TEXAS WATER COMMISSION

BULLETIN 6413

WATER-SUPPLY LIMITATIONS ON IRRIGATION FROM THE RIO GRANDE IN STARR, HIDALGO, CAMERON, AND WILLACY COUNTIES, TEXAS

By

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FOREWORD

The water-supply problems of the Lower Rio Grande Valley in Texas have been continuous since 1948. Beginning in that year, a voluntary association or compact was formed to promote the equitable distribution of the waters of the Rio Grande in Starr, Hidalgo, Cameron, and Willacy Counties, Texas. In 1952 the voluntary restrictions on diversion of water collapsed due to severe drought conditions and consequent shortage of water supply. During the same year, the District Court of Cameron County took custody of the waters of the Rio Grande in the four counties, and appointed a master in chancery to distribute waters equitably between the parties during pendency of suit. A temporary injunction to this effect was entered.

Falcon Dam was closed in 1953; the reservoir filled in 1954. The State Board of Water Engineers in 1953 was designated by the Governor of Texas to request releases of water stored in Falcon Reservoir. From the fall of 1953 until June 1956, the Board performed this function.

In January 1956 approximately 710,000 acre-feet of the United States' share of water was in storage. Water was being released upon demand for the irrigation of more than 700,000 acres of land, together with releases of water for municipal, domestic, and industrial uses, and to various individuals, water districts, and cities. In June 1956 the Board of Water Engineers determined that the United States' share of impounded water was approximately 50,000 acre-feet, which amount would provide municipal, domestic, and livestock demands for only three months without additional inflow into Falcon Reservoir.

History reflects that this period coincided with the severest drought in recorded annals not only in the Lower Rio Grande Valley but in most of the entire State of Texas.

On June 7, 1956 the Board entered an order reserving all water then impounded in Falcon Reservoir for municipal, domestic, and livestock watering purposes. On June 9, 1956 the Rio Grande ceased to flow at Brownsville, Texas. Subsequent releases from Falcon Reservoir to immediately provide municipal, domestic, and livestock water never reached the destination, because upstream irrigation diverters intercepted the water.

The State of Texas, acting in behalf of the Board of Water Engineers, joined by the cities of Brownsville, Raymondville, Harlingen, Mission, McAllen, San Benito, Edinburg, and Pharr, brought suit in the District Court of Hidalgo County, Texas, on June 28, 1956 seeking to restrain and enjoin diversion of water for irrigation when the United States' share of water impounded in Falcon Reservoir was 50,000 acre-feet or less. Plaintiffs also sought the appointment of a Water Master to regulate the diversion of water from the Rio Grande, and asked that upon final hearing all relief be made permanent.

On June 29, 1956 the Court took judicial custody of the waters of the Rio Grande from the point of entrance into Falcon Reservoir to the river's mouth for so long as the United States' share of water impounded in the reservoir was less than 50,000 acre-feet. In subsequent proceedings, the temporary order was extended to prorate water above 50,000 acre-feet for the irrigation of lands that were in cultivation and under irrigation on October 17, 1956.

The defendants' claim of riparian right was severed and tried separately as a spurious class action. The opinion of the Texas Supreme Court affirming the opinion of the San Antonio Court of Civil Appeals, holding that Spanish and Mexican land grants had no riparian right for irrigation, became final on April 11, 1962. Trial of the merits of the main case began in January 1964 on plaintiffs' fifth amended original petition. In its petition, the State alleged that the Texas Water Commission (formerly Texas Board of Water Engineers) was specifically authorized to adopt and enforce rules, regulations, and orders governing the orderly release of water stored in Falcon Reservoir for downstream uses. It was further alleged that the Commission could not perform its statutory duty or trust until and unless the validity, priority of use in point of time, and the duty of irrigation water for each and every right claimed by defendants were judicially declared by the Court.

For the purposes of trial, the Texas Water Commission was requested by the Attorney General to determine the amount of water necessary to satisfy municipal and industrial requirements, to project the total number of acres of land that could be irrigated each year from the available water supply of the Rio Grande, and to prepare a report setting forth its conclusions. This report summarizes the results of the Commission's study.

Management of the release and distribution of the United States' share of water stored in Falcon Reservoir is an engineering function rather than a matter for judicial decree. Apparent in the sections concerning "Irrigation Diversion Requirements" and "Reservoir Operation Guides," this subject is not susceptable to accurate and final determination until the relative rights and claims to the Rio Grande's water are adjudicated.

Article 7550a of the Revised Civil Statutes of 1925 directs the Texas Water Commission to adopt necessary rules, regulations, and orders to affectuate the orderly and efficient release of water stored in Falcon Reservoir. The relief sought by the State of Texas in its Fifth Amended Petition in this suit is directed toward this end.

Looking into the future, present conditions and techniques no doubt will necessitate periodic adjustment of water duty and reservoir management in order to achieve the maximum beneficial use of the water of the Rio Grande. Amistad Reservoir and other upstream changes will compel river and reservoir regulation of substantially the entire Texas portion of the Rio Grande in order to assure that the relative rights of all who possess a right to water are fully protected.

For this reason, the purpose of this report is to assist the Court in reaching judicial decision of the issues in the case before the Court rather than to provide a specific answer for the many problems involved in management of release and distribution of water stored in Falcon Reservoir subsequent to the time final judgment is entered.

TEXAS WATER COMMISSION

Joe D. Carter

Joe D. Carter, Chairman

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INTRODUCTION

General

Direct farm cash income from agricultural production provides an average 35 percent of the annual economy of the Lower Rio Grande Valley of Texas comprised of Starr, Hidalgo, Cameron, and Willacy Counties. This wealth, mainly dependent on irrigation water from the Rio Grande, creates additional wealth in the Valley (1) by providing markets for services, farm equipment, machinery, and materials related to and necessary for agricultural production; (2) by supplying farm products to food processing industries and distributors; (3) by supporting local commercial establishments serving personal needs of the farmer and related workers; and (4) by constituting a valuable asset to the State and National economics and governments. Government in return assists areas of the State and Nation by providing technical and many other services, and in the development of natural resources.

One such governmental accomplishment is International Falcon Dam and Reservoir on the Rio Grande near Roma, Texas, completed in 1953 through the joint efforts of the United States and Mexico. This monumental benefit resulted from the many years of efforts and dreams of numerous individuals and groups along the Rio Grande and from both countries. This reservoir, soon to be joined by Amistad Reservoir currently under construction on the Rio Grande near Del Rio, Texas, provides storage space for conservation of flood waters to be released for beneficial uses during periods when sufficient waters to serve the Valley needs would not be occurring naturally. Both reservoirs will also have storage space for flood-control purposes.

This conservation storage asset in the two reservoirs provides the basis for determinations of estimates by the Texas Water Commission of the limitations in the future areas of lands which can be irrigated with the available water supply.

Summary

Based on the studies made, it is concluded that:

1. The domestic, municipal, and industrial water requirements for the study area will increase from a present use of about 70,000 acre-feet per year to about 130,000 acre-feet per year during the period around the year 2000. Domestic, municipal, and industrial water requirements will continue to increase beyond 2000 but estimates of such future requirements were not made for this study.

2. By the control and conservation of flood waters, Amistad and Falcon Reservoirs can be operated to provide the Valley with: (1) a full water supply for the irrigation of at least 70,000 acres of land cropped in accordance with the 1957-63 average cropping pattern; (2) 124,000 acre-feet of water for domestic, municipal, and industrial requirements; and (3) 60,000 acre-feet of water in storage as a reserve for further assurance of a domestic supply during a drought such as the most severe drought year experienced from 1900 to 1956. This can be done with the combined initial storage capacities of the two reservoirs depleted by at least 50-years sedimentation.

3. After providing for the future domestic, municipal, and industrial water requirements in the amount of 124,000 acre-feet yearly, a full irrigation water supply for optimum crop production can be expected for 600,000 acres 95 percent of time, or for 650,000 acres 89 percent of time, or for 700,000 acres 70 percent of time, or for 750,000 acres 63 percent of time, or for 800,000 acres 47 percent of time.

4. It is concluded that the Amistad and Falcon Reservoirs will provide an adequate water supply for only 650,000 to 680,000 acres, and that with this acreage shortages will periodically occur. This is based on the very small increase in area that could have been irrigated when water demands for larger areas were used in the 57-year study period.

5. The duty of water at the farm headgate averages 0.25 acre-foot per acre less than the irrigation diversion requirement at Falcon Dam which averages 2.21 acre-feet per acre per year. The duty of water at Falcon Dam varies from a minimum of 0.98 acre-feet per acre to a maximum of 3.52 acre-feet per acre. Variations in the total length, wetted bed, and exposed water-surface area of canals supplying the study area, together with increasing river channel conveyance losses downstream from Falcon Dam to canal diversion points, cause a variation in the amount of distribution losses to farm headgates from the upper Valley eastward.

Purpose and Scope of Study

By his letter of September 6, 1963, the Attorney General of Texas requested the Texas Water Commission to determine the amount of water necessary to satisfy domestic, municipal, and industrial requirements, to project the total number of acres of land which could be irrigated each year from the available water supply of the Rio Grande. Also to:

> "1. Review the IBWC computations of the water requirements per acre of irrigated land in the Lower Rio Grande Valley, the diversion requirements by months and years, and the

total number of acres which could be irrigated. Such a study would also show the shortages which would occur on a year-by-year basis for various total numbers of acres to be irrigated, and a determination of the range of the maximum areas that could be economically irrigated in the Lower Rio Grande Valley.

"2. Review similar computations by the U. S. Bureau of Reclamation to obtain the same type of information shown in item 1 above."

and to prepare and present exhibits, a report, and testimony to the 93rd District Court as based on these reviews and independent studies by the Texas Water Commission's Engineering Services employing its methods of computation and analysis.

This request was made of the Commission because certain testimony and evidence presented to the 93rd District Court in the water rights litigation styled "The State of Texas, et al. vs. Hidalgo County Water Control and Improvement District No. 18, et al." caused the question to be raised as to the total number of acres of irrigation the Rio Grande will support.

In response to this letter request, the Commission's Engineering Services reviewed the pertinent work and reports of the International Boundary and Water Commission, United States Section, and of the United States Bureau of Reclamation concerning irrigation and other water requirements and related data in the Lower Rio Grande Valley of Texas. Also, a comprehensive study of extensive detail was made of the projected irrigation diversion requirements for the 4-county Valley area.

The Commission's studies covering the period 1904-1956 by months were based on standard water resource analytical methods, detailed considerations, and use of data pertinent to the soils of the Valley, their use and watershed characteristics; variations in climate; rainfall; crop water requirements; water losses inherent with transport of water in lined canals and in the Rio Grande; and water losses through farm use for irrigation. Also used were an average cropping pattern for the Valley, estimates of future water available in Falcon and Amistad Reservoirs to provide a regulated supply, information on water shortages and tolerances, current and projected domestic, municipal, and industrial water requirements, and economics of the Lower Valley agricultural production under irrigated and dry-land farming.

The period of time chosen for the detailed study, 1904-1956, corresponds with the period 1900 to 1956 used by the International Boundary and Water Commission in its Amistad-Falcon Reservoirs studies contained in Senate Document No. 65, 86th Congress of the United States, 1st Session. The years 1900 to 1903 were omitted from the State's study because of inadequate data for those 4 years. The end year, 1956, was chosen to correspond with the IBWC study.

These studies were made and this report was prepared by the Texas Water Commission, in addition to other services performed for and engineering testimony presented to the 93rd District Court of Hidalgo County, as contributions to the people and associated interests of the Lower Rio Grande Valley of Texas. These contributions were made to aid the Court in resolving the many questions before it arising from the effects of a limited water supply.

In this report, computations and analyses of data, and conclusions based on considered interpretations of the results of the studies are described, discussed, and evaluated qualitatively. Individual studies and reports based on direct investigations in the Valley by members of the Commission's staff were made on specific subjects for expansion of details and technical features.

The study was made on the basis of the total United States' share of the waters of the Rio Grande at Falcon Dam applied to total irrigated areas in the Valley. For the purposes of this study, no consideration was given to specific tracts of land, nor were assumptions made as to which lands had specific valid water rights.

The numerous hydrologic, engineering, and statistical analyses made during the course of this investigation were each done using generally accepted practices and procedures.

Physical Considerations

The geography, geology, topography, climate, soils, salinity, drainage, irrigation practices, available water from the Rio Grande, rainfall, ground water, location of points of diversion, lengths and areas of open canals and laterals, closed-conduit distribution systems, and probable operation schedules for Falcon and Amistad Reservoirs were considered in planning the details of studies for this report.

Previous Investigations and Reports

During the course of study in preparation for this report, many reports and working files concerning agricultural practices and production, and land and water requirements in the Lower Rio Grande Valley were reviewed. These reports are acknowledged in the list of references at the end of this report. They include study material and reports of investigations concerning irrigation supportable in the Valley by total flows of the Rio Grande, rainfall, and by underground water in the area.

Agencies responsible for the material and reports reviewed were the United States Reclamation Service and its successor, the U. S. Bureau of Reclamation; the International Water Commission, United States and Mexico, and its successor, the International Boundary and Water Commission, United States and Mexico; the U. S. Department of Agriculture's Agricultural Research Service, Economic Research Service, Soil Conservation Service, and Statistical Reporting Service; the Texas Agricultural and Mechanical College System and its successor, the Texas A&M University System; the University of Texas; the United States Study Commission-Texas; records of the Special Water Master for the 93rd Judicial District of Texas; and the State Board of Water Engineers and its successor, the Texas Water Commission. A few reports by private consultants were also reviewed.

Acknowledgements

The Texas Water Commission extends its thanks and acknowledges its appreciation to the administrative and technical personnel of the many government agencies and the educational institutions who provided published reports and

working files and gave their assistance, counsel, and guidance to members of the Commission's Engineering Services staff throughout the period of study for this report. These agencies are as follows:

U. S. Department of Agriculture,
Agricultural Research Service, Weslaco,
Soil Conservation Service (SCS) Texas State Office, Temple,
SCS Engineering and Watershed Planning Unit, Fort Worth,
SCS Area Office in the Lower Rio Grande Valley, Harlingen,
SCS Work Unit Office, Austin,
Statistical Reporting Service, Austin;

U. S. Department of Commerce,
Weather Bureau, State Climatology Office, Austin;

U. S. Department of Interior,
Bureau of Reclamation, Area Planning Office, Austin,
Bureau of Reclamation, Project Office, Weslaco;

U. S. Department of State,
International Boundary and Water Commission, United States Section, El Paso and Laredo;

State of Texas 93rd Judicial District, Hidalgo County, Special Water Master's Office, McAllen;

State Soil Conservation Board, Temple;

Texas A&M University System,
Texas Agricultural Experiment Station, College Station and Weslaco,
Texas Agricultural Extension Service, County Agents Offices, Starr, Hidalgo, Cameron, and Willacy Counties,
College of Agriculture, College Station,
Department of Agricultural Economics and Sociology,
Department of Agricultural Engineering,
Department of Soil and Crop Sciences;

Lower Rio Grande Valley Chamber of Commerce, Weslaco;

Cameron County Water Control & Improvement District No. 1, Harlingen;

Cameron County Water Control & Improvement District No. 5, Brownsville;

Cameron County Water Control & Improvement District No. 13, Lozano;

Donna Irrigation District, Hidalgo County No. 1, Donna;

Hidalgo County Water Control & Improvement District No. 1, Edinburg;

Hidalgo County Water Control & Improvement District No. 6, Mission;

Hidalgo County Water Control & Improvement District No. 7, Mission;

Hidalgo & Cameron Counties Water Control & Improvement District No. 9, Mercedes;

Hidalgo & Willacy Counties Water Control & Improvement District No. 1, Monte Alto;

La Feria Water Control & Improvement District Cameron County No. 3, La Feria; and,

Starr County Water Control & Improvement District No. 2, Rio Grande City.

The Commission's appreciation for assistance and counsel provided its staff is also extended to farm managers in the Valley and to attorneys for the Districts.

Special thanks are extended to Assistant Attorney General Frank R. Booth for his assistance.

Personnel

This report was prepared in the Texas Water Commission's Engineering Services by John J. Vandertulip, Chief Engineer; Louis L. McDaniels, Research Program Coordinator in the Planning Division; Manton A. Nations, Director; and C. Olen Rucker, Hydrology Program Coordinator in the Surface Water and Permits Division, Seth D. Breeding, Director.

The studies culminating in this report were planned, designed, and supervised by Messrs. Vandertulip, McDaniels, and Rucker. The studies were coordinated in Engineering Services by Mr. McDaniels who also directly supervised the portions of the investigation on climate and economic evaluation of agricultural water use in the Planning Division. Mr. Rucker directly supervised the portions of the investigation concerned with cropping patterns, soils information, water losses, computational procedures and irrigation diversion requirements, and reviews of the hydrology of the Rio Grande.

The personnel and their specific assignments in this investigation are as follows:

Climate of the Lower Rio Grande Valley, Texas, by John T. Carr, Jr.;

Cropping Pattern of the Lower Rio Grande Valley, Texas, 1957-1963, by Robert L. Warzecha;

Economic Evaluation of Agriculture Water Use in Starr, Hidalgo, Cameron, and Willacy Counties, Texas, by Paul T. Gillett;

Computational Procedures and Irrigation Diversion Requirements in the Lower Rio Grande Valley, Texas, 1904-56, by Henry H. Porterfield, Jr.;

Soils of the Lower Rio Grande Valley, Texas, by Ignatius G. Janca;

Review of Reports by the United States Section, International Boundary and Water Commission, United States and Mexico, on the Hydrology of the Rio Grande, 1900-1956, by Allen E. Richardson;

Water Transmission Losses to Irrigators of the Lower Rio Grande Valley, Texas, by Ralph B. Hendricks.

In the Electronic Data Processing Division, Ivan M. Stout, Director, Mrs. Lura C. Bentz programmed and processed voluminous computations of monthly crop and fallow land consumptive use and irrigation requirements for the period 1904-1956 on the IBM 1401 Data Processing System used by this Agency. The tabulations of the results of these computations are bound separately and are a part of the Commission's permanent files available for inspection by interested parties.

Method of Presentation

This text summarizes the results of the several separate portions of this investigation. Information describing the Valley and some of its natural characteristics is presented to provide an understanding of the agricultural associated problems for people outside of the area who are interested in but not familiar with these details. The criteria and their basis for selection are described. The method of computing crop consumptive use and water requirements is explained. Analyses of the results of the computations are described, and the interpretations of the significance of the findings are presented.

Charts depicting the irrigation requirements at the farm and procedures for computing the irrigation diversion requirements at Falcon Reservoir for the principal crops considered in this report are presented for each of three study areas. These study areas were selected on the basis of similarity of general climate, characteristic rainfall, potential evaporation, soils, topography, and cropping. They are not rigidly defined by boundaries but are transitional in order to minimize the computations required for this report yet be representative of the changes from east to west within practical limits.

These charts are tools affording evaluation of limitless future conditions and cropping patterns as may be desired by any individual, including respective irrigation diversion requirements and the economic value according to any selection.

The potential risks of water shortages are presented for various acreages generally supplied a full water requirement, as duration, probability and frequency of recurrence information.

Evaluations of the gross economy for various assumed irrigated acreages can be estimated for comparison as desired by interested individuals.

The conclusions contain charts illustrating the inter-relationships of the water resource and its use, and recommendations for future management.

RESULTS OF STUDY

Location

The four southernmost counties in Texas--Starr, Hidalgo, Cameron, and Willacy--are collectively known as the "Lower Rio Grande Valley." The parts of these counties using Rio Grande waters for domestic, municipal, and industrial purposes and for the irrigation of agricultural croplands, pasture lands, and orchards are covered by the studies discussed in the report. The four-county area and the parts generally irrigated with Rio Grande waters, known more simply as the "Valley," are shown in Figure 1.

Geography

The Lower Rio Grande Valley has about 4,230 square miles of land area. It is wholly within the West Gulf Coast Plain Section of the Coastal Plain Province of the Atlantic Plain Major Division of North America. It is a part of the Rio Grande Plain Land Resource Area in the Texas Geographic Region known as the South Texas Plain.

Most of this area is a broad, flat, upland plain of young land lying to the north of the Arroyo Colorado and extending inland from the Gulf of Mexico and Laguna Madre to mature coastal plain generally marked by the Bordas escarpment near the center of Starr County. Land surfaces slope gently from sea level at Laguna Madre to an elevation above mean sea level of about 100 feet in the middle of Hidalgo County and more rapidly to about elevation 250 feet in western Hidalgo County. There, rolling hills begin and rise to above elevation 500 feet near the middle of Starr County. The eastern slopes of this plain have long shallow depressions and undulations grading into sinks and dunes in the northern part. Along the southern edge of the upland plain, the land slopes southeastward to merge with the Rio Grande delta extending to the south of the Arroyo Colorado.

The Rio Grande Valley bottomland, averaging about 3 miles wide in Starr County, slopes gently southeastward and merges with the delta beginning in Hidalgo County. The delta slopes eastward and northeastward away from the Rio Grande bordering the Valley on the south. The delta is prominently scarred with old river channels known as "resacas." Many of these form narrow lakes bounded by ridges preventing natural drainage of much of the lowlands between the Arroyo Colorado and the Rio Grande.

