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A SOCIOTECHNICAL SURVEY OF GUAYULE RUBBER COMMERCIALIZATION

A State-of-the-Art Report

For the National Science Foundation
Division of Policy Research and Analysis
Grant No. PRA 78-11632

By The Office of Arid Lands Studies
University of Arizona, Tucson, Arizona &
Midwest Research Institute
Kansas City, Missouri

April 1979

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A SOCIOTECHNICAL SURVEY OF GUAYULE RUBBER COMMERCIALIZATION

by

Dr. Kennith E. Foster
Dr. William G. McGinnies
Mr. Jonathan G. Taylor
Ms. Jean L. Mills
Ms. Suzanne J. Alexander
Mr. N. Gene Wright
Office of Arid Lands Studies
University of Arizona

Mr. David de Kok
Dr. Lay J. Gibson

Department of Geography
and Regional Development

Dr. Ralph R. Wilkinson
Mr. Fred C. Hopkins
Dr. Edward W. Lawless
Ms. Joy L. McCann

Midwest Research Institute

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A SOCIOTECHNICAL SURVEY OF GUAYULE RUBBER COMMERCIALIZATION

ERRATA

Page 138: Footnote 3. High projection based on T.W.D.B. predictions of increasing irrigation efficiencies; 78 percent in 2000, 85 percent in 2020.

Footnote 4: Low projection based on constant irrigation efficiency of 50 percent.

Page 207:

		Value of Production
Hay	1976	39,592.0
	$\overline{X}$	35,526.6

Page 216:

		Planted Acreage
Corn	1977	13,510

Page 217: Footnote 1. Value of production aggregated for Upland and American Pima cotton.

Page 220 and 221: In "Year" column, all X's should read $\overline{X}$

Page 223: In "Year" column, all X's should read $\overline{X}$

		Harvested Acreage
Corn	1969	0

Page 278: Line 7; change (10.7 million acres) to (14.3 million acres)

Page 141: County Data under year 2000, Agricultural withdrawal should be shifted to 1974 irrigated acreage.

Page 315: Jenny, W.M. is with the Energy Resource Development Division, Department of Energy, Kansas City, Missouri.

ABSTRACT

The purpose of this sociotechnical survey is to determine the state-of-the-art of the agricultural and industrial aspects of guayule technology. Information on guayule rubber chemical and industrial properties, production history and trends in research and development is being assessed. An in-depth review of the prospects for guayule commercialization is being conducted to include national and regional interests in guayule development. U.S. rubber supply and demand; Hevea rubber production and synthetic rubber development; economic uncertainty; and environmental, sociocultural, land and governmental considerations all are being identified. Finally, alternative technologies which could alter rubber supply or produce changes in rubber demand are being assessed.

PREFACE

A substantive technology assessment (TA) is being made of the potential commercialization of the desert shrub guayule (*Parthenium argentatum*) as a domestic source of natural rubber. The technology assessment project is divided into five major task phases: orientation, sociotechnical survey, technology forecasting, impact assessment, and policy assessment. This report culminates the Phase II, the sociotechnical, state-of-the-art survey of guayule technology. The material in this report is preliminary in nature, and may be subject to revision in the final TA report. The TA is being made by a project team consisting of staff members from the University of Arizona Office of Arid Lands Studies (OALS) and Midwest Research Institute (MRI) with inputs from selected technical consultants and the oversight of an Advisory Committee of diverse experience. This study is supported by the National Science Foundation, Grant No. PRA 78-11632 and MRI Project No. 4628-L. Dr. G. Patrick Johnson is the NSF project officer.

The core members of the project team include: for OALS, Mr. Jonathan Taylor, Research Specialist and Ms. Jean Mills, Coordinator of the Guayule Information Center, under the direction of Dr. Kennith Foster, Associate Director of OALS; and for MRI, Dr. Ralph Wilkinson, Associate Technology Scientist, and Mr. Fred Hopkins, Assistant Scientist, under the supervision of Dr. Edward Lawless, Head, Technology Assessment Section. The full list of staff members, consultants and Advisory Committee members is appended.

The project team is deeply grateful to the many persons who reviewed and critiqued portions of this state-of-the-art report on guayule technology and thanks these individuals at this time. The team also expresses its sincere appreciation to the editorial and manuscript preparation staff for their tireless efforts.

Approved for:

MIDWEST RESEARCH INSTITUTE

L. J. Shannon, Executive Director
Environmental and Materials
Sciences Division

Approved for:

OFFICE OF ARID LANDS STUDIES

J. D. Johnson, Director
Office of Arid Lands Studies
University of Arizona

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I. INTRODUCTION

Rubber is one of the most critical materials used by modern civilization. About 10 million tons of it are consumed annually worldwide in a host of uses that demand its elastic, friction or waterproof properties. These uses include tires and tubes for wheeled vehicles (bicycles, autos, trucks, tractors, airplanes, military and mass transportation), V-belts (for appliances, industrial and agricultural machinery, etc.), industrial and commercial conveyor belts, hoses, shock absorbers, seals, bridge supports, boots and other rainwear, and school and office supplies. Although rubber was obtained originally from the rubber tree, synthetic rubbers were developed during World War II that now supply more than 60 percent of the world demand.

The U.S. rubber supply--both natural and synthetic--is precarious. The increasing worldwide demand for the limited production of natural rubber and for the petroleum that serves as a raw material for synthetic rubber is one factor. In addition, the international situation poses major uncertainties for the Western World; dependable sources of inexpensive natural rubber and petroleum are not assured.

The most promising alternative source of natural rubber is the guayule (pronounced wy-ōō-lee) plant, a native shrub of semiarid plateaus of the U.S. Southwest and northeastern Mexico. The rubber industry long has known that guayule contained a rubber very similar to that of the rubber tree. Now, much attention again is being given to developing guayule as a domestic source of rubber. Several interested parties in industry, government and universities are actively studying the technological and economic potential of guayule. It is estimated that by the end of this century, one to two million acres of land in the U.S. Southwest eventually may be devoted to guayule production, and perhaps even more in other arid countries.

A. A State-of-the Art Report on the Prospects of Guayule Commercialization

The objective of this study is to perform a comprehensive technology assessment (TA) of the commercialization in the U.S. Southwest of the guayule plant as a major domestic source of rubber. The range of technical, economic, social and national forces will be examined that might stimulate the development of this technology, the range of impacts or consequences that this commercialization may bring, the alternative approaches that are open to governmental agencies and the private sector, and the results that might be expected in exercising different policy options.

The overall TA project is divided into several work phases. Phase I included a "walk through TA session," and refining the project tasks and final report outline and resulted in publication of the document, "Technology Assessment of the Commercialization of

Guayule--Domestic Rubber Source of the Future; Orientation Report," December 1978.

The phase of work reported herein presents the results of tasks undertaken to prepare a state-of-the-art review of the agricultural and industrial aspects of guayule technology. Included is information on the chemical and physical properties of guayule rubber; production history and trends in research and development; discussion of the prospects for guayule commercialization, including national economic concerns, incentives for guayule production and constraints on guayule production; and identification of alternative technologies which may effect rubber supply or demand.

Future phases of the TA project include technology forecasting, impact forecasting and public policy issue assessment.

The final product of this Technology Assessment will be a report that constitutes a platform for informed discussions and decisions regarding this new technology. This TA should be of use to: (a) federal agencies including the Departments of Energy, Interior (including the Bureau of Indian Affairs), Agriculture, Defense, Labor and Commerce; the Small Business Administration; and the Environmental Protection Agency; (b) state and local government agencies and Indian tribes, particularly in California, Arizona, New Mexico and Texas; and (c) private sector parties, including citizens participation groups, guayule growers, rubber-producing companies and industries that depend critically on rubber products.

The present Sociotechnical Survey has three major chapters plus appendices. Major chapters include:

State-of-the Art of Guayule Technology;
Prospects for Guayule Technology; and
Alternate Elastomer Technology

B. Brief Background Development

Although approximately 2,000 species of plants are known to contain some kind of rubber, very few ever have been sources of significant supplies. Only two, the rubber tree (*Hevea brasiliensis*) and the guayule shrub (*Parthenium argentatum*) have been commercial sources of natural rubber. Of these two, the Hevea has been the foundation for developing a rubber products industry and an important factor in developing many industries that rely on rubber components.

Hevea brasiliensis, the rubber tree, is indigenous to the Amazon River Basin and other tropical areas of the Western Hemisphere. The Indians already knew at the time of Columbus' visit to the Western Hemisphere that a natural gum which had elastic and waterproofing properties could be drawn from the trees. European scientists studied the Indian product* during the 1790s. In 1839, the American Charles

* The Indian name was "cahutcha," from which the French derived the word "Caoutchouc." The English word "rubber" was given by the scientist Joseph Priestly in 1770 because the balls of material could erase lead pencil marks from paper. Chemically, Hevea rubber is cis-polyisoprene, $(C_5H_8)_x$.

Goodyear discovered that heating and adding sulfur and certain metallic oxides to rubber changed it from a thermoplastic to a more elastomeric material. This vulcanization process greatly improved the properties of the rubber and spurred interest in its use and commercialization. In 1876, Great Britain began to study the possibilities of growing rubber trees in its colonies in Southeast Asia. By the end of the 19th century, some 4,000 acres of rubber plantations were under cultivation (although only four long tons of rubber per year were harvested) in such British, French or Dutch colonies as Ceylon, Malaya, Indo-China and Indonesia. Southeast Asia became and remains the major source of natural rubber.

The 20th century brought rapid production and demand growth for rubber and rubber products, both natural and, in the 1930s, synthetic. By 1970, the estimated worldwide annual production of Hevea rubber was three million tons; synthetics accounted for another four million tons. Malaysia was the major producer of natural rubber, producing more than 1.1 million tons on 4.2 million acres and the United States was the major consumer with 20 percent of world consumption. By 1970, in addition, a large rubber chemicals industry had developed to produce new vulcanizing agents, accelerators, rubber stabilizers, antioxidants, fillers, softeners, hardening agents, blowing agents and other additives that modern rubber products require; nearly 150,000 short tons of these rubber chemicals worth about $200 million were produced annually. The value of rubber products amounted to billions of dollars. The goods and services that relied on these products were major components of the national economy, defense and quality of life.

World War II brought a forceful realization to the United States that rubber played a critical role in the economy and national defense, and that 90 percent of U.S. supplies in Southeast Asia were being rapidly cut by the Japanese. This development had two immediate consequences:

1) An enormous research and engineering effort was initiated to develop synthetic rubber to replace natural rubber.

2) A substantial effort was initiated to develop new sources of natural rubber.

The second is of most concern to this technology assessment.

U.S. efforts to develop synthetics were built on research studies dating back to 1910, on German efforts during World War I, on German and Russian developments in the 1920s and 1930s, and on the American development of neoprene rubber in 1932. By 1945, American chemists and chemical engineers had developed production processes for several types of synthetic rubber and American industry

was producing 0.7 million tons annually. The Germans also developed a wartime synthetic rubber.

1. The Emergency Rubber Project (ERP): On June 11, 1941, Representative John Z. Anderson, California, introduced H.R. 5030 to establish 45,000 acres of guayule. An identical bill, S. 2152, was introduced in the Senate by Senator Sheridan Downey, California. Hearings were held on these bills but they were not enacted.

On January 7, 1942, a revised bill, 2152, was introduced with an amendment restricting guayule cultivation operations to the United States. The bill was passed but vetoed by President Roosevelt because he wanted the bill to apply to all American Republics. The revised version was passed by the House and Senate and signed by the President March 5, 1942, and became Public Law 473, 77th Congress.

This legislation authorized planting guayule on 75,000 acres, purchasing Intercontinental Rubber Company properties for no more than $2 million, leasing land for growing guayule for no more than 10 years, constructing and operating guayule mills, and conducting research.

On March 12, 1942, Department of Agriculture Secretary Wickard issued a memorandum making the Forest Service responsible for administrating the Act. He also stated that it was his desire that the Bureau of Plant Industry* do the necessary research within its usual field of endeavor under a plan to be worked out jointly by the two agencies. He further authorized the Forest Service to call upon other bureaus in the Department of Agriculture when necessary to secure essential technical and other services or assistance of any kind.

a. U.S. Forest Service operations: Two months before the Secretary issued the formal order, the Forest Service was doing preliminary work to get the project started. Major Evan W. Kelley,** Regional Forester at Missoula, Montana, and Paul H. Roberts,*** Director of the Prairie State Forestry Project, arrived in Salinas, California, about the middle of February 1942 and by March 5, the day the Guayule Rubber Act was signed, had brought in personnel and organized work so that 39,000 guayule seedlings were planted that day to celebrate the occasion.

The Forest Service brought to the project expertise that had been developed in the Prairie States Shelter Belt Program, where many people gained experience in nursery production and field plantations. Although Shelter Belt personnel had worked with larger trees, it took little adjustment for them to take shift to guayule production. The basic processes were the same, the first being to get seeds, ensure germination, plant the nurseries, and finally, transplant the seedlings in the fields.

*The identity of this unit has undergone several changes. It has been included in the Agricultural Research Service and more recently in the Science and Education Administration.

**Major Kelley later became project leader.

***Mr. Roberts later became associate director and director of the project.

One of the first ERP activities was to appraise and to arrange for purchasing all Intercontinental Rubber Company holdings. The appraisal was completed in February and transfer of the properties to the government was completed by the end of that month. The purchase included seven tracts of land totaling 1,484 acres; a nursery with an overhead irrigation system; a guayule processing mill built by the company in 1930-31 which had produced three million pounds of rubber; offices, laboratories and greenhouses, miscellaneous supplies and equipment; and most important, 722,867 pounds of seed and 11 million usable seedlings. The inventory also included 557 acres of mature shrubs and 97 acres of young plantations. These items added to consideration for intangible values brought the total purchase price to $1,721,235.

When the Forest Service arrived in Salinas, it was time to sow the nursery if a crop was to be produced in 1942. Land was leased to establish three nurseries with a net acreage of 530 acres, the nurseries started, a seed treating house was built, and 23,000 pounds of seed were planted in 11,800, 4-by-400-foot seedbeds. Nine hundred acres were planted with seedlings grown the year before by the Intercontinental Rubber Company.

The original guayule act authorized planting 75,000 acres, but the authorization was later increased to 500,000 acres. On the basis of this authorization, it was decided to aim at planting 208,000 acres by spring 1944. To meet labor needs, 17 labor camps housing 9,000 laborers were constructed. Leased lands totaled 60,000 acres and 32,000 acres were planted during the life of the ERP.

The planted acreage curtailment was a result of limitations placed on the project by the Rubber Director in March 1943. No additional planting occurred after that date although changes occurred in the program because of policy changes dictated by Congress and the Rubber Director. Authorization was given in 1943 to continue rubber processing at Salinas, California, and to build a rubber extraction mill at Bakersfield, California.

Many and varied influences during the life of the project made sustaining the program difficult. In August 1942, Assistant Secretary Hill gave guayle production high priority in agricultural programs and Secretary Wickard commended the guayule program. On September 17, 1942, a rubber director was appointed to coordinate all synthetic and natural rubber activities. In February 1943 the Santa Maria Farm Center Director opposed diverting crop lands to guayule. His opposition had an important bearing on the decision of the Rubber Director and the Secretary of Agriculture to stop the program in March 1943 "to minimize interference with the food program." However, they agreed that the project should be maintained on a "standby" basis.

In August 1943 the Rubber Director suggested that the program be resumed and expanded as a matter of insurance to produce

20,000 tons of rubber annually on non-critical lands. Later a committee appointed by the Governor of California recommended continuance of the project. In 1944 the U.S. House of Representatives Committee on Agriculture investigated the program and based on field studies and hearings recommended in January 1945 that guayule should be established as a farm crop in the U.S. Southwest. A bill to fund this activity was introduced in the House in May but failed to pass in the Senate.

A committee instituted by the Rubber Reserve Committee with concurrence of the Director of Rubber Programs recommended building four factories to mill the entire rubber crop before April 1, 1947, but when the war ended, the Rubber Director requested that the expansion program be dropped. The committee consisted of members from The B.F. Goodrich Company, U.S. Rubber Company and a former employee of the Goodyear Tire and Rubber Company.

Plantation liquidation began January 1946. In some cases, arrangements were made for landowners to take possession of the land and to destroy the shrub; in others, ERP destroyed the shrub and reconditioned the land for return to owners. Except for a few experimental areas all land was released by June 30, 1946, and all remaining property was turned over to surplus property agencies for disposition.

Rubber milled during the life of the ERP amounted to approximately three million pounds including 900,000 pounds from Intercontinental Rubber Company plantations and 500,000 pounds from native shrub harvests in Texas.

Epilogue

From the Final Report of the Emergency Rubber Project: "The enormous stresses caused by war have diverse effects; they pile up appalling wreckage in some quarters and make scintillating gains in others. The same forces which left billions of dollars worth of useless munitions factories and cantonments in their wake also gave birth to advances in medicine, manufacture and science which might have required a generation.

"Occasionally, some luckless program found itself both the beneficiary of the progressive forces and the victim of those of destruction. Such a one was guayule. With 85 percent of its crop destroyed, unharvested, it was a 37 million dollar casualty of the war. At the same time, however, cultural and processing developments made greater strides during the brief life of the Project than in the shrub's entire previous history. It is said that a greater weight of scientific investigation was brought to bear on guayule than was ever before devoted to any plant in an equal length of time " (ERP Final Report, 1946).

b. Cooperative relationships: At the time the Secretary of Agriculture named the Forest Service to administer the program authorized by the Guayule Act, he suggested that the Bureau of Plant Industry*, do the necessary research under a joint plan to be worked out between the two agencies. The Forest Service was authorized to call on any other department agencies for essential technical and other services and assistance of any kind.

The Forest Service and the Bureau of Plant Industry together developed a memorandum of understanding on ERP plant research phases. The original agreement, dated October 9, 1942, stipulated that the primary purpose of the research program was to furnish information for the operations program. It delineated in broad terms research work to be conducted and provided for joint planning and approval of research work by the Forest Service and the Bureau of Plant Industry. The research work was to be subject to revision and modification upon mutual agreement by the two bureaus.

The work of the Bureau of Plant Industry was limited mostly to botanical and cultural research. ERP personnel early recognized a need for milling process research. Accordingly, a memorandum of understanding between the Forest Service and the Bureau of Agricultural and Industrial Chemistry (BAIC).** This agreement followed the same general lines of administration and responsibility as did the Forest Service-Bureau of Plant Industry agreements.

A similar memorandum of understanding between the Forest Service and the Bureau of Entomology and Plant Quarantine (BE&PQ) was written December 1, 1942. The BE&PQ conducted surveys and research having to do with insect control.

For BPIS&AE, BE&PQ and BAIC the Forest Service built and equipped laboratories, greenhouses, a pilot plant and other research facilities at Salinas. These facilities have been said to be among the finest in the country. And they had to be since the overall program called for the most intensive research that had ever been attempted at any time on a single crop plant.

As the program developed and additional needs became apparent, further lines of cooperative endeavor were established with the U.S. Weather Bureau, the Soil Conservation Service, the Regional Salinity Laboratory of BPIS&AE at Riverside, California, the Agricultural Adjustment Administration and Extension Services in each of the guayule states. Aid was solicited from various colleges and universities, including California Institute of Technology, University of California, Leland Stanford University, University of California at Los Angeles, Texas A. & M., and the University of Arizona, all of which responded enthusiastically and furnished valuable information and assistance. Most of these arrangements were less formal in lieu of the memoranda

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*The Bureau of Plant Industry, later known as the Bureau of Plant Industry, Soils and Agricultural Engineering (BPIS&AE).

**Formerly the Bureau of Agricultural Chemical Engineering.

of understanding used in conjunction with the work of the BPIS&AE and BAIC. In some instances the research work was performed without any close tie to the ERP although the resultant information was made available to the project as it developed. In other cases personnel, equipment and services were made available to the project.

i. Botanical and cultural research: BPIS&AE research was botanical and cultural. More specifically its work was conducted along seven lines.

Soils experimentation involved mechanical studies of soils and various soil fertility and moisture relationships to guayule culture. The BPIS&AE Soil Survey Division loaned to the Forest Service many soil scientists to make soils surveys for the land acquisition phase of the ERP. Administratively, these personnel worked for and reported to the Forest Service.

Agronomy research included the optimum planting conditions of stock, planting methods, direct seeding, proper spacing and irrigation practices.

Physiology involved studies on functional behavior of guayule plants and means of inducing beneficial changes in plant growth; storing and shipping nursery stock; functional deposition of rubber; determining plant chemical constituents; and similar lines of investigation.

Genetics studied all phases of plant breeding, ranging from cytological investigations to selecting and hybridizing plants to produce superior strains.

Morphology investigations considered the form and structure of the plant. These studies ranged from root development to leaf anatomy. In addition to research at Salinas, Dr. Ernst Artschwager, a BPIS&AE plant anatomist stationed at Las Cruces, New Mexico, made excellent contributions to the work. He had been working on the morphology and anatomy of guayule for years.

Chemistry work in the BPIS&AE, except for that done in physiology, was mostly devoted to service analyses for the other sections, but some original research was conducted.

Pathology specialists made valuable contributions to ERP success. Surveys were made to determine the incidence of disease both in the United States and Mexico. Research on the various diseases encountered was conducted and advice and help were given to both field planting and nursery personnel.

The BPIS&AE and the Forest Service began planting early in 1942 numerous so-called indicator plots which later proved extremely valuable in determining the range and growth characteristics of

guayule under varied soil and climatic conditions.

Eventually, 146 indicator plots were established throughout the four states in areas assumed capable of supporting guayule. The BPIS&AE made many studies on these plots and the Forest Service Division of Surveys and Operational Investigations made some analyses and interpretations of results. The plots were maintained by the Forest Service or through contract with landowners in accordance with the BPIS&AE standards. The indicator plots were established primarily to identify the areas in which guayule could be grown and to secure information on growth characteristics and rubber formation in a wide range of localities. Field research also was conducted in designated experimental areas in the nurseries and administrative plantations. In all, there were 39 experimental areas involving 1,949 acres ranging in size from a few hundredths of an acre to 233 acres. These experimental areas were spread throughout the potential guayule planting region from the tip of lower Texas to northern California.

ii. Entomology: The BE&PQ conducted entomological surveys in the United States and Mexico to determine what insects might prey on guayule or be introduced with guayule to create hazards to other crops. It also developed control methods and assisted in applying various control methods. And, it rendered valuable service at the labor camps, mills and elsewhere where ants, cockroaches or other pests were bothersome.

iii. Rubber extraction research: The research phases of BAIC were split into four main subdivisions. The Pilot Plant staff was concerned primarily with exhaustive studies of the conventional pebble milling process and possible improvements. Later, it engaged in exploring new methods for removing the crude rubber from the plant tissues.

The Microbiology Section conducted studies on means of improving the millability of the shrub and the quality of the crude by the retting action of various microorganisms.

The Latex Section sought methods of recovering guayule rubber in the form of latex to improve purity and quality.

The Analytical Section subdivided its work into chemical research on the shrub and crude rubber; chemical analyses for other sections of the BAIC, BPIS&AE and for the Forest Service; and physical testing guayule rubber as a service for other sections of BAIC, BPIS&AE and the Forest Service. In addition, it carried out investigations on compounding and vulcanizing guayule crude alone and in combination with other natural and synthetic rubbers.

iv. Miscellaneous research activities: The Soil Conservation Service contributed much of its Division of Irrigation staff to make water surveys and soil survey staff were

provided from time to time. The U.S. Weather Bureau was very cooperative in supplying climatological data.

The BPIS&AE Regional Salinity Laboratory at Riverside, California, contributed the services of its water analysis section as well as supplying both services and equipment for physical soil analyses.

The Mare Island Navy Yard contributed to ERP work by undertaking all chemical analyses and physical tests on guayule crude until the ERP laboratories were built, and by giving advice on processing and using guayule rubber.

Aerial photographs greatly speeded up soils survey work. They were made available to the Project through the help of the Agricultural Adjustment Administration. This agency and the Extension Service in the various states helped to bring ERP work to the attention of the farm people in these areas where Project activities were centered.

Experiment Stations and Extension Services in the guayule states supplied much information on the suitability of land for guayule production as did the state departments of agriculture in Texas and California. State government agencies were helpful also in getting shrub shipments through quarantine.

The California Institute of Technology had been conducting research on guayule before the war. Its findings on rubber structure, chemical by-products, essential oils, rubber formation in the plant, and extraction methods were made available to the Project. The Institute undertook fundamental physiologic research on rubber formation in relation to temperature change and diurnal fluctuation. This institution had established a cooperative arrangement with the War Relocation Authority at Manzanar, California, where certain of the Japanese internees were interested in guayule. The internees did a considerable amount of research work, particularly in extraction.

The University of California loaned many of its staff to make soils surveys and water analyses. It furnished laboratory space, reports and maps and addressed several research problems, particularly in genetics. Assistance from the University in developing oil spray methods for weed control was valuable.

Leland Stanford University assigned men to crop research problems and from its Hopkins Marine Station, Pacific Grove, gave valuable assistance on shrub retting. Other specialists in cytology and genetics also were made available.

Anatomical studies of the guayule plant were made at the University of California at Los Angeles (UCLA). This work was valuable to ERP personnel engaged in developing cold resistance

and higher rubber content in guayule. UCLA did additional work in soils and plant chemistry.

Other contributions to Project work were made by Texas A & M, and the University of Airzona and New Mexico. The War Department supplied prisoner-of-war labor for fieldwork.

During the life of the ERP, more than 800 technicians and classified personnel were employed by the Forest Service and another 130 were employed by the various research organizations. Total funds expended amounted to $41,630,605. Approximately $3.5 million was spent on research. In evaluating expenditures, it must be remembered that ERP was a wartime project emphasizing speed to meet critical rubber needs. During this time period, costs of materials were high and maximum operating efficiencies could not be met because of wartime exigencies.

The accomplishments of the Forest Service and associated agencies are covered in Sections II B, C, D, E, F, and G of this report.

2. Recent developments: In the early 1970s, the oil embargo and subsequent petroleum price increases were followed by cost increases of petroleum-derived products such as synthetic polyisoprene rubber. These circumstances, plus uncertainties about continued availability of natural rubber supplies from foreign sources, and the growing pressures to use land in the U.S. Southwest and to conserve natural resources such as water, all contributed to rekindling interest in obtaining natural rubber from guayule.

Mexico began a guayule research and development project in 1973. Later in the 1970s five important events occurred to stimulate U.S. and Mexican interest in guayule research.

An international guayule conference was held in Tucson, Arizona, in 1975. Technical papers were presented by scientists who had worked in the ERP and others. The proceedings of the conference were subsequently published. In 1976 a pilot plant to develop an industrial guayule process began operating in Saltillo, Coahuila, Mexico, and has been processing harvested wild guayule on a small scale. The National Academy of Sciences, Washington, D.C., organized a guayule study panel in 1975 and in 1977 published a review of available guayule research data and recommended research needs. A second international conference was held in Saltillo, Coahuila, Mexico, in 1977 to discuss the new Mexican processing procedures, the chemistry of guayule rubber, and the agronomic and ecological implications of recent developments. The proceedings of this conference were published in 1978. Recently the Native Latex Commercialization Act of 1978 was enacted by the U.S. Congress. It authorizes a $30 million program for research and development, and guayule rubber production and manufacture demonstrations. As of March 1979 no funds had been appropriated, but members of the Joint Commission mandated by the Act have been appointed and the first organizational meeting was held in February, 1979.

Most U.S. Research and development programs underway are government-sponsored projects either within the U.S. Department of Agriculture or through National Science Foundation, Southwest Border Regional Commission or the Four-Corners Regional Commission grants to researchers at universities and research institutions. The State of California sponsors a guayule development program and some guayule propagation and rubber processing research is being conducted by several of the major rubber companies.

Germ plasm has been collected from natural guayule stands in Mexico and Texas; plantings have been established for yield tests and seed increases; and some plant breeding studies are underway. Significant research also is being conducted to increase guayule rubber yield by treating the entire plant with chemical or bio-regulatory agents.

Test plots have been established to develop data on appropriate planting and cultivating practices. Recent guayule seed-coating process and selective herbicide developments could make direct seeding field plantations a possibility. These developments are significant since eliminating nursery or greenhouse propagation and transplanting seedlings in field plantations could produce considerable production-cost savings.

Improved processing methods have been developed at the Mexican pilot processing plant in Saltillo, Coahuila and rubber produced has been analyzed and tested. Experimental radial tires containing 30 percent to 40 percent guayule rubber have passed U.S. Department of Transportation high speed and endurance tests in evaluations by Goodyear Tire and Rubber Company. A Department of Defense project at the Naval Air Rework Facility, San Diego, California is in progress to evaluate guayule rubber as a substitute for Hevea rubber in U.S. military applications.

Other guayule activities underway include planning another conference, scheduled to be held in Los Angeles, California in October 1979; publishing a guayule newsletter containing technical, economic and political information; and cataloging all published and unpublished guayule information stored at the National and U.S. Department of Agriculture archives including ERP workers' records and research notes.

A Guayule Research Society was organized in October 1978 by guayule research scientists to aid cooperative efforts and to aid coordination of needed research.

II. STATE-OF-THE-ART OF GUAYULE TECHNOLOGY

Findings of a State-Of-The-Art review of the agricultural and industrial aspects of guayule technology and information on chemical and physical properties of guayule rubber, production history and trends in research and development are presented in this chapter.

A. Regional Climatic and Agricultural Conditions

1. Relation of Climate: Natural guayule stands in the United States and Mexico are shown in Figure II-1. Guayule is native to a region with an arid and semiarid climate and grows on outwash fans and foothills slopes. The climate affecting guayule in its native range is discussed by Bullard (1946b) and may help show the importance of climate as a factor in commercial guayule production. Mean annual rainfall varies from 8 inches to 15 inches with highs of 25 inches recorded. Rainless periods four months long are common and periods up to seven months long have been recorded. Rainfall generally is biseasonal, peaking during spring and fall, although in some areas, most of the rain falls during summer and fall with little falling during winter and spring. Seasonal and diurnal temperature variations are fairly broad. Maxima of 115°F and minima of 15°F have been recorded. However, climate is comparatively moderate and no cold season exists in much of the area. The warm season is the wet season, but cloudiness tends to reduce temperatures. Winter and early spring are drier and more sunny so that guayule on slopes often is not exposed to extreme cold. Dry winds occur during the winter, but during the growing season humidity is rather high.

Guayule grows in its native habitat on 8 inches to 15 inches of rainfall but slopes provide it with more moisture. Runoff and percolation from higher areas could increase effective rainfall moisture by as much as 50 percent. Guayule does not grow rapidly in its native habitat. More moisture is required for commercial production because tonnage must be grown quickly. Guayule roots extend to depths of 20 feet or more and ultimately deplete soil moisture nearly to that depth if rainfall is insufficient. Fifteen inches is considered the minimum requirement for good guayule dryland culture. However, 20 inches of rainfall are probably better for good yields. Twenty-five inches or more of rainfall, on the other hand, are unsatisfactory, especially if more or less equally distributed throughout the year when no periodic droughts occur. Rainfall distribution bears considerably on guayule production. An ideal climate for guayule production would have a rainy season during the late winter, the spring and the early summer and the last half of the summer-fall growing season would be dry. Early rains replenish soil moisture so that growth could begin when temperatures became favorable in spring.

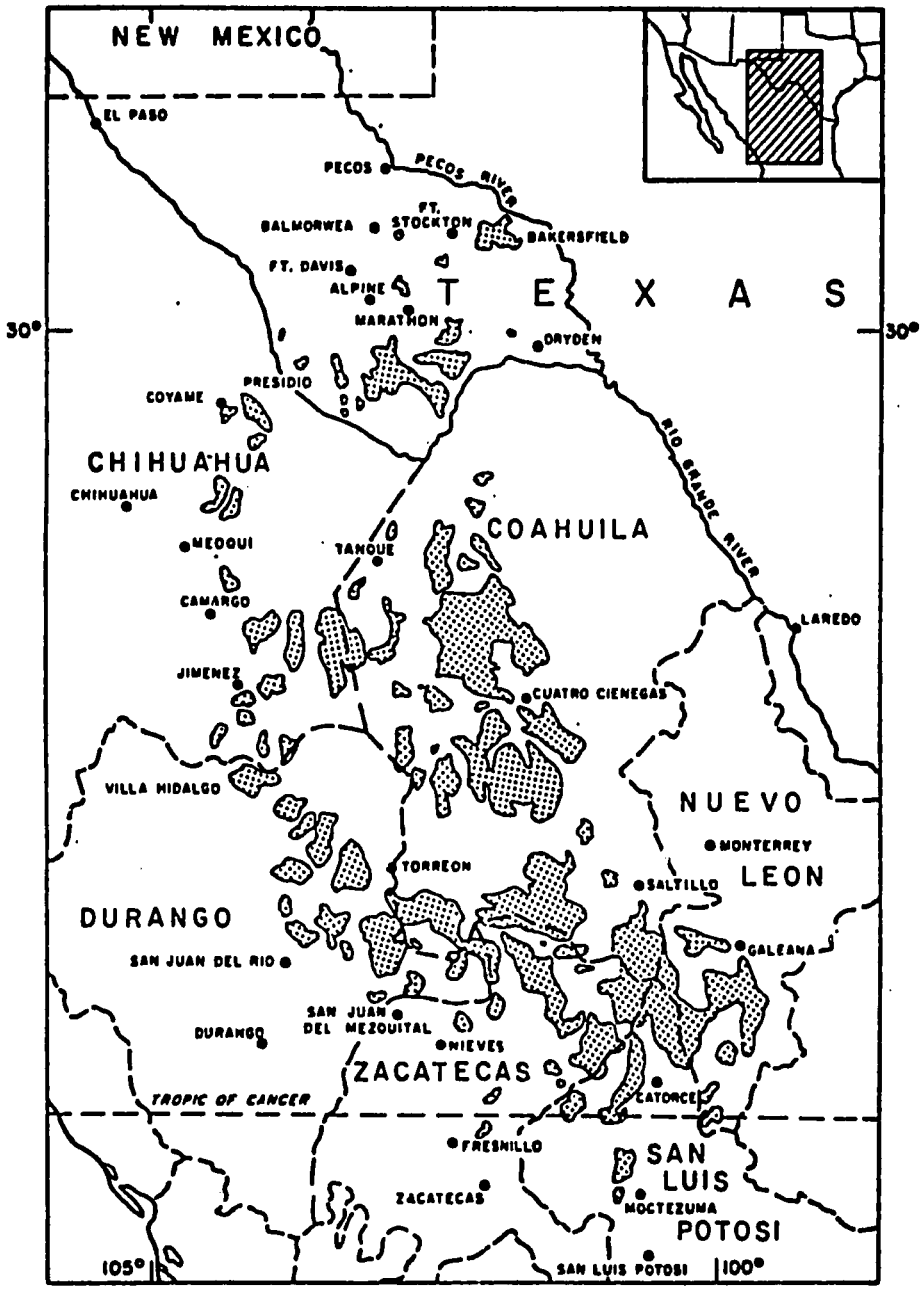

Figure II-1. Distribution of native guayule in Mexico and Texas.
Source: National Academy of Sciences, 1977.

Subsequent rains promote continued vigorous growth for three or four months. At the end of the rainy season, growth proportionate to available residual soil moisture and drought dormancy begins. The climate in some of the California production areas are somewhat similar except that rains do not extend into the summer and rain received and stored as soil moisture during the winter was in some cases exhausted too early in the season.

In other areas where guayule trials were set out, rainfall occurred in a biseasonal pattern with peaks in spring and fall as in Texas, or in summer and winter as in Arizona.

The biseasonal pattern also produced good yields of rubber where total precipitation was only enough to produce a gradually developing xeric-type shrub. In the high rainfall belt at the lower end of the Rio Grande Plain in Texas, guayule grew year-round since no marked drought periods occurred and temperatures were high enough to permit plant growth. In this area, rubber content was usually low, except where moisture competition was increased by closer plant spacing.

Normally, insufficient rainfall was augmented by other sources of moisture in certain areas. Along the California coast on agricultural lands, rainfall varies between 10 inches and 15 inches, somewhat low for guayule. Summer fogs and night condensation help maintain soil moisture and suppress daytime temperatures. While guayule did not grow as vigorously under these conditions as in hotter areas, its growth was adequate and rubber production was very good. Guayule apparently has no pronounced seasonal growth adaptations or mechanisms and seems to be well adapted to moderate environment.

Precipitation distribution, particularly individual storm frequency, affected plant establishment and survival in new plantations. Where drainage was poor, storm frequency and intensity were correlated with increased plant mortality. Certain soil moisture conditions are necessary to soil preparation before direct seeding or transplanting. Planting was not successful when the soil was either too wet or too dry. Mechanical difficulties with planting equipment were experienced or the plants failed to become established because of inadequate moisture. Planting was most apt to succeed when accomplished between storms. Sufficient rainfall after planting was a necessity under dryland culture (Bullard, 1946b).

Guayule grew best under temperatures of 90°F to 100°F; grew markedly less when the temperature was below 60°F; was not damaged by maximum temperatures of 120°F; and was often injured by temperatures below 15°F. The most suitable climate for dryland guayule culture would be one with a mean annual temperature range of 56°F to 62°F and extreme minimum temperatures always above 15°F. For irrigated culture, mean annual temperatures up to 70°F would be satisfactory with minima not lower than 25°F.

Warm, dry summers were conducive to growing guayule with a higher rubber content, although maximum rubber production demanded relatively low night temperatures. Daytime temperatures from 65°F to 80°F combined with night time temperatures of 35°F to 45°F promoted satisfactory rubber accumulation in young shrubs. This temperature regime is similar to fall conditions in most planting areas. Diurnal temperature fluctuations seemed to affect rubber deposition more or less without regard to vegetative growth, although growth tended to be slow during cool nights.

Cold injury to guayule was related to available soil moisture and to growth activity in the plant. Degree of cold injury was in inverse ratio to dormancy and high soil moisture appeared no hazard to dormant plants. When favorable growing temperatures and available soil moisture generated a spurt of shrub growth just before critical cold periods, injury resulted. In Texas, dormant plants on some test plots withstood temperatures of 1°F to 4°F without appreciable injury while on other plots, considerable damage occurred at temperatures of 14°F and 15°F (Bullard 1946b).

Effects of cold included defoliating the shrub, killing back small twigs, killing the bark and cambium near the ground surface, and injuring root crown tissues to a depth of perhaps 2 inches below the surface. Severe injury killed the plants outright; but recovery from moderate cold injury usually was rapid. Minor injury did not seem to impair shrub vigor. When defoliation was caused by cold, new leaves were produced earlier and in greater abundance than on undamaged plants (Bullard 1946b).

Disease incidence in guayule also was affected by temperature. Cotton root-rot was most severe in hot, humid weather, or after irrigation in hot weather. Verticillium wilt became serious in spring and fall when temperatures were near 70°F and surface soil moisture was relatively high. Crown-rot was worst in wet soils when temperatures were high. Pink root-rot in the nurseries was most common in cooler, foggy weather with high humidity. While insect epidemics were know to be correlated generally with climate, the few local outbreaks could not be tied to specific temperature or moisture conditions (Bullard 1946b).

2. Relation to soils: Guayule is very sensitive to soil conditions. Soil is the dominant factor in rubber production because of its relation to moisture control, and because it has considerable bearing on shrub production. The shrub varies in size, weight and rubber content according to minor changes in soil moisture retention and availability (Retzer and Moyen 1945).

The best growth of both irrigated and dryland plantings was in light and medium-textured soils. With the same cultural treatment and planting stock on a single plantation, larger shrubs were developed in loam and sandy loam than on other soils. But the highest percent of rubber occurred in smaller plants grown in other soils.

Plants grown in clay soils showed a higher concentration of rubber than those in light soils.

Soil moisture availability, the principal factor affecting guayule growth, varies with soil texture. For best growth, guayule requires permeable, well-drained, well-aerated soils with a reasonably good supply of soil moisture most of the year. Optimum vegetative growth, however, usually is not combined with maximum rubber increment of content in the shrub. Those soils that make water available slowly to the plants promote the highest rubber content per unit shrub weight and, if growing conditions otherwise are favorable, give the highest yields of rubber per acre.

Unsatisfactory growth and yields result when soil conditions make moisture easily available for short periods followed by extremely dry periods. These results occur in both light and heavy soils with very coarse substrata at shallow depths. Guayule grown under such conditions has spurts of luxuriant growth and then dies back a little under heavy stress. The succulent "growing" leaves are lost rapidly and photosynthetic activity is reduced greatly during the dormant stress period; little rubber accumulates. When available, moisture is reduced slowly and the shrub has time to "prepare" for the dry dormant period, a xeric type leaf develops and rubber deposition shows marked increases.

Hardpans and claypans, including plowsole, tend to restrict guayule growth in inverse relation to their depth below the surface. Where pans are shallow and drainage is poor due to heavy soils, guayule is small, lacks vigor and is susceptible to disease and drowning. In lighter soils the pans restrict growth but have a much less adverse effect on plant survival.

Guayule roots penetrate pans with difficulty. If the pans are within 30 inches of the surface, root extension is limited, the feeding area small, and shrub growth is never satisfactory. There were relatively few extremely stunted plants in the ERP test plantings and they showed poor rubber development. Per-acre yields, however, always were reduced by growth restrictions.

Water tables at or below 5 feet provide conditions similar to continuous irrigation and promote continuous shrub growth, but those at 2.5 feet produce smaller plants that are subjected to severe stress when the water level recedes. Waterlogging destroys parts of the root systems where water tables are high, but death does not occur where the shallow lateral roots are well aerated and still able to function. Poorly aerated, water-soaked soils cause drowning out of considerable areas in affected plantations.

Soil moisture also is important in relation to disease. Attacks by various fungi usually coincide with excessive moisture, especially on heavier soils with slow drainage. On the other hand,

the extent of cold damage is usually inversely related to the moisture content of the soil and the plant.

Competition between plants is affected strongly by spacing and moisture availability. Furthermore, moisture relationships change under cultivation, especially with respect to aeration. On newly cleared brushlands with fine sandy loan soil, the soil is loose at first and shows a moisture deficiency similar to that caused by high evaporation. Clays, usually considered too heavy and poorly aerated for guayule, are suitable if they are friable and have good internal drainage. Dryland production on problem soils is impractical, as is irrigated production on very loose sandy or gravelly soils because of the impossibility or high cost of meeting water requirements for best growth. On soils of very open, porous structure, a low survival rate often occurs because of poor contact between the soil and plant roots.

Like other plants, guayule grows best in more fertile soils, but it does not respond noticeably to most fertilizers except in soils with low fertility. While it is native to calcareous soils, guayule grows well on granitic or sedimentary noncalcareous soils. Required fertility levels, like moisture capacities, seem related more to spacing and competition between plants than to general plant needs. Low fertility may limit growth in a few instances, but if so, the soil moisture relationships are so far from optimum that any fertility factor measurement is obliterated.

Guayule tolerated iron or manganese deficiencies but was very sensitive to boron deficiency. Potassium and calcium seem to be required for best plant growth. Guayule showed no marked response to nitrogen unless the soil was nearly sterile. In one instance, on a sandy and almost sterile soil in a hot interior valley, measurable shrub growth occurred only by adding nitrogen. Slight variations in the soil nitrogen content on guayule plantations related to differences in stand density and to season. Highest nitrogen concentrations occurred during the cooler months.

Guayule grows well in a soil pH from 6.0 to 8.5 but is stunted at pH 4.5 or 10.5. Optimum growth occurs from pH 7.2 to 8.3 (Bullard 1946b).

The soil salt content is important. Guayule tolerates up to 0.3 percent salt anywhere in the soil profile, but soil salt content from 0.3 to 0.6 percent in the top 2 feet of soils greatly retards growth. More than 0.6 percent salt in the surface soil kills the plants (Bullard 1946b).

The lower leaves of the shrub actually increase in number with soil alkali concentrations up to the limits of tolerance, but shrub weight and survival decrease. The physiological drought brought about by increased soil moisture tensions apparently causes reactions in the plant similar to those caused by natural drought (Bullard 1946 b).

3. Potential guayule growing areas: Areas considered suitable for potential guayule cultivation have appropriate temperature and moisture ranges, as well as appropriate soils. (See Figure II-2)

The North Coastal Hydrographic Region of California was excluded due to excessive precipitation. The northern extreme of the Sacramento Basin also was excluded because of excessive precipitation and increasing elevation and associated cold in the northernmost portion of this hydrographic region. The mountainous region of eastern California has low temperatures which restrict guayule production potential.

Nevada, north of Clark County, is considered to be too cold for successful guayule cultivation.

In Arizona, the Basin and Range physiographic province is included within the potential guayule growth area. The Mogollon Rim bisects Arizona and marks a dramatic elevation change. Low temperatures north and east of the Mogollon Rim restrict the growth of guayule.

Areas north and east of the New Mexico potential guayule growth region are excluded in some instances due to high elevation and in others due to winter temperature fluctuations. In eastern New Mexico, warm and cold period spells tend to alternate. The warm periods break dormancy in guayule and the subsequent cold periods damage or kill the shrubs despite the fact that minimum temperatures may remain above 15 F.

The Edwards Plateau lies between two potential guayule growth regions in Texas but has restricted potential for guayule production due to low temperatures and poor soil quality. Eastern Texas has annual precipitation of 36 inches or more which restricts guayule production.

Potential guayule cultivation regions are delineated by county boundaries, to allow assessing guayule in relation to county agricultural and water statistics. Figure II-3 shows the relationship of these potential guayule regions (showing county boundaries) with the physiographic provinces considered appropriate during the ERP (solid lines) and with Bullard's 15 F minimum temperature line (shaded area) (Bullard 1946a).

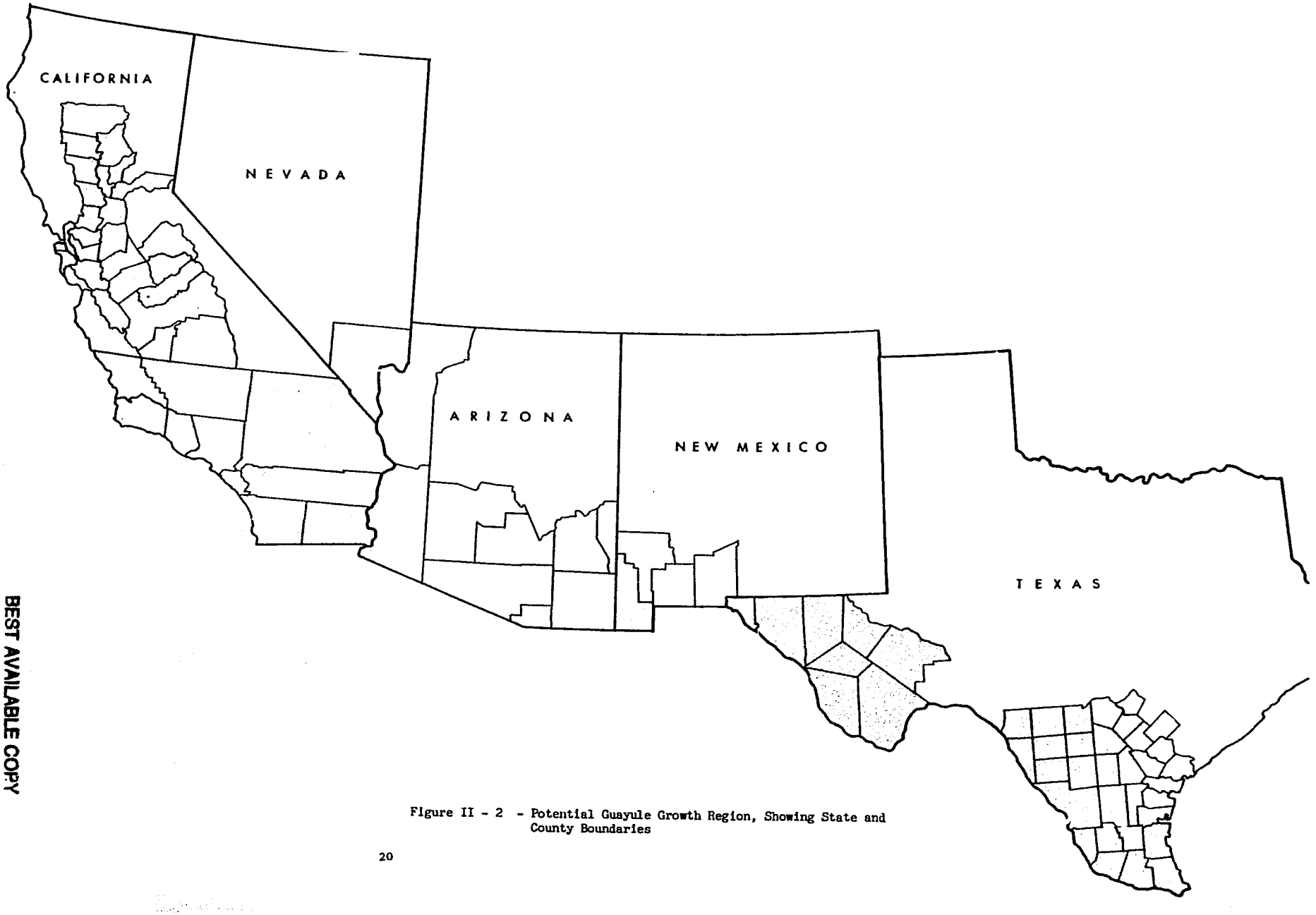

Figure II - 2 - Potential Guayule Growth Region, Showing State and County Boundaries

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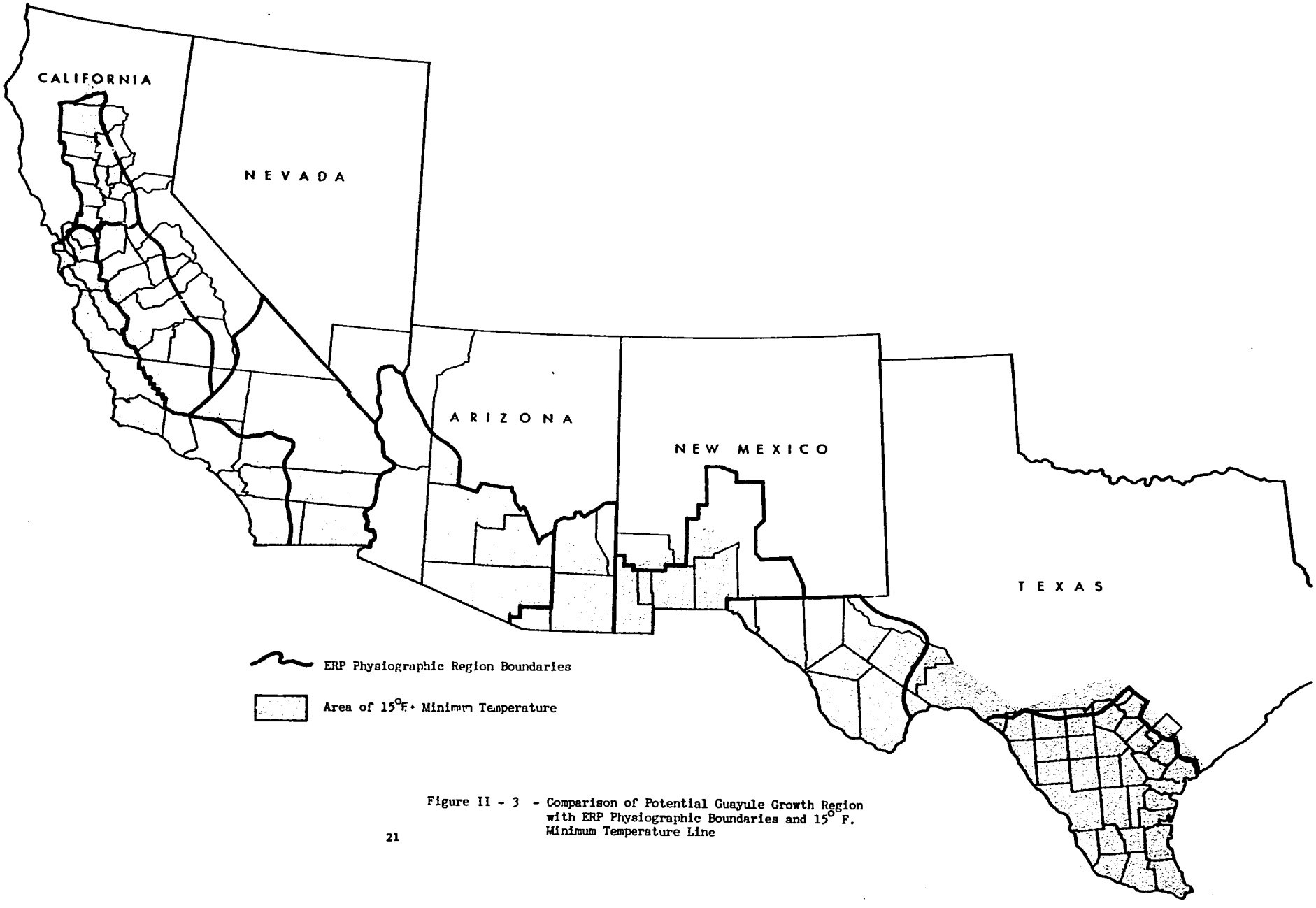

Figure II - 3 - Comparison of Potential Guayule Growth Region with ERP Physiographic Boundaries and 15° F. Minimum Temperature Line

B. Guayule Plant Modification and Manipulation

1. Rubber formation: Rubber in guayule exists as a colloidal suspension, or latex, confined to individual cells. No organized latex canals exist as they do in **Hevea**. In general, plants older than one year carry most rubber in the cortex and vascular rays of phloem and xylem. Small quantities of rubber occur in the primary cortex, pith, xylem parenchyma and epithelial cells of resin canals, and very small amounts in the leaf parenchyma (Lloyd, 1911).

The branches constitute approximately two-thirds of the defoliate dry weight of the plant and contain more than two-thirds of all rubber in the plant; thus branches have a higher rubber concentration than either roots or crowns. The bark contains 75 percent to 80 percent of the plant's total rubber. Rubber concentration in the roots is higher in secondary roots than in main roots. A strong tendency exists for uniform rubber concentration in the stem segment to correspond to successive annual elongation increments because of the greater proportion of bark in the younger stems. The proportion of bark to wood is low in the primary root but by comparison more is in the younger branches with smaller diameters (Artschwager 1945).

Marked seasonal fluctuations occur in the overall concentration of rubber during the year. Concentration is highest during cool seasons and periods of moisture stress, and lowest during periods of lush growth. The ratio of the radius of the wood to the bark is directly related to plant weight and water supply; lush growth increases the production of xylem tissue, which produces little rubber, at the expense of phloem tissue which has a higher rubber-producing potential. (Hammond and Polhamus, 1965)

The function of rubber in guayule is not known. Rubber is not a storage product that the plant can draw on for nutrition, does not help resist drought nor does it seem to have any protective value against browsing because the plant is eaten by both wild and domestic animals. (Benedict, 1949)

Resin canals occur throughout the plant in well-defined systems but are principally in the bark where they are distributed rather uniformly. The resins include essential oils, parthenyl cinnamate and partheniol, betaine, fatty acids, and an unidentified wax and other chemicals or constituents. Resin concentration in guayule bark, green stems and roots varies from approximately 7 percent to 10 percent dry-weight. Resin concentration is considerably less in the wood and even lower in the roots. Stems less than one year old show higher resin concentrations than do older stems. When a branch dies under field conditions, a considerable portion of the rubber is converted to acetone-soluble substances. The effect of the dead plant parts is to lower rubber

concentration and raise resin concentration. (Hammond and Polhamus, 1965) The ratio of rubber to resin is highest in dryland shrubs and lowest in shrubs under irrigation in hot climates.

Research on the guayule rubber-producing mechanism has been underway by Thomas E. Bauer at Lawrence Berkeley Laboratory, University of California, Berkeley, where the electron microscope has been used in efforts to solve the problem of hydrocarbon production in guayule.

Results of tracer experiments indicate that researchers may be able to determine much of the hydrocarbon-producing potential by examining chloroplasts. Bauer believes that the high resolving power of the electron microscope may aid significantly in breeding and selecting that produce greater amounts of rubber. Implications also exist that it may be possible to follow the biosynthetic steps even further and determine what biochemical steps are occurring in the chloroplasts as well as in other areas of the plant. (Bauer, 1977)

2. Reproduction and genetics: Cytologically the plant has chromosome numbers ranging from 2n=36 to 2n=108. A 144-chromosome plant has been produced under controlled breeding. An important characteristic is facultative apomixis, especially in the 54 and higher chromosome numbered plants.

Many aspects of potential guayule rubber production and improvement are, genetically controlled at least in part. In a given plant, the genetic make-up determines potential rubber content, resin content, disease resistance, ease of defoliation and cold and drought tolerance. The rate and amount of growth and rubber production are determined by the interaction between genetic factors and environmental conditions. Genetic characteristics are amenable to improvement. Guayule's unique and versatile reproductive capacity simplifies plant breeders' tasks and assures a more rapid rate of success than could be achieved with many or most other plants. (National Academy of Sciences, 1977)

Guayule plants initiate seed formation in several ways. In some groups the female reproductive cell is fertilized in the usual way by the male or pollen gamete. Both male and female nuclei carry genes which transmit characteristics to the offspring. In other groups the pollen only stimulates the female cell without actually fertilizing it. Such apomixis in guayule was discovered during studies by Powers (1945), Rollins (1945) and others.

In obligate apomictic reproduction, unlike sexual reproduction, the orderly sequence of stages in embryo formation and the

resultant progeny duplicates only the characteristics of the mother plant. This is not always true, however, of guayule. A few individuals deviated from the mother plant to some degree. Since the seed is developed through a multiplication of the unfertilized female cell, progeny from such a seed inherits the characteristics of the mother plant only. This latter type of reproduction has two classes: in the first, and most common type, the female cell with a non-reduced number of chromosomes receives only "stimulation" from the pollen; in the second, which is rare, the female cell with a reduced number of chromosomes similarly is induced to grow without fertilization. In the first case progeny cells and overall character duplicates the female parent; in the other case each offspring is slightly different from the parent and all such offspring are genetically different from one another although the differences may be only biologically minor (Rollins, 1979).

Inheritance of apomictic lines has been the subject of much research as well as the mechanisms whereby plants may be opened up to cross-fertilization. In breeding studies it was found that certain strains were only facultatively apomictic and that it was possible to develop strains that will cross even where apomixis predominates. As a result, in practice it is possible to open up plants for breeding and then close them so that they become fully apomictic (Rollins, 1979). In this way, it is possible to fix a hybrid so that it will be uniform from the first generation onward; thus the long process of plant selection to obtain true breeding hybrid lines is avoided.

Various other irregularities occur in guayule chromosome complements including anueploidy, polyploidy, chromatic bridges and fragmentation resulting in sterile pollen and other cytological irregularities.

Plants collected from Mexico and from the Trans-Pecos region of Texas have 36, 54, and 72 chromosomes. Plants in the 36-chromosome group were all or nearly all normal, sexual plants in which both reduction and fertilization took place. This group also was predominantly self-incompatible. With one exception, no predominantly normal sexual plants were found among the 54- or 72-chromosome groups. They were apomictic and also self-incompatible.

The 54, 72 and 108 chromosome groups are multiples/half-multiples of the basic number 36. Abnormal sexuality among plants with 36-chromosomes sometimes yields offspring with 54 chromosomes; those having 54 chromosomes would stabilize at the number 72 if they reproduce by non-reduction of the egg cell which was fertilized without an 18 chromosome gamete. However, a more likely mode of origin of the 72-chromosome type is a doubling, through autopolyploidy, of the 36-chromosome complement in an individual plant. Random occurrence of the number 108 was associated with occasional abnormal sexuality of a 72-chromosome plant.

Principal guayule strains used for commercial production during World War II and earlier were from 72-chromosome groups. Mariola (P. incanum) plants with 72 chromosomes closely parallel 72-chromosome guayule reproductive behavior.

The major objectives of the World War II guayule breeding work were to develop varieties yielding more shrub per acre with a higher percentage of rubber in the plant; having greater resistance to disease, particularly to charcoal rot in Texas; having the ability to produce higher rubber percentage under hot climatic conditions such as occur in Texas and in other regions where guayule might be grown; and being capable of surviving in cooler areas where some freezing occurs.

The breeding nursery at Salinas did not furnish all the genotypes necessary to attain these objectives which prompted LeRoy Powers, W.B. McCallum and D.S. Olson to make extensive seed collections in Texas and Mexico in 1942. (Hammond and Polhamus, 1965)

A number of major discoveries were made in guayule breeding and genetics during the Emergency Rubber Project from 1942 to 1946. A significant finding was the interspecific crosses could be made between Parthenium argentatum and P. incanum, P. tomentosum var. stramonium, P. tomentosum and P. hysterophorus.

Interspecific hybrids between P. tomentosum var. stramonium and guayule were tested in Texas and California. Those tested in Texas were highly resistant to charcoal rot, a disease prevalent there caused by Sclerotium bataticola Taub. Although these hybrids always were lower in rubber percent yields than the high-rubber-yielding strains of pure guayule, some of them yielded more than the commercial variety 593 because of greater vigor. The lower rubber percentage in the vigorously growing hybrids would raise the cost of milling the shrub correspondingly. (Hammond and Polhamus, 1965) In addition, postwar plant milling studies established that these crosses are more difficult to mill (USDA Natural Rubber Research Station, 1953). However, back-crosses to guayule were not carried out and the full potentials of interspecific crosses were never realized.

The commercial variety 593, developed by the Intercontinental Rubber Company, was used as the standard of comparison with new strains and hybrids. It appeared to be the best for general use and most plantings were of this strain. Among the several hundred seeds collected by Powers in 1942, one group from Durango, Mexico identified as 4265 appeared to be superior to 593 in rubber yield. However, this strain was extremely variable because it reproduced sexually.

Individual guayule strains respond differently to environmental conditions in yielding rubber. Strains used by the

ERP varied considerably with respect to the time growth began, to general adaptability to hot or cool climates and wet or dry climates and to disease resistance. Variety 593 established readily, had high survival rates, grew rapidly, was fairly resistant to drought and root rot, and gave high rubber yields when properly managed in the cool Salinas Valley of California. In the warmer California valleys and in southwest Texas 593 plants were small and formed a number of relatively small branches; rubber accumulation tended to level off after two or three years' growth. By contrast all other varieties that were poor yielders in the Salinas Valley consistently yielded more rubber in Texas than did 593.

3. California Institute of Technology studies: Arrangements were made for researchers at the California Institute of Technology (CIT) to work on guayule physiology and biochemistry with Intercontinental Rubber Company support. That work was begun during the fall of 1939. When the Intercontinental Rubber Company was taken over by the U.S. Government in March 1942, the CIT arrangement continued with the U.S. Forest Service. When the ERP ceased operating in 1946, CIT work was supported by the Stanford Research Institute with funding from the Office of Naval Research. In 1950 the program became the responsibility of the U.S. Army Office of the Quartermaster Corps and was supported by the U.S. Army until 1958 (Bonner, 1975).

CIT researchers had use of controlled-temperature air-conditioned greenhouses. These greenhouses were used in studies of the cyclical behavior of guayule rubber production.

The study findings indicated that moisture stress does not increase rubber accumulation rates or rubber accumulation amounts under optimum temperature conditions. However, it was discovered that moisture stress increases rubber accumulation effectively in plants grown under high temperature conditions normally associated with guayule growth. But increased rubber percentages in these plants occurs at the expense of total rubber produced because water stress diminishes photosynthesis rates and total plant growth (Bonner, 1975).

The relation of mineral nutrition to rubber accumulation also was studied. Study findings indicated that the greatest growth and greatest rubber accumulation occurred in plants grown outdoors where they grew vegetatively during the summer and accumulate rubber during the winter to have the most dryweight growth. This study used classical mineral nutrition experimental techniques. Those plants that received large amounts of nitrogen and phosphate grew most and accumulated the most rubber. Nitrogen nitrate or phosphate deficiency reduces growth and rubber accumulation. These research results did not contradict ERP findings that applying fertilizer to guayule in the field did not produce increased rubber accumulation. Soils used to grow guayule during

the ERP were mostly high in fertility, so, that in fact, applying more fertilizer did not produce further growth or rubber accumulation (Bonner, 1975).

In a report published in 1941, W. B. McCallum stated that a total of 2,400 pounds of rubber per acre were produced in 10 years. ERP data presented to the Poage Committee indicated 2,700 pounds of rubber per non-irrigated acre after a 10-to-13-year period.

Using 1946-48 guayule-growing technology, it would be reasonable to expect a yield of about 500 pounds per acre annually during a four-year period under irrigated conditions and appropriate climate: a total yield of about 2,000 pounds (Bonner, 1975).

4. Stanford Research Institute studies: After the ERP was discontinued in 1946, the Office of Naval Research supported a research program at Stanford Research Institute for one year. Achieved through this program were evaluating critically the three most useful analytical methods for determining rubber content; developing a technique to make reciprocal grafts successfully of rubber-bearing and non-rubber-bearing plant species; using molecular weight determinations to follow certain rubber formation steps within the plant; discovering through designed experiments that guayule can accumulate rubber rapidly at high temperatures; discovering that under properly controlled environment conditions, guayule plants could maintain good vegetative growth and rapid rubber accumulation simultaneously determining indications that acetate and acetone are possible links in the chain of precursors leading to rubber hydrocarbon; and designing a long-range plan to study guayule apomixis (Stanford Research Institute, 1947).

