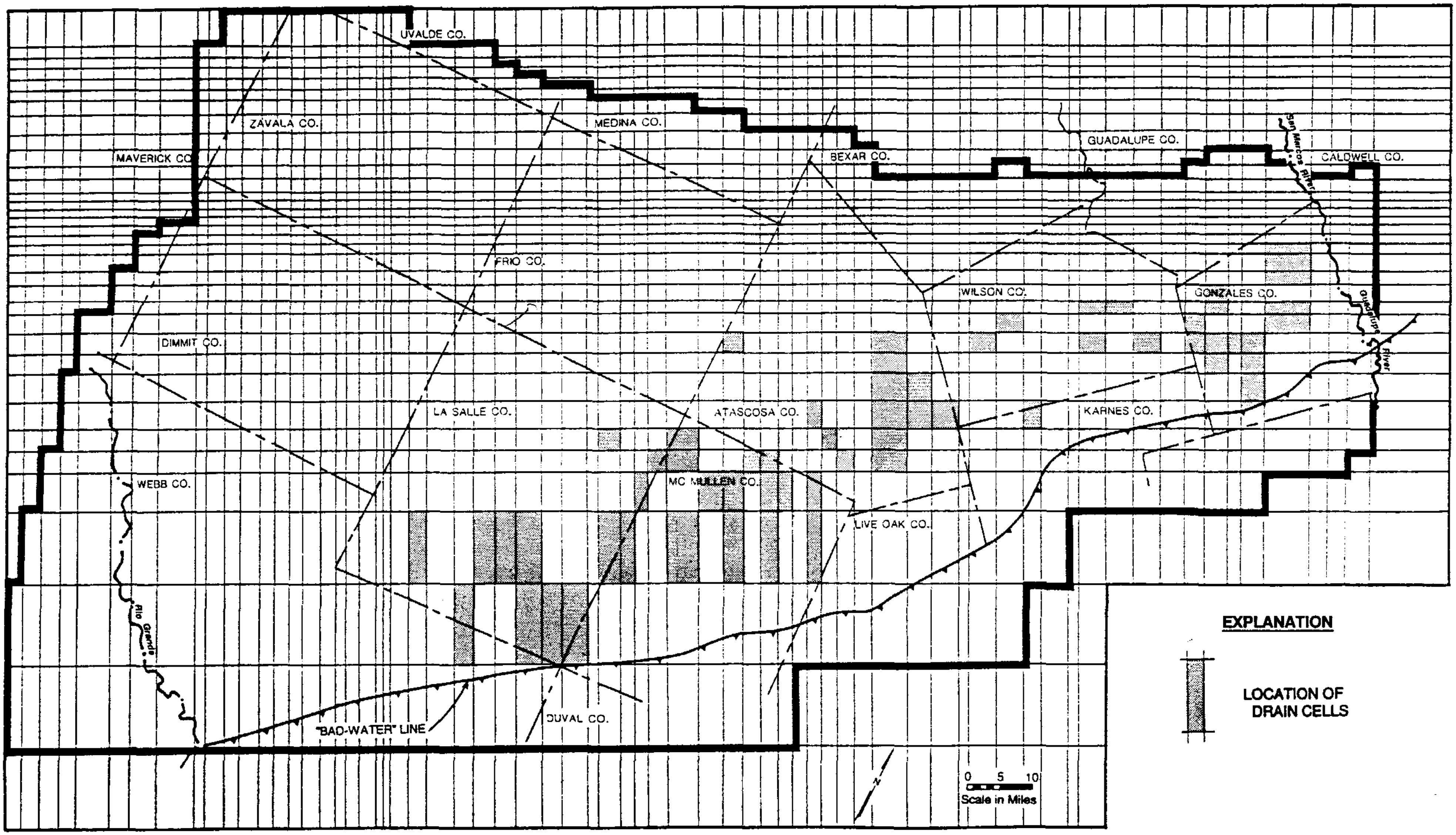
LBG-GUYTON ASSOCIATES



OUTCROP CELLS IN STUDY AREA

FIGURE 6-2

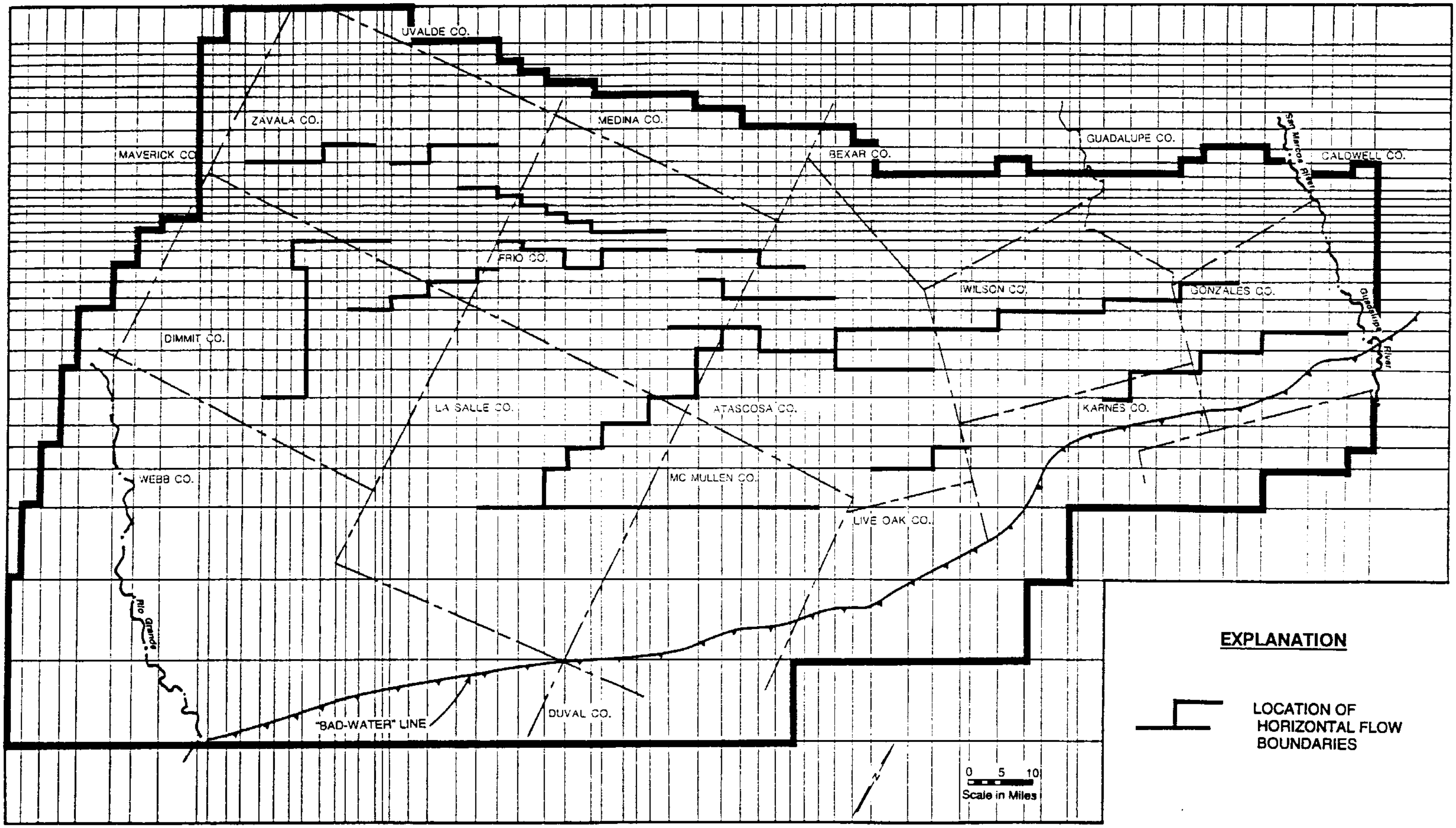
LBG-GUYTON ASSOCIATES



DRAIN CELLS INCLUDED IN GROUND-WATER MODEL

FIGURE 6-4

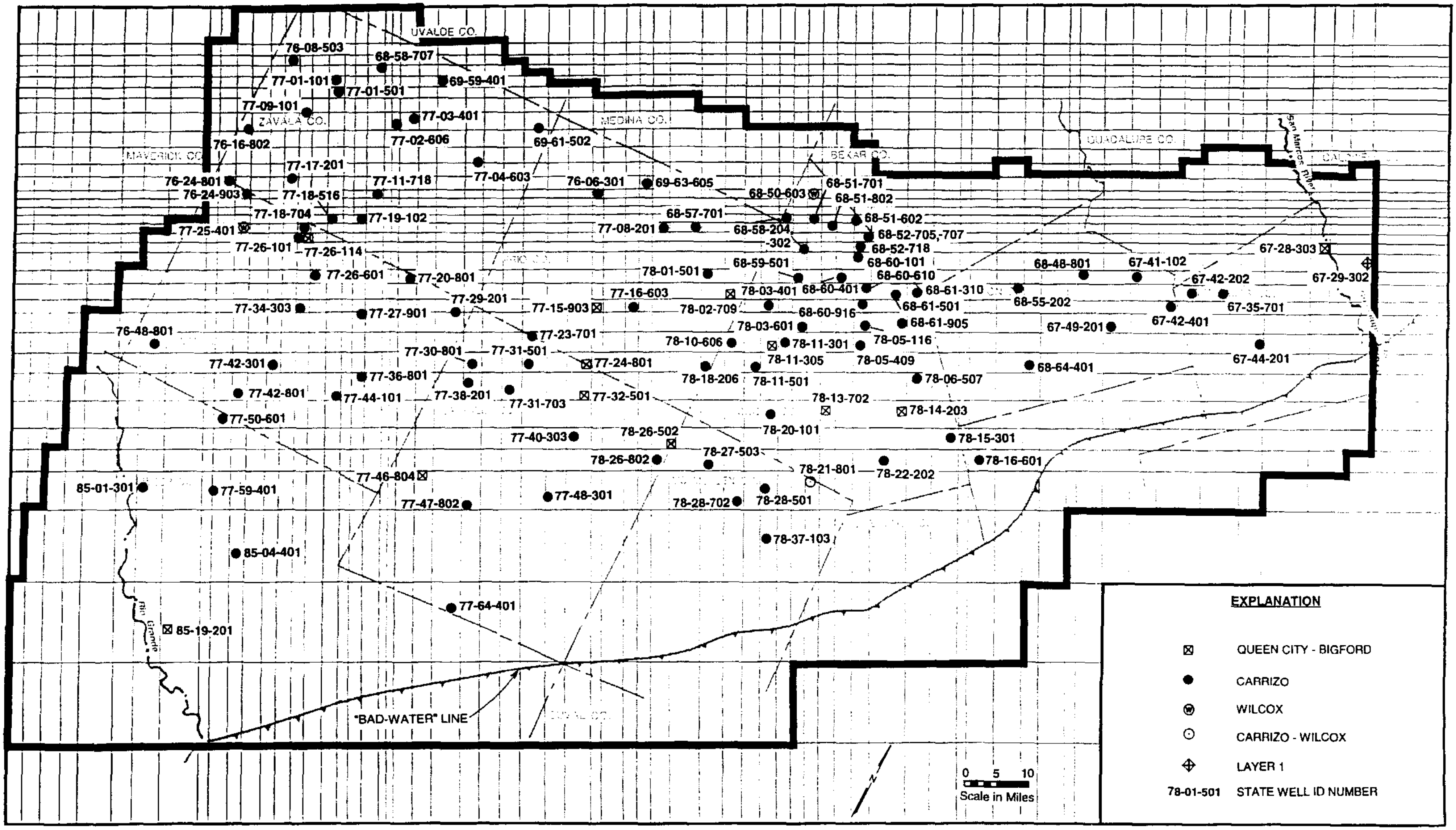
LBG-GUYTON ASSOCIATES



HORIZONTAL FLOW BOUNDARIES INCLUDED IN GROUND-WATER MODEL

FIGURE 6-5

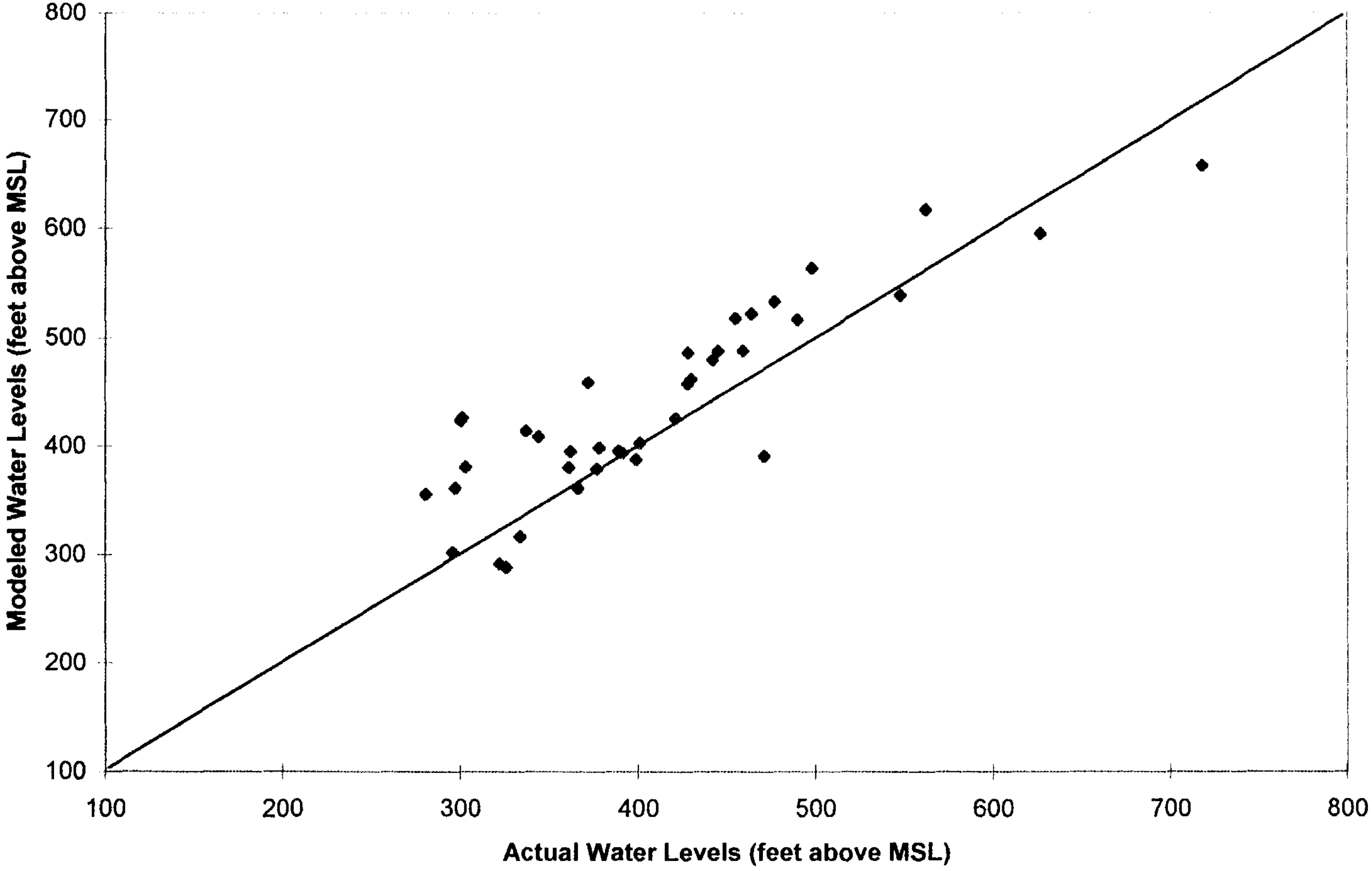
LBG-GUYTON ASSOCIATES



LOCATION OF MONITORING WELLS

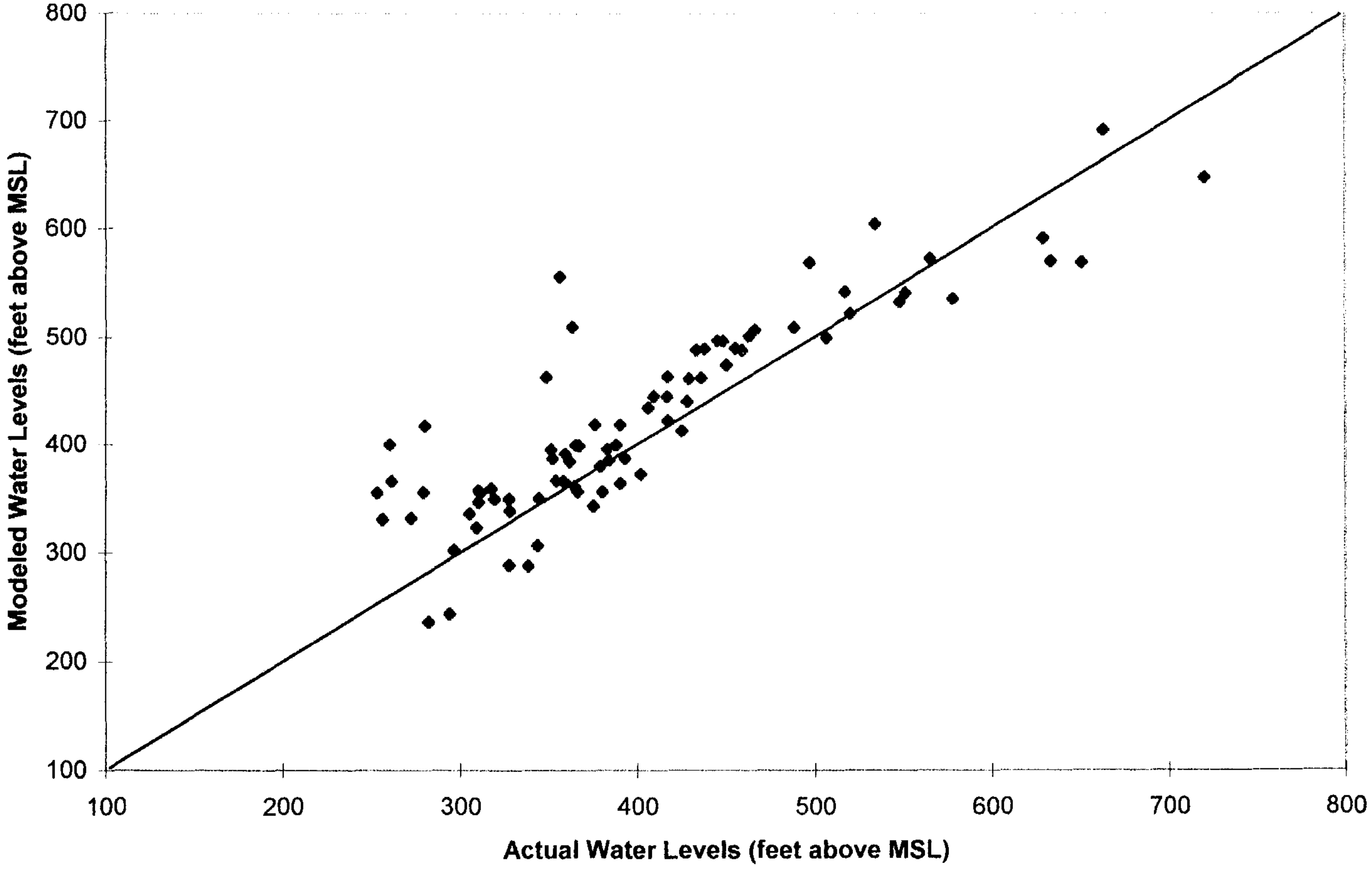
FIGURE 7-1

LBG-GUYTON ASSOCIATES