The Rio Grande drains part of the Valley. The most downstream drain from the upland plain drains rolling hills, and is tributary to the river about 10 miles west of Mission in southwestern Hidalgo County. A low ridge known as Mission Ridge extends from the southern edge of the upland plain near Mission to the east of Donna in eastern Hidalgo County where it flattens and merges with the general land level. This ridge prevents drainage of the upland plain to the Rio Grande. The eastern part of the Valley is drained into Laguna Madre by small coastal streams, by the Arroyo Colorado, and by the former distributary channels of the Rio Grande known as resacas. Artificial floodways and the International Falcon Reservoir have decreased the threat of frequent flooding in parts of the delta east of Weslaco, Hidalgo County, and in the lower Rio Grande.

Geology

Formations containing deposits of silt, sand, gravel, and clay underlie the Lower Rio Grande Valley, and dip toward the Gulf Coast with the more recent formations cropping out inland in parallel belts. These subsurface materials are complexly interbedded layers of largely Rio Grande flood plain and deltaic deposits, which have not been identified with certainty as to specific formations forming three of the four major ground-water reservoirs. However, for

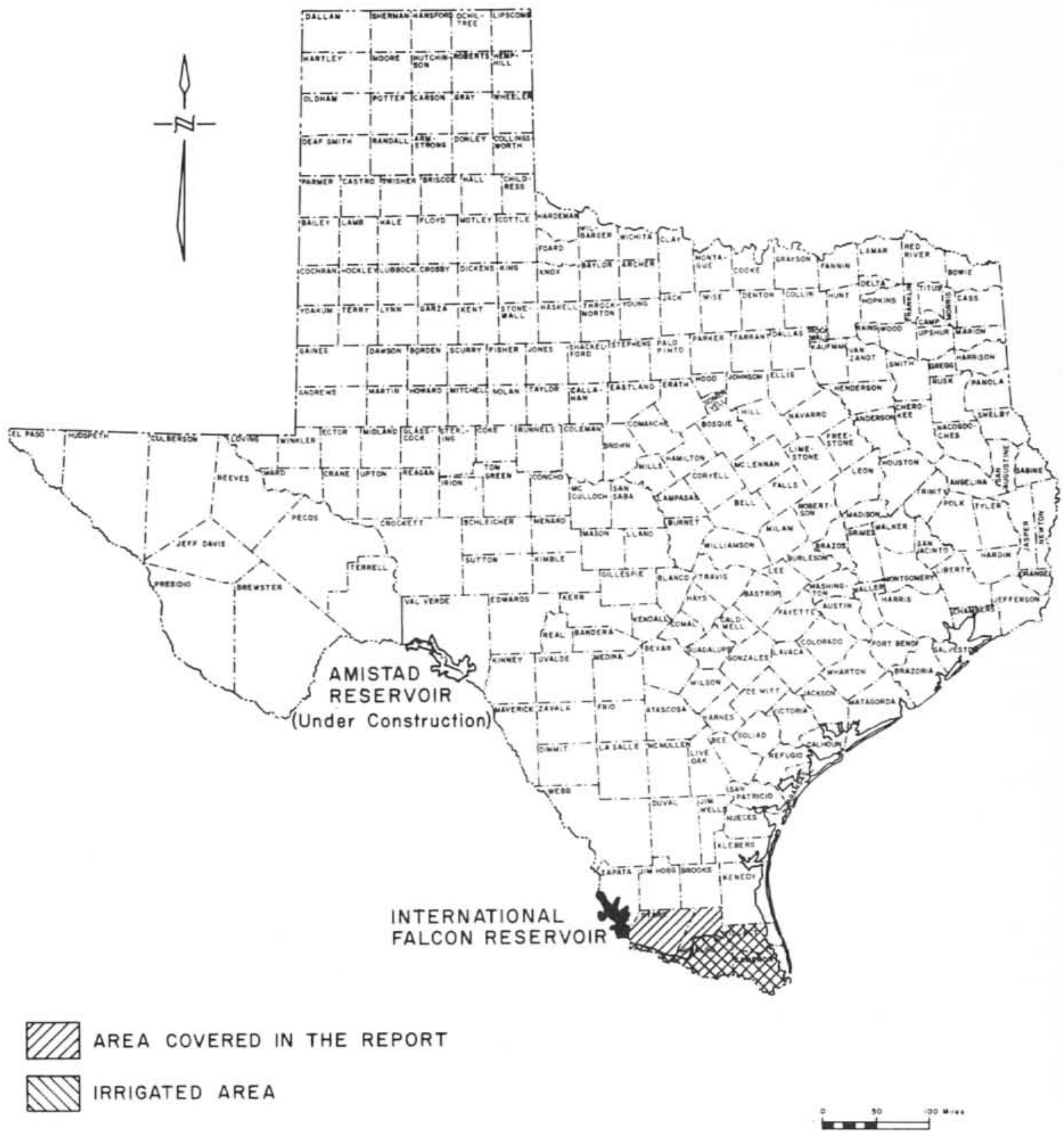

Figure 1

Location in Texas of the Lower Rio Grande Valley, Showing Extent of Irrigation

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convenience in discussing ground-water conditions, three major sources of ground water have been named. In northeastern Starr County, the Oakville sandstone is an important source of water for industrial use; in central Hidalgo County the Linn-Faysville ground-water reservoir is a source of irrigation water; and the lower Rio Grande and the Mercedes-Sebastian ground-water reservoirs are sources of irrigation water in southeastern Starr, southern Hidalgo, western Cameron, and southwestern Willacy Counties.

More complete and detailed discussions with presentations of basic data on geography, geology, and ground water are contained in Bulletin 6014, Volumes I and II, "Ground-Water Resources of the Lower Rio Grande Valley Area, Texas," February 1961, prepared by the Texas Board of Water Engineers and the U. S. Geological Survey in cooperation with the Lower Rio Grande Valley Chamber of Commerce, Inc., which can be obtained from the Texas Water Commission.

Climate

The climate of the Lower Rio Grande Valley varies east to west from sub-humid to semiarid according to the criterion that the line of 20-inch average annual rainfall is the boundary separating the two.

Average annual rainfall varies from more than 26 inches along the Gulf Coast in eastern Cameron and Willacy Counties to less than 17 inches in southern Starr County.

Average annual-mean air temperature varies from less than 73.5°F in northern Starr and Hidalgo Counties to more than 74°F in southern Starr, Hidalgo, and Willacy Counties and nearly all of Cameron County.

Average annual potential lake evaporation varies from 56 inches in the eastern tip of Cameron County to more than 63 inches along the western edge of Starr County.

The prevailing winds are generally from a southeasterly direction bringing into the Valley maritime-tropical or modified maritime-tropical air and Gulf of Mexico moisture in varying amounts.

The variations in the prevailing winds exert a marked influence on rainfall and evaporation in the Valley. The more southeasterly winds along the coast transport moisture-laden Gulf air directly into Cameron and Willacy Counties providing water vapor contributing to the higher annual rainfall and higher humidities. More southerly winds taking a more circuitous route across the hot Mexican countryside south of the Rio Grande into Hidalgo and Starr Counties are hotter and relatively drier and thus contribute to lower annual rainfall, lower humidities, and higher maximum temperatures.

The effect of these variations in climatic characteristics in the Valley on agriculture is to increase the amount of water required for comparable crop production from the east to the west. For this reason, three study areas in the Valley were selected for separate investigation of irrigation requirements. The boundaries of the three areas are not rigidly defined but do approximate Starr County as Area 1, Hidalgo County as Area 2, and Cameron and Willacy Counties as Area 3. Generally representative central points for the irrigated portions of these Areas are respectively Rio Grande City, Edinburg, and Harlingen.

The mild winter air temperatures of the Valley are favorable to citrus production and to successive cropping, especially winter vegetables. The favorableness of temperatures in the Areas is demonstrated by the annual minimum temperature for the consecutive 45 years 1919-1963 of being 32°F or higher for 15 years in Harlingen and for 11 years in Edinburg. During the consecutive 36 years 1928-1963 at Rio Grande City, the annual minimum temperature was higher than 32°F for 1 year.

There is a 45-percent probability of having an annual minimum free-air temperature equal to or less than the average annual minimum of 26°F at Rio Grande City, a 42-percent probability of having an annual minimum free-air temperature equal to or less than the average annual minimum of 28°F at Edinburg, and a 40-percent probability of having an annual minimum free-air temperature equal to or less than the average annual minimum of 29°F at Harlingen.

The characteristic monthly distribution of climatic elements and historical annual climatic data for the standard climatological 30-year base period 1931-60 for Areas 1, 2, and 3 in the Valley are depicted on Figures 2 through 7.

Soils

The dominant soils in the Lower Rio Grande Valley are the Willacy, Brennan, Hidalgo, Victoria, Harlingen, Laredo, Cameron, Medio, Delfina, and Orelia series. Their surface texture ranges from heavy clays to fine sandy loams and include intermediate gradations of sandy clays, silty clays, clay loams, sandy clay loams, silty clay loams, silt loams, and sandy loams.

These soils vary in depth and profile, with surface textures as named overlying subsoils of similar textures in varying combinations. These overlie substrata principally comprised of calcareous materials including deltaic and marine earths, deltaic clays, sandy clays, sediments from the Rio Grande Basin, and stratified sandy and silty alluviums.

Their internal and external characteristic drainage grades from none to moderately rapid. Surface, subsurface, and substrata salinities exist in amounts often related directly to the water table.

For this report, the studies were concerned with the available moisture-holding capacities of the soils and the moisture-replacement depths for crops grown in the Valley. The available moisture is the quantity of soil water available for plant use and is the quantity of water retained in the soil between field capacity and permanent wilting content. The moisture-replacement depth is the depth of soils from which the roots of a plant utilize water for growth. Also of concern was the degree of depletion of available soil moisture which could be tolerated by each Valley crop before injurious plant stresses occurred. This amount is generally accepted as 50 percent of capacity.

The soils of various series were grouped according to types having similar profile characteristics of depth, texture, permeability, available moisture-holding capacities, and consistency of the various horizons including similar crop adaptabilities and productiveness.

These groupings of soil types were consolidated into three soil groups within which the available moisture-holding capacity per foot of depth for the

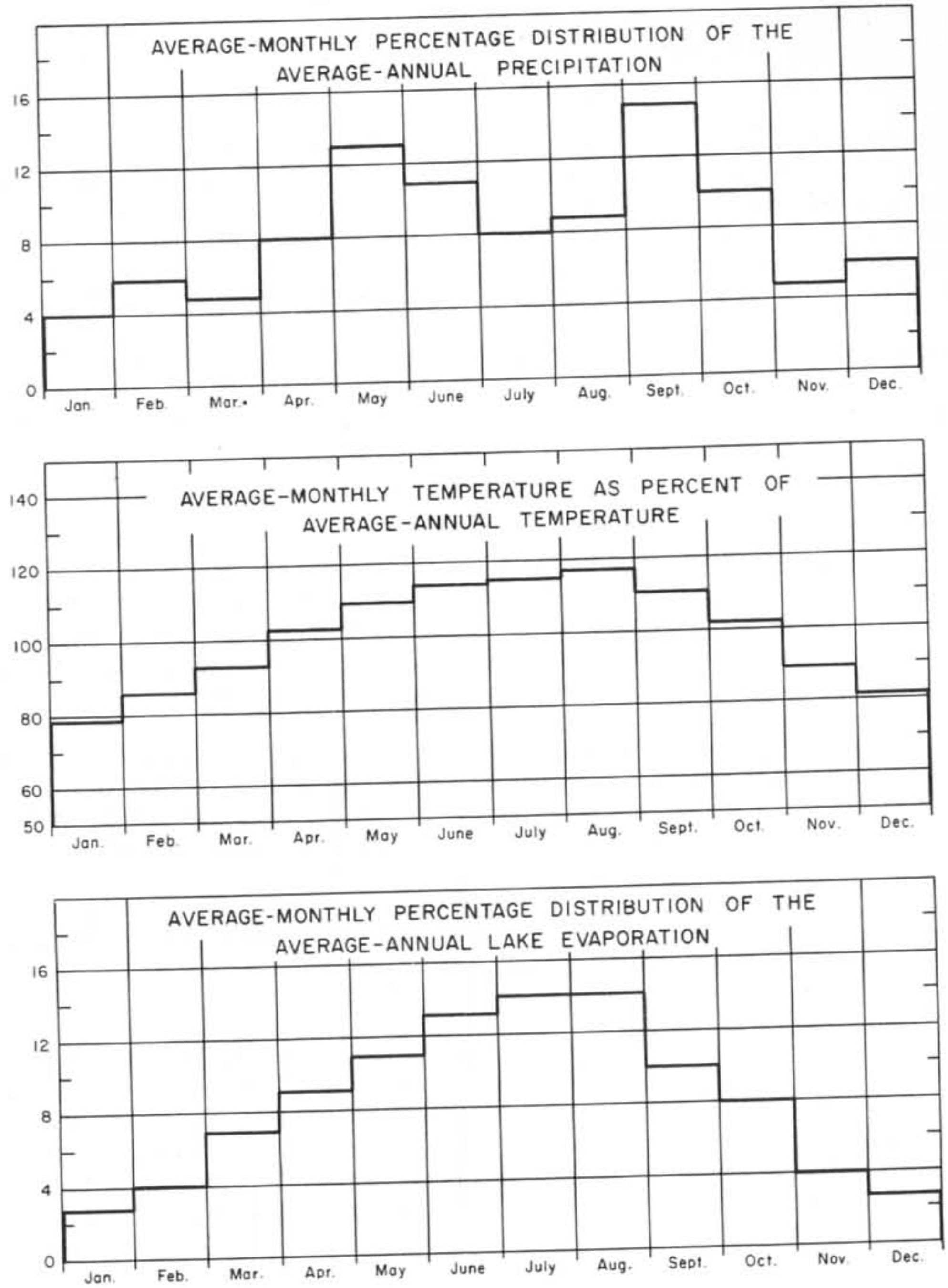

Figure 2

Characteristic Distribution of Climatic Elements, Valley Area I

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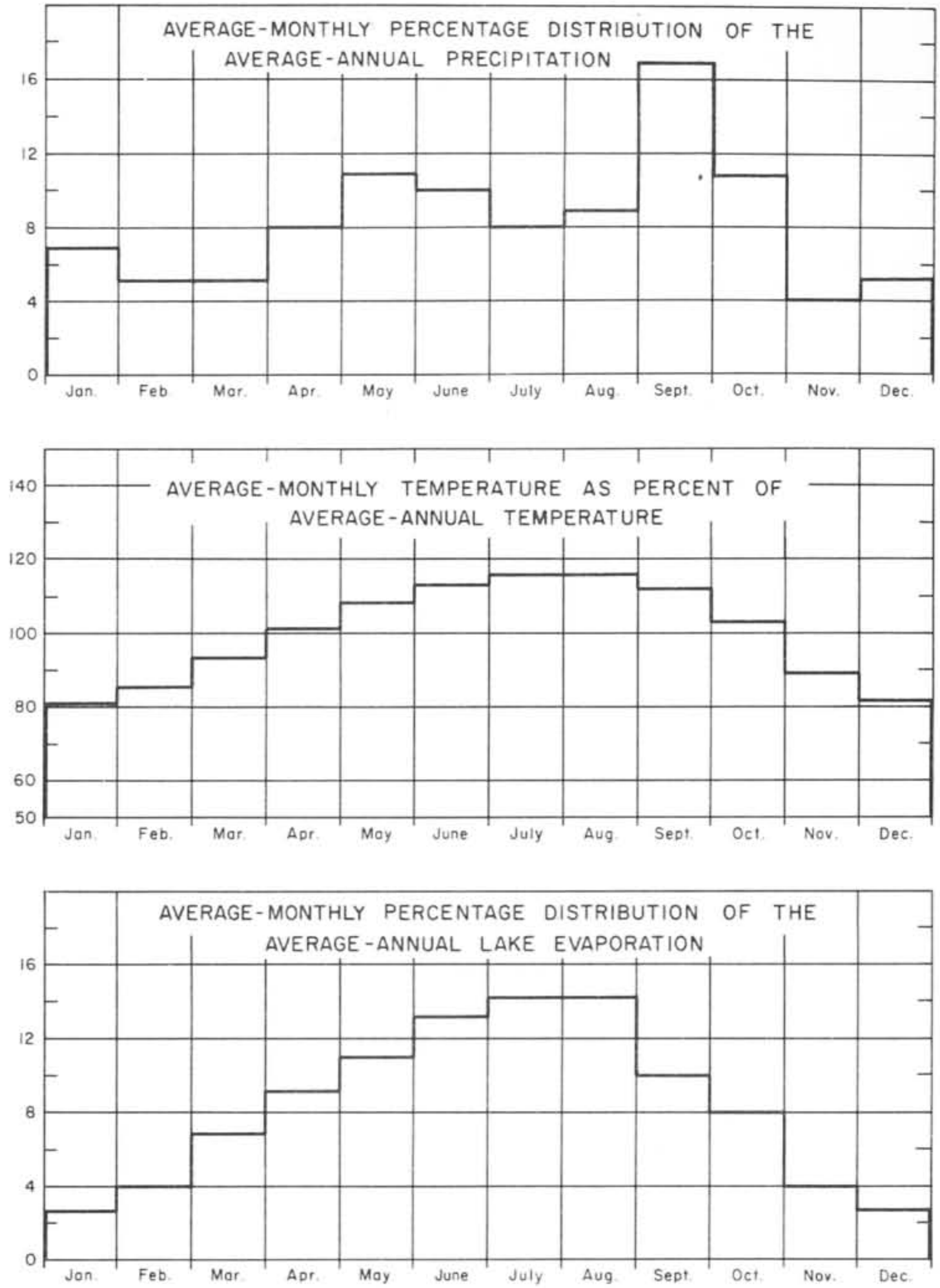

Figure 3

Characteristic Distribution of Climatic Elements, Valley Area 2

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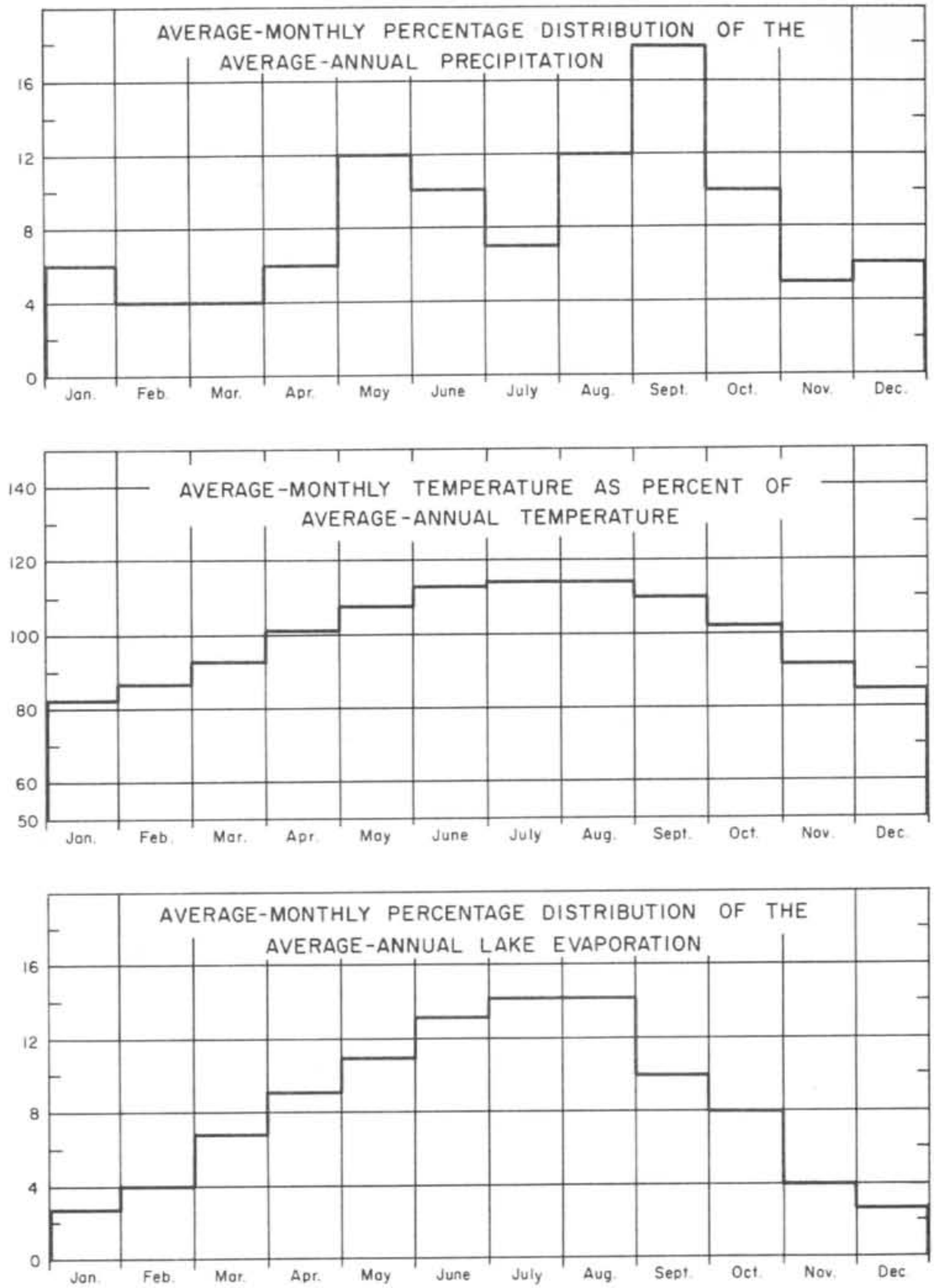