A significant finding at the Stanford Research Institute was identifying the nature of progenies derived from crossing *P. argentatum* and *P. tomentosum* var. *stramonium*. Rubber content is depressed markedly when guayule is crossed with *Parthenium tomentosum* var. *stramonium* even on a chromosome basis. Even when guayule chromosomes predominate in a ratio of about four guayule to one stramonium, the rubber content is inferior to that of straight guayule. All hybrids of this constitution, however, were not inferior to all plants of straight guayule tested, indicating an opportunity to improving the hybrids selectively with respect to rubber yields percentage. In all instances, hybrids were superior to standard guayule in size, vigor and growth rate. These characteristics are desirable and seemingly, are worth the efforts required to improve other hybrid characteristics. Among the hybrids grown, the 90-chromosome plants appear to hold greatest promise for developing an apomictically reproducing strain.

In a preliminary study of self-incompatibility genetics, a breeding program complication was discovered that included low-chromosome sexual types and should be disregarded. Cross-incompatibility

was found between parent and progeny in one pair. If this unusual incompatibility is found in further tests to be the rule, special experimental designs will be required in back-crossing programs involving guayule sexual lines.

A scheme to use 36-chromosome haploid guayule plants in a breeding program to develope high rubber-yield lines within predominantly apomictic strains tend to produce a small percentage of haploids in which genetic segregation has occurred. Preliminary research findings indicated that one cross produced a plant with unusually high rubber content.

5. Natural Rubber Research Project 1948-1959: Guayule breeding research was conducted by the USDA Natural Rubber Research Project at Salinas, California from 1948 to 1959.

Seed collections made in Mexico by Hammond in 1948 were planted at Salinas during winter 1948-49 and some were transplanted in Texas when seedlings were available. Several outstanding plant selections were made from these plantings. One was a highly apomictic, single plant selection which proved not only to be more resistant to charcoal rot in Texas but was more vigorous and contained higher rubber precentage than variety 593. Tests during a two-year period in Texas showed the definite superiority of this selection, designated N 396. In the Salinas Valley, however, N396 did not show the outstanding vigor displayed in Texas. Furthermore, it was more susceptible to verticillium wilt in the Salinas Valley climate than any other of the introductions and advanced strains (Hammond and Polhamus, 1965).

When the USDA Natural Rubber Research Project was discontinued in 1959, seeds from the highest rubber-yield lines, N593 and a 36-chromosome selection were sent to the National Seed Storage Laboratory at Fort Collins, Colorado (See Table II-1). Excess high-yield rubber line seeds also were stored in airtight metal drums and later were declared government surplus to be given away, sold or discarded. A private California company acquired much of this seed stockpile. There were 25 seed lines and are the only seed known to have been salvaged from the 1942 or 1959 breeding program.

Five of these 25 lines, were progeny of selections from Powers' 1942 Mexico collections Number 4265 from which the highest rubber-yield selections were made during the ERP. Six of the 25 lines were derived from 1948 collections made by B.L. Hammond. They were found about 50 miles from the area where 4265 originated (Rubis, 1978).

Postwar studies conducted by BAIC and BPIS&AE show the need to determine milling characteristics of varieties or crosses that appear to have production promise. Limited milling-study findings conducted after World War II are summarized in Table II-2.

TABLE II-1
SEED VARIETIES STORED AT THE NATIONAL SEED

STORAGE LABORATORY, FORT COLLINS, COLORADO*

Selection Number	Comments
11591	Hammond selection from 4254-I, better than 593 at Salinas
11600	Hammond selection from 4254-I, better than 593 at Salinas
11604	Hammond selection from 4254-I, better than 593 at Salinas
11605	Hammond selection from 4254-I, better than 593 at Salinas
11609	Hammond selection from 4254-I, better than 593 and 42654 at Salinas
11619	Hammond selection from 4254-I, higher rubber percent than 593 or A265X
11633	Mexican introduction
11634	72-X-36-chromosome cross
11635	72-X-54-X-36-chromosome cross
11646	Hammond collection, superior performance at Salinas
11693	4265-I selection, 72 chromosomes
11701	4265-I-x-36-chromosome cross
A48118	Hammond collection
A48143	Hammond collection from Zacatecas, good at Salinas
N396	Vigorous in Texas, resistant to charcoal rot
N565	Hammond collection
N566	Selection from 4265-I, higher rubber-yield percent than 593 or 4265-X
N575	Mexican introduction, better than 593 or 4265-X at Salinas

*Information from National Seed Storage Laboratory Records.

TABLE II-1 (Cont.)

Selection Number	Comments
N576	Hammond selection, better than 593 and 4265 at Salinas
N596	See 11635
12229	Cross with *P. tomentosum* var. *stramonium*
12231	Hammond collection
593	Variety developed by Intercontinental Rubber Company
4265X	Selected from 4265-I, 72 chromosomes, higher rubber yields
4265FX	Seed yield increase from 4265-X

TABLE II-2
VARIETIES AND HYBRIDS TESTED*

Strain	Parentage	Chromosomes	Age (years)
D-65	Guayule 593 Stramonium 43700	90	3
D-118	Guayule 42268 X Stramonium 43691	90	3
D-153	Stramonium 43691 X Guayule 4265	54	3
D-155	Stramonium 43691 X Guayule 4265	54	3
593	McCallum collection	72	3
4265-I	Feral: Durango, Mexico	54	3
4265X	Selection 4265, Durango, Mexico	72	3
Mariola Number 1	(Guayule x Stramonium) X Mariola	90	3
Mariola Number 2	Guayule X Mariola	72	2

*Source: USDA Natural Rubber Research Station, 1953

The following information is from the Natural Rubber Research Station Final Report published in 1953.

Strain D-65. Wood fibers were very long. Small worms of rubber were observed after one hour of milling. After milling was completed, the worms were a bright olive-green and very buoyant in flotation tanks, but were difficult to recover because of fineness.

Strain D-118. Wood fibers were long and stringy. Flower stems were profuse. No distinct rubber worms were discernible after milling one hour. Rubber worms were very small, bright green and difficult to skim after milling because of small size and because buoyancy was only average.

Strain D-153. Wood fibers were long. No worms of rubber appeared after milling one hour. When milling ceased the rubber worms were exceedingly fine and dull and olive-green in color.

Strain D-155. Wood was tough and fibrous and much more difficult to process. Flower stems were profuse. Indistinct rubber worms were small and difficult to handle, and olive-green in color. Dried deresinated rubber was not rubbery but more like dried putty.

Strain 593. Wood fibers were very much shorter than in any hybrid but about the same as two 4265 varieties. Rubber worms formed after milling one hour. At milling-period end, rubber worms exhibited normal characteristics.

Strain 4265-I. Defoliation was very difficult. Wood fibers compared with usual guayule. After milling, rubber worms were typically gray-green and normal size. Rubber was very buoyant and floated more readily than most.

Strain 4265-X. Defoliation was not difficult. Wood character was ordinary and worm characteristics were the same as 4265 and 593.

Mariola hybrids. Little material was available. It was not possible to process material in small, batch pebble mills. It was milled in the attritor. After milling, rubber aggregates were very fine, not worm-like, and could not be recovered by conventional skimming.

In conclusion, it was observed that preparing the shrub usually was not difficult; that Strain 4265-I was difficult to defoliate; and that hybrids that had one *Parthenium stramonium* parent had tough, long-fibered wood.

It was observed that all hybrids produced very small worms that were difficult to recover in the flotation system and that hybrid D-155 produced a dry deresinated crude that was not rubber-like in texture.

It was observed that the highest rubber yields per acre might be expected from strains 4265-I and 4265-X but that all guayule hybrids gave less rubber per acre than any of the straight guayule strains; and that guayule X mariola hybrids were the least promising of all strains tested. If new rubber extraction methods are developed, it could be that some of these processing difficulties would be overcome.

Rubber recoveries varied from 34 percent to 98 percent and 100 percent for 4265X and 4265I. Strain 593 gave a 78 percent rubber recovery and mariola crosses gave 45 percent. Mariola crosses also had the lowest rubber production per acre, 46 pounds compared with 294 pounds for 593 and 476 pounds for 4265X.

6. Plant breeding studies: Plant breeding is an important key to unlocking guayule potential. Two to four years are required before a plant breeder can determine how good a new rubber-producing plant is. However, plants produce seeds at an age of six months and plant crossings can be accomplished once or twice a year because many wild plant populations seem to contain the required genetic diversity (National Academy of Sciences, 1977). However, a possible difficulty is that plant variations are very diverse, very scattered and very numerous so that it would require many selections and much testing to develop improved strains (Rubis, 1979).

Guayule breeding research has scarcely begun. The post-war breeding program indicated that yields at least could be expected to double those of the standard Number 593 strain used during World War II. Some researchers predict strain 593 rubber yield can be quadrupled. These strain 593 improvements could come from cross-breeding with strains yielding a high proportion of rubber, strains developing rubber more rapidly and strains producing bigger plants. Research on hybridizing guayule with larger *Parthenium* species was very promising when all guayule research was abandoned in 1959. Some hybrids developed are seven times larger than guayule and some contain some rubber (National Academy of Sciences, 1977).

According to the National Academy of Sciences guayule study panel report, it is highly probable that plant breeders could select strains with increased cold tolerance to extend guayule cultivation into more temperate regions, for dryland agriculture and for other geographical conditions. Strains also could be selected for specific rubber qualities such as for molecular weight or zero gel-content, for example.

The National Academy of Sciences report notes that new research tools including phytotrons, radiotracers and gas chromatography help researchers investigate the peculiar physiology of guayule and help researchers understand the biochemical mechanisms that produce its rubber. Factors such as cold, moisture, temperature, dormancy, day length, fertilizer and age that affect rubber yield and rubber quality also can be determined. Recognizing

these factors will benefit guayule production because cultivation requirements are known imprecisely and are based largely on empirical observation.

Plant-growth regulators such as 2,4,5-trichlorophenoxy acetic acid and 2-chloroethyl phosphonic acid have revolutionized Hevea rubber production. These and others also may benefit guayule, but possibly in different ways by defoliating the shrubs or by stimulating unstressed plants to produce rubber for example (National Academy of Sciences, 1977).

In conducting research to develop high rubber-yielding guayule plants it is necessary to have a broad germ plasm base from which to select high-yielding plants. It also is necessary to have technology and equipment to grow plants rapidly from seed to harvestable plants in the field and to select germ plasm efficiently (Hanson, 1977).

7. Recent plant breeding studies: A guayule breeding program was begun at the University of Arizona in February 1976. Twenty-five seed lines were obtained from the National Seed Storage Laboratory and direct-seeded in April 1976 at the University of Arizona Experiment Station, Mesa, Arizona. Two hundred seeds of each line were planted. A 5-percent-to-10-percent stand was grown including some plants of almost every line. Seed has been gathered almost continuously since September 1976 (Rubis, 1978).

Dr. Reed Rollins collected seed in Mexico in 1976. He made 114 seed collections at 45 sites. He collected guayule and *Parthenium incanum*, *P. confertum*, *P. fruticosum* and *P. bipinnatifidum*. Seeds from each collection were planted in the Tucson greenhouse in March 1977 and transplanted in May 1977 to two field sites. During June and July 1977, Dr. Charles Mason, University of Arizona, collected *P. tomentosum* and other species in two trips to Mexico (Rubis, 1978).

Crosses involving *P. fruticosum*, *P. incanum* and *P. argentatum* were made during July and August 1978. Good seed set was obtained using these species as both male and female parents. The F_1 will be used to develop more desirable characteristics in the guayule plant. Crosses between *P. argentatum*, *P. stramonium* and *P. tomentosum* will be made during the appropriate blooming period. Chromosome numbers in both parents and progeny are being determined (Gomez, 1978).

8. Variety testing: Most guayule project efforts in Arizona during spring 1978 were devoted to growing guayule in the greenhouse and transplanting seedlings to the field to establish guayule in the greenhouse and transplanting seedlings to the field to establish guayule-yield tests at Yuma, Litchfield Park, Mesa and Tucson. A total of 30,000 plants were established (Rubis, 1978).

Good seed increases were obtained in Arizona during 1978 from the Rollins Collection and from the 25 seed lines obtained from the National Seed Laboratory planted in Mesa.

9. Cold tolerance research: Mariola (P. incanum) collections were made by Dr. J.W. Whitworth, in New Mexico, as part of a study to determine the potential for extending cold tolerance in guayule. At present, guayule will grow only in the southern one-quarter of New Mexico, particularly by experimenting with mariola crosses (Taylor, J., 1978).

At Las Cruces, New Mexico, seven higher-yield rubber lines and one sexual line of guayule were interplanted with six mariola collections in a crossing block to attempt to produce crossed seed to begin developing cold-tolerant guayule. At Las Cruces, Artesia and Clovis, New Mexico, observation of nurseries planted with the 25 lines from Fort Collins, Colorado indicated cold-survival variations ranging from 69 percent to 100 percent. Lines that had 100 percent survival were 11609, 11634, 12229 and N565II (Rubis, 1978).

Guayule research also is being undertaken by the Nevada Division of Forestry. Cold tolerance is of particular concern and attempts are being made to achieve successful guayule adaptation to the southern half of Nevada. Two greenhouses are operating. Nevada researchers received seed from the National Center in Fort Collins and the seed germinated well, but researchers had transplanting difficulty near Las Vegas and plan to move plots farther south to Boulder City (Taylor, J., 1978).

10. Recent germ plasm collections and sampling: The guayule germ-plasm base at the Los Angeles State and County Arboretum, Arcadia, California was obtained from Hugh Anderson, Pacific Rubber Growers, South Pasadena, California; the USDA Seed Storage Laboratory at Fort Collins, Colorado; and from Meir Forti, Ben-Gurion University, Beer-Sheva, Israel. Some seeds also were obtained from Reed Rollins collections in Mexico during summer 1976 (Hanson and Mehta, 1977).

During an August, 1977 field trip sponsored by NSF, Himayat Nagvi and George Hanson, Los Angeles Arboretum, explored 53 guayule sites in the states of Coahuila, Durango, Zacatecas and Nuevo Leon, Mexico to collect seeds. Plant samples also were obtained for rubber analyses and other scientific studies. Study results revealed that some sites carried guayule plants having a high rubber percentage (Nagvi, 1978).

Firestone Tire and Rubber Company staff are pulling samples of natural seedlings in Texas. Texas A & M personnel are sampling guayule growing in Western Texas near Fort Stockton, Bakersfield and south of Alpine from perhaps the largest and best natural populations in Texas. Natural-stock collections made for Dr. Glymph,

Firestone, varied in rubber content from 5.46 percent to 19.38 percent (Taylor, J., 1978).

Agricultural University at Juarez, Mexico staff are cultivating germ plasm and could be a future material source. A Texas A & M remote sensing project is pending which, if implemented, could help locate additional natural stands (Taylor, J., 1978).

11. Field techniques for ascertaining rubber content of plants: Indira Mehta, Los Angeles Arboretum, has developed a correlation between rubber concentration and trichome characteristics among guayule isolates collected from Mexican natural stands to extend Reed Rollins' 1944 observations. She relates trichome morphology differences to mariola introgression and confirms that a quick method to select high-yield rubber bearing plants from natural stands is trichome morphology. In effect, she states that the greater the mariola influence, the lesser the stem rubber concentration (Mehta, 1978).

Mrs. Alison McIntyre has developed a simple field test to determine quickly the relative amount of rubber in guayule plants. Only a very small sample is needed for field testing, however, actual rubber percentages cannot be determined. Rudolph Garzo, University of Arizona, is studying a guayule bark-sampling technique that could develop a field technique to estimate rubber content.

12. Cytology and morphology: Cytological studies on meiosis in guayule are being conducted at the University of Arizona. Univalents, bivalents and multivalents have been observed -- chromosome numbers 18, 36, 54, 72 and 108+. This research relates to possible strain crosses including mariola as well as to vegetative reproduction, or "automatic cloning," potentials involving apomixis (Taylor, J., 1978).

Guayule morphology studies have been undertaken at the Los Angeles State and County Arboretum, since the plant chromosome number can influence breeding behavior as well as determine morphology. Procedures are being developed to monitor selected strain chromosome numbers. In conducting interspecific hybridization between guayule and several of its relatives, plant selection in subsequent generations may be easier by knowing the relative number of guayule chromosomes vs. other species chromosomes in a putative hybrid. Recognising guayule chromosomes will help this selection; to this end a karyotype of guayule is being developed at the Arboretum (Hanson, 1978).

In studies on geographic influences on guayule rubber at the Centro de Investigacion en Quimica Aplicada (CIQA), Saltillo, Coahuila, Mexico, the physiochemical characteristics of rubber produced by natural guayule in Zacatecas, Coahuila, Nuevo Leon and Durango were analyzed using Gel Permeation Chromotography (GPC).

Study findings indicate molecular size and distribution are not affected markedly but that rubber percent content correlates with geographical region. It also was found that guayule rubber is quite uniform and unimodal while Hevea rubber is bimodal and shows marked variations depending on clonal type. This gives guayule a great advantage because variations in rubber characteristics can be avoided during genetic improvement (Angulo-Sanchez and Campos-Lopez, 1978).

13. Future guayule breeding studies: Some plant breeders believe it will take five to ten years to develop good guayule varieties that can be recommended for cultivation in various growing areas. These varieties would yield approximately twenty percent rubber content and produce a high yield. Other plant breeders believe that genetic material presently available will produce plants that yield 20 percent rubber under favorable cultural practices and that commercial production could begin as soon as seed is available.

It is expected that on a long-term basis, 10 to 20 years, improved varieties will be developed that will have increased rubber yield percentages and other special characteristics. For example, such potential varieties might have cold tolerances that could expand cultivation areas and could be faster growing plants, probably to shorten growing cycles.

14. Bioregulation: Another approach to improving agricultural crops yields has emerged from studies on bioregulation of plant constituents. This concept is based on the discovery of bioregulators that appear to depress specific genes thereby inducing production of additional quantities of certain constituents. Genes basically determine plant enzymic potential. It is within this potential that bioregulators exert influence. The concept of bioregulation and its relationship to plant biochemical systems readily could complement plant breeders work and should be a fertile research area leading to improved technology in agricultural crop production. Plant constituent bioregulation should improve certain features of cultivars that are not achieved readily by breeding, which, in turn, might reduce development time for new cultivars or allow use of crosses having broader genetic bases (Yokoyama, et al., 1978).

Results of experiments conducted by Henry Yokoyama at the USDA Fruit and Vegetable Chemistry Laboratory, Pasadena, California, suggest that it is possible to increase rubber yield by treating the entire plant with bioregulators; these preliminary studies indicate that bioregulators stimulate rubber accumulation in guayule. A 2.2-to-six-fold increase in rubber yields was observed when young guayule plants were treated with 2-(3,4-dichlorophenoxy)-triethylamine.

Preliminary study suggests that the use of 2-(3,4-di-

chlorophenoxy)-triethylamine is a major step in developing feasible, economic rubber production from guayule plants. The effect of the triethylamine on molecular-weight distributions and on resin-fraction composition remains to be determined. Most importantly, the bioregulator may provide a new, powerful tool for learning more about plant gene control mechanism (Yokoyama, et al., 1978).

In a private communication, Dr. Yokoyama stated: "From strictly biochemical considerations, without taking into account the stress, penetration and other relevant factors, bioregulatory treatment should work equally well on 3 or 4 year old irrigated and dryland shrubs. Bioregulatory agents, affecting rubber synthesis, directly influence the isoprenoid biosynthetic pathways.

Based on our preliminary experiments the degree of the magnitude of response to bioregulators appears to be influenced by the particular strain of guayule. Stimulation appears to be greater in strains with larger amounts of parenchymatous tissues. Thus, if the plant has a capacity for 20 percent rubber, then it should be feasible to induce that amount of rubber in the plant's parenchymatous tissues, provided the bioregulatory agents can penetrate and reach most of the active site(s). Effective penetration is an important factor and may vary with different strains.

"Any improvement of yield of rubber in guayule must be accomplished without diminishing the physico-chemical characteristics of the rubber. Very little is known about the effect of bioregulators on the composition and the composition and relative quality of rubber in guayule. In our preliminary work on the chemical bioinduction of rubber in guayule, no determination was made on the influence of rubber product in guayule. However, based on our related work on chemical bioinduction of isoprenoid constituents, it is plausible that bioregulators will cause a more uniform rubber product in guayule. And, it is essential that the microstructure of highly stereospecific cis- 1,4-isoprene units be maintained unaltered and that uniformity of molecular weight distribution be attained.

"However, genetic characteristics may determine the ratio of parenchyma to nonparenchyma tissues and these would in turn affect the response of the plant to bioregulators. We have observed as high as 30 percent induced rubber content on treatment of older (4 years old) strain 593. We believe that with the use of bioregulators it is quite possible to obtain maximum yield of rubber in younger plants...." (Yokoyama, 1978). Thus, it might be possible to harvest guayule economically and feasibly at one to two years rather than the present four years.

Among studies needed are: correlating chromosome numbers with rubber production potential (initial thoughts are that there is no correlation); correlating stress conditions with a larger magnitude of response; and investigating the parameters of treatment and designing a bioregulator that can promote growth and at the same time induce rubber synthesis. It should be noted that a number of multi-effect bioregulators already have been developed in conjunction with other work.

Other research efforts must be directed at optimizing yield stimulation and enhancing rubber quality in guayule: studying structure activity relationships, developing improved bioregulators and studying those factors involved in putting bioregulators to use (Yokoyama, 1978).

15. Summary of present status of guayule plant modifications: A variety of genetic material is available for breeding purposes and a limited amount of seed is on hand. Test plantings have been made and can be expanded rapidly because guayule is a prolific seed producer after the first year of growth and can produce up to several hundred pounds of seed per acre in later years. Ample seed supplies to go into production will be available in three or four years.

The available varieties will produce good to excellent growth under irrigation and could yield 10 percent to 20 percent rubber by weight during the fourth year, and perhaps 5 percent to 10 percent rubber after one year in the shorter growth cycle. Up to 763 pounds per acre have been produced in a year with close plantings, and up to 2,000 pounds per acre when harvested at the end of four years. Strains are available that produced plants having 20 percent rubber yields. If this rate could be maintained under field conditions, a yield of 20,000 pounds of shrub with a rubber yield of 4,000 pounds is possible based on shrub weights obtained by ERP.

Equally important as breeding studies are agronomic-physiological studies to determine rubber production under various environmental conditions. No positive information exists on the effects of external conditions on plants achieving genetic potentials fully. While "stress" is believed to be necessary to high rubber yields, some conflicting evidence shows that slow growing plants produce the highest percent of rubber, but that faster growing plants almost always produce more pounds of rubber per acre. Attempts to stress more rapidly growing plants by reducing irrigation have not been entirely successful.

It is not known yet just how much rubber existing strains can produce. It is entirely possible that the major problem is how to grow existing strains rather than how to continue plant breeding explorations that could create potentially higher rubber producers but that could fail under field conditions or produce material difficult to mill. A many-faceted re-

program should be evolved that will have interlocking dependencies to prevent failure in any critical area that would jeopardize the success of the whole (Rollins, 1979)

C. Propagation Methods and Alternatives

1. Seeds: Guayule seed germination characteristics differ from those of most other seeds. Only a few guayule seeds will germinate if sown immediately after being collected from the plant. Due to two types of dormancy: an embryo dormancy of short duration; and a seed coat dormancy that makes the inner seed coat impermeable to gas exchange.

Seed coat dormancy can be eliminated by chemical treatment or shortened to a period of a few months by threshing and removing floral parts normally attached to the seed. Aeration and moisture content of the seed affect the persistence of seed-coat dormancy as well as the keeping qualities of the seed. Dormancy could persist for years under some storage conditions.

Most guayule varieties are prolific seed bearers. When soil moisture and air temperature are favorable plants of all ages bloom and set seed profusely throughout the growing season. Seed yields* per acre vary widely according to the number, age and vigor of surviving plants. Each flower stalk bears an average of seven composite-type flowers; and each flower consists of five female florets with two attached sterile disk-florets, each of the former may produce an achene, or seed (U.S. Forest Service, ERP, 1946b).

Yields of clean, unthreshed seed in 1943 from ERP plantations established in 1942 ranged from 10 pounds to 300 pounds per acre, depending on plant size and blooming season length as influenced by moisture. In a few instances, under especially favorable conditions, yields of 1,000 pounds per acre were recorded. Usually, the collected seed yield is only 25 percent to 30 percent of all seed produced because of losses from wind, cultivation and shattering of seed before harvest (U.S. Forest Service, ERP, 1946a).

a. Seed collection: Several types of harvesters that employ revolving brushes or beaters to dislodge the seed into pan or trough receptacles proved successful and economical in ERP guayule production. New equipment has been modified and adopted for large-scale seed collection at the Los Angeles State and County Arboretum, Arcadia, California.

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*The term "seed" in this discussion includes an achene (or true seed) with attached bract and a pair of dry male florets. "Threshed seed" refers to the achenes alone; "filled seed" refers to seeds either normal or threshed that contain fully developed embryos; and "empty seed" refers to seed either threshed or unthreshed in which the achenes do not contain embryos but usually a pithy proliferation of the inner wall of the pericarp.

Collecting seed by hand cannot compete with mechanical harvesting in speed and cost per pound of seed, but it is practical when seed-picking machines are not available, when quantities of seed are small or when it is important to obtain the highest possible percentage of the seed produced by the plant (Taylor, C., 1946).

Seeds should be hand picked when collecting from individual or small numbers of plants created from such genetic manipulations as hybridization. These seed lots should be kept as separate, properly identified entities to maintain research data integrity (Taylor, K., 1979).

The number of times seed can be collected from the same plants during one season is influenced by cultural operations, blooming continuity stimulated by irrigation, ripening uniformity and winds (U.S. Forest Service, ERP, 1946b). In some instances six collections were made in the same area during a single growing season.

b. Seed cleaning, handling and storage: Cleaning removes foreign matter such as stems, leaves, sand, clusters of sterile florets, insects and weed seeds, and separating and removing empty seeds. Standard commercial equipment was used by the ERP. Seed cleaning was a very dusty operation, but properly placed suction fans and ducts withdrew the dust effectively (Taylor, D., 1946).

Air-drying collected seed to a moisture content of 6 percent to 10 percent permits temporary storage without danger of molding or heating. The recommended ERP practice was to reduce the moisture content of sacked seed by sunning because only ripe, dry seeds part easily from plants during seed collection. The principal moisture in the collected material will be from green seeds removed by excessive plant beating. Collecting in the early morning when dew is heavy also contributes moisture (U.S. Forest Service, ERP, 1946b).

c. Seed treating: On recently harvested seed the inner seedcoat, a thin, tough membrane enclosing the embryo, is nearly impermeable to oxygen and must be broken or made permeable. In addition, some seeds have an embryo dormancy that generally lasts about two months after harvesting. Until this dormancy disappears, the seeds will not germinate even if the seed coat is physically punctured or otherwise made permeable. Embryo dormancy can be broken, however, by exposing moist seed to light or by treating with gibberellin (Emparan and Tysdal, 1957).

Guayule seeds also become germinable after treatment with sodium or calcium hypochlorite which renders the seed coat permeable to oxygen, presumably by oxidation of resins. This treatment was the germination procedure most used by the ERP. The hypochlorite treatment also disinfects the seed, but is a supplementary action not associated with relieving seedcoat permeability

Sodium hypochlorite (chlorox) is preferable to calcium hypochlorite because it mixes with water more readily, can be handled in large volumes of solution by pumps and is less injurious to workers; but it is less stable in storage. There is little difference, if any, in the effectiveness of the two hypochlorites. Other oxidants, such as hydrogen peroxide, perchloric and nitric acid have been successfully used experimentally, but lack the economic or other advantages of sodium hypochlorite. Hypochlorite solution fumes are disagreeable and may be injurious in high concentrations. Good ventilation should be provided in the treating room because the solution is irritating to skin and can damage cloth or leather. Calcium hypochlorite is more dangerous than sodium hypochlorite because the fine dust drifts in the air and affects mucous membranes (U.S. Forest Service, ERP 1946b).

Sodium hypochlorite solutions deteriorate after use and sodium chloride and sodium chlorate are formed. The chloride is not particularly harmful to the seed, but some residue, possibly the chlorate, is so highly toxic that any minute quantity remaining in the seed after rinsing is sufficient to inhibit seedling growth. Chlorate does not hamper germination, but seedlings become chlorotic a few days after emerging and soon die; therefore, thoroughly rinsing treated seeds is important (Taylor, K. 1946).

Treatment duration is immaterial if treatment duration periods are accompanied by reducing the solution strength.

d. Seed threshing: The natural seed dormancy persists in varying degrees for a number of years in untreated and unthreshed seed. Threshing seed, however, can cause a substantial proportion of seed to become viable at once. Dormancy of the remaining seeds disappears in four to six months if the seeds are stored in a well-aerated but dry area and the need for costly chemical treatment of stored seed is eliminated (U.S. Forest Service, ERP, 1946a).

When it was necesary to plant when part of the seeds were still dormant, chemical treatment to overcome residual dormancy was inexpensive compared to treating unthreshed seed because the solution strength could be reduced to only one-sixth of that needed for unthreshed seed and the seed volume to be treated was reduced by about 10 percent (Taylor, C., 1946).

Threshed seed germinated more quickly in ERP seeding trials than unthreshed and better seedling stands generally were grown from threshed seed (U.S. Forest Service, ERP, 1946a). Being heavier and having more uniformity in shape and size, threshed seed flowed better in the mechanical drills used for sowing (Taylor, C. 1946).

Cleaning and threshing seeds and then treating with a sodium hypochlorite are the procedures now used by guayule researchers at the University of Arizona, at the Los Angeles Arboretum and at the California Farm Management Company, Bakersfield. The Company plans to try to introduce this chemical treatment into a seed pelletizing operation (Rivers, 1979).

e. Seed drying and storage: A dehydrator similar in design to food dehydrators proved successful during the ERP is being used to dry large quantities of seed. Small quantities can be dried in the sun, but the trays of seed must be protected from wind and temperature higher than 120 F should be avoided.

Seeds can tolerate great temperature extremes for limited periods and moderately high temperatures for long periods if they are kept dry. Storage method and type used depend on seed type and length of time stored. Experiment findings indicate that moisture is the principal determinant of seed longevity. Metal drums with tight-fitting lids are best for long-term seed storage because they prevent moisture content from changing and reduce fire, water and rodent damage hazards. When short-term storage of two to three years is planned, seeds do not need drying before storage in sacks or drums if the moisture content does not exceed 8 percent.

f. Pre-germination: The International Rubber Company pre-sprouted threshed seeds but ERP research determined that seeds kept moist and warm for a few days to stimulate the germination process before sowing outdoors emerged as well as or better than if actual sprouting had begun. Seeds can be dried following the moist, warm treatment without losing treatment effects. Pre-germination provides the advantage of an additional few days' margin of safety to allow for unexpected delays in sowing schedules (Taylor, C., 1946).

Hypochlorite treatment disinfecting action effectively controls molds, thus heating treated pre-germinated or pre-sprouted seeds does not occur, even when seeds are stored for days in deep containers (Taylor, C., 1946).

g. Germination tests: Greenhouse sowings in flats were better than blotter germination for testing guayule seed germination because they eliminate interpretation errors involving seeds with enough germinative energy to produce a root but not enough for normal seedling emergence (Taylor, C., 1946).

2. Stem cuttings: Vegetative reproduction by stem cuttings has been considered impractical because of cost and technical difficulties. Experiments were conducted in which treatment with indolebutyric acid or other root-stimulating hormones was beneficial. The cuttings were started in water and later transplanted to the field. Establishment was more rapid than nursery transplant and the plants were stronger and grew faster. At Manzanar, California, Nishimura obtained excellent results with rooting cuttings in specially prepared sand beds (Hammond and Polhamus, 1965).

However, preparing and rooting cuttings costs many times more per planting unit, and the labor involved in hand planting is many times that of machine-planted seedlings. No exact data are available because no extensive field cutting plantings were attempted.

The most satisfactory method for large-scale guayule production probably is propagation from seeds, but propagation from cuttings might be a useful technique under some circumstances such as in a breeding program or when expanding a valuable variety is desired (Nishimura, et al, 1944).

In vegetative propagation all the inherent characteristics of the parent plant are retained, hence it is a useful method for plant breeders to supply plants in which each plant is identical to an original individual (Taylor, C., 1946). However, apomictic strains or varieties also retain the characteristics of the mother plant and in such cases cuttings are not needed as a means of reproducing identical plants.

3. Nurseries*: Two methods of establishing field plantings were used by the ERP. The one most widely used involved transplanting nursery shrubs four to twelve months old or occasionally older. The other method, used only experimentally, involved direct seeding in the fields. The direct seeding experiments demonstrated that guayule could be grown successfully using this method, but the amount of labor and cost to prepare a very level seedbed, the frequent irrigations necessary to establish seedlings, and control of weeds appeared to make the nursery seedbed method more practical.

The general plan for producing guayule seedlings developed by the International Rubber Company was adopted by the ERP, however, it was modified from time to time as warranted by conditions or later experience. The plan consisted of selecting land with well-drained

*Nursery operations are described in much more detail than greenhouse operations because more information is available on nursery seedling production. This does not imply that greenhouse production is less important.

sandy or fine gravelly, sandy loam soils and a level or gently sloping terrain, and installing underground water mains to feed overhead sprinkler pipes spaced at about 50-foot intervals. Posts supporting the sprinkler pipes also supported lath fencing that served as windbreaks at 50-foot intervals.

Nursery methods used by the ERP to produce guayule seedlings were not greatly different from general nursery techniques used to grow many species of forest tree seedlings, particularly those irrigated with overhead systems. Seeds were sown by mechanical drills in 4-foot beds irrigated by an overhead irrigation system. Plants were weeded, watered, cultivated and otherwise cared for during a four-to-eight month period. Then plants were lifted, culled, packed and distributed for field planting. Under optimum conditions seedlings normally attained planting size at about four months of age.

Growing young shrubs in nurseries presents many problems similar to those involved in field culture, although the nursery stands are more dense. Young guayule is very sensitive to soil conditions. The best nursery production is achieved on deep, well-drained, fine sandy loam soils.

Research and experience have contributed materially to the knowledge of growing guayule with sprinkler irrigation systems and recent improvements in sprinkler equipment provide increased efficiency and lower cost. Experiment findings indicate that it also may be feasible under limited conditions to produce seedlings using furrow irrigation methods, but this method has not been used for large-scale production.

a. Climate: Climates suitable for growing guayule in the field also are favorable for growing good nursery stock. Qualifying limitations are: 1) seasonal succession of temperatures that permit sowing at a time when minimum daily temperatures are high enough for good germination--50°F to 60°F--but maximum daily temperatures are not high enough to severely injure newly emerged seedlings--more than 100°F; 2) the sowing season must be followed by several months' of temperatures favorable to growth and then by a season sufficiently low in precipitation and/or low in temperature to induce a state of relative dormancy; and 3) the season when plants in the nursery can be held dormant should correspond to the season when transplanting to the field can be done with good prospects of success.

Nurseries should be in areas not subject to severe storms, especially hail. An abundance of sunshine without excessive heat is best.

b. Soil: A loose, friable soil that permits tillage over a wide range of soil-moisture conditions is necessary in guayule nurseries. A fine sandy loam is ideal. The soil should be neutral or only slightly alkaline (U.S. Forest Service, ERP, 1946b).

Subsoil must be permeable. Loamy sand or sandy loam is desirable; dense layers, such as claypans and hardpans, prevent downward percolation of water. Guayule seedlings require an abundance of moisture but are easily drowned and good soil aeration is important. Soil depth should be at least 18 inches to permit preparation of a deep seedbed.

Alkali tolerance of guayule seedlings has not been determined definitely but water considered satisfactory for irrigating farm crops is probably safe for guayule (U.S. Forest Service, ERP, 1946b).

c. Seedbeds: In the ERP nurseries each 50-foot space between irrigation pipelines was divided into either nine or ten beds four feet wide and separated by 10- or 12-inch paths traversing the length of the beds to provide space for cultivating equipment wheels.

Experience in guayule nurseries proved the desirability of the band-sowing arrangement used by the Intercontinental Rubber Company. Within the 2-inch bands, guayule seedlings compete with each other, thus developing a compact form desirable for planting. The nursery bed interband cultivator developed by the ERP made it possible to cultivate seedbeds economically during the early life of seedlings and reduced considerably the hand labor required for controlling weeds and improving soil tilth.

Snowfence or trees planted as windbreaks helped control wind erosion and wind damage to seedlings and contributed to more even water distribution from overhead irrigation. Most wind damage to guayule seedlings occurs as mechanical injury from wind-driven sandy soil particles. Damage from wind alone rarely occurs if the nursery has been irrigated adequately. If nursery soil has dried out too much, desiccation of young seedlings by wind can occur (Taylor, K., 1979).

Pernicious perennials such as morning glory (field bindweed), Johnson grass and bermuda grass were the most serious weed problems in ERP plantings (U.S. Forest Service, ERP, 1946 b). Some of the newer herbicides might be useful such as "Round Up" which appears to have a short residual lethal life in the soil (Taylor, K., 1979).

d. Pests: A number of pests may jeopardize guayule seedling nursery production. Common pests include: pocket gophers, ground sqirrels, birds and various insects. University of Nevada researchers reported that a Washoe Valley planting in July 1978 was decimated by rodents, and jack rabbits jumped a 4-foot rabbit fence to get to the plants. Mice were very attracted to the peat moss pots in use (Rubis, 1979).

e. Diseases: Diseases are of particular concern not only as local problems but because of the danger of spreading infection in shipments of planting stock to other areas. Although guayule nursery

seedlings generally are not more susceptible to disease than seedlings of other species grown under similar conditions. Some of the diseases prevalent in soils may cause severe losses locally when the infection rate is high and soil conditions are favorable to rapid growth of disease organisms (Taylor, 1946).

Guayule seed germination requirements--moist surface soil for one or two weeks after sowing--create conditions that also are favorable to disease growth. However, disease should not be a serious problem if soils are well drained, good tillage practices are used, and irrigation is reduced as soon as possible after germination and emergence to that necessary for continued growth (Taylor, 1946).

Dr. S.M. Alcorn, Department of Plant Pathology, University of Arizona, has begun a study of guayule diseases. Research initially is concentrated on Verticillium albo-atrum because of its wide host range, its occurrence in agricultural lands in the southern border states and Mexico and of difficulties in chemically controlling the fungus economically, and because World War II guayule researchers noted tolerance in certain guayule lines.

Procedures for screening guayule cultivars for resistance to this pathogen in the greenhouse have been developed and efforts are underway to determine the most effective inoculum concentration, inoculation technique and the youngest susceptible plant growth stage.

Plans include refining inoculation techniques, testing various lines and beginning observations on the influence of the Texas Root Rot pathogen, Phymatotrichym omnivorum, on guayule (Rubis, 1979). The California Department of Food and Agriculture is planning a test plot in Salinas for virus testing.

f. Sowing: The most critical factor to consider in choosing the sowing season in guayule nurseries is temperature, particularly night temperature. Germination and total emergence slow progressively when night air temperatures are below 60°regardless of higher daytime temperatures; when temperatures are lower than 50°F, germination is inhibited and stands are poor or fail entirely. Pregerminating seed before sowing can counteract this inhibiting effect somewhat. This method was used extensively by the ERP (Taylor, 1946).

Temperatures during the growing season that follows should fall within the proper range for a time sufficient to allow seedlings to grow to a usable size. It generally was considered that maximum daily temperatures should not exceed 95°F, although good stands sometimes were obtained when temperatures rose to 100°F or even higher for a limited time each day (Taylor, 1946).

Temperatures of 10° F to 15° are dangerous for guayule seedlings, and damage can be expected from prolonged temperatures of about 20° F. Damage increases if plant foliage is wet or if soil moisture is excessive and a combination of both is particularly harmful.

Sowing in nursery beds must be correlated with field planting requirements, which in some nurseries means almost continuous sowing except during the winter months when temperatures are not favorable for germination. Guayule seed requires a certain number of heat units for good germination. Germination is very prompt and the germination curves are nearly perfect when moisture and temperature conditions become optimum.

Seed cover varies with the type of soil in the nursery. On heavier soils, a sand covering should be used; on light soils that do not crust or bake, a native soil covering can be used. Material containing any amount of very coarse particles, or sands containing salts should be avoided.

The seed covering depth that should be used differs with the coarseness of the material used, varying from .1 inches for fine sands, to about .19 inches for coarser sand (U.S. Forest Service, ERP, 1946b). It was found that better emergence was obtained when pure sand cover was used rather than a soil cover.

Guayule seed has so little emergence that it is very sensitive to depth of cover. However, in both the greenhouse and nursery trials, the absence of any cover reduced germination.

g. Irrigation: It was an ERP practice to irrigate several days before sowing to germinate weed seeds, which later were destroyed during final ground preparation (U.S. Forest Service, ERP, 1946b).

ERP recommended that if dry seeds are sown, irrigation should be delayed until a block or other convenient unit has been sown. However, to protect against wind erosion, newly sown beds should never be left overnight or exposed to even moderate wind without having been moistened. When sowing moistened seed, watering the beds should begin as soon as possible. Throughout the germination period, irrigation should be frequent, but only enough water should be applied to moisten the beds. The frequency and amount of water depends on the kind of soil and the type of sand cover used (U.S. Forest Service, ERP, 1946b).

The liberal moisture supply needed by guayule seed at the shallow soil level where the seed is sown is difficult to maintain without creating puddling and soil crusting or creating conditions favorable to disease organism growth. Also, overwatering causes seedlings to become succulent and top-heavy. However, guayule is rather tolerant to drying after germination is well under way, but before actually sprouting (Taylor,

Once the plants have developed substantial root systems, irrigation frequency can be decreased. The amount of water applied at each irrigation should be increased, however, when transpiration increases as the seedlings grow. Weather conditions also must be considered. Evaporation increases on warm, windy days and more during the

day than at night. When seedlings are small, daytime irrigation is best because water distribution can be more easily checked. When seedlings grow larger, more water can be applied at one time. Night irrigation is better because evaporation is less, risk of sun scalding on hot days is reduced and wind velocities generally are lower, therefore water can be applied more evenly to all beds.

h. Cultivation, fertilizing and pruning: Cultivating soil during the germination period is likely to increase losses from "soil splash." Cultivation does not aid germination and should not be undertaken until germination is complete and plants are well established. If cultivation is essential due to abnormal weed conditions, the utmost care should be taken (U.S. Forest Service, ERP, 1946b).

At first cultivation should be shallow; later, deeper cultivation is better to eliminate weed competition and improve absorption of irrigation water, especially on heavier soils (U.S. Forest Service, ERP, 1946b).

In ERP plantings guayule was a low user of the major nutrients. In nursery production, where seedling densities were high, demands on the soil did not seem greater than with field crops and may have been less. However, poor growth on cultivated land where moisture and drainage are adequate probably indicates a need for fertilizers.

Seedling growth may be stimulated by a moderate application of nitrogen combined with a much heavier proportion of phosphorus. Nitrogen excess was considered undesirable because it probably increases plant succulence, thus predisposing the plants to disease and retarding hardening off and induced dormancy. There appears to be no need to add potash(Taylor, C., 1946).

Pruning seedlings eight to ten weeks after sowing opens the canopy to permit surface soil to dry to reduce the possibility of disease, and to stimulate plant growth diameter. The plants should be pruned to about six inches above the ground (U.S. Forest Service, ERP, 1946b).

i. Weed Control: Weed problems generally are severe in young guayule stands. Because guayule seedlings are very intolerant of shade, it is particularly important to eliminate or reduce weed competition during the 45 to 60 days while seedlings are becoming established. Man power, conservation, operation economy and speed justify using a proven herbicide to eliminate weed competition because seedling growth is retarded seriously if suppressed by weeds for even a few days (Whitworth,1978).

During the ERP life oil sprays were used because modern herbicides were not available. When the Korean conflict renewed interest in guayule in 1952, 885 acres were grown under contract near Crystal City, Texas. ERP weed control methods were refined and modified. The stove oil used during the ERP as a post-emergence

selective herbicidal spray was not available in Texas in 1951, so a naptha, trade name "Varsol" (Exxon), was substituted (Whitworth, 1978).

The dinitroanilines or other new herbicides undoubtedly will be selective on guayule, but like the oils, also will be selective on many weed species. Results of preliminary herbicide experiments by the University of New Mexico with guayule seeded into soil treated with two of the dinitroaniline herbicides, "Treflan" and "Rydex" showed that seeded guayule had a questionable degree of tolerance to these herbicides. The other herbicide tested, Methachlor (Dual), was unquestionably too toxic (Whitworth, 1978). Work in progress by Nancy Elder under the supervision of Dr. George Hanson at the Los Angeles State and County Arboretum indicates that trifluralin is an effective pre-plant, pre-emergence herbicide and that a combination of siazin and oryzalin would be an effective pre-emergence post-plant herbicide. (California Arboretum Foundation, 1979).

In the New Mexico experiments guayule transplants one or two months old showed adequate tolerance to the two dinitroaniline herbicides as measured by shoot growth, but root growth was retarded measurably. Transplants ordinarily would be set in the field below the depth of incorporation of these types of herbicides which are moved little, if any, by the leaching action of water. Again, the Metachlor severely inhibited guayule growth (Whitworth, 1978).

Using selective herbicides to control weeds in crops always presents the problem of survival and buildup of resistant weed species although certain susceptible weeds essentially are eliminated. A similar problem was experienced in 1951 in using "Varsol" in guayule nurseries in Crystal City, Texas (Whitworth, 1978).

Herbicide research at the University of New Mexico is being expanded to determine what herbicide combinations are tolerated by guayule to solve the problem of tolerant weed species buildup.

Weeds sheltered by guayule plants are hard to eradicate, but once guayule achieves a relatively closed canopy it competes well with weeds and the problem is solved without need for chemicals.

j. Hardening off: Hardening or conditioning nursery stock before transplanting is very important. Bringing young plants into dormancy slowly by gradually reducing irrigation water toughens them to withstand the shocks of topping, root pruning, lifting and transplanting. Severely stressed stock becomes susceptible to injury from *Fusarium* and similar fungi, but properly hardened stock begins new growth readily, establishes quickly, grows vigorously and has a high survival rate.

The percentage of plants that survive transplanting and the promptness with which they start new growth are directly related to the degree of dormancy, or hardening off, to which they have been subjected.

Dormancy is accompanied by changes in the quantity and kind of food reserves stored in the plant, and possibly by other changes less well understood. Since guayule growth is responsive to moisture and warmth, independently of other seasonal influences, dormancy may occur during any season when moisture or heat is sufficiently limited.

Where irrigation sustains plant growth during periods of favorable temperature, it is possible to induce dormancy, or harden off, plants by reducing or withholding irrigation. It is possible to grow guayule seedlings with such a limited moisture supply that they are continually hardened. These seedlings could be transplanted successfully during any season of the year, but these plants are very small. Field experience as well as experiments generally have indicated that large plants survived better than small ones when both were properly hardened off (Taylor, K., 1946).

Extended periods of high moisture stress or dormancy can reduce the number of leaves remaining on seedlings and bear directly on survival. Findings of studies indicate that the remaining leaves actually form a toxic substance that impedes regrowth.

Low temperature also limits guayule growth and induces dormancy. When temperatures are sufficiently low during an extended period, the plants may reach hardened off condition even in the presence of abundant moisture (Taylor, K., 1946).

When to begin hardening off depends on plant size and the approach of the lifting season. If additional growth is stimulated after the plants are large enough for field planting, they become more succulent and susceptible to infection and disease spread. Therefore, if growth can be arrested as the plants approach the proper transplanting size, the hardening off will serve a double purpose. However, approach of the lifting date must also be considered. If certain blocks of stock have not attained optimum development yet are large enough for field planting, then hardening off should begin at least 30 days before the date of lifting (U.S. Forest Service, ERP, 1946b).

The period between waterings should be gradually lengthened to induce dormancy. If all stock in a block is of uniform size, plants can be allowed to reach a high moisture stress for at least two days before applying more water. But, when moisture stress is more severe and abrupt than the plants can manage by induction of dormancy, injury or death is likely. Drought injury also predisposes the plants to disease (U.S. Forest Service, ERP, 1946b).

The amount of water applied during the growing season, soil characteristics and stand density all have a marked influence on the type of seedlings produced. Excessive watering of plants in sandy soils often produces plants with tall, succulent tops particularly if stands are dense and fertilizers are used. Even though water applications are reduced gradually, hardening such plants usually produces

severe drought symptoms and only a few functional leaves survive (Taylor, K., 1946).

Cultivation needs are not as great during the hardening period, but the soil should not become baked or crusted, and weeds must be controlled (U.S. Forest Service, ERP, 1946b).

k. Transplanting: Tops of seedlings ready for transplanting should be topped just before lifting. During ERP operations topping was done by a machine set to cut the plants 1.5 inches above the ground to remove seven-eighths of the above-ground plant. It was considered best to top the same day the plants were to be dug. However, topping can precede digging by as much as four days if necessary to properly use equipment and labor. If watering is necessary to facilitate digging and pulling, it should precede topping but should not precede pulling by more than two days (U.S. Forest Service, ERP, 1946b).

Preparing nursery stock for distribution to the field involves two separate but dependent operations: 1)digging; and 2) pulling and packing. Lifting is a term frequently used to include both operations.

Digging operations are designed to undercut seedling beds at a specified depth to secure uniform root length and loosen the soil, thus reducing injury in pulling and easing hand pulling. Because of lack of uniformity in ground conditions, some variation in cutting depth from bed to bed is necessary (U.S. Forest Service, ERP, 1946b).

Little heating danger exists to hardened, relatively leafless plants in storage. Such plants can recover from considerable desiccation. Guayule can be transplanted successfully during any month if it is irrigated. Nursery stock can stay in beds for a year or more.

Relatively large plants with seven-eighths of the top removed and a root 7 inches in length are suited best for transplanting. Stem diameter at the root collar should be between six-and-twelve-thirty seconds of an inch.

During ERP operations, plants were crated after digging. They were firmly packed and the last layer was high enough that the lid bulged about 2 inches when it was nailed in place.

Shingletow was the packing material. The recommended moisture content was 50 percent to 55 percent on a dry-weight basis, but moisture and the amount of material used varied with climatic conditions, length of time that elapsed between packing and resetting in the field, and the storage method planned. A thin layer generally was placed on the bottom and top of the crate and two layers within, dividing the plants into three layers of about equal thickness. Dividers were inserted

between layers. Under some conditions it might be better to divide the plants into as many as six layers with dry shingletow (U.S. Forest Service, ERP, 1946b).

It is possible to hold properly packed seedlings in storage with a temperature range of 32°F to 38°for as long as 30 days without injury. Moisture content of the packing material should be less than 50 percent and crates should be lined on only four sides. Wax paper liners should never be used on all six sides because moisture would condense the crates to produce molds and rots (Taylor, C., 1946). Refrigerated freight was used for long hauls and was satisfactory.

4. Greenhouse techniques: Field nursery plants face potential hazards from extreme temperatures, storms, and high evaporation rates. In addition, past ERP experience indicates that guayule transplants from field nurseries must be at least four months old.

It is possible that new technology in greenhouse management could provide more economical means to produce nursery stock for year-round transplanting. Current research at the University of Arizona indicates that greenhouse-grown seedlings two to three months old can survive transplanting successfully, thus reducing the total time of nursery stock production (Rubis, 1979).

In greenhouse propagation at the Los Angeles State and County Arboretum seeds have been treated with 200 parts-per-million (PPM) gibberellic acid to break dormancy. More than 90-percent germination has been achieved in freshly harvested guayule seeds (Naqvi and Hanson, 1978).

Pre-treated seeds are germinated in flats filled with a mixture of peat moss and vermiculite. Freshly harvested guayule seeds require light to germinate, but using the treatment described above, light does not seem to be critical. The flats are moistened, covered with glass, and stored in a shaded section of the greenhouse. Alternating greenhouse temperatures of 90°F and 70°F are most suitable for germination and growth. Guayule seeds germinate in two-to-three days and are ready for pricking in seven to ten days. They are pricked in 2-inch plastic pots and later shifted to larger pots if needed, depending on growing conditions and the length of time plants must remain in the Arboretum greenhouse or nursery.

Proper irrigation management and regular fertilizer applications are considered essential for healthy growth of guayule plants in the greenhouse. Plants remain in the greenhouse for two to three months, then pots are moved to the nursery for two to four weeks to harden plants before transplanting them to the field.

Greenhouse-grown guayule plants are subject to various diseases and pest infestations. The Arboretum reports that aphids,

thrips, loopers and mites are constant threats, but can be eliminated by sprays or fumigations. Insecticides or miticides usually are damaging to young seedlings and are avoided. Various fungicides to overcome frequent, but not serious, damping off are under investigation.

When the greenhouse seedlings are about two-to-three months old they are transplanted in the field with a spacing of 4 feet between rows and 2 feet within the rows. Plants in the field require an equivalent of about 17 inches of rainfall per year for optimum growth. Exact requirements, however, depend on soil type and plant age. Various weed control measures and fertilizer management schemes are under investigation (Naqvi and Hanson, 1978).

Current techniques for guayule greenhouse propagation at the University of Arizona include using compressed peat moss fertil pots 2 inches round and 3.5 inches deep. The pots are thin-walled to make it easy to tear off the bottoms at transplanting time (Rubis, 1979). Many fertil pot users also remove the upper rim of the pot when transplanting because it has been observed that a projecting upper rim acts as a wick, causing moisture loss to the atmosphere and excessive planting mixture drying within the pot before new growth occurs (Taylor, K., 1979).

Using peat moss pots costing $.04 to $.06 each in 1978 would be expensive for a commerical operation. Although styrofoam trays would be more economical, fibrous roots of two-month-old guayule seedlings are not developed sufficiently for easy removal from styrofoam trays. There is some indication, however, that growing seedlings for three to four months and topping several times would produce stronger seedlings with more fibrous roots for transplanting (Rubis, 1979).

The potting mixture used by the Arizona researchers consists of peat and vermiculite on a 1:1 ratio with plant nutrients added. It also was found that with use of Viterra-2, a gel for holding more moisture, watering frequency could be reduced.

5. Direct seeding: Initial establishment of a stand of plants in the field is a major problem when growing guayule for rubber. Common practice has been to sow seed in nurseries and transplant when the plants are four to twelve months old. This is a major cost item in production of a guayule crop and is often accompanied by plant losses. Since customary harvesting procedure was to dig up the entire plant, the cost and labor for transplanting was repeated for each crop (Taylor, C., 1946).

Germination and emergence behavior of guayule seed determines the conditions under which successful direct seeding can be accomplished. These conditions are a minimum daily temperature no lower than 50°F (with possible five to seven degrees leeway if pregerminated seed is used); a maximum daily temperature not far above 90°F except for limited periods of the day; very shallow cover, not exceeding one-eighth inch for best results, and no crusting of soil

to impede emergence; and abundant soil moisture at the sowing level during the germination and emergence period (Taylor, C., 1946).

Weed control must be initiated soon after seed emergence. The common weeds come quickly and can soon overtop the guayule, which is intolerant of shade and competition. Surface soil can be allowed to dry, reducing the risk from damping-off disease when the primary leaves appear on the seedlings indicating a root depth of 8 to 10 inches. This drying causes some loss of weaker seedlings but losses are fewer than from disease when higher moisture is maintained (Taylor, C., 1946).

Seedlings must be thinned to the desired spacing because production of viable seeds that will produce seedlings is so variable that sowing at a rate to produce uniform stands of predictable spacing is not possible. Thinning by mechanical means was tried by the ERP with indifferent success. Tractor cultivators equipped with weeding sweeps were driven crosswise to the planted rows. Theoretically, this should leave single plants spaced in checkrows for subsequent cross cultivation, but unless the sweeps were set far enough apart to leave considerable undisturbed space at each plant location there were many final blanks where short blanks in the initial stand coincided with intended plant locations. In any event, it was found in the ERP trials that further hand thinning was required (Taylor, C., 1946).

Direct seeding trials at Salinas, California, gave rather promising results. The trials were made on small plots where precise leveling and control of irrigation as well as excellent seedbed preparation could be practiced. The trials were conducted during the summer, when temperature range was favorable, and included the use of pre-germinated seed sown in hills as well as in drill rows along the edge of irrigation furrows. Sowing depth of one-eighth to one-quarter inch with no packing of the covering soil gave much better stands than deeper sowing. Thorough soaking of the soil immediately after sowing followed by sufficiently frequent irrigations to maintain good soil moisture at the seed level during the germination period seemed essential. Emergence of pregerminated seed was better than dry sown seed at prevailing Salinas temperatures. Threshed seed was not as dependent upon pre-germination and dry-sown threshed seed germinated as well as pre-germinated unthreshed seed (Taylor, C., 1946).

Further trials at Salinas evaluated the effects of soil temperature, type of land preparation, type of sowing bed, presowing treatments of seed, dry-land sowings and production of stock in field sowings for transplanting. Partial or total failure of stand emergence occurred whenever any of the previously cited factors were unfavorable beyond critical limits but in the better combinations 10 percent or more of viable seeds produced seedlings (Taylor, C., 1946).

In the Salt River Valley, Arizona, temperatures too high in summer and too low in winter limited direct seeding to spring and fall. However, fall seedings were found impractical because temperatures after November 1 were too low for seedling growth and the young plants were destroyed by disease, insects and unidentified winter injury which destroyed the tops. Problems of tilth in seed-bed preparation and crusting during emergence also could have been serious in the heavy clay loam soil of the area but from recorded evidence they were not as serious as other factors (Taylor, C., 1946).

In Texas, erratic results were obtained from direct-seeding trials in 1943-1944 on both irrigated and dry-land areas. Climatic conditions in southern Texas were considered generally unfavorable for the establishment of guayule seedlings in the field, especially on land where irrigation is not possible (Taylor, C., 1946).

In the fall of 1951 and the spring of 1952, 1,166 acres of field nurseries were seeded in Zavala and Maverick Counties of Texas under the sponsorship of the Guayule Seedling Stockpile Project (GSSP). A severe winter killed all the fall-seeded plants but the spring seedings were more successful and 770 acres of the 885 acres seeded survived into the fall of 1952 with an average of six plants per foot of row. Shallow seeding into well prepared beds and repeated irrigations to keep the seed area moist were the main requirements (Whitworth, 1979).

Stand irregularity was associated with temperatures above 50°F and the difficulties of maintaining a uniformly shallow cover with an adequate moisture supply. Blank or scant stands occurred where cover exceeded half an inch (Taylor, C., 1946).

Direct seeding is beset with many difficulties especially under dry land conditions. However, if satisfactory stands can be readily established, elimination of transplanting costs and loss of time while plants recover from transplant shock makes it desirable to overcome direct seeding problems. Possibly, direct seeding will be feasible only with irrigation and transplanting may be the only practical seeding method for dry land conditions or for particular soil types (Benedict, 1979).

Many of the difficulties encountered in direct seeding efforts are a result of the large percentage of non-germinable seed in even the best seed batches and the difficulty of handling each achene as a unit. Equipment is available today that is better able to separate the filled from the unfilled achenes than the gravity separator. Also, a method has been developed by the California Farm Management Company in Bakersfield for pelletizing achenes making it possible to easily separate the individual achenes and handle them as a unit, introducing more precision into the direct seeding process (Benedict, 1979).

By employing two developments it should be possible to plant seed at uniform depth at a specified distance from each other in the row and obtain a single plant in at least 90 percent of the expected locations. Obviously some over-planting would be required, but thinning could be accomplished by machinery and selective herbicides could control weeds. These results should eliminate many of the difficulties now encountered in direct seeding of guayule (Benedict, 1979). Plans are underway now for direct seeding experiments on a 10-acre demonstration plot in Bakersfield, California, by the California Department of Food and Agriculture in cooperation with the California Farm Management Company.

D. Alternative Agronomic Practices:

For a crop that is not now produced, guayule's agriculture is remarkedly well-known; almost 1,000 scientific papers have been written about the plant, including excellent manuals for germinating seed, caring for seedlings, transplanting, fertilizing, irrigating, and harvesting (National Academy of Sciences, 1977). This knowledge is based largely on empirical observations made during 20 to 30 years of commercial production and is supplemented by empirical observations and research by ERP agencies during World War II and by the ARS Crops Research Branch during an approximate 10-year period ending in 1957. The scope of observations made possible during World War II is indicated by the fact ERP cultivated more than 30,000 acres of guayule largely in California (Taylor, 1979).

Wartime urgency demanded that good-quality agricultural land and adequate irrigation be used. Thus, ERP work is perhaps a misleading model for a desert plant; but, basic features of guayule agriculture were learned and many agronomic techniques were developed (National Academy of Sciences, 1977).

The ERP experience showed that there were no insurmountable difficulties growing guayule; there are no fundamental barriers to be overcome before production can begin (National Academy of Sciences, 1977). The ERP plantations and experimental plantings provide guidelines for producing rubber under a wide variety of soil and climatic conditions. W.A. Bullard reviewed the planting program carried out by ERP and most of the following general statements, unless otherwise credited, are from his report (Bullard, 1946b).

1. Spacing: Under irrigated conditions, standard spacings of 28 by 20 inches and 28 by 16 inches were employed by ERP. The first figures denote spacing between rows; the second figures denote spacings between plants within individual rows. The 28-by-20-inch spacing was used on irrigated plantings in California, Arizona and New Mexico; but, 28-by-16-inch spacing was used in Texas on the basis that soil and moisture conditions in the areas concerned were suitable for supporting the closer spacing while at the same time allowing a safety factor in the face of possible heavier insect and disease losses. On dry land the project employed a standard spacing of 28 by 24 inches in California, Arizona and New Mexico (U.S. Forest Service, ERP, 1943a).

Wider or closer spacings and longer or shorter rotations than those used by the project may be desirable. There is evidence that the 28-by-20-inch spacing, as most of the irrigated plantations were laid out, is too close for a crop rotation of more than three years. Under irrigation, losses of small branches by breakage from farm equipment and drying shaded branches were considered undesirable. On the other

hand, greater competition from closer planting appeared to favor high rubber percentage. Close spacing gave high shrub yields per acre with young plants, but very dense plantings soon stagnated, especially on irrigated plantations. Spacing, combined with survival (expressed as stand density), was found to have considerable effects on rubber development. In denser stands, competition for soil moisture was keener, and the plants grew under a certain degree of stress most of the time. The resulting, somewhat slower, growth favored a higher rubber deposition.

In young shrub, close spacing promoted higher rubber content in the first year of growth. The closest spacings showed the greatest yield of plant material and rubber, although even then the plants were noticeably smaller than those on wider spacings. At the end of the second year, the close spacing still showed the greatest total yield and the highest percent of rubber. With irrigated shrubs, the percent of rubber was lower than in dry-farmed shrubs, but yields were greater. Where competition was sufficient to retard growth, the spacing which produced the most dry weight of shrub also produced the most rubber per unit area.

Beyond effect due to number of plants per acre spacing had another effect on shrub yield. Guayule apparently tended toward a rather constant ratio of crown diameter to crown height. Where the plants were widely spaced they also grew taller. Losses in yield due to reduced stand density were compensated, to varying extents, by this change in plant size.

While ERP used rather close spacings in order to obtain high yields within a short time, somewhat wider spacings may be preferable. Irrigated shrubs in the third year of growth on better soils with 28-by-20-inch spacing formed a closed canopy that made cultivation unnecessary but made irrigation operations difficult. Also, as a result of shading some inner and lower branches contained a fraction of dead wood reducing the quantity and quality of the rubber.

2. Survival and stand density: Within reasonable limits, the yield of any crop is related to number of plants per unit area. This is held true for guayule. Stand age, soil fertility and moisture availability also had considerable effects. Since ERP's objective was to produce the most rubber in the shortest time, rather close spacings were used in plantations. By the same token, high survival rates were desired.

Greatest losses in survival occurred at establishment. After the first growing season reductions were relatively small, except where disease occurred. Possible high survivals were shown in old plantings made by the Intercontinental Rubber Company and in a few of the 1944 ERP plantings. A 10-year-old tract in the Salinas Valley had 93 percent survival even after extensive sampling. Presumably, this tract was hand-planted. The 1944, machine planted San Clemente plantings in the Southern California District had about the same survival in their

second year. Both tracts mentioned were dryfarmed on good soils and were subject to climatic conditions allowing moderate growth rates.

As might have been expected, there were considerable correlations between soil type and survival and between nursery stock conditions and survival. Poor survival usually was related to the difficulty of preparing a transplanted bed in fine-textured soils of poor structure during the rainy season. With respect to establishment and establishment survival, soil conditions seemed primarily important as they affected the transplanting operation. Survival was generally good when tilth, texture and soil moisture conditions permitted firmly setting plants in the ground with roots in contact with damp soil. In gravelly or cloddy soils survival was poorer. Because of drowning and disease hazard and tillage problems, heavy soils led to poor survival.

Cultural practices were important: first, to put the soil in proper condition for planting; and second, to time the plantings taking advantage of the weather. Hardening the nursery stock prior to transplanting improved field survival. Rain before and after planting was desirable to maintain soil moisture. Although hardened transplant stock could withstand drought and remain dormant for a long time awaiting good growing conditions, the poorer the planting conditions the lower the survival rates became. After initial establishment, the bulk of the losses were from cultivator damage, flooding or disease.

There was some compensation for low survival and low stand density resulting from increased growth of the remaining shrub. Remaining plants grew taller as well as wider when given more room. This compensation was greatest for shrub volume and weight rather than for rubber yield. On the average, it did not make up fully for decreases in numbers of plants in terms of total shrub yield.