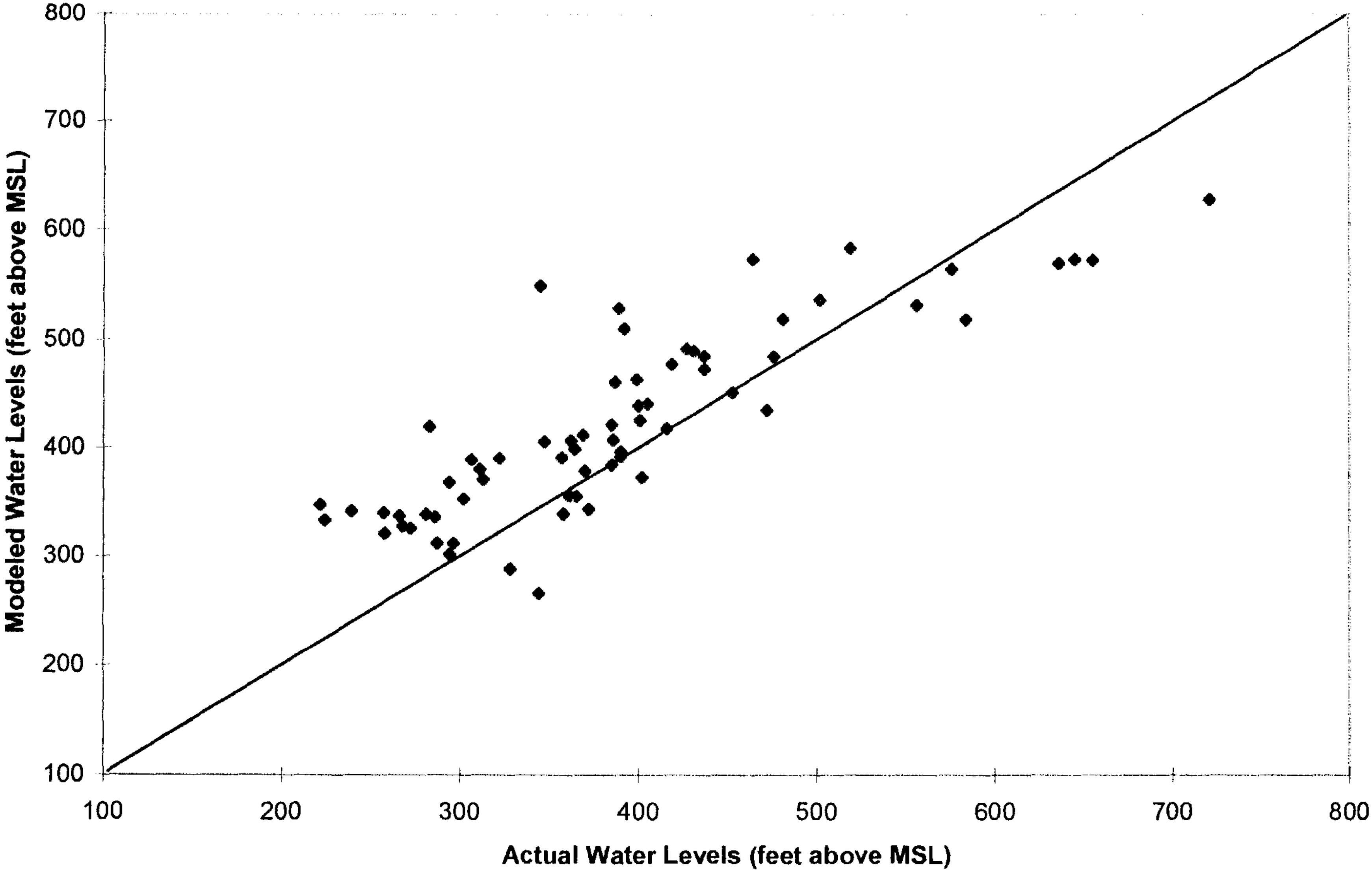
ANALYSIS OF MODELED VERSUS ACTUAL WATER LEVELS FOR 1964

FIGURE 7-2



ANALYSIS OF MODELED VERSUS ACTUAL WATER LEVELS FOR 1970

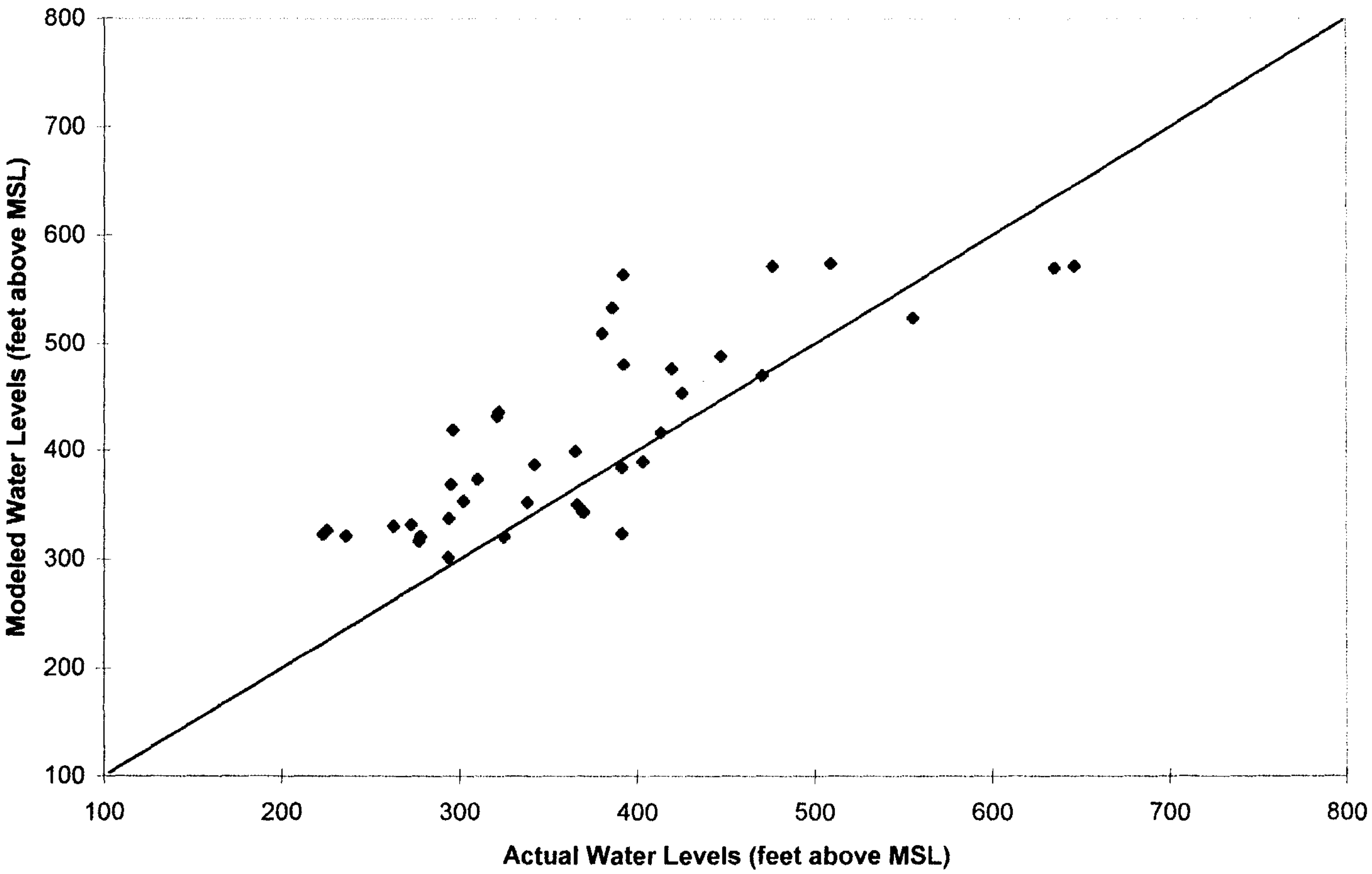
FIGURE 7-3



ANALYSIS OF MODELED VERSUS ACTUAL WATER LEVELS FOR 1985

FIGURE 7-4

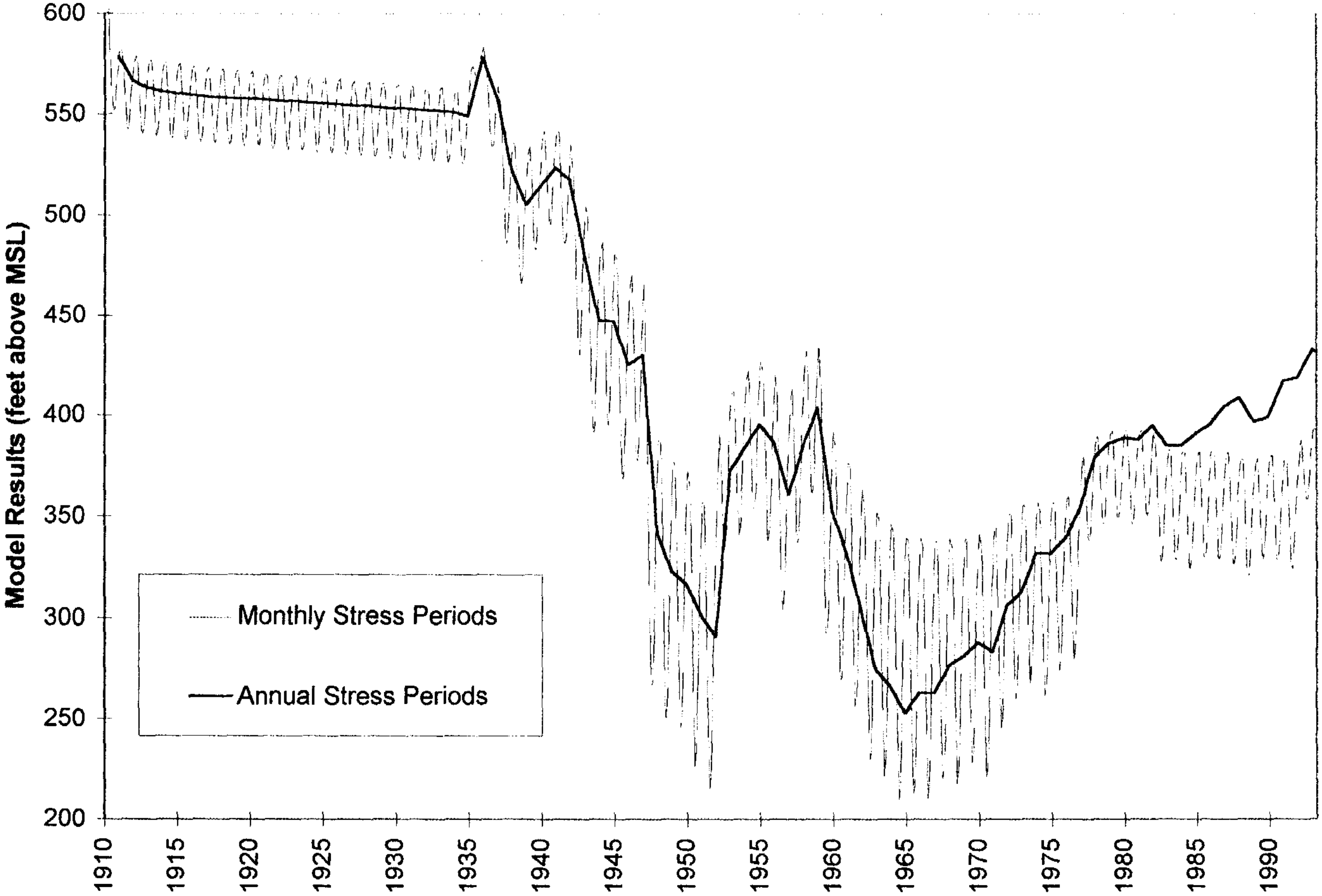
LBG-GUYTON ASSOCIATES



ANALYSIS OF MODELED VERSUS ACTUAL WATER LEVELS FOR 1994

FIGURE 7-5

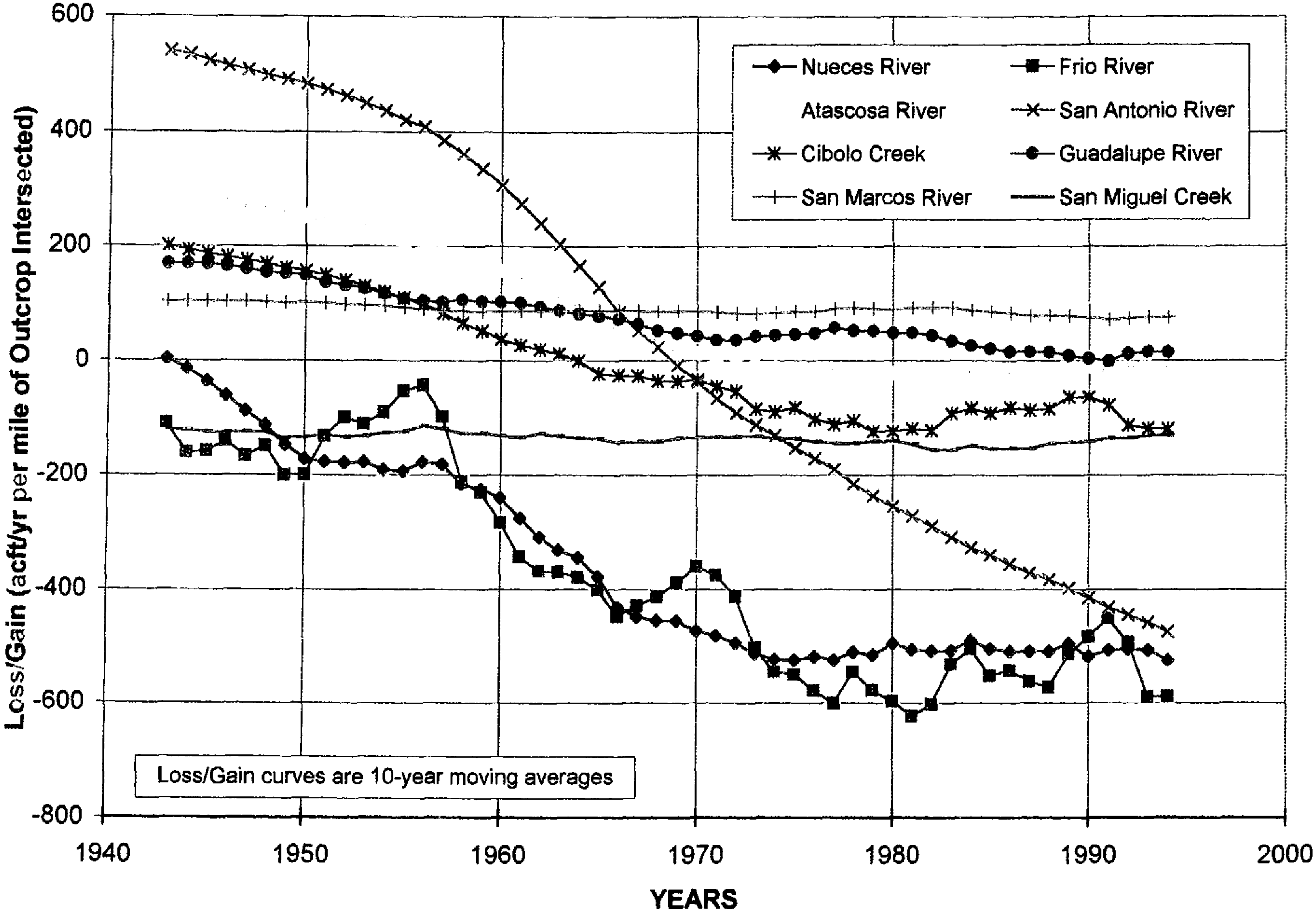
LBG-GUYTON ASSOCIATES



COMPARISON OF THE EFFECT OF MONTHLY VERSUS ANNUAL STRESS PERIOD LENGTHS