Figure 4

Characteristic Distribution of Climatic Elements, Valley Area 3

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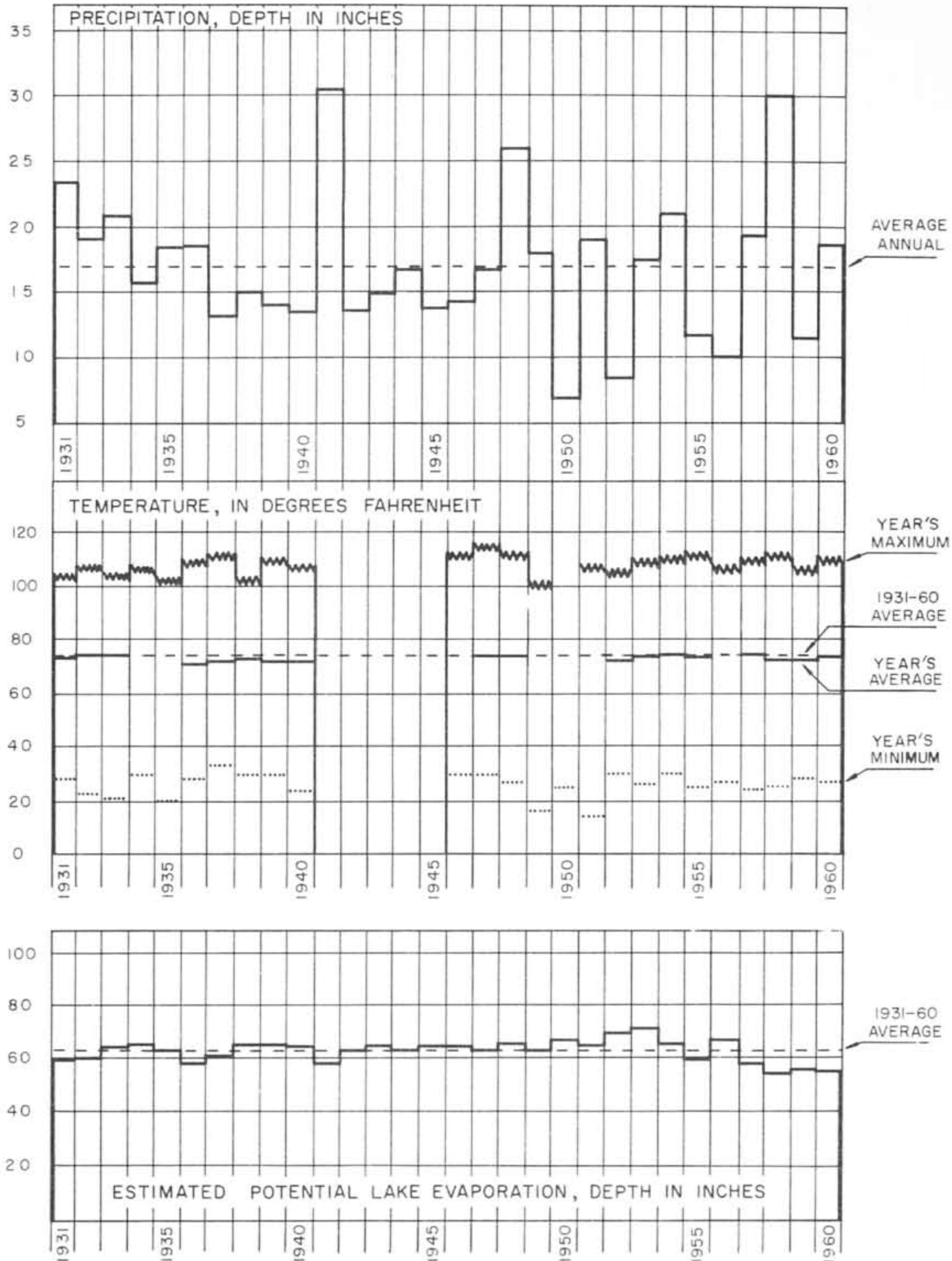

Figure 5

Historical Annual Climatic Data for Valley Area I, Base Period 1931-60

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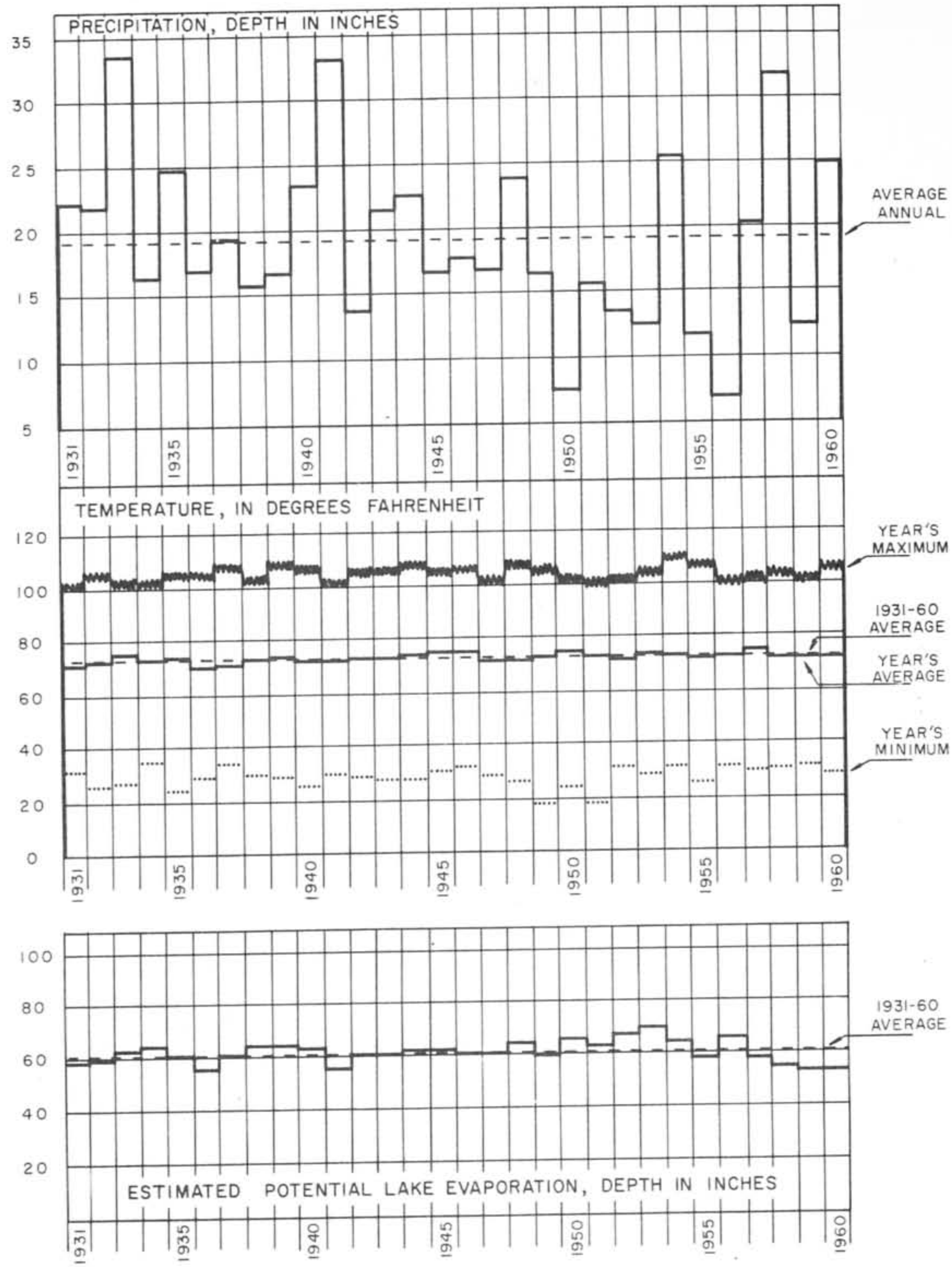

Figure 6

Historical Annual Climatic Data for Valley Area 2, Base Period 1931-60

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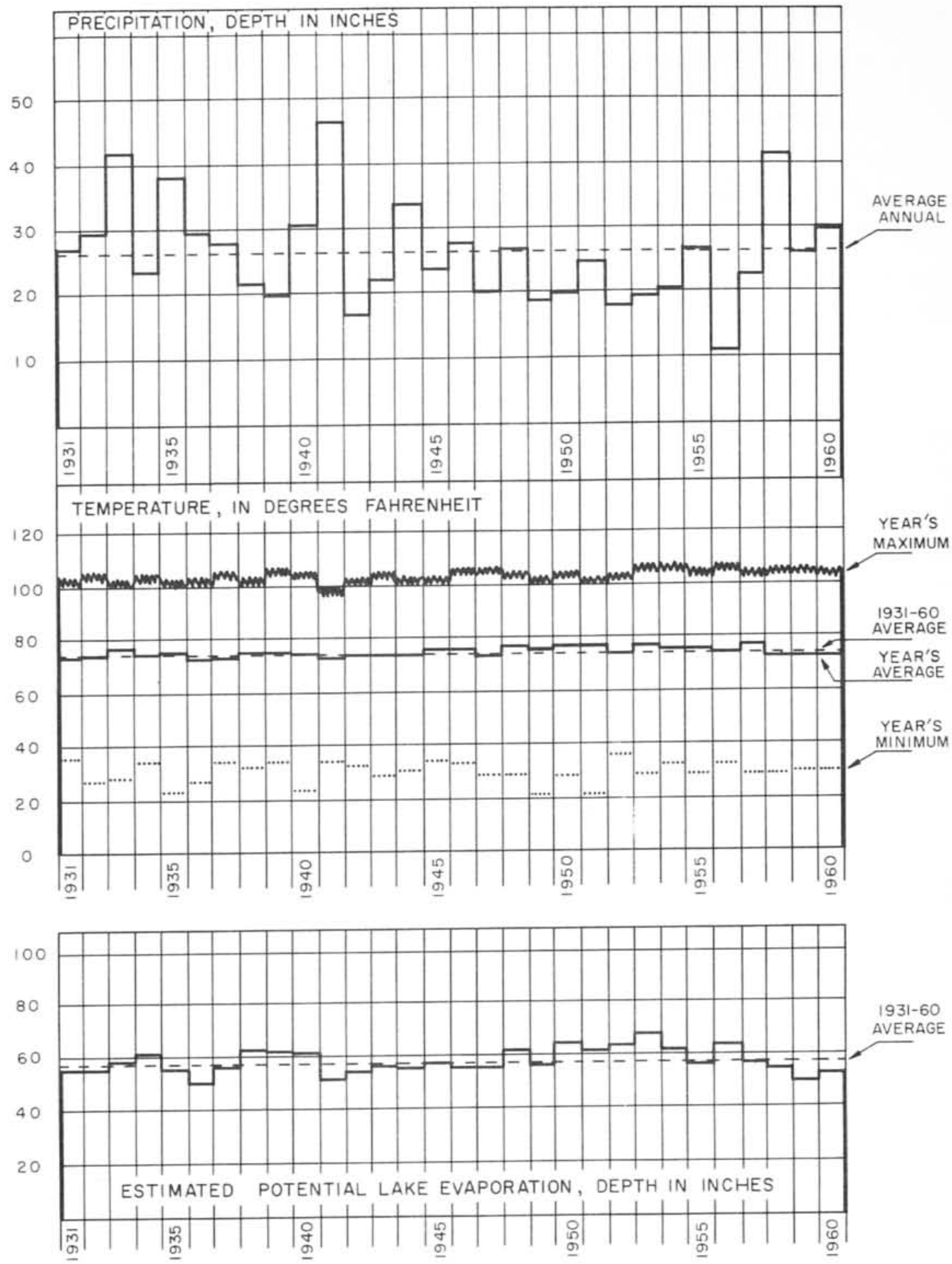

Figure 7

Historical Annual Climatic Data for Valley Area 3, Base Period 1931–60

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soils included did not vary more than half an inch, and the moisture-replacement depths for crops in the medium, deep, and shallow-rooted crop groups were practically equal for each group.

Soil Group I was comprised of clays; Soil Group II--clay loams, sandy clay loams, and silty clay loams; and Soil Group III--fine sandy loam. The medium, deep, and shallow-rooted crops were grouped as Crop Group 1, 2, and 3, respectively.

Table 1 shows the moisture-replacement depth and the available moisture-holding capacity for the three soil groups and the three crop groups in each.

The percentages of irrigated cropland in each soil group in each study area in the Valley are shown in Table 2.

Salinity and Drainage

The Valley soils content of soluble salts and the poor natural drainage in some areas have long been a problem. Generally, the soils respond to leaching by rainfall and by extra irrigation. However, the characteristically high water table following heavy rainfall and extensive irrigation combined with poor surface and subsurface drainage do not contribute to successful treatment and correction of salinity problems.

Federal and State agencies, including the U. S. Bureau of Reclamation, the U. S. Department of Agriculture's Agriculture Research Service and Soil Conservation Service, the Texas A&M University System's Agricultural Experiment Station and Agricultural Extension Service, and numerous water districts are working toward the correction of the surface and subsurface drainage problems. When adequate drainage has been accomplished, rains and irrigations should reduce the soluble salts in the soils to such small amounts that corrective treatment by artificial leaching will not be required.

This study has been made on the basis that adequate corrective measures will be taken to provide proper drainage. Water for leaching purposes has not been included as a crop water requirement.

Cropping Pattern

The percentage of the principal crops grown in the Lower Rio Grande Valley irrigated areas during the 7-year period 1957-63 were combined into an average cropping pattern per unit of Valley irrigated cropland for use throughout the period of study of crop consumptive use of water and the determination of irrigation requirements.

The long growing season in the Valley afforded by the favorable climate for winter agricultural production and the availability of water for irrigational use to supplement rainfall and soil moisture allows intensive use of land units for the production of several crops each year. To facilitate the computation of irrigation requirements, the Valley cropland use was consolidated into a unit-use per year which credits the two or more annual vegetable crops and other double-cropping practices instead of single crops and subsequent fallowing only.

Table 1.--Valley soil group moisture capacities

Soil group	Crop group	Moisture replacement depth, in feet	Available moisture holding capacity, in inches
I	1	2	4.9
I	2	3	7.1
I	3	2	4.9
II	1	4	7.7
II	2	5	9.3
II	3	2	4.0
III	1	5	8.1
III	2	6	9.7
III	3	3	4.0

Table 2.--Percentage of irrigated cropland in each soil group in Valley study areas

Area	Soil group	Percentage in irrigated cropland
1	I	8
1	II	41
1	III	51
2	I	12
2	II	61
2	III	27
3	I	23
3	II	70
3	III	7

As determined by the field investigations, the monthly irrigated acreage for the principal crops varied because of staggered planting dates and the related shifts in acreages cropped. For practical purposes of computations in this study, the planting dates and acreages were consolidated into an average annual figure for each crop. In all cases, the planting dates were selected as the first day of a month. These dates and the length of growing season for each crop were selected in accordance with the data contained in the Texas Board of Water Engineers Bulletin 6019, "Consumptive Use of Water by Major Crops in Texas," November 1960.

This consolidation of the cropping pattern results in 111-percent crop use per unit of cropland annually. The principal crops grown in the Valley and their respective unit percentages of cropping are shown in Table 3.

These crops were combined into three groups with medium, deep, and shallow-root depths respectively, for use in each of the three soil groups and study areas as follows:

Crop Group 1 -- Corn, Cotton, Grain Sorghum, and Deep-Rooted Vegetables;

Crop Group 2 -- Perennial Pasture and Citrus;

Crop Group 3 -- Shallow-Rooted Vegetables.

Consumptive-Use Data

Consumptive use of water by the major crops grown in the Valley as discussed under "Cropping Pattern" was computed by the Texas Water Commission on a month-by-month basis for the 53-year study period 1904-1956. The Commission's method for computing crop consumptive use of water under optimum conditions was used throughout the study. This method is described in its November 1960 Bulletin 6019, "Consumptive Use of Water by Major Crops in Texas." The method is based on crop consumptive-use experiment data correlated with climatic indexes computed from climatological data. The crop consumptive-use experiment data were obtained from the Valley and also from other agricultural research and experiment stations in Texas and other states.

The climatic indexes are numbers expressing the complex composite relationship of air temperature, dew point temperature, solar radiation, and wind movement as derived by an equation discussed and referenced in Bulletin 6019. These four climatic factors are the principal elements causing evaporation of moisture from land, vegetal, and water surfaces. Climatic indexes for the entire State have been computed and compiled by months for the period 1903-1963 by the Commission's staff for each area of Texas for use in computing estimates of consumptive use of water by agricultural crops and beneficial vegetation, consumptive waste of water by nonbeneficial vegetation, and evaporation of moisture from land and water surfaces.

The consumptive-use coefficients for the crops grown in the Valley as given in Bulletin 6019 are shown in Table 4 for the crops included in the average yearly cropping pattern used in this study. These coefficients were applied to climatic indexes month by month to compute the estimates of consumptive use of water by each crop grown during each year of the 53-year period of study.

Table 3.--Average cropping pattern in the Valley, 1957-63

Crop	Distribution, in percent
Corn	2
Cotton	41
Pasture, perennial	8
Vegetables, deep-rooted:	
1st crop	11
2nd crop	11
Vegetables, shallow-rooted (two crops or more)	10
Sorghum, grain:	
1st crop	9
2nd crop	9
Citrus (mixed)	10
Total effective unit cropping	111

Table 4.--Crop consumptive-use coefficients for Valley Study Areas 1, 2, and 3.

(Data from TBWE Bulletin 6019 for sub-areas 4A and 4B)

Crop	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Corn, Planted on 1st of month........	--	--	0.15	0.45	0.81	1.35	1.00÷2*	--	--	--	--	--
Cotton, Planted 1st of month......... (5-1/2 month growing period)	--	--	.23	.24	1.03	.83	.61	0.10÷2*	--	--	--	--
Pasture, perennial...................	0.53	0.53	.74	.69	1.03	.90	.93	.64	0.94	0.92	0.74	0.43
Vegetables, deep-rooted:												
1st crop...........................	.38	.48	.93	.78	.57	--	--	--	--	--	--	--
2nd crop...........................	--	--	--	--	--	--	--	.38	.48	.93	.78	.57
Vegetables, shallow-rooted, Planted 1st of September...........	.81	.58	.53	--	--	--	--	--	.25	.70	1.03	.75
Sorghum, grain:												
1st crop...........................	--	--	.43	.84	1.01	.60	--	--	--	--	--	--
2nd crop...........................	--	--	--	--	--	--	--	.43	.84	1.01	.60	--
Citrus (mixed)......................	.60	.66	.56	.69	.61	.67	.57	.64	.72	.65	.66	.68

* Applicable for half a month; applied to climatic index for a month.

To account for the moisture evaporated from croplands during periods of rest between crops, the lands were assumed fallow and the rate of evaporation was estimated to be 30 percent of the potential rate of free-water evaporation. Using the climatic indexes as equivalent to free-water evaporation rates, estimates of monthly moisture losses from fallow land were computed for use with the crop consumptive-use amounts in determining crop irrigation requirements.

Irrigation Requirements

Irrigation requirements for each crop included in the average cropping pattern used for the Valley in this study were computed month by month for the 53-year period 1904-1956. These irrigation requirements are the amounts of water estimated to have been needed in the field to supplement the available amounts of water occurring as rain in order to fully supply the consumptive-use requirements of the crops. The supplementary amounts were determined on a continuous basis by water-balance accountings of moisture losses from fallow land, consumptive-use requirements of crops, rainfall, and available soil moisture occurring naturally for crop use.

Generally, the total rainfall is not effective in supplying water directly for crop use. Some of the causes of total rainfall not being fully available for crop uses are: surface runoff, interception by foilage and subsequent evaporation into the air, rainfall in excess of crop needs and the soil reservoir's lack of capacity to store these excesses, saturation of soils and percolation through soils to levels below which crop roots are not able to recover and use the moisture, and evaporation from fallow land.

The effective rainfall as computed and used in this study is the total rainfall minus the portion estimated as producing surface runoff. Although runoff conditions in the Valley as a whole are indefinite, consistent allowances for runoff following rainfall were made on the assumption that adequate surface and subsurface drainage of the Valley lands will be accomplished in the future.

Specific monthly amounts of rainfall were computed on the basis of rainfall-effective rainfall relationships established by Thompson, Townsend, and McGill[1/] while employed as staff hydraulic engineer and staff hydrologists, respectively, with the U. S. Study Commission-Texas, Houston, Texas. The relationships established were based on data collected by the U. S. Agricultural Research Service, Soil and Water Conservation Research Division, in water-balance investigations of cultivated and cropped watersheds at the agricultural experiment stations at Riesel and Tyler, Texas.

The amount of effective rainfall accounted for crop use each month in the Commission's study was that amount needed to supply crop consumptive use and to replenish the soil reservoir available-moisture content only up to field capacity during periods when lands were cropped and fallow.

[1/] Charles B. Thompson, Water Resources Engineer, U. S. Agency for International Development, Kumasi, Ghana; G. E. Townsend, Supervising Hydraulic Engineer, Federal Power Commission, Regional Office, Fort Worth, Texas; and H. N. McGill, Hydraulic Engineer, U. S. Department of Agriculture, Soil Conservation Service, Temple, Texas.

The accounting of available moisture in a soil reservoir is done in a manner similar to the procedure used for computing the hypothetical operation of surface conservation storage reservoirs. There are several methods and sets of criteria accepted as standard practices for making soil moisture studies. In this study, the available moisture capacity for each soil group and each respective crop root depth as described under "Soils" was used in separate computations to determine the monthly irrigation requirements. The available moisture was allowed to be depleted to 50 percent of reservoir capacity during crop growing seasons before requiring irrigation water. Between crops, fallow land moisture was allowed to be depleted up to 100 percent by evaporation until the month preceding the month in which a crop was planted in which case a pre-irrigation was required to bring available soil moisture to field capacity before planting. The combined preplanting irrigations and irrigations during the growing seasons comprised the yearly irrigation requirement for each crop grown in each soil group.