3. Growth: Cultural methods affected the growth habit of guayule. Shrub grown with plenty of water tended to have open crowns with coarse, heavy branches and no central stems. Dry-farmed guayule, especially with increases in age, tended to take on an arborescent habit. Dry-farmed shrubs maintained a plant moisture content of about 44 percent while irrigated shrubs, put under heavy stress at times, dropped to about 34 percent. There was more shrub growth, and a greater efficiency in rubber production per unit of water available with dry-farmed shrubs than with irrigated shrubs.

Usually the greatest shrub weight increment on irrigated tracts in the hot interior climate was made in spring and early summer. The dry-farmed shrubs and irrigated shrubs in the cooler coastal climates made the most rapid gains somewhat later in the season. During the winter season, shrub growth was negligible. With respect to shrub age, the highest gains probably would have been made in the third and fourth growing seasons with irrigated shrubs, and in the fifth and sixth seasons with dry-land shrubs under normal climatic conditions. This probably would be more marked on spacings slightly

wider than those used for the majority of the plantations. No adequate data were available for final conclusions on older shrubs. Close spacing inhibited large gains even by the third year in some rapidly grown irrigated plantings.

It was found that three phases of growth important to harvesting and milling operations were affected by the kind of culture the plants received. Dry-farmed plants had relatively higher leaf bulk per unit weight of entire dry shrub than did irrigated plants. This increased transportation and other handling job loads per unit of mill capacity (the leaves were non-productive and the shrub usually was defoliated prior to milling). Dry-farmed shrubs had a higher rubber content and could be milled more efficiently. They also had the highest rubber-to-resin ratio and therefore tended to produce a better grade of crude rubber; but, irrigated shrub produced more pounds of rubber per acre in almost all instances.

a. Root development: From the time of transplanting on root systems guayule plants provided the most important contact between the shrub and the environment. Growth was related closely to the amount of water the roots could extract from the soil. Although planting stock condition at time of planting was important at first, subsequent root growth largely was contingent upon soil depth, aeration, penetrability and moisture capacity and availability. In turn, these characteristics depended on soil texture, stand density, rainfall and irrigation treatment.

In porous soils guayule roots penetrated to a depth of 8 to 10 feet the first growing season; 14 to 16 feet the second season; and ultimately, some roots reached down more than 20 feet. Thick strata of clay, gravel or coarse sand prevented such penetration. Where plow sole or other layers in the soil caused stunted shrub growth, the roots tended to form coralloid mats. Root distribution also was poor in loose, sandy or gravelly soils where water relations were poor. Top growth was limited when root growth was poor.

Guayule in its native habitat often showed a "dual-type" of root system: shallow surface roots which collect water from showers, and a taproot system which collects deep moisture. The shallow phase was not developed as prominently under cultivation, perhaps because. Plantation soils usually were deep and had a plentiful moisture supply. Deep-rooted, dry-farmed shrubs could exhaust soil moisture to the 16-foot level, far below the normal draft for most agricultural crops. In irrigated plantings on highly permeable sandy soils, root extension was great and water was used to considerable depths.

b. Top development: Above-ground shrubs contained the greatest proportion of guayule rubber content and provided the bulk of harvested material. Although good top growth required, and was a consequence of, good root growth, the tops were of primary importance. Top material comprised 85 to 90 percent of the mill shrub bulk.

Shrub appearance was a good indicator of health and soil conditions and, within certain limits, of rubber content. Leaf size and color provided an index to shrub condition with respect to growth rates. Branching habit (within a given strain) was related to moisture conditions and seasonal growth rate variations. Although plant crown shape and leaf color and shape varied according to genetic strain, they were fairly reliable indicators of other factors. In spite of minor differences in size and shape, plants of different strains tend to fall into the same size groups according to soil conditions. Top growth was limited by spacing and the room available for branch extension, but apparently there was a rather constant ratio between diameter and crown height.

c. Growth rates: Most of the transplants started new growth soon after planting, and by the end of the first growing season had attained fair size. In the first season, growth extent seemed largely related to establishment time. Establishment was delayed one year on a few dry-farmed plantations having soils difficult to prepare in advance of planting. Some transplants remained dormant through the hot summer and began growth with the following winter rains; but, survival losses were fairly great. By the end of the first year, differences in soil and moisture relations and culture showed their effects on the shrub. These divergences became more pronounced as the shrub matured.

Irrigated plantations, urged on with abundant moisture during the first and sometimes second years, grew more rapidly than the dry-farmed plantations. The growing season of irrigated plantings was much longer than the dry-farmed growing season because irrigation, especially during the first season, continued into the fall, whereas the dry-farmed plantings exhausted the bulk of available soil moisture by late summer. During the third year, the best of the irrigated shrubs were at least two times as large as the best of the dry-farmed shrubs. Shrub yields per acre, not considering differences in survival, were even greater because irrigated stands were more closely spaced.

Guayule requires several years to attain an economic size and rubber content. Irrigation is the most important factor in hastening the growth rate; guayule can be brought to economic harvest size in three years with irrigation. In experiments, productive harvests have been made even at the end of the second year. Under dry-land farming it is generally thought that much longer periods are required to attain economic production (National Academy of Sciences, 1977).

d. Relation to climate: Moisture is perhaps the most important determinant in growing guayule. Although the plant can produce rubber in very dry climates, it is not clear that it can be cultivated economically in regions as arid as much of its native habitat. This is because the plant is hard to establish and may take more than seven years to develop commercially useful quantities of rubber where rainfall is deficient and drought is common (National Academy of Sciences, 1977).

A detailed analysis of the possibilities for growing unirrigated guayule in California was made in the 1940s. It was shown that under dry-land conditions guayule roots are able to penetrate porous soils (if devoid of thick gravel and coarse sand strata) to depths of 8 to 10 feet during the first growing season and to depths of 14 to 16 feet during the second season. A moisture reservoir often accumulates below the root zone of conventional crops, such as grains and therefore is unavailable to their roots. This was found to be the case in areas of California where grain crops (with roots 5 to 6 feet deep) were grown. But guayule, with its deeper root system, could obtain the moisture that existed from 5 to 20 feet deep in the soils (Dortignac and Mickelson, 1945).

4. Field plantations: Guayule is suited to highly mechanized agriculture; ERP engineers developed and used machinery to handle each production step from seed gathering to baling the harvested shrubs. Guayule lends itself to many modern agricultural implements: conventional tillage equipment to prepare the land; vegetable planters to transplant seedlings; corn or cotton cultivators, digger-harvesters and hay balers to bale the shrubs for easy transportation (National Academy of Sciences, 1977).

During ERP activities all field plantations were established from nursery stock produced as outlined in Section III-B. This planting stock consisted of hardened bare-rooted seedlings 6/32 to 12/32 inches in diameter at the root collar and having 5-to-7-inch roots and 2½-inch tops. Stock was packed in crates at the nurseries and was delivered to the field as needed for machine planting.

Soil preparation was similar to that required for most farm crops. On irrigated land some special care was needed to avoid over and under irrigation because of field irregularities.

An ERP four-row standard machine was constructed from commercially manufactured transplanting units. Four units were placed 28 inches apart on a special chassis, a spacing not common to other crops.

Under ERP operations with the standard four-row machine run by an average crew, approximately 100,000 transplants were set out each nine-hour day, or about one acre per hour with 28-by-20-inch spacings. The average good planter consistently could feed about 55 to 60 plants per minute into the machine (U.S. Forest Service, ERP, 1946a).

On the basis of many ERP plantings, the best planting season appears to be the dormant or winter season. On irrigated lands the beginning of the planting season can be hastened by pre-irrigating the site. In the California valleys preirrigation should begin about September 1, so that soil moisture conditions will be favorable to good planting as soon as the planting stock is in a dormant condition; generally, this will be about October 1 (U.S. Forest Service, ERP, 1943a).

Planting operations in Texas, Arizona and New Mexico can be extended during October 1 to April 1. The more friable soils and a rather even distribution of rainfall in the planting areas provide generally favorable planting conditions during this extensive period. On non-irrigated lands in Texas this planting season frequently may need to be modified because of drought periods (U.S. Forest Service, ERP, 1943a).

a. Irrigation: Process water from a variety of factories, including Hevea rubber mills, has been used advantageously as irrigation water. It is possible that guayule fields located near a guayule milling operation could be irrigated, at least in part, with water effluent from that operation (Bonner, 1979).

The following discussion of guayule irrigation is from the ERP handbook on plantation management (U.S. Forest Service, ERP, 1943a). Because of the shrubs special susceptibility to injury from flooding and waterlogged soils, all land used for irrigated guayule production should be checked for proper preparation. Lands already devoted to other irrigated crops ordinarily will require little or no heavy leveling.

Because guayule is much more sensitive to flooding than most cultivated crops, it is better furrow irrigate all plantations except those on very well-drained soil. For the same reason and also because of the need for economic water use, special care must be exercised in distributing water to the furrows.

Generally there will be waste water to be disposed of at the lower end of each guayule field because with furrow irrigation it is seldom possible to secure satisfactory water penetration without ponding the water at the lower end of furrows or allowing some surface runoff. In some instances winter rains will produce runoff. For these reasons providing surface drainage is one of the most important phases of the land preparation problem.

Because of the wide variety of conditions encountered in the guayule-producing areas, no hard and fast rules can be set down regarding amount and frequency of irrigation. Depth available for root growth and water-holding capacity are important soil factors governing required frequency and quantity of irrigation.

Little information is available on guayule's water transpiration rate. Moreover, experience with the crop under irrigation has been so limited that, other than serious slowing in growth, the degree to which plants may wilt or otherwise show need of water is unknown.

The ultimate aim of irrigating guayule is to supplement soil moisture derived from rainfall in amounts necessary to ensure early and rapid growth. At the same time, irrigation must be applied presenting no hinderance to maximum rubber production. Disease losses resulting from improper irrigation also must be avoided.

Rubber formation seems to take place during periods of semidormancy and is produced either by low temperatures or limited soil moisture. In hot areas it may be necessary to induce or prolong this semidormant period by appropriate irrigation practices. Since it is impossible to bring or maintain the root zone moisture content at any given point between field capacity and wilting, it may be necessary to fully moisten only a part of the root zone. In appropriate cases this may be done by allowing the water to penetrate to shallow depths or by irrigating only in alternate furrows.

Because of soil type and crop age variations, controlling factors in applying irrigation water should be: 1) getting free water into the surface soil at the plant row to ensure moisture content and soil packing around newly planted roots; 2) moistening the upper 1 or 2 feet of soil during the first season when the root zone is limited to that depth; 3) getting moisture 3, 4 or more feet into the subsoil when the roots are working at those depths; or 4) moistening a limited part of the root zone to permit rubber formation without encouraging rapid growth.

The need to get free water to newly established plant roots without saturating the soil sometimes presents a serious problem. Irrigating alternate furrows may be advisable under these conditions.

Stock, especially if succulent, planted in dry soil should be irrigated as soon as possible. In hot weather not more than a few days should elapse between such planting and irrigation.

During first year growth, when roots are chiefly in the upper 1 or 2 feet, plants cannot be expected to tolerate drying out of the soil below the surface without suffering growth setbacks. At the same time, the leaf area will be small and the rate of transpiration therefore will be slow. Irrigation can be delayed until there is evidence that soil moisture, below that influenced by direct evaporation, is being depleted.

During second year growth, roots will be found rather well distributed 3 to 4 feet deep, provided that moisture has been available in these depths and when no impervious layer or stratum interferes with root growth. Irrigation then can be withheld until the soil becomes nearly dry in the lower portion of the upper foot. During the second year, the leaf area will be much greater than during the first year; also, water use will be much more rapid.

Complete dormancy will not occur from lack of moisture until the moisture content of the major portion of the root zone is reduced to the wilting point. This indicates that to induce or continue semidormancy to aid rubber production, irrigation should be withheld until the soil moisture in the major root zone, i.e., 2 to 3 feet deep, is reduced to about the wilting point.

b. Survival counts: Special counts, or surveys, to determine guayule survival and growth provide a basis for determing whether a field in question should be plowed up, replanted or retained.

Where survival is low, successful fill-in planting will tend to improve milling quality (rubber content) in the final stand because of more even stress among plants; however, it does not markedly increase total shrub yield. It probably is not necessary where first-year survival is 80 percent or greater (U.S. Forest Service, ERP, 1943a).

c. Cultivation: The principal function of machine cultivation is to control weeds in order to conserve moisture. Standard models of integral and pull-type vegetable cultivators can be used. The actual job of cultivation presents few problems that are not found in cultivating other closely spaced row crops such as sugar beets and beans. In general, it should begin in the early spring as soon as the ground can be worked, or at the approximate peak of weed seed germination. Disadvantages of machine cultivation are stirring the soil thereby causing some soil moisture loss and breaking branches from the shrub. Where the soil is wet cultivating can lead to soil compaction. Hand hoeing was used as a supplement to machine cultivation by the ERP, and oil spraying was found necessary to prevent weed growth within the planted row (U.S Forest Service, ERP, 1943a).

d. Weed, pest, and disease control: In the wild, guayule appears remarkably free of disease and insect pests; but, under cultivation the plants are susceptible to both. Although few plants died from disease or pests in cultivated ERP plantations, infestations were found. Diseases affecting guayule are common ones affecting other crops such as cotton and lettuce. Some are quite serious, such as cotton root-rot, charcoal rot, dieback and wilt. A few days in standing water encourages *Phytophthora* rot on guayule roots (National Academy of Sciences, 1977).

Oil sprays used by ERP permitted weed killing in planted rows without resorting to hand hoeing. During periods when rain and wet soil prevented using other methods, spraying provided control and was especially useful in cleaning up the winter weed crop. During other seasons, spraying was done after irrigating to get at newly germinated weeds while they were young and tender.

Several chemical weed eradicators were tried out during World War II, but most of them were toxic to guayule. Sodium arsenite completely killed nursery guayule. Zinc sulfate and borax retarded guayule growth. Aluminum sulfate had little effect on guayule, but was not too effective on the weeds. Kerosene was not particularly harmful to guayule, and was a good weed killer; however, a somewhat heavier, less expensive diesel oil was used most widely as a spray component but injured very young plants. A mechanical hoe was developed by ERP which proved to be very effective in weed control and in most cases, less expensive than the oil spray. Recently trifluralin has been used as a pre-emergence pre-planting herbicide; the combination of simazin and oryzalin has been used as a pre-emergence, post planting herbicide (Benedict, 1979).

Several species of insects were found in the ERP guayule plantings, but only grasshoppers and lygus bugs were serious economically. In limited areas grasshoppers fed on guayule leaves and on the bark of young stems, while lygus bugs fed on terminal buds, flowers and immature seeds. Defoliation by grasshoppers occasionally killed the shrub, or at least retarded its growth. Lygus bug damage retarded shrub growth and reduced seed yield. Grasshoppers were controlled with poison baits and by destroying their breeding grounds. No widespread lygus bug control was deemed necessary.

Ants and termites have caused some minor damage either by defoliation or by eating the bark of the roots. Lacebugs, which suck juices from the leaves, also have caused some injury in restricted areas in Texas. None of the insect attacks ever assumed serious proportions. Undoubtedly these insects can be controlled with insecticides today (National Academy of Sciences, 1977).

Fungus attack control has been obtained primarily through preventive measures. Soil moisture, in excess of field capacity for extended periods, was hazardous. Irrigation, particularly on heavy soils, had to be managed to avoid such situations. Disease losses were reduced by wider row spacing, deeper furrows and increased slope, or by planting in soils with high infiltration rates.

E. Harvesting Techniques:

It is the concensus of people associated with guayule research and production during World War II that considering all phases of guayule production must be interrelated. The end result of all phases should be to deliver to the mill: 1) shrub in a form fitting the milling process selected; 2) shrub with the highest practical hydrocarbon content (milling costs are directly related to per-plant rubber percentage); 3) shrub produced at a cost which, when added to milling costs, is a competitive marketplace product; and 4) a continuous supply, consistent with storage facilities, allowing continuous operation of the mill (Byrne, 1979).

1. Rubber deposition: While methods of growing the shrub and extracting the rubber are highly important, it is equally necessary to know something about the occurrence of rubber in the plant in order to develop the richest and most productive shrub. Guayule stems and roots contain most of the rubber although all parts of the guayule plant contain some rubber. Leaves contain so little as to be literally non-productive. In young plants and in new growth, the bulk of the rubber is principally in the cortex and pith; in older plants the phloem parenchyma tissues found in the bark contain the greatest amount. Rubber does not occur in latex canals, but as granules or globules within individual cells. Stem tissues are richest in rubber, and the relative volume of rubber-bearing tissue varies with bark thickness and stem diameter. Where the ratio of bark to wood is greatest, rubber content of the shrub is highest (Bullard, 1946b).

Timing and relative amounts of rubber formed are related to culture. Of course, there are other variations related to soil conditions. Dry-farmed shrubs deposit proportionately more rubber, early in the season than irrigated shrub. This is a result of the effects of the two types of culture on rubber-bearing tissues. Xylem cells (wood) are differentiated early in the growing season while growth is rapid, but phloem formation (bark) begins later when growth slows down. ERP researchers found that the dry-farmed shrub made most of its vegetative growth by midsummer, then tapered off because of soil moisture deficiency. Rubber deposition was nearly complete by fall. Shrub that was regularly irrigated throughout the season did not begin to increase rubber content in measurable amounts until winter (Bullard, 1946b).

Irrigated shrubs, large in bulk, gave high rubber yields per acre; but, the percentage of rubber content was not as great as dry-farmed shrubs. Under irrigation continued vegetative growth led to greater development of xylem tissue than phloem tissue. Delaying dormancy apparently permitted hardening of the thin walled phloem cells before rubber deposition could take place (Bullard, 1946b).

Increments in the rate and amount of rubber has been correlated to amounts of physiologic stress (within limits of individual plant tolerance) induced by cold, drought and other factors. One such factor is the alkali content of the soil. Genetic differences and soil fertility also affect rubber yield, but still are affected largely according to the stresses imposed. In California, with a mild winter climate, temperature apparently was less important than moisture availability in inducing stress and dormancy (Bullard, 1946b). However, all evidence accumulated during World War II showed that even with stressing, total rubber per acre was greatest when total shrub weight was greatest, in spite of the fact that the rubber percentage might be greater on smaller more slowly growing plants.

2. Preharvest conditioning: It is desirable to condition shrubs before harvest for two reasons: 1) to reduce the moisture content and leaf bulk to lighten the load on harvesting and transportation facilities; 2) to increase the shrub's rubber content improving per-acre yields and making the most efficient use of available mill capacity (Bullard, 1946b).

Preparation should begin many months before milling to insure that the shrub is conditioned to produce the maximum amount of rubber. Lush shrubs may be easy to mill, but the rubber returns may be low. On the other hand, if the shrub is too dry there may be a loss of the small branches carrying the greatest percent of rubber.

Several methods for bringing plants to suitable harvesting conditions have been tried. One method was to prune lateral roots by running a blade along the sides of plant rows to deprive the plants of their water supply; but, this method has been found to be unsatisfactory. A complete undercutting at various depths usually kills the plant (Taylor, 1946).

It was thought that defoliating living plants would slow down and induce the kind of dormancy which speeds up rubber production. Preliminary ERP attempts to burn off leaves set the guayule field on fire, therefore this method was abandoned. Using a sand blast or some form of beater also was tried; but, it was found that mechanical means of removing leaves, particularly those leaves in the interior branches, of densely foliated plants were ineffective. Chemical defoliation was attempted, but guayule has a strong general resistance to oils and hydrocarbons and results were discouraging. Hormones were tried without success since guayule leaves have no abscission layer through which the hormones might work. Trimming back and discarding the tops was advocated as an aid to milling. However, preliminary studies indicated that the small branches contained the highest percentage of rubber and a greater total amount than any other part of the plant. Moreover, the quality of the rubber in the small branches was superior; hence, the idea of trimming and discarding the trimmings was abandoned (Taylor, 1946).

Also, it was suggested that interplanting with a quick-growing annual to deplete the soil moisture would bring about a stress condition which, in turn, would increase the rate of rubber formation. This method held promise in the dryland areas in Texas, but in actual practice did not prove feasible (Taylor, 1946).

One factor causing stress is the alkali content of the soil. But very high salt concentrations resulted in a low rubber content even though the shrub had only limited growth. Genetic differences and soil fertility also affected rubber yield, but largely according to the stresses imposed (Bullard, 1946b).

Soil moisture stresses operate at any season of the year. Plants with limited water supply, as on dry-farmed tracts or on salty soils under irrigation, consistently showed a higher rubber content than plants with plentiful supplies of moisture (Bullard, 1946b). Moderate interplant competition for available soil moisture is, at best, one of the most practical and desirable means of developing desired stresses within the plant. Plant spacing, as adjusted to a planned harvest period, thus becomes important (Lobenstein, 1979).

While low winter temperatures caused cessation of vegetative growth and provided a slowing-down period in which rubber was formed (Bonner and Galston, 1947), temperatures most effective in instigating rubber development were never definitely determined in the field. When temperatures were so low, as to cause damage to the plant, there was no increase in rubber (Bullard, 1946b).

The most effective conditioning treatment found in irrigated land culture was to reduce amounts of irrigation water applied during the growing season immediately preceding harvest and to use such irrigation very sparingly or not at all during the latter part of that season (Lobenstein, 1979). Also, it was found that best results were obtained when water was withheld at periodic intervals to obtain the best balance between extractable rubber and shrub growth (Taylor, 1946).

Occasionally, stress was overdone. With soils of low moisture-holding capacity, abruptly ceasing water application resulted in sudden shock rather than slowly developed stress and dormancy. Wilting was prolonged under heavy stress, and many of the leaves and small twigs died back. Where growth stopped abruptly and absolutely, there was little or no opportunity for rubber formation, nor was there much storage space made available in that season's growth. Heavily stressed shrubs nearly always showed a low rubber content, and total shrub yields were reduced (Bullard, 1946).

Insect damage and disease also retarded growth; but apparently in a different manner from moisture stress because no evidence was obtained resulting in an increase in rubber deposition (Bullard, 1946b).

When guayule was grown in California climates, conditioning dry-farmed tracts was more or less automatic. Further tests should be made to determine the effect of curtailing cultivation during the growing season preceding harvest (Lobenstein, 1979). Late summer, fall and early winter were season of greatest rubber deposition. Fall was too dry and the winter was too cool for continued growth. Moisture in the soil was used up by midsummer and the shrub became dormant and dry soon after. The highest rate of rubber increment usually took place before November. Harvesting could be started then. Winter harvest was found to be the best, according to both Intercontinental Rubber Co. and ERP experience (Bullard, 1946b). But as will be discussed later, year-round harvesting can be carried out.

Conditioning irrigated shrubs presented several problems. Main sources of difficulty were light sandy soils in areas of high temperature. Moisture in such soils was rapidly depleted. Instead of moving gradually into stress conditions, shrubs were forced to change suddenly from a state of vigiorous growth to one of acute stress when the water supplies were shut off. Very heavy stress was found to adversely affect rubber development. Moderate stress provided the greatest rubber buildup and left the shrub healthy (Bullard, 1946b).

Once formed rubber is not lost, but may appear to decrease in percentage as additional shrub growth is added. Rubber content in guayule (as a percentage of the weight of the defoliated shrub) rose through the fall and winter and dropped when spring growth began. The lowest percentage usually occurred in May. This seemed to be the rule for all ages and strains. Low temperatures restrict vegetative growth, stimulating rubber development.

However, during periods of greatest rubber formation, shrubs need a crop of healthy leaves to carry on photosynthesis which should continue under relatively cool conditions. In the growing season, loss of leaves from heavy stress may have led to poor rubber content because of a reduction in photosynthesis. Moderate stress to promote dormancy in late summer and fall appeared essential for the best rubber yields (Bullard, 1946b). Here the effect of interplant competition for soil moisture will further develop a desirable ripening process and was lengthen the dormancy process (Lobenstein, 1979).

As indicated, moisture control afforded the only artificial means of pre-harvest conditioning, sometimes upset by soil or climatic conditions. On soils where moisture could not be withdrawn slowly, it was necessary to wait for cool temperatures to bring on shrub dormancy. In such cases the highest rubber content was not reached until late winter. Again, early fall rains during warm weather induced renewed shrub growth resulting in reduced rubber content percentages since rubber deposition does not take place during that period (Bullard, 1946b). This was particularly true in Arizona where September rains sometimes occur (McGinnies, 1979).

Although rubber accumulation is usually greatest in cool weather or under reduced moisture conditions, guayule can be harvested for rubber at any time during the year. Thus, guayule shrubs can be milled year round. It would be necessary to adjust milling practices to shrub conditions, but this would not entail any major modification in milling methods.

3. Harvesting methods: Guayule harvesting methods may have a very important effect on the quality and quantity of rubber obtained.

In an ERP postwar recommendation for additional research, it is pointed out that virtually no basic work has been done on the problem of harvesting. It has been demonstrated that guayule must be processed within as short a time as feasible after plants are harvested. The first problem to be solved, however, is the manner in which the harvest is carried out. There are two approaches to the problem. In one the plants that have reached a suitable age may be undercut and completely removed from the field. In the other approach, plants may be mowed or pollarded leaving root systems in the ground for re-establishment. Decisions regarding the manner in which shrubs as harvested depend, in part, on the processing techniques to be used (USDA Natural Rubber Research Station, 1953).

From information available, it would appear that the best time to harvest guayule would be when the canopy is nearly closed. Delaying harvest until after this point will result in losses of lower branches (because of shading) and subsequent losses of rubber. Dead branches cause milling difficulties and tend to lower the rubber quality. The time of closure of the canopy will depend on soil and moisture conditions and the original plant spacing. The canopy would close in the second or third year with a 28-by-20-inch spacing, under irrigation and favorable soil condition. Wider or narrower spacing would result in a longer or shorter harvesting cycle. Also, available evidence indicates that the older plants would have a higher rubber percentage but not necessarily a higher yield per acre (USDA Natural Rubber Research Station, 1953).

a. Digging: The Intercontinental Rubber Company developed a system for harvesting guayule using an undercutting device for severing plants roots at depths of about 8 inches; a side delivery rake for gathering undercut plants into windrows; and a large ensilage cutter, mounted on a tractor-drawn running gear, for cutting the shrubs into fairly small pieces to be loaded into trucks and hauled into the mill (Taylor, 1946).

ERP used the same general system of undercutting, but a lighter, more readily portable shrub digger was developed. This served not only as an undercutter but also lifted the plants from the earth and dropped them onto a smooth-packed soil surface, facilitating raking and pickup. The shrubs were gathered and baled. Since individual bales were too heavy to be loaded by hand, a bale-loading device was perfected so that trucks could move down the field and pick up bales without stopping (Taylor, 1946). Baled shrubs should be removed from the field as soon as possible after baling to avoid undue dirt accumulations in lower parts of the bales (Lobenstein, 1979).

Usual field harvesting operations took all the above-ground portion of plants and 6 to 8 inches of the root system. Although the roots contain fair amounts of recoverable rubber, they do not contain as much as the stems and branches; it was judged not worth the effort involved to get more of the roots when lifting out the plants (Bullard, 1946b).

Dormant guayule tends to be very brittle; and, branches are broken off easily. Digging, raking, windrowing and drying before baling caused a good deal of breakage and losses of smaller branches and twigs rich in rubber. Some tracts were raked twice to recover such material. When conditioning operations were changed to baling immediately after digging, losses were reduced because there was less mechanical handling (Bullard, 1946b) and plant tissues were not further embrittled to exposure to the drying wind and sun (Taylor, 1979).

Shrub type noticeably affected harvest losses. Dry-farmed shrubs, or the more slowly grown irrigated shrubs, were easliy dug and the fields were left clean. In contrast, the large, rapidly grown irrigated shrubs left more fractions in the ground because of their heavy roots and because of light soils which did not permit clean cutting (Bullard, 1946b).

b. Pollarding: The practice of clipping or "pollarding," rather than digging the entire plant would eliminate the expense of ground preparation and replanting. At the same time, the new shoots should grow more vigorously because of an establshed root system. Furthermore, there is nc decrease in the amount of rubber once it is formed in the roots, and the rubber would be retained for a future harvest of the entire plant (Hammond and Polhamus, 1965).

In 1948, experiments were begun at Salinas to determine the effects of clipping on rubber yield as compared to harvesting by digging. Completely harvested five-to-seven-year-old plants, with 36-by-24-inches spacings, yielded 1,003 to 1,459 pounds of rubber per acre in 1948 and 1949. Tops clipped from comparable plants yielded 686 to 1,064 pounds, amounting to 68 to 75 percent of the rubber in the entire plant (Hammond and Polhamus, 1965).

"After 5 to 6 years in the field, the cumulative yields in rubber from plants harvested by clipping and then completely harvested by digging 1 to 4 years later were greater than the yields from

unclipped plants of comparable age. At the final harvest in 1953, the accumulated rubber yields of the plants first clipped and then dug exceeded a ton per acre. The yield of rubber of unclipped plants was significantly lower than that of clipped plants of the same age" (Hammond and Polhamus, 1965).

Time of clipping was an important factor in plants survival. In general, the best survival resulted from clipping during the dormant season when the highest rubber yield could be obtained. Non-irrigated plants survived clipping better than irrigated plants, regardless of time of clipping (Hammond and Polhamus, 1965). However, clipping during the latter part of the dormant period usually promotes better regrowth (Lobenstein, 1979).

Only very limited trials have been made with pollarding. Before this method can be recommended it will be necessary to determine the effects of mowing and the number of times a plant can be pollarded before it becomes necessary to renew the planting stock. In addition, it is necessary to learn more about milling "tops." In limited studies performed so far it has been found that removing leaves is a problem. Finally, an economic study of pollarding as compared with undercutting will have to be made (USDA Natural Rubber Research Station, 1953).

Although these experiments demonstrated that the cumulative total yields of clipped plants exceeded those of unclipped plants, data on actual costs of producing rubber by these methods were not available. However, it could be concluded that a single harvest of unclipped plants would involve less expense, without risking the loss of plants, than clipping followed later by harvesting the entire plant. Costs of additional harvesting operations and price of rubber would determine the feasibility of clipping (Hammond and Polhamus, 1965).

c. Postharvest conditioning: Since the rubber hydrocarbon is distributed through the shrub roots, stems and branches, some means must be found for disintegrating the plant tissues, releasing the rubber from the individual cells and then recovering the rubber. It is necessary for the rubber in the plant tissues themselves to be in such a form and condition that subsequent separation and recovery can be accomplished. The possible "cure" or "conditioning" during which the latex in the cell coagulates to a flocculated mass was the subject of much research and many empirical studies. Tried methods included sunning, parboiling, defoliating prior to storage and retting whereby plants were exposed to fungal and bacterial action. At first, during the wartime emergency it was thought that field curing prior to milling was desirable. Therefore, plants were sunned for four to seven days after digging. Then they were baled in the field and were hauled to the mill where they were placed in storage until the moisture content dropped to about 18 to 20 percent. Later this procedure was found not only unnecessary but resulted in lowered quality and rubber loss. Best results were obtained by milling freshly harvested shrub (Taylor, 1946).

F. Processing Alternatives

Rubber occurs in the growing guayule plant dispersed in liquid of the plant cells. The rubber can be extracted in a dispersion of the latex, by solvent extraction, or agglomorated as a resinous or deresinated rubber (this has been the standard practice).

Processing guayule consists of a number of sequential operations carried out to release the rubber from plant tissues: separating the rubber, so far as practical, from other plant constituents; freeing the crude rubber from contaminant materials; applying necessary preservatives; and drying and packaging it for ultimate consumer use. Conventional processing begins with the stored harvested shrubs and ends with the crude boxed rubber. In addition, processing may include recovering various by-product materials having existing or potential use. There are alternative possibilities for accomplishing many of the operational steps.

ERP experience the best shrub for milling was not necessarily those which gave the most per acre shrub tonnage for rubber poundage. Rather, it was the shrub with the highest rubber content, harvested in late fall or winter when the moisture content and leaf bulk were lowest and the maximum gains in rubber had been made. However, for economic reasons it may be necessary to harvest and mill shrub throughout the year. Generally, dry-farmed shrubs were preferable to irrigated ones and old plants were preferable to young ones. According to J. Byrne (1979), the greatest problem of continuously milling young shrub was the comparatively small size of the resultant rubber "worms" which were difficult to recover by flotation.

It is probable that future guayule production will be obtained from mature shrub. Planting could be close enough so that there would be a full canopy and very little increase in rubber accumulation at the scheduled time of harvest. This would make full use of the land and result in more uniform raw material.

ERP mill capacity in tons of prepared shrub per hour was more or less constant, which some variations in milling time according to milled shrub conditions. More efficient milling and a higher recovery of available rubber were possible with the richer shrubs. Factors affecting rubber content, therefore, affected milling.

It should be pointed out that conditioning plant material for processing involves not only the amount and quality of the rubber within the shrub but also the chemical composition of the shrub itself. For instance, the shrub can be dried very rapidly to a low moisture content (one to two percent) without a loss of rubber as shown by chemical analysis. Drying under the conditions stated cause little chemcial change. Most of the change is physical, not chemical. Water removed by rapid drying is, to a large extent "free water," i.e., not chemically bound to other constituent materials. Some of the more volatile components of the resin complex are driven off at

high drying temperatures and, to this extent at least, the chemical nature of the shrub is altered (Taylor, 1977). Milling this type of shrub will give a rubber of acceptable quality, but yields will be low. Low yields (less than 50 percent of the hydrocarbon) were attributed to increased difficulty in milling because the shrub particles were so hard. Low yields were not only occasioned by entrapping rubber as "sinks," but also by losing much rubber because of too small rubber aggregates. When discharged into the flotation tanks, small aggregates were distributed through the flotation medium (hot water). Convection currents in the water kept the aggregates in constant movement so they could not be recovered by the collection equipment then in use (Taylor, 1979).

Leaf bulk, which lowered the productive milling capacity, varied with the shrub age, culture type and harvest season. In the first year, leaf weight was about 30 percent of shrub weight for both dry-farmed and irrigated plants. In the second year, it was 20 percent for irrigated and 25 percent for dry-farmed plants. Data were not available for older age classes, although on one dry-farmed tract, with 10-year-old shrubs sampled in midwinter, leaf bulk was less than 5 percent of shrub weight. Generally, in the winter season shrubs had fewer and smaller leaves than when they were growing vigorously in spring and summer.

Shrub age and time of harvest appeared to be the most important factors affecting milling. Young shrubs were poorer in rubber than mature shrubs and, because of their relatively high resin content, tended to yield a poorer quality crude. Winter harvested shrubs were at the peak of their rubber buildup and were at the lowest moisture content. Less drying was needed prior to milling, and deterioration between the time of harvest and milling presented less of a problem when storage was necessary.

1. Post-harvest handling and storage: Handling the shrub after it is harvested poses problems. After harvest it has been advocated that shrubs be cut into short lengths by some device such as an ensilage cutter and then elevated into a conveyance to be taken to the factory for processing. According to Byrne (1979), this method of handling was discarded by ERP due to high labor costs. Also, the Intercontinental Rubber Co. found that cut shrub deteriorated in storage and that removing leaves was impossible.

One of the major problems in handling guayule for milling is maintaining a constant shrub supply. This may involve storage for some period of time. Therefore postwar studies were made to determine the effect of various storage conditions. The results of these studies were compared with results obtained by milling shrub directly from the field (USDA Natural Rubber Research Station, 1953).

Two methods of storage were tried: 1) shrubs were dug and field cured for seven days, baled with leaves on and stored up to six weeks, then parboiled, defoliated and milled; and 2) shrubs were dug and hualed to the pilot plant at once, parboiled and defoliated,

stored up to six weeks and then milled. The control consisted of shrubs harvested and processed with a minimum delay. In all cases it was found desirable to protect the shrub from weather conditions which might result in deterioration or even spontaneous combustion following rain (Taylor, 1979).

Under the conditions of this experiment, increased periods of storing plants with leaves on caused decreased yields of rubber hydrocarbon in the crude rubber. There was an apparent decrease of rubber in the shrub; and, there was a slight decrease in the resin in the crude rubber, but not enough to make any appreciable difference in rubber quality. The total amount of crude recovered per ton of harvested shrub decreased as the length of shrub storage time increased.

The crude rubber recovered from shrubs stored after defoliation showed an increase in the percentage of rubber hydrocarbon as shrub storage time increased, and was accompanied by a decrease in the percentage of resin.

Two factors appeared to have opposite effects on the physical characteristics of crude rubber recovered from stored defoliated shrub. The physical properties of the curde rubber deteriorated progressively because of the continued degradation of the rubber hydrocarbon in the shrubs during the storage period. On the other hand, the physical properties of the crude rubber were enhanced by a depletion of resins during the storage period. The optimum improvements occurred at about five weeks of storage. Deterioration resulted thereafter.

The rubber recovered from milling freshly harvested shrubs had Mooney (viscosity) values and molecular weight markedly higher than any rubber produced from the stored shrubs. The lowered Mooney values and molecular weights after storage are strongly indicative of rubber deterioration through oxidative processes. The amount of insolubles (material not soluable in water, i.e., benzene and acetone) in crude rubber from freshly harvested shrub were markedly lower than in rubber obtained through other methods.

Storing shrub, either as whole plants or in comminuted form, after defoliation and exposing it to a microbiological process which reduces certain resin constituents has been termed "retting." The actual "ret," induced by the mixed microfloral population present in the atmosphere, varies greatly from season to season and from location to location. A pure cultural ret would necessitate a costly installation to provide sterilize the material and to maintain a pure culture inoculum, and would require appartus for maintaining the proper environmental conditions throughout the period of ret. It is doubtful that this process would be economically feasible as a method of reducing resin, as retting does not result in rubber with the physical properties approximating that obtainable from newly harvested shrub.

Some ERP investigative work was done on storing shrubs as ensilage under essentially anaerobic conditions. This work gave some indication that the shrub could be stored as ensilage, but further study is needed.

2. Cleaning and defoliation: As an initial step in defoliation parboiling has been an accepted practice. Leaf materials constitute approximately 25 percent of the dry weight of the plant and obviously constitute an unproductive load on the milling system, since the leaves contain no recoverable rubber. There is some evidence that milling the shrub with leaves only increases the amount of metals, especially copper, iron and maganese, in the raw rubber. These materials in particular are deleterious to the keeping quality of the rubber. Parboiling induces coagulation of latex within the cells, but more research is needed into the time required and the effect of parboiling on variations in the character of the rubber as reflected by its molecular weight and cleanliness (USDA Natural Rubber Research Station, 1953).

A rotary trommel has been developed for successfully defoliating plants after parboiling, except in the case of pollarded shrub. One ERP field was harvested by pollarding. In this case, twigs and branches lost through the screened section of the trommel approximated 30 percent of the original dry weight. Some other form of defoliator would have to be developed if pollarding became the standard harvest practice. Other developments may be necessary to keep abreast of advances in plant breeding. Some of the guayule stramonium hybrids have very large leaves. Using the trommel, equipped with screens large enough to pass these leaves, probably would result in excessively high losses of branches and twigs (USDA Natural Rubber Research Station, 1953).

Chemical leaf defoliation prior to harvesting has been tried without success (Taylor, 1946) but still may be possible. However, because of processing difficulties it is doubtful that using the leaves for by-products will prove to be economically feasible (Bonner, 1979).

3. ERP processing operations: Becuase of the wartime urgency of the work, the ERP program might be defined as an attempt to secure the "maximum amount" of rubber of "acceptable quality" in the minimum amount of time. The process evolved, based on the factory operation experience of the Intercontinental Rubber Co., is outlined below:*

1. The shrubs were undercut in the field to a depth of about 8 inches.

2. The dug shrubs were windrowed in units of four rows each;

*Outline from USDA Natural Rubber Research Station, 1953.

3. *The shrubs were field-cured for an indefinite period of time based on the end moisture content;

4. The foliate shrubs were baled in the field and transported to the mill;

5. *The baled shrubs were stored in covered or open storage 30 to 60 days, presumably depending on the degree of latex coagulation;

6. Whole bales were parboiled in a continuous parboiler. The wires were removed and the bales were broken open;

7. The shrubs were defoliated in a screened rotary trommel;

8. Defoliate shrubs were comminuted in a hammermill and were conveyed pnuematically to a surge storage bin;

9. Shrubs were automatically discharged from the surge bin and weighed.** A weightometer automatically controlled the rate of discharge from the surge bin;

10. The weighed shrubs were dried in a rotary drier to the accepted optimum moisture of 13 to 15 percent;

11. The cut and dried shrubs were passed through two sets of grooved crushing rolls of consecutively decreased clearance;

12. Crushed shrubs were mixed with water at an approximate water-to-solids ratio of 5.5:1 and charged to the first of four tube pebble mills (five at Bakersfield). The dry weight of shrubs fed and water-to-solids ratios could not be controlled accurately but were an improvement over previous operations;

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*It was found later that field curing and storage were both detrimental, and that milling freshly harvested shrub gave best results. The former method was eliminated and the storage period was determined by processing schedules.

**Actually, automatically controlled rate discharge from the bin was never very successful. For the most part feeding the raw material to the process line was accomplished manually. Continued use of the weightometer to record the amounts of shrub fed permitted, to some degree, a controlled feed rate even though it was not automatic.

13. Slurry from the fourth mill was diluted to a water-to-solids ratio of approximately 40:1 and was discharged into a flotation tank;

14. Bagasse was removed from the bottom of the tank by an air lift and was sent to a continuous certrifugal filter. (A vacuum filter was used at Bakersfield.) The bagasse was further dried by flue gasses to about 35 percent moisture content and was charged to Dutch ovens as boiler fuel;

15. The rubber and cork were skimmed from the top of the tank and were charged batchwise alternately to two "pailas" pressure vessels and held for an hour and a half to two hours at 250 psig.

16. The rubber and cork were discharged pneumatically to a second tank;

17. The cork was removed from the tank by air lift and was added to the bagasse;

18. The rubber was skimmed from the top of the tank and, together with a small amount of soap, was charged to a scrub mill;

19. With clean hot water the rubber was charged to a second small tube pebble mill, the rinse mill;

20. The rinsed rubber was discharged from the rinse mill into a high-temperature (around 150°F) retention tank, from which it was discharged and dewatered over a vibrating screen to the drier;

21. The rubber was treated with an antioxidant and was dried at atmospheric pressure in a five-zone single- or two-belt drier at increasingly higher temperatures. (The single-belt drier was more successful); and

22. The dried rubber was blocked into 100-pound bales and was boxed for shipment.

The ERP process had certain distinct advantages over the one used by private industry. The variables in the process line were more closely

controlled than in the previous case. An anti-oxidant of one kind or another was used consistently; a rubber of better keeping quality resulted. Because of the increased use of hot water and innovations, such as the rinse mill, the end product was cleaner and more uniform. Drying was a continuously controlled process, and the dried rubber was superior in uniformity and quality. Of particular importance during wartime was the fact that personnel requirements were lowered materially. This was especially true for shrub handling prior to milling rubber drying and packaging (USDA Natural Rubber Research Station, 1953).

4. Postwar studies of guayule processing operations: During the postwar research period a series of pilot plant studies was initiated to investigate modifying various processing operations. A flow chart of alternate milling processes is shown in Figure II-4. Additional research or machine design is needed in several areas.

One of the first steps necessary was to develop of a standardized technique or control process to measure variations in plant material and various processing equipment and techniques (Taylor, 1979). In those studies the raw material entering the milling process had widely differing characteristics due to differences in age, rubber percentage, and variations in the field cure and climate fluctuations. Irregularities in the type and duration of shrub storage also played a role (USDA Natural Rubber Research Station, 1953).

Parboiling and defoliation generally were used under all the tests made. A number of changes in the general processing were tried with varying results. The first was experimenting with cutters. It was found that using any sharp-edged cutting device was not efficient in processing guayule. Towards the close of the ERP conventional four-speed hammer mill was installed in factories at Salinas. It functioned with only minor maintenance until the project ended. A similar machine was installed at Bakersfield. Based on the results from these hammer mills, they would be recommended for future operations. Also, It was found that using crushing rolls was desirable. Repeated crushing up to eight times resulted in hydrocarbon recovery up to 98.5 percent. Turning the front and rear rolls at differential speeds imparted a "smearing" action to the rubber-bearing cells that was highly advantageous in securing rubber release (USDA Natural Rubber Research Station, 1953).

The storage studies demonstrated that latex coagulation in freshly harvested shrubs could be completed easily by parboiling and subsequent mechanical treatment without adding coagulent chemicals (USDA Natural Rubber Research Station, 1953). As part of this study, investigations were made to determine whether the rubber hydrocarbon was being degraded by the various processing steps. Degradation was judged by the molecular weight of the rubber hydrocarbon. A drop in molecular weight probably would indicate degradation by oxidation and chain scission. It was found that none of the separation or milling processes resulted in a significant drop in molecular weight. But a drop did take place during drying when the rubber was not protected by an antioxidant. When the rubber

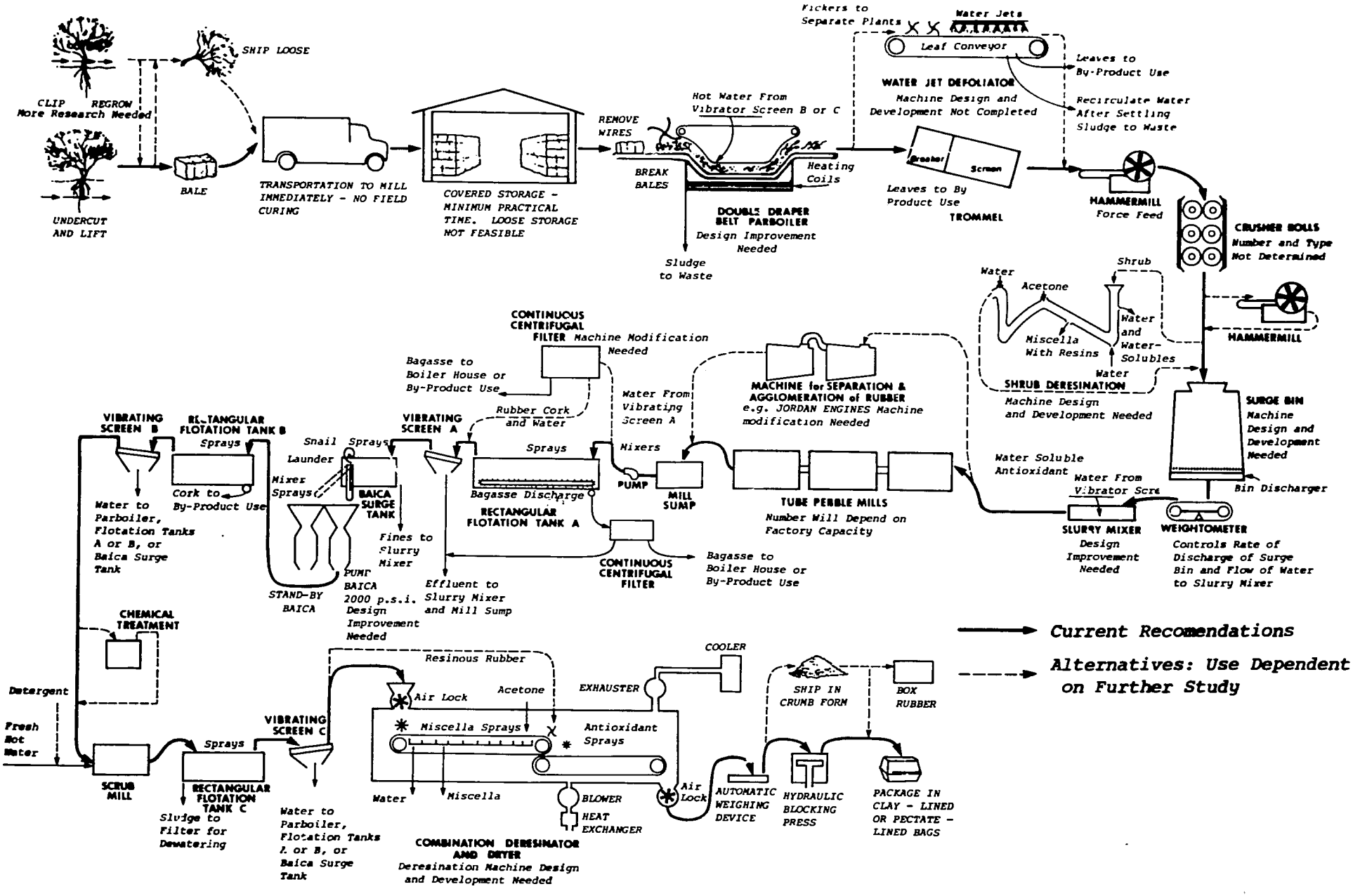

Figure II-4 - Flow Chart for Processing Rubber from Guayule

was protected by a suitable antioxidant such as "AgeRite White" and when the maximum drying temperature was lower, degradation did not result (USDA Natural Rubber Research Station, 1953).

ERP milling was done with pebble mills; but, some tests were made using Jordan mills. This was followed up in the postwar research. Rubber hydrocarbon yields, ranging from 69.8 to 78.8 percent, from factory-scale Jordan mills were not satisfactory. Mean recovery was 76.25 percent. Most of the losses consisted of unmilled rubber in the bagasse. These losses ran as high as 21.6 percent. However, small-scale Jordan milling studies gave up to 90 percent recovery by careful conditioning using adequate flotation. Based on these studies it was believed that some type of paper milling equipment might prove to be equal to or better than the pebble mill and could operate at a lower power cost per ton of shrub (USDA Natural Rubber Research Station, 1953).

5. Deresination: Guayule contains from 5 to 15 percent acetone-soluble constituents, or resin. During the pebble milling process commonly used for recovering rubber, part of the resin becomes incorporated with crude rubber, a major impurity. In most cases the crude rubber is found to contain about half the total resin originally present in the shrub. Analysis of a large number of samples reveals that the ratio of resin to rubber hydrocarbon in the crude rubber obtained from freshly harvested, defoliated whole shrubs is closely related to the ratio of resin to rubber in the shrub tissue (USDA Natural Rubber Research Station, 1953).

Based on postwar research, it was believed that rubber approaching Hevea rubber in quality could be produced from guayule in several different ways. Of these, flooded percolation on relatively thin beds of rubber worms from lush millings seemed to give the most uniform and reliable results. Comminuted guayule shrubs also can be deresinated using the same method. The advantages of shrub deresination over worm deresination are: possibly recovering water-solvent materials; and recovering more resin possibly containing fractions not found in the resin from worm deresination (USDA Natural Rubber Research Station, 1953). Whether communited shrub or crude rubber is to be deresinated may depend primarily on the economic value of the resin as a by-product (Taylor, 1979).

6. Latex Production: Several attempts were made to remove the rubber from the young plants as latex; but, this process offers less chance for economic development than other methods of rubber extraction. It was found that the shrub had to be in very fresh condition for latex to be recovered. The environmental work revealed that physiological fluctuations of the plant from season to season have a profound bearing on latex stability. When shrubs were brought in from the field they were kept fresh by adding fresh water during cutting. They were pressed and then milled again with fresh water and dispersing agents. The resultant slurry consisted of dispersed latex, water and a fairly high proportion of finely divided plant solids. The solids were removed by clarifying the liquor in a

modified cream separator. After removing the plant solids, the liquor again was run through the separator, resulting in two dispersion fractions; one contained a major portion of the dispersed latex and the other was principally water. The fraction containing the latex, termed "flushcream," contained about 7.5 percent rubber. Before it could be used practically, the flushcream was concentrated to a rubber content of 35 to 50 percent by adding a chemical creaming agent. The rubber produced by this method was of high quality with a very low insoluble content and resin, but it was difficult to produce. The amount of rubber hydrocarbon recovered as latex was less than half of that originally present in the shrubs (Taylor, 1946).

7. Rubber extraction methods developed in Mexico: An improved method of rubber extraction was developed by the Centro de Investigacion en Quimica Aplicada in Saltillo, Coahuila, Mexico. A pilot guayule processing plant, operating there since 1976 has been producing rubber for experimental purposes.

Baled shrubs are first dipped in hot water for 10 minutes at 167°F to coagulate the rubber and to remove foreign material and leaves. The plants are then passed through a hammer mill and a Bauer mill (a device used in paper making, somewhat similar to the Jordans mill in action on comminuted shrub) which break open the rubber-filled cells. Caustic soda (sodium hydroxide) is added during the pulping process to help break open the rubber-filled cells separating the rubber from the vegetable matter. The pulping is done in water and the rubber and brown, pungent resins conglomerate into the spongy form known as worms. Then this material is run through a series of flotation tanks where the waterlogged bagasse sinks to the bottom and is pumped off. The rubber worms float and are skimmed from the surface. This process is repeated twice; further separating occurs in each successive tank. The resinous worms are rinsed with detergent added to the water to remove the caustic soda. The guayule worms, containing 17 to 25 percent resins, are extracted with acetone carrying away about 95 percent of the resins. Then the acetone is distilled from the resin-water mixture, filtered, and recycled. After steam treatments to remove residual acetone, the gray-white guayule rubber contains about two percent resin, as well as a small amount of cork and debris that failed to sink in the slurry tank. In a final purification process, the deresinated rubber is dissolved in hexane and is filtered to remove the residual insolubles (cork, fiber, dirt). This filtered solution is homogeneous and the rubber can be bleached, protected with anti-oxidants or treated with reagents to give a high-quality, uniform product. While in solution the rubber can be altered by polymerization chlorination, copolymerization with methacrylates and other chemical reactions producing rubbers with different properties. The end product is a rubber of high quality with very low amounts of ash, copper and iron (National Academy of Sciences, 1977).

The rubber-hexane solution is mixed with steam and is pumped into a series of two coagulators where the solvent is vented off and rubber is recovered as variable-size crumbs depending on

operation conditions (surface agents stirring, etc). The wet, purified rubber is carried to an extruder dryer where all but .6 percent of the moisture is eliminated. The crumb rubber is then cooled in a long aereated gutter, baled, and packaged as a 75-pound block (Campos-Lopez, 1979).

8. Research needs: Alternative approaches still may prove to be simpler and cheaper, or may produce a better product. The National Academy of Sciences guayule study panel has suggested testing the following:

1. Extracting latex from the shrub without coagulating it to rubber. (Perhaps this should have a low priority because the process is extremely complex and the latex characteristics would vary tremendously) (Campos-Lopez, 1979);

2. Removing the resins from shrubs before the rubber is removed. This method may have advantages because during milling some rubber may be degrading while it is in contact with the resins; and

3. Retting the shrubs before extracting the rubber to selectively decompose the most deletrious resins thus producing rubber with improved physical properties. It is a simple, inexpensive process and, although not relevant for large-scale guayule processing, may prove suitable for small-scale rubber extraction in rural areas (if a somewhat resinous crude rubber is a saleable product).

The National Academy of Sciences panel further suggests that other research is needed to optimize each stage in the existing extraction method such as testing different pulping mills, various deresination solvents, new extraction procedures, and methods other than parboiling for coagulating the rubber and defoliating the shrubs

The Firestone Tire and Rubber Company is currently investigating a direct solvent extraction method for both resins and rubber. However, considerably more research on this method must be done before it can be considered an alternative method of processing (Glymph, 1979).

In the opinion of Dr. Enrique Campos-Lopez, Centro de Investigacion en Quimica Aplicada Director, extracting rubber from the shrub is the most important stage of the process because it has the greatest impact on total cost of the process. Also, it is the stage at which the greatest amount of water is used and resultant effluents could be a problem. Campos-Lopez recommends that research

emphasis be placed on aspects of the rubber recovery process: testing with various types of mills; ultrasonic experimentation to obtain cellulose fiber by means of recently developed high pressure systems (Campos-Lopez, 1979).

G. Rubber Quality and Utilization:

Four grades of isoprene rubber may be obtained from the guayule shrub: 1) resin-containing rubber produced from unretted shrub; 2) retted rubber containing about half the resins removed by retting; 3) latex; and 4) deresinated rubber which may be obtained by removing resin from the shrub prior to shrub-milling or removing resin from the pulverized shrub in either a wet or dry state after milling. In the past, most guayule rubber used in industry has been of the resin-containing variety. Some retted rubber and some deresinated rubber has been produced and sold in commercial quantities (Taylor, 1946).

These four grades of rubber are of different quality. Rubber processed without resin removal contains a 20 to 25 percent resin. For general industrial use, the resin-containing rubber is the poorest quality. However, it was sold in the greatest quantity because of its low cost. The amount of low grade guayule rubber used per year in the United States was a very small part of the total U.S. rubber consumption and was used for specialized purposes. Its inferior quality was not detrimental for uses such as for friction tape, wire insulation, low performance molded articles and other goods when high tensile strength was not a factor. Improving the quality increased the cost of processing This added cost was not compensated for by an increase in the market price of the crude (Taylor, 1946).

When other sources of rubber were cut off during World War II, interest increased in the quality of rubber available from guayule stimulated research by private individuals and the federal government (Taylor, 1946).

The resins in guayule rubber adversely affect its stress-strain characteristics decreasing the cure rate and requiring compounding adjustments. Also, the resins contain a pro-oxidant which speeds the degradation of guayule rubber. Since guayule rubber does not contain a natural antioxidant as does Hevea rubber, the guayule rubber tends to degrade and become tacky during storage unless protected by adding antioxidants. Removing the resins reduces this degradation and improves the physical properties of guayule rubber vulcanizates (Taylor, 1975).

Solvent extraction of resin from the guayule shrub or rubber without adding antioxidants produces little improvement of the rubber's quality until virtually all the resin is removed. Retting, however, results in quality improvement of the rubber by removing 50 percent or less of the resin, and possibly is due to the exact fraction of the resins destroyed by the microorganisms or because of a change in some other component associated with the rubber (Taylor, 1975).

Arguments for removing resin are compelling. Rubber quality is vastly improved, and the resin recovered may have a profitable market. The major argument against removing resin is the added costs of equipment and operation. However, these costs may be offset by market for the recovered resins and a higher price for the higher quality rubber (Taylor, 1975).

1. Nonrubber constituents: Because guayule rubber is recovered from the whole shrub (including the roots), dirt and rocks as well as cork and bagasse are potential contaminants. Contaminants are largely removed in the process for solution-phase purification carried out at the Saltillo pilot plant. Although the ash content is higher than in the best grades of Hevea rubber, it is not excessive (National Academy of Sciences, 1977).

2. Chemical structure: It is well known that the microstructure of natural isoprene rubber is one of the determining factors in its mechanical properties (e.g., "green strength")*; and that its capacity to crystalize under stress is due to a highly-regular polyisoprene chain exclusively composed of head-to-tail cis-1,4 structure (within the detecting limits of modern equipment). The synthetic polyisoprenes available on the market scarcely reach 98 percent of this structure. While in the past it has been said that guayule rubber has microstructure identical to that of Hevea rubber, it was claimed later that only 97.8 percent was made up of the head-to-tail cis-1,4 structure; recently, using nuclear magnetic resonance (H-300 MHz and C^{13}) it has been shown that guayule has a microstructure made up exclusively of head-to-tail, cis-1,4 structure. Although questions about the presence of carbonyl groups in the chain (correlated with gel formation in Hevea rubber) still exist, the identical microstructures of guayule and Hevea essentially are assured (Campos-Lopez et al, 1978).

Molecular weight is another very important characteristic of the elastomer. During storage and processing of the guayule shrub the rubber will be subjected to different degradation conditions. This can cause fluctuations in the ultimate properties. In synthetic rubbers the molecular weight can be controlled easily; however in Hevea rubber biosynthesis makes molecular weight hard to control, which could imply that considerable variations exist (Campos-Lopez et al, 1978).

Guayule rubber in its native state presents important differences compared to Hevea rubber. Recent studies by gel permeation chromatography show that the molecular weight (Mn) is in the order of 10^6 and is unimodal with a polydispersity lower than 2.5. In tests showing the characteristics of guayule rubber from four regions of Mexico (Zacatecas, Coahuila, Nuevo León and Durango (Angulo-Sanchez et al, 1978), it has been found that the variation in macromolecular size in guayule rubber is not materially influenced by geographical locations. However, the rubber content is influenced by geographical

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*See Section G-3, "Mechanical Properties".

locations and shrub variety. On this basis it is possible to foresee that, unlike Hevea the genetic improvement of guayule will be helped as the characteristics of the rubber are not markedly affected by modest genetic changes (Campos-Lopez et al, 1978).

Once the shrub is harvested the rubber undergoes degradation with storage. This aspect is very important and noticeably will influence the manner in which the shrub has to be handled during the period between harvesting and processing (Campos-Lopez et al, 1978).

While molecular weight is a critical property, methods generally used to measure it use the soluble fraction of the rubber, thus eliminating the gel. The gel is an important fraction and noticeably influences the physical properties of the elastomer. It has been found that the gel content (macro and micro) of native guayule rubber is noticeably low (less than four percent) and that it is not increased during storage, as is Hevea rubber; nor does it require any chemical treatment to be prevented. This is an important advantage for guayule rubber that will reflect advantages in its rheological properties and processing (Campos-Lopez et al, 1978).

The amount of branching in guayule rubber molecules has not yet been reported. Research is now being done both at the Institute of Polymer Science at Akron University and the Centro de Investigacion en Quimica Aplicada to determine the extent of linearity. Preliminary results show that guayule rubber predominantly made up of linear chains (Campos-Lopez et al, 1978).

Glass transition temperatures (Tg), crystallization, heat capacities (Cp), etc., are very similar in guayule and Hevea rubber. Stuides are being carried out aiming to determine the crystallization efficiency of guayule rubber by differential scanning calorimetry (DSC) and electron microscopy. Preliminary results indicate that the crystallization rate of these pure rubbers is similar, slightly faster in guayule, which could be additional evidence of a greater linearity in the guayule rubber macromolecules. Thermal and thermo-oxidative stability also have been studied. Activation energies of chain scission in both rubbers are very similar (20 Kcal/mole), irrespective of the model used (Campos-Lopez et al, 1978).

The amount of branching and crosslinking among guayule rubber molecules has not been defined quantitatively, although the ease with which the rubber dissolves in solvent suggests that it is low. Guayule does not appear to be a highly crosslinked species. Little gel is produced during in the plant rubber formation and little forms after extraction. In fact, the Saltillo pilot plant relies on dissolving the rubber in aliphatic solvent as a step in the purification process (National Academy of Sciences, 1977). Dissolution would be very troublesome in the presence of moderate amounts of gel (Gregg, 1979).

The rheological porperties of non-vulcanized guayule rubbers are just beginning to receive attention. Flow properties of this material, because of its macrostructure (low gel and high linearity),

should present important behavioral advantages compared to Hevea rubber. These will begin to be discovered (Campos-Lopez et al, 1978).

On a commercial scale Hevea rubber is produced with a series of impurities (proteins, sugars, etc.); some are of great importance as they assist further processing steps (milling, vulcanization, etc.). In the same way guayule rubber now produced on a pilot scale contains impurities; the chemical composition of its components is different from those present in natural rubber. This is one of the biggest differences between the two rubbers which will be reflected both in the processing characteristics (milling, vulcanization, extrusion, etc) and the mechanical properties (tensile, modulus, etc.) if identical curing formulations are used (Campos-Lopez et al, 1978).

3. Mechanical properties: Green strength is a measure of the strength of raw rubber during extension. Imperfections in the microstructure are believed to be a major factor contributing to reductions in the green strength of a polyisoprene rubber. The similarity of microstructure might be expected to result in similar green strengths between guayule and Hevea rubbers, but measurements show that guayule's green strength is intermediate between that of synthetic polyisoprene and Hevea rubber. If this proves to be a general feature of guayule rubber (and not just that of early samples from a new pilot facility), it might limit the percentage of guayule that would be added to the blend of rubbers used for tire making by large manufacturers. Green strength is important only during fabrication, i.e., before vulcanization. It does not affect the quality of the final manufactured product, and it is important primarily to large factories manufacturing tires (National Academy of Sciences, 1977). Also, preliminary studies indicate that if guayule rubber has an apparent green strength less than that of natural rubber, this could be increased by using chemical promoters (Campos-Lopez et al, 1978).

"Building tack" measures how well layers of raw rubber stick together before they are vulcanized. It is a very important property in fabricating certain types of tires. Synthetic elastomers have less building tack than Hevea rubber. Because Hevea and guayule rubber have good building tack, adding ingredients to increase tack is not necessary. The excellent flow and tack characteristics of guayule rubber should make it suitable for tire manufacturer (National Academy of Sciences, 1978).

The Mooney viscosity, which tests the flow of a rubber under applied force, has been measured at 95 to 105 in modern guayule samples. This is in the same range as Hevea rubber and means that guayule rubber should not exceed Hevea rubber in the amount of softening needed for extrusion. But guayule rubber, like Hevea rubber, probably will be more difficult to process than synthetic isoprene rubbers (National Academy of Sciences, 1977).

The placticity-retention index measures a rubber rheological stability. Although the guayule sample tested fell short of the

standards of the highest quality Hevea rubber, it is in the range of the Hevea rubber used in tires (National Academy of Sciences, 1977).

Systems for handling elastomers in solution, modern technology for extracting oils using solvents, "ad hoc" drying systems, etc., are recent technological achievements which make possible recovering guayule rubber and by-products with the necessary economic and technical quality requirements (Campos-Lopez et al, 1978).

In the past little or no efforts were made to standardize the individual processes to a point where the products had specifications similar to the Technically Specified Rubbers (Hevea). Consequently, this lack of specifications left potential users with no consistent opinion of guayule's capabilities for their commercial products (Campos-Lopez et al, 1978). Studies have been conducted to evaluate the Mexican guayule rubber which is being produced at Saltillo using American Society for Testing and Materials (ASTM) and Efficient Vulcanization recipes for determining the vulcanization characteristics and physical properties of guayule rubber produced by modern techniques (Winkler et al, 1978).