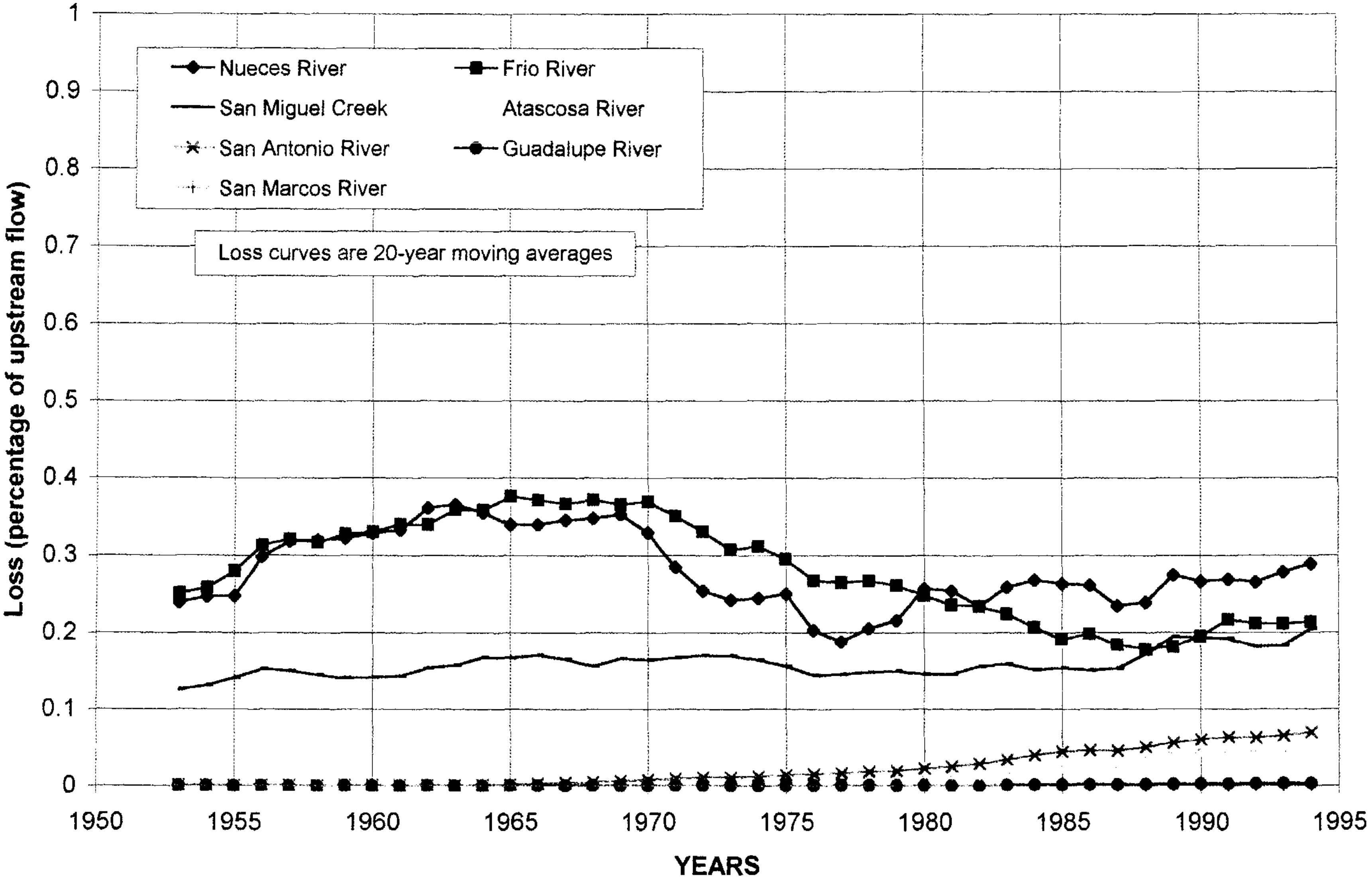
FIGURE 7-6

LBG-GUYTON ASSOCIATES



MODFLOW SIMULATED STREAMBED LOSSES/GAINS

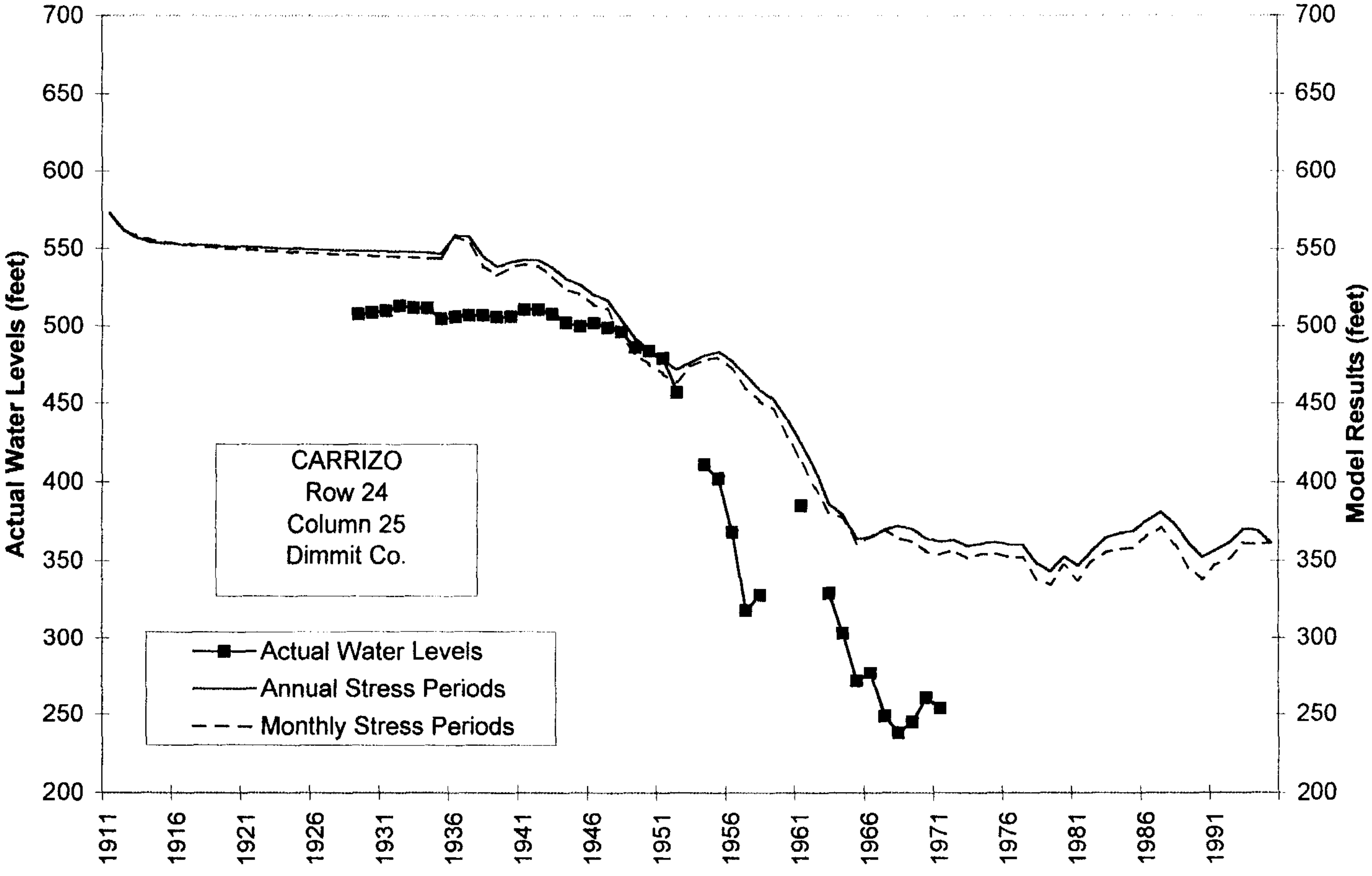
FIGURE 7-7



MODFLOW SIMULATED STREAMBED LOSSES AS A PERCENTAGE OF UPSTREAM FLOW

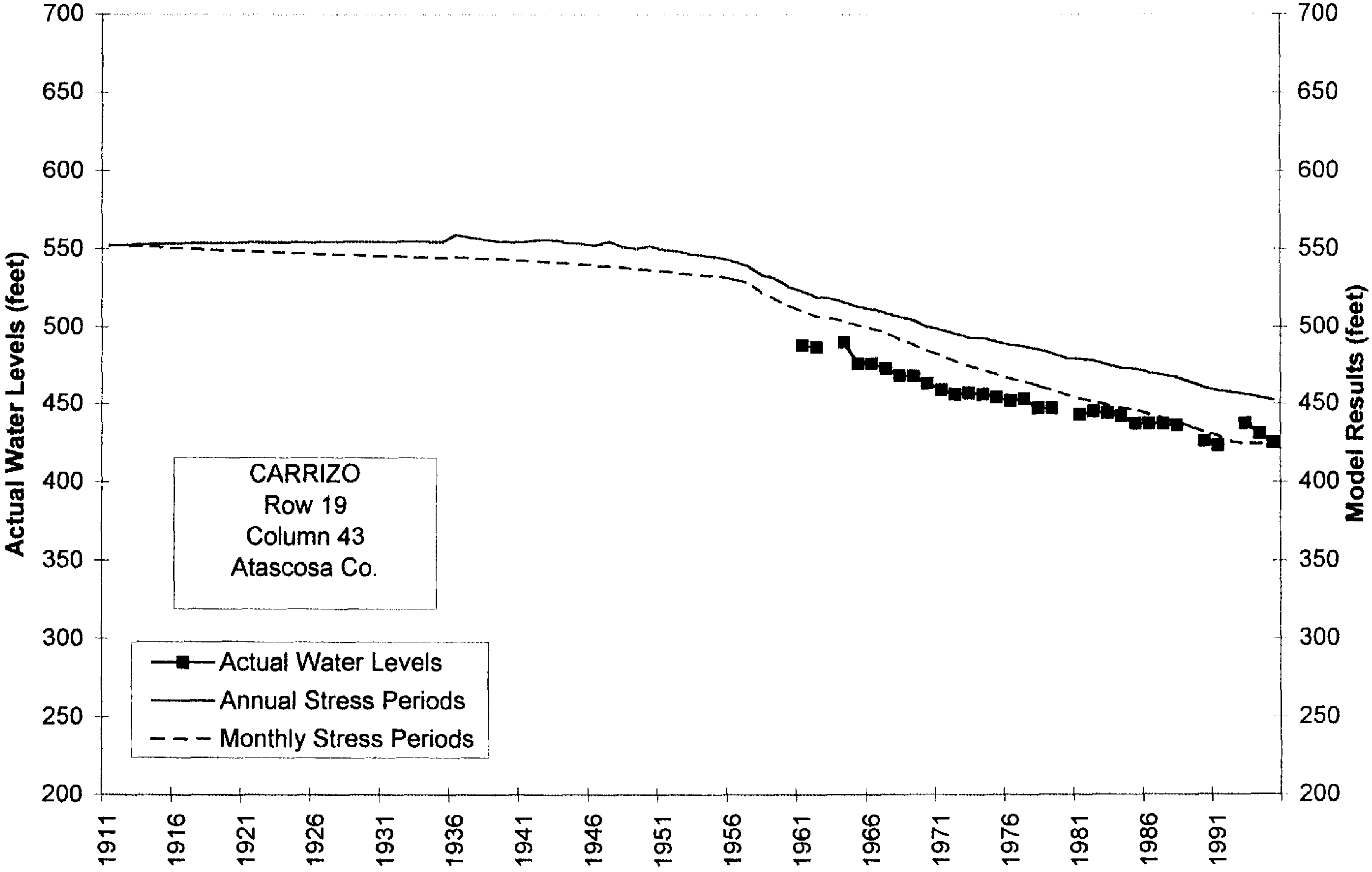
FIGURE 7-8

LBG-GUYTON ASSOCIATES



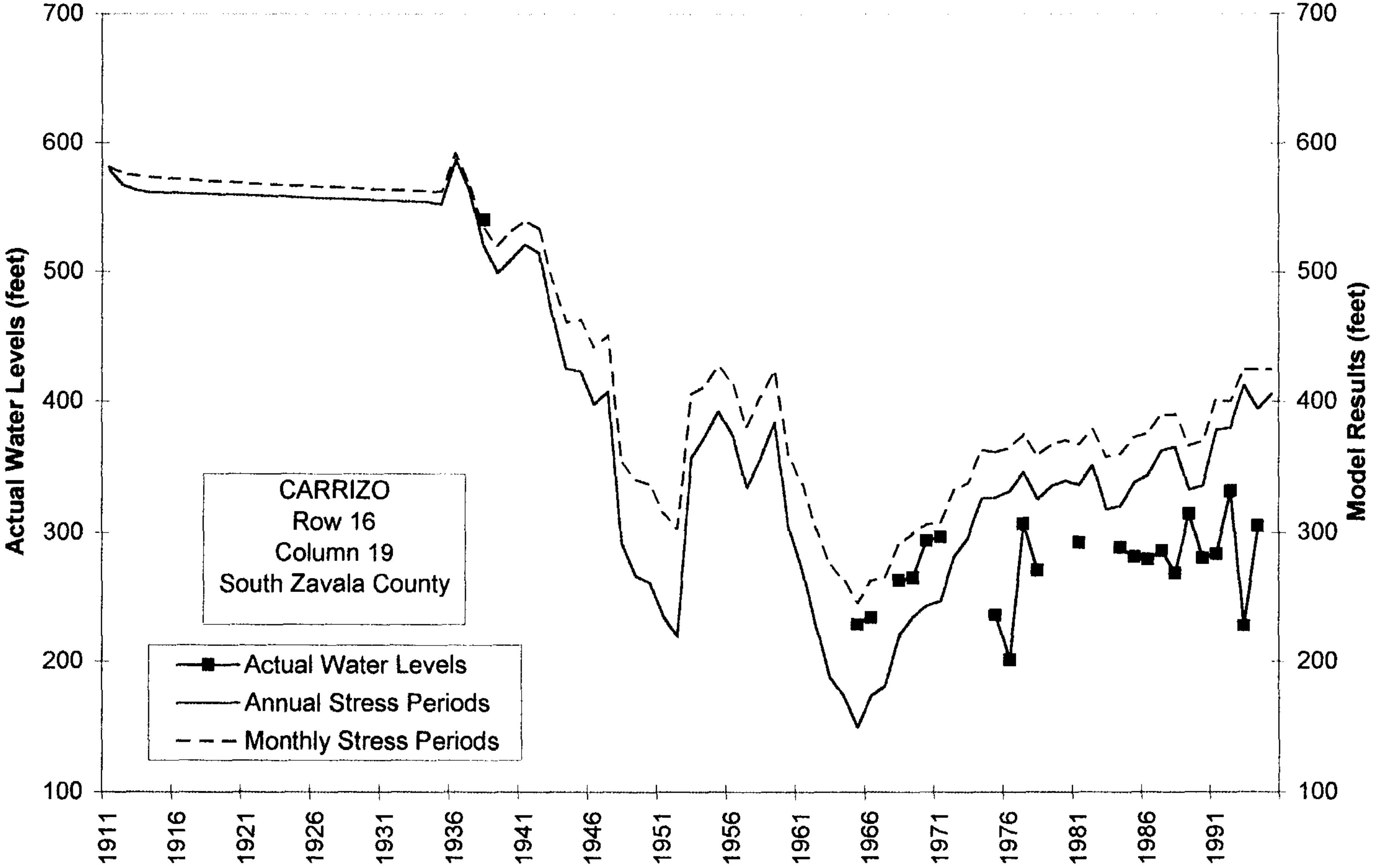
COMPARISON OF MONTHLY VERSUS ANNUAL STRESS PERIODS FOR WELL 77-29-201

FIGURE 7-9



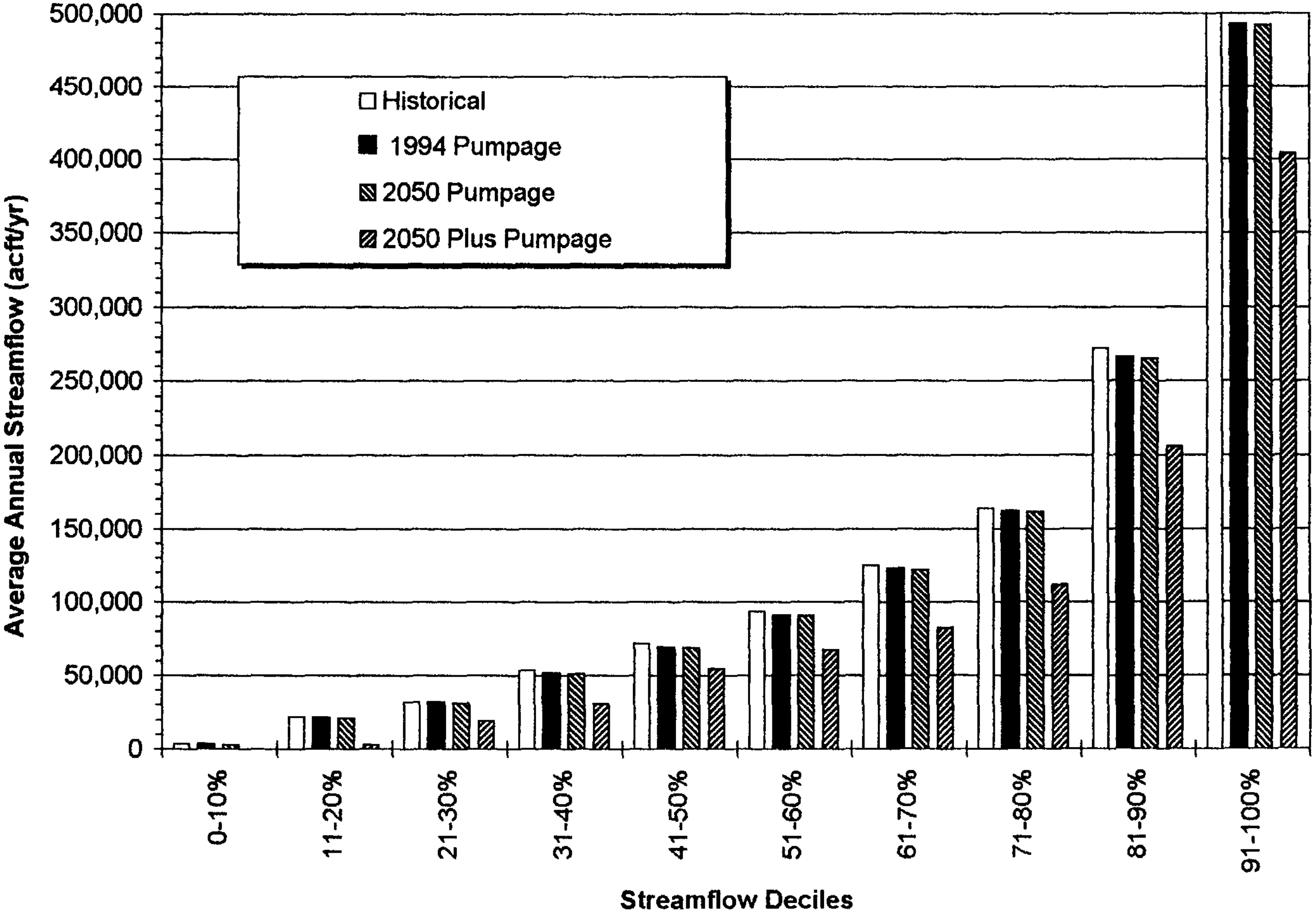