Beginning on January 1904 with available soil moisture at 50 percent of field capacity for each soil group, the available moisture was increased by the effective rainfall and was depleted for fallow land by 30 percent of the climatic index. This computation was made each month in sequence until a crop was planted. Then the soil reservoir was filled to capacity with irrigation water as needed in the preceding month. That amount was the preplanting irrigation requirement. In crediting the effective rainfall and depleting the fallow land evaporation, the available soil moisture was allowed to range from 0 to 100 percent of capacity only. Effective rainfall amounts in excess of the monthly available moisture deficiencies were discarded as lost through deep percolation, and fallow land evaporation amounts in excess of monthly available-moisture content of the soil reservoir were also discarded.

In the same manner as above, monthly consumptive-use amounts were computed by multiplying the climatic index by the respective crop consumptive-use coefficient. Then the effective rainfall amount was added to the available moisture content of the soil reservoir and the consumptive-use amount was subtracted. When the resulting figure was 50 percent or less of the soil reservoir capacity, the amount needed to fill the reservoir to available-moisture capacity was accounted as an irrigation requirement. When the resulting figure from the first step computation was more than the available-moisture capacity of the soil reservoir, caused by effective rainfall amounts occurring in excess of the amount needed to fill the soil reservoir to capacity and to supply the consumptive-use requirement, the excess rainfall was discarded as lost by deep percolation. Irrigations on the last month of a crop growing season were computed as needed to fill the soil reservoir to 50 percent of the available moisture capacity only when the cropland was left fallow in the following month. By this criterion, irrigation water was not added to be subsequently lost through evaporation while crop lands were rested.

Irrigation requirements were computed separately for points representative of the climate and soils of the Valley delta, the upland plain, and the upper river valley bottomland areas. This was necessary because of the significant variation in rainfall and potential evaporation in the Valley from Laguna Madre westward as described under "Climate"; and because of the variations in soils ranging from the fine sandy loams to heavy clays, their moisture replacement depths for Valley crops, and their available moisture-holding capacities. The Areal representative points used in this study were Harlingen, Edinburg, and Rio Grande City, respectively.

The computations of crop consumptive-use amounts and irrigation requirements for these three points were made with rainfall data as observed, with estimates for periods of missing record based on correlations with nearby rainfall stations. The monthly climatic indexes were selected from isogrammatic charts based on data for the South Texas Plain. Three soil groups and three crop root depth groups were used for each point.

The resulting crop consumptive-use amounts determined for the three Areal representative points reflect the combined effects of the variations in climate and soil characteristics and the conditions affecting plant responses as sensitive to each except soil fertility. Optimum fertility-water-yield relationships are embodied in the basic consumptive-use research and experiment data used to develop the method employed in this study. Soil fertility was assumed as optimized throughout.

The three Areas, represented by the cities of Harlingen, Edinburg, and Rio Grande City used for computational purposes, are not rigidly defined. The numerical values for the basic data used are approximately mean values of the extremes in transition between and beyond the points from west to east. The Areas represented are numbered (1) for Rio Grande City, (2) for Edinburg, and (3) for Harlingen. Roughly, the Areas represented by each point are Starr County, Hidalgo County, and Cameron and Willacy Counties, respectively.

In Areas 1, 2, and 3, the yearly irrigation requirements for each crop grown on each of the three soil groups were combined in proportion to the percentage of each soil group in the respective Area to obtain a weighted irrigation requirement for each crop grown in each Area. Then the composite yearly irrigation requirement was computed by multiplying each crop irrigation requirement by the percentage of that crop contained in the average cropping pattern for the Valley and summing the products.

The figures obtained by these computations are unit values and can be applied to any proper acreages to determine total irrigation requirements in the three respective Areas. In succeeding computations, these figures were used with adjustments for distribution losses from the water-supply source to compute the irrigation diversion requirements for each Area and the Valley as a whole.

In recognition of the variations between individual farming practices and the cropping programs in the Valley, the following table and charts were prepared as aids to individuals or groups desiring to evaluate particular cropping patterns as different from the average cropping pattern used in the study. The average crop irrigation-requirement figures for the three soil groups in each Area were sufficiently close enough to justify using the weighted average figure for each crop grown in each Area in making the estimates desired. The tabulations in Table 5 show the extremes in irrigation requirements for crops by Areas as caused by variations in climatic conditions and naturally available moisture. The extremes cannot be combined for different crops because they do not necessarily occur during the same year. The charts can be used to provide figures for making estimates of the average yearly irrigation requirement for croplands in each Area for any combination of cropping as different from the one used in the study. Table 5 shows the maximum year, average yearly, and minimum year irrigation requirement in inches depth for the 53-year period 1904-1956 for each crop grown in the Valley Areas 1, 2, and 3 as used in average cropping pattern. Figure 8 contains charts showing the average yearly

Table 5.--Valley crop irrigation requirements[1/], in inches depth, 1904-1956

Crop	Year[2/]	Area 1	Area 2	Area 3
Corn	Max	28.8	27.9	25.2
	Avg	19.5	16.6	13.6
	Min	9.5	4.1	1.8
Cotton	Max	26.3	28.3	21.6
	Avg	16.8	14.4	11.9
	Min	4.8	6.0	4.5
Perennial pasture	Max	49.0	45.2	42.3
	Avg	35.9	32.5	27.1
	Min	19.8	16.5	12.3
Vegetables, deep-rooted 1st crop	Max	18.8	17.6	14.0
	Avg	12.5	9.8	7.4
	Min	2.2	.8	.0
Vegetables, deep-rooted 2nd crop	Max	18.0	17.6	14.2
	Avg	11.4	9.6	6.5
	Min	4.5	2.0	.1
Vegetables, shallow-rooted	Max	17.9	15.6	15.3
	Avg	12.0	10.3	7.9
	Min	6.5	4.3	1.8
Sorghum 1st crop	Max	22.2	22.1	19.9
	Avg	14.9	12.1	9.6
	Min	6.5	.0	.0
Sorghum 2nd crop	Max	21.3	20.1	15.4
	Avg	12.7	11.0	7.6
	Min	5.3	4.7	.0
Citrus	Max	36.2	35.4	31.5
	Avg	26.3	22.8	18.1
	Min	13.7	8.7	6.1

1/ Includes preplanting irrigation.
2/ Maximum year, average yearly, and minimum year requirements, respectively.

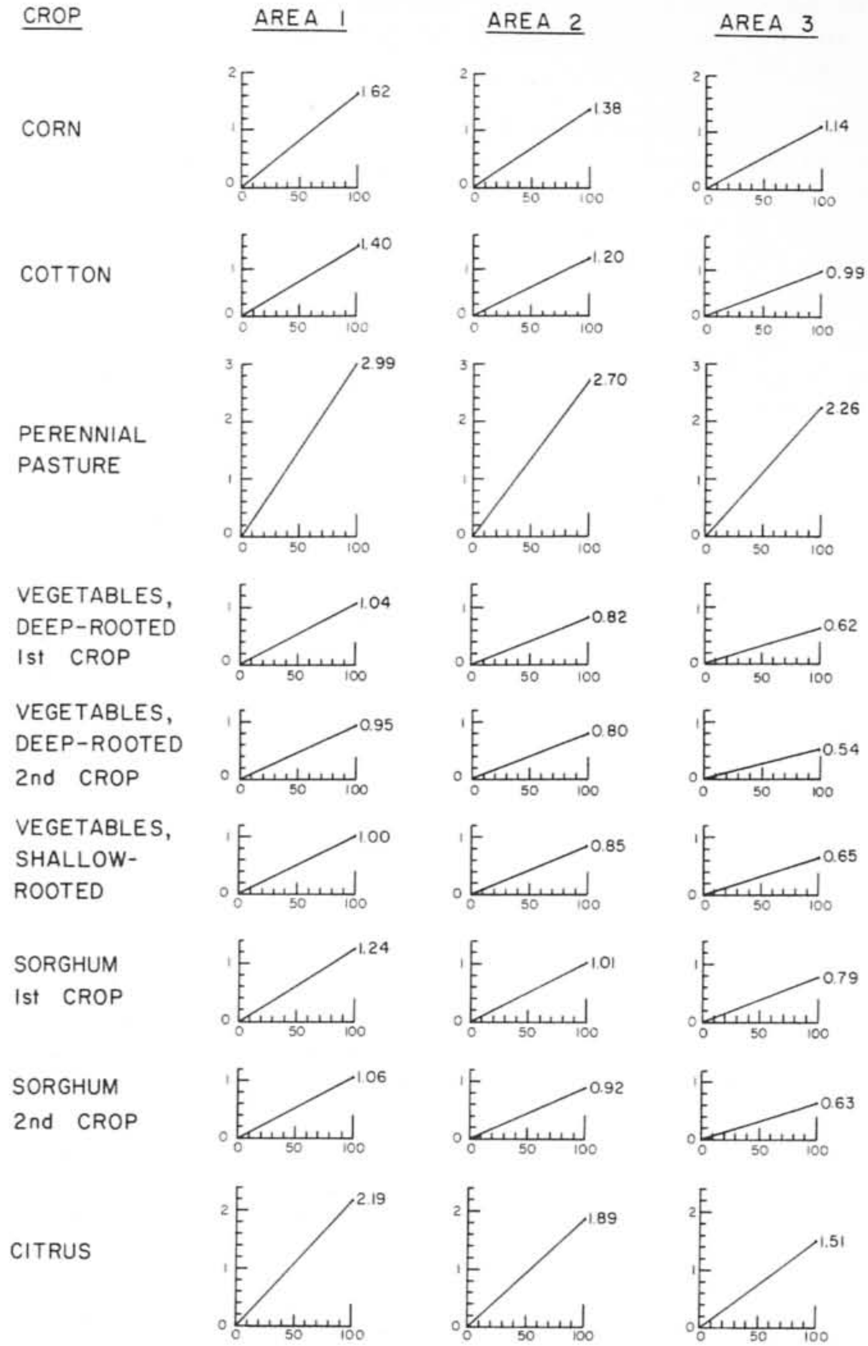

Figure 8

Average Yearly Irrigation Requirements for Valley Crops, 1904-1956

Note: Requirements, in acre-feet per acre, include preplanting irrigation. Vertical scale is in feet; horizontal, percentage of requirement.

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irrigation requirements in acre-feet per acre for each crop grown in Areas 1, 2, and 3. The horizontal scales, or abscissas, are percentages of Area unit requirements and the vertical scales, or ordinates, are irrigation requirements in feet as shown on the charts.

For example, to estimate the average yearly irrigation requirement for a cropping pattern comprised of 60 percent cotton, 20 percent pasture, and 20 percent citrus grown in Area 3, read the ordinates opposite the average curves at the intercepts of the respective percentages for these crops and Area, and sum the amounts. The sum will be the estimated weighted average yearly irrigation requirement, as follows:

60 percent cotton = 0.5 acre-feet per acre
20 percent pasture = 0.4 acre-feet per acre
20 percent citrus = 0.3 acre-feet per acre

Total = 1.2 acre-feet per acre.

Irrigation Water Losses--Falcon Dam to the Crop

The duty of water or the irrigation diversion requirement at Falcon Dam and Reservoir exceeds the irrigation requirement for crop consumptive use by an amount equal to the sum of the losses of water conveyed from the reservoir to the crop. These losses occur in and along the Rio Grande channel and the diversion distribution system of open canals and closed conduits, and on the farm. Natural losses are caused by evaporation from land and water surfaces, transpiration by vegetation, seepage, and deep percolation. Other losses occur from farm application procedures.

Irrigation diversion requirements at Falcon Dam for a specific crop or cropping pattern are determined by adding these losses to the irrigation requirement at the crop. The standard mechanism for computing these increases of the irrigation requirement is a set of efficiency percentages or coefficients expressing the magnitude of the losses inherent with farm applications of water on crops, the distribution system, and the river channel or other conveyance facility from the source of supply, or a combination of these efficiency percentages or coefficients in a single value. The usual method of applying these efficiencies is to divide the irrigation requirement at the crop by such values.

The duty of water at a farm headgate is an amount equal to the water added to the soil that is used to supply consumptive-use requirements of crops plus the sum of the losses incurred through application of the irrigation water, deep percolation, and waste from the ends of rows or runoff from the fields. The amount of irrigation water delivered to a farm field that is available in the soil for consumptive use by crops is often called the field irrigation efficiency or, more simply, the farm efficiency.

Farm efficiencies often range from 15 percent to 90 percent, dependent on soil characteristics, stage of plant growth and degree of plant stress, method of irrigation, climatic conditions, occurrence of rainfall, need for irrigation, control of water applied, amount of waste or runoff, deep percolation, and consumptive waste by nonbeneficial vegetation. The textures and depths of the Valley soils and their internal drainage rates contribute to a lower efficiency coefficient than experienced in some other areas of Texas. The farm efficiency was selected as 65 percent for use in this study and was based on estimated efficiencies of use made by agriculturists and agricultural agencies in the Valley.

The amount of water diverted from the Rio Grande that is delivered to the farm headgate through the distribution system of open canals or closed conduits is called the distribution efficiency. This efficiency may be expressed as a percentage, as a coefficient, or as an amount of water per irrigated acre served by the system.

The difference in the amount of water diverted from the Rio Grande and the amount delivered at the farm headgate is the distribution loss. In unlined earth canals, these losses may be high. For the purpose of conservation of the available water supply for the Valley and to utilize that supply to serve the maximum acreage in each of the study areas, all distribution media in the Valley distribution systems were assumed to be concrete-lined open canals or closed conduits assuring a minimum of seepage and evapotranspiration losses.

Based on the U. S. Bureau of Reclamation studies of losses of water from concrete-lined open canals, the average loss of water per mile of canal length was estimated to be 21.8 acre-feet annually. Using an average number of acres irrigated per mile of canal length in the three study Areas, the average annual loss of water per irrigated acre was determined to be 0.145 acre-feet in Areas 1 and 2, and 0.109 acre-feet in Area 3.

Because of the intensive cropping pattern per unit of irrigated land in the Valley, the per-acre average annual distribution loss of water was added to the duty of water at the farm headgate as a constant amount for each year in the respective Areas. In this manner, the amount of water required in the Rio Grande at the point of diversion for the distribution systems serving each Area was determined on a per-irrigated-acre basis each year. These amounts were the estimated duty of water each year at the canal headgates or the equivalent on the Rio Grande.

The amount of water released from Falcon Reservoir into the Rio Grande that is delivered to the points of diversion on the river for the distribution systems supplying water to the Valley is called the channel efficiency. This efficiency is conveniently expressed as a percentage or as a coefficient, and may vary in relation to the quantity of flow and the length of river channel between point of release and points of diversion.

The difference in the amount of water released at Falcon Dam and the amount delivered to the point of diversion on the Rio Grande is the channel loss. Channel losses per mile of length were determined for specific river reaches on the basis of IBWC records and computations of losses of water in these respective reaches of the Rio Grande from Falcon Dam to the Gulf of Mexico during periods of release of water for irrigation and other uses during the years 1954-57 and 1960-63. These amounts are shown in Table 6.

Reaches of the Rio Grande below Falcon Dam were selected as generally supplying water to the distribution systems for Areas 1, 2, and 3. A weighted loss-per-mile-of-reach figure for each of three selected reaches was derived from data in Table 6. An estimated average annual loss of water from each reach was computed, from which channel efficiencies applicable to Areas 1, 2, and 3 were derived as 98, 94, and 92 percent, respectively.

Table 6.--Water loss per mile of river channel as a function of releases

(From U. S. share of waters in the Rio Grande from Falcon Dam to the Gulf.)

River reach	Length of reach in miles	Water loss per mile in reach
Falcon Dam to Fort Ringgold Gage..........	40	0.000250 Q 1/
Fort Ringgold Gage to Anzalduas Dam...............	63	.000318 Q
Anzalduas Dam to Progreso Bridge Gage.........	47	.000453 Q
Progreso Bridge Gage to San Benito Gage.............	27	.000185 Q
San Benito Gage to Lower Brownsville Gage.......	48	.000092 Q
Lower Brownsville Gage to Gulf of Mexico..............	49	.000039 Q

1/ Q is quantity of release from Falcon Reservoir.

The per-acre duty of water at the points of diversion for respective Areas divided by the channel efficiency expressed as a coefficient increases that amount by an amount of the respective channel loss. The resulting figure is the estimated per-acre duty of water or irrigation diversion requirement at Falcon Dam for each study Area.

These losses and respective channel efficiencies do not reflect the effect of intervening inflows between Falcon Dam and the Gulf of Mexico, which amounts were assumed to be equal to the historical annual waste to the Gulf, including water wasted because of operational inefficiencies at Falcon Dam and at diversion facilities for the Valley.

Irrigation Diversion Requirements

Irrigation diversion requirements differ from irrigation requirements, as discussed in the report, by the amounts of water needed at a specific water resource development to supply the amounts of irrigation water needed at a crop. The differences between the two requirements are equal to the losses of water caused by distribution from the source of supply to the point of use. Under "Irrigation Water Losses," these are discussed and separated as: (1) river channel conveyance losses to points of diversion for Areas 1, 2, and 3 by river reaches; (2) canal distribution losses in Areas 1, 2, and 3; and (3) farm-use losses commonly called farm efficiencies.

Yearly irrigation diversion requirements were computed for each study Area in three steps. Firstly, the weighted irrigation requirement for each year was increased by the farm loss--the difference between the selected farm efficiency and 100 percent efficiency of water use. For each Area, the farm efficiency coefficient was used as 0.65 as derived and previously explained. The resulting figures were the amounts of water required at the farm headgate. Secondly, the Area service canal distribution loss was added to the farm requirement. The resulting figures were the amounts of water required at the points of diversion from the river channel to the service canals distribution system. Thirdly, these figures were increased by the percentage of water lost in the respective river reaches serving the diversion points for each Area. The resulting figures were the amounts of water required for release from Falcon Reservoir to supply the irrigation requirement in each Area.

Areas 1, 2, and 3 irrigation diversion requirements were combined on the basis of the proportional irrigated acreage in each to the whole to obtain a weighted Valley irrigation diversion requirement. These figures are diversion requirements at Falcon Dam and do not include evaporation and other losses from water in storage in Falcon Reservoir.

The yearly irrigation diversion requirements computed in this study for Areas 1, 2, and 3, and the Valley as a whole, are listed in Table 7.

Irrigation diversion requirements for cropping patterns other than used in the study can be determined by adding the appropriate farm, distribution, and channel losses to the irrigation requirements as may be estimated for varying cropping patterns selected for each respective Area.

Using the total figure from the example on page 28 and adjusting it by the farm efficiency coefficient 0.65, the canal distribution loss of 1.31 inches

Table 7.--Irrigation diversion requirements for the Lower Rio Grande Valley at Falcon Dam, 1904-1956

Year	Acre-feet per acre			
	Area 1	Area 2	Area 3	Valley
1904	2.14	2.43	2.20	2.33
1905	2.42	1.44	1.51	1.51
1906	2.01	1.42	1.65	1.54
1907	3.02	2.21	2.06	2.19
1908	2.54	1.85	1.89	1.90
1909	3.24	2.21	1.95	2.16
1910	3.31	2.66	2.30	2.55
1911	3.16	2.68	2.26	2.54
1912	2.22	1.74	1.79	1.78
1913	2.39	1.80	1.65	1.76
1914	2.27	2.12	1.61	1.92
1915	2.59	2.77	1.99	2.45
1916	2.91	2.40	2.13	2.32
1917	3.05	3.21	2.29	2.84
1918	2.74	2.74	2.02	2.45
1919	2.13	1.75	1.40	1.63
1920	2.79	2.53	2.47	2.52
1921	3.36	2.97	1.89	2.56
1922	2.55	2.71	1.38	2.17
1923	2.91	2.44	2.22	2.38
1924	2.64	1.97	2.04	2.03
1925	2.85	2.87	1.94	2.50
1926	2.15	1.36	1.30	1.37
1927	2.91	2.79	1.92	2.45
1928	2.58	2.59	2.15	2.41
1929	2.58	2.27	1.69	2.05
1930	1.87	1.19	1.22	1.23
1931	1.49	1.70	1.31	1.53
1932	2.53	1.62	1.41	1.58
1933	2.34	1.59	1.71	1.68
1934	2.59	2.84	2.28	2.61
1935	2.55	2.01	.85	1.57
1936	1.99	1.96	1.33	1.71
1937	2.58	2.41	1.83	2.19
1938	2.75	2.75	2.29	2.57
1939	3.16	2.41	2.25	2.38
1940	3.00	2.59	2.25	2.47
1941	1.21	1.15	.71	.98
1942	2.73	2.48	1.66	2.17
1943	2.75	2.42	2.33	2.40
1944	2.59	2.13	1.20	1.78
1945	2.85	2.54	1.97	2.33
1946	2.86	2.56	1.80	2.27
1947	2.71	2.72	2.12	2.48
1948	2.24	2.52	1.96	2.28
1949	2.28	2.55	2.23	2.41
1950	3.48	3.29	2.39	2.94
1951	2.91	2.97	2.21	2.67
1952	3.61	2.93	2.72	2.87
1953	3.42	3.75	3.21	3.52
1954	2.57	2.46	2.48	2.47
1955	2.69	2.88	2.13	2.58
1956	3.39	3.51	3.02	3.31
Average yearly	2.65	2.37	1.94	2.21

(0.109 ft), and the river channel efficiency coefficient of 0.92, the irrigation diversion requirement computations are as follows:

$$[(1.2 \text{ ft} \div 0.65) + 0.109] \div 0.92$$

$$= 2.2 \text{ acre-feet per acre.}$$

Domestic, Municipal, and Industrial Water Requirements

According to Lower Rio Grande Valley water-use reports to the Texas Water Commission for 1962 as compiled by the Commission's Electronic Data Processing Division, the combined surface and ground water used for domestic, municipal, and industrial purposes in the four-county area was 73,192 acre-feet. Table 8 shows the reported amounts by counties.