Neglecting recipe modifications, guayule rubber does have physical properties similar to those obtained with Hevea rubber vulcanizates. If a "technically specified" type of guayule is commercially feasible, it can become a direct substitute for Hevea rubber. In order to obtain the optimum physical properties available with guayule rubber, additional work attempting to find vulcanication recipes needs to be done (Winkler et al, 1978).

On aging, the percent changes in tensile properties of Hevea and guayule rubbers were equivalent, thus indicating that the guayule was sufficiently stabilized to age at the same rate as Hevea (Winkler et al, 1978).

4. Processing characteristics: The presence of resins in guayule rubber could be beneficial to processing by facilitating milling and extrusion and even by reducing energy consumption during these operations. These aspects are being studied now. Some preliminary experimental results on the Hevea and guayule energy consumption during milling show guayule rubber requirements two percent lower than those necessary for Hevea rubber (pale crepe No. 1 NBS and smoked sheet RSS No. 1). As the resin content of guayule rubber increases, energy consumption falls considerably. With respect to flow during extrusion, important results recently have been found regarding advantages of the resin in guayule rubber and its possible use as a plasticizer in Hevea rubber and styrene-butodiene rubbers (Campos-Lopez et al, 1978).

Because of its structural similarity to Hevea rubber, no difficulties are expected in processing guayule rubber with standard equipment. It softens readily and is expected to extrude readily and to flow properly in molds. Guayule rubber differs slightly from Hevea rubber in the ratio of chemicals needed to compound if for

adequate cure rates. This is due to the slightly different non-rubber impurities in commercial Hevea rubber. Both contain small amounts of moisture, dirt, terpenes and triglycerides; but, guayule lacks the protein and amine "impurity" that is beneficial to the curing properties of Hevea rubber (National Academy of Sciences, 1977).

Guayule's lack of vulcanizing activators cause it to vulcanize more slowly than Hevea rubber. By adding accelerators to the formulation this can be readily overcome (National Academy of Sciences, 1977).

5. Performance: Almost nothing is known of guayule's performance under full operating conditions. Virtually all the 120,000 tons of resin-containing rubber purchased by rubber companies between 1903 and 1946 were blended with Hevea rubber and may have been used as much for its tackiness as for its rubbery nature (National Academy of Sciences, 1977).

While the federal guayule project was winding down in the early 1950s, several tons of deresinated guayule rubber were distributed to industry for performance testing. Results were erratic (not always attributable to the rubber); but in, a federally supervised test, Firestone Tire and Rubber Company placed one guayule tire and one Hevea tire on the back wheels fo three gravel-laden trucks. To ensure equal wear, the tires were switched regularly. The guayule tires performed as well as the Hevea tires. One guayule tire survived 50,900 miles without showing a body break (National Academy of Sciences, 1977).

Various Mexican, U.S. and European rubber companies have been testing guayule rubber for both tire and non-tire use (Campos-Lopez et al, 1978). Table II-3 shows some of the results of these tests obtained by Goodyear Oxo Mexicana in 1977 with tires made by Cia. Tornell.

Based on laboratory and field trials, the University of Akron and the Goodyear Tire and Rubber Company have recently confirmed that guayule is capable of yielding high quality natural rubber. Automobile and truck tires containing 35 to 40 percent guayule rubber have passed vigorous U.S. Department of Transportation high speed and endurance tests and a number of the diagnostic tests (Dyckman, 1978).

Results of these tests have led Goodyear to conclude that the technical qualities of purifield guayule rubber make it acceptable for use as a replacement of Hevea rubber and synthetic natural rubber (cispolyisoprene) in many tire formulations. It is believed that the variability found in testing pilot plant batches of guayule rubber would be improved greatly by large volume commercial production; and, if guayule was available today at a competitive price, it would find its place in the rubber market. Based on its evaluation of guayule rubber, Goodyear is optimistic that additional research will make guayule a viable product, competitive with Hevea prices of the 1980s (Riedl, 1978).

TABLE II-3

RESULTS OBTAINED IN ACCELERATED TEST ON PICK-UP TIRES IN WHICH HEVEA RUBBER WAS SUBSTITUTED BY GUAYULE RUBBER OBTAINED AT THE PILOT PLANT IN SALTILLO

Load Resistance

Date of Test:	December 17, 1976
Number of Tires:	2
Required Duration:	67 Hours
Actual Test Duration:	67 Hours
Defects:	None

High Speed Test

Date of Test:	January 3, 1977
Number of Tires:	2
Required Duration:	41½ Hours
Actual Test Duration:	41½ Hours
Defects:	None

Penetration Test

Date of Test:	January 13, 1977
Number of Tires:	2
Required Value:	4 055.7 K/cm minimum
Actual Value:	7 943.88 K/cm

Source: Campos-Lopez et al, 1978

If guayule rubber production were resumed, it would likely be used, initially at least, in blends with Hevea and synthetic polyisoprene rubbers and with the more widely used styrene-butadiene synthetic rubbers. Under such circumstances, slight differences from Hevea rubber in processing or properties are noticeable, a factor which could greatly facilitate commercial guayule introduction (National Academy of Sciences, 1977).

6. Research needs: According to the NAS guayule study panel, guayule is to become a commercial crop, research must determine how well the "best" grades of guayule rubber compare with those of Hevea rubber; what levels of unextracted resin and other impurities are permissible in guayule rubber for the most demanding uses (e.g., truck tires); and how pure and uniform guayule rubber can be made economically.

K. W. Taylor, speaking at the 1977 Saltillo Conference, recommended that plant breeding research be paralleled by some form of guayule shrub milling research. He noted that milling research strongly showed wide differences in processing characteristics. In several hybrids the rubber aggregates were so small that they could be recovered only with great difficulty, if at all. He said that in two of the hybrids tested, the crude rubber resembled wet putty.

7. NAS guayule panel research recommendations: Since uniform properties are particularly important, a major research goal should be to develop a standard guayule rubber of known properties. To do this, standards will have to be set, and all stages in the milling will have to be controlled and standardized.

More extensive study of the mechanical properties of both raw guayule rubber and its vulcanizates are needed. Initially, they should use the purest material available, but tolerable levels of impurities also should be determined. Particularly needed are more extensive measurements of rates of crystallization, especially of elongation at elevated temperatures (194° to 212°F).

Compounding is an area demanding research. Tests of different formulations, fillers, reinforcements, softeners (including the use of guayule resins themselves), phenolic resins for high temperature curing, etc. are needed.

More work is also needed to determine guayule rubber's sensitivity to ozone, oxygen, nitrogen oxides, sulfur oxides and oils, and to humidity, sunlight, cold and other climatic conditions.

Testing guayule rubber's compatibility in blends with other rubbers and formulating graft copolymers from it are also promising research areas.

H. By-Products Characterization and Utilization:

Perhaps more than any other factor, commercial use of guayule by-products could affect guayule rubber production economics. Each ton of rubber extracted produces about two tons of wood fiber (bagasse), half a ton of resins, and about one ton of leaves (National Academy of Sciences, 1977).

The components of harvested guayule shrubs are shown in this table from the National Academy of Sciences (1977) report on guayule.

TABLE II-4

COMPONENTS OF HARVESTED GUAYULE SHRUBS (%)

Moisture	45 - 60
Rubber	8 - 26*
Resins	5 - 15*
Bagasse	50 - 55*
Leaves	15 - 20*
Cork	1 - 3*
Water Solubles	10 - 12*
Dirt and Rocks	Variable

*dry weight basis

1. Resins: Identifying and characterizing the guayule's acetone-soluble constituents received major attention during 1940 guayule research efforts. The resins seemed to offer the most promise of financial return in connection with producing deresinated rubber. It was found that with shrub deresination of variety 593 approximately one-half pound of resin could be obtained from each pound of rubber produced. Deresinating rubber extracted in the form of worms resulted in a yield of about half that amount. Resin availability varies with varying resin contents of different strains of guayule. The resin differs with respect to percentage composition of principal components depending on whether it is essentially a total extractive as with "shrub resin" or a partial extractive as with "worm resin." Essentially, all the resin could be obtained by solvent extraction of the shrub before extracting the rubber (Hammond and Polhamous, 1965).

"Small-scale pilot tests were conducted to explore the feasibility of removing resin and coagulating the rubber in the cells by extraction with water-miscable solvents such as acetone and alcohol. The tests indicated that by milling the residual shrub, high recovery of excellent rubber could be obtained" (Byrne, 1979).

Resin components as described by Hammond and Polhamus (1965) are as follows. Some 37 percent of the resins obtained from the rubber worms consist of unsaturated long-chain fatty acids, notably linoleic acid, along with traces of linolenic and oleic acids. Linoleic acid had held an established position in the paint and varnish industry.

Cinnamic acid is present in resin as the ester of partheniol and can be released by saponification. It has an established value in the cosmetics and pharmaceutical industries.

A "drying resin" fraction readily obtainable from shrub resin is a hexane-insoluble, alcohol-soluble shellaclike gum resin easily polymerized to a heat-resistant clear coating of good solvent resistance. This fraction constitutes 35 to 50 percent of the shrub resin but constitutes a much smaller proportion of the worm resin.

Guayule terpenes constitute a potentially valuable "naval stores" type of byproduct. Three to five percent of the worm resin, a much higher proportion of leaf resin, are comprised of volatile terpenes including alpha-pinene, dipentene, cadinene, partheniol and others. Sesqui-, di-, and higher terpenes also are readily obtainable in significant quantities from the nonvolatile, unsaponifiable fraction.

The "drying resin" fraction is of greatest interest and probably is of most economic value. Apparently all rubber-making plants make larger or smaller amounts of cyclic tri-terpene alcohols, such as lupeol and β-amyrin which are combined as esters. In some cases these same cyclic tri-terpenes are present as oxidized carboxyl group-containing derivatives. The drying resin fraction may be of a tri-terpene nature and possibly may contain diterpenes such as abietic and pinaric acids. If this is true, the drying resin fraction could compete in the "naval stores" industry. This would be of economic importance as this industry needs a new source of the higher cyclic di- and tri-terpenes for paint, paper sizing and so on (Bonner, 1979).

Betaine is a constitutent of guayule resins, and is found in water extracts of guayule shrub. This substance commonly is obtained as a byproduct of the sugar beet industry. It has a limited market as a pharmaceutical and as an intermediate in producing surface-active agents, disinfectants and other chemicals (Hammond and Polhamus, 1965).

In recent research at the Institute of Polymer Science, University of Akron, studies have been made of possible guayule resin applications as a peptizing agent for natural rubber, aiding to breakdown gel or high molecular weight fractions in the rubber which now are broken down by mechanical shear.

Studies of guayule resin also have been underway at the Centro de Investigacion en Quimica Aplicada. Work has been carried out there to develop varnishes and adhesives. Possible other uses such as pigment dispersors for rubber and tackifiers are being evaluated.

Research is needed to devise commercially feasible techniques for separating the resins into their saleable products. It is conceivable that the resins could prove to be more valuable than the rubber (National Academy of Sciences, 1965). If a use is found for guayule resin, that fact would influence profoundly production methods and the quality of the rubber recovered (Taylor, 1946).

2. Water solubles: The water solubles of guayule can be classified as three types: polysaccharides, amino acids, and inorganic salts. The polysaccharides comprise levulins (fructose polymers) and pentosans, including possibly xylan. The amino acids include betaine, discussed above. Inulin-derived levulins are present in the defoliated shrub to the extent of 8 to 12 percent, and are extracted readily by hot water. They are of interest as a possible source of low-cost alcohol (Hammond and Polhamus, 1965). Levulins are readily extracted by hot water (80°C). Thus, they will concentrate in the milling and other processing waters to the extent of three - five percent. Further concentration might result from greater reuse of process waters. The direct conversion of the high polymeric inulin to alcohol in 90 percent yield can result from fermentation with the proper strain of Saccharomyces fragilis (NRRL). Despite the high concentration of pentosans (xylan) in the guayule tissue (12-15 percent) its low solubility in hot water precludes the presence of much of this material in processing waters. If readily obtainable in significant quantity, it could be used as source material in the producing furfural (USDA Natural Rubber Research Station, 1953).

3. Effluent: Large quantitites of water are used in guayule rubber mill extraction. In milling, some of the plant material is dissolved and an additional portion is reduced to a near colloidal condition and is held suspended in the water. Also, there is some inorganic material present in the water from field dirt still clinging to the shrubs. The water and its dissolved and suspended solids is waste. Removing solids and reusing the water has not been feasible or practical. It was felt that the waste water might not be deleterious to plant growth if it was wasted to irrigation ditches. Experiments were set up by ERP researchers to determine the effect of this disposal method (Taylor, 1946).*

However, in field trials it was found that plants irrigated with full strength effluent grew better than those irrigated with tap water. Diluting effluent with water lowered the growth improvement but was better than water alone. Also, the effluent improved the soil structure by adding organic matter (Taylor, 1946).

In similar experiments carried out under greenhouse conditions, similar results were obtained. It may be concluded that if the need

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*Effluent from the Bakersfield mill was discharged into the city sewer. The total effluent passed through the primary digestion after which it was used to irrigate alfalfa (Byrne, 1979).

should arise, effluent from guayule processing mills could be used for irrigating agricultural crops (Taylor, 1946).

However, it is entirely possible that future milling operations will not require a great amount of water, or at least not as much as the conventional milling procedure. This is based upon the assumption that solvent extraction of resins will be used followed by solvent extraction of rubber from the ground shrub. If there are some effluents of an aqueous nature from guayule mills they certainly could be used as irrigation water. Process water from a variety of factories including Hevea rubber mills have been shown to be advantageously usable as irrigation water (Bonner, 1979).

4. Bagasse: Based on weight, the bagasse constitutes the largest and perhaps least valuable by-product. Nevertheless, its importance as a source of fuel for guayule processing is indisputable. ERP work showed that properly dried bagasse can be made to supply all heat requirements needed for large processing operations. For this purpose bagasse must be dried down to 35 percent moisture content. This can be accomplished in two stages: first, a reduction to 63-65 percent moisture in a centrifugal filter; followed by further drying by means of stack gases. The entire operation, including the stoking, can be handled mechanically (USDA Natural Rubber Research Station, 1953). Some of the first work by ERP contemplated using bagasse for covering guayule seed in the nurseries and as a soil amendment. Using bagasse in this manner did not introduce any pathogens; although, under certain conditions it adversely affected young seedling growth. The effect, which not persist, was ascribed to the fact that the soil microorganisms tied up the nitrogen normally available for plant growth when bagasse was added to the soil (Taylor, 1946).

Studies of bagasse use as a soil amendment and fertilizer indicated, as a general rule that guayule bagasse should not be added to the soil as an organic material unless nitrogen is added with it. It would appear then that bagasse could be used as an amendment to the heavier soils for its lightening effect, but its value as a fertilizer is limited (Taylor, 1946).

Bagasse also was pressed into fuel logs and burned in a fireplace on an experimental scale. The logs burned in a satisfactory manner and there was no objectionable odor. Bagasse and guayule leaves were mixed in varying ratios and subjected to a pressure of about 8,000 pounds per square inch, and heated at temperatures varying from 90°C to 110°C. The resulting products indicated possible use of these waste materials for insulation or wallboard (Taylor, 1946).

In the Saltillo pilot plant guayule shrubs are comminuted in a mill designed to produce pulp for paper manufacture. The resulting bagasse has not yet been tested for use in paper, cardboard or pressed board, but it seems to have promise for lower-quality uses. It is thought that returns from its sale could significantly lower the overall rubber-extraction costs (National Academy of Sciences, 1977).

In 1977, preliminary studies were undertaken at the USDA Northern Regional Research Center, Peoria, Illinois, to determine the yield of fibrous materials and fiber dimensions in guayule plant residue. Both of these characteristics are crucial to any use of the plant for making paper or boards. The yield of cellulosic material was approximately 36 percent; the fiber length was at the lower end of the range considered to be useful. Such fiber, in any potential papermaking uses, probably would have to be used in a blend with longer fibers (Hofreiter, 1977). In view of the short fiber length of guayule cell wall fibers, the probably end use of bagasse will be as fuel (Bonner, 1979).

5. Leaves: Large amount of leaves accumulate at a guayule mill and must be disposed of in one way or another. In early attempts to dispose of them, they were dried for use as boiler fuel as was done with bagasse. The practice was not practical because of the large amounts of heat required to dry them enough so they would burn (Taylor, 1946).

Investigations then were started on their use as fertilizer. Investigators of the Special Guayule Research Project of the Bureau of Plant Industry, Soils, and Agricultural Engineering obtained favorable growth responses when leaves were applied at rates comparable to those commonly used for farm manure. Soil applications of dry guayule leaves which were removed from the plants without boiling retarded crop growth; they tied up the nitrogen available for plant growth. Parboiled leaves did not have this effect. It may be concluded that leaves removed by parboiling may be used as fertilizer (Taylor, 1946).

The leaves represent an important untapped source of guayule resins, especially volatile terpenes, wax and plant pigments. However, much of the leaf value for resins would be dissipated in the parboiling process. Leaves constitute an excellent soil amendment, especially when composted. After parboiling, they can be compressed into a building board which, due to the structure of the leaves, possesses a pleasing pattern. As a source of livestock feed, leaves appear to have no value because of their unpalatability (USDA Natural Rubber Research Station, 1953).

6. Wax: Guayule leaves contain 2.5 percent of their weight (dry matter basis) as a cuticle wax. This is a hard wax with one of the highest melting points (169°F) ever recorded for a natural wax, particularly important today because hard waxes are in universal demand (National Academy of Sciences, 1977). Its relative hardness, molecular weight and melting point justify its consideration as a substitute or extender for carnauba wax (USDA Natural Rubber Research Station, 1953).

It may be that none of the suggested uses for the leaves will be useful in the long run. It would appear that extracting the cuticle wax would be most promising. However, in view of the small quantity involved and the fact that the wax would have to be removed by solvent extraction, this process may not be economically viable (Bonner, 1979).

7. Oil: A volatile oil with a distinctive lingering, spicy odor can be separated from the resins and leaves by steam distillation. The oil contains mono- and sequiterpenes (including α and β pinene, limonene, cadinene and partheniols 3 and 4), and may be valuable to industry (National Academy of Sciences, 1977).

8. Cork: The cork is conveniently obtained in a waterlogged condition from the last flotation tank discharge. It has been suggested as a possible linoleum filler; but no tests have been conducted (Hammond and Polhamus, 1965).

9. Seeds: Guayule seed contains oil and has a protein content of 11-14 percent. Its potential use as human and animal food are unknown, therefore research is needed to test guayule as an oilseed crop. It produces many seeds. During the 1940s seed collecting and processing equipment was designed but the seed was used for propagation (Natural Academy of Sciences, 1977).

10. Other uses for guayule: Animal feed is scarce in the semiarid regions where wild guayule grows. Thus, even with their resins and wax, guayule leaves are grazed by sheep, goats and rabbits. Palatability and nutritional studies are needed to see if guayule could be a supplemental browse shrub (National Academy of Sciences, 1977).

The growing shrub also has potential as a windbreaks, for controlling soil erosion and for landscaping, all of which are concerns in semiarid regions. A possibility suggested by Dr. Walter Federer at the 1975 guayule conference in Tucson, Arizona was to plant guayule every two or three miles and harvest a quarter of it in a four-year cycle thus having a shelter belt which yields an economic gain. Research on these uses is encouraged. Intercropping guayule with food crops might also prove useful (National Academy of Sciences, 1977).

Traditional uses of guayule considered removing and recovering rubber from the shrub as the primary objective. Occasionally the thought has occurred that guayule could be used in its entirety without separarely recovering the rubber. In 1945 Albert Fosher obtained a patent for a process which adds amounts of shredded guayule shrub to a suitable binder, such as blown asphalt, heated until fluid. The material was thoroughly mixed and was formed under pressure into sheets of composition strip which was said to be suitable for waterproof roofing or other structural purposes (Taylor, 1946).

That same year, Paul Kenda patented another process for using guayule bagasse and all rubber and resin after pebble milling. His process contemplated chopping lush shrub into pieces, then milling it in a pebble mill. The pulp was placed in a revolving cylinder and digested with steam in a five percent solution of acetic acid. The steam pressure was raised to 175 pounds psi and was released suddenly to explode the plant cells. The mixture of rubber and fiber was dried to form a paste and then ground to a homogenous mass. It was claimed that the resulting material could be used as a filler for compounding with rubber and rubber-like materials (Taylor, 1946).

It is not known if these two processes and the resulting materials were ever used. However, it has been suggested that shredded guayule shrub could be mixed with various waste fibers, such as the refuse from cotton gins and used in preparing wallboard. Further research for new uses for guayule without removing the rubber seems warranted (Taylor, 1946).

It is the opinion of reviewer Bonner that these suggestions for using whole ground guayule are unrealistic and would not be economically or practically viable.

I. Projected Yields:

Expected guayule yields are subject to several unknowns. Results from previous production experiences do not provide a completely reliable base for projections. The varieties grown and the conditions under which they were grown may not represent future production possibilities as new varieties and cultural practices are developed.

The predicted yield for future projections may be inferred from the available data, but some assumptions must be made on the basis of interpreting recorded yields and past estimates. Rubber yield varies according to age of the plants and spacing. It is conditioned by both high and low temperatures and the amount and distribution of moisture. All known varieties and new varieties that may be developed are subject to these parameters. New varieties may increase the amount of rubber through changes in plant anatomy and physiological processes; but, it is not expected, at least in the near future, that they will materially modify the age-space relationship. On the other hand, bioinduction procedures might stimulate higher rubber production in young plants or may eliminate the need of stressing conditions for producing rubber.

Under the present state of the art we may be justified in evaluating the chances for early changes in expected productivity and perhaps offer a higher level in case rubber producing capacity improvements arise sooner than can be justifiably predicted at the present time.

Two broad types of production may be considered: 1) rubber production from plants grown from seed and harvested in three years or less; and 2) rubber production from plants grown from seed in a greenhouse or nursery, transplanted to the field and harvested at the end of three or more years in the field. This type would include both plants grown with rainfall only and those grown under irrigation. An alternate practice would be to mow the tops (and harvest for rubber at two or more years and dig the entire plants after one to several years of regrowth).

1. Previous yield studies and past production information: During the ERP there were two reported studies of harvested plants grown from seed.

Kelly et al (1946) took advantage of four nurseries from which guayule transplants had not been taken because of the program termination. The study used existing nursery beds, and obtained reduced densities by eliminating one to five of the seven original rows and thinning within the rows. Two of these nurseries were adjacent to the coast and two were in interior valleys. One of the former showed the highest rubber production (1,336 pounds per acre in 21 months) under the closest spacing. All four nurseries produced more than 800 pounds in 21 months under the closest spacing. Irrigation increased rubber production at the interior nurseries but not at the coastal nurseries. Fertilizers did not increase rubber production.

D.C. Tingey (1952) direct seeded guayule at Salinas, California, and by thinning provided spacings of 28 by 20 inches, 28 by 12 inches, 28 by 6 inches, 14 by 12 inches and 14 by 6 inches. Some 28-inch and 14-inch spacings were left unthinned. There were three irrigation treatments: a) heavy; b) light; and c) none in the second year and one in the third year. He found that the number of plants per unit area was the most important factor affecting rubber and shrub yields. Difference in irrigation was the most important factor affecting rubber percentage. Guayule, grown in rows 14 inches apart, unthinned and with light irrigation, produced 1,708 pounds of rubber per acre in 33 months. The widest spacing yields only 569 pounds per acre.

A.C. Hildreth (1946) reported that 100,000 to 400,000 direct seeded shrubs per acre are practical under irrigation. Yields of 1,200 to 1,500 pounds per acre have been produced in less than two years.

Producing rubber from native stands offers little help in arriving at yield standards because acreages are not known. There are no reliable figures from Mexican harvests but a harvest of shrub from native stands in Texas during World War II provides some information. Approximately 3,400,000 tons of shrub were harvested with an average of 15 percent rubber, producing 510,000 pounds of rubber. It was estimated that the stands occupied 25,000 acres which would make the average yield 200 pounds per acre (U.S. Forest Service, ERP, 1946a).

There are several sources of information on rubber production in various parts of the United States in fields established from nursery transplants. All of these have to be viewed in light of the particular conditions under which the shrub was grown and harvested. First, one must consider the particular strain or variety involved, the plant spacing in the field, climate (both temperature and precipitation), soils, irrigation and age at time of harvest. It is difficult to isolate the effects of these individual items; so in arriving at a representative value it is necessary to make some comparisons and interpretations. There are five main sources of information.

1. Harvesting data from the Intercontinental Rubber Company;

2. Field production under the ERP;

3. Experimental ERP plots;

4. ERP indicator plots; and

5. Estimates based on growth and rubber content of small samples.

The information on yields obtained by the Intercontinental Rubber Company is of limited value because of variations in treatment, spacing, and harvest age. Figures available from harvests in the vicinity of Salinas, California, do not provide information on spacing and time of harvest. Hammond and Polhamus (1965) report a yield 880,286 pounds of rubber from 598 acres or 1,472 pounds per acre. The shrub age is not given. Spacing is assumed to be 36 by 24 inches, the standard used by the Intercontinental Rubber Company.

In 1941 W.B. McCallum, chief botanist for the Intercontinental Rubber Company reported. "As the plants remain in the fields and become older, the rubber content continues to increase so that in considering the amount of rubber in the plants, their age must be taken into consideration." In one field of essentially 600-acres the rubber content is now 22 percent of the total dry weight of the plants. But this shrub is ten years old; yet, at the age at which it is normally harvested, which is five years, the rubber ranged between 18 and 19 percent. The best strains are very constant in this respect and yield 20 percent rubber or a little better at the end of five years. At the end of six years the average of the varieties now in large acreages gives 2,160 pounds of rubber per acre, but in the same field at the same age the average of the three best varieties is 2,460 pounds of rubber per acre." McCallum does not specify the last mentioned varieties but they probably were 593, 406 and 111. These figures cited by McCallum were higher than those shown in other reports by the Intercontinental Rubber Company and are higher than yields obtained by the ERP without irrigation. The fields mentioned were near Salinas and were not irrigated.

Prior to the ERP, production under irrigation was not successful in terms of rubber yields per acre. The Intercontinental Rubber Company gave up their 6,000-acre irrigated plantations at Continental, Arizona (25 miles south of Tucson, Arizona) because according to McCallum (1941) "the rubber was slow in forming in the plant because of irrigation and also because the rains came in the summer and promoted plant growth just when the plants should be drying out." In contrast to McCallum's experiences, one of the highest producing indicator plots (which will be discussed later) was located at Marana, Arizona 25 miles north of Tucson.

In spite of McCallum's advice it was decided by ERP technicians to make major plantings on irrigated land because war needs were critical and the earliest possible production was desired. It was believed harvests could be made in four years or less under irrigation, while shrub grown under rainfall alone would require five or more years to mature. Unfortunately, the life of the ERP was too short to provide a sufficient base for projected yields.

Because of lack of adequate previous experiences the ERP acre yields probably were lower than might be attainable under the best cultural practice. The necessity of stressing was not fully recognized in the beginning and the season and amount of stressing (by withholding moisture) was determined empirically and was not applied uniformly on all fields. Hence, there was a large difference in percentage of rubber and rubber yields. Furthermore, the magnitude of yield was subject to very small differences in the moisture capacities of soils, often within the same field. Plant spacing and survival also were important factors in yield determination.

Based on comprehensive sampling W. E. Bullard (1946b) arrived at the following estimates of expected yields (See Table II-5).

On the matter of spacing Bullard (1946b) made the following observations. Close spacing gave high shrub yields per acre with young plants, but very dense plantings soon stagnated, especially on irrigated plantations. The spacings most commonly used were found to be satisfactory for three-year-old irrigated shrub and four-year-old dry-farmed shrub. Spacing, combined with survival and expressed as stand density, was found to have considerable effect on rubber development. In denser stands, competition for soil moisture was keener, and the plants grew under a certain degree of stress most of the time. The somewhat slower growth resulting favored a higher rubber deposition.

In young shrub, close spacing promoted higher rubber content in the first year of growth. At one year, the shortest spacings showed the greatest yields of plant material and rubber, although even then the plants were noticeably smaller than those on wider spacings. At the end of the second year, the close spacing still showed the greatest total yield and the highest percent of rubber. In irrigated shrub, the percent was lower than in dry-farmed shrub, but yields were greater. Where competition was sufficient to retard growth, the spacing producing the most dry weight of shrub also produced the most rubber per unit acre. With 28 inches between rows in irrigated shrub, the 12-inch spacing showed signs of stagnation in one year. Spacing and competition stress were important with mature seven-year-old plants. Then the closely spaced shrub weighed only half as much as those widely spaced, but had more than twice the rubber content and, therefore, a greater total yield.

Spacing had another effect on shrub yield beyond that due just to number of plants per acre. Guayule apparently tended toward a rather constant ratio of crown diameter to crown height. When

TABLE II-5

ESTIMATES OF SHRUB AND RUBBER PRODUCTION ON GUAYULE PLANTATIONS IN CALIFORNIA

Age of Shrub in the Field	Estimated Survival 1/	Entire Dry Plant Weight	Rubber Hydrocarbon 2/	Shrub Weight per acre 3/	Crude Rubber per acre 4/	
Years	Percent	Grams	Percent	Short tons	Pounds	
		Irrigated - 28x20-inch spacing			total	per year
Salinas & Co. California						
1	70	150	3.1	1.7	110	
2	67	420	5.3	4.5	510	255
3	65	700	7.4	7.3	1140	380
4	63	800	9.9	8.0	1700	425
5	61	865	11.3	8.4	2050	410
Bakersfield						
1	80	200	3.1	2.6	170	
2	77	550	5.3	6.8	780	390
3	75	825	7.4	9.9	1560	520
4	73	965	9.9	11.3	2390	598
5	71	1040	11.3	11.8	2880	576
Tracy-Newman						
1	69	185	3.1	2.0	140	
2	66	500	5.3	5.3	600	300
3	64	760	7.4	7.8	1230	410
4	62	860	9.9	8.6	1800	450
5	60	925	11.3	8.9	2160	432
		Dryfarmed - 28x24-inch spacing				
Salinas & So. California						
1	65	65	3.2	0.6	40	
2	63	300	6.0	2.5	320	160
3	62	520	8.8	4.2	810	270
4	61	640	11.1	5.1	1230	308
5	60	725	11.7	5.7	1440	288
Colusa						
1	55	60	3.9	0.5	40	
2	53	230	7.3	1.7	260	130
3	52	390	10.4	2.8	620	207
4	51	520	11.6	3.6	900	225
5	50	630	12.0	4.3	1120	224

1/ Based on records of the 1943 plantings.
2/ As percent of entire dry weight of shrub.
Source: Bullard, 1946 b

3/ Shipping weight at 25 percent moisture content.
4/ Assuming 70 percent rubber hydrocarbon content in the crude and 100 percent mill recovery.

plants were widely spaced they also grew taller. Losses in yield due to reduced stand density were compensated, to varying extents, by this change in plant size. Ultimately, the best yields might be expected on 30-inch or 36-inch spacings.

While ERP used rather close spacings in order to obtain high yields within a short time, somewhat wider spacings normally would be required. Cultivation was easier and cheaper on wider spacing. With close spacing the shrub formed a closed canopy that made cultivation and irrigation operations difficult. Also there was considerable loss of shrub material from limb breakage by the cultivating machines. Inner and lower branches were shaded out. Hence, the shrub at harvest contained a fraction of dead non-rubber-bearing wood.

Bullard also noted that there was enough compensation through greater growth of shrubs adjacent spaces left by dead plants, with at least 80 percent survival. The total tonnage of shrub and pounds of rubber per acre were equal to stands with 100 percent survival. Eighty percent or greater survival generally was achieved in the ERP California plantations.

Early in the ERP it was essential to make some production predictions. These figures later were used in the Poage Report (Poage, 1945).

TABLE III-6

ESTIMATED RANGE OF CRUDE-RUBBER CONTENT PER ACRE OF DIFFERENT AGES OF CULTIVATED SHRUB IN CALIFORNIA PLANTATIONS*

Field Age (years)	Irrigated Lands	Unirrigated Lands
1	140 - 240	49 - 70
2	550 - 900	280 - 450
3	1100 - 1700	600 - 1050
4	1700 - 2700	900 - 1600

*From U.S. House of Representatives Report No. 2098.

Hilgeman (1946) carried out extensive studies in Arizona and also reported on results from some of the indicator plots. In the introduction to his report, Hilgeman states that yields were lower than might be expected because of poor seedling establishment.

Most of his work was centered around the effects of irrigating (time and amount) and fertilizing. Except on sandy soils near Yuma, the latter did not increase rubber production in any case and, in some instances, it lowered rubber production. Hilgeman observed that "guayule is lavish with the use of water when it is available but is extremely drought resistant when water is not available."

Hilgeman tried both direct seeding and establishment by transplants. He had fair success with direct seeding but found irrigation tricky during germination. Weed control was a problem; but, good yield was obtained with close spacing, especially with 48-inch rows without thinning. For both direct seeding and transplanting disease losses were high following irrigations during warm weather (air and soil temperature above 65°F). Best results, in regards to disease and yields, were obtained spring and fall irrigation where the moisture capacity of the soil was sufficient to prevent extreme summer drought.

Because of incomplete information on age, spacing and survival rates, it is difficult to derive yield figures from Hilgeman's experiments; but, it can be inferred that yields, based on three-to-four-year old plants, of 300 to 400 pounds per acre per year were produced under wide spacing (28 by 20 inches), and 500 pounds per acre were produced under the closest direct seeding spacing.

The better one-acre indicator plots which had been planted properly and received good care (weed control and optimum irrigation), showed somewhat better results. The Litchfield plot, corrected for 100 percent survival, had a three-year yield of 1,400 pounds with a 25-by-12 inch spacing. The Marana plot, with standard 28-by-20 inch spacing yielded 1,391 pounds in three years. Picacho and Queen Creek produced an average of 1,500 pounds. The Date Garden at Indio, California, produced 1400 pounds.

In the Mesilla Valley, New Mexico, the experimental work during World War II was curtailed before any definitive results were obtained. However, experimental direct seeding plantings near Anthony, New Mexico, produced 300 to 400 pounds of rubber per acre per year under irrigation (Davis, 1945).

Wartime studies in Texas were more extensive and continued over a longer time span (1943 to 1946). Rainfall farming studies in the vicinity of Pearsall showed some direct seeding potential; but, often produced eratic results because of weather vicissitudes. Production from transplants was more consistent with generally high survival rates, but production was lower than that obtained on unirrigated areas in California after three years under a 28-by-20-inch spacing, the average rubber percentage was about eight percent. The average rubber production was 500 pounds from three tons of shrub.

2. Estimated future yield: In arriving at expected yield estimates, several conditions need to be considered as follows.

1. The Intercontinental Rubber Company never faced the problem of producing rubber within a short cycle. Most of their yield estimates were based on relatively long time growth (seven to ten years) under rainfall farming.

2. The Intercontinental Rubber Company did not obtain acceptable yields at Continental, Arizona, under irrigation. This may be due in large part to lack of knowledge as to how rubber accumulation may be obtained in warm climates under irrigation. Successful rubber production has since been obtained at Marana, Arizona, and in the vicinity of Phoenix and Gila Bend, Arizona.

3. World War II production activities were curtailed before the planned full four-year growth was made. Most of the shrub was harvested at an age of two or three years.

4. At the initiation of the World War II production effort, there was practically no information on shrub growth and rubber accumulation control by irrigation. Irrigation practices were based on judgment and were modified as experience was gained. As a result, the harvested shrub had not been exposed to the most efficient irrigation practices throughout its life cycle. Hence, it did not produce maximum amounts of rubber.

5. At the beginning of World War II production the age-space relationship was not recognized. As a result, optimum shrub growth and rubber accumulation were not achieved.

6. The 146 small indicator plots scattered from northern California to southern Texas gave erratic results because of poor establishment, improper or inadequate care and immature harvest at two or three years. A few plots provided reliable indications of guayule rubber production.

7. Experimental studies in Texas were subject to changes in program development and most were ploughed up before maximum yields could be obtained.

8. On the basis of information available there are four regions with distinct production

potentials: a) California rainfall production areas—coastal valleys, Riverside and northern Sacramento Valley; b) warm irrigated areas including warmer and drier parts of California, Arizona, New Mexico and the northern Rio Grande Valley in Texas; c) Texas rainfall farming areas; and d) the southern tip of Texas.

Based on a review of the information available, the following yield estimates are considered to be realistic predictions of production that can be obtained under modern cultural practices, using the best guayule varieties available.

TABLE II-7

EXPECTED SHRUB AND RUBBER PRODUCTION USING GUAYULE VARIETIES AVAILABLE IN 1979

Region	Age at Harvest	Spacing	Rubber (percent)	Short Tons shrub per acre	Pounds rubber per acre per year
California Rainfall	5	28" x 24"	12	6	288
Warm Irrigated Valleys	4	28" x 20"	10	10	500
Texas Dryland	5	28" x 24"	8	6	192
Southern Texas		Probably same as for warm irrigated valleys if growth can be controlled.			

Table II-7 is based on actual production under field conditions. As several varieties of guayule now in seed production have potentially 20 percent rubber without further genetic changes, it is possible that production could be increased for all these regions with improved cultural practices, biochemical regulation or both.

Based on rubber production at 20 percent rubber content level the above estimates would become as follows (Table II-8).

TABLE II-8

ESTIMATED RUBBER PRODUCTION BASED ON
FULFILLMENT OF 20 PERCENT POTENTIAL

Region	Age of Harvest	Spacing	Rubber (percent)	Short Tons Shrub per acre	Pounds Rubber per acre per year
California Rainfall	5	28" x 24"	20	6	480
Warm Irrigated Valleys	4	28" x 20"	20	10	1,000
Texas Dryland	5	28" x 20"	20	6	480
Southern Texas	4	28" x 20"	20	10	1,000

The utlimate potential of guayule production involves possible increases in percentage of rubber or tonnage of shrub. These would largely be the result of intra- and interspecific changes resulting from plant breeding. The limits for each of these is unknown, but a conservative estimate might include a 50 percent increase in either one or both. On the basis of these increases the following yields can be postualted (Table II-9).

TABLE II-9

POTENTIAL RUBBER PRODUCTION BASED ON
A 50 PERCENT INCREASE IN RUBBER PERCENTAGE AND/OR
A 50 PERCENT INCREASE IN SHRUB PRODUCTION

Region	50% Tonnage Increase		Rubber Percent Increase		Combination
	Shrub (tons)	Pounds Rubber per acre per year	Rubber percent	Pounds Rubber per acre per year	Pounds Rubber
California Rainfall	9	720	30	720	1,080
Warm Valleys	15	1,500	30	1,500	2,250
Texas Drylands	9	720	30	720	1,080
Southern Texas	15	1,500	30	1,500	2,250

Tingey (1952) and Kelly et al (1946) have shown more than 500 pounds of rubber per year can be produced in two to three years by close spacing. Selected production results show that similar results can be expected by harvesting four-year-old irrigated shrub grown under wide spacing. Without irrigation, rubber production has lower potential. Several strains undergoing breeding tests have shown rubber percentages up to 20 percent. Yokyama (1977) has been able to increase rubber percentage 2.2- to 6-fold under experimental conditions. Artschwager (1945) has shown that a storage area for a higher rubber percentage is within anatomical expectations. Finally, the biomass capabilities, as determined for other plants, are far above the tonnage yield that has been achieved for guayule.

It is also possible that under irrigation with a spacing allowing for more than 11,000 plants per acre, harvesting after three years would prove to be more economical than at four years. In this case the yield per acre per year could be as much as 25 percent greater than shown in tables II-7, II-8 and II-9.

If direct seeding becomes successful plants may be spaced closer within and between the rows. Under such conditions the plants might be harvested in one or two years (Tingey, 1952, Kelley et al, 1946). However, it is not expected that the yields on a yearly basis would vary much from those outlined below.

Finally, clipping or pollarding plants once or several times before digging may prove advantageous as it would lengthen the cycle between planting and digging, thus spreading the cost of planting and digging over a longer period.

III. PROSPECTS OF GUAYULE COMMERCIALIZATION

Commercial production of guayule in the United States depends not only on the technical and agronomic aspects of production, but also on the interactions between economic, environmental, social and political factors which can encompass regional, national and international concerns. These factors, which could promote or constrain the development of guayule, receive an in-depth analysis in this section of the report.

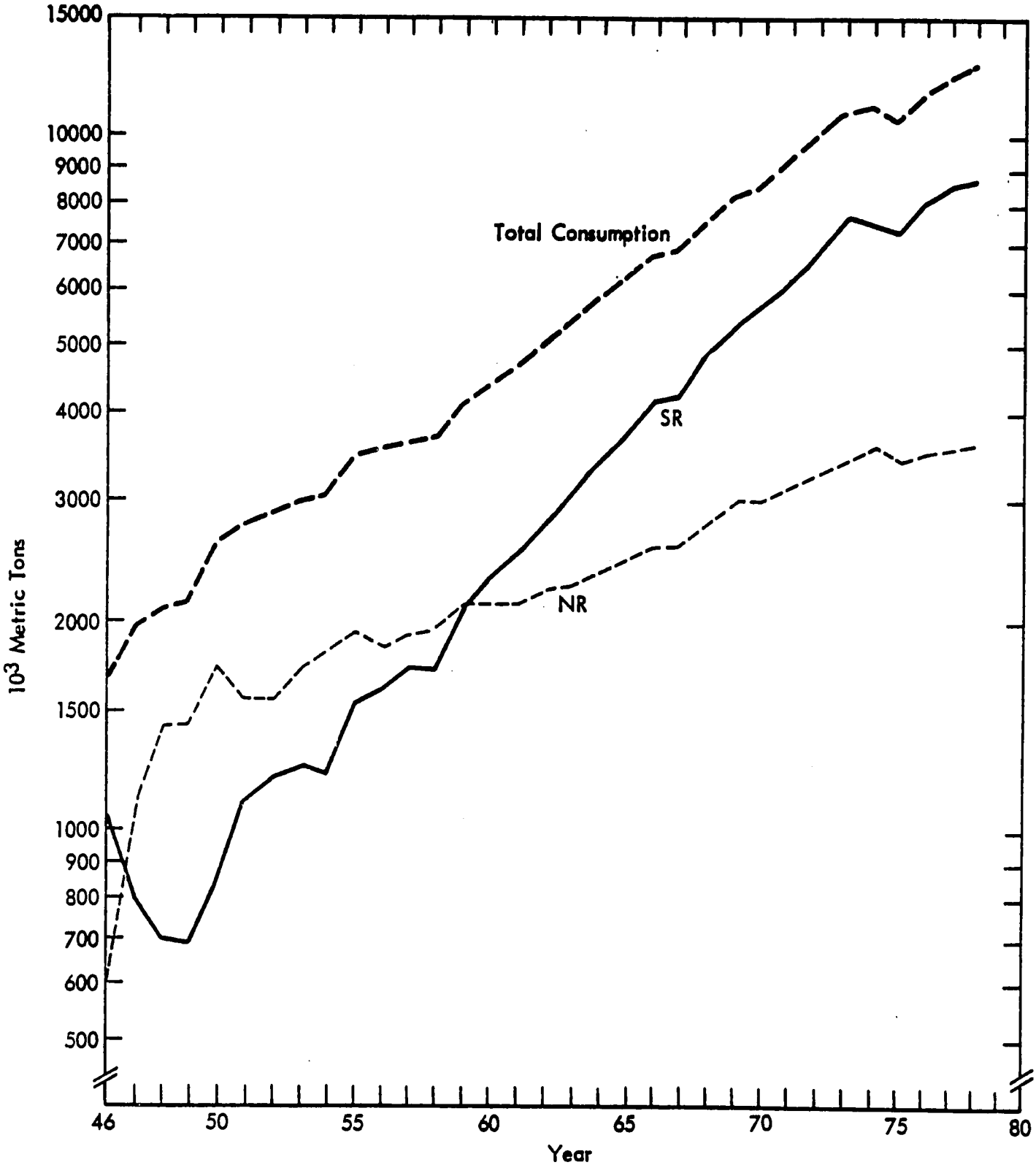
A. National and International Economic Concerns

The success or failure of guayule rubber commercialization in the United States hinges, in part, on the future demand for natural rubber. With this in mind, the following discussion addresses past and predicted trends in elastomer consumption.

1. World consumption of elastomers: Prior to the 1940s, Hevea natural rubber was the only elastomer of worldwide commercial importance. During World War II, necessity forced the development of synthetic rubber to the point where synthetic rubber consumption exceeded natural rubber consumption. Following World War II, natural rubber regained dominance of the world market but synthetic rubber technology had become established and successfully met increasing demands. Economics of scale, relatively inexpensive petroleum feedstocks, and agressive research and development allowed synthetic elastomers to command a progressively larger fraction of the world rubber market. From approximately 1945, the inability of natural rubber production to keep pace with the growing world demand for rubber encouraged the use of synthetic rubbers for many industrial and consumer products which had traditionally been composed of natural rubber; the most notable example was vehicle tires.

Natural rubber use increased on a worldwide basis at an annual average of 3.3 percent between 1948 and 1973, while synthetic rubber use increased at an annual average rate of 9.3 percent (Grilli, et al, 1978). As a result of this disproportionate expansion rate, synthetic rubber had claimed more than 50 percent of the total world elastomer market by 1960, and by 1973, it supplied close to 69 percent of the total world demand for elastomers (Grilli, et al, 1978; Rubber Statistical Bulletin, 1979).

Figure III-1 illustrates the growth in world elastomer consumption between 1946 and 1978. During that period, there was a significant increase in consumption; approximately 1.7 million metric tons were consumed in 1946 and 12.1 million metric tons in 1978. The growth of synthetic consumption during this period was substantially greater than that of natural rubber. Synthetic rubber consumption increased from approximately 1.1 million metric tons to 8.5 million metric tons in 1978; natural rubber consumption increased from approximately



Source: Adapted from Grilli et. al. (1978) and Rubber Statistical Bulletin (1979).

Figure III-1. World elastomer consumption, 1946-1978.

600,000 metric tons in 1946 to 3.6 million metric tons in 1978 (Grilli et al, 1978; Rubber Statistical Bulletin, 1979).

Figure III-2 provides a close look at more recent world elastomer consumption trends. The figure traces the percentage growth or decline per annum in both natural rubber and synthetic rubber consumption between January 1968 and December 1977. In order to better portray these statistics for the individual countries and geographic areas which combine to form this world aggregate, Table III-1 has also been included. These seven countries plus the Eastern European Communist Bloc accounted for approximately 70 percent to 75 percent of the total world elastomer consumption during the period noted.

The four countries showing the greatest percentage growth in natural rubber consumption are Brazil, India, the People's Republic of China, and the United States. The United Kingdom provides an illustration of the rubber consumption decline that is possible following a slowdown in economic growth in a mature Western economy. The decline in natural rubber consumption by the Communist Bloc countries of eastern Europe demonstrates the success of their move toward greater use of internally produced synthetic cis-polyisoprene.

Since the early 1970s, two events have altered the elastomer consumption growth trends that were established in the 1950s and 1960s. First, the Organization of Petroleum Exporting Countries (OPEC) oil embargo caused crude oil prices to quadruple between 1973 and 1975*. This resulted in a corresponding rise in the price of butadiene, styrene and polyisoprene, the primary feedstocks for synthetic rubber manufacturing. Similarly, the cost of petroleum derived energy required for processing and transportation also increased well beyond the existing rate of inflation. Stated quantitatively, production costs for synthetic rubber rose 70 percent to 100 percent as a direct result of the Arab oil embargo. This estimate does <u>not</u> include increases due to labor and other non-petroleum related overhead. By contrast, natural rubber had a corresponding direct production cost increase of approximately 10 percent (Grilli, et al, 1978).

Second, radial tires, which require approximately twice as much natural rubber and one-third less synthetic rubber as do bias ply tires, have been capturing an increasing share of the world demand for tires (Anon. 1979a). Since tire production and other automotive products account for 65 percent of world elastomer consumption, continued or increased popularity of radial tires is a significant factor in the demand for natural rubber (Grilli, et al, 1978).

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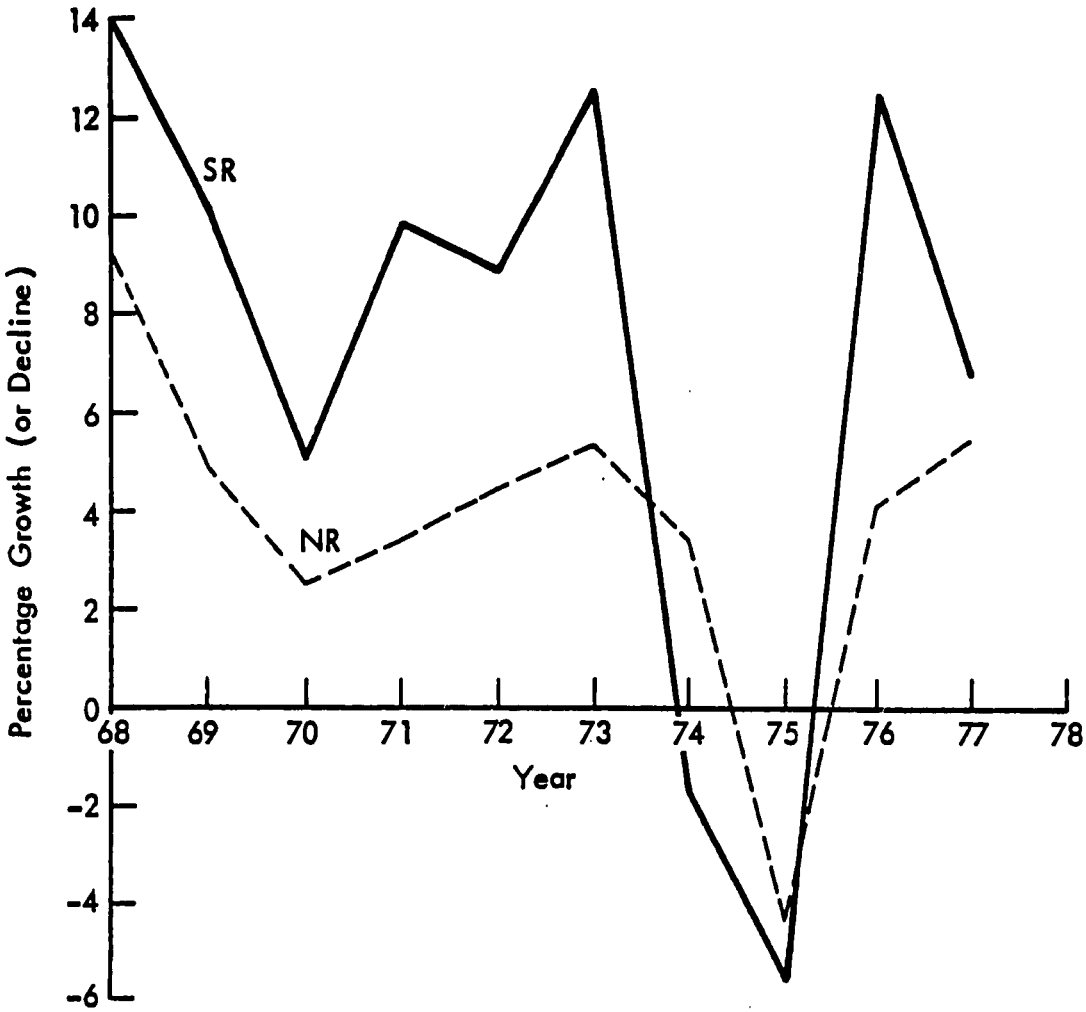
*Between 1973 and 1975, crude oil prices increased from an average of $3.75 to $12.0/bbl in Western Europe, $3.30 to $11.90/bbl in Japan, and $4.10 to $10.40/bbl in the U.S. (Grilli, et al, 1978).



Source: Rubber Statistical Bulletin (1979)

Figure III-2. World elastomer consumption, percentage growth per annum, 1968-1977.

TABLE III-1

TRENDS IN WORLD ELASTOMER CONSUMPTION

Country	NR			SR		
	1967 10^3 Mg	1977 10^3 Mg	% Change	1967 10^3 Mg	1977 10^3 Mg	% Change
United Kingdom	187	172	-8	216	321	49
Eastern Europe (Communist Bloc)	445	435	-2	865	2,250	160
Japan	243	320	32	273	690	153
Federal Republic of Germany	141	194	38	201	440	119
United States	497	803	62	1,654	2,481	50
People's Republic of China	172	280	63	38	70	84
India	73	143	96	25	35	40
Brazil	32	71	122	57	205	260

Source: Rubber Statistical Bulletin (1979)

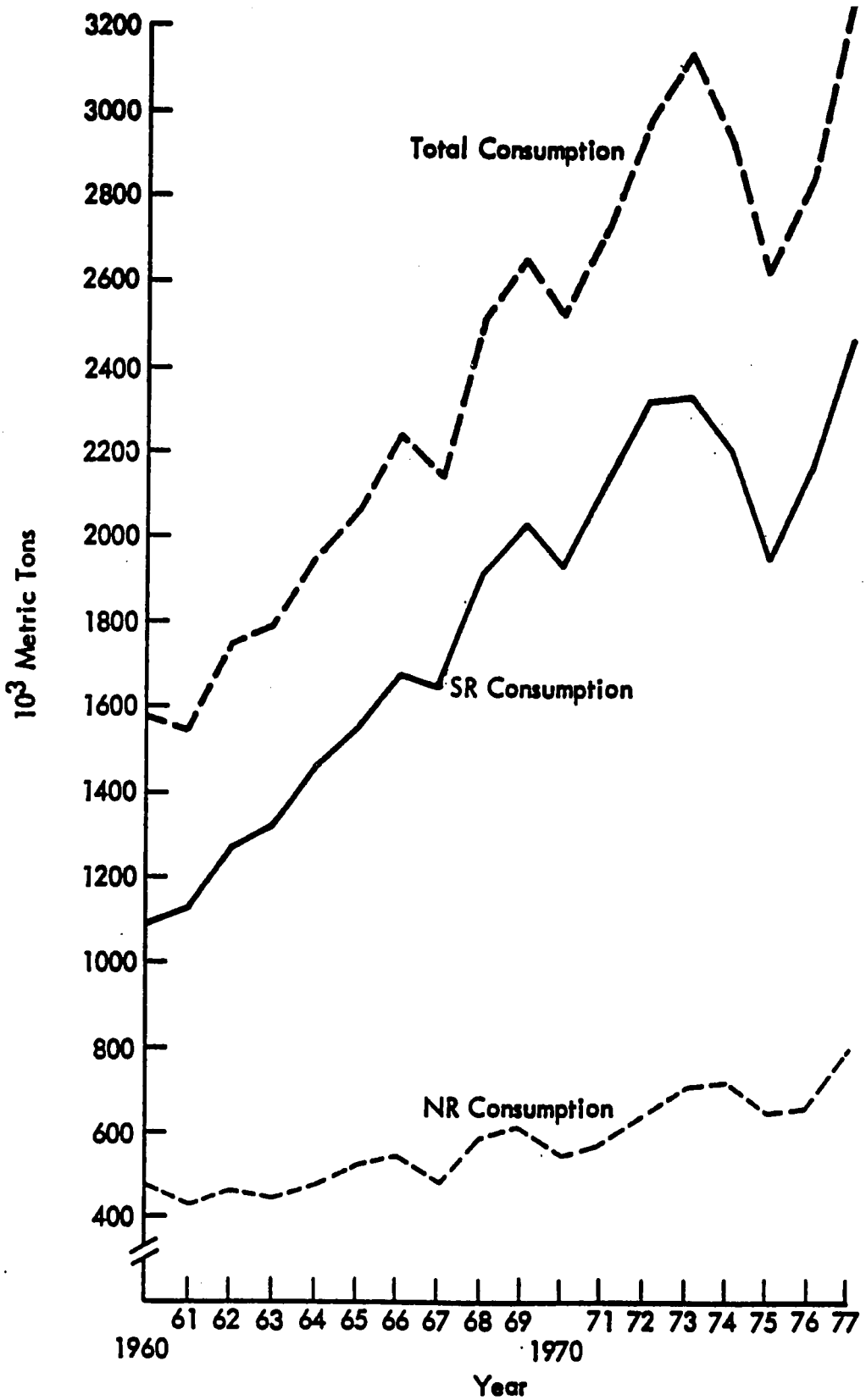
The outlook for natural rubber was not seriously affected by the world recession in industrialized countries during 1975. Though world elastomer demand did shrink due to this economic downturn, the average price of natural rubber was more competitive than either synthetic cis-polyisoprene or styrene butadiene rubber. Consequently, natural rubber's share of the total market continued to increase, while synthetic rubber producers bore a disproportionately larger share of losses caused by the recession (Grilli et al, 1978).

Between 1975 and 1978, there was renewed growth in the demand for and consumption of natural rubber. Synthetic rubber showed excellent recovery in 1976, but the market since then appears to have stabilized at a per annum growth rate very close to that of natural rubber (Rubber Statistical Bulletin, 1979).

2. U.S. consumption of elastomers: The history of the competition between natural rubber and synthetic rubber in the United States has been similar to that in the world marketplace. During the last 30 years, synthetic rubber has taken a commanding lead in providing elastomeric materials for industrial and individual consumers. Figure III-3 and Table III-2 illustrate the dominance of synthetic rubber in the U.S. market over the past 18 years. Since 1960 natural rubber use has not reached 30 percent of the total elastomer demand, and the actual levels have shown a tendency to remain at or below 25 percent. Table III-3 indicates elastomer consumption for natural rubber and synthetic rubber in 1970. It is apparent from this table that the tire market consumes the major portion of elastomers in the United States just as it does worldwide.

Since World War II, the United States has relied on synthetic rubber as much as possible. Dependence on a predictable petroleum supply, instead of Southeast Asian rubber, was a reasonable approach to satisfying elastomer demand in the postwar era. Manufacturers had just experienced a total cutoff from Southeast Asian rubber during the War, and they were continuing to experience shortages of natural rubber because demand was outstripping supply. For these reasons, synthetic rubber production grew steadily and was supplying more than 50 percent of the United States' demand for elastomers by the early 1950s (Grilli et al, 1978).

As shown in Figure III-3 and Table III-2, elastomer consumption, particularly synthetic rubber, increased rapidly



Sources: Rubber Statistical Bulletin (1979) and Current Industrial Reports (1952-1975).

Figure III-3. U.S. elastomer consumption, 1960-1977.

TABLE III-2

U.S. ELASTOMER CONSUMPTION, 1960-1977

Year	Total Elastomer Consumption 10^3 Mg	NR Consumption 10^3 Mg	% NR	SR Consumption 10^3 Mg	% SR
1960	1,583.2	486.7	30.7	1,096.5	69.3
1961	1,553.9	434.1	27.9	1,119.8	72.1
1962	1,746.2	470.2	26.6	1,276.0	73.4
1963	1,792.2	464.5	25.9	1,327.7	74.1
1964	1,963.9	489.2	24.9	1,474.7	75.1
1965	2,087.6	522.9	25.0	1,564.7	75.0
1966	2,247.2	554.4	24.7	1,692.8	75.3
1967	2,151.0	496.6	23.1	1,654.4	76.9
1968	2,517.7	591.2	23.5	1,926.5	76.5
1969	2,664.4	607.9	22.8	2,056.5	77.2
1970	2,516.8	568.2	22.6	1,948.6	77.4
1971	2,725.6	587.0	21.5	2,138.6	78.5
1972	2,983.6	650.8	21.8	2,332.8	78.2
1973	3,152.0	711.9	22.6	2,440.1	77.4
1974	2,948.3	738.3	25.0	2,210.0	75.0
1975	2,629.5	665.9	25.3	1,963.6	74.7
1976	2,858.8	686.7	24.0	2,172.1	76.0
1977	3,284.4	803.5	24.5	2,480.9	75.5

Source: Rubber Statistical Bulletin (1979) and Current Industrial Reports (1952-1975).

TABLE III-3

ELASTOMER CONSUMPTION BY MAJOR END-USES IN THE UNITED STATES DURING 1970

	Consumption by End-use (%)	NR (%)	SR (%)	Tonnage Consumed (10^3 Mg)
Tire Uses				
Passenger Car	21.8	14.5	85.5	855.2
Truck/Bus	39.1	50.0	50.0	444.0
Tractor/Industrial	5.3	30.0	70.0	100.0
Aircraft	1.4	90.0	10.0	8.9
Retreading	2.3	10.0	90.0	130.0
Inner Tubes	0.03	5.0	95.0	40.0
Other	0.02	5.0	95.5	20.0
Total	70.4	24.9	75.1	1,598.1
Non-tire Uses				
Latex Products	11.8	33.0	67.0	203.0
Belting and Hose	2.1	15.0	85.0	80.0
Footwear	3.9	25.0	75.0	88.0
Wire and Cable	0.01	3.0	97.0	3.3
Other	11.6	13.0	87.0	507.7
Total	29.6	19.0	81.0	882.0
Total Consumption	100.0	22.6	77.4	2,480.1 a/

Source: Reference Grilli, et al (1978)

a/ There is a difference of approximately 1% between this U.S. total consumption figure and that given in Table 2 due to the different sources.

in the United States during the 1960s. However, as illustrated in Figure III-4, the percent per annum growth statistics for natural rubber and synthetic rubber from 1968 on indicate that natural rubber has made a more substantial progress in recent years. Between 1968 and 1978 the average percent per annum consumption growth rates for natural rubber and synthetic rubber were 5.3 percent and 5.6 percent respectively, compared to a more typical 2.9 percent and 8.0 percent, respectively for the 1961 to 1968 interim. From 1973 to 1977, the average natural rubber and synthetic rubber percent per annum growth statistics, 4.7 percent and 1.8 percent, respectively, show increasing growth in natural rubber consumption and reflect the impacts of the Arab oil embargo and the resulting elevation of feedstock prices, the rapidly increasing popularity of radial tires, and the recession in the developed nations of the world in 1975 (Rubber Statistical Bulletin, 1979; Current Industrial Reports 1952-1975).

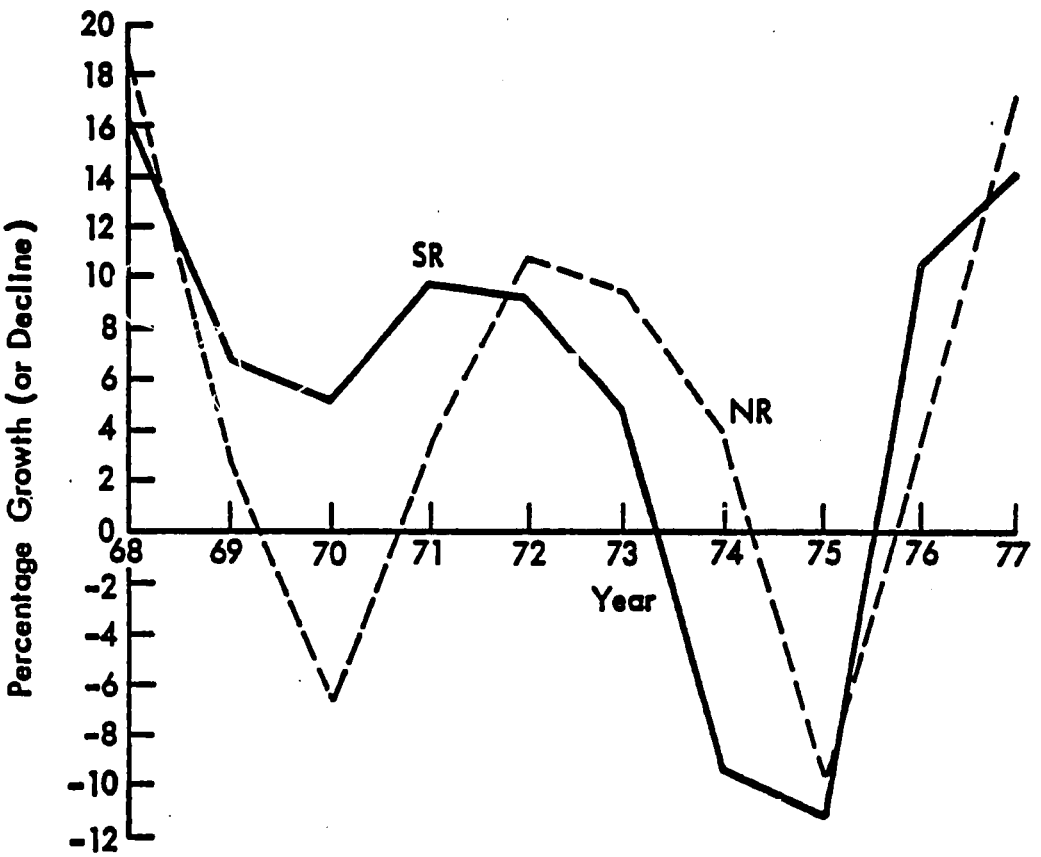
After 3.28 million metric tons total consumption in 1977, elastomer consumption dropped slightly in 1978 to approximately 3.24 million metric tons (Rubber Statistical Bulletin, 1979; Anon. 1979b). It is difficult to predict consumption for 1979 because of possible strikes within the rubber and automobile industries. The latter possibility is significant because 28 percent of the tires manufactured in this country are purchased for the automobile original equipment market in Detroit (Anderson, 1979).

3. Projected world elastomer consumption through 2000: If demands for natural rubber continue to grow, it is possible that Hevea rubber production will not meet world natural rubber demands in the near future. Figure III-5 illustrates the possibility of a shortage in world natural rubber supplies in the next 20 years. Growth curves in Figure III-5 are postulated on the assumption that present growth trends will continue. The total elastomer consumption curve assumes a starting point of 14.5 million metric tons in 1980. This figure is at the lower end of the range of projections made public by international experts which range from 14.4 to 14.8 million metric tons (Rubber Statistical Bulletin, 1979; Ruebensaal, 1978; Agostini, 1977).