COMPARISON OF MONTHLY VERSUS ANNUAL STRESS PERIODS FOR WELL 68-59-501

FIGURE 7-10



COMPARISON OF MONTHLY VERSUS ANNUAL STRESS PERIODS FOR WELL 77-19-102

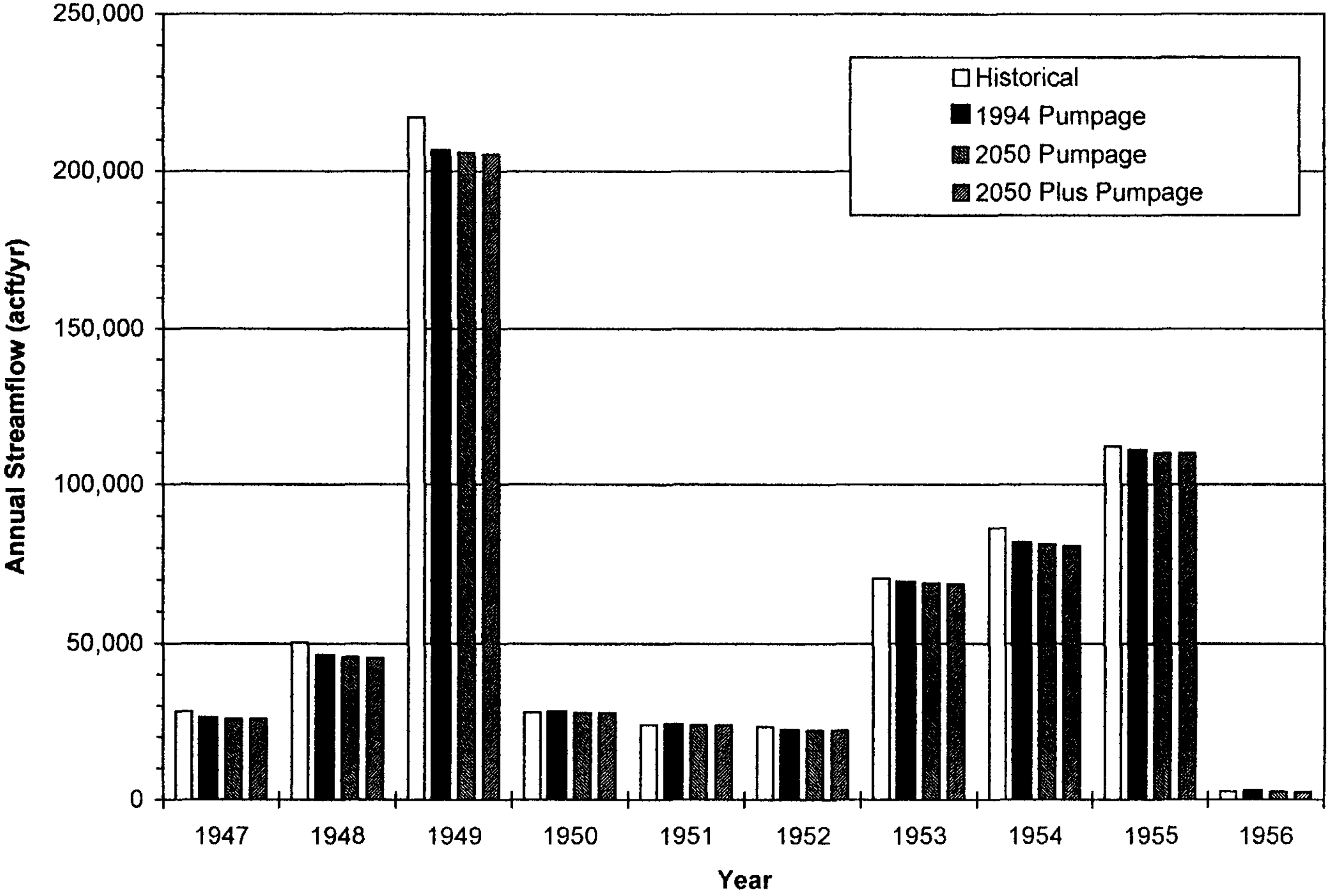
FIGURE 7-11



STREAMFLOW DECILES FOR NUECES RIVER AT ASHERTON

FIGURE 8-1

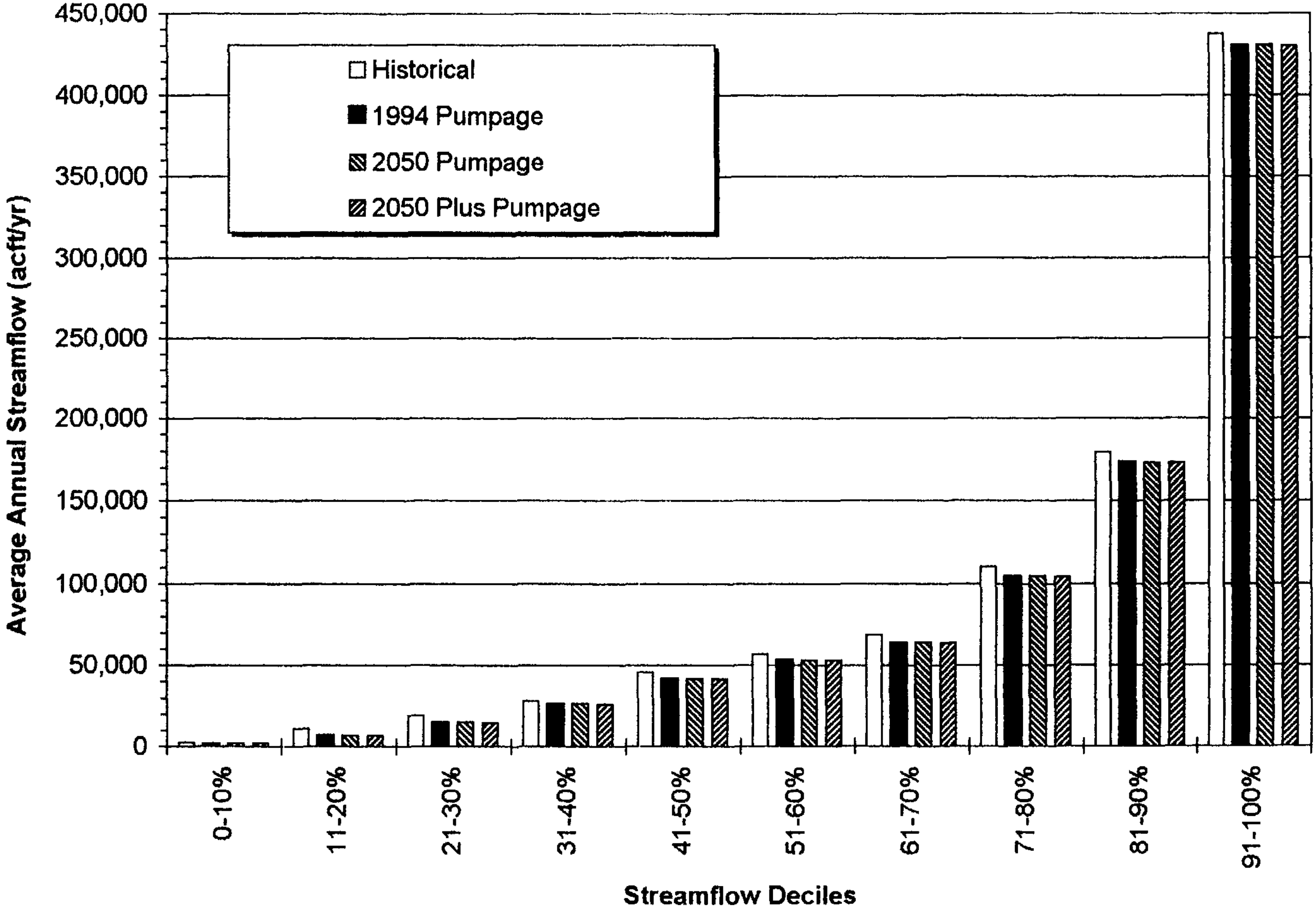
LBG-GUYTON ASSOCIATES



10-YEAR DROUGHT ANNUAL STREAMFLOWS FOR NUECES RIVER AT ASHERTON

FIGURE 8-2

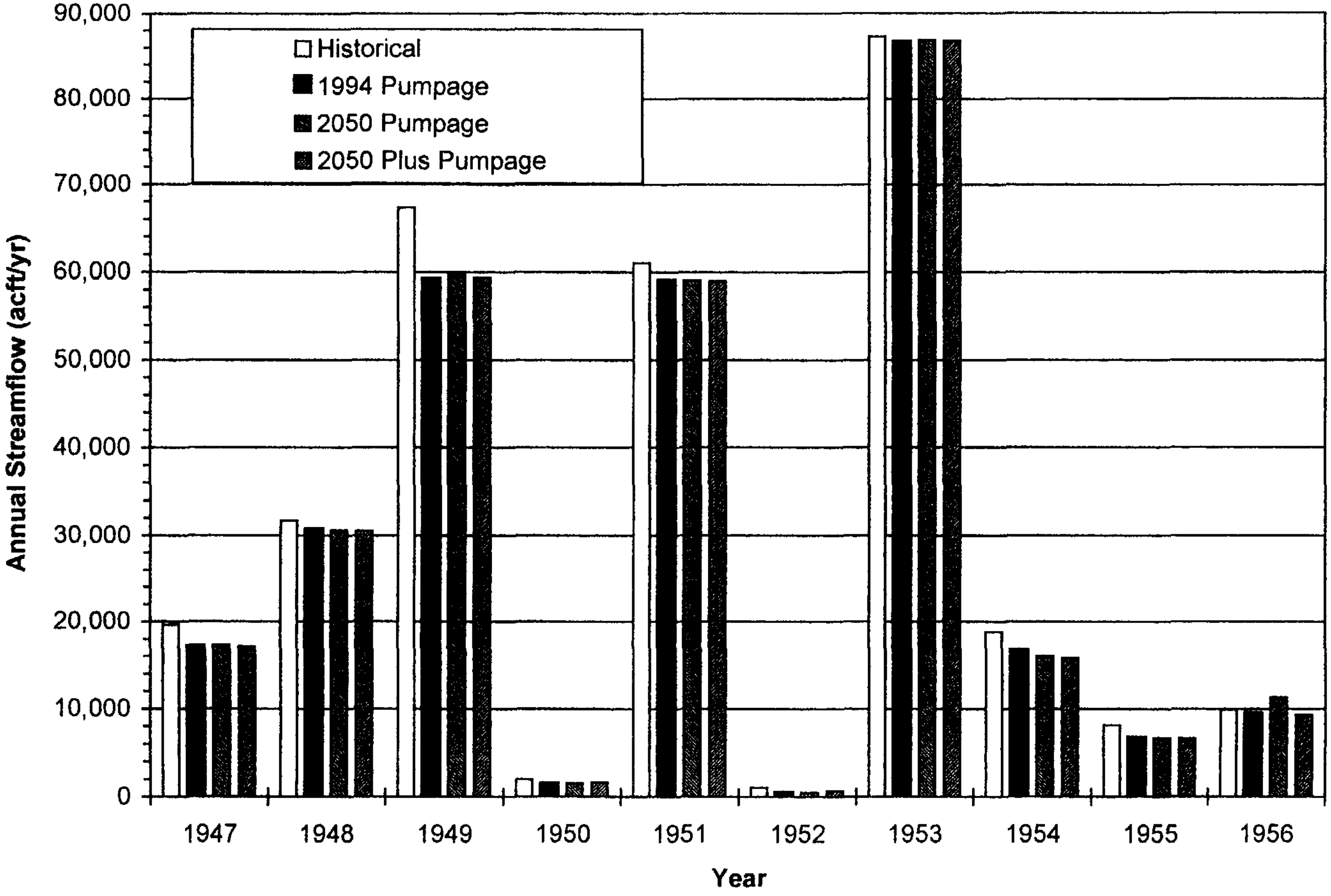
LBG-GUYTON ASSOCIATES



STREAMFLOW DECILES FOR FRIO RIVER AT DERBY

FIGURE 8-3