Mixed reports of water use for domestic, municipal, and industrial purposes in 1960, 1962, and 1963 for 24 cities and Cameron County Water Control and Improvement Districts No. 10, No. 11, and No. 13 show a use of 6,060 acre-feet of ground water and 56,292 acre-feet of surface water for a combined total of 62,352 acre-feet per year.

Future domestic, municipal, and industrial water requirements for cities in the Valley for 1965, 1975, and the year 2000 were compiled from and projected on the basis of work done by the Bureau of Business Research, University of Texas, in cooperation with the Texas Board of Water Engineers and published in its Bulletin 5910, "Water Requirements Survey for Texas," July 1959. Population and water requirement projections for 1965, 1975, and 2000 are contained in Bulletin 5910 for cities with a population of more than 5,000 in 1957. These cities, 12 in number, with their projected populations and the 1960 census count are shown in Table 9.

Twelve other Valley cities having less than 5,000 population in 1957 and therefore not included in Bulletin 5910 were added to those shown in Table 9. Water requirements for domestic, municipal, and industrial uses for these 12 smaller cities were projected by the Commission's staff using as a basis the Bureau of Business Research data for the cities of Mercedes, Raymondville, and Rio Grande City. These three cities were considered as representative of the future growth of the smaller cities in study Areas 1, 2, and 3. These 24 cities, their 1960 population, and their projected water requirements are shown in Table 10.

The impreciseness of population projections is recognized. Table 10 shows examples of the actual census enumerations in 1960 that are more than the projected population for 1965. These are minor differences which are areally compensated for by some of the other projections. Although any projections of future water requirements are subject to error, a comparison of the preceding projections when expressed on a per-capita-day basis for Valley cities suggest the reasonableness in using the total requirement in this study.

Combined per-capita-day water requirement projections for Mercedes, Raymondville, and Rio Grande City as representative of smaller cities are shown in comparison with figures for Brownsville, Harlingen, and McAllen in Table 11.

Table 8.--Water supplied for Valley domestic, municipal, and industrial uses in 1962

(Reported surface- and ground-water amounts, in acre-feet)

County	Domestic and municipal uses	Industrial uses	Total
Starr	830	860	1,690
Hidalgo	35,815	843	36,658
Cameron	30,200	4,630	34,830
Willacy	14	--	14
Four-county total........................			73,192

Table 9.--1960 Census and projected population of Valley cities in TBWE Bulletin 5910

City	Population			
	Census	Projected		
	1960	1965	1975	2000
Brownsville	48,040	55,900	67,000	95,000
Donna	7,522	12,800	15,000	20,000
Edinburg	18,706	19,900	22,500	29,000
Harlingen	41,207	43,000	52,000	90,700
McAllen	32,728	36,300	43,800	76,400
Mercedes	10,943	14,700	16,900	21,100
Mission	14,081	20,900	25,000	35,000
Pharr	14,106	14,100	16,300	20,000
Raymondville	9,385	14,300	16,300	24,200
Rio Grande City	5,835	7,300	9,600	15,000
San Benito	16,422	20,000	23,400	29,500
Weslaco	15,649	15,000	16,300	21,600

Table 10.--Future domestic, municipal, and industrial water requirements in the Valley

City	Population 1960 census	Projected water requirements, in acre-feet		
		1965	1975	2000
Alamo	4,121	845	1,170	2,089
Brownsville	48,040	10,020	12,484	22,035*
Donna	7,522	2,925	4,048	7,422*
Edcouch	2,814	577	799	1,427
Edinburg	18,706	2,830	3,762	6,178*
Elsa	3,847	789	1,093	1,950
Harlingen	41,207	7,976	10,029	21,743*
Hidalgo	1,078	221	306	547
La Feria	3,047	625	865	1,545
La Villa	1,261	259	358	639
Los Fresnos	1,289	264	366	654
Lyford	1,554	319	441	788
McAllen	32,728	6,356	8,571	17,793*
Mercedes	10,943	2,084	2,863	4,570*
Mission	14,081	3,360	4,505	8,142*
Pharr	14,106	2,084	2,777	4,367*
Raymondville	9,385	2,164	2,876	5,466*
Rio Grande City	5,835	1,114	1,679	3,222*
Rio Hondo	1,344	276	332	681
Roma	1,496	307	425	758
San Benito	16,422	2,771	3,947	6,350*
San Juan	4,371	896	1,241	2,216
Santa Rosa	1,572	322	446	797
Weslaco	15,649	2,265	2,971	5,137*
Total:	262,418	51,649	68,404	126,516

* Projected water requirements given in TBWE Bulletin 5910. Other projections were made by Texas Water Commission staff.

Table 11.--Average per-capita-day water requirement projections for Valley cities

Representative cities by size	Projected water requirements in gallons per day per capita		
	1965	1975	2000
Small	130	155	195
Large	160	170	210

Rounding the projected total water requirement for 2000 as shown in Table 10 to 130,000 acre-feet, and assuming that at least the 6,000 acre-feet of ground-water use reported to the Commission will be available and used in the year 2000, it was further assumed that the future domestic, municipal, and industrial surface-water requirements in the Valley from the Rio Grande for the period around the year 2000 is reasonably represented by the figure of 130,000 less 6,000, or 124,000 acre-feet per year. This amount was provided for each year in the studies of the water supply limitations on irrigation from the Rio Grande in the Valley.

The Water Resource

The water resources supplying the water required for domestic and municipal, industrial, irrigational, and other uses in the Lower Rio Grande Valley of Texas are rainfall, ground water, and part of the United States' share of the flow of the Rio Grande between Fort Quitman, Texas, and the Gulf of Mexico.

Rainfall and its inadequacy to supply the water requirements of the Valley is evident in the report under "Irrigation Requirements." Ground water was not considered pertinent to the problems and purposes under study, and was not accounted as a source of supply.

By the Treaty of 1944 between the United States and Mexico on "Utilization of Waters ... of the Rio Grande," the United States' share of the waters of the Rio Grande below Fort Quitman is comprised of:

> "(a) All of the waters reaching the main channel of the Rio Grande (Rio Bravo) from the Pecos and Devils Rivers, Goodenough Spring, and Alamito, Terlingua, San Felipe, and Pinto Creeks.
>
> "(b) One-half of the flow in the main channel of the Rio Grande (Rio Bravo) below the lowest major international storage dam, so far as said flow is not specifically allotted under this Treaty to either of the two countries.
>
> "(c) One-third of the flow reaching the main channel of the Rio Grande (Rio Bravo) from the Conchos, San Diego, San Rodrigo, Escondido, and Salado Rivers and the Las Vacas Arroyo, provided that this third shall not be less,

as an average amount in cycles of five consecutive years, than 350,000 acre-feet (431,721,000 cubic meters) annually. The United States shall not acquire any right by the use of the waters of the tributaries named in this subparagraph, in excess of 350,000 acre-feet (431,721,000 cubic meters) annually, except the right to use one-third of the flow reaching the Rio Grande (Rio Bravo) from said tributaries, although such one-third may be in excess of that amount.

"(d) One-half of all other flows not otherwise allotted by this Article occurring in the main channel of the Rio Grande (Rio Bravo), including the contributions from all the unmeasured tributaries, which are those not named in this Article, between Fort Quitman and the lowest major international storage dam."

The water resource as considered specifically herein for hypothetically supplying the projected and estimated water requirements for domestic and municipal, industrial, irrigational, and other uses in the Valley was the total amount available from the Rio Grande during the period 1900-1956.

The total amount of water available from the Rio Grande for use in the Valley was derived by the Commission's staff from computations of the United States' historical share of water in the Rio Grande, adjusted for future upstream conditions and requirements, that could have been provided for use below Falcon Dam. These historical computations were made by the United States Section of the International Boundary and Water Commission, United States and Mexico, in preparation of the report, "Rio Grande International Storage Dams Project: Proposed Amistad Dam and Reservoir" contained in Senate Document No. 65, 86th Congress of the United States, 1st Session, 1959. The computations provided figures of outflow from International Falcon Reservoir consisting of hypothetical releases of a regulated supply of water and spills, and figures of residual contents in conservation storage in Falcon and Amistad Reservoirs. Inflows to Falcon Reservoir were adjusted to estimated future upstream uses and depletion of the United States' share.

A month by month summary tabulation of these computations for the period 1900-1956, furnished by the United States Section of the IBWC, was used by the Commission's staff to derive and compile the total amount of water available each year during the 57-year period. These yearly amounts of water estimated as hypothetically available from the Rio Grande at International Falcon Reservoir for use in the Valley constituted the water resource evaluated herein. These amounts are shown in Table 12.

Reservoir Operation Guides

Operational guides for Amistad and Falcon Reservoirs will be needed in order to maximize the benefits to the Lower Rio Grande Valley as potential in the described water resource. The variation from year to year in the irrigation diversion requirement as shown in Tables 7 and 12, and the variation in the amount of water available as the water resource for respective years shown in Table 12 are indicative of the complex problems involved with the establishment of operation guides for these reservoirs. This is an engineering endeavor not feasible for study until such time as the issues concerning water rights,

Table 12.--Valley cropland irrigable from adjusted IBWC water supply at Falcon Dam

Year	TWC adjusted supply[1] in 1,000's acre-feet			TWC irrigation diversion requirements in acre-feet per acre	Total cropland irrigable in acres		
	DF(1)	DF(2)	DF(3)		DF(1)	DF(2)	DF(3)
1904	1,289	1,386	1,502	2.33	553,200	594,800	644,600
1905	1,157	1,244	1,347	1.51	766,200	823,800	892,100
1906	1,197	1,285	1,392	1.54	777,300	834,400	903,900
1907	1,669	1,792	1,937	2.19	762,100	818,300	884,500
1908	1,426	1,529	1,655	1.90	750,500	804,700	871,100
1909	1,598	1,712	1,854	2.16	739,800	792,600	858,300
1910	1,603	1,719	1,860	2.55	628,600	674,100	729,400
1911	1,608	1,729	1,280	2.54	633,100	680,700	503,900
1912	1,263	854	830	1.78	709,600	479,800	466,300
1913	1,134	1,148	1,161	1.76	644,300	652,300	659,700
1914	1,194	1,283	1,390	1.92	621,900	668,200	724,000
1915	1,497	1,609	1,739	2.45	611,000	656,700	709,800
1916	1,454	1,560	1,688	2.32	626,700	672,400	727,600
1917	1,975	2,117	2,007	2.84	695,400	745,400	706,700
1918	1,358	1,028	905	2.45	554,300	419,600	369,400
1919	1,167	1,252	1,298	1.63	716,000	768,100	796,300
1920	1,536	1,651	1,785	2.52	609,500	655,200	708,300
1921	1,668	1,790	1,934	2.56	651,600	699,200	755,500
1922	1,171	1,259	1,365	2.17	539,600	580,200	629,000
1923	1,354	1,454	1,575	2.38	568,900	610,900	661,800
1924	1,437	1,541	1,669	2.03	707,900	759,100	822,200
1925	1,056	1,136	1,231	2.50	422,400	454,400	492,400
1926	1,052	1,132	1,228	1.37	767,900	826,300	896,400
1927	1,561	1,677	1,837	2.45	637,100	684,500	749,800
1928	1,215	1,307	1,416	2.41	504,100	542,300	587,600
1929	1,265	1,359	1,471	2.05	617,100	662,900	717,600
1930	843	910	988	1.23	685,400	739,800	803,300
1931	1,240	1,335	1,444	1.53	810,500	872,500	943,800
1932	1,166	1,254	1,360	1.58	738,000	793,700	860,800
1933	1,185	1,156	1,254	1.68	705,400	688,100	746,400
1934	1,362	1,463	1,583	2.61	521,800	560,500	606,500
1935	1,137	1,224	1,325	1.57	724,200	779,600	843,900
1936	1,301	1,162	1,239	1.71	760,800	679,500	724,600
1937	1,404	1,505	1,629	2.19	641,100	687,200	743,800
1938	1,451	1,558	1,686	2.57	564,600	606,200	656,000
1939	1,441	1,548	1,674	2.38	605,500	650,400	703,400
1940	1,293	1,388	1,504	2.47	523,500	561,900	608,900
1941	651	703	766	.98	664,300	717,300	781,600
1942	1,628	1,637	1,728	2.17	750,200	754,400	796,300
1943	1,329	1,429	1,546	2.40	553,800	595,400	644,200
1944	1,289	1,383	1,499	1.78	724,200	777,000	842,100
1945	1,569	1,684	1,822	2.33	673,400	722,700	782,000
1946	1,447	1,553	1,681	2.27	637,400	684,100	740,500
1947	1,538	1,649	1,246	2.48	620,200	664,900	502,400
1948	1,521	1,239	1,225	2.28	667,100	543,400	537,300
1949	1,371	1,474	1,594	2.41	568,900	611,600	661,400
1950	1,784	1,681	1,520	2.94	606,800	571,800	517,000
1951	605	606	606	2.67	226,600	227,000	227,000
1952	202	208	208	2.87	70,400	72,500	72,500
1953	383	383	383	3.52	108,800	108,800	108,800
1954	1,077	1,151	1,243	2.47	436,000	466,000	503,200
1955	1,635	1,756	1,899	2.58	633,700	680,600	736,000
1956	1,421	1,520	1,353	3.31	429,300	459,200	408,800

1/ U. S. share of IBWC regulated releases from Falcon Reservoir less 124,000 acre-feet per year for future domestic, municipal, and industrial requirements.

priority of rights, and water and irrigable-land quantities for each right in the Valley have been resolved by the Texas Judiciary. This study is within the province of this Commission, and can be pursued at the proper time.

Limitations on Irrigated Area

The potential limitations of the water resource in providing a full water supply for irrigation of a specific acreage are erratic. This erraticism can be caused by the variations in the amounts of available water in relation to variations in the irrigation diversion requirements and management of the water resource as evident in Table 12.

The IBWC report "Rio Grande International Storage Dams Project: Proposed Amistad Dam and Reservoir" contains yearly summarizations of monthly hydrologic studies of the Rio Grande below Amistad (formerly Diablo) Dam site for the period 1900-1956. In these studies, evaluations were made of the capability of the United States' share of the flow of the Rio Grande and the conservation storage capacities of Amistad and Falcon Reservoirs to supply assumed future water requirements in Texas along the Rio Grande below Amistad Dam. These studies were identified as "DF(1)," "DF(2)," and "DF(3)."

The average annual future demand was assumed equal to the 1957 demand of 1,706,000 acre-feet (IBWC) in the DF(1) study. This demand was assumed to increase by 6 percent to an average of 1,810,000 acre-feet annually in DF(2), and to increase by 13 percent to an average of 1,934,000 acre-feet annually in DF(3). In each study, the amount of water available to serve the demands was determined as the regulated supply.

The Texas Water Commission's staff utilized the IBWC total regulated supplies for each of the three conditions, and obtained the amounts of water annually used by the IBWC to supply the assumed future demands of the Valley below Falcon Dam. IBWC spills from Falcon Reservoir for each of the three conditions were credited as available water and added to the adjusted amounts. These adjusted amounts of available water for each future demand were used to determine the number of acres of Valley cropland that will have been served a full water supply as based on the Texas Water Commission's estimates of the yearly irrigation diversion requirements at Falcon Reservoir for the period 1904-1956. In making this yearly comparison, it was assumed that any differences in storage and in evaporation and other losses of water that might occur in monthly operations of Amistad and Falcon Reservoirs because of possible differences in IBWC and TWC monthly demands would be compensating on a yearly basis.

Table 12 contains tabulation of the Texas Water Commission adjusted available water supply as based on the IBWC regulated-supply studies for DF(1), DF(2), and DF(3); the Texas Water Commission irrigation diversion requirements at Falcon Reservoir; and, the number of acres of Valley cropland that could have received full irrigations from the respective water supply by years from 1904 to 1956.

Using all of the United States' share of available water at Falcon Reservoir each year, as derived from the adjusted IBWC regulated releases to supply the TWC Valley requirements, would result in the wide variations in the irrigable acreages tabulated in Table 12.

Additional hypothetical reservoir operations were made in order to obtain more uniform results, to maximize the benefits from the reservoirs, and to stabilize the wide variations in acreages irrigable each year. The data furnished in detail by the IBWC were reevaluated as the total United States' share of water available for Valley use. This reevaluation was made on the basis that the total water available for Valley use consisted of the IBWC regulated supply plus the contents in conservation storage in Amistad and Falcon Reservoirs at the end of each year according to IBWC hypothetical reservoir operations. These yearly amounts were assumed to have been depleted by evaporation and other losses in the same degree by compensation of differences although the yearly regulated supply and contents in storage may vary from the IBWC end-of-year figures.

In this approach, the United States' share of the combined initial conservation storage capacities of Amistad and Falcon Reservoirs were used to reoperate the water resource for the period 1900-1956. The IBWC studies began in 1900. To simplify the computations in restudy, the average irrigation diversion requirement for the 1904-1956 period was used to compute cropland requirements for the years 1900-1903.

Total irrigation diversion requirements were computed each year as needed to provide a full supply for irrigating 600,000; 650,000; 700,000; 750,000; and 800,000 acres. These demands were applied against the water available at Falcon Reservoir each year, including contents in storage in Amistad and Falcon, after adjustment of the supply to provide 124,000 acre-feet of water yearly for estimated future domestic, municipal, and industrial requirements in the Valley. The combined initial capacity of 3,661,000 acre-feet at top of the conservation storage spaces in Amistad and Falcon Reservoirs was depleted each year beginning in 1900 by the average sediment rate of 8,200 acre-feet per year as derived from IBWC data for the 57-year period 1900-1956. The usable yearly content in storage in Falcon Reservoir was reduced by 60,000 acre-feet to provide the reserve water supply for domestic use in the Valley during critical drought as ordered by the State.

In the ensuing hypothetical operations and management of the water resource, irrigation water was supplied in accordance with the yearly demands for the stated acreages, and the balance of water available was accrued in storage for future use. Storage was not allowed to exceed the United States' share of the combined conservation storage capacity of the reservoirs. In these computations, spills occur only under demands for 600,000 and 650,000 acres. Shortages occurred during the 57-year period for each of the total acreages irrigated. Tables 13 through 17 contain a summarization, for each Valley cropland acreage tested, of the number of years that a full water supply for irrigation could have been provided; the years when the supply was inadequate and the amount of shortage in acre-feet and acreage denied; and the number of acres that could have been irrigated with the available supply. Detailed computations from which the following tabulations were extracted are available for inspection in the Texas Water Commission's offices in Austin, Texas.

Water Shortages

Every farmer has a living experience with risk in crop production, and considers his chances of having an adequate water supply and other favorable conditions bringing about high yields before putting in a crop. Also, he has

Table 13.--The irrigation potential for 600,000 acres of Valley cropland, 1900-1956

Number of years a full water supply was provided: 54 out of 57.

Shortages			Irrigation potential
Year	Irrigation supply in 1,000's acre-feet	Acreage denied	Number of acres provided a full supply
1951	486	182,000	418,000
1952	1,520	530,000	70,000
1953	1,729	491,000	109,000

Table 14.--The irrigation potential for 650,000 acres of Valley cropland, 1900-1956

Number of years a full water supply was provided: 51 out of 57.

Shortages			Irrigation potential
Year	Irrigation supply in 1,000's acre-feet	Acreage denied	Number of acres provided a full supply
1947	731	295,000	355,000
1950	798	272,000	378,000
1951	1,131	423,000	227,000
1952	1,664	580,000	70,000
1953	1,905	541,000	109,000
1956	1,098	332,000	318,000

Table 15.--The irrigation potential for 700,000 acres of Valley cropland, 1900-1956

Number of years a full water supply was provided: 40 out of 57.

Shortages			Irrigation potential
Year	Irrigation supply in 1,000's acre-feet	Acreage denied	Number of acres provided a full supply
1902	87	40,000	660,000
1912	327	184,000	516,000
1917	251	88,000	612,000
1918	686	280,000	420,000
1928	603	250,000	450,000
1929	784	382,000	318,000
1939	263	110,000	590,000
1940	582	236,000	464,000
1945	355	152,000	548,000
1946	485	214,000	486,000
1947	917	368,000	332,000
1948	61	27,000	673,000
1950	1,069	364,000	336,000
1951	1,264	474,000	226,000
1952	1,807	630,000	70,000
1953	2,081	591,000	109,000
1956	1,515	458,000	242,000

Table 16.--The irrigation potential for 750,000 acres of Valley cropland, 1900-1956

Number of years a full water supply was provided: 36 out of 57.