The curve assumes a per annum growth of 6.0 percent through the year 2000,* and represents a continuation of past trends. Rubber consumption increased at a fairly steady 6.3 percent per annum between 1948 and 1973, with a slight drop to 4.2 percent per annum from 1973 to 1977 (Grilli, et al, 1978; Rubber Statistical Bulletin, 1979).

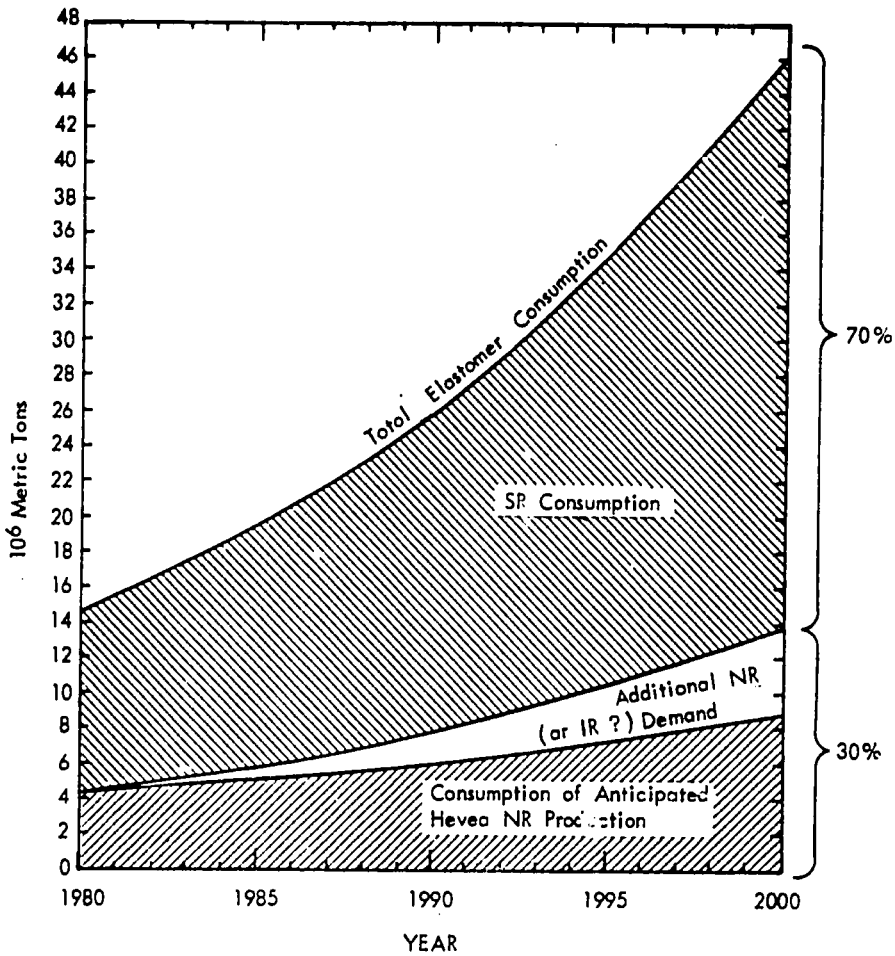
The upper limit for world natural rubber consumption in Figure III-5 is plotted at 30 percent of total rubber consumption.

*This approach yields statistics which closely resemble the consumption projections made by the Food and Agriculture Organization (FAO) through 1985 (Agostini, 1977).



Source: References Rubber Statistical Bulletin 1979 and Current Industrial Reports 1952-1975

Figure III-4. U.S. consumption of natural and synthetic rubber percentage growth per annum, 1968-1977.



a/ The total world elastomer consumption assumes a total consumption of 14.47 x 10^6 metric tons in 1980 and increases 6.0% per annum through the year 2000.

b/ The upper limit shown for NR consumption is 30% of the total elastomer consumption. If this percentage were lowered to 25%, a short fall would still appear between 1985 and 1990--and grow to 2.8 million metric tons by the year 2000.

c/ The upper limit shown for consumption of anticipated hevea NR produc- is obtained by plotting FAO estimates of hevea rubber production through 1990 (3.2 to 3.7% per annum growth) and then assuming a 4.0% per annum growth in production between 1990 and 2000 (Agostini, 1977).

d/ The gap in between the consumption of hevea and SR represents a possible shortfall in the future supply of isoprenic rubber--a gap which could be filled by expansion of hevea production, expansion of IR production (synthetic polyisoprene), commercialization of guayule, or some combination of these three options.

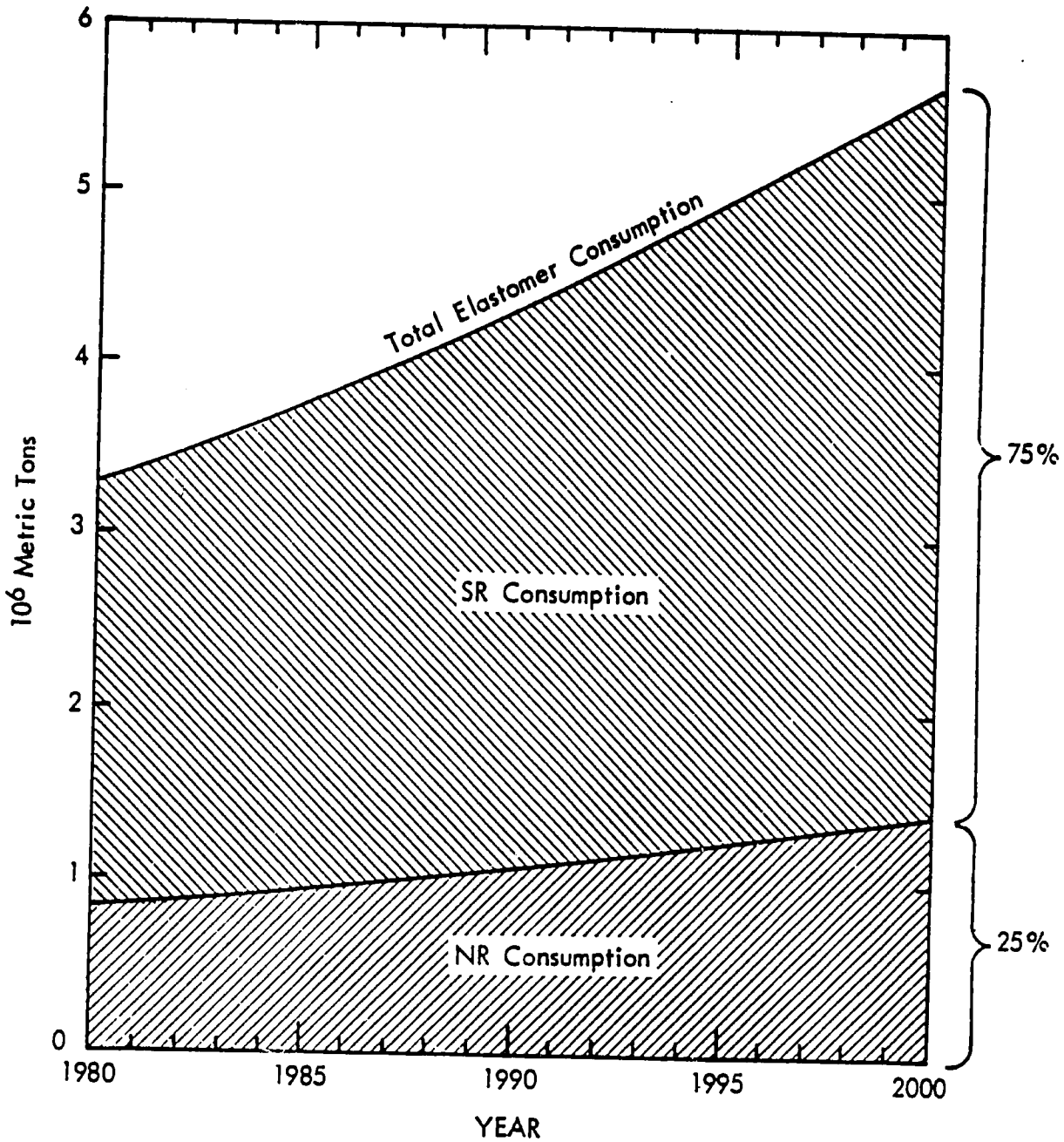
Figure III-5. Projected World Elastomer Consumption and the Potential Disparity Between NR Supply and Consumption if Current Trends Continue[a-d/].

Due to end-use demands which continue to require natural rubber, world consumption of natural rubber could remain close to 30 percent ± 5 percent through the year 2000. However, division of the demand for "isoprenic rubber" between Hevea, synthetic polyisoprene, guayule, or some new technology is difficult to forecast. If the natural rubber share of total elastomer consumption falls to 25 percent or below, the decline will probably be due to a shortage of natural rubber and a stopgap substitution of more expensive or lower quality synthetic polyisoprene will be necessary (Allen, et al, 1975; Agostini, 1977; Riedl, 1977). The 30 percent figure represents an approximation of potential natural rubber consumption if production is able to supply the world market with tonnage required to maintain that level.

The upper limit for anticipated Hevea rubber production was obtained by plotting the FAO projections for Hevea production through 1990 and then assuming a growth of 4 percent per annum to the year 2000 (Agostini, 1977). A 4 percent per annum growth rate represents a return to the average growth rate of the 1960s, which is slightly higher than the 3.2 percent to 3.7 percent growth rates now occurring and anticipated through 1990 (Rubber Statistical Bulletin, 1979; Agostini, 1977).

4. Projected U.S. elastomer consumption through 2000: Projecting the future of elastomer consumption in the United States is complicated by international petroleum pricing and the energy crises, the extent to which the U.S. public responds to the need for conservation of natural resources, and the U.S. economy itself. However, an extrapolation of U.S. elastomer consumption to the year 2000, based on current-trends-continue assumptions, is presented in Figure III-6.

Several factors were taken into account in determining the starting point and the per annum growth rate for projected growth in U.S. elastomer consumption between 1980 and 2000. An examination of data for the 20 years preceding and including 1977 showed that the average per annum increase in total elastomer consumption was 4.4 percent (Rubber Statistical Bulletin, 1979; Current Industrial Reports, 1952-1975). Continuing this trend to 1980, an annual consumption of approximately 3.50 million metric tons can be forecast. However, a recent publication by the International Institute of Synthetic Rubber Producers, Inc. (IISRP) indicates that member companies see a definite slowdown of new rubber consumption in the United States (Anon 1979b). Pointing to a 1.3 percent decline in consumption in 1978 (total U.S. consumption 3.24 million metric tons), and anticipating an additional 3 percent decline in 1979 (total U.S. consumption 3.14 million metric tons), the IISRP suggests that consumption of new rubber in the United States is leveling off. The IISRP ten-year industry forecast through 1989 indicates an annual 2.3 percent gain in total consumption of new rubber, an increase of 1.9 percent per annum in the tire sector and 3.1 percent in the non-tire sector.



Sources: Grilli, et al (1978); Rubber Statistical Bulletin (1979); Current Industrial Reports (1952-1975); and Anonymous (1979a).

Figure III-6. Projected U.S. elastomer consumption, 1980 through 2000.

According to the World Bank, the per annum growth of elastomer consumption in the developed countries will average 4 percent between 1976 and 1990 (Grilli et al, 1978). This projection is based, in turn, on projections of motor vehicle park* and automobile production during the 1980s. Because these statistics show North America to be in a slower than average position relative to the other developed areas of the world, a percent per annum growth in elastomer consumption of something less than 4 percent is indicated for the United States.

The IISRP elastomer consumption growth rate estimate of 2.3 percent per annum and the World Bank estimate of 4 percent per annum through 1990 both suggest a significant decline from the average growth rate of the past twenty years of approximately 4.4 percent per annum. A compromise of the IISRP and World Bank figures provides the basis for Figure III-6; a total U.S. elastomer consumption growth rate of 2.8 percent per annum was assumed for 1980 to 2000, and the 1980 consumption level is estimated to be 7.3 billion pounds.

Natural rubber consumption has slowly fallen since the late 1940s. This decline may have lost its momentum in the wake of the recent petroleum related problems which have hampered synthetic rubber producers. During the ten-year period from 1958 to 1967, the average natural rubber percentage of the annual tonnage consumed was 27.9 percent. From 1968 to 1977, this fell to 23.3 percent but it appeared to rise steadily after hitting a low of 21.6 percent in 1971 (Rubber Statistical Bulletin, 1970; Current Industrial Reports, 1952-1975). Based on these observations total consumption rates through the year 2000 are expected to average 25 percent for natural rubber and 75 percent for synthetic rubber.

B. Incentives for Guayule Production

Incentives for guayule commercialization in the United States are related to national security and hinge upon political events in Southeast Asia which may affect the availability of Hevea rubber. These incentives are vulnerable to political events in

*Motor vehicle park refers to the number of existing vehicles and is sub-divided into two categories, private automobiles and commercial vehicles.

the Middle East that could affect the availability and the price of crude oil. This section discusses national security concerns and the effect of recent events in Cambodia, Vietnam and Iran, and concludes with a short discussion of natural rubber as a strategic material in the United States.

1. Natural rubber supply and crisis in Southeast Asia: The recent invasion of Cambodia by Vietnam and the subsequent invasion of Vietnam by the People's Republic of China threaten the supply of Hevea rubber to the United States from Southeast Asia. Political uncertainties and changes in the balance of power in this part of the world are powerful driving forces causing the United States to seek other sources of natural rubber, such as guayule, to guarantee access to this strategic and economically important resource and thereby preserve national security.

Two weeks after invading Cambodia in mid-December 1978, Vietnam occupied more than 25 percent of Cambodia. By mid-January the Cambodian government had collapsed. In February, the People's Republic of China attacked Vietnam and in early March 1979 announced a withdrawal of all troops. These events placed all of Southeast Asia in a highly visible and critical position in international politics. Thailand, although not directly involved in the Vietnamese situation of 1978-1979, cautioned the United States that the stability of all of Southeast Asia was threatened. The international superpowers focused on the area; Vietnam needed Russian backing to avert collapse, China had been outmaneuvered by Russian diplomatic successes, and Thailand, which had recently received $11 million of ammunition and a promise of $50 million of arms per year from the United States, felt threatened by the political atmosphere. The entire region was economically shaken, and natural rubber production had been seriously interrupted.

Beyond issues of political influence and the balance of powers are concerns over natural resources in Southeast Asia. This part of the world contains the principal deposits of tin ores, and supplies approximately 94 percent of all Hevea rubber. These two commodities are strategic materials for all technologically advanced countries and of extreme importance to developing countries.

At present the Hevea rubber supply from Southeast Asia is threatened, but not yet affected. The rubber plantations in Cambodia, although intact, are becoming overgrown with vegetation. However, at full production, these plantations supplied less than 2 percent of the world's natural rubber needs. Plantations in Thailand are supplying approximately 12 percent of the world's natural rubber needs. To ensure continued availability of natural rubber, it seems advisable to develop a domestic source of natural rubber to make up for potential shortfall in natural rubber im-

ports from Southeast Asia.

2. Crude oil supply and the crisis in the Middle East: At present, the world consumes 57 million barrels of oil a day, 31 million barrels of which come from the Middle East. Three percent to 5 percent of total U.S. consumption of approximately 19 million barrels per day comes from Iran. Since the 1973-1974 Organization of Petroleum Exporting Countries (OPEC) embargo, it has been clear that this oil supply is politically vulnerable. Since the recent crisis in Iran, prices have risen higher than had been anticipated and the Iranian supply has been cut drastically, causing a worldwide shortage of up to two million barrels per day.

Serious trouble erupted in Iran only recently, but for years many events had been building toward the present situation; by the Arab-Israeli wars; the turnover of governments in Ethiopia, Lebanon, Pakistan, Afghanistan; scattered fighting between regions; and the broad social impact of the flow of billions of dollars in oil revenues into non-industrial societies.

The Shah of Iran had pressed for modernization of his country at a rapid pace. Opposition to the Shah's tactics grew as did repression of his opponents until political demonstrations began in January 1978. Even before that, however, there had been resurgence of Islamic fundamentalism occuring in the Moslem world which the Shah had ignored. He had taken away the mullahs' (local Moslem leaders) annual subsidies and this act and other differences brought the force of Moslem leaders out against the Shah.

In early November 1978 Iran's 30,000 oil-field workers went on strike. Iran's normal oil production had been six million barrels per day, almost five million of which were exported. The strike sent production below two million barrels per day.

Widespread rioting and anti-Shah demonstrations occurred, and the Iranian government was badly shaken. The world became more aware that the Shah's control of the militarily strong and pro-Western Iran had been a key to oil availability and moderate prices in the West. Another key was the moderate pro-Western position of Saudi Arabia, which would be affected by any major change in Iran. Together the two countries produced almost one-quarter of the world oil supply and had considerable moderating influence on the other members of Organization of Petroleum Exporting Countries (OPEC).

In mid-November, the Shah set up a military government to try to restore order and force oil workers back to work. Production went up briefly, only to drop again in early December when renewed strikes and rioting occurred. By mid-December foreigners were leaving, among them many oil technicians, and oil production fell below Iranian domestic needs by the beginning of the new year.

In early January 1979, the Shah appointed Shahpour Bakhtiar to form a civilian government. By this time, Ayatullah Khomeini, the exiled leader of the Shiite Moslems was showing his strong influence. From Paris he demanded the overthrow of the Shah's government and the establishment of an Islamic republic.

Late in January 1979, the Shah left Iran, which was in economic collapse and near civil war. Khomeini returned to Iran and made plans to set up an Islamic government. The Bakhtiar government and the army struggled against growing Khomeini influence and mobs, but was forced out of power and Khomeini's provisional government, under Mehdi Bazargan, took over.

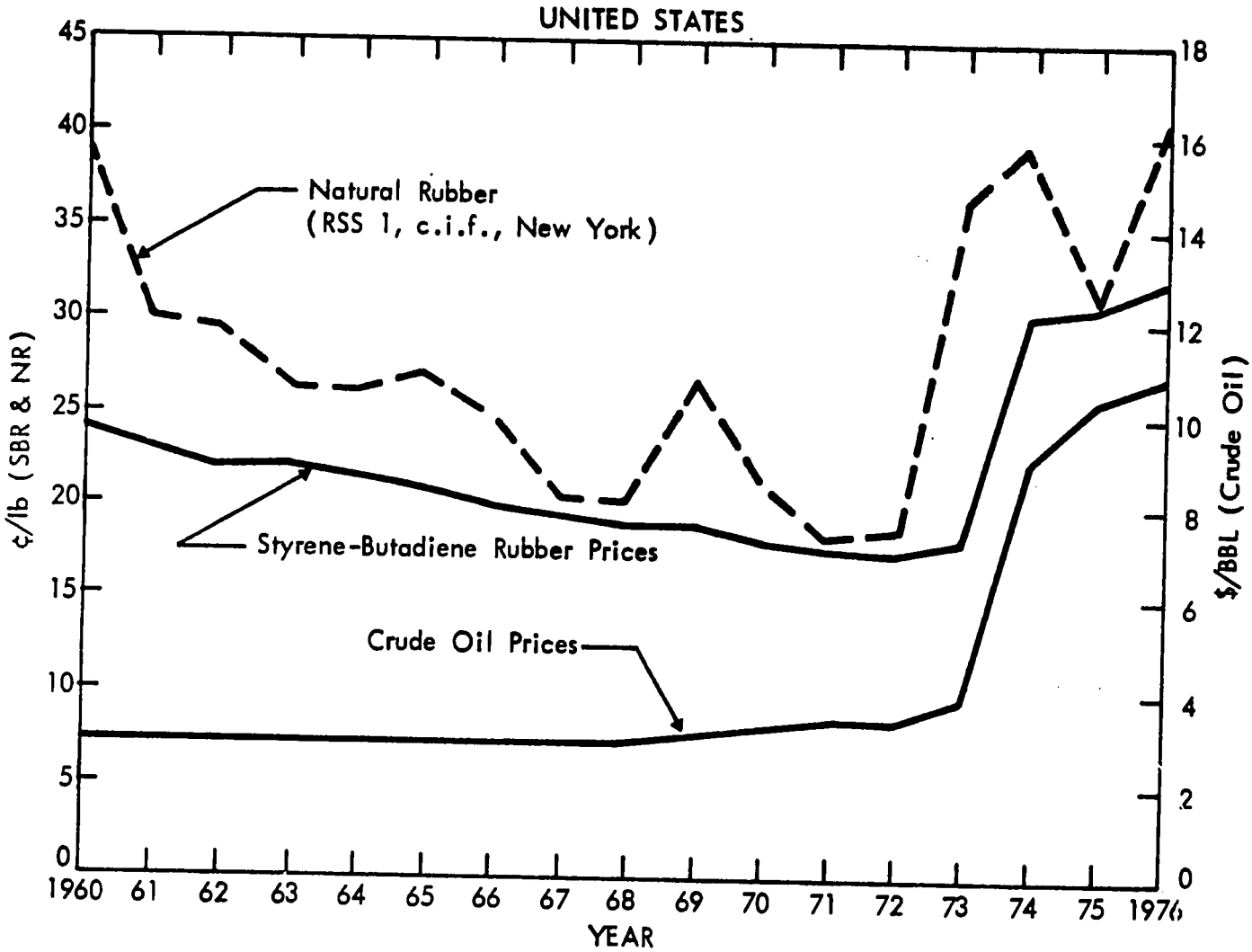
By early March 1979, the Khomeini/Bazargan government had restored some order, the economy was improving, shops were reopening and oil production was again above domestic needs and was being exported.

It is too early to predict with any kind of certainty the future of Iranian oil exports. If a new government becomes well established, the world oil supply will be affected. Iran probably cannot return immediately to precrisis production of six million barrels per day because this production level depended on Western technicians who have since fled the country. Recent Iranian government predictions indicate Iran will be exporting three to four million barrels per day. U.S. predictions for Iranian export levels estimate a range of two to three million barrels per day. Assuming three million barrels per day is a realistic figure and depending on countries who increase their production during this shortage to keep up production levels, the supply should cover present demand. Without Iran's return to this level of production, however, the present U.S. shortfall of 500,000 barrels per day will continue.

A successful Islamic government can affect the economic and political balance of the Middle East. Some Iranians feel their oil is for use by Moslems and that selectivity should be employed when exploiting it for outsiders. Iranian oil supplies have been shut off to Israel and South Africa for political and religious reasons. It is possible this sentiment could spread, especially to Saudi Arabia, a strong Moslem country and a major oil exporter.

It is possible that oil prices will rise faster than the OPEC-predicted rise to $14.54 per barrel by the end of 1979, perhaps reaching $20.00 per barrel. Many factors could cause supply to fall below demand. Continuing price increases seem inevitable as does the possibility of shortages resulting from the unavailability of affordable oil from the Middle East.

Figure III-7 shows the dramatic effect the 1972-1973 oil embargo and sharply rising prices had on synthetic rubber prices; oil prices doubled, rubber prices doubled. It would appear that the



Adapted from World Bank (1977).

Figure III-7. U.S. price history for imported crude oil, styrene-butadiene rubber, and natural rubber.

rising oil prices and the potential shortfall in supply will cause general price increases and/or shortages in all primary petrochemicals and petrochemical products including synthetic rubber, rubber products and rubber processing chemicals. These price increases and/or shortages can be met by finding other sources of oil besides the Middle East, by importing and using more natural Hevea rubber, or by commercialization of domestic guayule rubber. The first two options have inherent difficulties and the uncertainty of the oil supply caused by change and instability in the Middle East point to the need for a reliable, domestic rubber source, such as guayule.

3. Regional sector: A number of regional factors have the potential to stimulate guayule commercialization. This section assesses the incentives to commercialize guayule to make good use of arid lands; the declining or restricted supply of agricultural water in much of the potential guayule growth region; the existing patterns of agricultural production and the stimulus of crop diversification; the economic opportunities that might be afforded U.S. Southwest communities; and the role federal price-support and land-use programs might play in promoting guayule.

a. Arid land usage: Future growth and cultivation of guayule would require the use of three categories of land: land in agricultural production; retired agricultural land; or undisturbed land not in production. Irrigation will be required for each land-use category in southern California, Arizona, New Mexico and west Texas. Only in portions of California and south Texas could rainfall conceivably sustain guayule production without irrigation. In those areas requiring irrigation, a dependable supply of water is the limiting factor in guayule production, not land availability.

Agricultural production with irrigation in the Southwest traditionally has been accomplished on the best land to maximize yields. Only in cycles of high crop return have farmers increased acreage. Land not considered prime agricultural generally lies fallow if commodity price increases do not merit its use.

In guayule's native habitat, annual rainfall can be less than 9 inches, but ERP researchers concluded that 11 to 25 inches annually is needed for commercial rubber production. The guayule plant can survive arid conditions, but if annual rainfall is less than 14 inches supplemental irrigation is needed to give a worthwhile rubber yield in a reasonable time.

The highest rubber yields recorded for cultivated guayule have been obtained with irrigation. Irrigation allows the farmer to control the moisture that the plants receive; it can force growth and shorten the production cycle.

Without sufficient water to sustain prime land agriculture, little hope is given for acreage expansion to accommodate guayule on new or "marginal" lands. Marginal lands are herein defined to be deficient in adequate water for traditional crops or having poor soil characteristics for plant growth. Instead guayule may be best integrated into the Southwest agricultural economy as a water-saving crop. In this manner existing prime land will become available as farmers search for crops requiring less water, hence requiring less energy to pump it. Those lands previously farmed, but now having marginal water supplies for existing crops, also may be prime guayule growth areas. Thus, no new land would have to be brought into

production and prime land that has been leveled for irrigation could be used.

b. Agricultural water use and conservation: As an arid-land adapted crop, guayule could be grown with less water than many of the agricultural crops being farmed in the U.S. Southwest. Figure III-8 compares water consumption of guayule with six other crops grown at El Paso, Texas.

Guayule can become a water-conserving crop in those irrigated agriculture areas where dwindling water supplies are impacting on the agricultural and economic potential of more conventional crops. A dwindling irrigation water supply typifies agricultural development in much of Arizona, New Mexico and western Texas.

This section presents data on agricultural water use by county for those portions of the five states within the projected potential guayule growth region.

In general irrigation in Arizona, New Mexico and western Texas can be expected to decline. Irrigated acreage in the Arizona potential guayule growth region is expected to decline from 1.2 million acres in 1970 to 0.7 million acres in 2020. New Mexico has only 200,000 acres of irrigated agriculture in the potential guayule growth region which is expected to decline to 140,000 acres by 2020. The El Paso-Trans Pecos region in western Texas had approximately 250,000 irrigated acres in 1974. If Texas Water Development Board projections of increasing irrigation efficiency to 87 percent were realized, irrigated acreage might remain relatively stable in this region. These efficiencies, although theoretically possible, appear high when compared with assumptions made by other state water resource agencies. If present water efficiencies are maintained, the El Paso-Trans Pecos region probably would experience an irrigated agriculture decline to less than 150,000 acres by 2020.

The south Texas area within the potential guayule growth region had nearly 1.25 million irrigated acres in 1974. Some areas, such as the Winter Garden Irrigation District, are experiencing declining groundwater due to overdraft. This situation, plus a reported 1.5 million acres of "potentially irrigable soils" (Texas Water Development Board, 1977) in an area where rainfall ranges from 20 inches to 34 inches, suggests a good possibility for dryland guayule development.

California's guayule growth region is unique because California has within its boundaries areas of water abundance, and can approach its water supply situation from the perspective of redistributing excess water to areas where water is less available. Irrigated acreage in one California guayule potential region amounted to

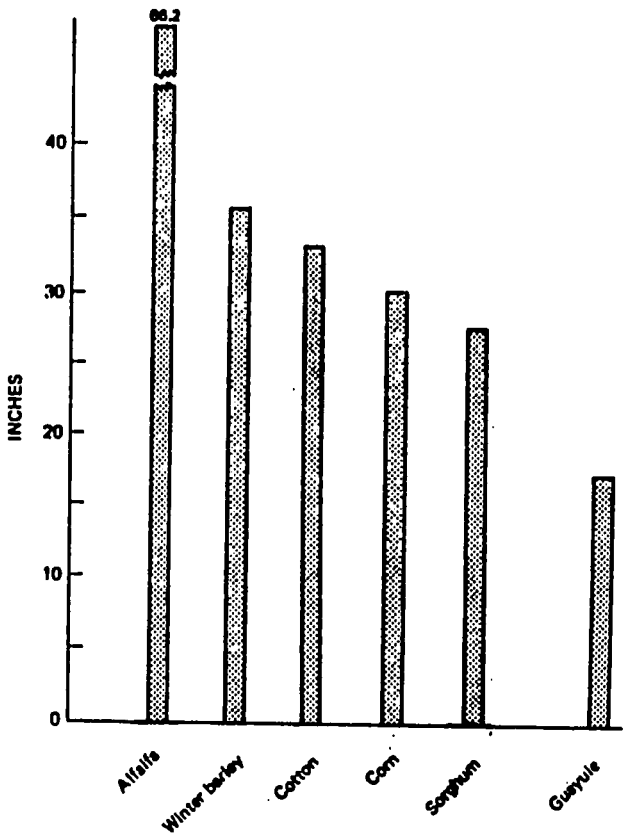


Figure III-8. Estimated consumption of water by guayule compared with selected irrigated crops grown at El Paso, Texas.

Source: National Academy of Sciences, 1977.

8.08 million acres in 1967 and is projected to increase to 9.2 million acres by 2020. An additional 1.3 million acres in the Colorado Desert and South Lahontan hydrographic units have Colorado River water rights. The bulk of the 1.5 million irrigated acres of the Sacramento Valley receive sufficient rainfall for dryland guayule production. The remaining agricultural area would require at least partial irrigation for successful guayule production.

Clark County, the only county in Nevada considered to have potential for guayule production, has 11,000 irrigated agricultural acres. This acreage is projected to remain fairly stable through 2020.

c. Agricultural water use in Texas: Seventy-five percent of annual fresh water use in Texas is by the food and fiber production sector, and 13 million acre-feet of water used to produce agricultural products is groundwater. The average water use in irrigated agriculture is 1.49 acre-feet per acre (Texas Water Development Board, 1977).

i. Texas water law: Groundwater in Texas is the absolute property of the overlying landowner, and may be withdrawn without regard for injury to neighbors. Although this exclusive ownership is restricted to percolating groundwater, and does not apply to underground streams, Texas courts historically have severely restricted definition of underground water courses. A second limitation on the absolute ownership rule is that the landowner cannot waste water, although again definition of "waste" has been severely restricted.

In 1949, the Texas Legislature authorized creation of Underground Water Conservation Districts (UWCD) to "provide for the conservation, preservation, protection, recharging, and prevention of waste of underground water...."[1] However, local control is exercised in creation and operation of UWCDs, and every county affected has the right to vote itself into or out of UWCD jurisdiction. Few UWCDs are anticipated, and those that are created can be expected to have little impact on the Texas groundwater situation.

Diffused surface water is the property of the landowner without regard to anticipated use by adjacent landowners at lower elevations, or anticipated use from receiving water courses. Impoundments of these waters, however, can be used only for domestic or livestock use unless applied for and permitted under Section 5.141, Texas Water Code.

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[1]Texas Water Code Ann. Section 52.021.

Surface water contained in lakes, streams or rivers is the property of the State, and is subject to both riparian and appropriative use rights. In many instances, these claims for surface water rights are in conflict, and in some areas, amount to more than supply. The Texas Water Rights Commission is involved in adjudication of thousands of surface water claims throughout the State, particularly in the more arid portions of western Texas. Allocations of surface waters will evolve as a result of this adjudication process (Templer, 1976).

ii. Texas guayule potential: Potential guayule production in Texas is limited to two general areas: the Trans-Pecos-Upper Rio Grande area (Figure III-9); and the south Texas area including the Lower Rio Grande, the Nueces River Basin, the San Antonio River Basin, a small portion of the Guadalupe River Basin and coastal basin areas of these same rivers (Figure III-10). Areas farther east have limited potential due to precipitation levels exceeding guayule tolerances. The Edwards Plateau area, which is between the two areas considered suitable, is extremely limited in soils that would be appropriate for guayule production (U.S. Forest Service, 1945). The Texas High Plains, to the north, are unsuitable to present strains of guayule due to excessive cold.

Rainfall in west Texas (Figure III-11) ranges from 8 inches to 18 inches per year. The bulk of agricultural cropland in this region, however, receives 12 inches of precipitation or less. Thus, growing guayule in this area necessarily would be by irrigated agriculture.

Rainfall in the south Texas area varies from 18 inches per year along the Rio Grande to 34 inches at the eastern edge of the region. Much of the central portion of this area have 20 inches to 28 inches of annual precipitation. This suggests the possibility of introducing dryland guayule production, particularly in basins where irrigation water is being depleted.

Inventories of irrigated acreages and agricultural water withdrawal are reported by county in Texas for the year 1974 (Texas Water Development Board, 1975) and are shown in Tables III-4 through 7. Figure III-12 shows the principal irrigation areas within the guayule growing region in Texas. The Texas Water Development Board (1977) further projects total water and irrigation water withdrawals for the years 2000 and 2020 by river basin resulting in aggregates of counties. These estimates for 2000 and 2020 are presented also in Tables III-4 through 7.

iii. El Paso-Trans-Pecos area: In 1974, nearly 250,000 acres were irrigated in the Upper Rio Grande area. More than 200,000 acre-feet of water were drawn from the Rio Grande for

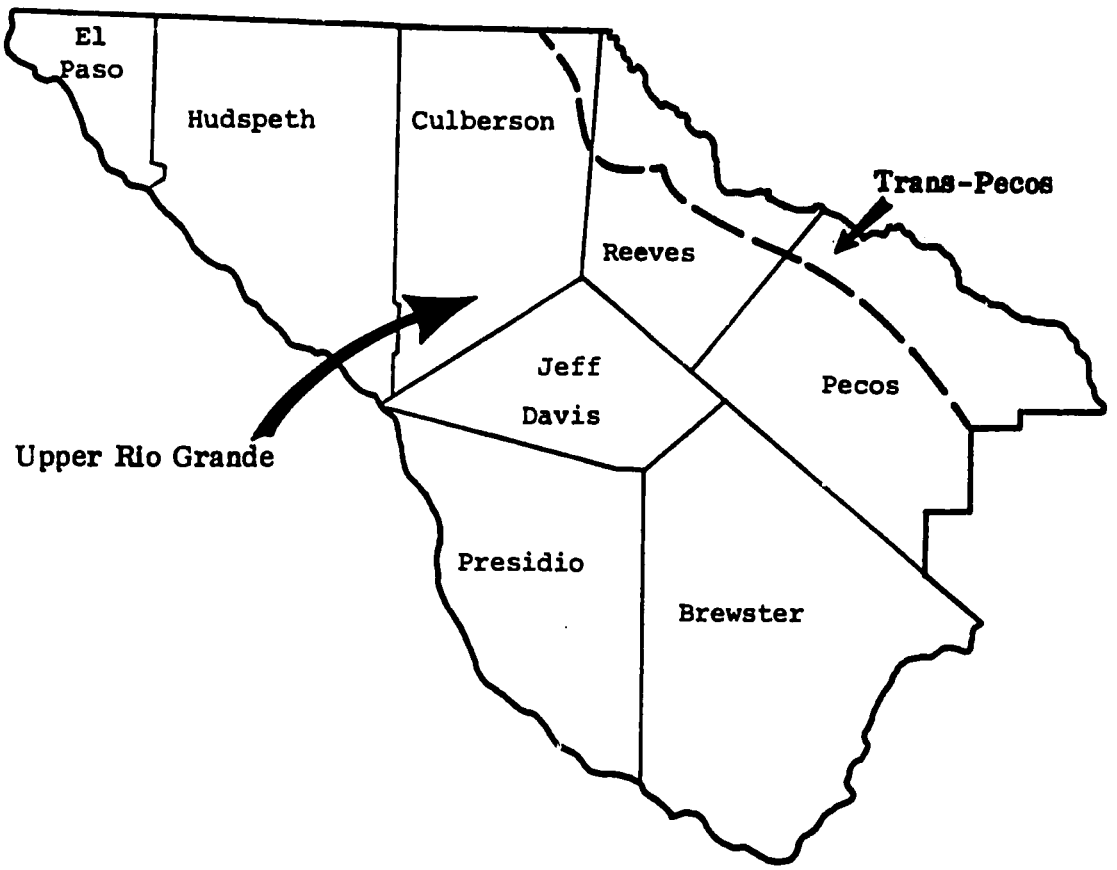


Figure III-9. River basin delineations in the guayule growth region west Texas.

Source: Texas Water Development Board, 1977.

Figure III-10. Basin delineations in the guayule growth region of south Texas.

Source: Texas Water Development Board, 1977.

Figure III-11. Mean annual precipitation isohyets, guayule potential growth area, Texas.

Source: U.S. Department of Commerce, Climatography of the United States No. 81 (Texas).

TABLE III-4

EL PASO VALLEY AND TRANS PECOS WATER WITHDRAWALS AND IRRIGATED ACREAGE; 1974, 2000 AND 2020

	1974 1/				2000 2/				2020 2/			
	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage
EL PASO VALLEY Counties:	352,051	466,500	75	101,847	235,000	471,700	50	106,055 (high) 3/ 68,000 (low) 4/	234,000	594,500	39	115,083 (high) 68,000 (low)
El Paso	179,310			56,375								
Hudspeth	172,741			45,472								
TRANS-- PECOS Counties:	557,031	600,400	93	145,236	345,100	413,700	83	141,332 (high) 3/ 89,900 (low) 4/	291,600	374,300	78	130,514 (high) 76,000 (low)
Reeves	319,785			78,170								
Pecos	183,669			51,795								
Brewster	379			148								
Culberson	28,935			8,429								
Jeff Davis	792			320								
Presidio	23,471			6,374								
REGION TOTAL	909,082	1,066,900	85	247,083	580,100	885,400	66	245,962 (high) 3/ 157,700 (low) 4/	525,600	968,800	54	242,900 (high) 142,900 (low)

1. T.W.D.B., 1975
2. T.W.D.B., 1977
3. High projection based on T.W.D.B. predictions of increasing irrigation efficiencies
4. Low projection based on constant acrefeet/acre agricultural withdrawal rate.

TABLE III-5

MIDDLE RIO GRANDE AREA WATER WITHDRAWALS AND IRRIGATED ACREAGE; 1974, 2000 AND 2020

	1974				2000				2020			
	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage
MIDDLE RIO GRANDE	146,607	182,500	80	85,003	153,300	220,000	70	138,658 (high) 3/ 88,900 (low)	152,000	241,000	63	149,820 (high) 88,100 (low)
Counties:												
Maverick	100,230			42,729								
Starr	26,155			25,576								
Webb	14,934			12,564								
Zapata	4,588			4,134								

TABLE III-6

WINTER GARDEN: NUECES, SAN ANTONIO AND GUADALUPE BASIN WATER WITHDRAWALS AND IRRIGATED ACREAGE; 1974, 2000 AND 2020

	1974				2000				2020			
	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage
NUECES BASIN	479,065	512,900	93	300,598	299,400	406,500	74	250,000 (high) 187,864 (low)	200,300	335,900	60	183,300 (high) 128,682 (low)
Counties:												
Kinney	14,317			8,550								
Uvalde	70,312			40,412								
Medina	69,667			34,450								
Zavala	146,315			81,382								
Frio	72,794			81,484								
Atascosa	57,096			34,735								
Dimmit	33,522			23,576								
La Salle	12,885			12,296								
McMullen	0			0								
Live Oak	2,157			3,713								
SAN ANTONIO BASIN	50,977	252,200	20	49,607	48,300	505,000	10	63,000 (high) 47,000 (low)	46,200	636,500	7	63,000 (high) 45,000 (low)
Counties:												
Bexar	27,652			26,462								
Goliad	955			2,031								
Karnes	4,663			1,493								
Wilson	17,707			19,631								
GUADALUPE BASIN	3,712	10,300	36	4,855	4,900	14,700	33	8,400 (high) 6,400 (low)	5,600	18,900	26	8,900 (high) 6,500 (low)
Counties:												
Guadalupe	2,725			3,599								
De Witt	987			1,256								

TABLE III-7

LOWER RIO GRANDE AND COASTAL BEND WATER WITHDRAWALS AND IRRIGATED ACREAGE; 1974, 2000 AND 2020

	1974				2000				2020			
	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage	Agricultural Withdrawals (Acrefeet)	Total Withdrawals (Acrefeet)	% Agric.	Irrigated Acreage
LOWER RIO GRANDE BASIN	1,057,202	1,184,400	86	783,732	1,047,100	1,345,300	78	1,211,000 (high) 776,200 (low)	1,047,100	1,453,200	72	1,330,000 (high) 776,200 (low)
Counties:												
Duval	2,909				3,845							
Jim Wells	2,961				6,336							
Nueces	83				250							
Kleberg	586				1,080							
Jim Hogg	129				386							
Brooks	1,632				2,619							
Kenedy	192				400							
Hidalgo	602,050				443,650							
Willacy	53,096				37,723							
Cameron	392,245				287,445							
COASTAL BEND BASIN	7,897	25,100	18	15,209	3,100	47,900	6	9,700 (high) 6,100 (low)	3,200	70,500	5	10,900 (high) 6,100 (low)
COUNTY												
Bee	1,611			4,479								
Refugio	0			0								
San Patricio	5,966			10,730								
Aransas	0			0								

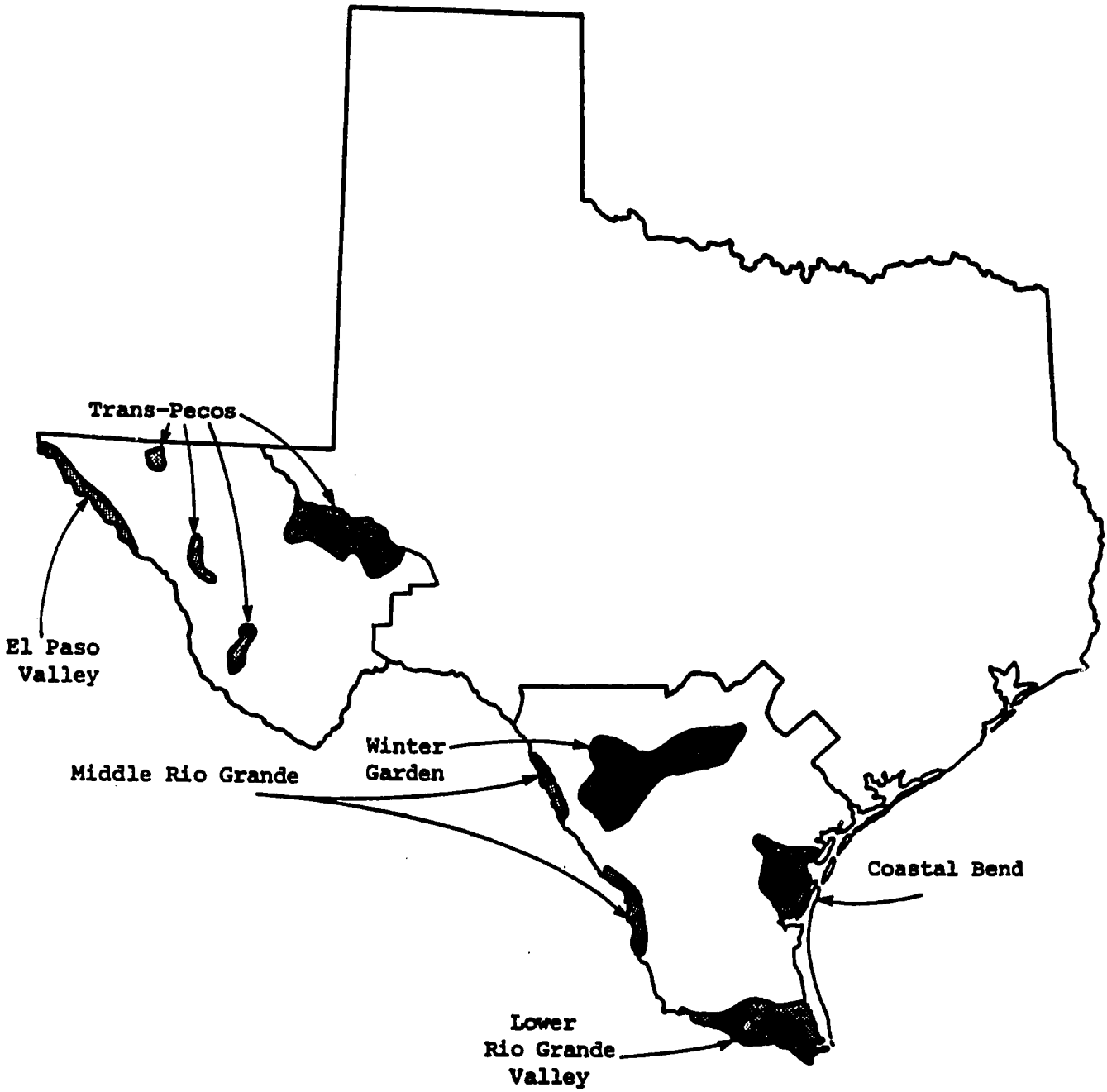


Figure III-12. Principal irrigation areas in the guayule growth region, Texas.

Source: Texas Water Development Board, 1977.

irrigation in the El Paso Valley in El Paso and Hudspeth counties. An additional 140,000 acre-feet of groundwater were pumped in these two counties for irrigation purposes. El Paso and Hudspeth counties contain 41 percent of the irrigated agricultural acreage in the upper Rio Grande area. In the Trans Pecos area, more than 90 percent of the 550,000 acre-feet per year of irrigation water is withdrawn from groundwater sources.

Irrigation water demands based on historical trends and available water supplies in El Paso and Hudspeth counties indicate that surface water use from the Rio Grande will remain fairly stable, at 210,000 acre-feet per year through 2020. Groundwater sources in these two counties are expected to decline from the 1974 level of 143,500 acre-feet per year to about 25,000 acre-feet per year in 2000 due to limited supply and high energy costs.

One-hundred thirty thousand acres were irrigated in Reeves and Pecos counties in 1974. The remaining four counties, Brewster, Culberson, Jeff Davis and Presidio, account for only 6 percent of irrigated agricultural acreage in the region, about 15,000 acres. Groundwater sources supply 95 percent of the water for irrigation in Reeves and Pecos counties.

Almost from the beginning of irrigation practices in the Trans Pecos area, excessively high mineralization has been a problem. Furthermore, groundwater is being pumped in excess of natural recharge in the area, and some saline water encroachment in the aquifer is occurring. Irrigation has declined dramatically from 1958 to 1974, and is expected to continue to do so. Groundwater withdrawal in Reeves and Pecos counties are expected to decline from the 1974 level of 493,000 acre-feet per year to 273,000 acre-feet in 2000. These declines result from aquifer depletion, excessive pumping lifts, and encroachment of poor quality water.

Estimated withdrawal rates from aquifers are expected to increase in El Paso and Hudspeth counties. These withdrawals, however, are expected to deplete total aquifer storage, and providing supplemental surface water supplies will be necessary if this area is to avoid severe economic decline (Texas Water Development Board, 1977).

Figure III-13 shows the irrigated acreage in the El Paso Valley and Trans-Pecos area from 1958 through 2020. The high and low acreage values are based upon predictions of future irrigation efficiency. The low value assumes that irrigation efficiency will not change from the 1974 value of 50 percent and the amount of water applied per acre will remain constant. This assumption accounts for a reduction in acreage as water supplies become depleted. The high value assumes that irrigation efficiency will increase to 85 percent

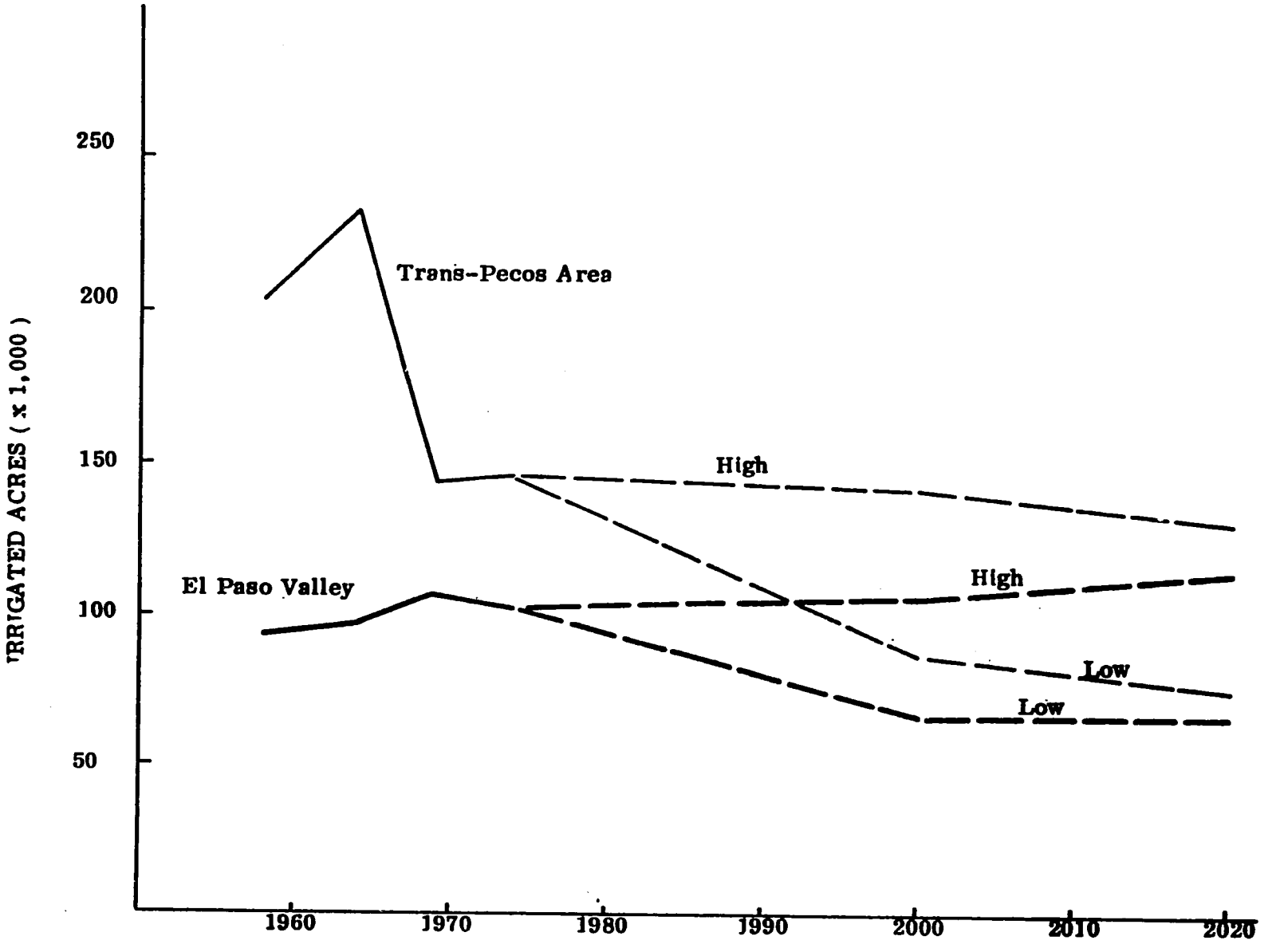


Figure III-13. Irrigated acreages in the west-Texas region.

(For explanation of high and low projections, see Table III-4)

by 2020. This assumption allows for the same amount, or more of acreage to be irrigated with a constant or slightly declining supply of water.

iv. Middle Rio Grande area: Approximately 85,000 acres were irrigated in the Middle Rio Grande area in 1974, most of which is on alluvial and terrace soils of the Rio Grande. Of the 147,000 acre-feet of irrigation water applied in the four-county area, surface water from the Rio Grande supplied all but 3,000 acre-feet. Adjudicated surface water rights provide a maximum of 200,000 acre-feet annually to irrigate 76,000 acres in this area. Surface water supplies are expected to remain relatively constant in this region, except during periods of low flow when some shortages should be expected. If irrigation water use efficiency increases, some growth in agricultural acreage could be anticipated. Figure III-14 shows the projected irrigated acreage through 2020. Increasing irrigation efficiency could increase significantly irrigated acreage. At a constant efficiency, both water supply and irrigated acreage are projected to remain stable.

v. Winter Garden area: The Inland South-Texas area embraces the bulk of the Nueces and San Antonio river basin agricultural acreage as well as a small portion of the Guadalupe River Basin. Irrigated agriculture used 355,000 acres in these three river basins in 1974, of which 322,000 acres were in the Winter Garden Irrigation District--an increase of 107,000 acres from 1958. The major source of irrigation water is groundwater, although surface water was used to irrigate 33,400 acres in 1974. Less than 5,000 acres were irrigated in DeWitt and Guadalupe counties in the Guadalupe River Basin.

Some acreages in the Winter Garden-San Antonio area are being withdrawn from production due to declining groundwater, deteriorating wells, and high labor and fuel costs. At the same time, new land is being brought into production and new wells are being drilled. Irrigation agriculture has been expanding since 1960. Ranchland and lands formerly diverted under government acreage control programs are being brought into cultivation. In a number of counties south and southwest of San Antonio, irrigation of speciality crops and irrigation on dairy farms is increasing.

The Winter Garden area is supplied groundwater by two major aquifers: the Cairizo and the Edwards Balcones Fault Zone. The Cairizo Aquifer has an average annual natural recharge of 100,000 acre-feet.

Excessive withdrawals of groundwater for irrigation have caused extreme "mining" of the Aquifer's artesian storage; especially in Zavala and Dimmit counties where water-level declined more than

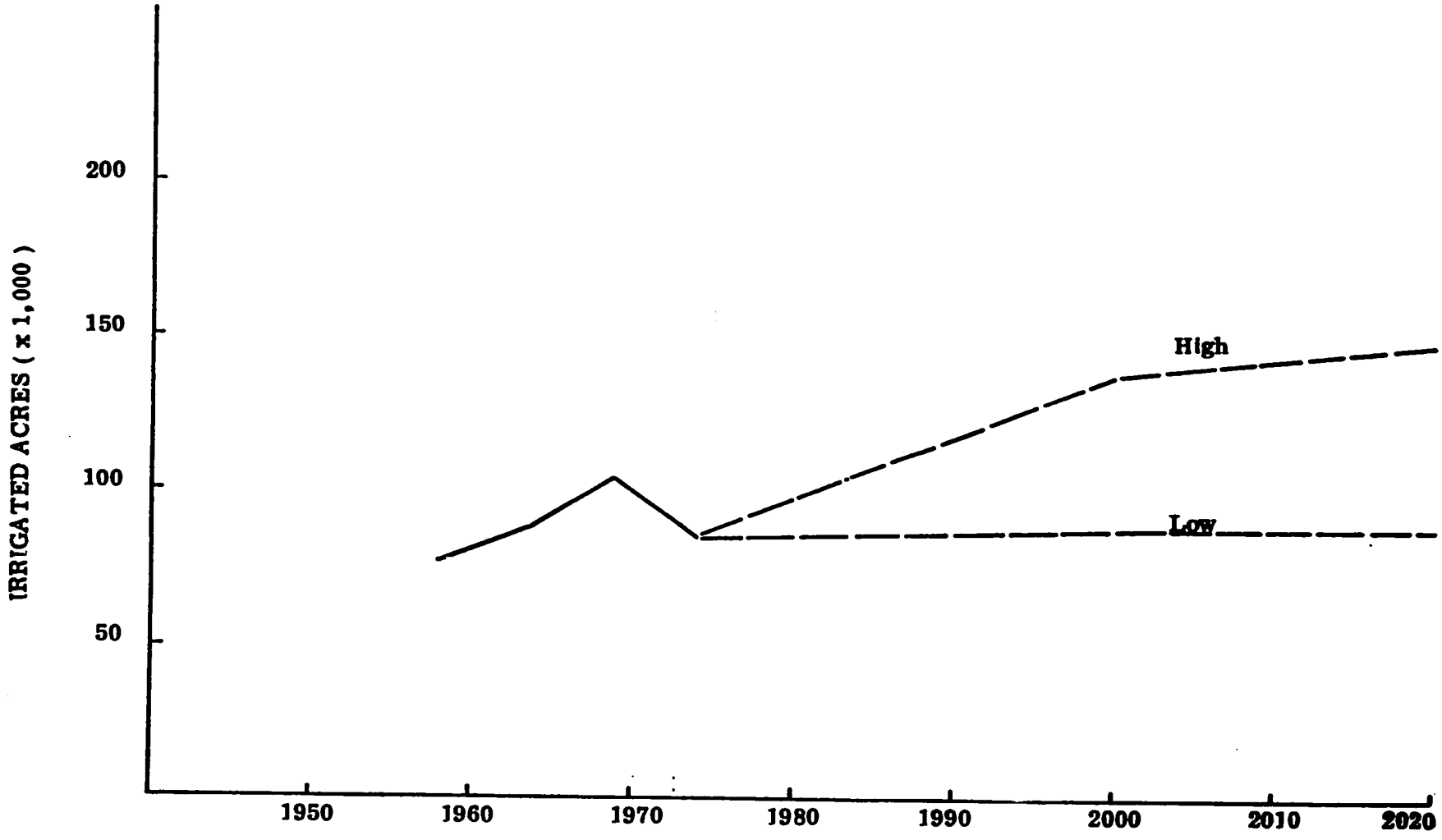


Figure III-14. Irrigated acreages in the middle Rio Grande valley.

400 feet from 1929-30 to the mid-1960s. During the 1960s, excessive pumping levels occurred in this area and caused some economic losses. Excessive pumpage also has and will probably cause reversals in the hydraulic gradient of the Aquifer, thus allowing encroachment of porrer quality water to areas previously having good quality water.

The Edwards (Balcones Fault Zone) Aquifer extends from central Kinney County east and northeast through Uvalde, Medina, Bexar, Kendall, Comal, Hays, Travis and Williamson counties, and into southern Bell County. It consists of the Edwards and associated limestones which are in hydraulic continuity.

The Edwards Aquifer supplies municipal and industrial water to most of the cities and towns in the area, including the total municipal and industrial water supply for the City of San Antonio. Capacities of wells operated by the City are among the largest in the world, some wells yielding more than 16,000 gallons per minute. Large irrigation supplies also are pumped from the Aquifer.

Total annual projected pumpage from the Edwards Aquifer to meet municipal, industrial, agricultural, and other demands is expected to be 636,000 acre-feet by 2000 and 906,400 acre-feet by 2020, if supplemental surface water supplies are not developed.

A supplemental surface water supply for the Edwards Aquifer region is needed to ensure an adequate water supply for agricultural, municipal, and other uses. The region's population and economy are much larger than in previous periods of water shortages, and both the population and the economy are continuing to grow, thus requiring more water (Texas Water Development Board, 1977).

The Winter Garden region contains nearly one million "irrigable" acres. Considering the 20 inches to 34 inches annual precipitation range of this area, developing dryland guayule farming here would seem plausible.

Figure III-15 shows the projected irrigated acreage for this region through 2020.

vi. Lower Rio Grand and Coastal Bend areas: The Lower Rio Grande Valley is a highly developed urban, industrial and agricultural region.

The irrigated areas, most of which are contiguous, constitute one of the largest single concentrations of irrigated land in the State. It is also the most intricately organized, densely settled, and intensively farmed area in Texas. It is one of three areas in the United States capable of producing citrus and certain vegetables.

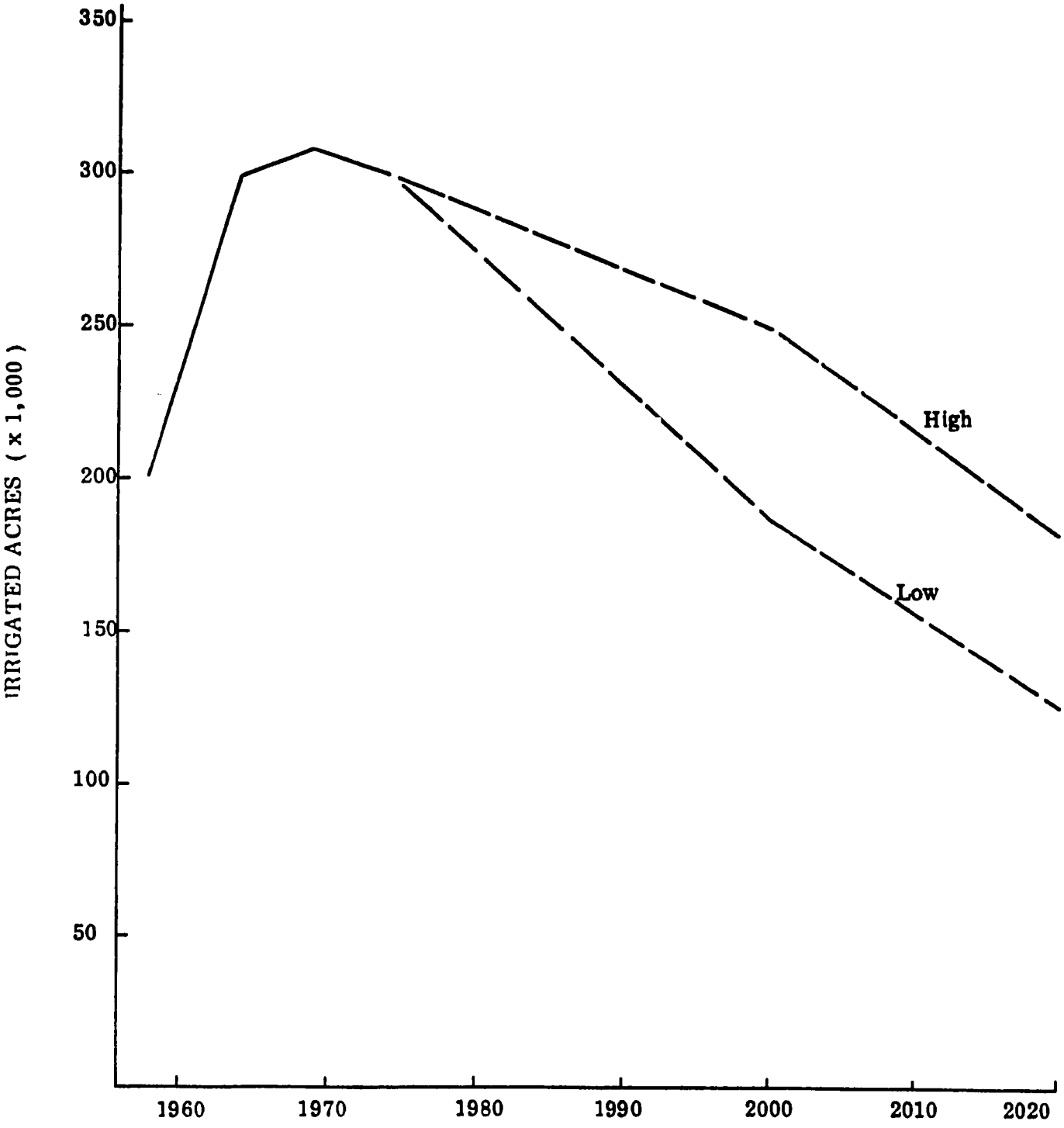


Figure III-15. Irrigated Acreages in the winter garden irrigation region.

Most water used for irrigation is obtained from International Falcon and Amistad reservoirs on the Rio Grande. In 1974, 986,000 acre-feet of surface water were used, which is 93 percent of the total water used for irrigation in the Valley. Groundwater accounted for less than 1 percent. Combined supplies (a mixture of groundwater and surface water) amounted to about 7 percent. Groundwater supplies suffered from saline water encroachment under 1974 conditions.

Studies made by the Texas Water Rights Commission in 1969 indicate that the available water supply would suffice for the 747,533 acres of adjudicated irrigation acreage only 35 percent of the time during the 1900-1956 period. These studies indicate that some shortage of irrigation water supply would occur 72 percent of the time during the 1900-1970 period. The average annual water shortage during this period would be about 464,000 acre-feet. Thus, it is clear that the area has a water shortage now and with continued urban and industrial growth the projected future shortages of this region are expected to become acute.

The Coastal Bend Region contains Nueces and San Patricio counties of coastal Texas and is in effect the southwestern extension of the Gulf Coast Prairie soils. The area uses irrigation only in the dry years to supplement rainfall. In 1974, with near normal rainfall adequate for crop production, 11,000 acres were irrigated. Greater acreages have been irrigated in former years during less-than-normal rainfall conditions.

Without importation of surface water into the area to supplement present supplies, irrigation water withdrawals would remain fairly constant in the Lower Rio Grande Valley, although subject to periodic drought interruption. Farming citrus and high-value vegetable crops tends to preclude replacement by such new crops as guayule.

The Coastal Bend Region has significantly less irrigated acreage, due in part to sufficient rainfall for dryland cropping. Figure III-16 shows irrigated acreage for the combined Lower Rio Grande and Coastal Bend areas.

The South-Texas Coastal Region has precipitation ranging from 20 inches to 34 inches per year, and has some 1.53 million acres of potentially irrigable soils (Texas Water Development Board, 1977). This suggests a real potential for introducing significant acreages of guayule as a dryland crop, particularly in the more northern counties.