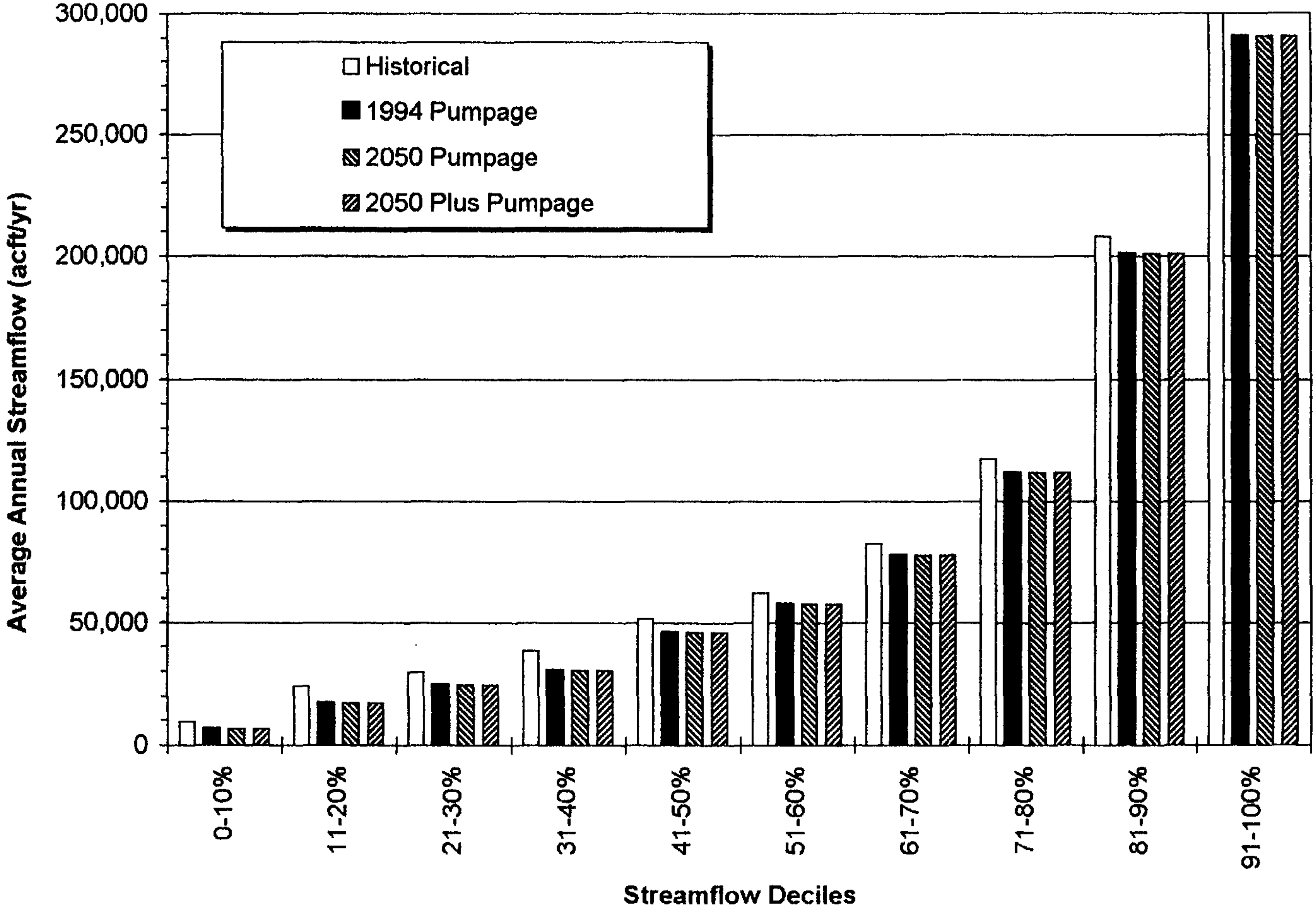
LBG-GUYTON ASSOCIATES



10-YEAR DROUGHT ANNUAL STREAMFLOWS FOR FRIO RIVER AT DERBY

FIGURE 8-4

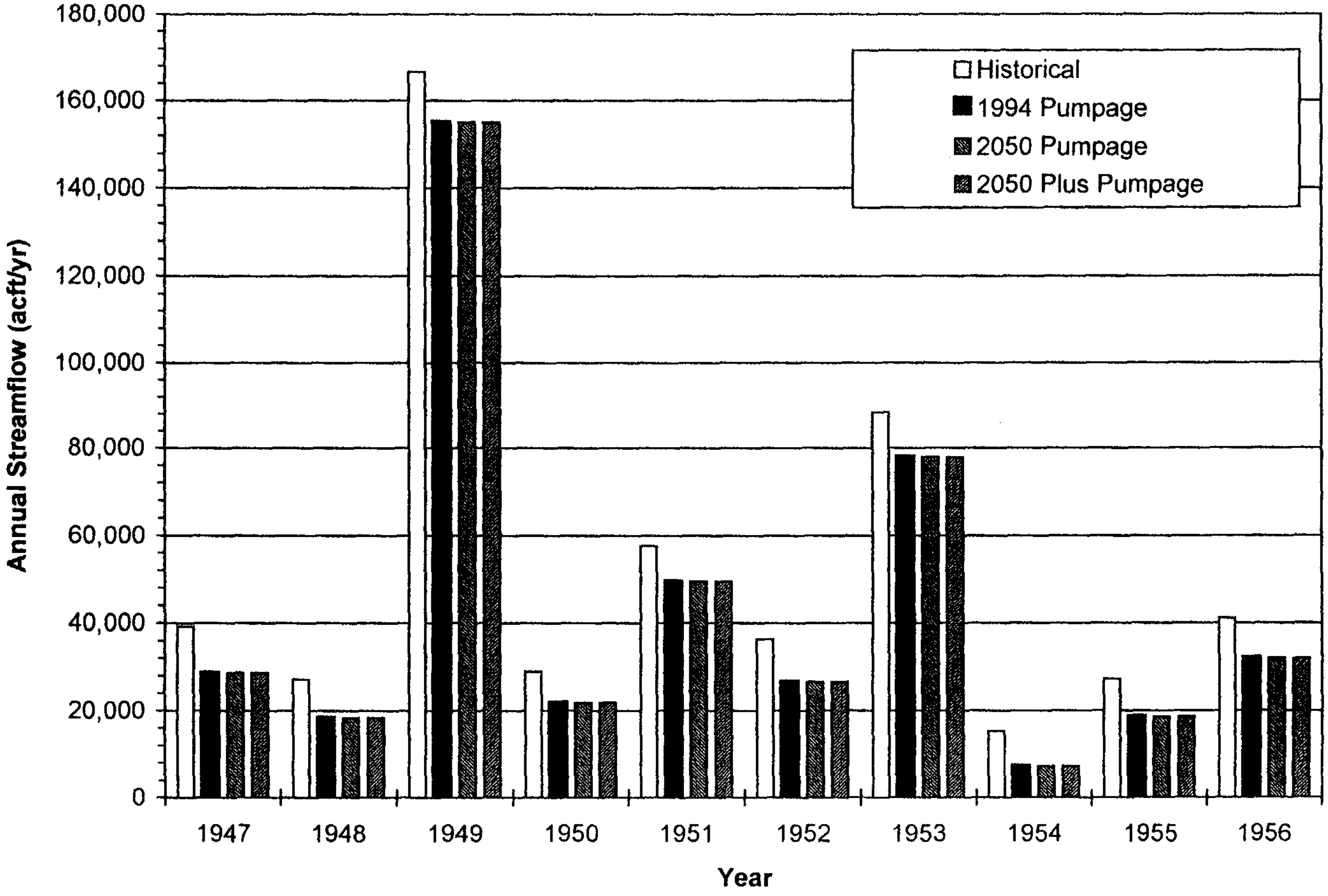
LBG-GUYTON ASSOCIATES



STREAMFLOW DECILES FOR ATASCOSA RIVER AT WHITSETT

FIGURE 8-5

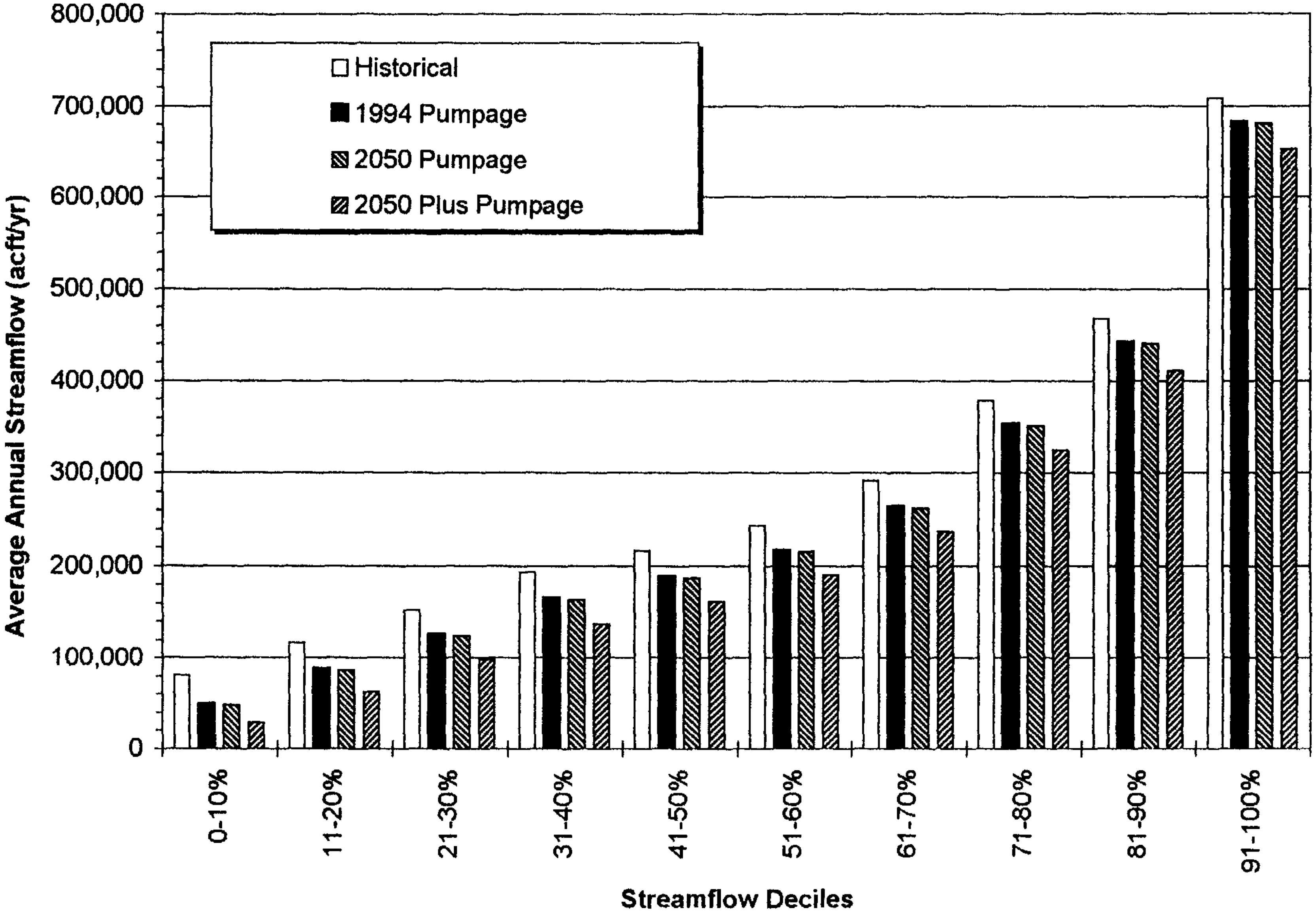
LBG-GUYTON ASSOCIATES



10-YEAR DROUGHT ANNUAL STREAMFLOWS FOR ATASCOSA RIVER AT WHITSETT

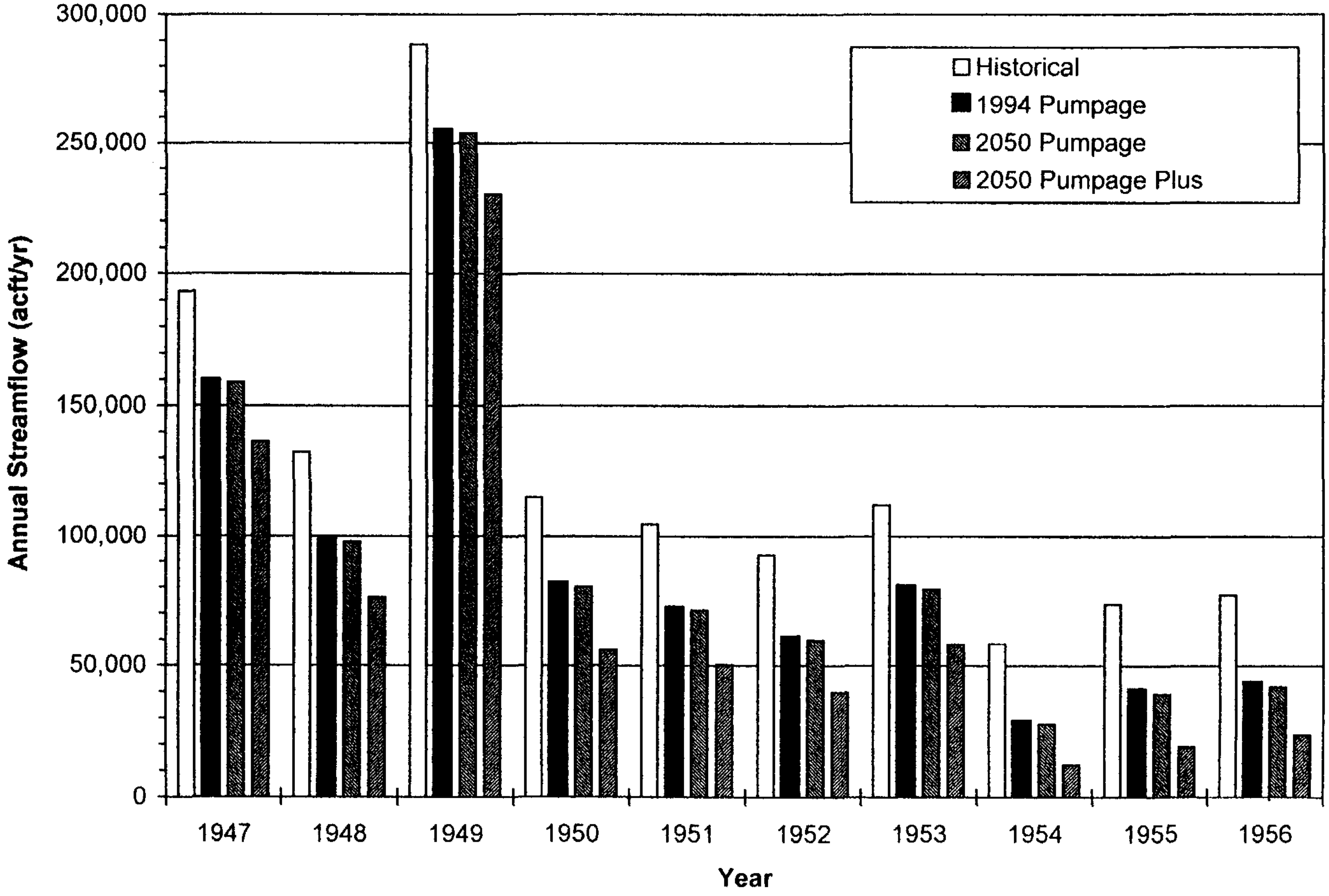
FIGURE 8-6

LBG-GUYTON ASSOCIATES



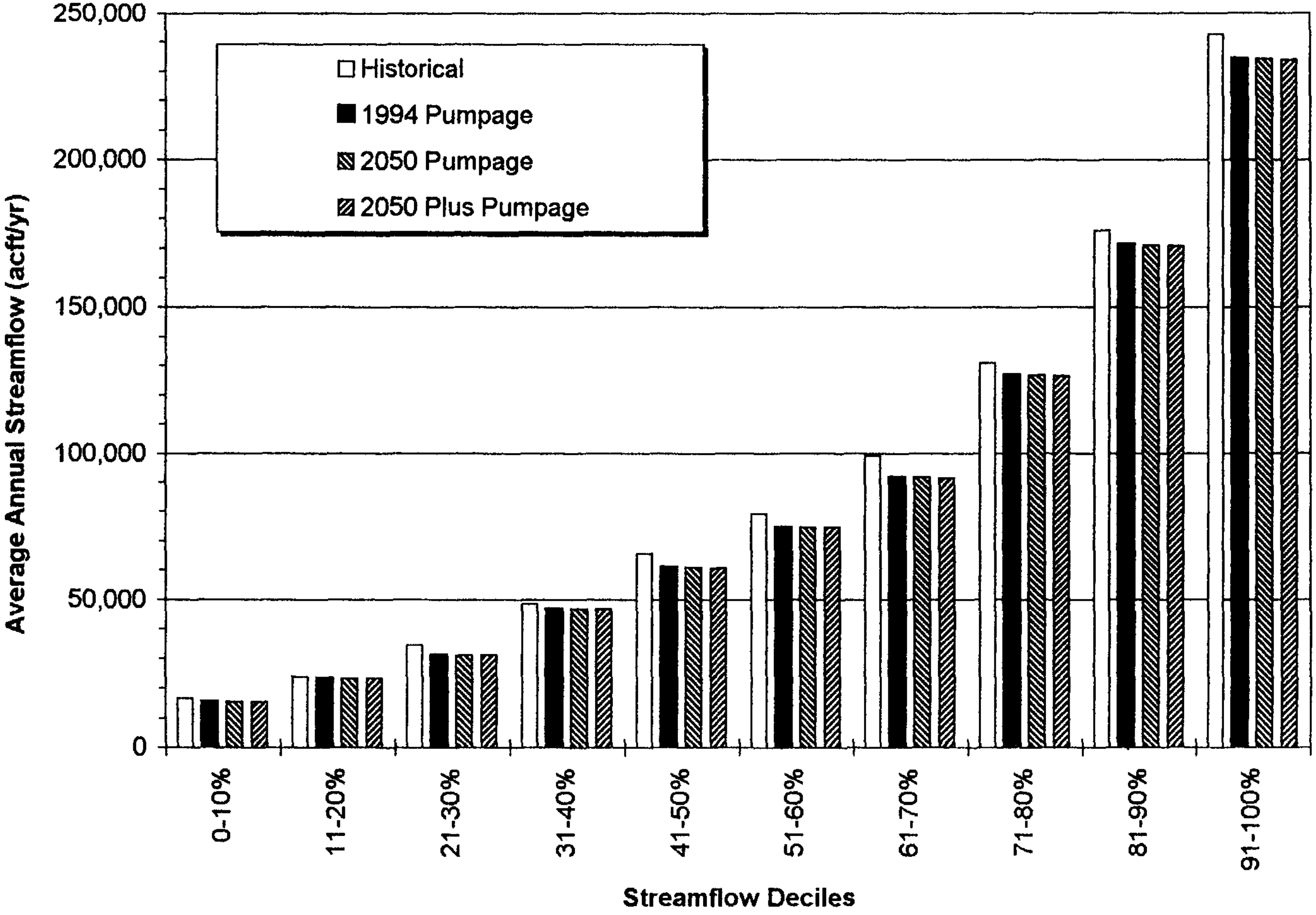
STREAMFLOW DECILES FOR SAN ANTONIO RIVER AT FALLS CITY