Shortages			Irrigation potential
Year	Irrigation supply in 1,000's acre-feet	Acreage denied	Number of acres provided a full supply
1902	420	190,000	560,000
1903	75	34,000	716,000
1911	819	322,000	428,000
1912	564	317,000	433,000
1917	816	287,000	463,000
1918	809	330,000	420,000
1927	961	392,000	358,000
1928	743	308,000	442,000
1929	887	433,000	317,000
1938	132	51,000	699,000
1939	1,089	458,000	292,000
1940	705	286,000	464,000
1945	839	360,000	390,000
1946	598	264,000	486,000
1947	1,037	418,000	332,000
1948	175	77,000	673,000
1950	1,337	455,000	295,000
1951	1,397	523,000	227,000
1952	1,950	680,000	70,000
1953	2,257	641,000	109,000
1956	1,932	584,000	166,000

Table 17.--The irrigation potential for 800,000 acres of Valley cropland, 1900-1956

Number of years a full water supply was provided: 27 out of 57.

Shortages			Irrigation potential
Year	Irrigation supply in 1,000's acre-feet	Acreage denied	Number of acres provided a full supply
1902	726	330,000	470,000
1903	177	80,000	720,000
1910	604	236,000	564,000
1911	1,056	416,000	384,000
1912	653	366,000	434,000
1916	151	65,000	735,000
1917	1,229	432,000	368,000
1918	931	380,000	420,000
1924	339	167,000	633,000
1925	129	52,000	748,000
1926	121	88,000	712,000
1927	1,353	552,000	248,000
1928	863	358,000	442,000
1929	989	482,000	318,000
1934	82	31,000	769,000
1937	287	131,000	669,000
1938	591	230,000	570,000
1939	1,208	508,000	292,000
1940	829	336,000	464,000
1944	257	145,000	655,000
1945	1,064	457,000	343,000
1946	712	314,000	486,000
1947	1,161	469,000	331,000
1948	289	127,000	673,000
1949	29	12,000	788,000
1950	1,575	536,000	264,000
1951	1,531	574,000	226,000
1952	2,094	730,000	70,000
1953	2,433	691,000	109,000
1956	2,351	710,000	90,000

vivid memories of wrong guesses and unforeseen disasters resulting in reduced yields or complete crop failure.

With the above in mind, the desire to express these risks based on studies for long periods as probabilities of occurrence or frequency of recurrence is strong and often succumbed to. The statements so made may be misleading and are often misunderstood. On the basis of the studies made as summarized in the preceding Tables 13 through 17, only two statements are offered for each Valley cropland acreage tabulated. These statements are: (1) the maximum period or percent of time of irrigation for a specific acreage, and (2) the related minimum-year acreage irrigable.

These statements are prefaced by the qualification that the recurrence of the results of the hypothetical studies summarized in the report are dependent on the recurrence of the same events and conditions in the same sequence, which is highly improbable, or on the occurrence of events and conditions in favorable sequences to produce the equivalent result over a like period of time. Thus, for the 57-year period 1900-1956, a full water supply could have been available to irrigate Valley cropland in the amount of:

600,000 acres for 95 percent and 70,000 acres for 2 percent of the time;

650,000 acres for 89 percent and 70,000 acres for 2 percent of the time;

700,000 acres for 70 percent and 70,000 acres for 2 percent of the time;

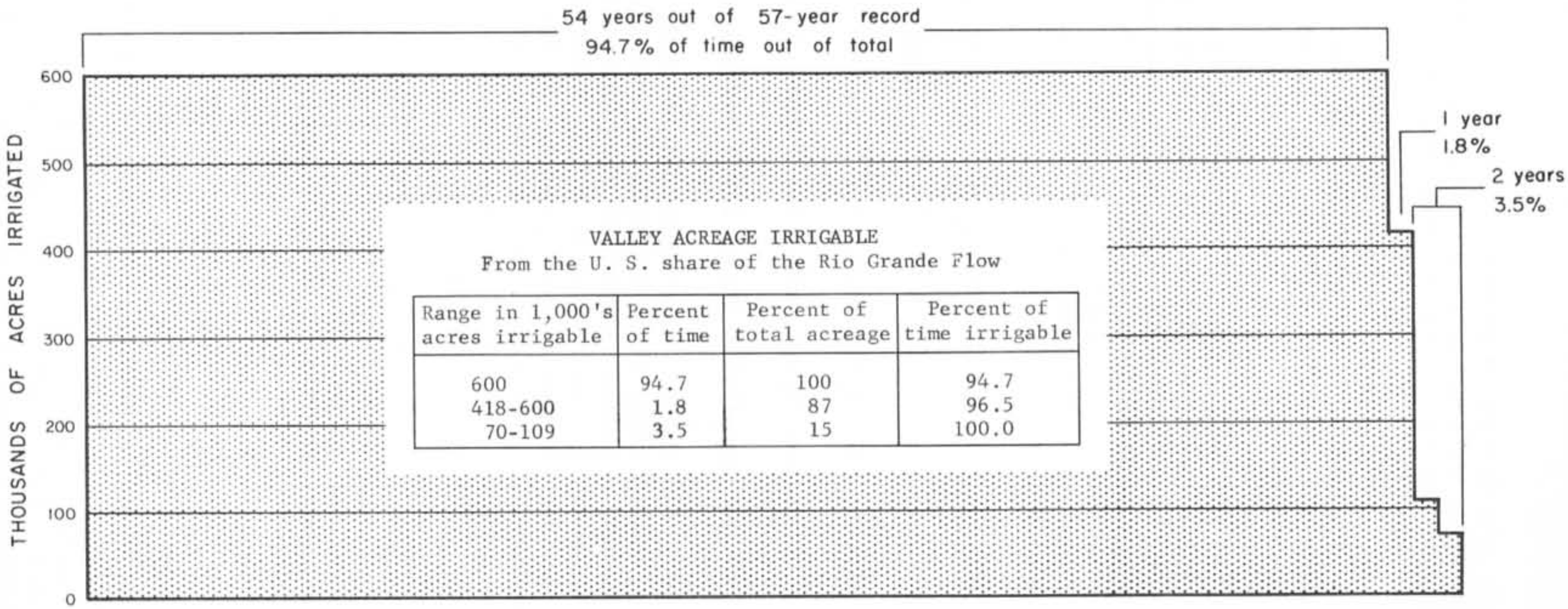
750,000 acres for 63 percent and 70,000 acres for 2 percent of the time;

800,000 acres for 47 percent and 70,000 acres for 2 percent of the time.

Shortages of water supply during the intervening percentages of time are not so severe throughout as indicated by the preceding statements. However, these intervening ranges are not entirely meaningful when expressed as frequencies or durations. The tabulation of the number of acres of cropland that could have been provided a full water supply each year during the periods of shortages for the total cropland in each study does provide a visible means of evaluating the water resource capabilities. A further visual evaluation of these variations is provided by Figures 9 through 13.

In the practice of applying a full irrigation requirement to part of a cropped area during periods of short supply and resting or dry farming the remainder, the gross economics can be evaluated within reasonable limits. In highly controlled water-management practices, where in water supplies are husbanded and applied in quantities less than the optimum during critical periods of crop growth to maintain a larger cropped area with probable reduced yields, the water-shortage effects on the gross economics are not, so easily evaluated.

In seeking solutions to specific problems of water management on individual tracts or groups of tracts, the Lower Rio Grande Valley agriculturists have available to them the many Federal, State, and private agencies and specialists active in the Valley. These personnel include those in agricultural research at the U. S. Agricultural Research Service Project Laboratory, and the Texas Agricultural Experiment Station in Weslaco; the Soil Conservation Service Field Office in Harlingen; the Texas Agricultural Extension Service County



VALLEY ACREAGE IRRIGABLE
From the U. S. share of the Rio Grande Flow

Range in 1,000's acres irrigable	Percent of time	Percent of total acreage	Percent of time irrigable
600	94.7	100	94.7
418-600	1.8	87	96.5
70-109	3.5	15	100.0

Figure 9
Acres Irrigable With a Full Water Supply in Time on a 600,000-Acre Demand, 1900-1956
Texas Water Commission

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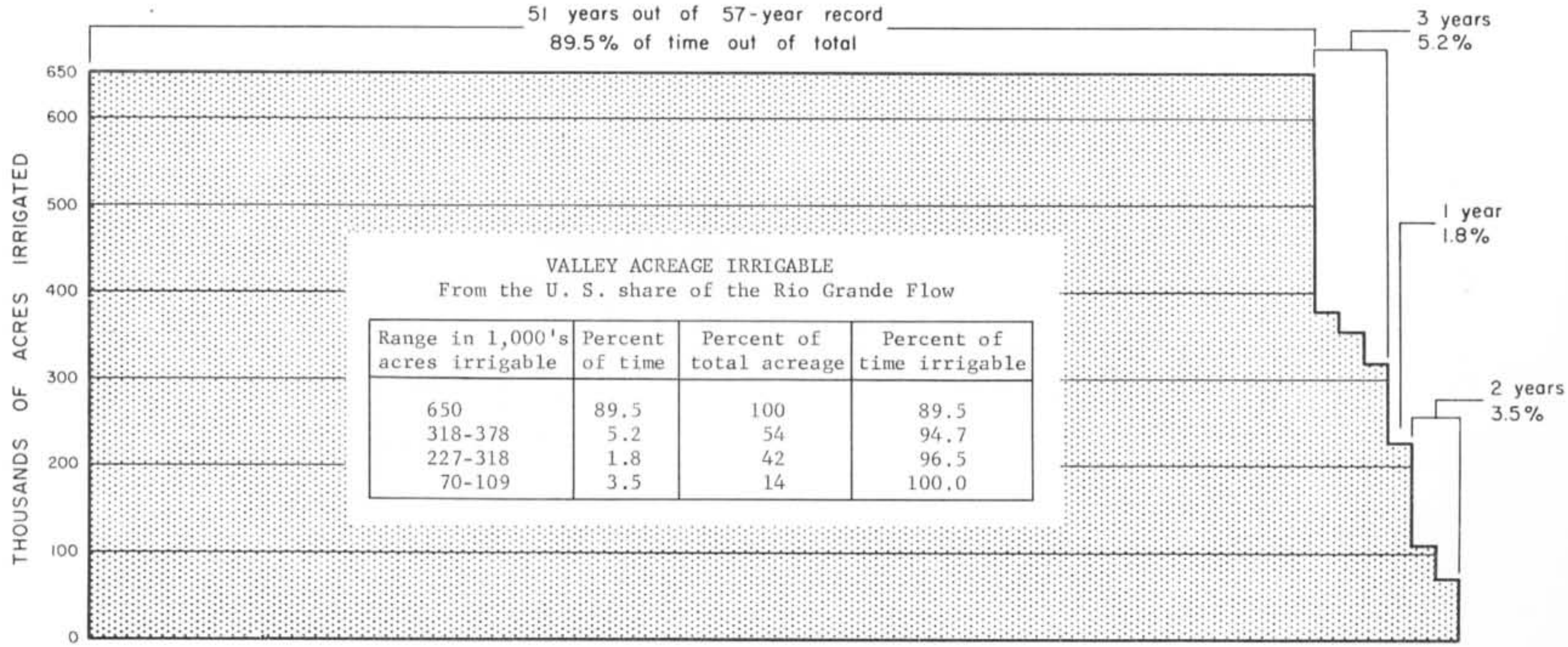

VALLEY ACREAGE IRRIGABLE
From the U. S. share of the Rio Grande Flow

Range in 1,000's acres irrigable	Percent of time	Percent of total acreage	Percent of time irrigable
650	89.5	100	89.5
318-378	5.2	54	94.7
227-318	1.8	42	96.5
70-109	3.5	14	100.0

Figure 10

Acres Irrigable With a Full Water Supply in Time on a 650,000-Acre Demand, 1900-1956

Texas Water Commission

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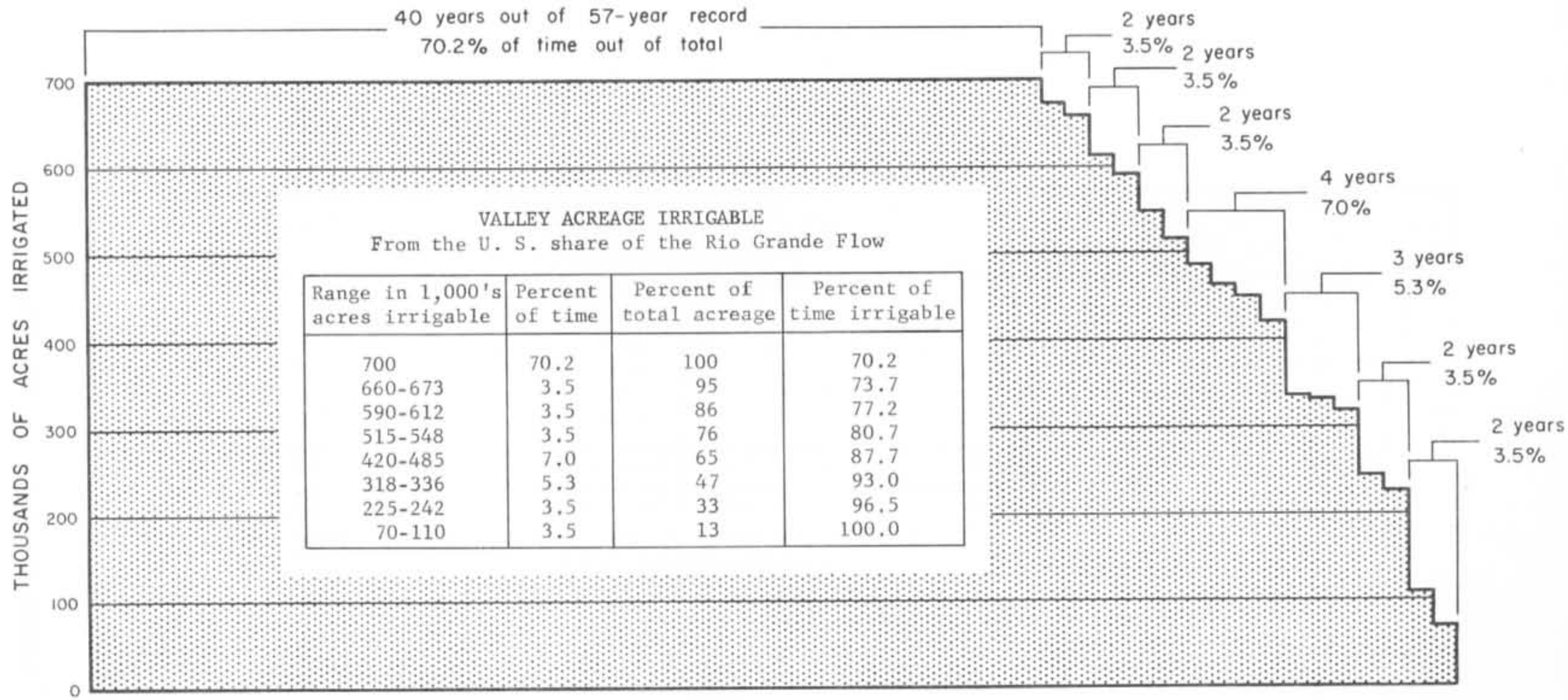

VALLEY ACREAGE IRRIGABLE
From the U. S. share of the Rio Grande Flow

Range in 1,000's acres irrigable	Percent of time	Percent of total acreage	Percent of time irrigable
700	70.2	100	70.2
660-673	3.5	95	73.7
590-612	3.5	86	77.2
515-548	3.5	76	80.7
420-485	7.0	65	87.7
318-336	5.3	47	93.0
225-242	3.5	33	96.5
70-110	3.5	13	100.0

Figure 11

Acres Irrigable With a Full Water Supply in Time on a 700,000-Acre Demand, 1900-1956

Texas Water Commission

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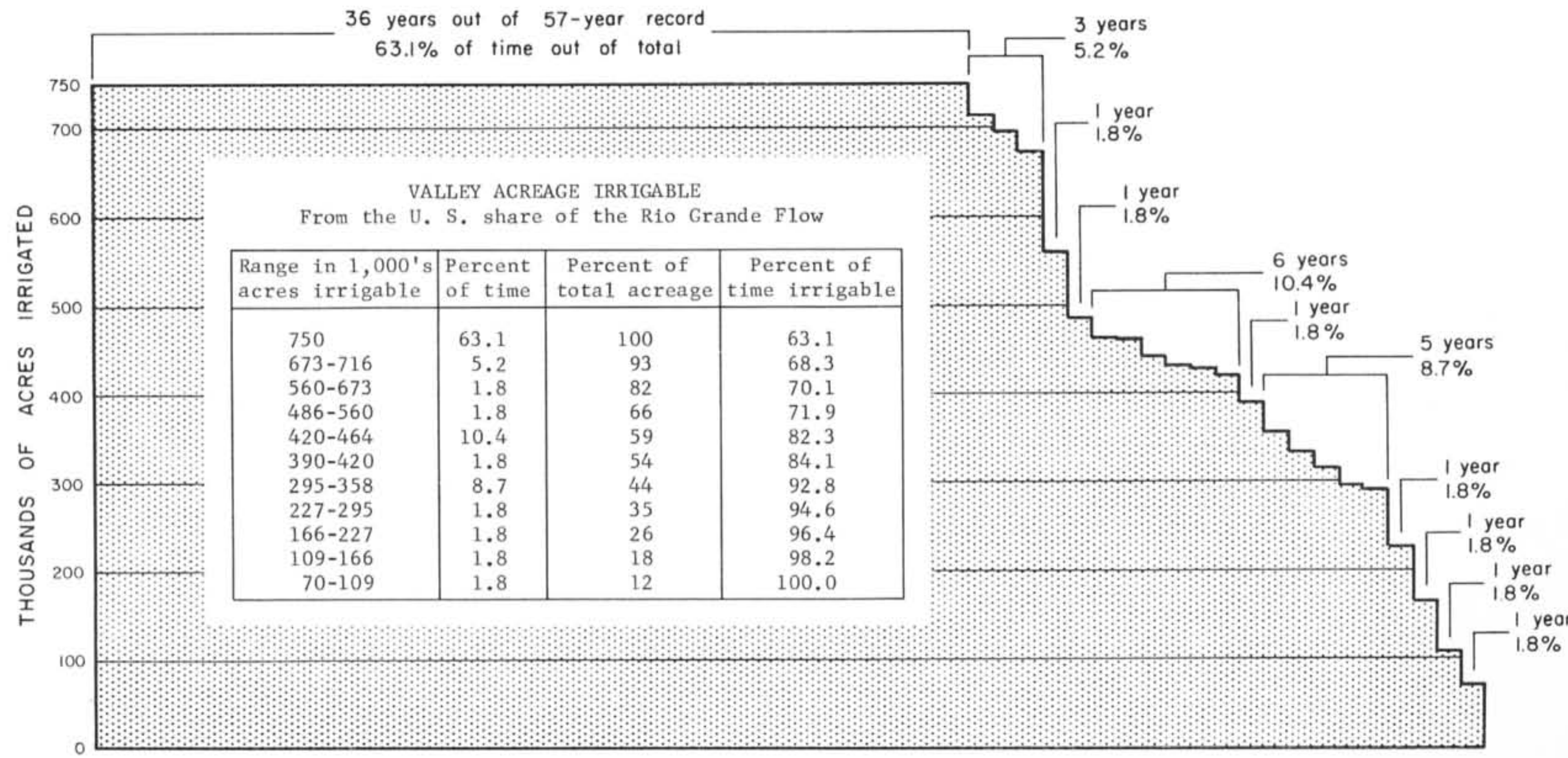

VALLEY ACREAGE IRRIGABLE
From the U. S. share of the Rio Grande Flow

Range in 1,000's acres irrigable	Percent of time	Percent of total acreage	Percent of time irrigable
750	63.1	100	63.1
673-716	5.2	93	68.3
560-673	1.8	82	70.1
486-560	1.8	66	71.9
420-464	10.4	59	82.3
390-420	1.8	54	84.1
295-358	8.7	44	92.8
227-295	1.8	35	94.6
166-227	1.8	26	96.4
109-166	1.8	18	98.2
70-109	1.8	12	100.0

Figure 12
Acres Irrigable With a Full Water Supply in Time on a 750,000-Acre Demand, 1900-1956
Texas Water Commission

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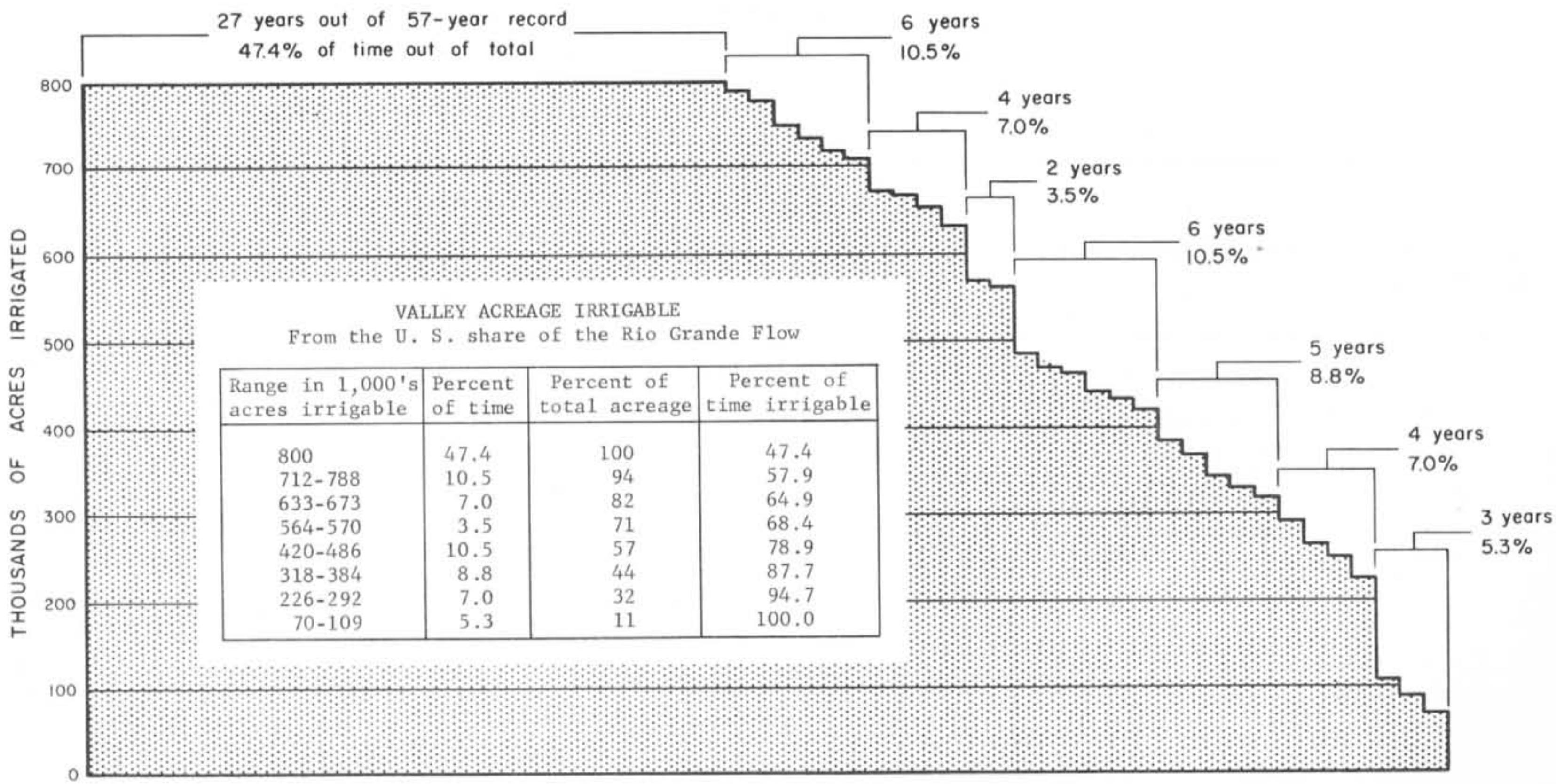

VALLEY ACREAGE IRRIGABLE
From the U. S. share of the Rio Grande Flow

Range in 1,000's acres irrigable	Percent of time	Percent of total acreage	Percent of time irrigable
800	47.4	100	47.4
712-788	10.5	94	57.9
633-673	7.0	82	64.9
564-570	3.5	71	68.4
420-486	10.5	57	78.9
318-384	8.8	44	87.7
226-292	7.0	32	94.7
70-109	5.3	11	100.0

Figure 13

Acres Irrigable With a Full Water Supply in Time on an 800,000-Acre Demand, 1900-1956

Texas Water Commission

Agents in Starr, Hidalgo, Cameron, and Willacy Counties; the U. S. Bureau of Reclamation Project Office in Weslaco; the many capable managers of the water districts; and the consulting engineers and farm specialists.