Potential for guayule development in Texas is mixed. In west Texas, declining irrigation water supplies are expected to

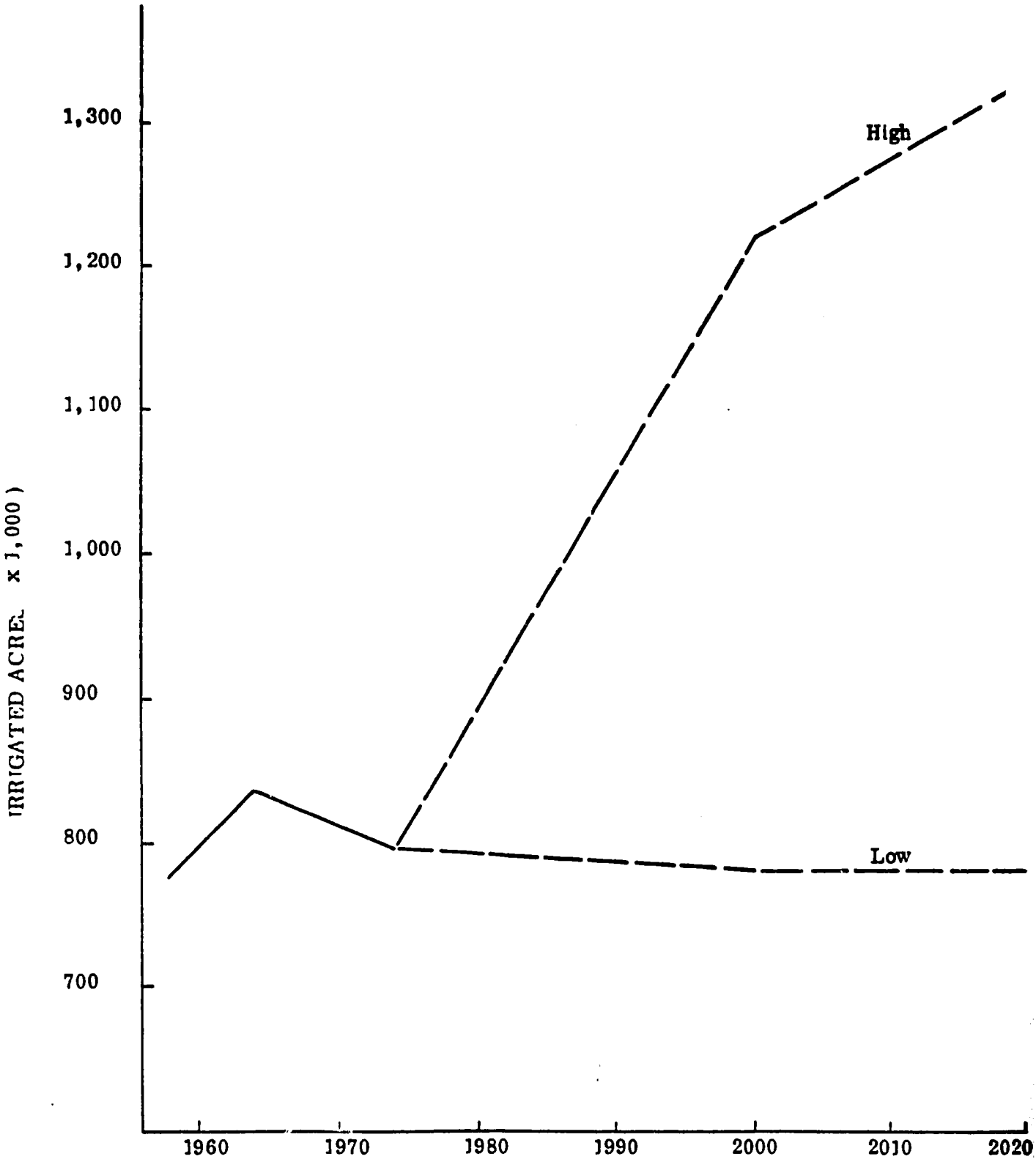


Figure III-16. Irrigated acreages in the south-Texas coastal region.

reduce agricultural activities significantly, particularly in the Trans-Pecos. Although guayule, as a desert-adapted, low water use crop, might offer some alleviation of water quantity problems; the poor quality of groundwater in the area could be expected, in turn, to limit guayule development.

In south Texas, some significant potential for guayule development exists. Desert-adapted crops could offer some buffering for farmers along the Rio Grande where drought conditions can disrupt irrigation water supplies severely. However, the most significant potential would appear to be in the Winter Garden and Coastal Basins area where possibly two million acres of dryland guayule farming could occur.

d. Agricultural water use in Arizona: The Arizona Water Commission estimated a dependable water supply of 2.8 million acre-feet for 1970 conditions. For that same year, groundwater withdrawal totaled approximately five million acre-feet, constituting a 2.2 million acre-foot overdraft. Surface water diversion for 1970 was approximately 3.3 million acre-feet. Combined withdrawal for that base year equalled 8.3 million acre-feet of which 4.8 million acre-feet were depleted, i.e., were not returned to the surface water or groundwater systems. Eighty-nine percent of the State's total water depletion was attributed to irrigated agriculture. Thus Arizona is shown to be depleting its water supplies at approximately three million acre-feet annually, a depletion-to-supply ratio of 1.7 to 1.

i. Arizona water law: The principle of prior appropriation has been applied to Arizona surface water rights establishment since territorial days. Section 45-401 of the Arizona Revised Statutes, stemming from the Arizona Water Code of 1919, declares all flowing surface waters to be public, subject to appropriation for beneficial use. Only through beneficial use can a surface water right be obtained from the State Land Department, the administering body. The relative values for beneficial use are defined in the statutes as: 1) domestic and municipal use; 2) irrigation and livestock water; 3) power and mining uses; and 4) recreation and wildlife.

Rights to groundwater, however, have been throughout the history of the State and are today a source of considerable controversy. In 1904, the Arizona Supreme Court ruled (in Howard vs Perrin) that percolating groundwater belongs to the owner of the overlying land, and as such is outside State jurisdiction to regulate or control. In 1948, the Arizona Legislature enacted the State's first groundwater code. This code reaffirmed the Howard vs Perrin ruling, but also established procedures whereby the State Land Department could designate "critical groundwater areas." These areas are

defined as those with insufficient groundwater to provide a reasonably safe supply for irrigation of lands currently cultivated in that basin. In these critical groundwater areas, drilling wells for irrigation of new lands not irrigated within the past five years is prohibited, although the extent of pumping or apportionment from existing wells is not controlled. Ten critical groundwater areas have been designated.

In 1977, the Groundwater Management Study Commission was formed by the State Legislature and directed to make recommendations by 1979 concerning regulation and apportionment of the groundwater of Arizona. The recommendations of the Commission will become automatically the law of groundwater unless the Legislature specifically intervenes.

Several federal actions affect water use in Arizona. The Winters doctrine [U.S. Supreme Court, Winters vs U.S., 207 U.S. 564 (1908)] states that establishment of Indian reservations implied reservation of water sufficient to irrigate the irrigable portions of those reservations.

A number of court decisions, interstate compacts, and treaties with Mexico govern the use of water from the Colorado River and its tributaries. These rulings and agreements, in aggregate, are referred to as the Law of the River. This Law of the River allocates 2.8 million acre-feet of Colorado River water to Arizona through construction of the Central Arizona Project, (CAP) scheduled for completion into Pinal and Maricopa Counties by 1985, and into Pima County by 1987. Irrigators accepting CAP water are required by the Central Arizona Water Conservation District contract to reduce groundwater pumpage by the amount of CAP water received. Further, CAP waters can be applied only for irrigation to lands with recent irrigation history, specifically between 1958 and 1968. Indian lands, however, are an exception to these restrictions. Thus, the only increase in irrigated agriculture that could result from the CAP would occur on Indian reservations.

ii. Arizona guayule potential: Guayule production in Arizona is limited to the Basin and Range physiographic province of the southern and western portions of the State, primarily due to higher elevation and associated cold temperature extremes in the remainder of the State. Yuma, Maricopa, Pinal, Pima, Santa Cruz, Chochise, Mohave, Graham and Greenlee counties constitute the potential guayule production areas in Arizona (See Figure III-17).

Normal annual precipitation ranges from as low as 3 inches along the western border of the State to as high as 30 inches in some mountain areas. Cropland in guayule production areas is in regions where annual precipitation ranges from 3 inches to 16 inches (U.S.

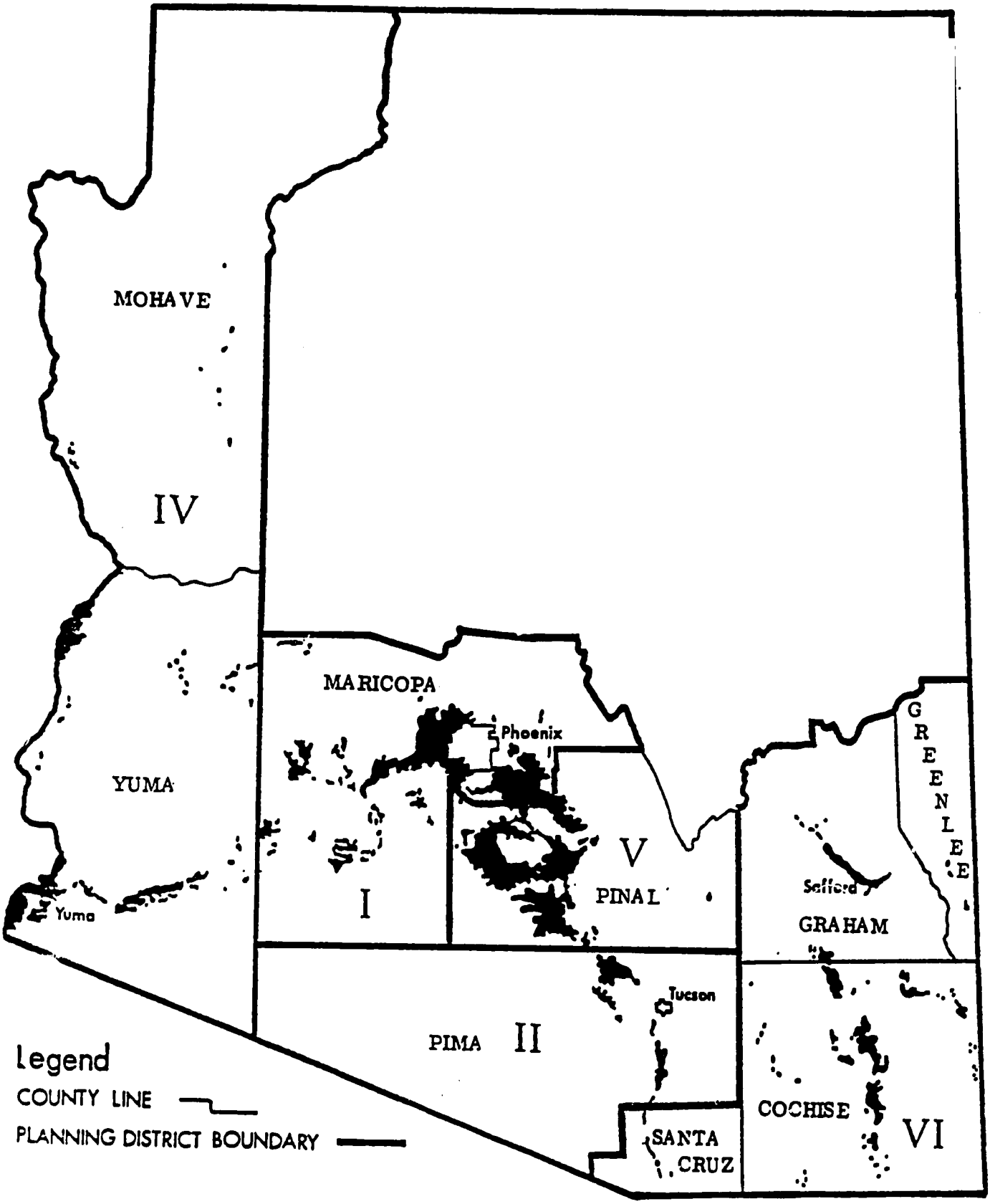


Figure III-17. Irrigated cropland in the potential guayule growth area, Arizona, 1973.

Source: Arizona Agricultural Statistics, 1973.

Bureau of Reclamation, 1971). Thus, commercial guayule production could be achieved only through use of supplemental irrigation water in Arizona.

Figure III-18 shows the designated critical groundwater basins within Arizona's potential guayule growing areas. Comparison of Figures III-17 and III-18 indicates that the bulk of potential guayule production on non-Indian lands would have to compete with existing agriculture since in the critical groundwater areas new lands could not be brought into irrigated production.

Irrigated acreage for the nine-county area was estimated to be 1,110,700 acres for 1970 by the Arizona Crop and Livestock Reporting Service.

Table III-8 reports current and projected irrigated acreages, agricultural water depletion and total water depletion by county for the years 1970, 1990 and 2020 (Arizona Water Commission, 1977). Table III-9 provides agricultural and total water withdrawals by county for the Arizona Water Commission base-planning year of 1970. A depletion-to-withdrawal ratio of .7 to 1 can be applied to project estimates of withdrawal for the years 1990 and 2020.

Acres irrigated differ from harvested acreage due to multiple cropping. Multiple cropping is practiced in Maricopa, Pima, Pinal and Yuma counties. As water supplies become more expensive or legislatively restricted, higher water-demanding crops can be expected to give way to more water-conservative crops, and multiple cropping can be expected to diminish.

The Arizona Water Commission, Phase II Report (1977) projects agriculture and irrigation water depletion based on dependable supplies of surface water and groundwater. Since Arizona is approaching effective regulation of groundwater withdrawal for the first time in its history, and since total water uses of the State must ultimately match dependable supply, the low projection has been selected.

As can be determined from data in Figure III-19 through III-21, a significant decline in irrigated agriculture is projected for Arizona. Loss of harvested acreage is expected to be 138,000 acres by 1990, and nearly .5 million acres by the year 2020. Seven of the nine guayule potential counties are expected to reduce agricultural production significantly. Only Yuma and Mohave counties, adjacent to the Colorado River and having a surplus water supply, are expected to increase in irrigated agricultural production.

Maricopa County was Arizona's largest agricultural producer in the 1970s. It also had 54 percent of the State's population in 1975, and is expected to increase to between 59 percent and 62 percent

TABLE III-8

WATER DEPLETION AND HARVESTED IRRIGATED AGRICULTURE, POTENTIAL GUAYULE GROWTH AREA, ARIZONA; 1970, 1990 AND 2020 1/

County	1970				1990				2020			
	Agricultural Depletions (Acre foot)	Total Depletions (Acre foot)	% Agric.	Harvested Acreage	Agricultural Depletions (Acre foot)	Total Depletions (Acre foot)	% Agric.	Harvested Acreage	Agricultural Depletions (Acre foot)	Total Depletions (Acre foot)	% Agric.	Harvested Acreage
Maricopa	1,681,000	1,873,000	90%	470,000	1,210,000	1,629,000	74%	342,000	633,000	1,402,000	45%	184,000
Pima	211,000	339,000	62%	54,000	123,000	291,000	42%	34,000	0	269,000	0%	0
Pinal	830,000	874,000	95%	231,000	839,000	935,000	90%	244,000	462,000	645,000	72%	143,000
Yuma	954,000	970,000	98%	247,000	1,120,000	1,166,000	96%	288,00	1,070,000	1,134,000	94%	295,000
Mohave	23,000	71,000	32%	8,000	92,000	148,000	62%	23,800	104,000	184,000	57%	28,900
Santa Cruz	11,000	13,000	85%	3,000	7,000	11,000	64%	2,000	1,600	8,000	20%	500
Cochise	335,000	353,000	95%	118,000	180,000	212,000	85%	68,000	17,000	97,000	18%	7,200
Graham	157,000	157,000	99%	56,000	136,000	152,000	89%	49,000	101,000	145,000	70%	37,000
Greenlee	17,000	33,000	52%	5,000	9,600	43,000	22%	3,000	0	74,000	0%	0
Arizona Guayule Potential Area	4,219,000	4,685,000	90%	1,192,000	3,716,600	4,587,000	81%	1,053,800	2,388,600	3,958,000	60%	695,600

1/ Source: Phase II, Arizona State Water Plan, Alternative Futures. Arizona Water Commission, February, 1977.

TABLE III-9

WATER WITHDRAWAL AND ACREAGE IRRIGATED IN 1970

POTENTIAL GUAYULE GROWTH AREA, ARIZONA[1/]

County	Agricultural Withdrawal (acre feet)	Total Withdrawal (acre feet)	% Agric.	Acres Irrigated
Maricopa	2,681,000	2,990,000	90%	430,000
Pima	272,000	412,000	66%	50,000
Pinal	1,263,000	1,312,000	96%	210,700
Yuma	2,037,000	2,419,000	84%	230,000
Mohave	32,000	86,000	37%	8,000
Santa Cruz	12,000	19,000	63%	3,000
Cochise	500,000	523,000	96%	118,000
Graham	277,000	281,000	99%	56,000
Greenlee	20,000	50,000	40%	5,000
Arizona Guayule Potential Area	7,094,000	8,092,000	88%	1,110,700

1/ Source: Phase I, Arizona State Water Plan, Inventory of Resources and Uses. Arizona State Water Commission, July 1975.

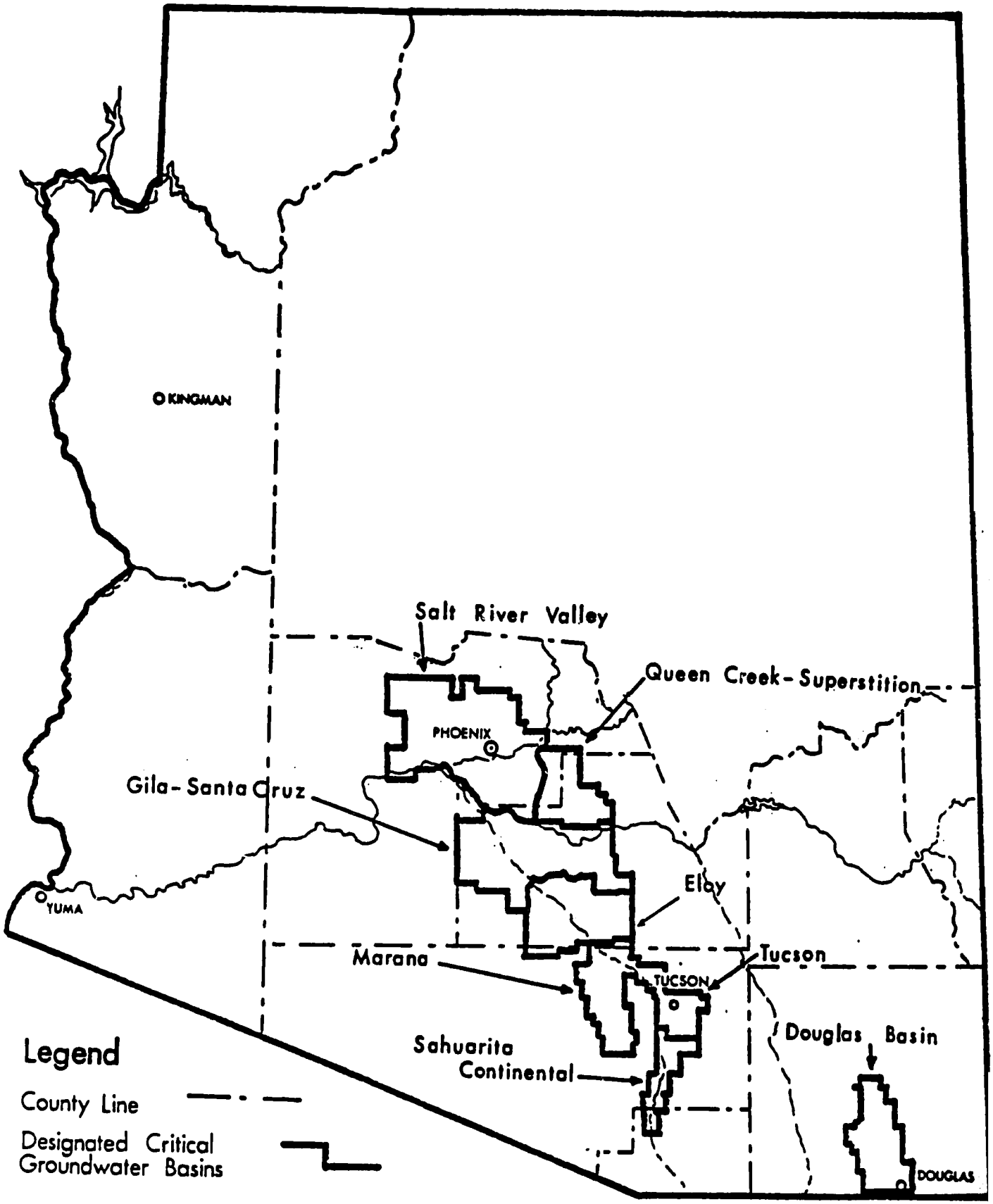


Figure III-18. Designated critical groundwater basins in the potential guayule growth area, Arizona, as of July 1975.

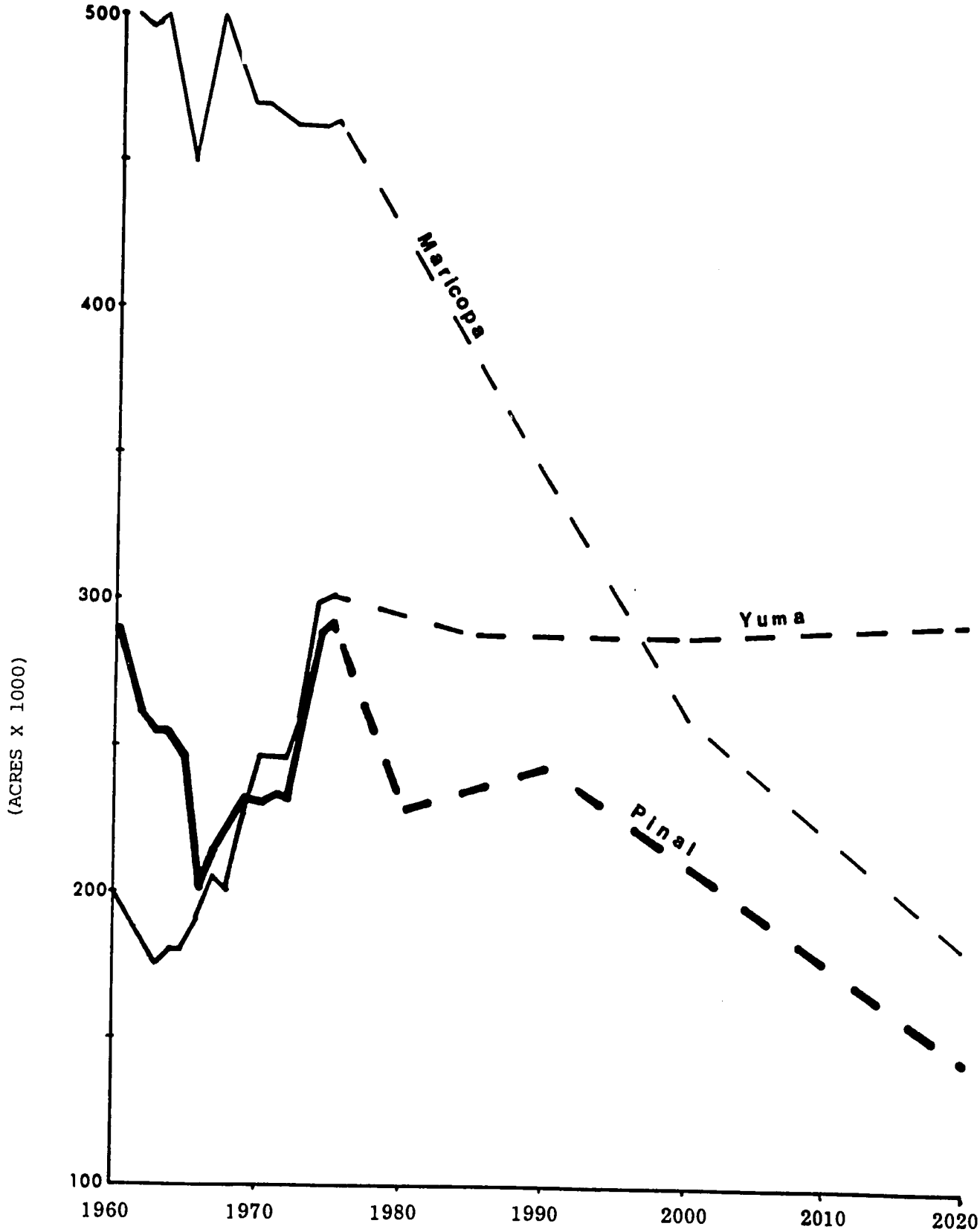


Figure III-19. Harvested acreages, 1960 to 2020, in high agricultural production counties, potential guayule growth area, Arizona.

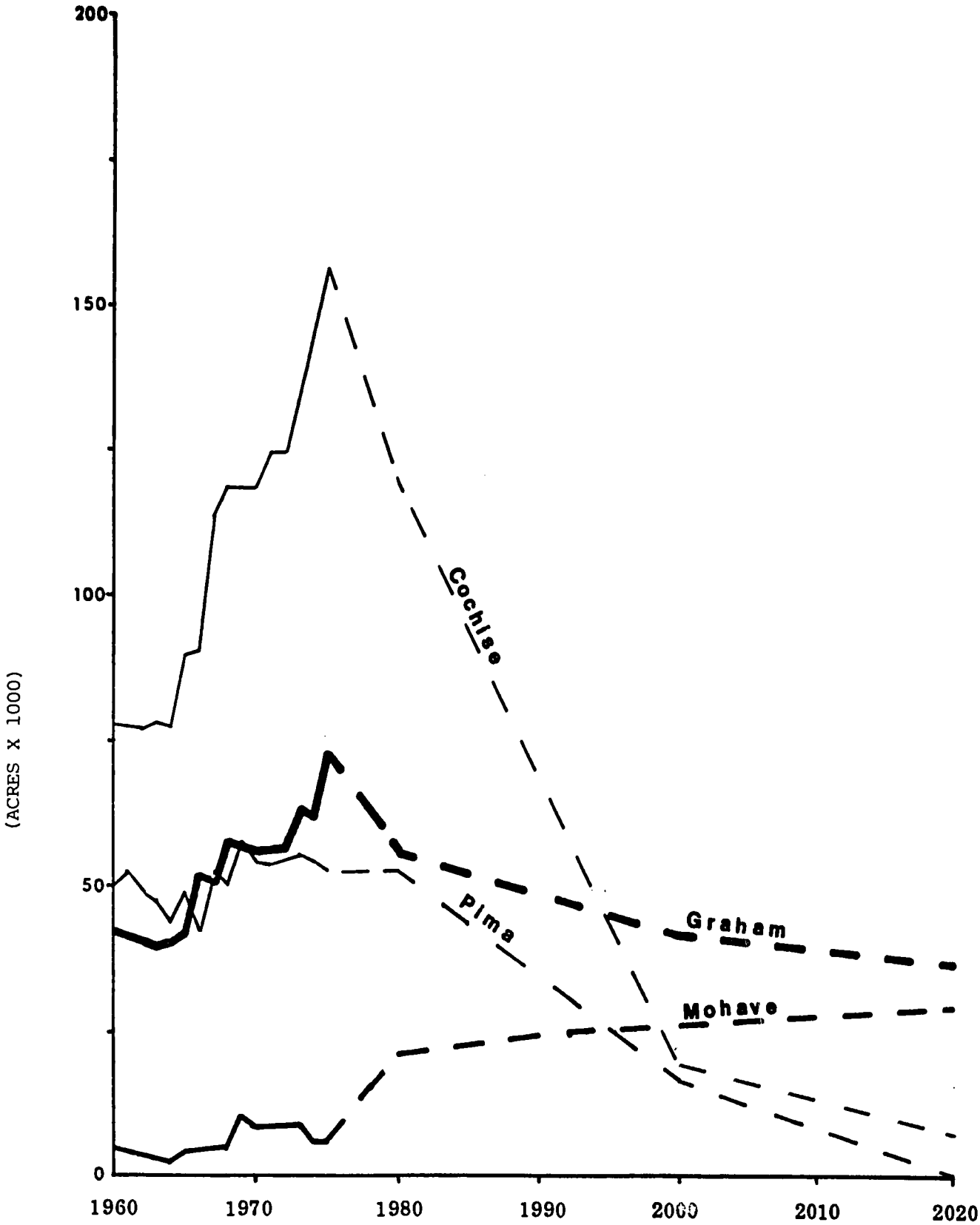


Figure III-20. Harvested acreages, 1960 to 2020, in medium agricultural production counties, potential guayule growth area, Arizona.

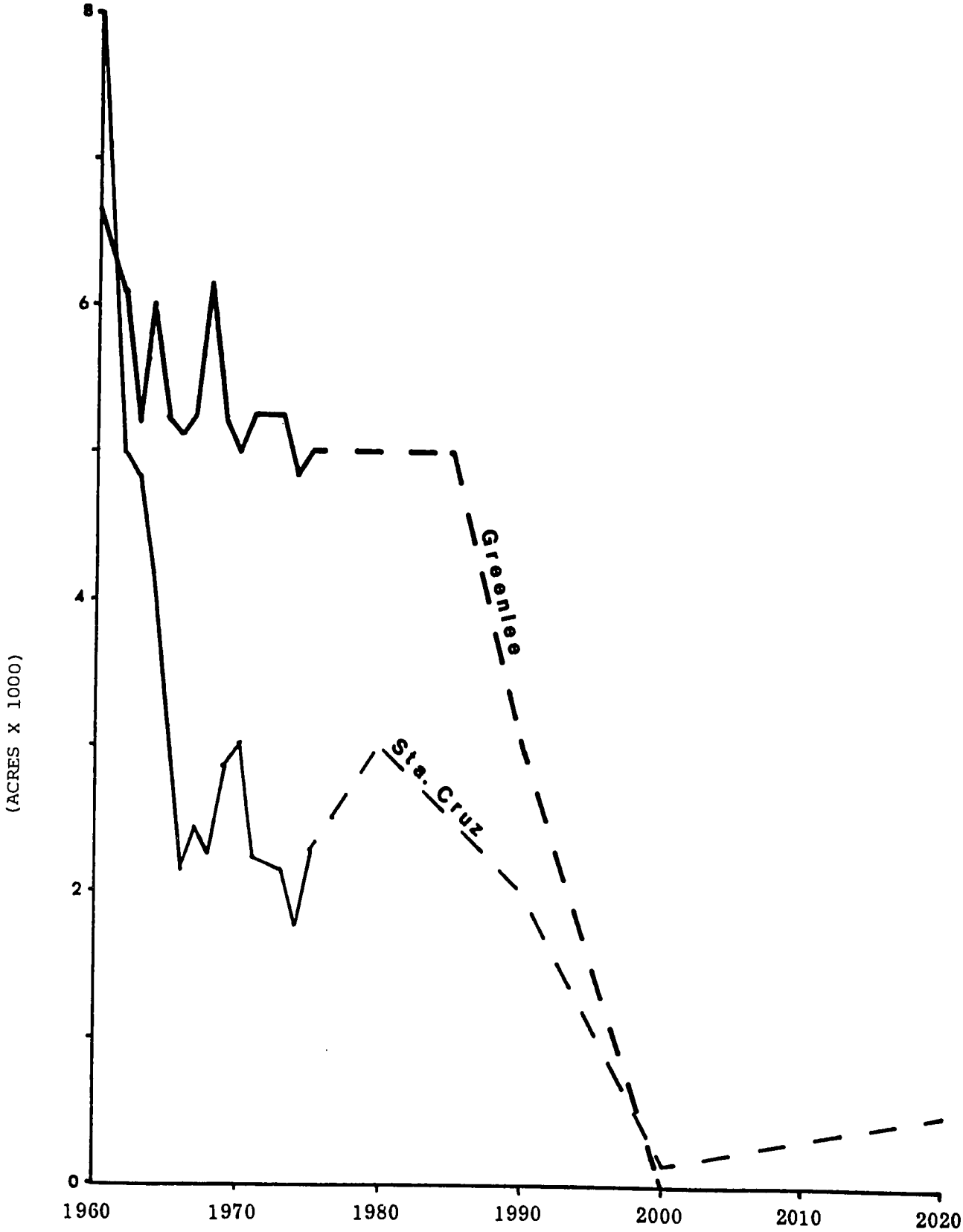


Figure III-21. Harvested acreages, 1960 to 2020, in low agricultural production counties, potential guayule growth area, Arizona.

by 2020. Expected growth of the Phoenix urban area is projected to replace directly a substantial portion of Maricopa County agriculture by 2000. By 2020, urban and power generation water demands are expected to reduce agricultural water depletion to 45 percent of the County total. In 1970, Maricopa County used an estimated 900,000-acre-foot groundwater overdraft.

Tucson, Arizona's second largest city, is in Pima County. In 1970, 62 percent of Pima County's water depletion was attributed to irrigated agriculture, 20 percent for urban water use, and 16 percent for mining. Pima County is the leading copper-producing county in Arizona, and water use for mineral production is projected to increase by 220 percent by 2020. As the Tucson population increases, urban water use is projected to increase 35 percent. Thus, increased mining activity and urban population are forecast to diminish agricultural water use to 42 percent of the County total by 1990, and to pre-empt agriculture altogether by 2020. In 1970, Pima County was overdrafting its groundwater at the rate of 270,000 acre-feet per year.

In 1970, about 95 percent of Pinal County's water use was for irrigated agriculture. Pinal County does not have a significant urban population compared with either Maricopa or Pima counties, but Pinal is second only to Pima County in mineral production. By 2020, water use by the minerals industry is expected to increase more than 400 percent while agricultural water use is expected to decline by almost half of its 1970 level, although it is forecast that agriculture still will use 72 percent of the County's dependable water supply. Groundwater overdraft amounted to 620,000 acre-feet in Pinal County in 1970.

Cochise and Graham counties showed significant agricultural production during the 1970s, accounting for 95 percent and 99 percent, respectively, of total county water depletion in 1970. Both counties are expected to have some reduction in irrigation water use by 1990. By 2020, Cochise County is expected to lose most of its agricultural water to mineral, urban and power generation uses. Graham County is predicted to reduce agricultural water use to about 70 percent of total water depletion by 2020, most of the remaining water to be drawn for mineral processes.

Greenlee and Santa Cruz counties had relatively little agricultural production in the 1970s, less than 10,000 acres in each county. Both counties are expected to have significant decreases in agricultural water use, to zero for Greenlee and 500 acres for Santa Cruz by the year 2020. Mineral depletions will take 97 percent of Greenlee County's water by 2020, while Santa Cruz County is expected to apportion about half of its water to urban use, the rest split between agriculture and mining.

Yuma and Mohave counties are the only two Arizona counties anticipating increases in irrigated agriculture by 2020. Yuma County was the only county in the State with a water surplus in 1970--116,000 acre-feet. Although dependable water supplies are expected to increase slightly, and 94 percent of water depletion is planned for irrigation, agricultural acreage is expected to increase by only 19 percent by 2020 in Yuma County. Nevertheless, Yuma County is predicted to be Arizona's largest agricultural producer from the year 2000 on. Mohave County is expected to experience a relatively dramatic increase in irrigated agriculture, although it will amount to less than 30,000 acres by 2020. Some difficulty might be experienced for guayule production in portions of Yuma and Mohave counties where groundwater levels are near the surface. By 2020, 57 percent of the County's water depletion is expected to be apportioned to agriculture, the rest shared among mineral, urban and power uses.

Overall, agricultural acreage and irrigation water in the potential guayule production areas of Arizona is expected to decline by 42 percent to 43 percent. Application of irrigation water to new lands for guayule production is highly unlikely other than in Yuma and Mohave counties. In Yuma and Mohave counties, harvested acreage is expected to increase by nearly 70,000 acres by 2020.

e. Agricultural water use in New Mexico: Long-term streamflow records show that New Mexico receives an annual water supply of about 5.7 million acre-feet. Precipitation within the State accounts for about 3.3 million acre-feet; and about 2.4 million acre-feet are received as streamflow from other states, mostly from Colorado via the San Juan River and the Rio Grande. New Mexico depletes about 2.3 million acre-feet of surface water annually, and about 3.4 million acre-feet are discharged each year to downstream states.

In addition to flow in rivers, about 4.4 billion acre-feet of recoverable fresh and slightly saline groundwater are estimated to be in aquifer storage. About three billion acre-feet of this water in storage is fresh and can be used for many purposes without treatment.

Water use in the State is subject to provisions of compacts entered into between New Mexico and other states on the Rio Grande, Costilla Creek, Pecos River, Colorado River, Upper Colorado River Basin, Animas-La Plata Project, La Plata River, and Canadian River. These compacts, however, are based on present water supplies and are not expected to alter significantly the New Mexico water supply picture in the future (U.S. Bureau of Reclamation, 1976).

i. New Mexico water law: Since Spanish colonial times, water rights in the State have been based on the principle of prior appropriation: no appropriation of water shall be exercised to the detriment of anyone having prior, valid and existing rights to the use of those waters.

Article XVI of the New Mexico State Constitution provides that water rights are to be administered by the State Engineer, and any right to the use of water--excepting rights acquired before March 19, 1907--must originate by application to the State Engineer. All natural waters flowing in streams and water courses in New Mexico and the waters of underground streams, channels, artesian basins, reservoirs, or lakes having reasonable ascertainable boundaries belong to the public and are subject to appropriation for beneficial use (New Mexico State Engineer, 1953).

Thus, rights to surface water for irrigation, industrial, municipal, mining, energy and other uses must be obtained by means of the State Engineer's determination that unappropriated waters exist in the water course. Further, the State Engineer is empowered to define and "declare" underground water basins in New Mexico. Withdrawal of groundwater from these basins, excepting for the purposes of domestic use and stock watering, are permitted only if the State Engineer determines that unappropriated water exists and that the proposed withdrawal will not impair existing water rights (New Mexico State Engineer, 1951).

ii. New Mexico guayule potential: Guayule production in New Mexico based upon suitable soil and climatic conditions is limited to Dona Ana, Grant, Hidalgo and Luna counties. These four counties are in the Lower Colorado River Basin and the Rio Grande Basin (Figure III-22). Total irrigated cropland in this four-county area amounted to approximately 210,000 acres in 1975. Mean annual precipitation in this southern desert region of New Mexico, as reported by the U.S. Weather Bureau, ranges from 8 inches in the southeast to 16 inches in the northwest. Thus, cultivating guayule in New Mexico could be achieved only by means of irrigated agriculture.

Figure II-23 shows those underground water basins declared by the State Engineer as of July 1976 that affect the potential guayule growing areas of New Mexico. Comparing Figures III-22 and III-23 illustrates that, with the exception of groundwater adjacent to the Rio Grande, all irrigation water that could be applied to guayule production is subject to the State Engineer permit system.

Irrigation water withdrawal and irrigated acreage data in 1975 for each of the four counties are presented in Table III-10. Projected water withdrawal and acreage for irrigated agriculture

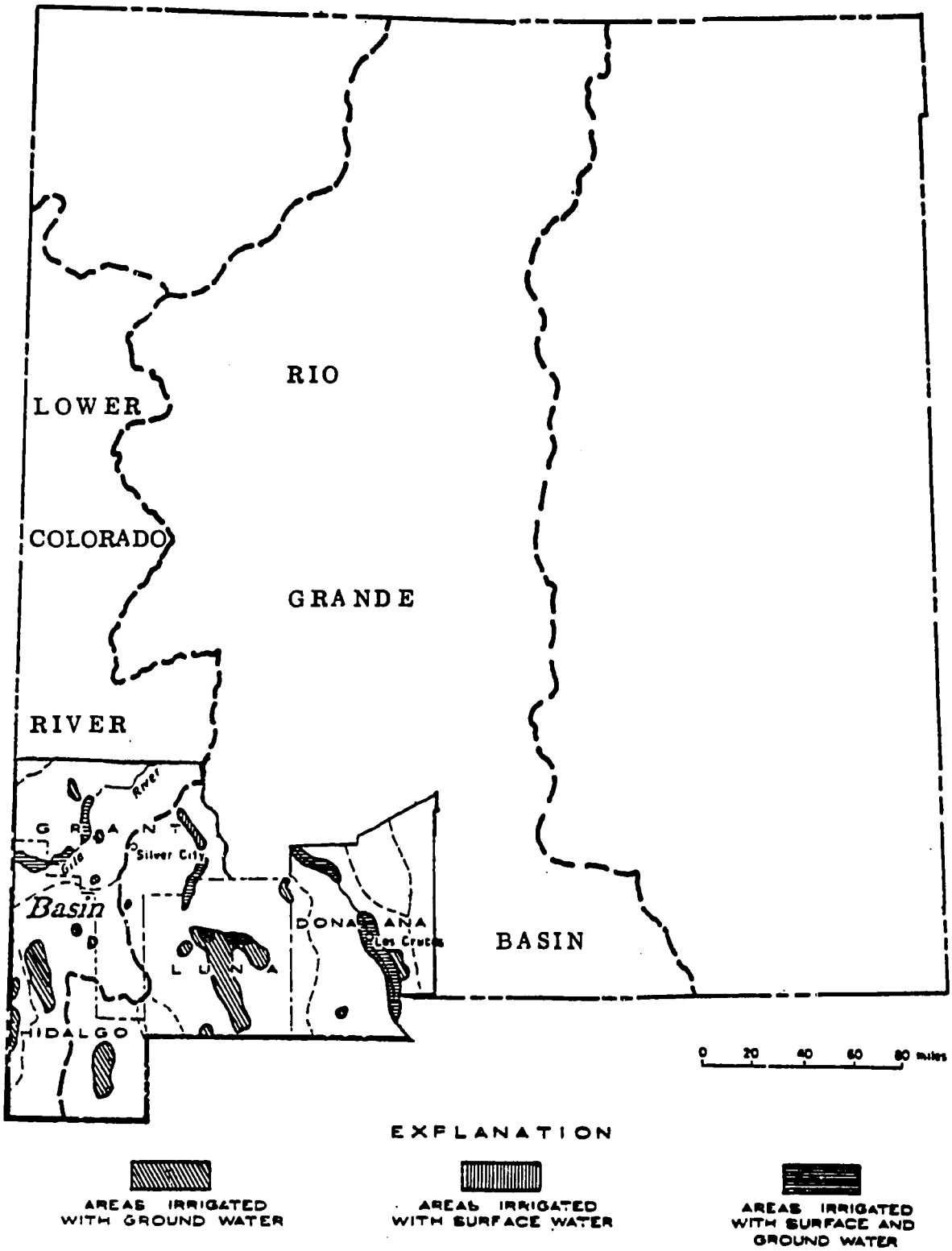
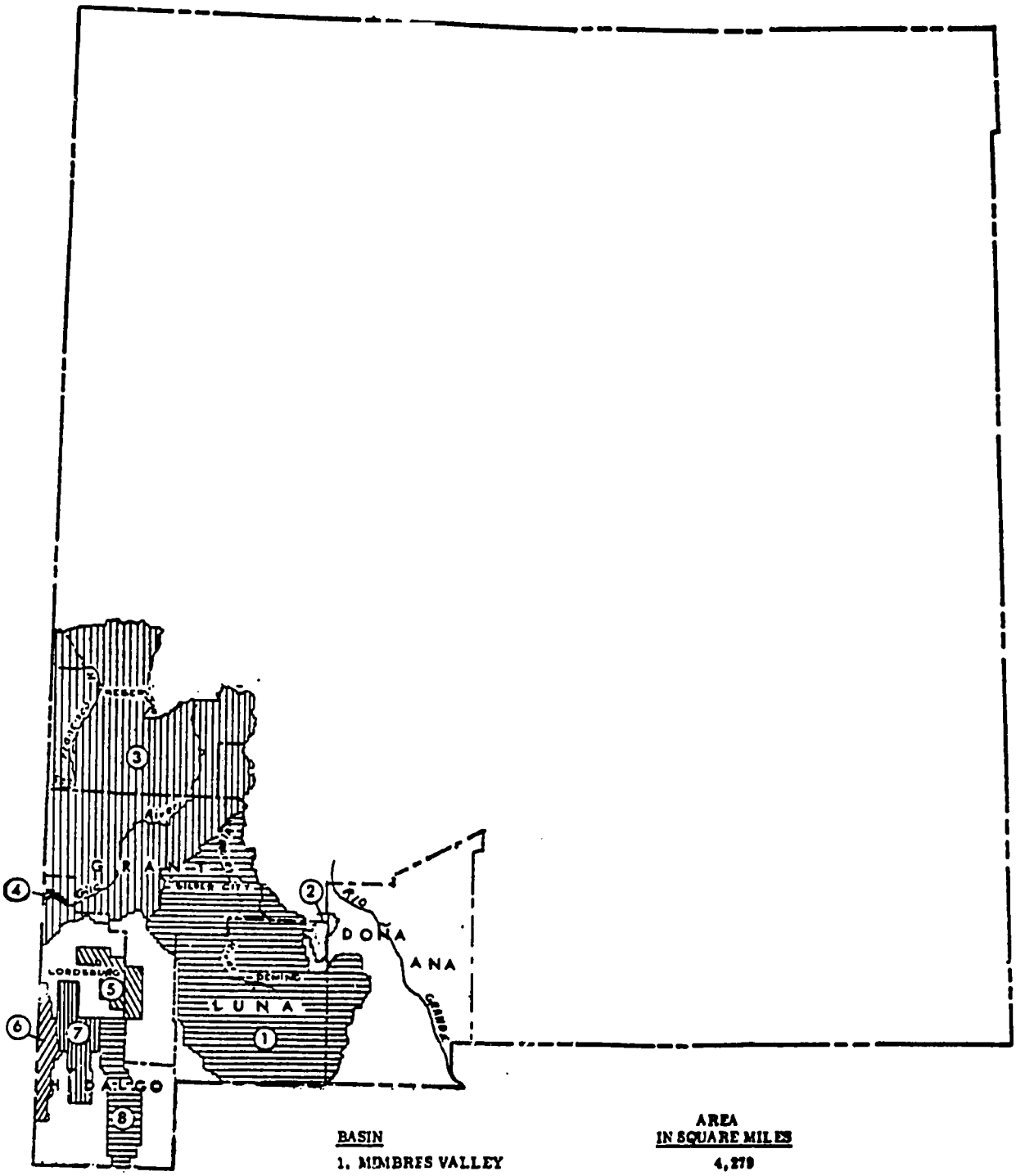


Figure III-22. Irrigated cropland in the potential guayule growth area, New Mexico, 1969.

Source: Sorensen, 1977.



BASIN	AREA IN SQUARE MILES
1. MEMBRES VALLEY	4,279
2. NUTT - HOCKETT	133
3. GILA - SAN FRANCISCO	5,639
4. VIRDEN VALLEY	19
5. LORDSBURG VALLEY	329
6. SAN SIMON	263
7. ANIMAS	426
8. PLAYAS VALLEY	518

Figure III-23: Declared underground water basins, July 1976 potential guayule growth area, New Mexico.

Source: Sorensen, 1977.

TABLE III-10

WATER WITHDRAWAL AND ACREAGE FOR IRRIGATED AGRICULTURE; 1975, 1980, 2000 AND 2020

DONA ANA, GRANT, HIDALGO AND LUNA COUNTIES, NEW MEXICO

County	1975				1980				2000				2020			
	Agricultural Withdrawal (acre feet)	Total Withdrawal (acre feet)	% Agric	Irrigated Acreage	Agricultural Withdrawal (acre feet)	Total Withdrawal (acre feet)	% Agric.	Irrigated Acreage	Agricultural Withdrawal (acre feet)	Total Withdrawal (acre feet)	% Agric.	Irrigated Acreage	Agricultural Withdrawal (acre feet)	Total Withdrawal (acre feet)	% Agric.	Irrigated Acreage
DONA ANA	485,200[1]	508,629[1]	95	94,110[2]	400,700[3]	431,200[3]	93	93,510[3]	391,400[3]	463,900[3]	84	92,260[3]	365,300[3]	480,100[3]	76	85,930[3]
GRANT	17,540[1]	44,834[1]	39	7,260[2]	23,200[6]	62,100[6]	37	9,948 [6]	23,400[6]	71,900[6]	33	9,948[6]	23,400[6]	85,200[6]	27	8,23[6]
HIDALGO	75,390[1]	92,474[1]	82	33,480[2]	111,400[4]	121.200[4]	92	39,289	120,600[4]	151,000[4]	80	39,287[7]	122,100[4]	162,000[4]	75	23,500[7]
LUNA	162,200[1]	167,882[1]	97	69,440[2]	155,800[5]	160,200[5]	97	66,700[7]	152,800[5]	161,100[5]	95	65,400[7]	145,300[5]	218,800[5]	66	25,250[7]
NEW MEXICO																
Guayule Potential Area	740,330	813,819	91	207,290	691,100	774,700	90	209,447	688,200	847,900	81	206,895	656,100	946,100	69	139,900

1. Sorensen, 1977
2. New Mexico State University, 1977
3. New Mexico State Engineer, 1975a
4. New Mexico State Engineer, 1974a
5. New Mexico State Engineer, 1974b
6. New Mexcio State Engineer, 1975b
7. extrapolated from county profile: $\frac{\text{irrigation withdrawal}}{\text{irrigation rate/acre}}$

also is reported for the years 1980, 2000 and 2020. The stated assumptions for these projections are that water rights will continue to be available through the market place; that New Mexico will operate within the constraints of its existing water supply; and that the economic value of water for various purposes will determine its application. Through economic allocation, it is assumed that new, high-value water uses will be met by retiring irrigated lands (See the "County Profile", New Mexico State Engineer, 1974a & b, 1975a & b).

Figure III-24 indicates that declines in irrigated acreage are expected for this four-county region, particularly in Luna and Hidalgo counties. Luna County irrigated agriculture is forecast to decline from a high of 69,000 acres in 1975 to 25,000 acres in 2020. The primary causitive factor for this reduction is the projected completion of a nuclear power plant in Luna County by the year 2020. It will withdraw an estimated 56,000 acre-feet annually. Urban population growth forecasts predict a two-fold increase from 1970 to 2000, a three-fold increase from 1970 to 2020 and will be a second significant source of irrigation water decline. Mining activities also are expected to greatly increase in Luna County, expanding water demand from 700 acre-feet in 1970 to 2,200 acre-feet in 2000 and 8,400 acre-feet in 2020.

Hidalgo County irrigated agricultural acreage is expected to decline from a high of 39,000 acres during 1980-2000 to 23,500 acres by 2020. Again, this is attributable primarily to planned construction of a nuclear power plant, which is projected to reduce irrigated acreage in the Animas Basin from 14,900 to 4,000 acres. Mining activities, particularly in the San Simon and Virden Valley basins, are expected to delete an additional 5,000 acres from agriculture in Hidalgo County by 2020, nearly half this acreage will be retired by 1980. A near doubling of Lordsburg's population also is projected to deplete agricultural acreage.

Dona Ana County is expected to have a much less significant decline in irrigated acreage; 8,000 acres less than the high of 94,110 in 1975 to 86,110 in 2020, less than a 10 percent reduction. Of this agricultural reduction, 68 percent is attributable to an expected urban population increase of 428 percent. The second strongest reduction factor is water use in power generation, expanding ten-fold from 1970 to 2020. Of the expected 8,000-acre decline in agriculture in Dona Ana County, 23 percent is expected to have been withdrawn by the year 2000.

Grant County has the least irrigated acreage of the four counties and is expected to have relatively little change by 2020.

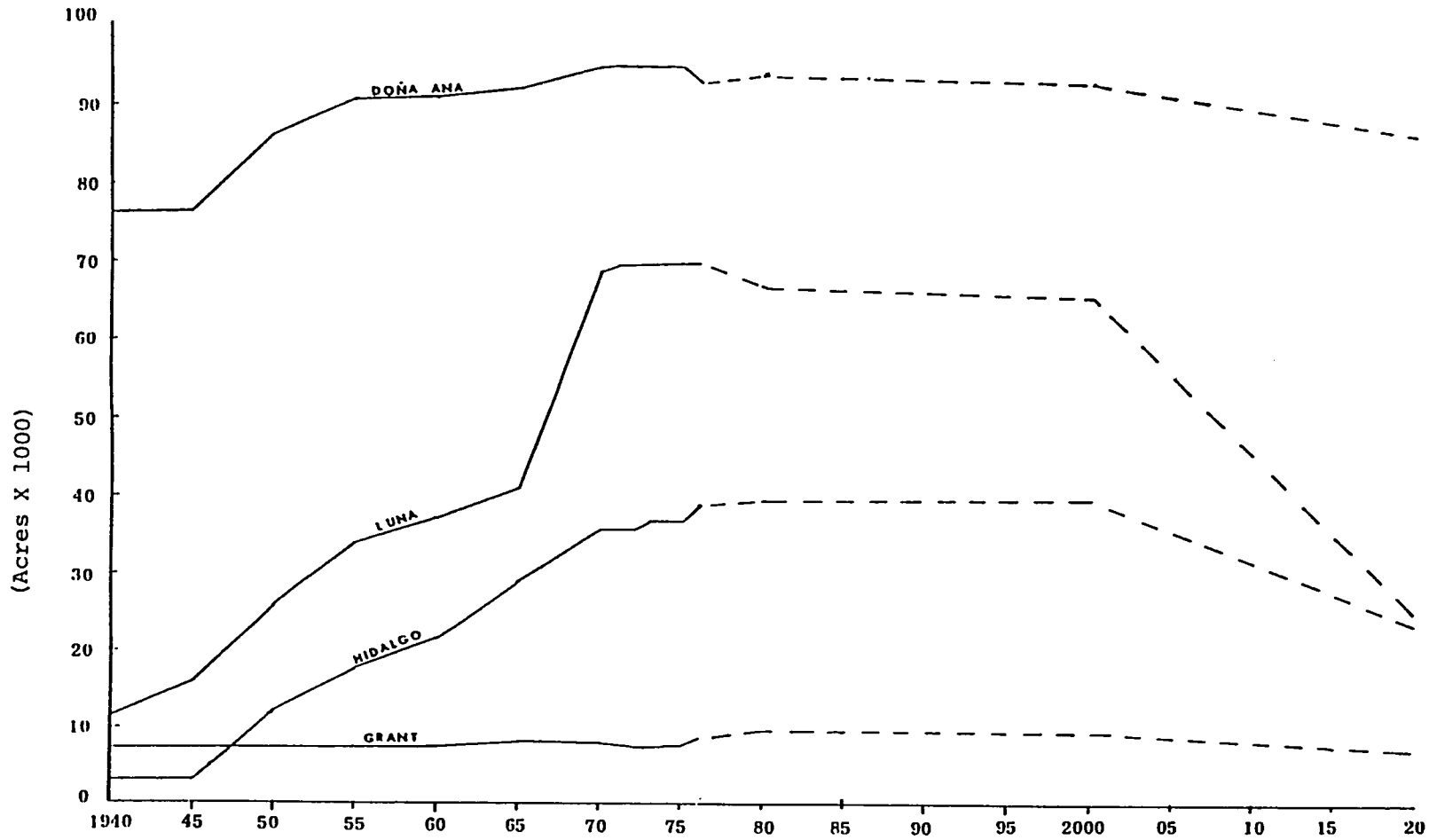


Figure III-24. Irrigated acreages, 1940 to 2020, Dona Ana, Grant, Hidalgo and Luna Counties, New Mexico.

Source: New Mexico State University, 1977 and New Mexico State Engineer, 1974 a and b, 1975 a and b.

In the four-county region of New Mexico where guayule could be grown, a 32 percent decline of irrigated acreage is forecast by 2020. Most of this decline is attributed to increasing demands for power production, urban populations and mining activities and is expected to occur between years 2000 and 2020.

f. Agricultural water use in California:

i. California water law: The California State Water Code designates that, "All water within the State is the property of the people of the State" (Sect. 102) and that "because of the conditions prevailing in this State the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent possible" (Sect. 100).

The California Legislature established the Department of Water Resources (Chapter 52, Statutes of 1965), which superseded the State Water Resources Board. Both of these entities were vested with the responsibility for conducting a statewide water resources investigation. This action resulted in the publication of the California Water Plan in May 1975 (Department of Water Resources, 1957). This document identified maldistribution as the primary water problem of the State, and set the stage for a massive statewide water redistribution plan. Since the mid-1960s, a second environmental goal has been established in California water resources management, "the management of the water and related resources of land and air to preserve and enhance the resources for indefinite use and enjoyment" (Department of Water Resources, 1970).

During 1940-1970, local water agencies in California have invested some $4 billion in surface and groundwater projects. Between 1966 and 1970, local agencies invested $1 billion, California has invested $1.4 billion in the State Water Project, and the federal government has expended some $400 million on the Central Valley Project and various flood control projects within California. As a result of these extensive efforts, the Department of Water Resources reported in 1970 that "Sufficient water is developed by completed water projects, or will be developed by those under construction, to satisfy more urban and irrigation needs for about two decades" (Department of Water Resources, 1970b). Additional conveyance systems will be needed to deliver developed supplies to certain areas.

Despite these optimistic predictions, the Congressional Research Service (Viessman, et al, 1978) reports that California's principal water supply problems are curtailed surface water supplies during protracted droughts, and excessive groundwater pumping. This report states that groundwater shortage is critical in the San Francisco and Los Angeles areas. Groundwater depletion is estimated to decline in the State by the year 2000.

California operates under a groundwater law approach unlike any other enforced in the U.S. Southwest. Three divisions of groundwater are recognized: 1) groundwater flowing in definite underground streams; 2) groundwater underflow of surface streams; and 3) percolating groundwater.

The first two divisions, groundwater in a prescribed flow, are protected and apportioned in the same manner as surface water flow to provide protection for proprietors in lower riparian areas.

A "correlative rights doctrine" for percolating groundwater was established by the California Supreme Court in 1902 (Katz vs. Wilkinshaw). Under this doctrine, rights for use of groundwater on the overlying land are subject to "fair and just proportion"; uses off the overlying land are limited to supplies not needed on that overlying area; and conflicting off-land uses are subject to the doctrine of prior appropriation.

"Mutual prescription," proportional reductions of water rights to the safe supply level, was established in the Pasadena vs. Alhambra case (1949). In this opinion, the Pasadena Court wrote that "the trial court has authority to limit the taking of groundwater for the purpose of protection the supply and preventing a permanent, undue lowering of the water table."

Thus, the State of California has assumed the right to equitably apportion groundwater, and to limit or prevent groundwater overdraft. Such limiting, however, occurs only in instances where adjudication is sought (Chalmers, 1974).

The California Department of Water Resources has divided the State into 11 hydrographic units: North Coastal, San Francisco Bay, Central Coastal, South Coastal, Sacramento Basin, Delta-Central Sierra, San Joaquin Basin, Tulare Basin, North Lahontan, and Colorado Desert (See Figure III-25). Of these, only the North Coastal and North Lahontan units do not have areas for potential guayule production.

In 1955, the State Water Resources Board transmitted the document Water Utilization and Requirements of California to the Governor and Legislature. In this bulletin, acreages of irrigated agriculture in 1950 and projected ultimate acreages were reported by county and by hydrographic unit. These data, as they pertain to the potential guayule growing areas in California, are presented in Tables III-11 through III-13. In 1970, the Department of Water Resources published data on irrigated acreages for 1967; projected acreages for 1990 and 2020; irrigation and total water demands for 1967; and irrigations and total water demands projected to 1990 and 2020 by hydrographic unit (California Department of Water Resources, 1970a). These data are presented in Table III-14. The 1955 data are useful since both county and hydrographic unit data are reported.

ii. California guayule potential: Guayule could be grown in a large part of California, including most of the central valley, the central and south coastal area, and the arid southeastern

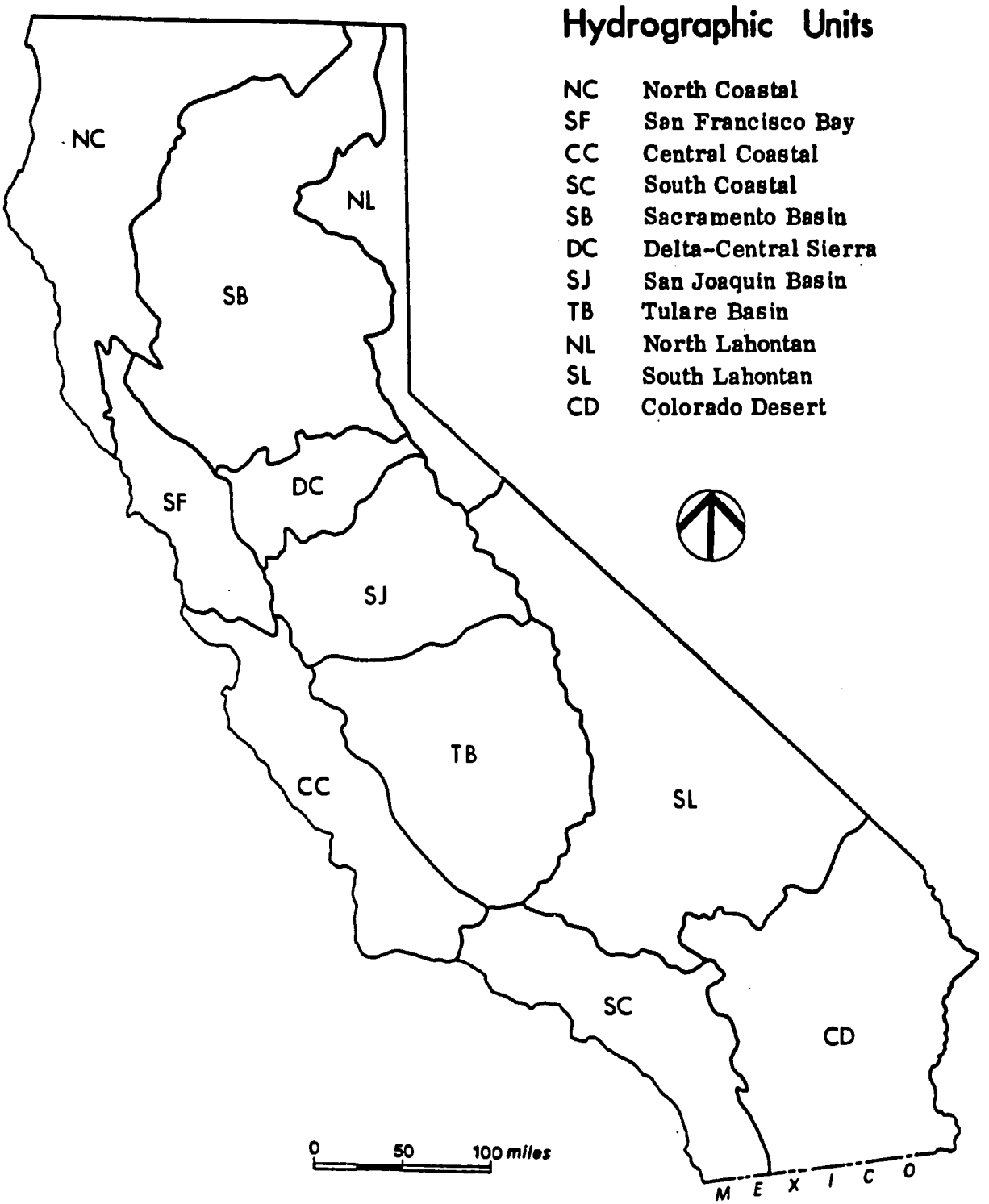


Figure III-25. California hydrographic units.

TABLE III-11

COASTAL GUAYULE POTENTIAL GROWTH AREA;
1950 AND ULTIMATE IRRIGATION[1]

	County Area in Hydrographic Unit (acres)	1950 Irrigated Acreage	Ultimate Irrigated Acreage
SAN FRANCISCO BAY UNIT	1,861,900	159,300	52,800
Counties:			
Santa Cruz	3,400	0	0
Santa Clara	597,000	105,000	8,900
San Mateo	291,300	9,100	4,900
San Francisco	29,200	0	0
Solano	221,000	8,300	33,400
Contra Costa	289,000	6,700	0
Alameda	431,000	56,700	5,600
CENTRAL COAST UNIT	7,196,400	336,700	1,162,300
Counties:			
Santa Cruz	279,000	14,900	31,000
Santa Clara	225,000	30,600	47,300
Monterey	2,129,000	152,000	357,000
San Benito	689,000	39,800	109,000
San Luis Obispo	2,025,000	24,300	375,000
Kern	6,400	0	700
Santa Barbara	1,625,000	74,100	242,000
Ventura	218,000	0	300
SOUTH COASTAL UNIT	6,995,400	616,700	1,024,500
Counties:			
Ventura	934,000	109,000	111,000
Kern	1,300	0	0
Los Angeles	1,768,000	135,000	76,700
Orange	503,000	129,000	54,800
San Bernardino	647,000	89,800	101,000
Riverside	1,198,000	95,400	302,000
San Diego	1,939,000	58,500	379,000
Santa Barbara	5,100	0	0

1:Source, California State Water Resources Board, 1955.