FIGURE 8-7



10-YEAR DROUGHT ANNUAL STREAMFLOWS FOR SAN ANTONIO RIVER AT FALLS CITY

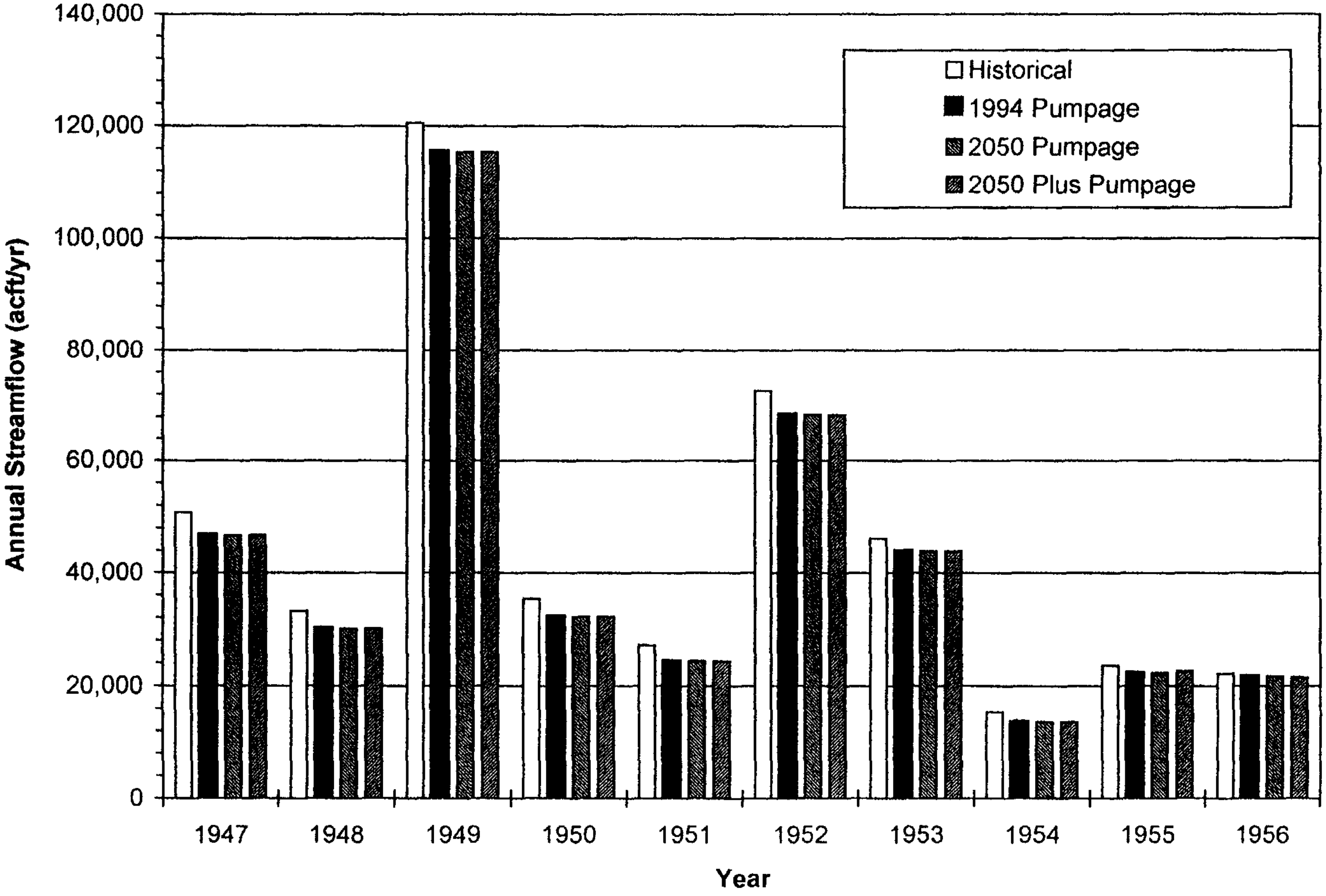
FIGURE 8-8



STREAMFLOW DECILES FOR CIBOLO CREEK AT FALLS CITY

FIGURE 8-9

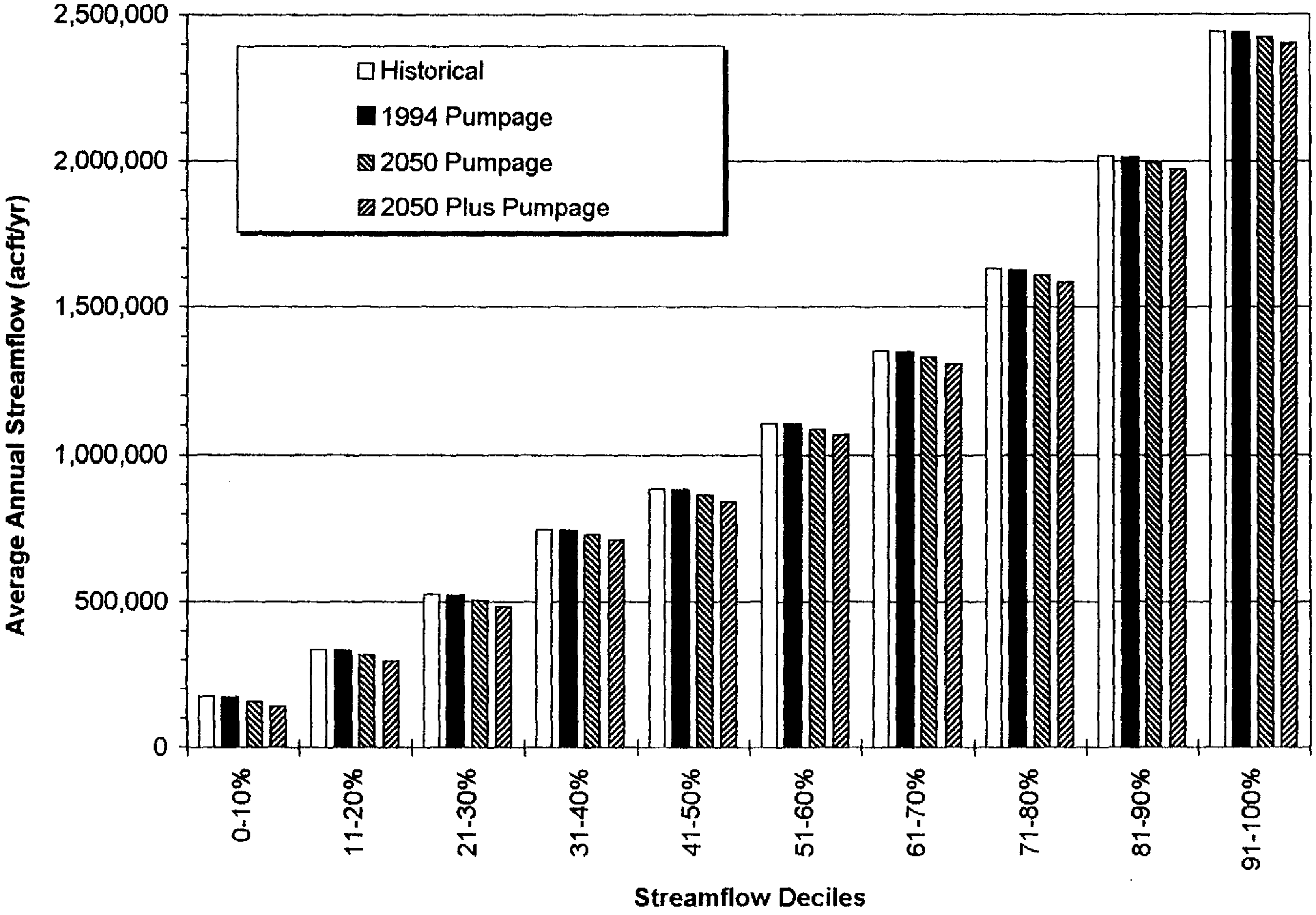
LBG-GUYTON ASSOCIATES



10-YEAR DROUGHT ANNUAL STREAMFLOWS FOR CIBOLO CREEK AT FALLS CITY

FIGURE 8-10

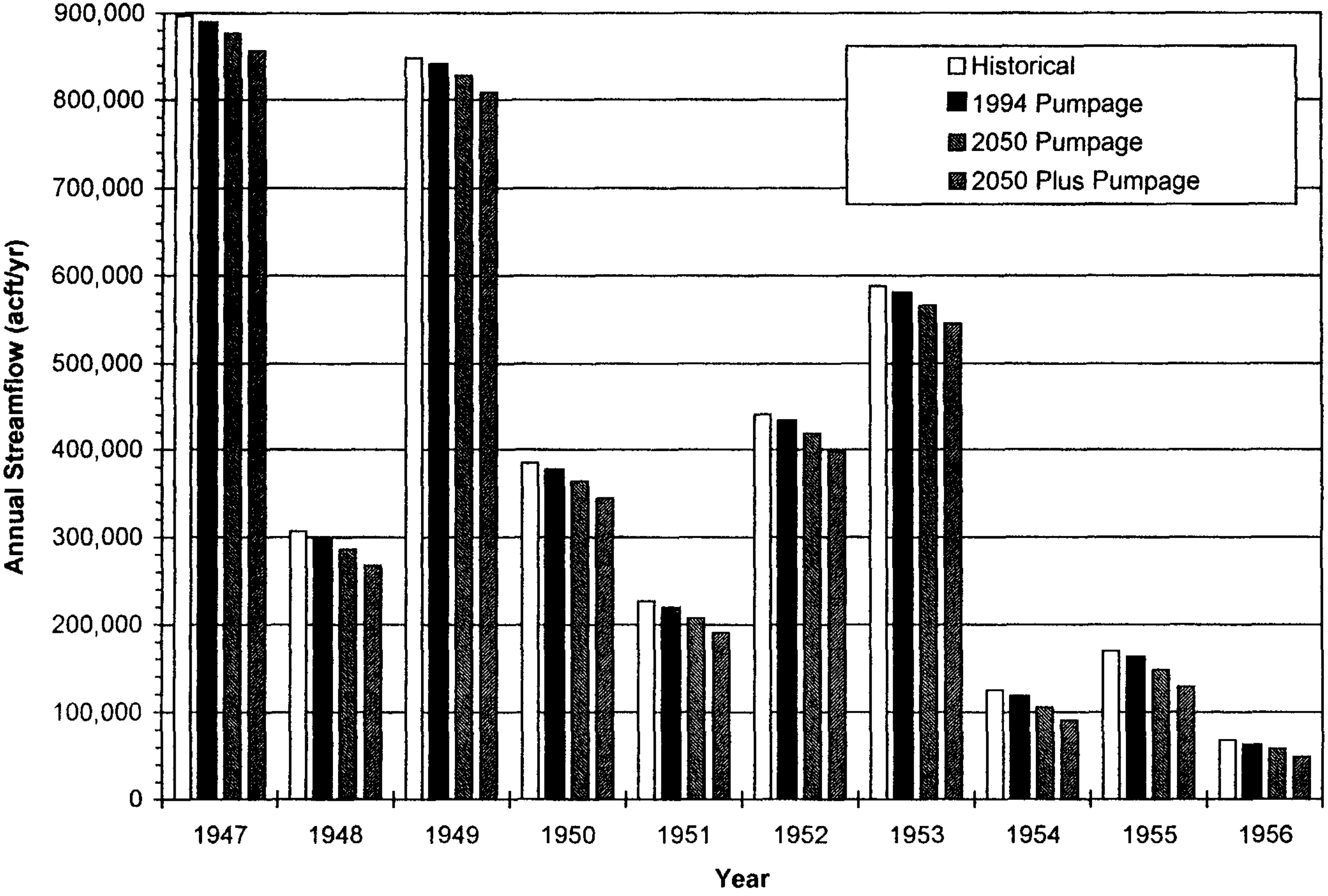
LBG-GUYTON ASSOCIATES



STREAMFLOW DECILES FOR GUADALUPE RIVER AT CUERO

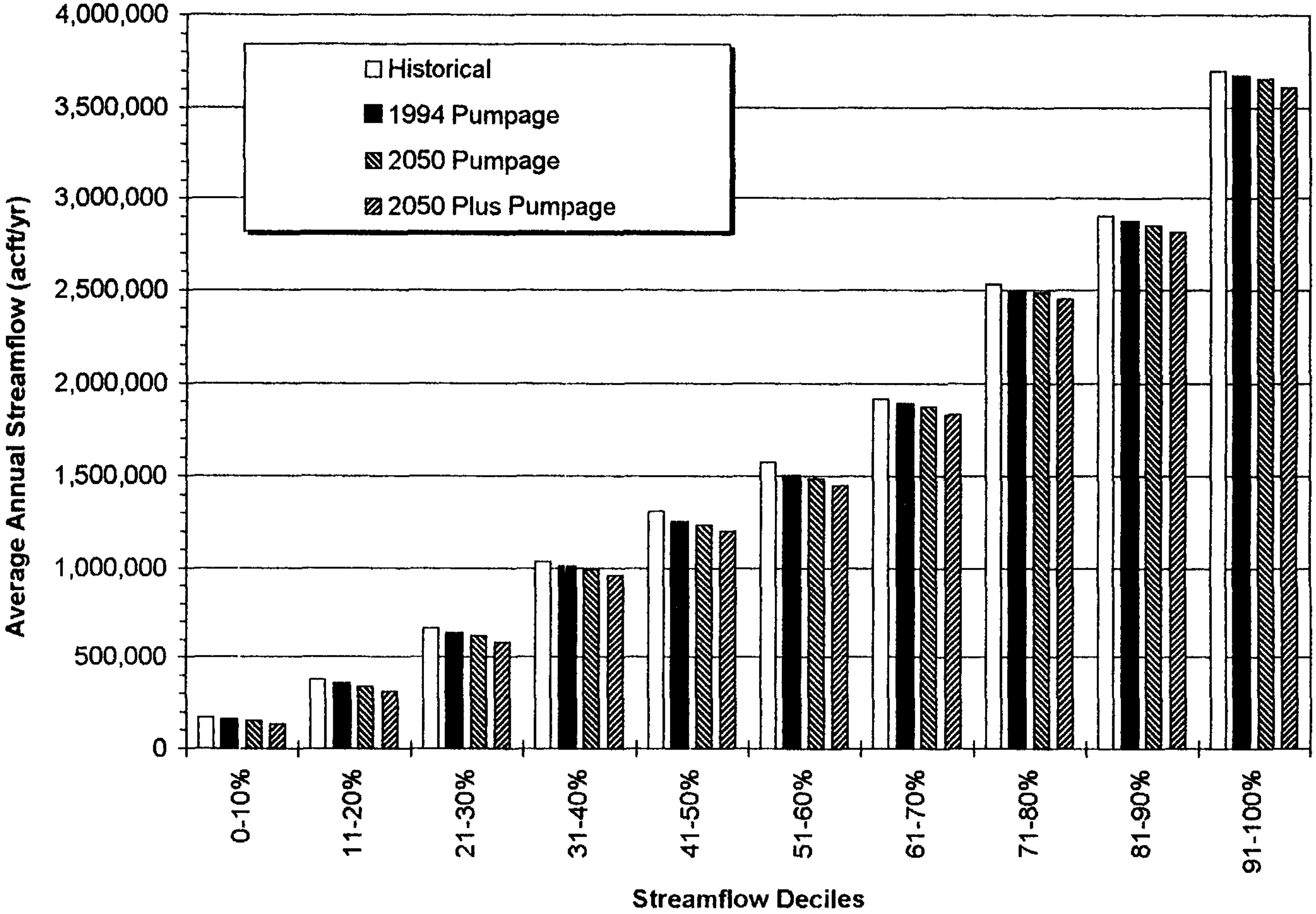
FIGURE 8-11