Economic Effects of Water Shortages

Of some 1,750,000 acres of cropland and pastured lands in the Lower Rio Grande Valley, about 750,000 acres were producing crops, livestock, and livestock products with the aid of irrigation during the 7-year period 1957-63. The water for irrigation was largely diverted from the Rio Grande below International Falcon Reservoir, but smaller amounts were obtained from ground-water sources and other surface-water sources. Parts of the land in irrigation produced two or more irrigated crops annually.

The average annual farm cash income (not adjusted to constant dollar value) from all agricultural production in the Valley during the period 1957-63 was $157,000,000. It is estimated that of this amount, the average irrigated farming production value was about $113,000,000. The gross value of the irrigated farm-produced agricultural commodities during the period averaged about $119 per acre-foot of irrigation water diverted.

These amounts include farm income from all crop and livestock sources, exclusive of government subsidies, both with irrigation and without. Income values from Valley farming during this period, except for temporary setbacks caused principally by adverse weather conditions, follow the same vigorous upward trend that has existed for many years, having grown steadily from an annual value in 1927 of only 13-1/2 million dollars. Since 1944, cash farm income value in these four counties has exceeded 100 million dollars annually (not adjusted to constant dollar value). This constitutes a major segment of the overall economy of the Lower Rio Grande Valley, not alone in the form of direct farm income values but especially in the form of large values derived from agriculturally dependent services, and machinery, equipment, materials, processing, marketing, and transportation businesses that agriculture supports or helps to support. These include: canneries, 15; wholesale fruit and vegetable shippers, 97; frozen food processors, 7; fruit package shippers, 19; agricultural chemical formulators, 12; concrete pipe manufacturers, 4; plastic bag and tube manufacturers, 2; cotton compresses, 12; cotton gins, 81; tin can plants, 1; meat packing plants and fabricators, 18; plus box factories, food machinery plants, and so on, combining to produce a large part of an additional 90-million-dollar annual industrial income. The direct farm cash income alone provides 35 percent of the nearly half a billion dollar annual economy of the Valley--a greater amount than from any other single source.

Irrigation farming provides much of the nearly 160-million-dollar annual direct farm income. Over 95 percent of the annual farm income derived from production of citrus fruit, vegetables, and nursery stock was produced from irrigated lands. Irrigated improved pastures provided over 88 percent of the cash farm income from all improved pastures. About 82 percent of the farm income value of corn, hay, and ensilage production, and 73 percent of the farm income value of cotton production was derived from irrigated crop acreage. Nearly 38 percent of the farm income from grain sorghum production came from irrigated land, while about 44 percent of the farm cash income value of all livestock and livestock products is estimated to have been produced with the aid of irrigated pasture and feed production. Overall, 72 percent of all cash farm income values in the Lower Rio Grande Valley for the 1957-1963 period, during which irrigation releases from Falcon Reservoir have been made under Water Master supervision, was derived from irrigation farming.

The gross values given above and used in the analyses that follow measure more clearly than would net farm income values the size of the Valley farming business and reflect the extent to which the secondary services and businesses, dependent on Valley agriculture, augment the economy. Although net farm income values are highly variable, affected by numerous production efficiency factors, efficient producers can usually obtain returns over chargeable operating expense (exclusive of unallocated costs for such expenses as interest on farm real estate, insurance, depreciation charges on farm buildings, and farm taxes) amounting to from one-third to one-half of the gross farm income value of the crops produced.

Irrigation farming in the Lower Rio Grande Valley is important, also, to the State of Texas and the Nation. Five percent of the State's agricultural production comes from the Lower Rio Grande Valley and, in 1959, its irrigated acreage was 11 percent of all Texas irrigated acreage.

Cotton has been providing, during the 1957-1963 period, about 43 percent of the gross farm income value from irrigation in the Lower Rio Grande Valley, while vegetables--largely tomatoes, carrots, cabbage, onions, sweetcorn, lettuce, snapbeans and green peppers--account for 23 percent, and citrus fruit nearly 12 percent. Livestock and livestock products make up over 11 percent of irrigated production values while all other commodity groups constitute the remainder. These percentages are based on U. S. Agricultural Census data, Economic Research Service data, and data made available by the Lower Rio Grande Valley Chamber of Commerce.

Relatively low production costs and high quality fruit gives the Valley a potential for citrus fruit production that compares favorably with other U. S. citrus-producing areas. Yields per tree are generally lower than in Florida or California but this factor is offset by low production costs. If it were not for damage caused periodically by freezing (experts are optimistic about overcoming this problem), the Valley with its capability of producing fruit of superb quality with relatively low production costs, maintenance of soil fertility, and other production factors would have distinct regional advantages for citrus growing. Even with the hazard of killing freezes, the area is competitive with other citrus-producing areas. Grapefruit, early and midseason oranges, and late oranges will share the acreage and almost all citrus fruit will be produced with irrigation.

Likewise, vegetable growing, largely with irrigation, will continue to be important in the Lower Rio Grande Valley, furnishing a significant part of the growing national demand for fresh market and, particularly, processed vegetables. Acreages are likely to fluctuate from year to year and from season to season, for given vegetables, with emphasis on winter-harvested vegetables and others required to fulfill market needs at times when supplies are not generally adequate or not available from other producing areas.

Cotton production can be expected to continue as a major farming enterprise in this area and undoubtedly a large percentage of it will continue to be produced with irrigation. Livestock producers are finding that irrigated improved pastures offer opportunities to improve their income from livestock and livestock products and are developing a growing acreage of irrigated improved pasture. Alfalfa and other hay, corn, grain sorghum, and other commodities will continue to be produced in the Valley, with some use of irrigation.

The Economic Research Service, U. S. Department of Agriculture, in conjunction with specialists of Texas A&M University and the Texas Agricultural Experiment Station, and the Soil Conservation Service, USDA, in 1960 and 1961 made an analysis of irrigated and nonirrigated crop yields and production values for the U. S. Study Commission-Texas. Yields from these studies, shown in Table 18, are consistent with basic yield projections for 1975 provided by specialists at Texas A&M University and are in close agreement with yields obtained by the Soil Conservation Service in an inventory made for the production study, reflecting yield levels that were being equalled or exceeded in 1959 by the 5 to 10 percent of all producers in the Rio Grande Plain area who were using the best management techniques and conservation practices. These levels were expected to be generally attained by all producers by 1975, under average climatic and other limitations expected to prevail at that time.

In the aforementioned studies by the Economic Research Service for the U. S. Study Commission-Texas, 1975 projections of production values for Rio Grande Plain irrigation farming showed an estimated per-acre dollar output on a composite acre, made up of proportionately weighted areas of each crop, ranging from 3 to over 10 times the dollar output from nonirrigated production on corresponding soils. Much of these differences is due to different land usage and cropping pattern, with and without irrigation, with high value crops being produced on the highest producing soils when and where irrigation can be given. Range, pasture, feed, and other lower investment, and lesser risk enterprises are depended on when the same soil is not irrigated. Since the yields and values in Table 18 do not reflect this difference in use and cropping of the same soil, with and without irrigation, values shown are conservative. Too, there are new techniques--improved varieties, cultural methods, knowledge of fertilizer needs and usage, and others--that have already been developed and are undergoing testing that can become "break-throughs" to additional production increases for irrigated crops.

Applying the irrigated and nonirrigated per acre values of each commodity shown in Table 19 to the proportionate irrigated acreages of each that have been grown in the Lower Rio Grande Valley (see section on "Cropping Pattern"), the composite irrigated acre production value is $305.16; the composite nonirrigated acre production value is $83.19--a difference in value of $221.97 per acre as shown in Table 19.

The composite irrigated-acre production values can be used to derive conservative estimates of the agricultural production values attainable with irrigation at any levels of irrigation water availability, based on the acreage that can be fully irrigated with water that is available. The difference between composite irrigated and nonirrigated production values can be used to estimate conservatively the economic significance of decreases or increases in irrigation water availability and to establish unit values of water that is made available for irrigation (value added, with irrigation). Table 20 gives these values per acre-foot of water diverted from Falcon Reservoir, based on diversion requirements to satisfy the composite-acre irrigation needs.

Table 18.--Projected yields and production values for major crops* in Starr, Hidalgo, Cameron, and Willacy Counties, Texas

Item	Cotton	Corn	Grain sorghum	Citrus fruit	Vegetables		Improved pastures
					Shallow-rooted	Deep-rooted	
Unit	Lbs of lint[a]	Bu	Cwt	Ton	Cwt	Cwt	AUM[b]
Irrigated yield/acre	860	75	49	12.4 [c]	276.4 [d]	132.2 [e]	14.0 [f]
Nonirrigated yield/acre	327	30	25	--	--	--	2.5 [f]
Difference in yield/acre	533	45	24	12.4	276.4	276.4	11.5
Unit price (dollars)[g]	.26[h]	1.48	2.40	32.90	1.90[i]	1.95[j]	10.92
Irrigated value/acre[k] (dollars)	278.71	111.00	117.60	407.96	525.16	257.79	152.88
Nonirrigated value/acre[k] (dollars)	105.97	44.40	60.00	--	--	--	27.30
Difference in value/acre[k] (dollars)	172.74	66.60	57.60	407.96	525.16	257.79	125.58

* Except as noted below, yields are derived from 1975 yield and acreage projections developed for the U. S. Study Commission-Texas by the Economic Research Service, USDA, working cooperatively with specialists of Texas A&M University and the Soil Conservation Service.

a/ Also 1.8 lbs seed per lb of lint.

b/ An AUM (animal unit month) is equal to the feeding value of approximately 450 lbs of corn and is the amount of grazing required for a cow and calf, steer (over yearling), or equivalent for one month.

c/ Irrigated yields based on data from Texas A&M Bulletin 1002, Guide for Citrus Production in the Lower Rio Grande Valley, Table 16, assuming 25-year tree age, prorating yields to full 25-year (nonbearing and bearing) period. Based on 1/3 acreage each of grapefruit, early and midseason oranges, and late oranges. All future citrus assumed to be irrigated.

d/ Yields for cabbage, onions taken from Texas A&M University MP-719, Production and Production Requirements, Costs and Expected Returns....Loam Soils--Lower Rio Grande Valley of Texas, and weighted by proportionate 1958 normalized acreage.

e/ Yields for tomatoes, carrots (from MP-719, cited above) and snap beans (from Snap Beans for Canning, Texas Agricultural Extension Service) weighted by proportionate 1958 normalized acreage.

f/ Based on SCS technical guide estimates, Harlingen Area work units, following good pasture management practices and complete conservation treatment.

g/ Unit prices are projected, using projections currently being used by the Bureau of Reclamation: Index of Prices Received By Farmers, 250 (1910-14=100).

h/ Plus $71.20 per ton for seed.

i/ Based on cabbage and onions.

j/ Based on tomatoes, carrots, snap beans.

k/ Values given are for a single crop: multiple cropping will increase proportionately value per acre.

Table 19.--Production values*--composite acre, Starr, Hidalgo, Cameron, and Willacy Counties, Texas

Crop	Percent of total acres of crops[a]	Value per crop acre (dollars)	Proportionate value-composite (dollars)
	Irrigated		
Cotton	41	$278.71	$114.27
Corn	2	111.00	2.22
Grain sorghum[b]	18	117.60	21.16
Citrus	10	407.96	40.80
Pasture	8	152.88	12.23
Vegetables[b] (shallow-rooted)	11	525.16	57.77
Vegetables[b] (deep-rooted)	22	257.79	56.71
Production value (weighted) - composite irrigated acre..			$305.16
	Nonirrigated[c]		
Cotton	60	105.97	$ 63.58
Corn	3	44.40	1.33
Grain sorghum	25	60.00	15.00
Pasture	12	27.30	3.28
Production value (weighted) - composite nonirrigated acre			$ 83.19
Difference - irrigated and nonirrigated acre............			$221.97

* Projected prices as currently used by Bureau of Reclamation. Base: 1910-14=100; Index, Prices Received by Farmers - 250.

a/ Percentages include double-cropped acreages, with irrigation only. "Irrigated" percentages reflect the same cropping pattern used for water requirement computations.

b/ Double-cropped acreage of these crops included in percentage.

c/ Acreage that would be used for citrus and vegetables, if irrigated, has been prorated to the nonirrigated crops shown, with no double cropping, without irrigation.

Table 20.--Future agricultural value estimates attainable from diversions from Falcon Reservoir for irrigation in Starr, Hidalgo, Cameron, and Willacy Counties, Texas

1.	Total Production value, composite acre	
	a. Irrigated	$305.16
	b. Not irrigated	83.19
2.	Value added through irrigation (1a - 1b)	$221.97
3.	Diversion requirement in acre-feet, irrigation of composite acre	
	a. Maximum	[redacted] 3.52 acre-ft
	b. Minimum	.98 acre-ft
	c. Average	2.21 acre-ft
4.	Total production value per acre-foot of diversion	
	a. With maximum diversion (1a ÷ 3a)	$ 86.69
	b. With minimum diversion (1a ÷ 3b)	311.39
	c. With average diversion (1a ÷ 3c)	138.08
5.	Value added through irrigation per acre-foot of diversion	
	a. With maximum diversion (2 ÷ 3a)	$ 63.06
	b. With minimum diversion (2 ÷ 3b)	226.50
	c. With average diversion (2 ÷ 3c)	100.44

Precipitation records since 1903 were used in computations, assuming the fulfillment of total irrigation needs of crops grown, and district and farm irrigation system efficiency that will hold transmissional and water management losses low.

CONCLUSIONS

The water resource for Valley use, as comprised of the available water supply afforded by conservation storage in Amistad and Falcon Reservoirs and the United States' share of water occurring in the Rio Grande, assures a more stable economy in the Valley through a more dependable agricultural production dependent on irrigation water from the Rio Grande than was available before the construction of these two projects.

The water resource is not limitless. It will support a large acreage of irrigated cropland part of the time only. During severe drought as occurring in the early 1950's, even the 3-1/2 million acre-feet of conservation storage space provided by Amistad and Falcon Reservoirs cannot provide an adequate water supply for a large acreage. In fact, the run of the river cannot be made wholly available for beneficial uses.

The greatest benefit for the Valley from year to year may be provided by establishing an acreage that can be irrigated yearly with a full water supply from the Rio Grande for the longest period of time compatible with a reasonable period and degree of water shortage for the established acreage. Such an amount is indicated by the relationships expressed by the curves shown on Figures 14 through 19.

Figure 14 shows the weighted average annual acreage served a full water supply in relation to an established total acreage demand. The best relationships are expressed by the portion of the curve having the least upward slope. As the slope sweeps upward, the relationship is shown as deteriorating rapidly.

Figure 15 shows the relationship of the percentage shortage in the acreage served to the total acreage demand. The sag in the curve at about 680,000 acres with a 10 percent weighted average shortage appears to be a favorable relationship as the curve begins to sweep upward from that vicinity.

Figure 16 further expresses the rapid deterioration in benefits derived from increased acreage under irrigation by the relationships of the net increase in irrigable acreage for each 50,000-acre increment added to a base of 600,000 acres. At the intercept of 680,000 acres on the curve, the abscissa shows that an average of 10,000 acres can be irrigated out of a 50,000-acre increase. This is an overall 20 percent gain and an 80 percent loss.

Figure 17 shows a rate of increase in the number of acres irrigable out of each 100 acres added to a base amount. At the intercept for 680,000 acres, the gain is 15 acres per 100. The relationship deteriorates rapidly for additional acreages from that point.

Figure 18 expresses the relationships of total irrigated acreage throughout the study period to the projected value estimated for the average cropping pattern used in the study. Total value of the annual crop increases with increased acreages irrigated. The degree of risk of more years of decreased income is implied by the upsweep above 650,000 acres.

Figure 19 shows the general relationship in a different manner by relating the incremental increase in the average annual crop value to the total irrigated acreage established for the full period of study.