TABLE III-12

CENTRAL VALLEY GUAYULE POTENTIAL GROWTH AREA;
1950 and ULTIMATE IRRIGATION

	County Area in Hydrographic Unit (acres)	1950 Irrigated Acreage	Ultimate Irrigated Acreage
SACRAMENTO RIVER BASIN	7,147,000	785,800	2,119,600
Counties:			
Tehama	1,910,000	30,100	194,000
Glenn	792,000	96,100	277,000
Butte	1,072,000	116,000	323,000
Colusa	740,000	105,000	321,000
Yuba	412,000	52,400	160,000
Sutter	390,000	170,000	278,000
Yolo	579,000	120,000	252,000
Placer	919,000	41,400	175,600
Solano	110,000	24,000	49,000
Sacramento	223,000	30,800	90,000
DELTA-CENTRAL SIERRA	1,680,500	618,100	1,142,000
Counties:			
Solano	221,000	37,000	147,000
Sacramento	415,000	123,200	271,000
San Joaquin	729,000	352,000	554,000
Alameda	52,500	2,400	3,300
Contra Costa	180,000	73,500	82,400
Yolo	83,000	30,000	84,300
SAN JOAQUIN VALLEY	4,976,000	1,075,000	1,823,000
Counties:			
San Joaquin	182,000	88,000	139,000
Stanislaus	973,000	314,000	481,000
Merced	1,270,000	383,000	667,000
Madera	1,378,000	161,000	381,000
San Benito	20,000	0	2,000
Fresno	1,153,000	129,000	153,000

TABLE III-13

SOUTH CENTRAL VALLEY AND SOUTHEASTERN CALIFORNIA POTENTIAL GUAYULE GROWTH AREA; 1950 AND ULTIMATE IRRIGATION

	County Area in Hydrographic Unit (acres)	1950 Irriaged Acreage	Ultimate Irrigated Acreage
TULARE LAKE BASIN	10,595,000	2,027,500	3,841,700
Counties:			
Fresno	2,690,000	730,000	1,117,000
Tulare	3,102,000	460,000	884,000
Kings	893,000	372,000	599,000
Kern	3,589,000	464,000	1,218,000
San Luis Obispo	106,000	0	4,500
Ventura	30,000	0	200
San Benito	185,000	1,500	19,000
SOUTH LAHONTAN UNIT	20,970,000	228,000	2,612,000
Counties:			
Kern	1,624,000	10,800	428,000
San Bernardino	6,761,000	22,500	1,042,000
Los Angeles	723,000	61,500	363,000
COLORADO DESERT UNIT	11,095,000	565,800	474,800
Counties:			
San Bernardino	5,494,000	2,000	334,000
Riverside	3,138,000	85,300	59,700
San Diego	805,000	2,500	68,600
Imperial	1,658,000	476,000	12,500
Additional land with Colorado River Water Rights		1,321,000	1,321,000

TABLE III-14

WATER WITHDRAWALS AND IRRIGATED ACREAGE: 1967, 1990 and 2020 HYDROGRAPHIC UNITS IN THE POTENTIAL GUAYULE GROWTH AREAS, CALIFORNIA[1/]

HYDRO UNIT	1967				1990				2020			
	Agric. With-drawal (1,000 AF)	Total With-drawal (1,000 AF)	% Agric.	Irrig. Acres (1,000)	Agric. With-drawal (1,000 AF)	Total With-drawal (1,000 AF)	% Agric.	Irrig. Acres (1,000)	Agric. With-drawal (1,000 AF)	Total With-drawal (1,000 AF)	% Agric.	Irrig. Acres (1,000)
San Francisco Bay	340	1,170	29	130	280	1,770	16	120	240	2,770	9	110
Central Coastal	1,030	1,200	86	350	1,180	1,480	80	380	1,260	1,780	71	390
South Coastal	1,110	3,180	35	480	820	4,280	19	290	560	5,960	9	210
Sacramento Basin	6,240	6,800	92	1,540	7,110	7,930	90	1,770	7,540	8,660	87	1,920
Delta-Central Sierra	2,300	2,420	95	730	2,510	2,810	89	810	2,580	3,020	85	840
San Joaquin Basin	5,550	5,740	97	1,200	5,760	6,090	95	1,400	6,000	6,560	91	1,520
Tulare Basin	9,530	9,910	96	2,940	11,180	11,710	95	3,430	11,890	12,700	94	3,520
South Lahontan	550	620	89	100	560	780	72	100	400	900	44	80
Colorado Desert	3,900	3,980	98	610[2/]	3,930	4,070	97	620[2/]	3,930	4,140	95	620[2/]
TOTALS	30,550	35,020		8,080	33,330	40,920		8,920	34,400	46,490		9,210

1/Includes Hydrographic Unit totals, which exceed guayule growing area for some units. See text for discussion.

2/Does not include 1,321,000 acres with rights to Colorado River water.

Source: California Department of Water Resources, 1970a.

region of the State (See Figure III-26). These areas inclue more than 90 percent of the irrigated and irrigable agricultural lands in the State (See Figure III-27).

Central Valley region, Sacramento Basin: The Sacramento Basin is the second largest water-producing area in the State. About 21 million acre-feet of natural runoff orginates annually in the Basin, amounting to about 30 percent of California's total natural runoff. The Sacramento River is the largest in the State.

The Sacramento Basin is subject to the periodic devastating floods. An extensive system of flood-control works has been constructed over the years by various agencies including the U.S. Army Corps of Engineers and reclamation and flood-control districts.

In all, the flood-control works within the Sacramento Basin have functioned well in recent years to minimize the disastrous flooding which has been part of Basin history.

More than 90 percent of the water used today in the Sacramento Basin is for farming. Agricultural water use is expected to increase moderately in the future with an annual applied water demand in 2020 of about 7.5 million acre-feet, an increase of approximately 20 percent over 1967 levels.

Agricultural demands are expected to rise at a more rapid rate before 1990; after that date the increase is expected to slow, partly because of urban encroachment and partly because most of the best land with convenient water supplies will be under irrigation by 1990 (See Figure III-28).

Approximately 75 percent of the present and projected irrigated acreage and irrigation water demand occurs in the Sacramento Basin counties that are suitable for guayule production.

Urban demands are expected to approximately double by 2020. Most urban growth is expected to continue near cities.

In summary, the overall outlook for water-supply sufficiency to meet future demands in the Sacramento Basin is excellent. Although much of the Basin will have surplus water, such surpluses generally are not transferable because of location, topography, or other factors; certain areas are expected to have a future deficiency. Most proposed local and federal projects, however, could satisfy these deficiencies (California Department of Water Resources, 1970a).

Annual precipitation in the Sacramento Basin ranges from just under 20 inches in the central valley to as high as 50 inches on valley slopes to the east and west, which suggests strong potential

Figure III-26. Counties in the California potential guayule growth area.

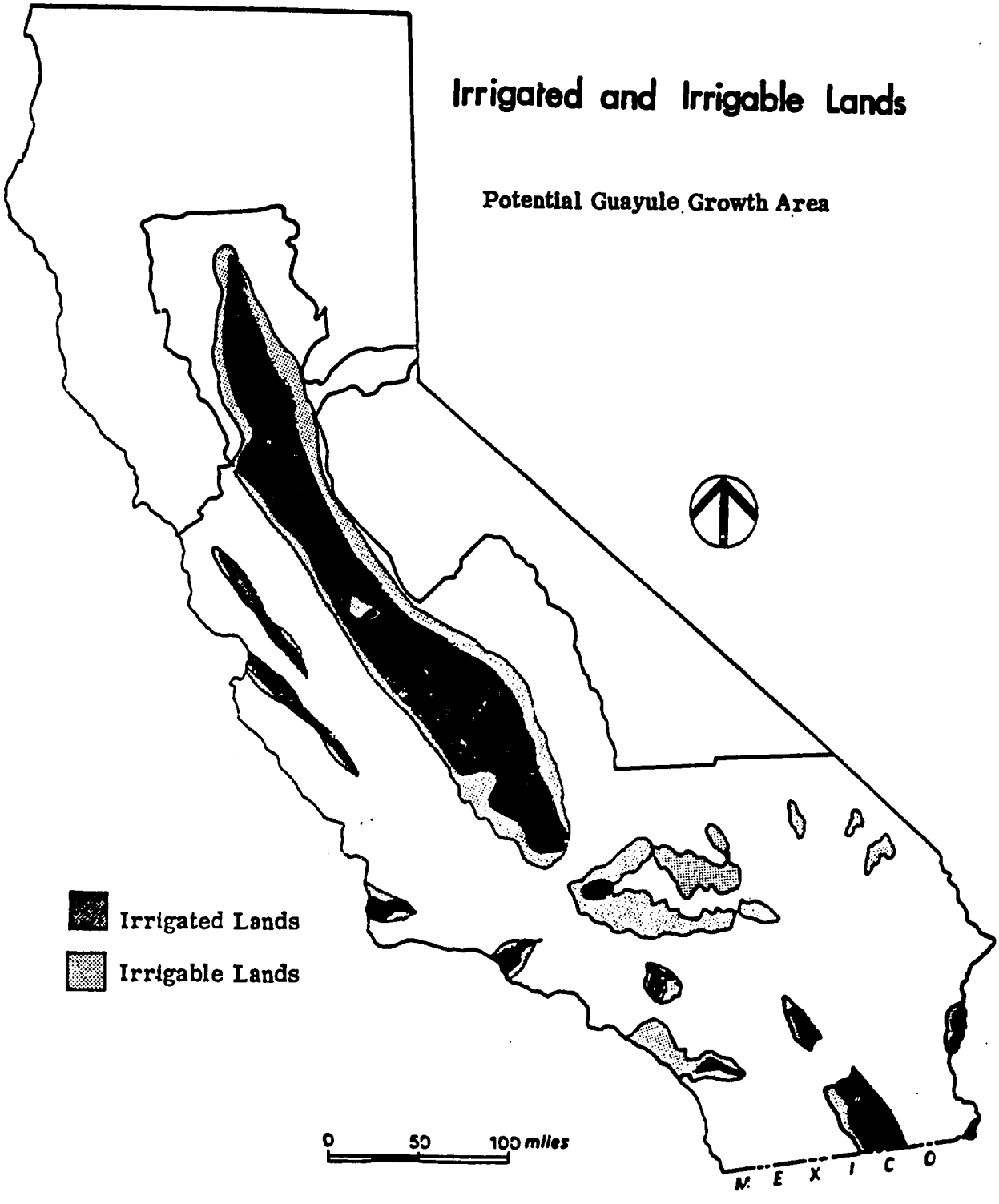


Figure III-27. Irrigated and irrigable lands in California; potential guayule growth area.

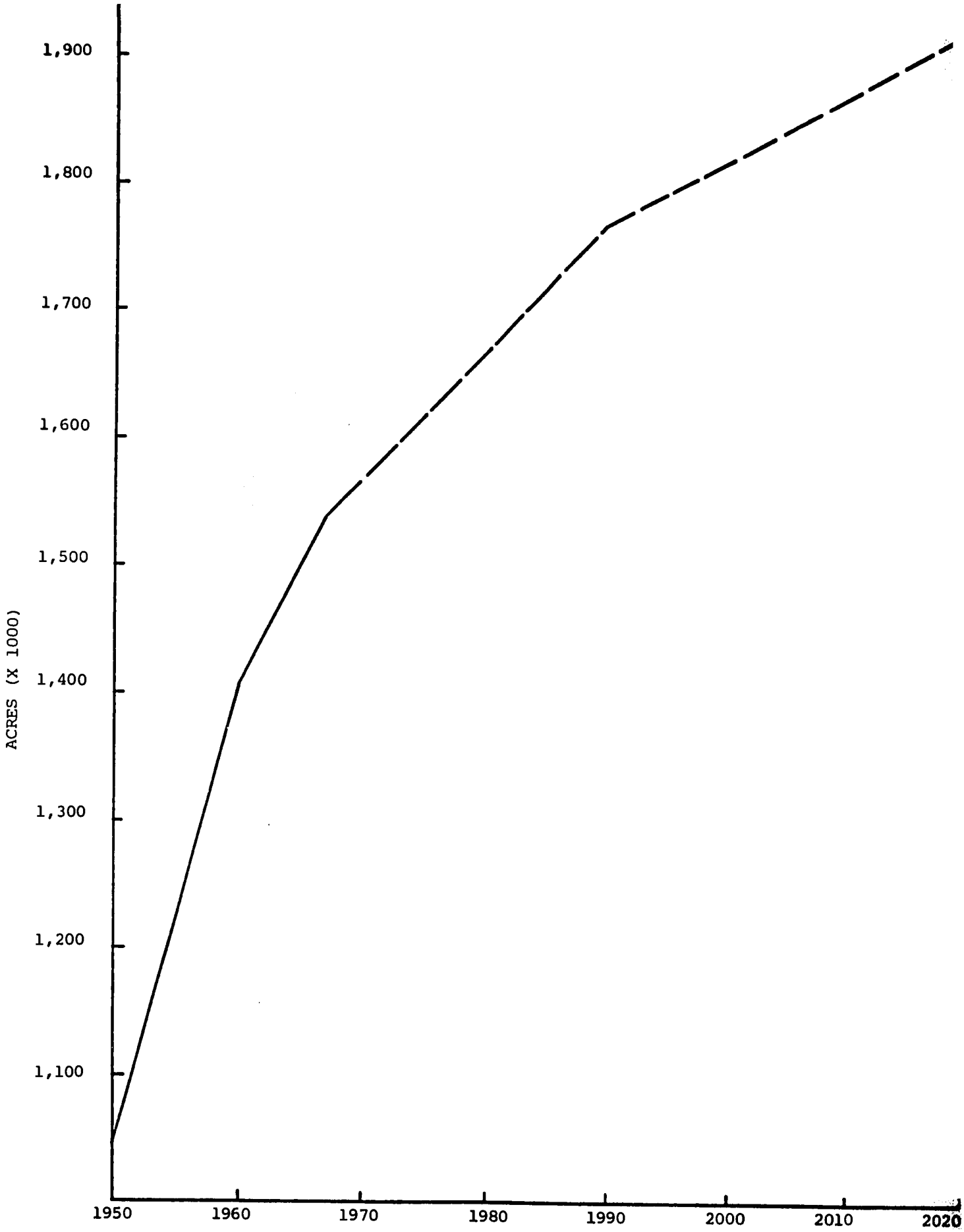


Figure III-28. Sacramento basin hydrographic unit; irrigated acres.

for dryland guayule farming in the Basin. The higher precipitation levels on the upper slopes, however, may preclude guayule production where excessive rainfall would not allow water stress control of the plants for maximum rubber production.

Central Valley region, Delta-Central Sierra: The Delta-Central Sierra area contains the Sacramento-San Joaquin Delta and the watersheds of the Calaveras, Mokelumne, and Consumnes rivers. The Delta consists of many islands, often below sea level, among meandering channels. Behind protective levees, irrigated agriculture has flourished on the rich peaty soils for many years. East of the Delta, Valley lands rise gradually for some distance before reaching the foothills that blend into the rugged mountins of the Sierra Nevada.

The flat Valley lands are similar in appearance and potential use to lands of the Sacramento Valley and the San Joaquin Valley. However more marine influence occurs due to prevailing summer winds coming in through the gap in the Coast Range to the west.

Estimated 1967 agricultural water demand was 2.3 million acre-feet per year, of which slightly more than half was in the Sacramento-San Joaquin Delta. Some increase in irrigated land is expected in the future, mostly in Valley areas surrounding the Delta. As a result, on-farm water demands are projected to increase to 2.5 million acre-feet in 1990 and 2.6 million acre-feet in 2020.

Nearly all of the irrigated acreage in the Delta Central Sierra Unit in the 1970s is within those counties suitable for growing guayule. Some future development of irrigated agriculture is projected for El Dorado, Amador and Calaveras counties which in general are considered to be climatically unsuitable for guayule production. Thus, approximately 85 percent of future irrigated acreages and irrigation water applications will be in the guayule potential areas. Total Unit irrigated acreages are shown in Figure III-29.

Water demands for urban purposes are expected to approximately triple by 2020.

Groundwater is an important water source and meets more than 30 percent of the current demand, partially at the expense of groundwater overdrafts which aggregate to slightly more than 100,000 acre-feet in the area east of the Delta.

A deficiency, or supplemental demand, of about 90,000 acre-feet in 1990 and 180,000 acre-feet in 2020 is forecast for the Delta-Central Sierra area.

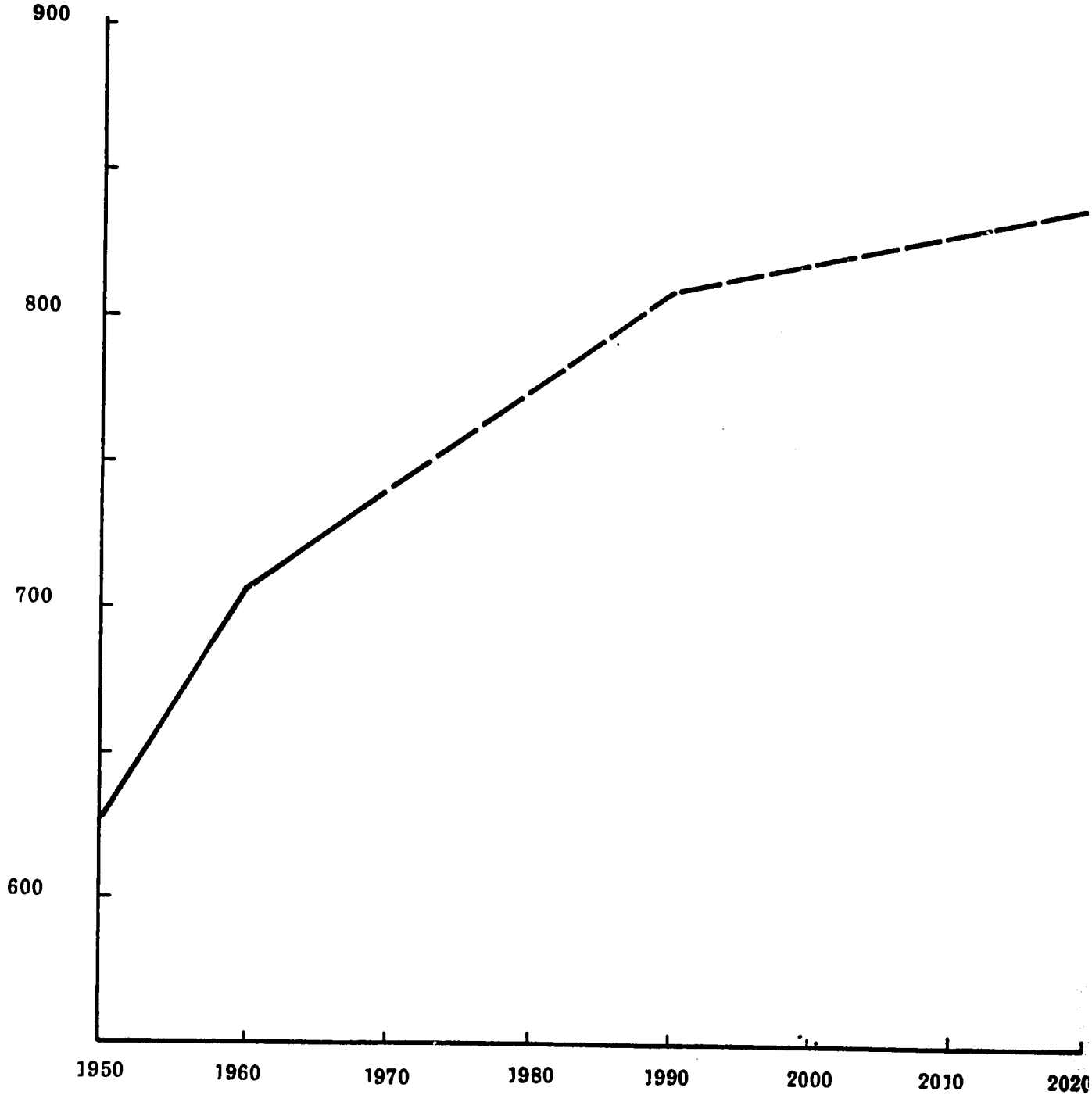


Figure III-29. Delta-Central Sierra hydrographic unit; irrigated acres.

In addition to local agricultural, industrial, recreational, and esthetic values, the Delta is the common collecting and diverting point of waters southward to meet the growing water needs of the San Joaquin Valley and Central and Southern California.

Water quality has been a problem in the Delta from the time that low-lying lands were originally reclaimed and farming began. In the past these problems have been caused primarily by the intrusion of ocean salinity from the tidal movement, especially during periods of very low fresh water outflow. During such low-flow conditions much of the Delta could not be irrigated because of the intolerable salinity in the channels and sloughs which served as water supply sources.

Summer releases of stored water from Shasta Reservoir, together with Folsom and Oroville reservoirs in recent years, have vastly reduced the salinity intrusion problem.

Water quality deterioration in the Delta has been intensified with increasing agricultural drainage and industrial wastes discharges into Delta channels, expanded use in the Central Valley, and increased Central Valley water export to the Bay area. It has been recognized that these problems will become more aggravated in the future unless steps are taken to protect and preserve the Delta environment (California Department of Water Resources, 1970a).

Annual precipitation in the Delta-Central Sierra ranges from 10 inches in western San Joaquin County to 20 inches in eastern Sacramento County. In general, guayule cultivations in this hydrographic unit would require some supplemental irrigation.

Central Valley region, San Joaquin Basin: The San Joaquin Basin consists of the entire drainage area of the San Joaquin River and its tributaries upstream from the San Joaquin River gauge near Vernalis at the southerly edge of the Delta.

The average annual runoff of the Basin is six million acre-feet. The major streams are the San Joaquin River and its three major eastside tributaries, the Stanislaus, Tuolumne, and Merced rivers. In addition, large amounts of water are imported via the Delta-Mendota Canal, partly as water exchange, permitting diversion of San Joaquin River water at Friant Dam.

As in other parts of the Central Valley a variety of crops can be grown in the San Joaquin Basin. Irrigation development began in the 1870s with diversions of water from major rivers. Expansion of irrigated acreage has continued at a rate of about 10 percent to 15 percent per decade.

Total water applied for all uses in the Basin in 1967 was about 5.7 million acre-feet, of which 5.5 million was for agricultural purposes. Corresponding total net water use (consumptive uses plus irrecoverable losses) was about 4.4 million acre-feet, which was provided by local and imported surface-water and groundwater developments, plus groundwater storage depeletions by nearly 200,000 acre-feet.

The rate of irrigated land expansion, as forecast by the Department of Water Resources, is expected to diminish appreciably, increasing about 25 percent over present levels by 2020 (See Figure III-30). Due to a predicted change in crop patterns, the need for agricultural water is forecast to increase at a slower rate from an estimated 5.5 million acre-feet at present to six million acre-feet in 2020 (California Department of Water Resources, 1970a). Residual salt from irrigation application became a problem in both the San Joaquin and Tulare Basins. Unless effective drainage systems are developed to counteract this problem, irrigated agriculture could decline significantly in these two basins.

More than 99 percent of irrigated agriculture in the 1960s and 1970s occurred in the area where guayule could be grown. Some irrigation development is anticipated for Calaveras, Mariposa and Tuolumne counties which lie outside the potential guayule growth area, but irrigaged acreages and water demands still should be 95 percent within the guayule area in future years.

Annual urban water demands, currently about 150,000 acre-feet, are expected to nearly triple by 2020, but will increase to only 7 percent of the total water demand.

Projected water supply deficiencies for the San Joaquin Basin occur primarily in the eastern Valley, most of which would lie outside the potential guayule growing area. These deficiencies, 300,000 acre-feet in 1990 and 560,000 acre-feet in 2020, are anticipated to be met by importing water via the East Side Canal of the Central Valley Project.

Annual precipitation in the San Joaquin Basin ranges from slightly under 10 inches in the central Valley floor to 15 inches along the Valley slopes. Guayule production in this area would require irrigation.

Central Valley region, Tulare Basin: The Tulare Basin encompasses the entire drainage area of the San Joaquin Valley south of the San Joaquin River. It is grossly deficient in the natural water resources; yet, by contrast, it is the largest agricultural area in the State. Satisfying water demands in the Basin, which are the greatest of the 11 hydrologic study areas, relies to a considerable extent on imported water and groundwater overdraft.

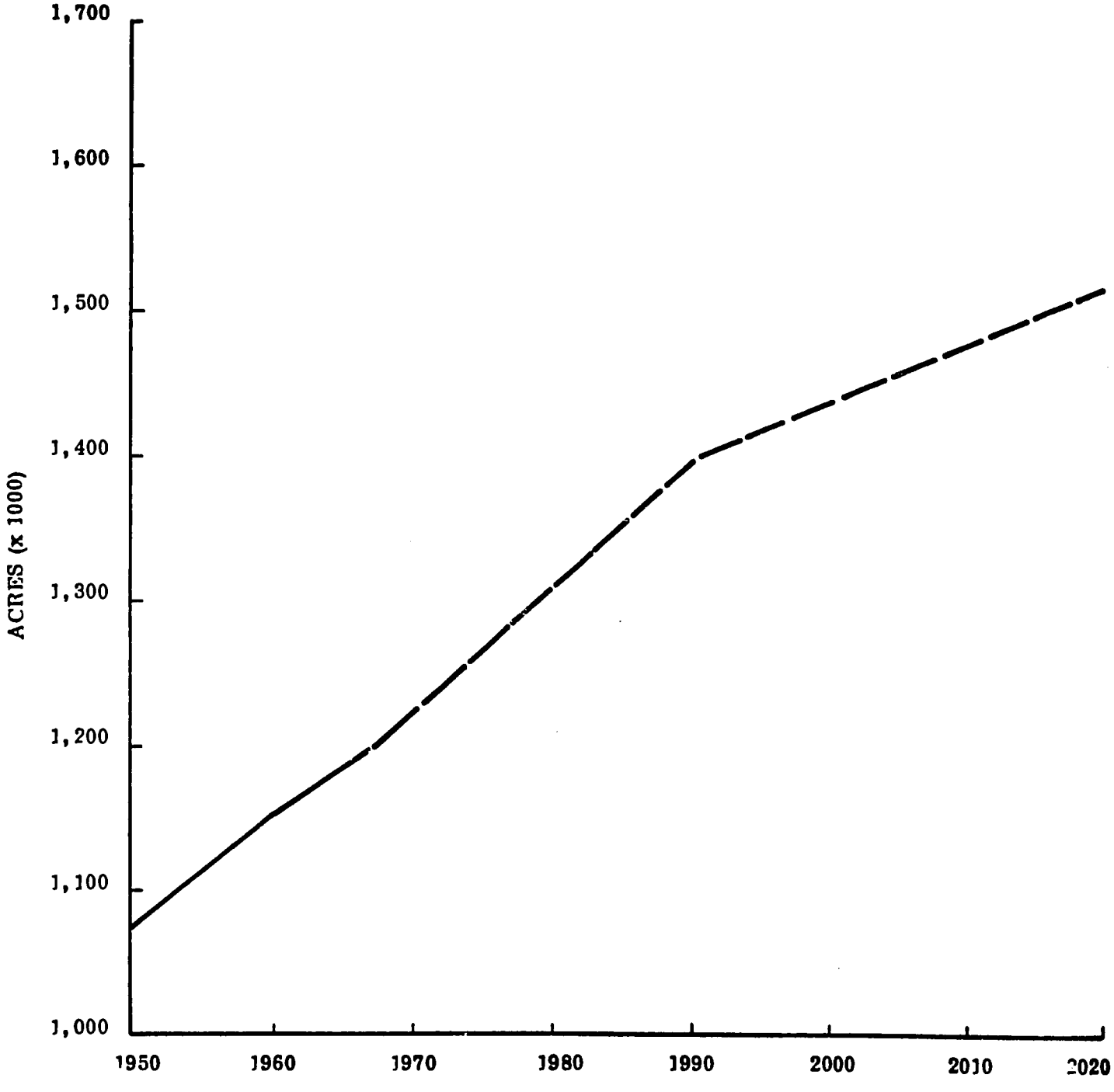


Figure III-30. San Joaquin basin hydrographic unit; irrigated acres.

Natural water supplies in the Basin are derived primarily from Sierra Nevada runoff in the Kings, Kaweah, Tule and Kern rivers. These rivers are sources of direct diversion for agricultural and urban uses, and replenish the underlying groundwater basin by direct percolation.

Water use in the Tulare Basin long has exceeded the natural water supplies, and supplemental supplies have been imported via the Central Valley Project Friant-Kern and Delta-Mendota canals. In 1967 the total amount of all water available for sustained use in the Basin averaged about 4.6 million acre-feet, while net water use amounted to about 6.4 million acre-feet. The excess of demand over firm supplies is met by a long-term average annual, 1.8-million-acre-foot groundwater depeletion.

Of the 6.4-million-acre-feet net water demand in 1967, 6.2 million acre-feet were consumed by irrigated agriculture. Agricultural withdrawals in 1967 were 9.5 million acre-feet, and are expected to increase to 11.2 million acre-feet by 1990 and to 11.9 million acre-feet by 2020. Associated irrigated acreages are shown in Figure III-31. All of the Tulare Basin Hydrographic Unit falls within the guayule potential area.

Currently, the State Water Project and the San Luis Unit of the Central Valley Project are delivering water to the Basin. Under full delivery those two projects will provide a total of about 2.6 million acre-feet annually. However, even with local developments and these large import projects operating at full contractual capacity, Basin economy is expected to grow to such an extent that the annual water demand in excess of its existing combined yield will be about 1.2 million acre-feet by 1990 and about 2.1 million acre-feet by 2020. This growth in economy is projected on the basis of the extremely favorable combination of soils and climate and advantageous market location.

In summary, it appears that because of the location of the Tulare Basin with respect to potential water supply sources, future water-demand increases most logically could be served by federal and state project facilities that already have the capacity to deliver four million acre-feet annually to the area (California Department of Water Resources, 1970a).

Annual precipitation of up to 20 inches occurs in some irrigated agricultural areas of the Tulare Basin Unit. However, most irrigated agriculture occurs in the Valley floor at the southern end of the Central Valley where rainfall ranges from 5 inches to 10 inches per year. If guayule were introduced again into the Tulare Basin, it would require irrigation.

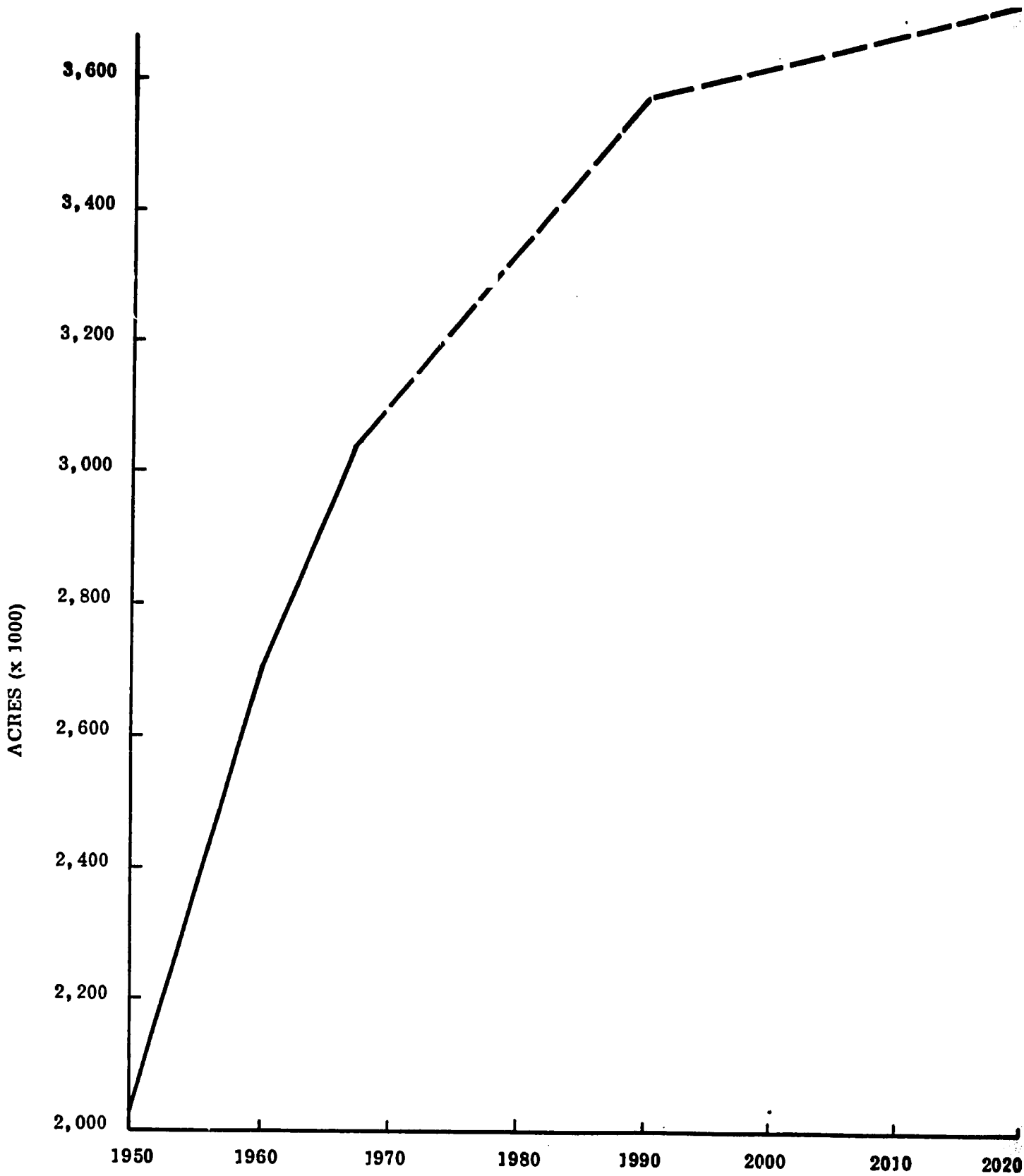


Figure III-31. Tulare basin hydrographic unit; irrigated acres.

Coastal region, San Francisco Bay area: When considered as a whole, the San Francisco Bay area has sufficient water supplies to meet its needs until sometime after 2000. Such a broad statement, however, neglects localized conditions that could lead to water deficiencies in certain areas at a much earlier date. The Bay area has a complex system of water supply and logically can be treated in two parts, the area north of and the area south of San Francisco Bay. With the exception of a relatively small area of irrigated agriculture in Solano County, approximately 40,000 acres in 1950, the guayule potential area is south of the Bay.

The Solano County irrigation area is expected to decrease by slightly more than 12 percent due to urban encroachment.

The South Bay area ranks second only to the South Coastal area in urban growth. It is highly urbanized and is expected to become more so in the future. Population is forecast to more than double between 1970 and 2020. Irrigated agriculture, with a net demand of 166,000 acre-feet in 1967, is expected to be virtually eliminated by urban encroachment by 2020 (California Department of Water Resources, 1970a). Thus, the potential for developing guayule agriculture in the San Francisco Bay Unit is remote. Irrigated acres for this unit are shown in Figure III-32.

Coastal region, Central Coastal area: The Central Coastal area essentially spans the coastal interval between the metropolitan centers of the San Francisco Bay and the South Coastal area. Mountain ranges that follow the coast extend through the area and many fertile valleys are between them. The major drainage basins are the Pajaro, Salinas, Santa Maria, and Santa Ynez rivers and tributaries.

The economy is based primarily on agriculture and related activities. In 1967 about 25 percent of the truck crops produced in California were grown in the intensely developed valleys of the area. About 800,000 acre-feet of water from local ground- and surface-water supplies were used in 1967 to irrigate approximately 350,000 acres. Irrigated acreage is not expected to expand greatly in the future (390,000 acres by 2020) because of scattered parcels that would be difficult to farm economically (See Figure III-33).

The entire Central Coastal Hydrographic Unit is within the potential guayule growing area.

The major urban centers of the Central Coastal area are situated in the Monterey Bay urban complex and the Cities of San Luis Obispo, Santa Maria and Santa Barbara. New urban water demands amount to about 150,000 acre-feet per year. A rapidly increasing population is expected to increase these demands to 470,000 acre-feet by 2020.

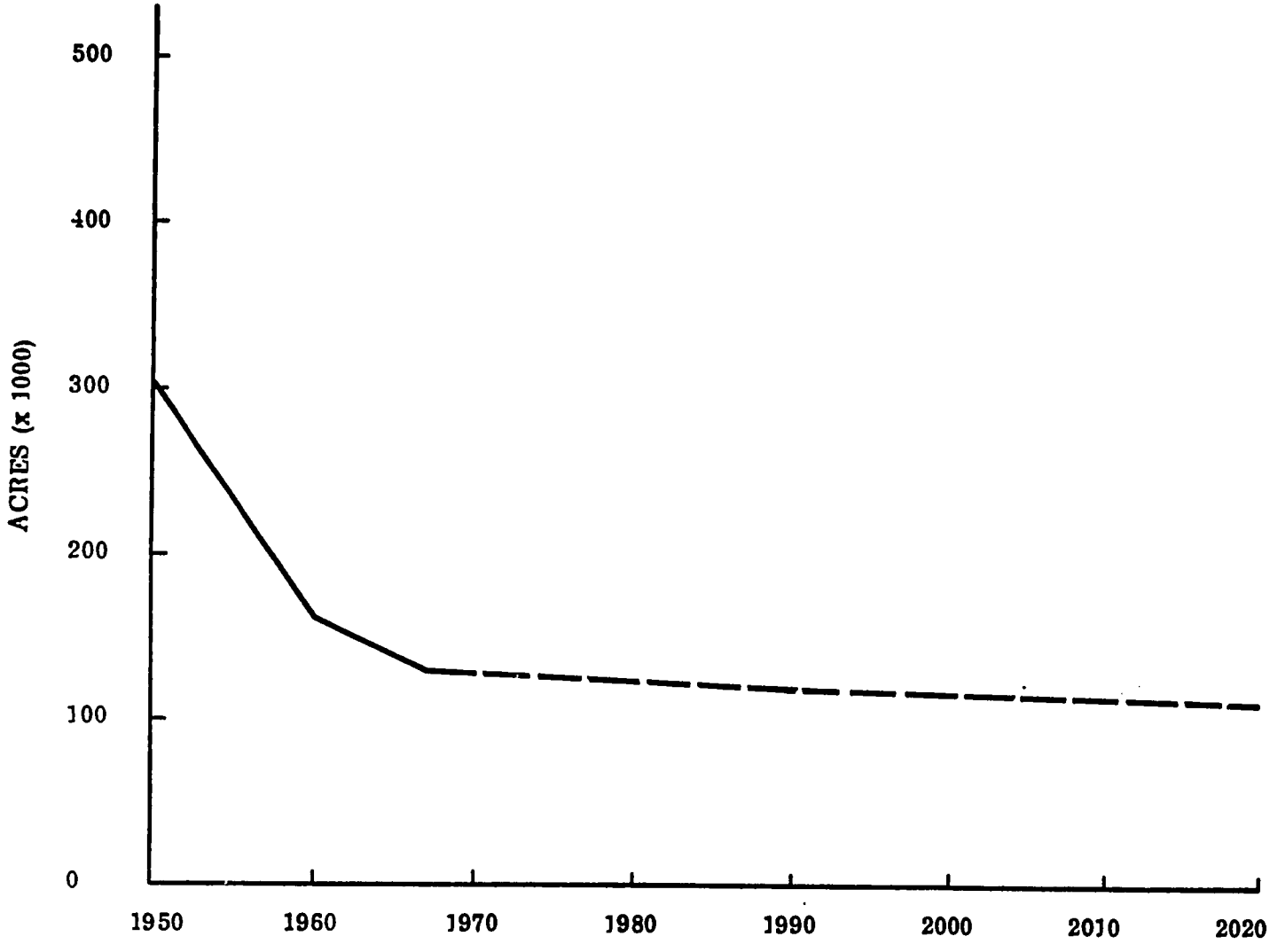


Figure III-32. San Francisco Bay hydrographic unit; irrigated acres.

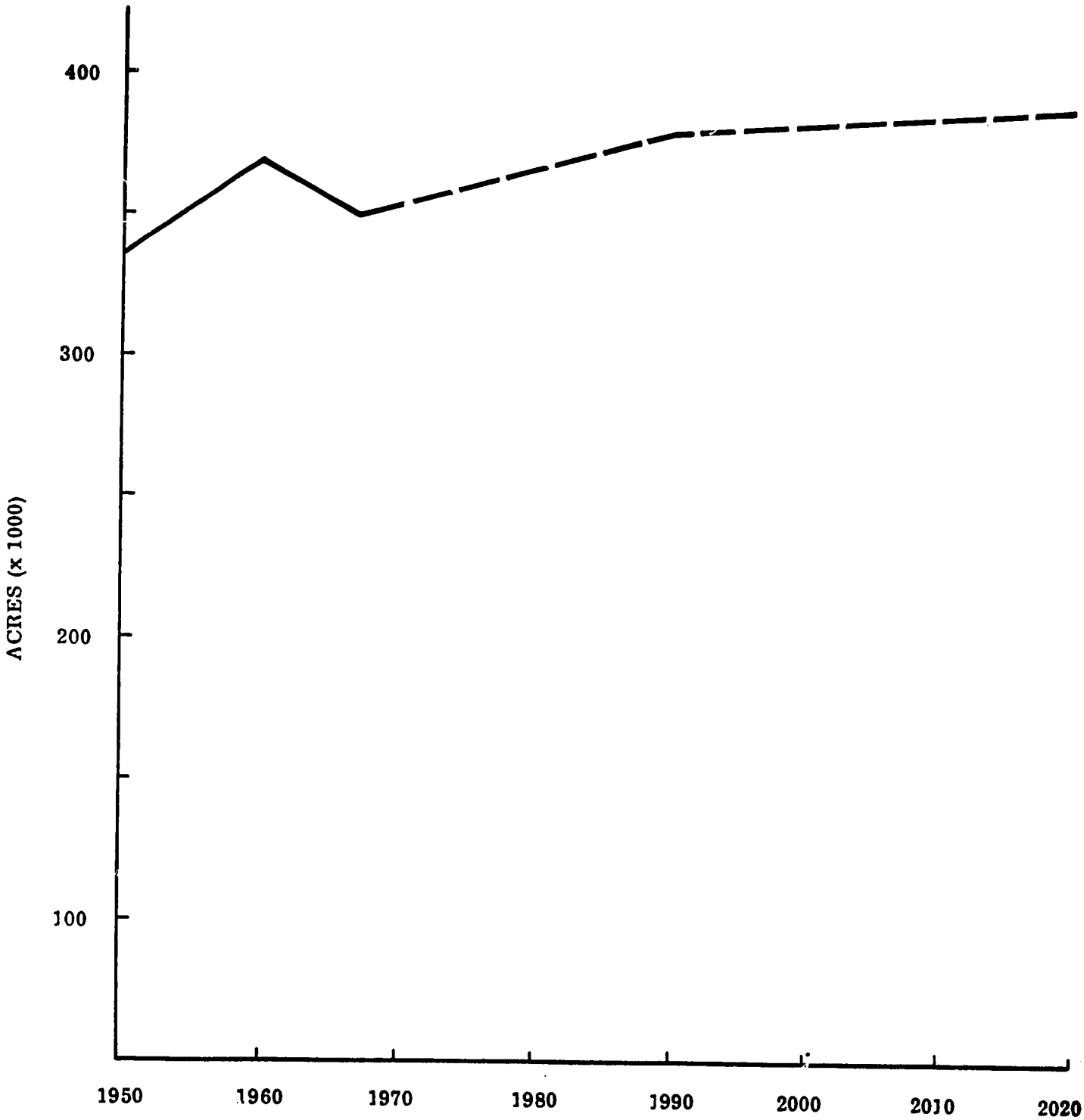


Figure III-33. Central coastal hydrographic unit; irrigated acres.

Also, the present water requirement of 5,000 acre-feet per year for fish, wildlife and recreation is expected to double by 2020.

Groundwater is the main source of supply in the Central Coastal area. However, agricultural growth and urban expansion has caused groundwater levels to fall in many areas such as the Salinas Valley. A complex of dams, canals and percolating basins has been constructed to conserve runoff from the principal streams and to place the water in aquifers.

The present annual net water demand of 940,000 acre-feet exceeds the firm water supply by 120,000 acre-feet. The difference is obtained by overdrafting groundwater.

Almost all of the 1990 estimated demand for supplemental water is in the northern portion of the Central Coastal area, mostly in the lower Salinas Valley and, to a lesser extent, in Santa Cruz County and the coastal Monterey Coast-Carmel Valley vicinity.

About half of the projected 360,000 acre-feet annual deficit in 2020 is estimated to occur in the lower Salinas Valley. The balance is forecast to be divided about equally between Santa Cruz County, Monterey Coast-Carmel region, and Santa Barbara and San Luis Obispo counties.

Studies indicate that there are large volumes of water in some Central Coastal area groundwater basins; it is likely that well owners will continue to deplete certain basins. Pumping will probably continue until limited by economics, quality problems, legal restrictions, or organizational controls (California Department of Water Resources, 1970a).

Rainfall for most of the Central Coastal Hydrographic Unit irrigated agricultural area, ranges between 10 inches and 20 inches per year. Although successful production of guayule in this unit generally would require supplemental irrigation, such low-water-demand crops as guayule might offer an attractive alternative for farmers in areas where groundwater is being depleted and supplemental water supplies appear unlikely to be forthcoming.

Coastal region, South Coastal area: the South Coastal area is the most populous and is the leading industrial and commercial center in the State. It is one of the fastest growing areas in the entire country, and this growth is likely to continue. There has been a shift from an almost entirely agriculturally based economy to one of industry and commerce.

Reflecting the increasing urbanization, the total water demands of the South Coastal area, including agricultural demand, are

projected to grow from about 2.5 million acre-feet per year to 5.3 million acre-feet in 2020, more than twice the present demand.

To meet present water demands, the South Coastal area depends on: 1) local surface-water and groundwater supplies, which are developed almost fully if water use is based on the average annual natural replenishment; 2) the Los Angeles Aqueduct, which was enlarged in 1970 to deliver approximately 280,000 acre-feet annually to the City of Los Angeles; and 3) the Colorado River Aqueduct, now delivering water at almost full capacity of about 1.18 million acre-feet per year to the Metropolitan Water District of Southern California. Currently, the total water supply available to the area is about equal to its water demand--2.5 million acre-feet in 1967.

In 1971, deliveries began from the State Water Project to the service areas of the Metropolitan Water District of Southern California and other water agencies in the South Coastal area. The total maximum entitlement to the Project is 2,204,000 acre-feet per year.

The water supply from the Colorado River will be reduced to about 550,000 acre-feet per year when the Central Arizona Project becomes operational. It is expected that this reduction will occur in the mid-1980s. Nevertheless, the total supply available to the South Coastal area, including State Water Project entitlements, should be adequate to meet water demands beyond 2000, when a demand for supplemental water is anticipated to begin (California Department of Water Resources, 1970a).

As indicated above a significant shift, however, continues to occur in the South Coastal area from agriculture to industry and commerce. Irrigated acreage in the area is expected to decline by 2020 to less than half the 1967 average (See Figure III-34). Irrigation water withdrawals are anticipated to drop from more than a third of total water withdrawals in 1967 to less than one-tenth by 2020.

Annual precipitation in most of the South Coastal area irrigated agricultural region is approximately 15 inches, although there are a few areas as low as 10 inches and a few as high as 20. All of the South Coastal area is within the potential guayule growing area.

Guayule conceivably could help to relieve pressures resulting from declining agricultural water supplies, but the probability of its introduction in an area of declining agriculture and rapid urban expansion is low.

Southeastern region; Colorado Desert: The Colorado Desert area occupies the extreme southeastern portion of California, encompassing Imperial County and portions of San Diego, Riverside, and San

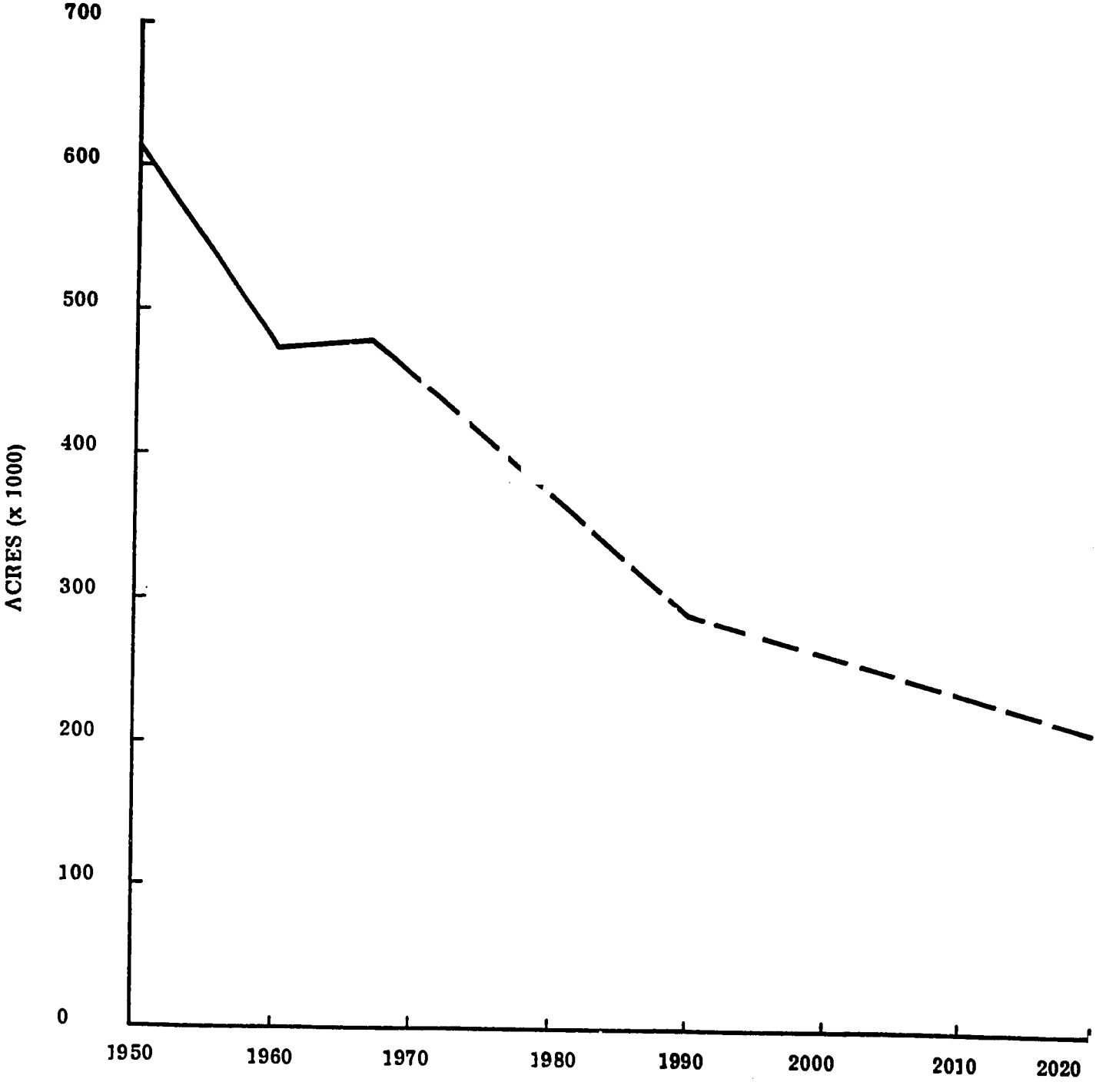


Figure III-34. South coastal hydrographic unit; irrigated acres.

Bernardino counties. The main geographic features are the Colorado River and the Salton trough that embraces the Salton Sea and Imperial and Coachella valleys. The area drains into the Colorado River and into the Salton Sea, the lowest part of the closed Basin.

The Colorado Desert area is characterized by the driest climate in the State and has generally mild winter and very high summer temperatures. This area has not had rapid urbanization because of its extreme summer temperatures and its distance from metropolitan centers.

Most of the Salton trough is below sea level and virtually frost-free which permits growing agricultural crops year-round. This, along with availability of low-cost water, has permitted developing an irrigated agricultural economy second only to the vast Central Valley area. Because of the substantial amount of land remaining that could be developed, urbanization is not likely to curtail irrigated acreage.

Four agencies in the area--the Palo Verde and Imperial irrigation districts, Yuma Project Reservation Division, and Coachella Valley County water districts--have annual diversion rights to 3,850,000 acre-feet of Colorado River water, according to the Seven-Party Agreement of August 18, 1931. The decision of the U.S. Supreme Court in Arizona vs. California and the Colorado River Basin Project Act will make it possible for water diversions to continue at that level. In addition to Colorado River water, more than 100,000 acre-feet of groundwater are used, mostly in Coachella Valley.

Total water demands of the area are projected to increase from 3,980,000 to 4,140,000 acre-feet in 2020.

Of these water demands, more than 95 percent is for irrigated agriculture. Associated acreages are shown in Figure III-35.

Colorado River water available to California historically has had a relatively high salt content. From 1963 to 1967 it averaged 740 parts per million dissolved minerals at Parker Dam and 850 parts per million at Imperial Dam, where diversions to the irrigation districts are made. These salt levels have required installing extensive networks of tile drains and applying quantities of water considerably in excess of the actual requirements for plant growth to prevent salt build-up and ensure continued successful farming operations.

Without implementing corrective measures, salinity of Colorado River water at Imperial Dam could be expected to increase to more than 1,300 parts per million by 2000. Salinity control projects are scheduled for the Colorado that are expected to hold salinity at Imperial Dam to about 1,000 parts per million.

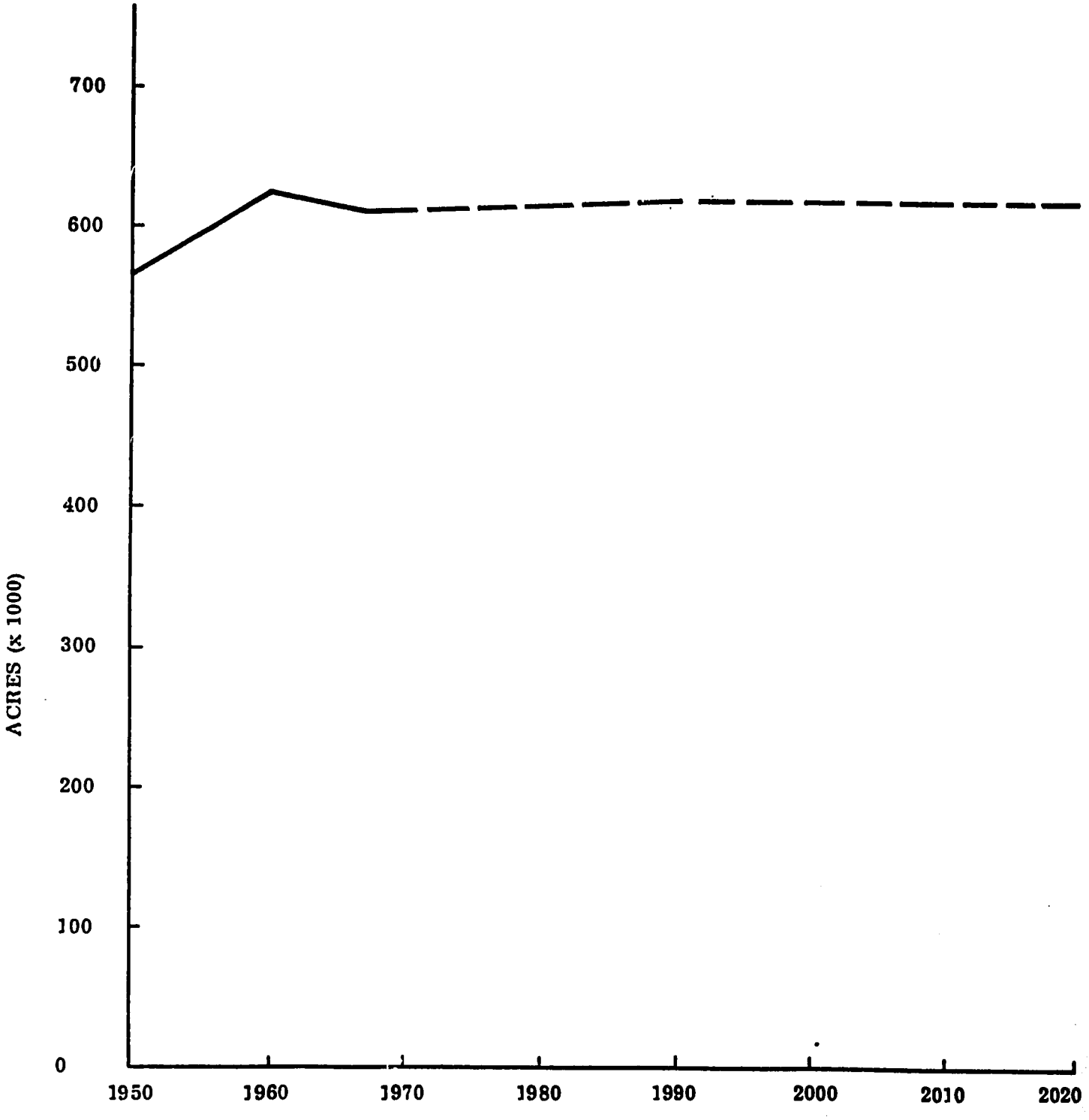


Figure III-35. Colorado desert hydrographic unit; irrigated acres.[1]

1: Does not include land with Colorado River water rights.

Groundwater quality in the Coachella Valley is good. Dissolved minerals in the area are generally less than 200 parts per million.

Imperial Valley groundwater quality is considered to be unsuitable for domestic and irrigation purposes except in a few isolated areas. This has limited the use of groundwater in the area to extremely small amounts (California Department of Water Resources, 1970a).

Irrigated agricultural acreages for the Colorado Desert Hydrographic Unit are expected to remain constant through 2020. This is primarily a function of water availability, because ample land is available to expand greatly agriculture in this region. Rainfall averages 5 inches or less per year in most of the region. Introducing low-water-demand crops such as guayule could effect an expansion of irrigated acreage in this desert area. The entire Colorado Desert Hydrographic Unit is within the potential guayule growing area.

Southeastern region, South Lahontan area: The South Lahontan area encompasses that portion of Lahontan Hydrologic Drainage Province from Mono Lake south and is characterized by a large number of enclosed basins and sinks. It has the greatest elevation extremes within the contiguous United States, ranging from 282 feet below sea level in Death Valley to 14,495 feet above sea level on Mount Whitney, only 80 miles distant.

The economic development of the area was slow in the 1960s, but has begun to quicken recently in Antelope Valley and south of Victorville, San Bernardino County.

Agricultural water demand in the area, about 550,000 acre-feet per year, is anticipated to remain approximately the same until 1990 and to diminish slightly thereafter due to forecast urbanization around Palmdale. The total net water demands in the area are estimated to be about 420,000 acre-feet per year in 1967 and 500,000 acre-feet in 2020 (California Department of Water Resources, 1970a).

Mono and Inyo counties are outside the potential guayule growing region. Thus, approximately 22 percent of the hydrographic unit's irrigated agriculture is outside the guayule area. The primary agricultural area in the Unit will continue to be the Antelope Valley--Mojave River area, which is within the guayule area. Eighty-seven percent of the projected acreages and irrigation water demands for 2020 are within the guayule potential zone. Figure III-36 shows projected irrigated acreages for the entire South Lahontan Unit.

California State Water Project water was scheduled for delivery to the Antelope Valley--Mojave River area in 1972. Maximum

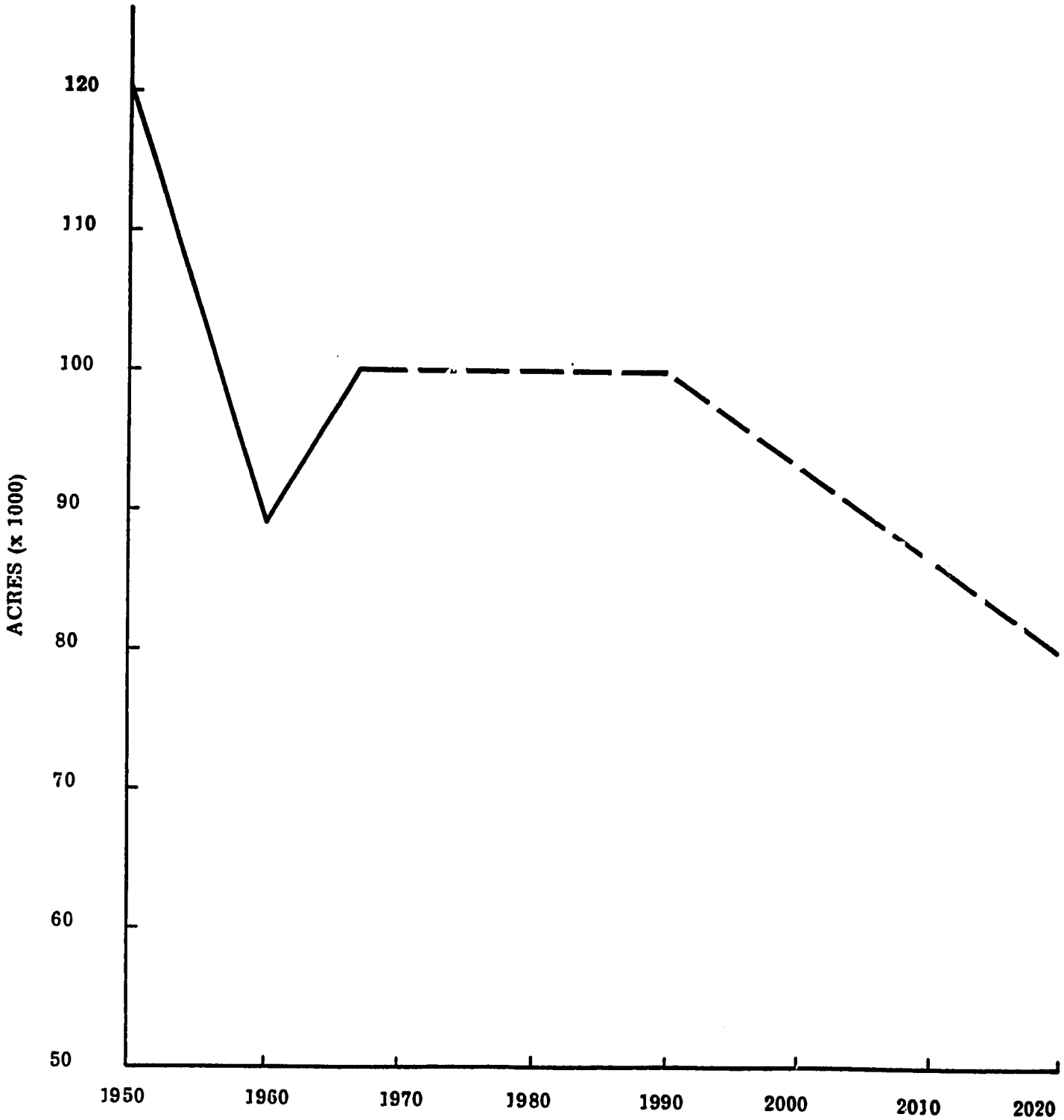


Figure III-36. South Lahontan hydrographic unit; irrigated acres.[1]

1: Does not include land with Colorado River rights.

entitlements are for 215,000 acre-feet per year. This supply meets the 1967 level of supplemental demand, thus allowing a relatively stable level of irrigated agriculture.

Annual precipitation in the unit ranges from 5 inches to 10 inches in Kern and Los Angeles counties to 5 inches or less in most of San Bernardino County. Guayule cultivation in this region would require irrigation.

iii. Overview: Several opportunities for guayule development exist in California. Possibilities for dryland guayule farming exist in the northern Central Valley, in the Sacramento Basin and the Delta-Central Sierra. These two areas have abundant water, but little pressure exists for planting low-water-use crops. The southern Central Valley area receives sufficient water supplies through federal, State, and local water development projects to accommodate continuous expansion of irrigated agriculture if salinity build-up is overcome. Guayule production should have strong impetus in this area if it can become economically competitive.

The Coastal Region shows the least potential for guayule production. The San Francisco Bay and South Coastal units are rapidly expanding in urban areas, hence have rapid reduction in agriculture. The Central Coastal area shows some promise for guayule development in areas where groundwater overdrafting and lack of supplemental water are expected to curtail irrigated agriculture.

In the southeastern region, guayule also should have good production potential. Water supplies are expected to be fairly constant over the next several decades while surplus, suitable land exists. This suggests some incentive for introduction of low-water-demand crops.

g. Agricultural water use in Nevada: The Water Resources Council "Great Basin Region" encompasses most of Nevada and Utah. This region is described as having insufficient surface and groundwater to meet demands placed upon it. Consumptive water use is projected to increase 28 percent from 1975 to 2000. Irrigated agriculture is expected to consume 83 percent of year-2000-water (Viessman, et al, 1978).

i. Nevada water law: Nevada administers groundwater conjunctively with its surface water under a doctrine of appropriation. The first Nevada water code, enacted in 1913, declared that "the water of all sources of water supply within the boundaries of the State, whether above or beneath the surface of the ground, belongs to the public" (Nevada Statutes 1913, Chapter 140, Section 1).

As a general policy, the State Engineer regulates water appropriations and has restricted groundwater withdrawals to average annual replenishment, or safe-yield levels in accordance with the Nevada Code intentions.

Problems of emerging population and industrial expansion, however, have not been adequately addressed. In Clark County, "temporary" groundwater mining is being allowed in the Las Vegas Valley (Chalmers, 1974).

ii. Nevada guayule potential: In the State of Nevada, only Clark County is in the potential guayule development region (See Figure III-37). Clark County is more characteristically urban and recreational than agricultural. Las Vegas is in the center of the County and had a 1970 population of 265,000. It has a projected population of 1.2 million by 2020 (Nevada State Engineer, 1971a). The southeastern border of the County contains a portion of Lake Meade National Recreation Area. Irrigated agriculture used 1.6 percent of Clark County land area in 1970 (Nevada State Engineer, 1971b).