LBG-GUYTON ASSOCIATES



10-YEAR DROUGHT ANNUAL STREAMFLOWS FOR GUADALUPE RIVER AT CUERO

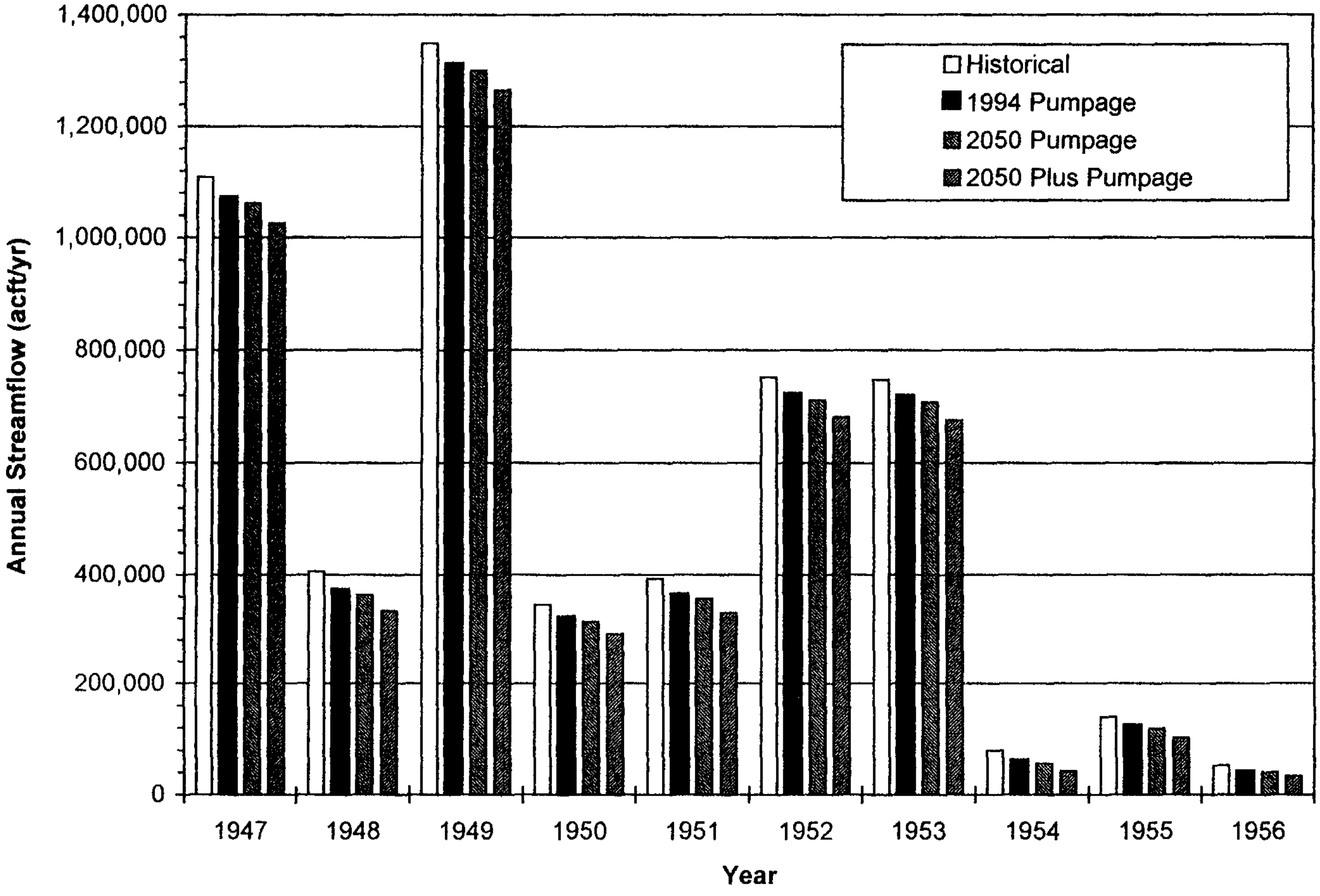
FIGURE 8-12



STREAMFLOW DECILES FOR GUADALUPE RIVER AT SALT-WATER BARRIER (TIVOLI)

FIGURE 8-13

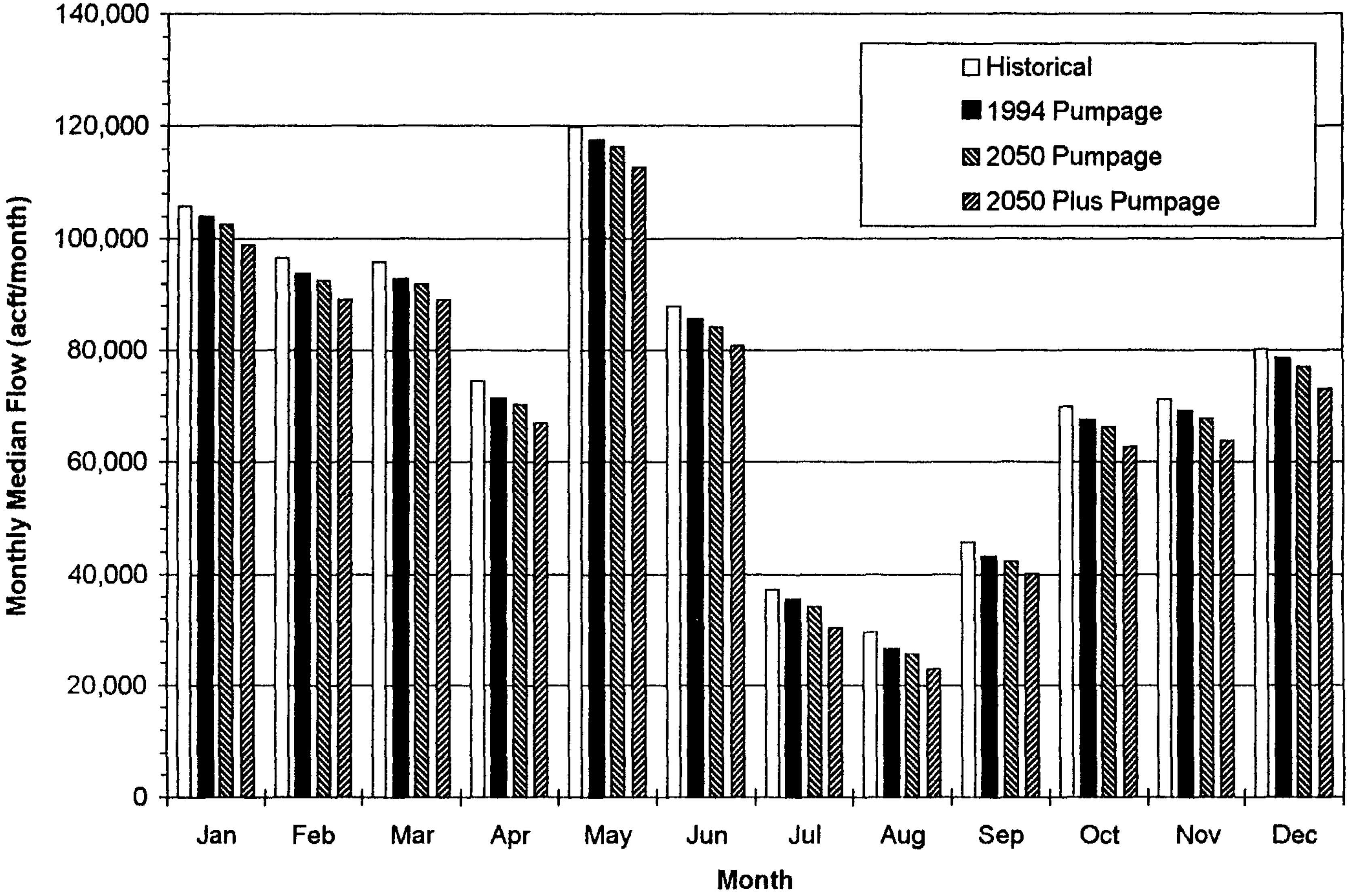
LBG-GUYTON ASSOCIATES



10-YEAR DROUGHT ANNUAL STREAMFLOWS FOR GUADALUPE RIVER AT SALT-WATER BARRIER (TIVOLI)

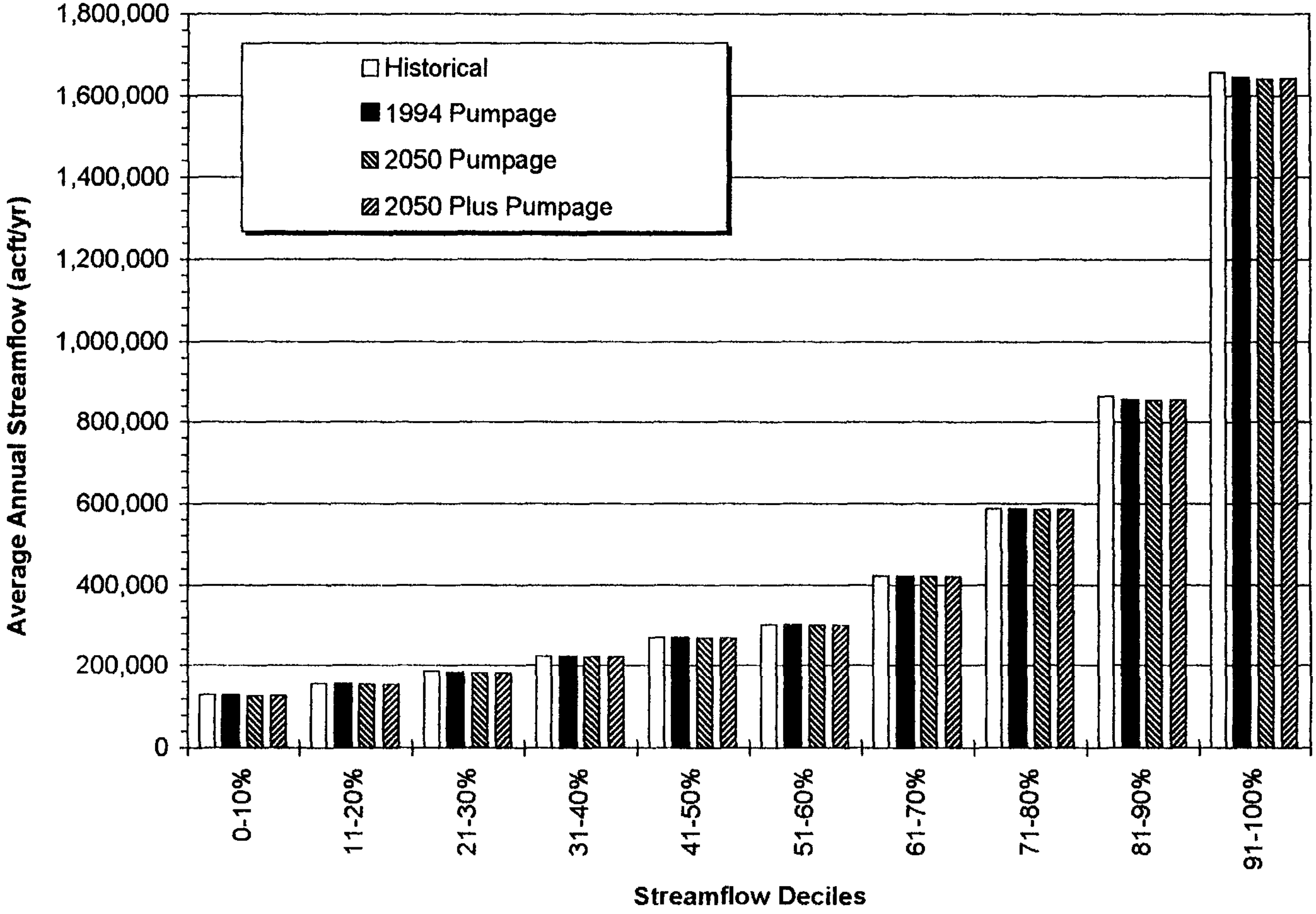
FIGURE 8-14

LBG-GUYTON ASSOCIATES



MONTHLY MEDIAN STREAMFLOWS FOR GUADALUPE RIVER
AT SALT-WATER BARRIER (TIVOLI)