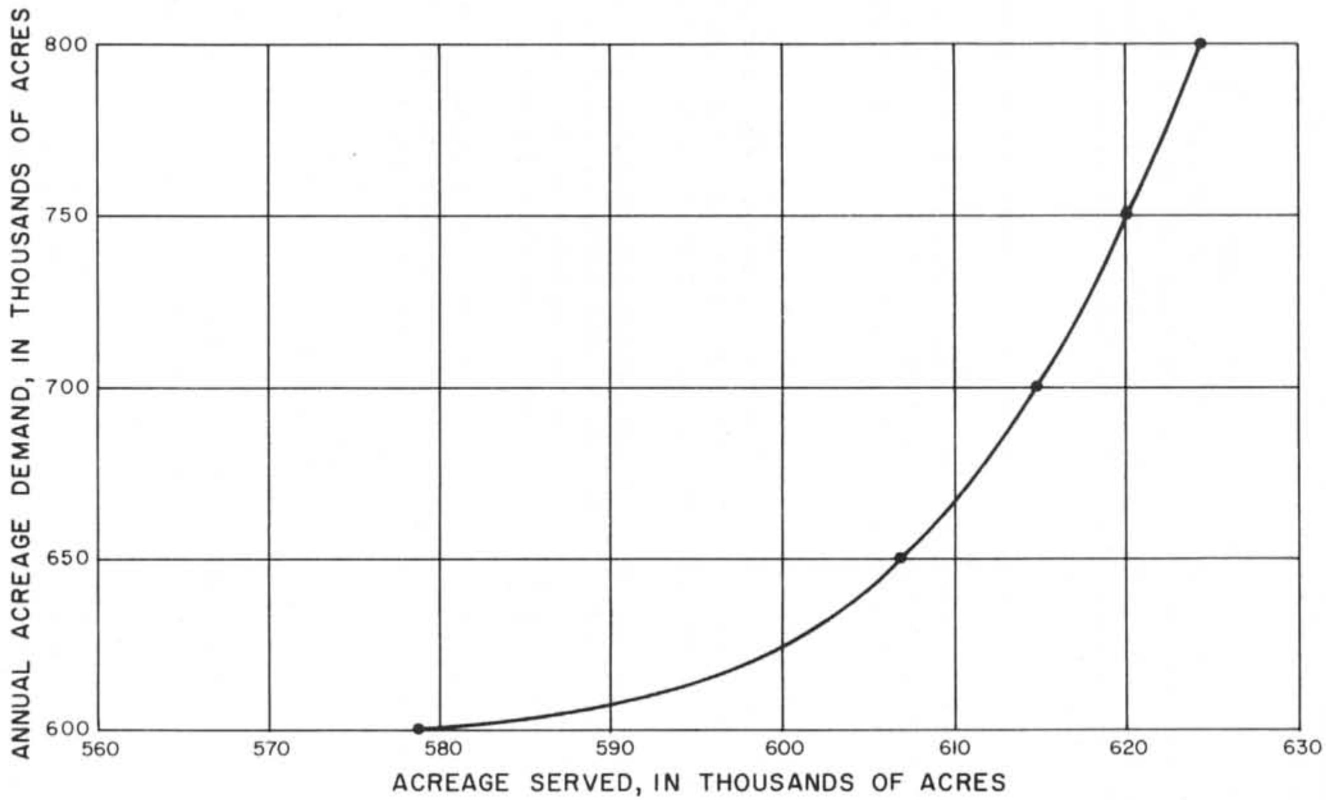

Figure 14

Weighted Average Annual Acreages Irrigable, 1900-1956

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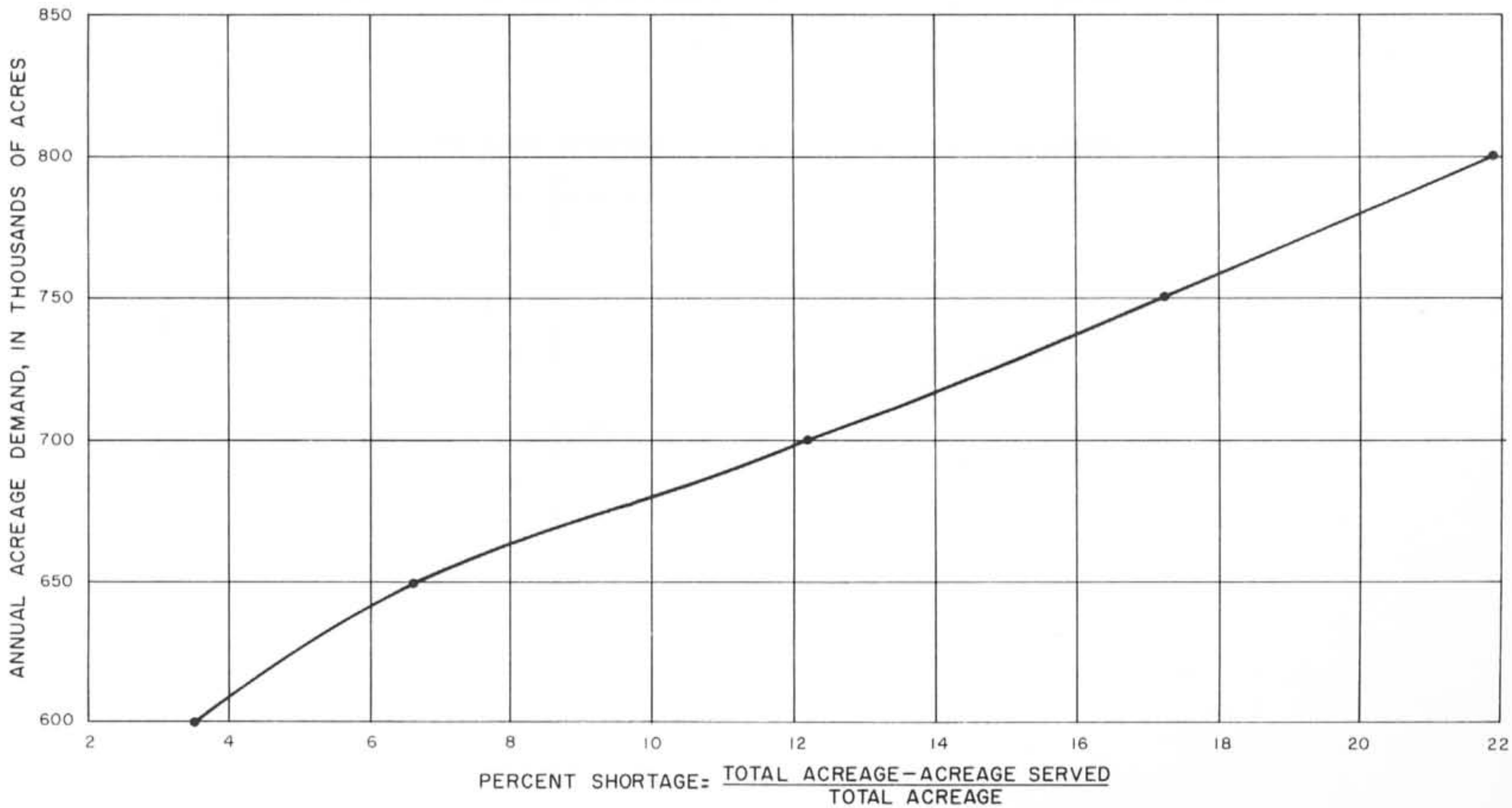

Figure 15

Percent Shortage in Weighted Average Annual Irrigable Acreage, 1900-1956

Texas Water Commission

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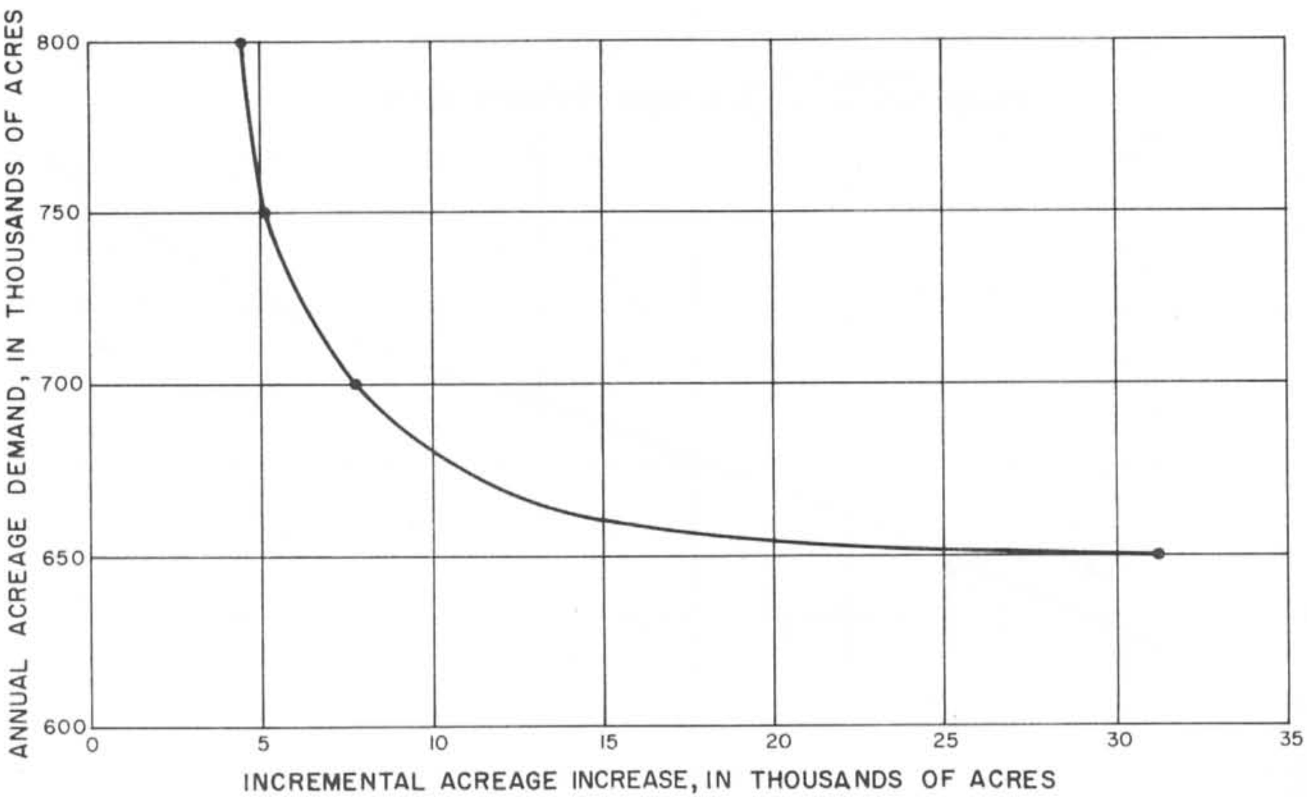

Figure 16

Incremental Irrigable Acreage Increase Per 50,000 Acres Added Cropland, 1900-1956

Texas Water Commission

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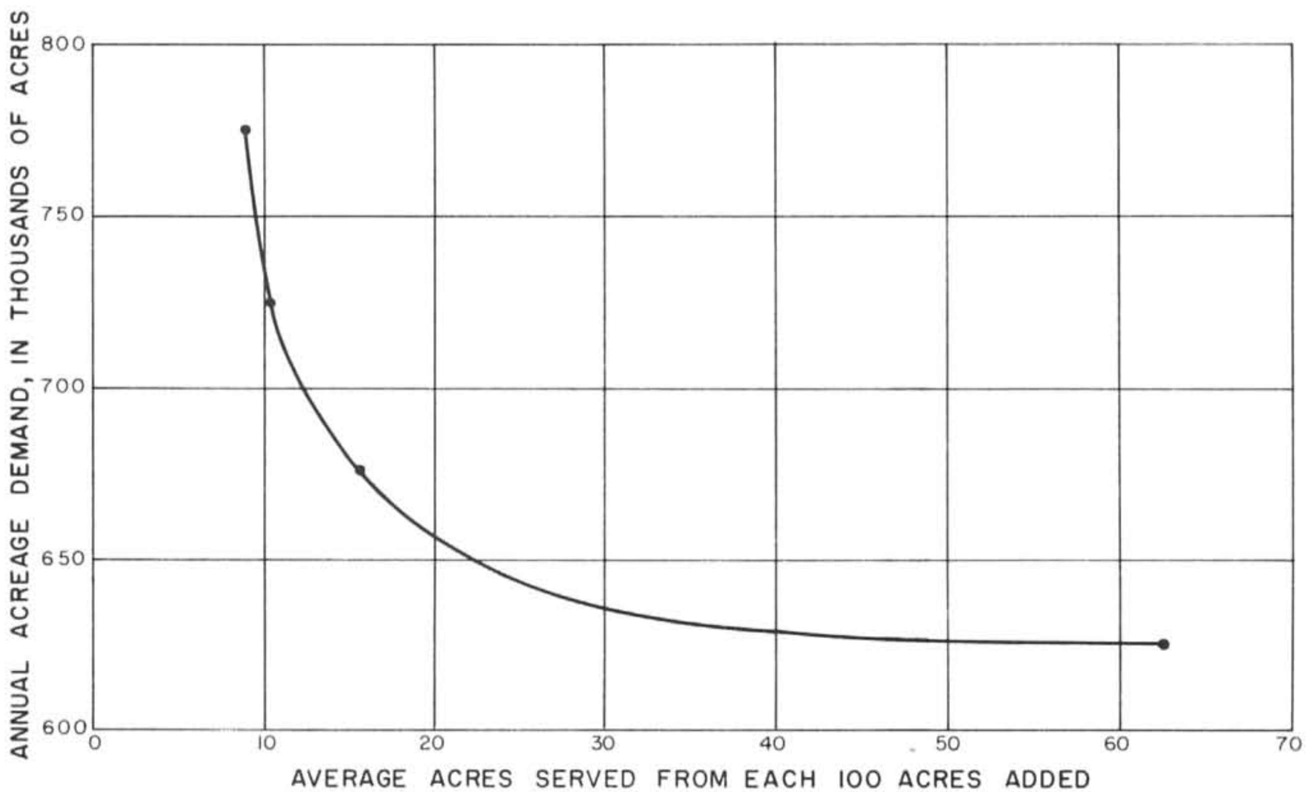

Figure 17

Average Number of Acres Irrigable From Each 100 Acres of Added Cropland, 1900-1956

Texas Water Commission

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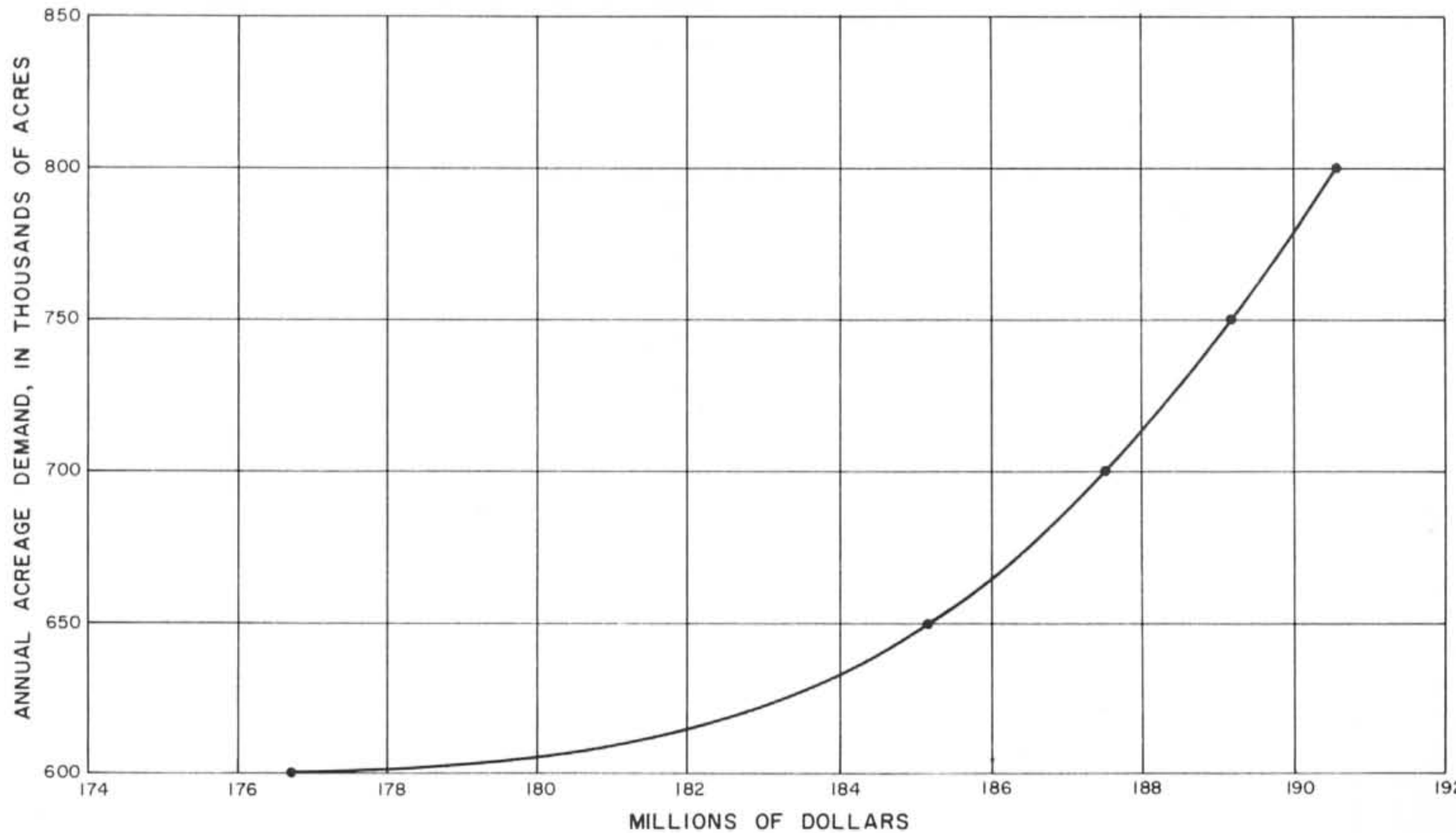

Figure 18

Weighted Average Annual Projected Crop Values for 57-Year Period

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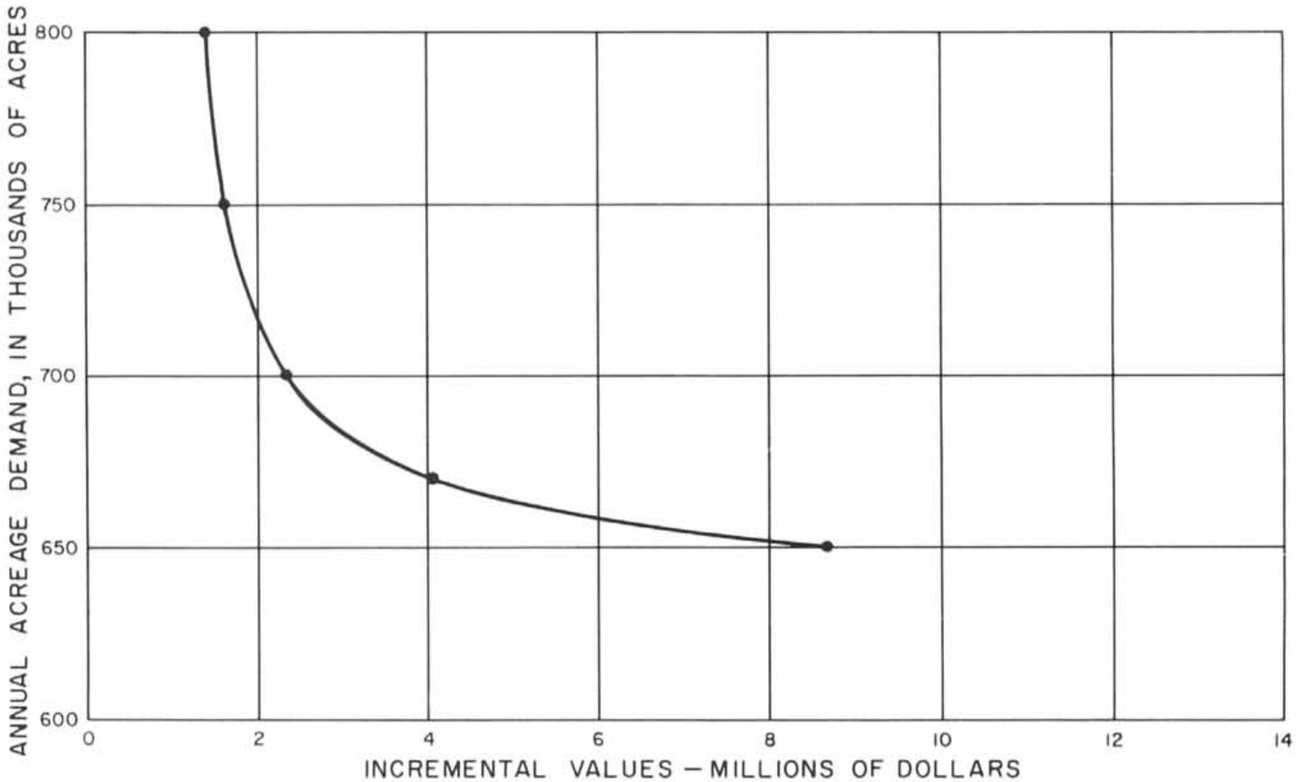

Figure 19

Incremental Increase in Gross Value of Irrigable Acreage Per 50,000 Acres Added Cropland

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It is concluded from the relationships expressed by Figures 14 through 19 that the maximum area to be irrigated below Falcon Dam should not exceed 650,000 to 680,000 acres. It is to be noted that the weighted average annual shortage is an index for comparison only and does not imply that conditions each year will be as illustrated by Figures 14 through 19.

Numbers as derived for plotting the preceding Figures 14 through 19 are shown in Tables 21, 22, and 23.

Highly controlled water management practices in the Valley can be a great benefit to the entire economy. Statistical tools and procedures for use in analyzing the relative risk and severity of occurrence of nature's actions are far from having the reliability desired. However, evaluations of the future available water supply each year can be made from end-of-year contents in storage in Amistad and Falcon Reservoirs plus the median annual inflow to provide a basis for initial estimates of acreage irrigable each future year. These estimates could be revised progressively on the basis of more current predictions. To provide bases for current predictions, a system of hydrologic index observation points established for weather evaluation and predictions, for computing climatic indexes for short periods, for determining available moisture content of soil reservoirs under crop, for computing consumptive use of water by crops for short periods, and for predicting inflows to the conservation storage reservoirs can be of material advantage. Also, such data can be used for optimizing irrigations and efficiency of water use to provide the greatest benefit with the least risk in supporting a large agricultural development.

Such management would require a permanent staff in the Valley to assist each irrigator in perfecting his use of water to accomplish the maximum development for the Valley as a whole.

Table 21.--Weighted average annual acreage irrigable, 1900-1956

Established acreage	Weighted average annual irrigable acreage	Average annual shortage, in acres	Average annual shortage, in percent
600,000	578,900	21,100	3.5
650,000	607,100	42,900	6.6
700,000	614,900	85,100	12.2
750,000	620,000	130,000	17.3
800,000	624,500	175,500	21.9

Table 22.--Incremental acreage irrigable from each 50,000-acre incremental increase, 1900-1956

Established acreage	Additional acreage attempted	Additional acreage actually irrigable	Incremental acreage served out of each 100 acres added
600,000	--	--	--
650,000	50,000	21,200	62.4
700,000	50,000	7,800	15.6
750,000	50,000	5,100	10.2
800,000	50,000	4,500	9.0

Table 23.--Projected estimated gross value of established acreages

Established acreages	Gross value of irrigated* crops in dollars	Incremental increase in gross value in dollars
600,000	176,700,000	--
650,000	185,300,000	8,600,000
700,000	187,600,000	2,300,000
750,000	189,200,000	1,600,000
800,000	190,600,000	1,400,000

* Based on irrigated acre value of $305.

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<u>Lower Rio Grande Valley Chamber of Commerce, Weslaco Division</u>

Farm Cash Income, Cameron, Hidalgo, Starr, and Willacy Counties.

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<u>Ninety-Third Judicial District of Texas</u>

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