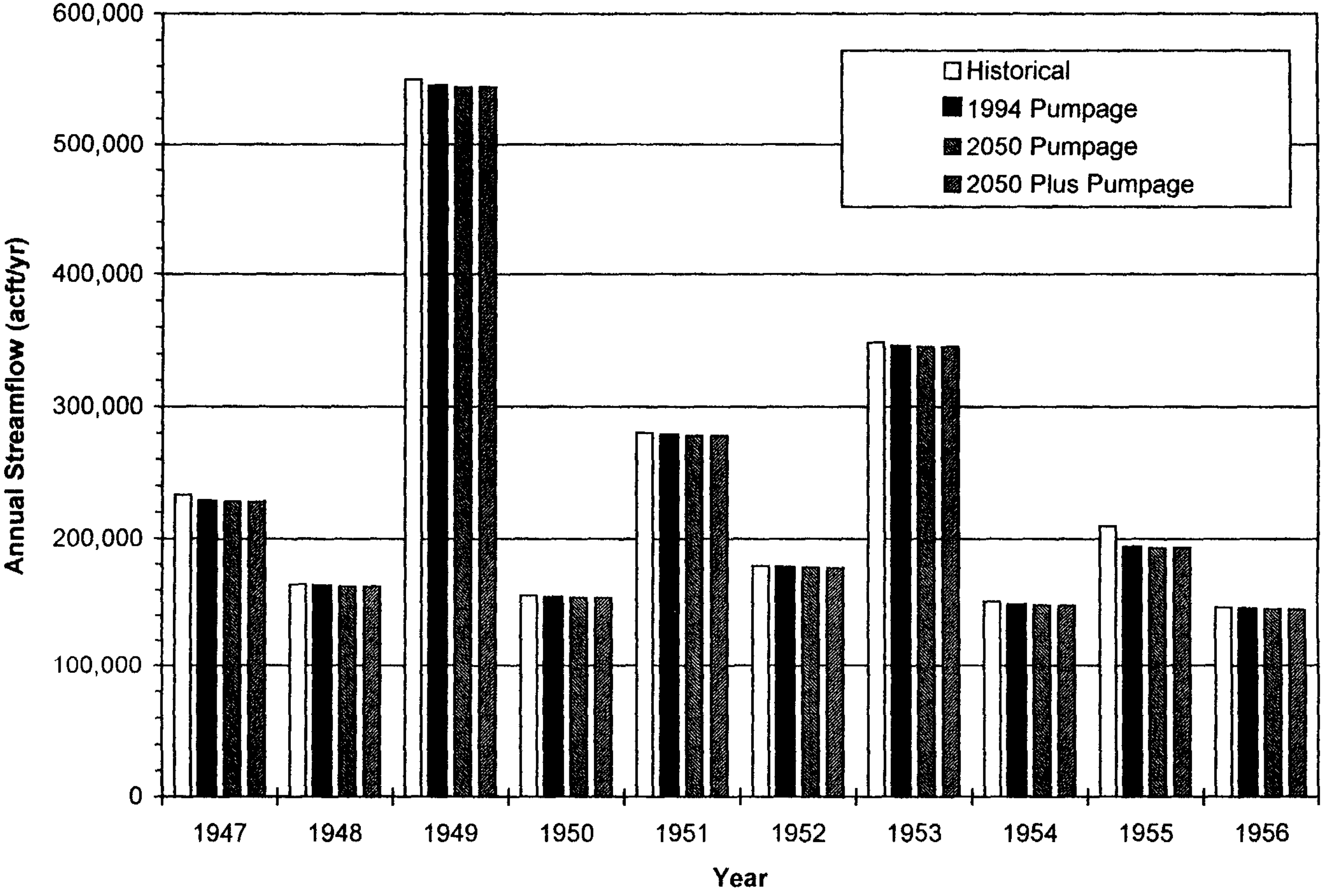
FIGURE 8-15



STREAMFLOW DECILES FOR FRESH-WATER INFLOWS TO NUECES ESTUARY

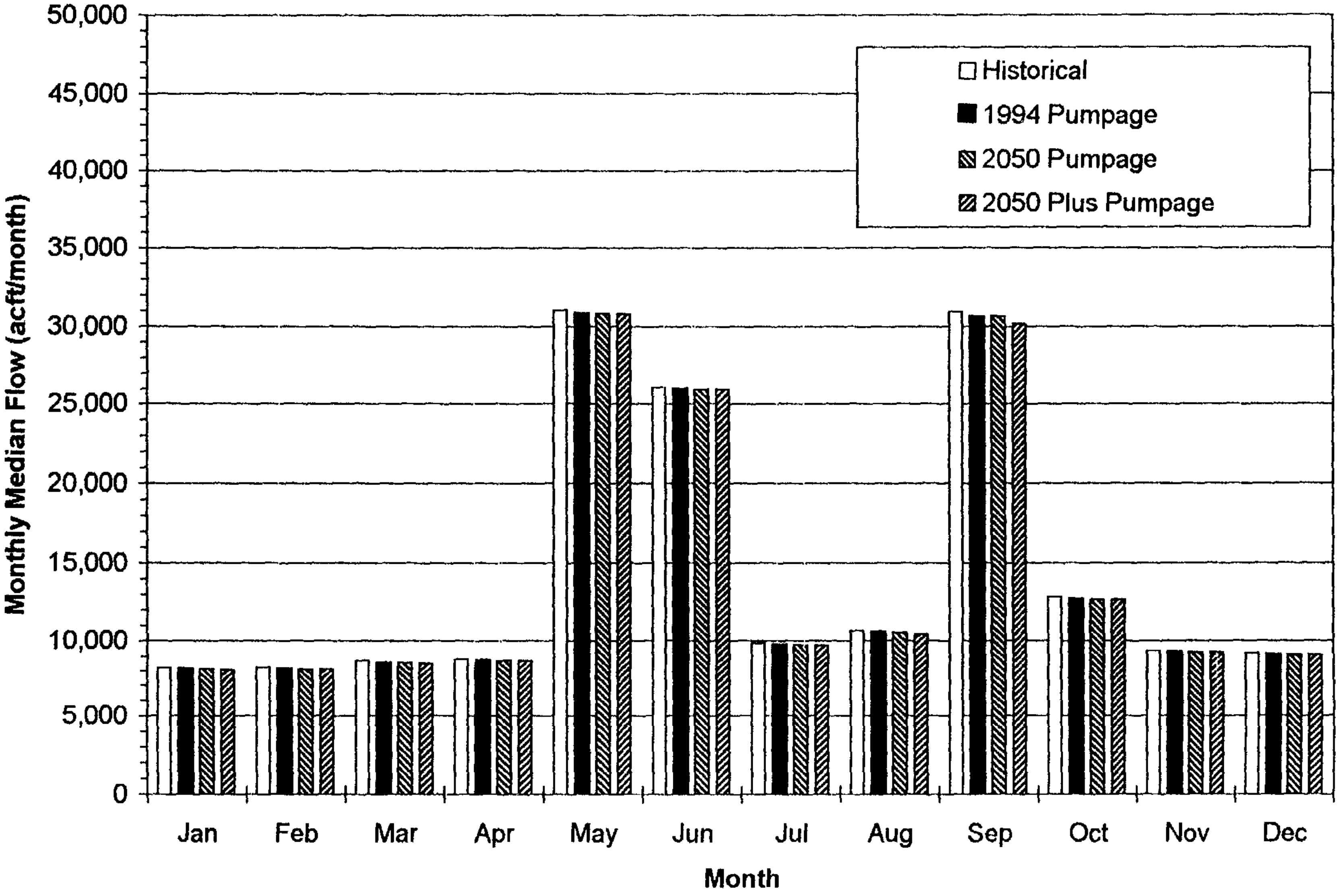
FIGURE 8-16

LBG-GUYTON ASSOCIATES



10-YEAR DROUGHT ANNUAL STREAMFLOWS FOR FRESH-WATER INFLOWS TO NUECES ESTUARY

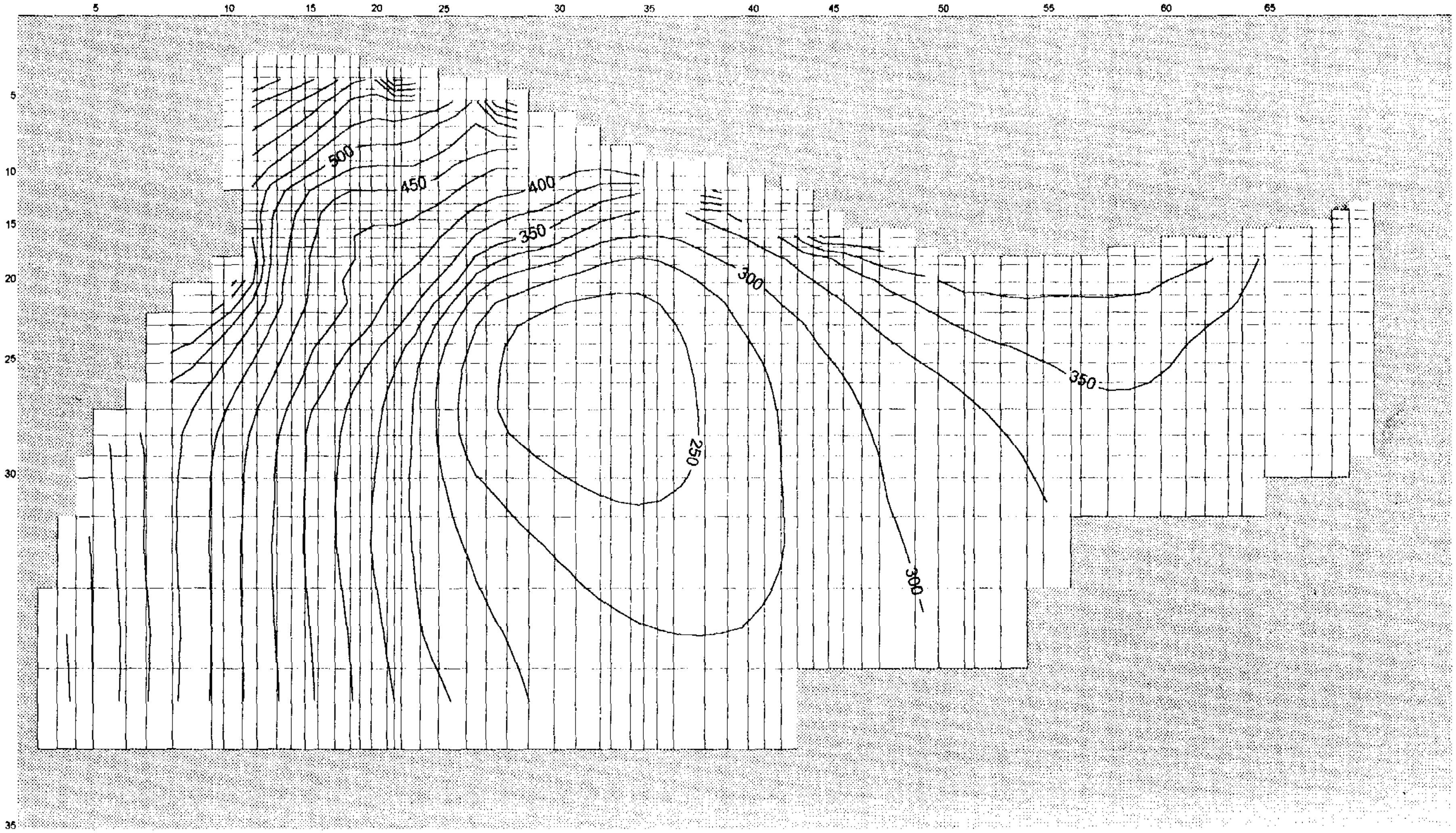
FIGURE 8-17



MONTHLY MEDIAN STREAMFLOWS FOR FRESH-WATER INFLOWS TO NUECES ESTUARY

FIGURE 8-18

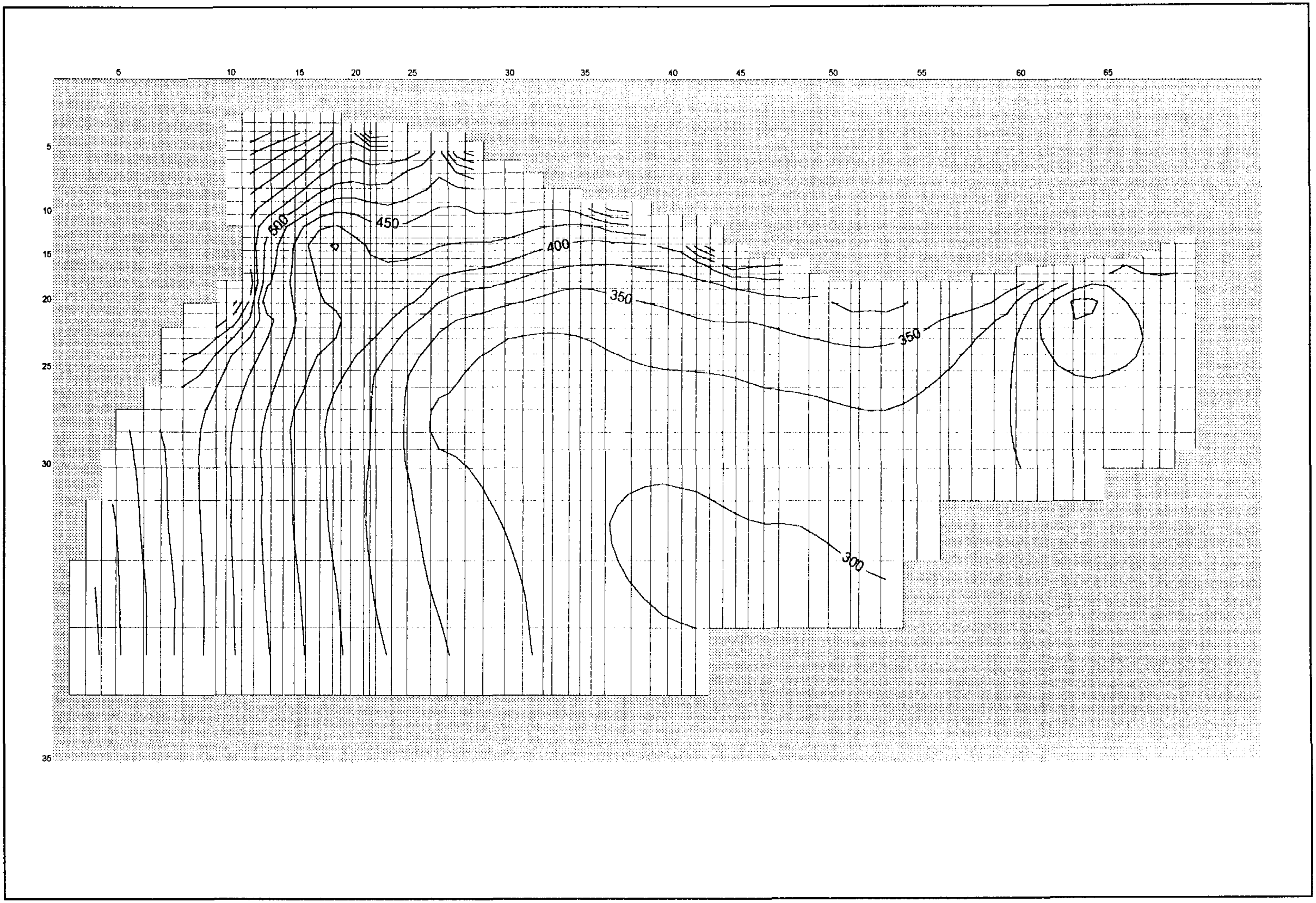
LBG-GUYTON ASSOCIATES



WATER LEVELS IN 2050 USING THE 1994 PUMPAGE SCENARIO

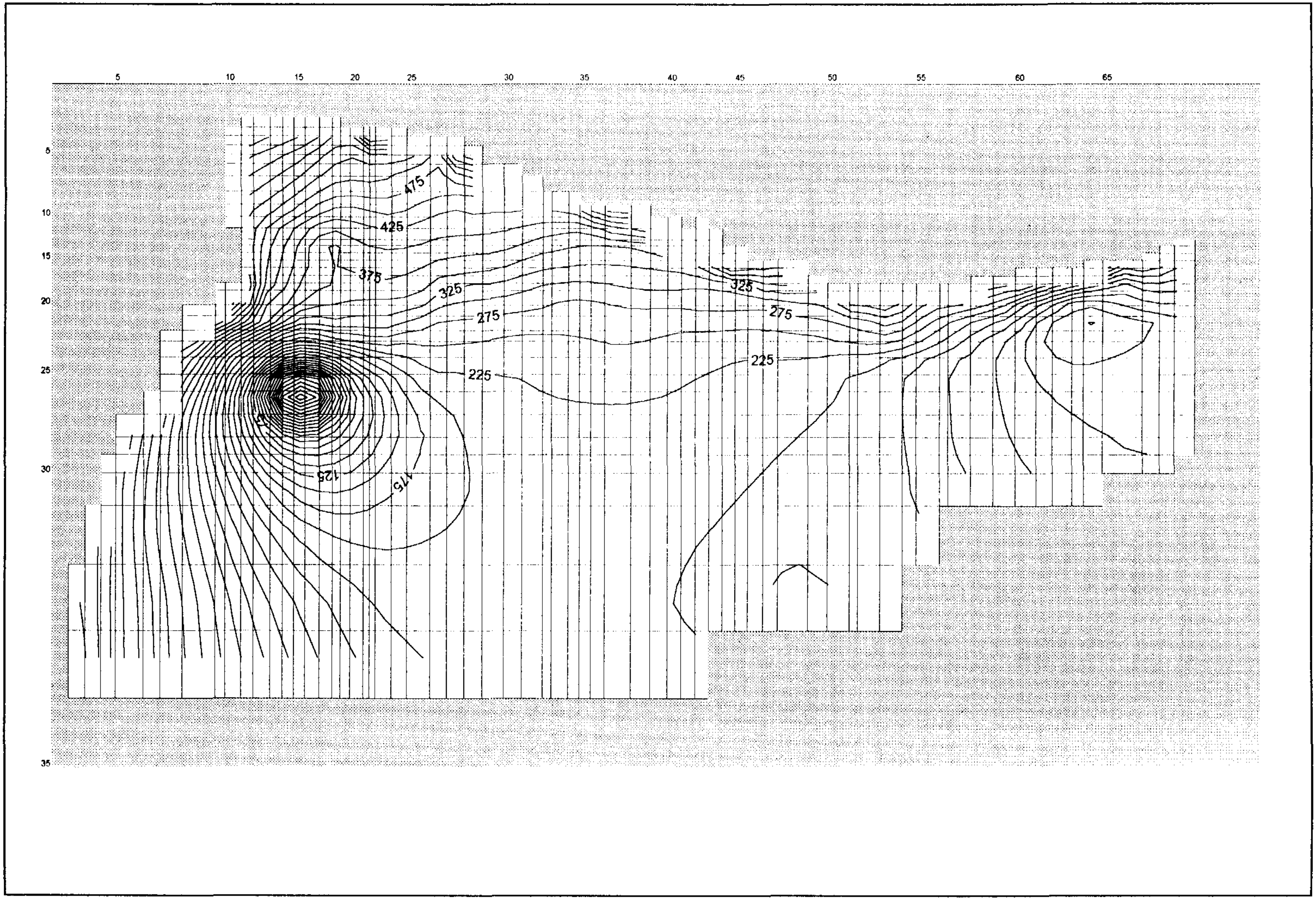
FIGURE 9-1

LBG-GUYTON ASSOCIATES



WATER LEVELS IN 2050 USING THE 2050 PUMPAGE SCENARIO

FIGURE 9-2



WATER LEVELS IN 2050 USING THE "2050 PLUS" PUMPAGE SCENARIO

FIGURE 9-3