Water planning for the future of Clark County concentrates primarily on projected expansion of urbanization and recreation. Nevada is planning to meet increasing water demands by using 300,000 acre-feet of allocated Colorado River water annually and by implementing some intrastate water transfer systems. Urban expansion can be expected to displace irrigated agriculture in the Las Vegas Valley, but some increases in agriculture are possible in the Virgin Valley and Fort Mojave areas where supplies are reported to be sufficient to meet demand projections (Nevada State Engineer, 1971a). Irrigated acreages and water applications therefore are assumed to remain fairly stable for Clark County (See Table III-15).

Average annual precipitation for Nevada is 8.25 inches (Nevada Crop and Livestock Reporting Service, 1978). Clark County reflects this low precipitation pattern of the State. Some areas such as the Las Vegas Valley receive as little as 4 inches per year (Nevada State Engineer, 1977b). Guayule production, therefore, would depend on irrigation. Introduction of guayule would depend on two factors: 1) successful economic competition; and 2) demonstration that guayule can be grown successfully in this area. The Nevada State Division of Forestry is conducting agronomic experiments with guayule in Clark County.

h. Crop patterns and diversification: In this section the current status of agriculture in Texas, Arizona, New Mexico, California and Nevada is presented. Information is provided on cropped acreage, production value and man-hours of labor.

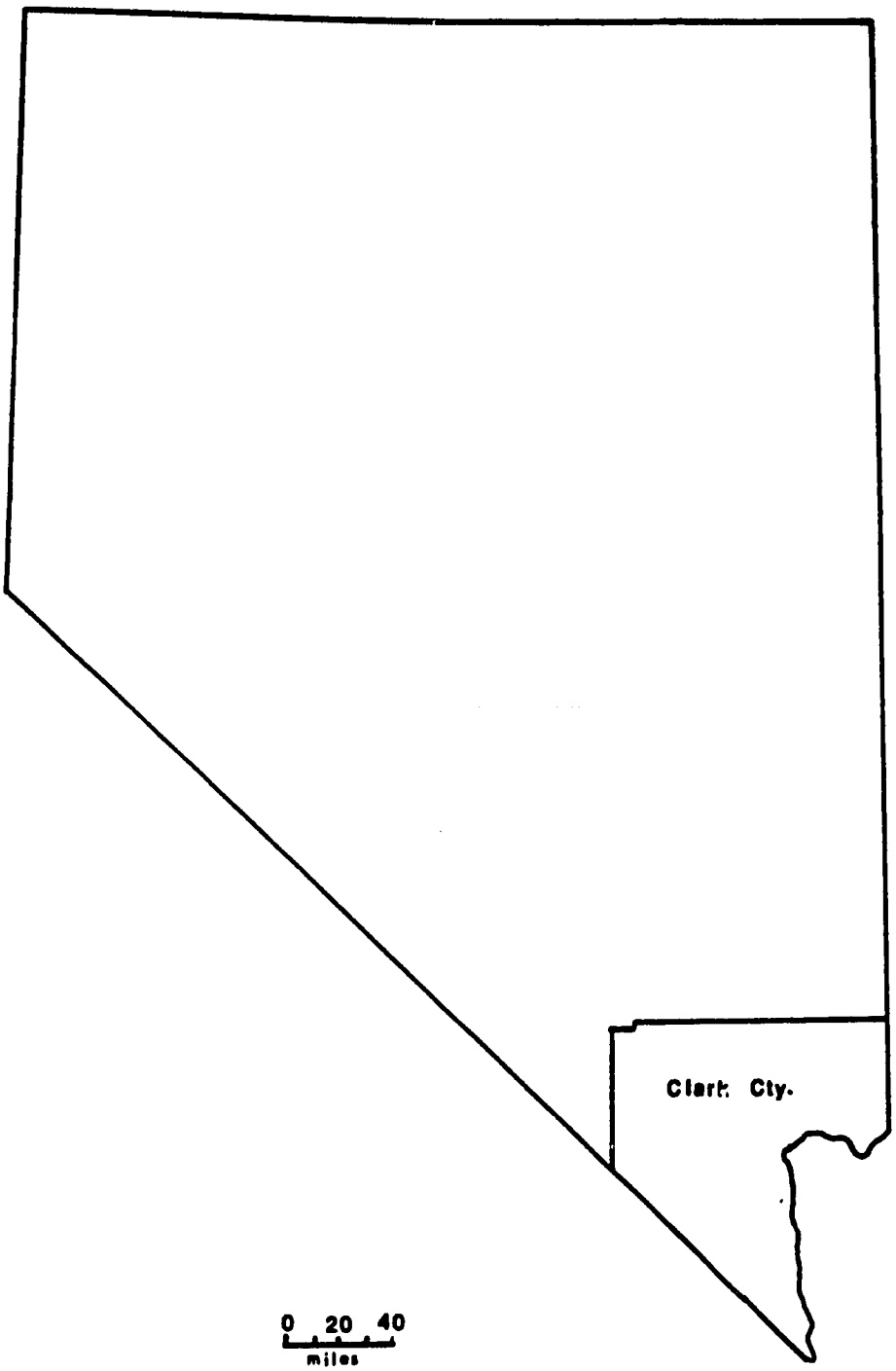


Figure III-37. Potential guayule growth area; Nevada.

TABLE III-15

CLARK COUNTY, NEVADA WATER WITHDRAWALS AND

IRRIGATED ACREAGE

1970 and 2020

	Agric. Water Withdrawals (acre-feet)	Total Water Withdrawals (acre-feet)	% Agric.	Irrigated Acres
1970	63,000	202,690	31	11,290
2020	63,060	781,000	8	11,000

Sources: Nevada State Engineer 1971a
Nevada Crop and Livestock Reporting Service 1978

When gathering and analyzing data on cropping patterns it must be considered that the nature of agriculture is constantly shifting. Not only does total cropland acreage change, because of new-field openings and old field losses to such actions as urban encroachment, but also year-to-year shifts in acreage among the crops grown occur.

Crop data were collected for the years 1975, 1976 and 1977, for each county in the 90-county potential guayule-growing region, except for Clark County, Nevada, for which no data were available. In an attempt to provide baseline data for subsequent regional impact analyses, information was collected on harvested acreage, quantity of agricultural production, value of agricultural production, and, with the aid of man-hour estimates, the relative amount of labor required to produce each crop.

Initial findings indicated that crops tended to fall into two distinct categories, field and tree, and fruit and vegetable crops. Field crops generally occupy large amounts of land, produce small cash receipts per acre, have minimal labor requirements, and vary greatly in acreage for any particular crop from year to year. Tree, fruit and vegetable crops, on the other hand, usually require small amounts of land, produce large per-acre cash receipts, have high labor requirements and have relatively stable acreages during the years of cultivation. Due to the relative stability and high economic return for orchard and vegetable crops, guayule can be expected to impact primarily on field crops.

Field crops in the potential guayule growing region, excluding Clark County, Nevada, average more than 10.5 million acres annually for the 1975-1977 period. Of this total, Arizona averaged 1.1 million harvested acres, New Mexico averaged 0.13 million harvested acres, Texas averaged 2.9 million harvested acres, and California averaged 6.4 million harvested acres of field crops. The basic field crops are upland cotton, American Pima cotton, hay--mostly alfalfa--wheat, barley, corn, soghum, safflower, sugar beets, rye, soybeans, sugar cane, peanuts, flaxseed, rice, and oats. The potential guayule growing region also contains nearly all of Arizona, much of Texas, and most of California's fruit, nut, and vegetable acreages.

Guayule has potential to increase crop and agricultural diversity in several aspects. As an additional crop, which is well suited to the area, guayule will increase the farmer's choice of crops. Guayule also can serve as a form of drought insurance since it can tolerate drought years with far less irrigation water than most conventional crops. Because guayule can be harvested any time after some four years, farmers can delay harvesting until years when the market value is high. Farmers also can schedule harvesting around other farm activities. Finally, since guayule is not likely to be

replacing tree and vegetable crops, it will have little impact on regional, high-value, high man-power crops.

i. Texas: The potential guayule growth areas in Texas consist of 42 counties in the Big Bend area and the southern extension of the State. These counties are listed in Table III-16. Approximately 23.2 million acres of field crops and vegetables were harvested in Texas in 1977; these counties accounted for 3,196,000 acres or 13.8 percent of the total. In 1977, however, 141,000 acres of vegetables were harvested in the 42 counties which constituted two-thirds of all harvested vegetable acreage in Texas. This region produced 20.5 percent of the total crop value in Texas in 1977.

In 1977, 10 percent of the 42 counties accounted for about 63 percent of the total harvested acreage of field crops and vegetables (See Table III-16). In descending order of importance, these counties were Hidalgo, Nueces, Cameron, San Patricio, Williacy, Jim Wells, Bee, Medina, Wilson, and Guadalupe. Together these same counties account for 67 percent of the total crop value in the area at that time. To consider the top ten counties according to total crop value, a somewhat different set emerges: Hidalgo, Cameron, Willacy, Nueces, San Patricio, Zavala, Frio, Starr, El Paso, and Uvalde. Together these counties accounted for 75 percent of the total crop value. Hidalgo County produced some 30 percent of the total value. While there is some change in the specific order of the counties, these units were equally important in 1975 and 1976.

Table III-17 presents agricultural statistics for the dominant crops in the 42-county area, but does not include tree crops or vegetables. For the years 1975 through 1977, sorghum, upland cotton, wheat, corn, and oats represent 93 percent of the total planted acres. Sorghum, upland cotton, hay, wheat and corn emerge as the dominant crops with 93 percent of the total harvested acres reported in Table III-17. The potential guayule growth areas produce more than $400 million worth of crops not including vegetables or tree crops. Eighty-nine percent of this production value is in sorghum (41 percent), upland cotton (26 percent), hay (9 percent), peanuts (6 percent) and corn (6 percent). Therefore, in terms of value per harvested acre upland cotton, peanuts, and corn perform quite well. Relative to value, sorghum and hay require larger inputs of land than do the other products.

The top five crops in terms of value also require the largest amounts of man hours to be produced in the region: sorghum (54 percent), upland cotton (21 percent), hay (12 percent), peanuts (4 percent) and corn (4 percent). Relative to value, sorghum and hay require larger inputs of labor than do upland cotton, peanuts and corn.

Nueces produces the most sorghum (18 percent), Cameron the largest quantity of upland cotton (23 percent), El Paso the most hay (13 percent), Frio the bulk of the peanuts (37 percent) and Uvalde the most corn (14 percent).

TEXAS TABLE III-16

COUNTY	TOTAL HARVESTED ACREAGE OF FIELD CROPS AND VEGETABLES 1975	1976	1977	TOTAL CROP VALUE (1000 DOLLARS) 1975	1976	1977
El Paso	52,100	57,030	50,465	17,327	16,941	18,794
Hudspeth	26,350	37,260	40,020	8,417	8,694	9,772
Culberson	6,680	4,055	17,435	4,153	1,605	5,285
Reeves	49,100	26,430	21,955	13,404	6,828	6,006
Jeff Davis	800	1,600	0	244	263	78
Pecos	29,550	19,815	19,190	9,884	5,503	7,570
Presidio	1,000	2,235	3,690	3,698	2,376	6,702
Brewster	1,100	0	0	42	1	3
Kinney	11,100	4,470	8,640	2,490	1,910	2,836
Uvalde	75,490	58,360	89,770	12,427	11,533	18,288
Medina	121,125	107,650	120,255	9,751	10,777	12,484
Maverick	25,700	18,165	15,880	3,892	5,161	5,065
Zavala	71,650	60,095	67,015	19,538	21,115	24,158
Dimmit	17,350	10,575	14,060	6,303	4,768	5,850
Frio	97,200	87,131	96,145	23,309	18,846	22,462
La Galle	83,450	28,845	40,750	8,426	4,423	4,860
Webb	9,200	4,945	4,105	2,725	2,822	3,745
Guadalupe	85,725	74,075	101,915	5,380	6,358	7,745
Atascosa	77,900	64,552	70,855	12,899	9,715	11,999
Wilson	89,800	84,975	102,505	8,089	10,261	10,675
Karnes	85,600	68,900	72,900	3,308	2,370	3,276
De Witt	48,900	33,420	31,650	2,270	1,557	2,004
McMullen	10,500	9,100	7,100	622	476	330
Live Oak	76,900	59,380	82,800	4,852	2,586	5,105
Bee	75,850	90,510	121,050	4,599	6,621	8,821
Goliad	12,700	15,700	20,000	420	883	1,399
Refugio	68,490	112,230	88,700	7,555	11,516	7,315
Duval	51,810	43,242	57,256	6,189	4,399	5,503
Jim Wells	126,550	84,960	143,170	10,282	6,587	11,201
San Patricio	271,700	271,250	240,055	34,183	36,345	38,987
Nueces	323,300	365,800	341,300	35,033	45,166	46,028
Kleberg	45,800	61,800	68,280	3,540	6,837	9,227
Aransas	4,800	3,100	3,700	506	256	417
Zapata	13,700	1,345	7,955	1,329	601	1,222
Jim Hogg	7,200	5,000	4,200	1,781	979	1,396
Brooks	14,700	12,300	15,520	2,214	2,106	2,519
Kenedy	500	0	1,900	47	21	214
Starr	55,400	65,280	92,180	21,476	20,104	21,377
Hidalgo	464,700	370,085	411,155	176,938	144,419	206,032
Willacy	177,900	195,490	181,490	34,870	40,212	50,293
Cameron	273,600	250,165	243,555	60,822	62,578	75,768
Bexar	78,300	62,159	76,370	8,662	9,828	11,212
TOTALS	3,220,670	2,933,209	3,196,450	593,896	556,347	694,653

1/Texas Crop and Livestock Reporting Service, 1975, 1976, 1977: Texas County Statistics

TABLE III-17

POTENTIAL GUAYULE GROWTH AREA, TEXAS AGRICULTURAL STATISTICS, 1975-1977

Crop	Year	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	1975	188,750	178,910	179,635	39,490.9	3,345,617
	1976	364,450	354,180	372,115	110,027.0	6,623,166
	1977	741,500	723,440	726,375	171,192.1	13,528,328
	$\bar{X}$	431,567	418,843	426,042	106,903.3	7,832,370
American Pima Cotton (bales)	1975	25,600	23,500	11,300	4,306.6	373,065
	1976	8,000	7,450	7,100	3,987.4	139,315
	1977	22,850	22,350	34,950	14,293.2	417,945
	$\bar{X}$	18,817	17,767	17,783	7,529.1	310,108
Wheat (bushels)	1975	294,100	216,300	5,177,900	17,501.3	1,687,140
	1976	256,700	158,450	4,253,200	12,929.7	1,235,910
	1977	173,100	117,200	3,695,100	8,314.0	886,080
	$\bar{X}$	241,300	163,983	4,375,400	12,915.0	1,269,710
Oats (bushels)	1975	168,400	37,200	1,205,000	1,819.5	290,160
	1976	168,800	15,800	477,600	783.3	123,240
	1977	160,300	35,900	1,367,600	1,777.9	280,020
	$\bar{X}$	165,833	29,633	1,016,733	1,460.2	231,140
Barley (bushels)	1975	24,000	17,100	700,600	1,457.2	133,380
	1976	15,600	13,400	651,200	1,400.1	104,520
	1977	19,600	13,550	653,700	1,078.6	105,690
	$\bar{X}$	19,733	14,683	668,500	1,312.0	114,530
Rye (bushels)	1975	1,600	0	0	0	0
	1976	500	0	0	0	0
	1977	500	300	3,600	6.5	2,340
	$\bar{X}$	867	100	1,200	2.2	780
Flaxseed (bushels)	1975	56,900	38,250	458,500	2,998.6	NA
	1976	62,700	48,600	347,500	1,685.4	NA
	1977	9,200	8,300	83,000	489.7	NA
	$\bar{X}$	42,933	31,717	296 333	1,724.6	NA
Sorghum (bushels)	1975	2,131,600	1,988,400	96,544,300	231,938.1	24,038,410
	1976	1,894,200	1,620,300	73,338,300	159,760.1	19,590,890
	1977	1,665,350	1,467,800	53,209,900	101,311.7	17,751,580
	$\bar{X}$	1,897,050	1,692,167	74,364,167	164,336.6	20,460,293

POTENTIAL GUAYULE GROWTH AREA, TEXAS AGRICULTURAL STATISTICS, 1975-1977

(Continued)

Crop	Year	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Corn (bushels)	1975	158,400	140,000	9,392,400	24,983.8	1,470,000
	1976	146,200	117,000	8 140,600	18,967.6	1,134,950
	1977	220,500	202,300	11,835,800	26,038.8	2,124,150
	$\bar{X}$	175,033	153,100	9,789,600	23,330.1	1,576,367
Soybeans (bushels)	1975	5,800	5,250	177,000	762.9	NA
	1976	900	900	20,000	122.0	NA
	1977	10,100	8,300	180,000	963.0	NA
	$\bar{X}$	5,600	4,817	125,667	616.0	NA
Peanuts (lbs)	1975	69,010	68,010	137,330,000	25,543.4	1,594,833
	1976	69,600	67,580	145,010,000	27,696.9	1,584,752
	1977	69,250	67,750	132,500,000	25,970.0	1,588,738
	$\bar{X}$	69,287	67,780	138,280,000	26,403.4	1,589,441
Sugarcane (tons)	1975	NA	35,500	1,264,000	24,774.4	NA
	1976	NA	35,900	1,354,000	18,549.8	NA
	1977	NA	33,900	989,000	18,395.4	NA
	$\bar{X}$	NA	35,100	1,202,333	20,573.2	NA
Guar	1975	700	600	850,000	NA	NA
	1976	500	500	600,000	NA	NA
	1977	-0-	-0-	-0-	NA	NA
	$\bar{X}$	400	367	483,333	NA	NA
Hay (tons)	1975	NA	300,400	681,300	32,021.1	4,322,375
	1976	NA	305,200	808,000	395,920	4,355,934
	1977	NA	308,700	706,400	34,966.8	4,484,725
	$\bar{X}$	NA	304,767	731,900	355,266	4,387,678
Cowpeas	1975	7,000	3,100	2,412,000	NA	NA
	1976	12,900	11,300	8,343,000	NA	NA
	1977	14,200	13,970	6,389,900	NA	NA
	$\bar{X}$	1,1367	9,457	5,714,967	NA	NA

POTENTIAL GUAYULE GROWTH AREA, TEXAS AGRICULTURAL STATISTICS, 1975-1977

(Continued)

Crop	Year	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Sunflowers (lbs)	1975	11,800	11,600	19,629,000	NA	NA
	1976	-0-	-0-	-0-	NA	NA
	1977	3,300	3,100	3,727,000	NA	NA
	$\overline{X}$	5,033	4,900	7,785,333	NA	NA
TOTAL						
	1975	3,306,930	3,064,120		407,597.8	37,254,980
	1976	3,001,050	2,756,560		395,501.3	34,892,668
	1977	3,109,750	3,026,860		404,797.7	41,169,596
	$\overline{X}$	3,139,243	2,949,180		402,632.3	37,772,415

ii. Arizona: The potential guayule growing areas in Arizona are nine counties (Cochise, Graham, Greenlee, Maricopa, Mohave, Pima, Pinal, Santa Cruz and Yuma) in the southern and western part of the State. In 1977, a total of 1,327,670 acres were harvested in Arizona; 1,288,580 of these acres were within the nine-county guayule region. Almost all of this acreage was irrigated. Maricopa County contained the largest amount of cropland, with about .5 million cultivated acres. It was followed by Yuma with about 300,000 acres, Pinal with about 250,000 acres, and Cochise with slightly more than 100,000 acres. The remaining counties have agriculture on a fairly limited scale.

There is great year-to-year variation in the harvested acreage, particularly in the larger agricultural counties (See Table III-18). The value of farm production varies even more markedly, as can be seen by comparing the years 1975 and 1976. Differences in crop values appear to be independent of amounts of harvested acreage.

The most common crops for the area are cotton, hay, barley, wheat and sorghum. In addition, a variety of melons and vegetables, of which lettuce is the foremost, are grown in Yuma, Maricopa, Pinal, Pima and Cochise counties. Citrus trees, primarily oranges, lemons, and grapefruit account for an additional 56,000 acres in Yuma and Maricopa counties. An increasing amount of pecans, about 13,000 acres in 1977, are grown in Pima, Pinal, Maricopa and Yuma counties.

Cotton is the region's major crop both in terms of acreage and value, taking up an average of more than 400,000 acres and generating $250 million annually. However, as revealed in Table III-19, acreage fluctuates radically from year to year. Wheat is second to cotton in terms of acreage, with a three-year average of 272,000 harvested acres but is even more variable than cotton; the 419,000 acres planted in 1976 fell to 138,000 acres in 1977. Hay production, mostly alfalfa, occurs on about 227,000 acres and is second to cotton in terms of value, at about $92 million a year. Hay acreage seems to vary hardly at all over the three years. Lettuce, produced on only 38,000 acres, earns more than $61 million annually. The remaining vegetables and melons tend to have fairly small and stable acreages which bring in relatively large amounts of cash per acre.

Man-hours of labor required to produce 15 of the crops listed in Table III-19 varied from a low of 26,912,906 in 1975 to a high of 32,876,840 in 1977, for an average of 29,751,139 man-hours or 3,718,892 man-days. Cotton required the most total labor, followed by lettuce, hay, wheat, cantaloupe and sorghum. The remaining crops each require considerably less than a million man-hours of labor.

ARIZONA TABLE III-18

COUNTY	TOTAL ACRES HARVESTED			TOTAL CROP VALUE (1000 DOLLARS)		
	1975	1976	1977	1975	1976	1977
Cochise	157,480	171,400	114,690	34,022	50,046	41,853
Graham	72,860	65,100	55,100	15,088	19,104	19,675
Greenlee	5,000	6,400	5,300	1,720	2,965	2,578
Maricopa	471,740	491,810	509,900	220,880	305,327	299,732
Mohave	6,950	6,900	6,940	2,463	3,588	2,401
Pima	52,880	52,050	45,770	20,048	31,320	28,670
Pinal	283,300	282,590	249,650	93,459	159,781	117,312
Santa Cruz	2,300	2,400	3,220	516	651	660
Yuma	299,040	322,360	298,010	166,144	196,004	191,649
Total	1,351,550	1,401,010	1,288,580	554,340	768,786	704,530

Arizona Crop and Livestock Reporting Service, Arizona Agricultural Statistics (for crop years 1975, 1976, 1977), Phoenix, Arizona,

TABLE III-19

POTENTIAL GUAYULE GROWTH AREA, ARIZONA AGRICULTURAL STATISTICS, 1975-1977

Crop	Year	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	1975	268,350	267,350	572,350	145,880.5	7,756,516
	1976	341,000	340,000	834,000	257,005.1	9,877,000
	1977	516,900	514,900	1,049,830	294,288.4	14,957,845
	$\bar{X}$	375,417	374,083	818,727	232,391.3	10,863,787
American Pima Cotton (bales)	1975	30,100	29,800	38,000	14,337.0	899,950
	1976	25,850	25,650	50,300	24,627.0	774,630
	1977	36,750	36,250	60,000	26,236.9	1,094,750
	$\bar{X}$	30,900	30,567	49,433	22,733.6	923,110
Hay (tons)	1975	-0-	229,800	1,413,200	83,378.8	4,342,350
	1976	-0-	224,400	1,489,700	102,044.0	4,238,400
	1977	-0-	227,300	1,397,700	90,850.5	4,292,825
	$\bar{X}$	-0-	227,167	1,433,533	92,091.1	4,291,192
Wheat (tons)	1975	268,300	258,400	543,630	57,443.6	2,480,640
	1976	437,800	419,000	966,530	126,075.7	4,022,400
	1977	145,400	138,800	300,540	26,351.0	1,332,480
	$\bar{X}$	283,833	272,067	603,567	69,956.8	2,611,840
Barley (tons)	1975	71,700	64,300	115,990	12,807.5	617,280
	1976	63,800	56,500	103,250	11,701.3	542,400
	1977	61,400	54,700	99,900	9,157.6	525,120
	$\bar{X}$	65,633	58,500	106,380	11,222.1	561,600
Corn (tons)	1975	9,100	3,400	5,460	623.8	35,700
	1976	26,700	15,500	40,520	3,762.6	162,750
	1977	48,600	36,900	77,690	6,104.3	387,450
	$\bar{X}$	28,133	18,600	41,223	3,496.9	195,300
Sorghum (tons)	1975	127,500	118,600	226,780	23,649.7	1,387,320
	1976	97,600	89,700	184,390	15,805.1	1,054,240
	1977	96,600	88,700	199,860	16,202.9	1,017,280
	$\bar{X}$	107,233	99,000	203,677	18,552.6	1,152,947
Safflower (tons)	1975	44,500	44,500	54,500	15,533.1	578,500
	1976	-0-	-0-	-0-	-0-	-0-
	1977	10,500	10,500	10,800	2,592.0	136,500
	$\bar{X}$	18,333	18,333	21,767	6,041.7	238,333

(Continued)

POTENTIAL GUAYULE GROWTH AREA, ARIZONA AGRICULTURAL STATISTICS, 1975-1977

Crop	Year	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Sugarbeets (tons)	1975	18,000	17,000	366,000	10,431.0	432,650
	1976	17,800	17,000	391,000	8,993.0	432,650
	1977	12,900	12,800	285,000	-0-	325,760
	$\bar{X}$	16,233	15,600	347,333	9,712.0	397,020
Lettuce (1000 cwt)	1975	39,200	39,200	8,029	57,434.0	6,213,200
	1976	37,500	37,500	7,762	59,878.0	5,943,750
	1977	38,400	38,400	7,973	66,506.0	6,086,400
	$\bar{X}$	38,367	38,367	7,921	61,272.7	6,081,117
Broccoli (1000 cwt)	1975	600	600	34	585.0	NA
	1976	600	600	36	715.0	NA
	1977	600	600	32	842.4	NA
	$\bar{X}$	600	600	34	714.1	NA
Cantaloupe (1000 cwt)	1975	7,800	7,800	956	13,360.0	1,209,000
	1976	8,550	8,550	1,055	13,595.7	1,325,250
	1977	10,450	10,450	1,585	16,544.0	1,619,750
	$\bar{X}$	8,933	8,933	1,199	14,499.9	1,384,667
Carrots (1000 cwt)	1975	1,500	1,500	155	1,719.0	171,000
	1976	1,700	1,700	204	1,408.0	193,800
	1977	1,720	1,720	254	2,926.8	196,080
	$\bar{X}$	1,640	1,640	204	2,017.9	186,960
Califlower (1000 cwt)	1975	1,000	1,000	66	1,593.0	NA
	1976	1,000	1,000	61	1,342.0	NA
	1977	1,460	1,460	100	2,951.0	NA
	$\bar{X}$	1,153	1,153	76	1,962.0	NA
Dry Onions (1000 cwt)	1975	1,400	1,400	686	6,332.0	154,000
	1976	1,800	1,800	720	3,419.9	198,000
	1977	1,400	1,400	616	4,464.0	154,000
	$\bar{X}$	1,533	1,533	674	4,798.6	168,667
Watermelon (1000 cwt)	1975	2,900	2,900	479	2,047.3	324,800
	1976	3,200	3,200	515	2,215.0	358,400
	1977	3,800	3,800	596	3,064.0	425,600
	$\bar{X}$	3,300	3,300	530	2,442.1	369,600

POTENTIAL GUAYULE GROWTH AREA, ARIZONA AGRICULTURAL STATISTICS, 1975-1977

(Continued)

Crop	Year	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Honeydews (1000 cwt)	1975	1,070	1,070	178	1,794.0	NA
	1976	2,100	2,100	187	2,034.0	NA
	1977	1,270	1,270	195	1,979.0	NA
	$\bar{X}$	1,480	1,480	187	1,935.7	NA
Potatoes (1000 cwt)	1975	6,200	6,200	1,519	9,114.0	310,000
	1976	6,800	6,800	1,836	9,290.0	340,000
	1977	6,500	6,500	1,755	8,986.0	325,000
	$\bar{X}$	6,500	6,500	1,703	9,130.0	325,000
TOTAL						
1975		899,220	1,094,820		458,063.3	26,912,906
1976		1,073,800	1,251,000		643,911.4	29,463,670
1977		994,650	1,186,450		580,226.8	32,876,840
$\bar{X}$		989,223	1,177,423		560,733.8	29,751,139

iii. New Mexico: The potential guayule growth areas in New Mexico are in Dona Ana, Grant, Hidalgo, and Luna counties in the southwestern corner of the State. Virtually all agriculture in this region is irrigated. The total irrigated cropland acreage including idle, fallow and diverted acreage was just under 210,000 acres during the years 1975-1977 (Table III-20). Dona Ana, in the Rio Grande Valley, has the greatest amount of cropland, followed in order by Luna, Hidalgo and Grant counties. The values of farm production follow the same pattern, with Dona Ana receiving the most money and Grant the least.

A relatively limited number of crops are grown in southwestern New Mexico. The primary crops are sorghum, upland cotton, hay, wheat, American Pima cotton, corn, and barley; these crops are grown in all four counties. Onions and lettuce are grown in substantial quantities only in Dona Ana. In addition, small amounts of chili peppers are grown in Dona Ana and Luna counties, and small amounts of apples are produced in Grant and Dona Ana counties. The only other significant crop in the region is pecans, with a few orchards in Luna County and 11,545 acres of pecans in Dona Ana County as of 1975.

There is great variation year to year in acreages of the individual field crops, both within each county and for the entire four-county region. Hay, vegetable, fruit and nut acreages tend to be far more stable. The total harvested acreage for the nine crops in Table III-21 remained quite steady at about 140,000 acres during the years 1975-1977. The total number of man-hours needed to work the crops also remained fairly stable at about 2.7 million man-hours or 344,000 man-days. The value of production increased, however, reflecting changing market values and weather-affected yields.

Cotton is by far the most valuable product of the area, averaging $18.4 million a year (Table III-21). Onions are the next most valuable crop in the region, with a three-year average of $8,291,700, followed closely by sorghum, lettuce, hay, and then wheat, corn, barley. The number of man-hours needed to work the crops follows a similar pattern, with cotton followed by lettuce, sorghum, hay, onions, wheat, corn and barley.

When the total irrigated cropland acreage of Table III-20 is compared with the total harvested acreage of Table III-21, it is evident that there are some 69,000 acres unaccounted for. If the 11,500 acres of pecans in Dona Ana County and the small acreages of chili peppers and apples are included, about 50,000 acres remain that are fallow, idle, or diverted. Thus, a quarter of the region's arable land is out of production in any given year.

iv. California: Potential guayule growth areas in California are in the 34 counties listed in Table III-22, including almost all of the counties in the agriculturally rich Central Valley. Table III-22 reports acreage and value for all crops including vege-

TABLE III-20

NEW MEXICO

COUNTY	IRRIGATED CROPLAND ACREAGE			VALUE OF ALL FARM PRODUCTION (1000 DOLLARS)		
	1975	1976	1977	1975	1976	1977
Dona Ana	94,110	92,550	92,550	32,092.8	39,021.6	33,901.3
Grant	7,260	8,180	8,180	491.6	522.8	439.2
Hidalgo	36,480	38,580	18,580	4,762.5	5,094.5	6,639.1
Luna	69,440	69,440	69,440	10,699.9	12,414.0	14,083.6
Total	207,290	208,750	209,910	48,046.8	57,052.9	54,063.2

Sources: U.S.Department of Agriculture, New Mexico Crop and Livestock Reporting Service and New Mexico State University, Department of Agriculture, New Mexico Agricultural Statistics 1977, Las Cruces, N.M. 1978.

TABLE III-21

POTENTIAL GUAYULE GROWTH AREA, NEW MEXICO AGRICULTURAL STATISTICS, 1975-1977

Crop	Year	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Barley (bushels)	1975	8,850	8,000	487,200	1071.8	62,400
	1976	5,050	4,360	247,320	536.7	34,008
	1977	6,320	5,400	361,100	595.9	42,120
	$\bar{X}$	6,740	5,920	365,207	734.8	46,176
Corn (bushels)	1975	7,300	3,590	265,620	695.3	37,695
	1976	6,270	4,350	485,200	1,086.8	45,675
	1977	3,510	11,030	1,268,900	2,537.8	115,815
	$\bar{X}$	9,027	6,323	673,240	1,440.0	66,395
Sorghum (bushels)	1975	48,600	45,000	4,087,500	10,055.2	544,500
	1976	52,000	49,870	4,648,700	9,390.5	603,427
	1977	23,500	22,650	2,250,050	4,230.1	274,065
	$\bar{X}$	41,367	39,173	3,662,083	7,891.9	473,997
Wheat (bushels)	1975	11,850	9,800	524,200	1,845.3	76,440
	1976	23,560	23,180	1,515,920	5,079.1	180,804
	1977	9,150	8,530	465,350	989.2	66,534
	$\bar{X}$	14,853	13,837	835,157	2,637.8	107,926
Upland[1/] Cotton (bales)	1975	33,020	32,150	30,050	11,173.3	601,205
	1976	24,250	24,150	35,510	16,222.5	451,605
	1977	52,050	52,050	79,180	27,726.3	973,335
	$\bar{X}$	36,440	36,117	48,247	18,374.0	675,382
American[1/] Pima Cotton (bales)	1975	13,140	12,390	5,050	NA	231,693
	1976	6,370	6,230	6,185	NA	116,501
	1977	9,270	9,175	11,910	NA	171,572
	$\bar{X}$	9,593	9,265	7,715	NA	173,255
Hay (tons)	1975	NA	19,900	100,010	5,400.5	300,825
	1976	NA	24,400	103,650	6,581.7	371,701
	1977	NA	23,750	112,360	6,460.8	361,062
	$\bar{X}$	NA	22,683	105,340	6,147.7	344,529

POTENTIAL GUAYULE GROWTH AREA, NEW MEXICO AGRICULTURAL STATISTICS, 1975-1977

(Continued)

Crop	Year	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Lettuce (cwt)	1975	3,800	3,700	731,900	5,920.7	595,000
	1976	4,200	3,700	914,700	11,681.5	595,900
	1977	4,800	3,070	599,000	5,101.5	495,910
	$\bar{X}$	4,267	3,490	748,533	7,567.9	562,270
Onions (cwt)	1975	2,200	2,200	756,800	11,882.0	242,000
	1976	3,600	3,400	1,156,000	6,573.6	374,000
	1977	2,900	2,650	833,700	6,419.5	291,500
	$\bar{X}$	2,900	2,750	915,500	8,291.7	302,500
TOTAL						
1975		128,760	136,730		48,044.1	2,691,758
1976		125,300	143,640		57,152.4	2,773,621
1977		121,500	138,305		54,061.1	2,791,913
$\bar{X}$		125,185	139,558		53,085.9	2,752,431

[1] Value at production aggregated for upland and American Pima cotton.

table and tree crops. As of 1974, approximately 66 percent of all harvested cropland in these areas was in only ten counties. These counties, in order of importance, were Fresno (14 percent), Kern (10 percent), Tulare (7.7 percent), San Joaquin (6.2 percent), Kings (5.8 percent), Imperial (5.8 percent), Yolo (4.8 percent), Merced (4.2 percent), Stanislaus (3.6 percent) and Monterey (3.3 percent).

As of 1977, the potential guayule growth region had a crop value of more than $7 billion. Sixty-three percent of this can be accounted for by 10 counties. Several of these counties are noted above as significant in terms of acreage, but there is some reordering in importance when value is considered. The following counties and percent of crop value attributed to each is: Fresno (12.5 percent), Kern (9.8 percent), Tulare (7.5 percent), Monterey (6.6 percent), San Joaquin (5.5 percent), Imperial (4.8 percent), Ventura (4.7 percent), Merced (4 percent), Kings (4 percent) and Riverside (3.8 percent).

Table III-23 presents data on the most significant crops in the region, not including tree and fresh vegetable crops. In terms of the mean value of acres grown between 1975 and 1977, cotton is most important with 18.1 percent of the total acreage. In terms of value, however, it provides 34 percent of the income for the entire region. It is also ranked first in terms of man-hours of labor requirements.

Alfalfa ranks second in terms of acreage, value and man-hours with 13.8 percent of the total acres and 17.2 percent of the total value. Wheat ranks third in importance with regard to acreage (13.3 percent) and man-hours but ranks only fifth in value (8.4 percent). Similarly, barley (13.2 percent), irrigated pasture (10.7 percent), and corn (6.4 percent) rank more predominantly in terms of acreage than they do in value (5.9 percent, 5.8 percent and 2.6 percent, respectively).

Rice ranks third in terms of value (8.5 percent) with only 6.1 percent of the area acreage and sugar beets capture fourth place in value (8.4 percent) with 5.3 percent of the land.

Considering value, Kern and Fresno counties are most important in growing cotton; Imperial and Kern counties in alfalfa; Butte and Colussa counties in rice; Imperial and Solano counties in sugar beets, and Imperial and Yolo counties in wheat. In terms of acres allotted to crops; Kern and Fresno counties have the most in cotton; Imperial and Kern counties in alfalfa; Imperial and Yolo counties in wheat; Fresno and Kings counties in barley; and Merced and Stanislaus counties in irrigated pasture.

CALIFORNIA TABLE III-22

COUNTY	1974 TOTAL[1] CROPLAND ACREAGE	1974 HARVESTED[1] CROPLAND ACREAGE	VALUE OF ALL CROPS[2] 1975	1976 (1000 DOLLARS)	1977
Tehama	139,000	68,500	32,111.4	37,841.7	44,623.9
Glenn	324,000	223,200	76,498.4	65,087.8	66,380.0
Butte	254,000	211,800	111,865.3	113,095.0	127,747.5
Colusa	287,000	244,200	130,640.0	94,980.8	119,002.2
Sutter	276,000	248,100	180,888.1	169,090.7	191,067.0
Yuba	79,000	56,500	47,060.0	43,502.3	55,136.8
Placer	72,000	33,000	16,960.0	16,408.0	12,729.1
Yolo	437,000	369,700	194,115.5	140,908.6	178,812.8
Sacramento	219,000	162,700	96,928.7	92,047.8	87,827.0
Solano	217,000	154,300	89,482.0	76,987.7	89,860.4
Contra Costa	74,000	47,400	37,793.8	33,449.3	37,767.9
San Joaquin	548,000	483,300	376,615.4	351,135.3	387,594.0
Alameda	63,000	27,800	34,089.4	36,184.5	36,125.2
Santa Clara	68,000	48,300	85,972.4	78,744.2	85,072.6
Stanislaus	374,000	280,900	187,159.3	185,878.7	242,858.5
Santa Cruz	22,000	16,700	64,879.0	78,232.0	85,072.6
Merced	435,000	326,200	212,456.0	247,576.7	283,860.5
San Benito	71,000	52,200	47,786.0	44,027.5	56,501.0
Monterey	338,000	254,500	375,317.5	417,361.9	463,464.4
Madera	290,000	226,500	129,559.0	145,105.0	169,873.0
Fresno	1,191,000	1,100,500	791,754.0	989,601.8	885,644.4
Kings	495,000	452,900	268,654.8	302,844.5	283,785.7
Tulare	674,000	601,200	557,013.6	548,135.6	533,127.0
San Luis Obispo	353,000	188,800	63,683.8	67,908.3	69,235.8
Kern	905,000	781,000	923,614.8	763,222.4	691,838.0
Santa Barbara	139,000	93,700	125,965.3	134,413.6	162,616.3
Ventura	128,000	103,800	31[illegible],111.3	290,685.0	331,796.7
Los Angeles	95,000	64,700	100,435.7	130,442.3	159,044.2
San Bernadino	71,000	53,400	40,763.8	47,908.8	50,288.5
Orange	46,000	34,900	124,281.0	139,119.7	155,896.6
Riverside	310,000	233,100	265,507.2	257,464.6	268,544.0
San Diego	107,000	70,900	211,604.8	235,424.2	251,894.7
Imperial	472,000	447,900	373,044.0	407,634.0	335,838.0
San Mateo	27,000	10,200	55,373.9	61,714.2	61,045.6
TOTALS	9,600,000	7,772,800	6,742,985.2	6,844,165.3	7,061,516.9

1/U.S. Department of Commerce, Bureau of the Census, County and City Data Book, 1977.

2/California Farmer - California at a Glance, A Comprehensive Analysis of Acreage and Dollar Value of California's Principal Crops, San Francisco, for crop years 1975, 1976 and 1977.

TABLE III-23

POTENTIAL GUAYULE GROWTH AREA, CALIFORNIA AGRICULTURAL STATISTICS, 1975-1977

Crop	Year	Harvested Acres	Production	Value of Production (1000 dollars)	Man Hours
Potatoes	1975	14,885	NA	22,662.2	760,048
	1976	16,712	NA	20,307.1	855,895
	1977	16,510	NA	23,427.6	844,880
	X	16,036	NA	22,132.3	820,274
Barley (bushels)	1975	851,661	58,444,760	146,111.9	8,175,945
	1976	805,064	49,848,588	127,113.9	7,728,615
	1977	867,515	61,388,136	135,053.9	8,328,143
	X	841,413	56,560,495	136,093.2	8,077,568
Wheat (bushels)	1975	1,029,936	74,376,994	242,469.0	9,887,386
	1976	918,604	61,043,251	221,587.0	8,818,598
	1977	600,447	42,819,228	116,468.3	5,764,291
	X	849,662	59,413,158	193,508.1	8,156,758
Oats (bushels)	1975	79,781	5,218,947	9,916.0	765,897
	1976	47,793	4,108,632	7,806.4	458,814
	1977	52,623	4,638,207	6,725.4	505,181
	X	60,066	4,655,262	8,149.3	576,631
Corn (bushels)	1975	383,589	42,956,540	135,313.1	4,027,683
	1976	473,213	55,626,571	155,754.4	4,969,736
	1977	370,115	46,907,667	112,578.4	3,886,208
	X	408,972	48,496,926	134,548.6	4,294,209
Sorghum (bushels)	1975	252,485	18,888,834	53,455.4	2,777,335
	1976	207,036	16,402,442	42,318.3	2,277,396
	1977	81,548	6,209,404	14,592.1	897,028
	X	180,356	13,833,560	36,788.6	1,983,920
Rice (lbs)	1975	531,766	3,057,654,500	258,691.3	NA
	1976	413,247	2,281,123,440	157,673.5	NA
	1977	227,622	1,322,483,820	170,617.0	NA
	X	390,878	2,220,420,587	195,660.6	NA
Safflower	1975	147,559	NA	36,626.4	1,918,267
	1976	59,209	NA	16,046.2	769,717
	1977	131,341	NA	36,216.4	1,707,433
	X	112,703	NA	29,629.7	1,465,139

POTENTIAL GUAYULE GROWTH AREA, CALIFORNIA AGRICULTURAL STATISTICS, 1975-1977

(Continued)

Crop	Year	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Alfalfa (tons)	1975	863,279	5,093,346	379,188.2	15,341,929
	1976	899,154	5,394,924	461,427.7	16,035,607
	1977	874,053	5,113,210	352,215.3	15,595,726
	X	878,829	5,200,493	397,610.4	15,657,754
Wild & Grain Hay (tons)	1975	441,167	860,276	46,721.5	7,728,790
	1976	415,584	748,051	67,452.0	7,302,778
	1977	283,638	567,276	28,212.9	4,876,894
	X	380,130	725,201	47,462.1	6,636,154
Irrigated Pasture	1975	700,909	NA	54,167.3	NA
	1976	686,460	NA	63,672.9	NA
	1977	669,105	NA	62,193.5	NA
	X	685,491	NA	60,011.2	NA
Cotton (lbs)	1975	909,485	974,967,920	605,023.3	26,420,539
	1976	1,141,360	1,214,428,320	913,408.4	33,157,089
	1977	1,418,515	1,367,448,460	826,749.7	41,207,861
	X	1,156,460	1,185,614,900	781,727.1	33,595,163
Dry Peas and Beans	1975	131,321	NA	61,044.6	NA
	1976	148,338	NA	63,999.1	NA
	1977	151,857	NA	80,904.4	NA
	X	143,839	NA	68,649.4	NA
Sugar Beets (tons)	1975	345,276	9,426,035	285,839.7	8,787,273
	1976	274,779	7,858,679	168,767.9	6,993,125
	1977	216,906	5,639,556	126,807.8	5,520,256
	X	278,987	7,641,423	193,805.1	7,100,218
TOTAL					
1975		6,683,099		2,337,229.9	86,591,092
1976		6,506,573		2,487,334.8	89,366,370
1977		5,961,795		2,092,762.7	89,133,901
X		6,383,822		2,305,775.8	88,363,788

v. Nevada: The potential guayule growing area in Nevada is Clark County. Unfortunately, agricultural data for Clark County are extremely limited. Table III-24 presents summary data for the county.

TABLE III-24

CLARK COUNTY, NEVADA;
CROPLAND AND CROP VALUE
1969 and 1974

	1969	1974
Total Cropland (acres)	11,829	12,052
Harvested Cropland (acres)	8,662	8,440
Irrigated Land (acres)	10,218	11,290
Value of all crops sold ($1000)	543	681

Irrigated lands increased from 86 percent of all cropland in 1969 to 94 percent in 1974. Table III-25 details various crops grown on these irrigated lands. The dominant crop is hay of several varieties, but mostly alfalfa. An average of 6,220 acres were grown between 1969 and 1974. This constitutes 58 percent of the mean acres of irrigated lands in the County. Another 13 percent of the irrigated acreage was in small grains, including rye, barley and oats.

The corn and sorghum reported in Table III-25 are used mainly for silage. Together, field seeds, hay, forage and silage account for $276,000, or 51 percent of the value of crops sold in 1969 and $617,000, or 91 percent in 1974. Vegetables represent 33 percent and 7.5 percent of total value in 1969 and 1974, respectively.

i. Economic opportunities for Indian and non-Indian communities in the U.S. Southwest: "Congress further recognizes that the development of a domestic natural rubber industry, based on Parthenium and other hydrocarbon-containing plants, would not only relieve the nation's dependence upon foreign latex sources but also convey substantial economic benefits to peoples living in arid and semiarid regions of the United States. Such an industry would comprise the agricultural production of the hydrocarbon-containing plants and the development of commercial processing and manufacturing facilities to extract the latex and other products." Native Latex Commercialization Act of 1978; Section 2 (d).

Economic opportunities for the arid and semiarid Southwest conveyed by commercializing guayule include both agricultural and commercial-industrial development.

U.S. Department of Commerce, Bureau of the Census. 1974 Census of Agriculture Vol. 1 Part 28, Nevada State and County Data. April 1977.

TABLE III-25

POTENTIAL GUAYULE GROWTH AREA, NEVADA AGRICULTURAL STATISTICS, 1969,1974

Crop	Year	Acreage	Production	Value of Production (1000 dollars)	Man Hours
Corn	1969		NA	NA	NA
	1974	313	NA	NA	NA
	X	156	NA	NA	NA
Sorghum	1969	572	NA	NA	NA
	1974	587	NA	NA	NA
	X	580	NA	NA	NA
Wheat	1969	23	1,563	NA	221
(bushels)	1974	34	1,121	NA	326
	X	28	1,342	NA	274
Other small grains					
(rye, barley, oats)	1969	2,370	NA	NA	NA
	1974	524	NA	NA	NA
	X	1,447	NA	NA	NA
Hay crops	1969	5,364	24,664	NA	89,847
(tons)	1974	7,076	27,244	NA	118,523
	X	6,220	25,954	NA	104,185
Vegetables	1969	294	NA	1,780	NA
	1974	53	NA	510	NA
	X	174	NA	1,145	NA
TOTAL					
1969		8,623			
1974		8,587			
X		8,605			

Commercial-industrial development would relate to constructing and operating guayule processing facilities in the U.S. Southwest, since marketing the rubber and by-products would occur only after processing the entire guayule plant. Locating processing operations close to the agricultural source is economically expedient to minimize transportation distances and costs. Preliminary analyses suggest that 50,000 planted acres of guayule would be needed to support a processing plant (Nivert, Glymph and Snyder, undated).

Opportunities for non-Indian agricultural development will depend primarily on water and land availability and the ability of guayule to provide an economic return commensurate with traditional crops. Economic benefits that would accrue from guayule development on these acreages will depend upon levels of governmental support; behavior of the international market for natural rubber; and scientific and agronomic breakthroughs which may be achieved under the stimulus of the Native Latex Commercialization Act. Preliminary economic analysis (Table III-26) based on present guayule agronomic technology applied to central Arizona agricultural conditions. indicates cost of growing rubber to be $.45 per pound delivered to the processing plant (Wright, 1979). If a conservative estimate of $.25 per pound is assumed for the cost of processing the shrub, guayule would currently cost $.70 per pound to produce. The New York price for smoked rubber was posted in mid-March, 1979, at $.6225 per pound. Therefore, production breakthrough and/or by-product value establishment would be necessary to ensure economic benefits to producers.

Opportunities for Indian communities would operate under the same economic constraints above; however, land and water availability for potential guayule production warrant separate consideration, particularly for Arizona and Nevada. There are no Indian reservations in the potential guayule growth area of New Mexico and only one 73-acre reservation in the Texas area (Tique Indians). In California, Indian reservations in the potential guayule growth area are small and widely dispersed. These reservation water needs are incorporated into the overall California water planning program, thus receiving water from the State Water Project, the Central Valley Project and local water development projects. These reservations are incorporated into the earlier discussion of California agriculture water demand with the exception of the Ft. Mojave, Chemehuevi, Colorado River and Ft. Yuma Reservations which have land in both California and Arizona, and which rely on Colorado River supplies.

Water rights for irrigation on Indian lands are subject to the Winters Doctrine. This doctrine is based on the U.S. Supreme Court decision in 1908 Winters vs. United States (207 U.S. 564) wherein the Court ruled that Ft. Belknap Reservation Indians had water rights attached to their lands upon creation of the reservation. Nelson and Brooke (1977) summarize the nature of the Winters Doctrine rights as follows:

TABLE III-26

ESTIMATED COSTS OF PRODUCING ONE ACRE OF GUAYULE IN CENTRAL ARIZONA, 1979[1/]

First Year		
Establish Stand (Idle Farm Land)		
Plow	$ 9	
Disc (2 x)	10	
Land Plane	7	
Laserplane	14	
List and Shape Beds	6	
Mulch	4	
Pre-irrigate (Labor + .5 AF water)	18	
Chemical Weed Control	6	
Seedlings -- 11,000 plants	110	
Planting	62	
Interest on Variable Costs	12	
		$258
Culture		
Irrigation (Labor + 1 AF water)	$ 36	
Cultivate (2 x)	4	
Chemical Weed Control	6	
Cash Farm Overhead	15	
Insect Control	6	
Management and Supervision	12	
Interest on Variable Costs	4	
Taxes	8	
Land Rent	40	
		$131
Second Year		
Irrigate (Labor + 1.5 AF water)	$ 54	
Cultivation	2	
Chemical Weed Control	6	
Cash Farm Overhead	15	
Insect Control	6	
Management and Supervision	12	
Interest on Variable Costs	5	
Taxes	8	
Land Rent	40	
		$148

ESTIMATED COSTS OF PRODUCING ONE ACRE OF GUAYULE IN CENTRAL ARIZONA, 1979

(continued)

Third Year

Irrigation (Labor + 1.5 AF water)	$. 54	
Insect Control	6	
Cash Farm Overhead	15	
Management and Supervision	12	
Interest on Variable Costs	4	
Taxes	8	
Land Rent	40	
		$139

Fourth Year

Irrigation (Labor + 1 AF water)	$ 36	
Insect Control	6	
Cash Farm Overhead	15	
Management and Supervision	12	
Interest on Variable Costs	3	
Taxes	8	
Land Rent	40	
Dig Plants	25	
Windrow	10	
Bale	28	
Roadside	20	
Haul (field to processing plant)	25	
		$228
TOTAL -		$904*

Yield: 20,000 pounds of plants from which 2,000 pounds of guayule rubber can be extracted from the roots and tops.

Yields, lbs/acre	Growing Costs	Cost/lb, guayule rubber
2,000 pounds	$904	$ .45

* These budgets do not include processing costs.

1/ Source: Wright, 1979

1. Winters rights attach to all Indian reservations, whether withdrawn by treaty, agreement, executive order or statute.

2. It is a reserved right to the quantity of water necessary to fulfill the purposes of the reservation.

3. The quantity of water is measured by the amount necessary to fulfill the purposes of the reservation, not the amount presently in use or the amount predicted to be used at some future time.

4. The right has a proprietary basis, it is based on the amount of land, and follows the land if it is allotted, leased, or sold.

5. Actual beneficial use is not the test of Indian reserved water rights.

6. Winters rights are not lost through non-use or forfeiture so long as the land is held by Indians.

7. The priority date for the Winters right is the date of the creation of the reservation.

Determining water quantity available to Indian lands is now undergoing extensive negotiation in Arizona, in response to the need for Central Arizona Project water and a diminishing groundwater supply. How the "quantity of water necessary to fulfill the purposes of the reservations" will be determined and/or obtained are unresolved at this time; however, negotiated settlements between Indian and non-Indians seem preferable to litigation. The Bureau of Indian Affairs (1976) reported the irrigated and potentially irrigable lands of the Indian reservations in Nevada, Utah and Arizona. Table III-27 lists the BIA reported acreages for the reservations under consideration in the potential guayule growth area. The potential irrigable acreages, however, are conservative compared with acreages reported by the tribes themselves (Foster, 1978). Based on the BIA data, a range of from 200,000 to 270,000 total acres on these reservations may be irrigated, although estimates by the tribes place the upper limit at more than 1.4 million acres.

If guayule becomes an economically viable crop, considerable reservation acreages could be devoted to it.

j. Federal price support and land use programs: Abundance, stability, conservation and security have been continuing farm program aims since 1933 when the first national legislation dealing with price support and production adjustment was passed.

National farm programs designed to assure adequate supplies, to stabilize markets and prices and to equalize the

TABLE III-27

PRESENT AND POTENTIAL INDIAN IRRIGATED LANDS IN THE GUAYULE POTENTIAL GROWTH AREA, ARIZONA AND NEVADA[1/]
(in acres)

Reservation	Reservation Acreage	Approximate 1976 Irrigated Acreage	Potential Irrigable Lands
Gila Bend (Papago)	10,409	710	1,900
San Xavier (Papago)	71,095	1,170	2,200
Papago	2,774,390	5,300	14,000
Ak Chin (Papago)	21,840	6,000	6,000
Hualapai	993,173	0	0[2/]
Gila Band (Pima & Papago)	371,933	75,000	80,000
Salt River (Pima & Maricopa)	49,294	15,000	25,000
San Carlos (Apache)	1,853,817	500	2,500
Ft. Yuma (Quechan)	9,282	6,800[3/]	7,400
Ft. Mohave (Mohave)	41,884	15,000[4/]	25,000
Ft. McDowell (Yavapai Apache)	24,680	600	1,300
Colorado River (Mohave, Chemehuevi, Navajo, Hopi)	268,691	73,700	100,000
Cocopah (Cocopah)	1,773	310	1,400
Chemehuevi (Chemehuevi)	30,654	0	1,500 (marginal)
Las Vegas	10	0	0
Maopa (Paiute)	1,186	480	1,000[5/]

1/ Source: BIA, 1976
2/ No Hualapai lands are suitable for guayule cultivation.
3/ Most of the Ft. Yuma Reservation lies in the Imperial Valley area of California
4/ 800 irrigated acres in California, none in Nevada
5/ 500 acres on the Moapa Reservation, 500 acres on BLM land

farmers' bargaining position historically have followed eight basic, and often closely interrelated, approaches:

1. Price support programs: using loans, purchases in lieu of loans, direct purchases and payments;

2. Acreage allotment and marketing quota programs used either separately or together and tied to price support programs;

3. Land retirement, adjustment or diversion programs, used in conjunction with price support programs or as separate programs, to bring production into reasonable balance with demand;

4. Commodity storage, handling, disposal, and surplus removal programs for both domestic and foreign use;

5. International commodity agreement programs, including the past International Wheat Agreement;

6. The sugar program;

7. Special food assistance programs, including the national school lunch program, the Child Nutrition Act, which includes the special milk program, the food stamp program, the commodity distribution program, which directly distributes foods to schools, charitable institutions, low income families and others; and

8. Marketing agreement and order programs.

Basic authorities for commodity and related resource programs are vested by Congress in the President, the Secretary of Agriculture, and the Commodity Credit Corporation (CCC).

The CCC was created to stabilize, support and protect farm income and prices, to help maintain balanced and adequate supplies of agricultural and other commodities, and to help in their orderly distribution.

The CCC also may make available materials and facilities required in producing and marketing commodities. In addition to its basic functions, it is used to administer and, in some cases, temporarily finance numerous special activities.

4. Stockpiling: The purpose of the stockpile is to ensure that the federal government will have available the necessary raw materials to support military requirements, and the basic civilian economy during periods of extended conflict and when normal foreign supplies of these materials are disrupted. By

maintaining appropriate levels of these materials in the stockpile, immediate dependence upon foreign nations can be prevented or reduced.

A major review of stockpile policy was conducted in 1972-1973 and resulted in a revised policy (GSA Fact Sheet, 1976). Specifically, the new policy calls for a materials stockpile capable of supporting U.S. Defense requirements as follows: during a major war, over a three year period, assuming large-scale industrial mobilization and providing a broad range of basic civilian economic needs to ensure the vitality of the wartime economy.

To meet the above requirements the Federal Preparedness Agency (1978) has established a stockpile goal of 513,000 long tons of crude natural rubber. The stockpile currently contains 119,000 long tons, thus there is an approximate 400,000 long ton shortfall to be filled by possible future natural rubber acquisitions.

a. Rubber stockpile specifications: Crude natural rubber acquired for the stockpile by purchase must conform to specifications published by the U.S. Department of Commerce (National Stockpile Purchase Specification, Crude Natural Rubber, 1977). These specifications cover the following grades of crude natural rubber:

No. 1 RSS - Standard Quality Ribbed Smoked Sheets

No. 2 RSS - Good Fair Average Quality Rubber Smoked Sheets; and

No. 3 RSS - Fair Average Quality Ribbed Smoked Sheets

These specifications conform to the type and quality described in the International Standards of Quality and Packing for Natural Rubber Grades (1968).

i. No. 1 RSS: Each bale must be packed free of mold. Very slight traces of dry mold on wrappers, or bale surfaces adjacent to wrappers, found at the time of delivery will not be objected to provided that there is no penetration of mold inside the bale.

Oxidized spots or streaks, weak, heated, undercured, over-smoked, opaque and burnt sheets are not permissible.

The rubber must be dry, clean, strong, sound and free from blemishes, resinous matter (rust), blisters, sand, dirty packing and any other foreign matter, except slight specks as shown in the sample. Small pinhead bubbles, if scattered, will not be objected to.

ii. No. 2 RSS: Slight resinous matter and slight amounts of dry mold on wrappers, bale surfaces and interior sheets, found at time of delivery will not be objected to. Should "rust" or "dry mold" in an appreciable extent appear on more than 5 percent of the bales sampled, it shall constitute grounds for objection.

Small bubbles and slight specks of bark to the extent as shown in the sample will not be objected to.

Oxidized spots or streaks, weak, heated, undercured, over-smoked, opaque and burnt sheets are not permissible.

The rubber must be dry, clean, strong, sound and free from blemishes, blisters, sand, dirty packing and all other foreign matter other than specified above as permissible.

iii. No. 3 RSS: Slight resinous matter and slight amounts of dry mold on wrappers, bale surfaces and interior sheets, found at time of delivery will not be objected to. Should "rust" or "dry mold" in an appreciable extent appear on more than 10 percent of the bales sampled, it shall constitute grounds for objection.

Slight blemishes in color, small bubbles and small specks of bark are permissible to the extent shown in the sample.

Oxidized spots or streaks, weak, heated, undercured, over-smoked, opaque and burnt sheets are not permissible.

The rubber must be dry, strong and free of blemishes, blisters, sand, dirty packing and all other foreign matter other than specified above as permissible.

Experimental tests of guayule rubber will be required to determine if it will meet the specifications for ribbed smoked sheets of Hevea natural rubber. The U.S. Department of Defense now has initiated a process for evaluating guayule rubber as a substitute for Hevea rubber used in military aircraft and truck tires (Dyckman, 1977).

This lack of guayule specification led Wrinkler, Schostarez and Stephens (1978) to evaluate Mexican guayule rubber in an effort to determine the physical properties and vulcanization characteristics. Guayule rubber gives physical properties similar to those obtained with natural rubber vulcanizates. They conclude that if a "technically specified" type of guayule is commercially feasible, this form of rubber can become a direct substitute for Hevea rubber.

b. International Stockpiling: In 1977 the Southeastern Asian countries submitted an international rubber coalition agreement to the United Nations. The United Nations agreed to review it. In November 1978, a conference was held in Geneva, Switzerland, by all of the nations that produce and consume natural rubber. The conference failed to produce an agreement, however, an international buffer rubber stock goal was set at approximately 700,000 metric tons.

Future operation and control of the international stockpile has not be determined.

C. Constraints on Guayule Production

Factors potentially inhibiting guayule commercialization include environmental restrictions, political and institutional commitments that might impinge directly or indirectly on guayule development, and regional constraints.

1. Environmental constraints: Those phases of commercial guayule rubber production constrained by environmental considerations include guayule cultivation and rubber processing.

a. Pesticide/herbicide regulations: The agronomic growth of guayule from greenhouse stock or direct seeding to field maturation will be subject to pesticide and herbicide applications as defined by federal and state regulations (Compilation of Federal, State and Local Laws controlling Nonpoint Pollutants, 1975). During the past 65 years, the Departments of Agriculture, and Health, Education and Welfare, the Food and Drug Administration and the Environmental Protection Agency have shared various responsibilities for regulating pesticides and herbicides. The overall intent of these efforts was to control by labeling, registering, or by other means, the quality, distribution, sale and even the production of these materials. A historical review of pesticide and herbicide regulation development is presented. In addition to these federal laws and regulations, it should be remembered that many state laws regulating pesticide use also exist which cannot be reviewed in detail here.

i. The Insecticide Act of 1910: The first legislation dealing with pesticide regulation, the Insecticide Act of 1910, was written with the intent to assure the buyer of product quality. It focused on Paris green and lead arsenate for specific regulation, but also was broadly written so that fungicides and other insecticides would be subject to regulation. The agency with main responsibility for enforcing this act was the Department of Agriculture.

Adulteration and/or misbranding were considered a misdemeanor (a criminal act) and were treated accordingly. Penalties were fines and/or imprisonment. To assure compliance with the Act's regulations, the manufacture and transport of adulterated products were also considered a misdemeanor and were punishable as such. Exports were exempted from the Act, but imports were subject to its regulations.

ii. The Federal Insecticide, Fungicide and Rodenticide Act: This 1947 Act, subsequently amended in 1959, 1961, 1964, 1972, and 1975, represented the first comprehensive effort to regulate "economic poisons." The Act provided a number of definitions, established stricter labeling measures and, for the first time, established registration requirements and procedures.

The Federal Insecticide, Fungicide and Rodenticide Act of 1947, in large measure developed in response to the inadequacy of the

Insecticide Act of 1910 in its regulation of the new herbicides synthesized during the 1930s and 1940s, also provided better control of new synthetic organic insecticides such as DDT. Consequently, FIFRA repealed the Insecticide Act of 1910. The 1947 FIFRA never used the word "pesticide," but rather refers to "economic poisons" including "insecticides, fungicides, rodenticides or herbicides." Economic poisons were "any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any insects, rodents, fungi, weeds and other forms of plant or animal life, or viruses, except viruses on or in living man or other animals...."

The 1947 Act required a product to be registered with the government before being introduced into the market. The new registration requirement established the power to punish violators and to remove the misbranded or adulterated products from the market. Violation of the Act was considered a misdemeanor and violators were subject to fines, imprisonment or both.

The registration requirements of FIFRA included:

1. The name of the registrant and the name to appear on the label if different from the registrant;

2. The name of the economic poison;

3. A copy of the label;

4. All claims made for the economic poison;

5. Directions for use; and

6. Any test results of the use of the material.

The labeling requirements of the Act sought that the label should include:

1. The name of the economic poison;

2. The name of the producer;

3. The net weight;

4. Direction for use; and

5. Appropriate warnings and antidotes.

In addition, FIFRA required that coloring had to be added to powdered white pesticides for safety consideration to distinguish them from household white powders such as salt or sugar.

As with the Insecticide Act of 1910, FIFRA prohibited the manufacture, sale and transport of adulterated or misbranded products. Also, materials intended for export would not be subject to the Act's requirements, but imports would. Intracompany shipments were not subject to FIFRA regulation.

The first amendment to FIFRAoccurred in 1959. It was entitled the Nematocide, Plant, Regulator, Defoliant and Desiccant Amendment of 1959. The Amendment broadened the 1947 Act to include the substances listed in the title. It included definitions for these terms, and provided for the control of their residues on raw agricultural commodities. The second amendment to FIFRA in 1961 was, in actuality, an amendment to the 1959 amendment and is of minor concern here.

FIFRA was again amended in 1964 to require that the label of economic poisons include a registration number, and to eliminate the so-called registration under protest. In place of registration under protest, a suspension and appeals process was provided whereby an applicant could correct an application and appeal for a new ruling. Specific mechanisms for appeal were part of the legislation.

The "Federal Environmental Pesticide Control Act of 1972" is legislatively an amendment to FIFRA, but in fact, is a major revision of it. The 1972 Act is the most ambitious and comprehensive regulatory structure for chemicals ever legislated. It transferred the joint responsibility of the Secretaries of Agriculture and Health, Education and Welfare for pesticide regulation to the Administrator of Environmental Protection Agency (established in 1970). It also placed pesticide regulation in an environmental context, that is, the "risk to man or the environment, taking into account the economic, social, and enviromental costs and benefits of the use of any pesticide."

The 1975 amendments to FIFRA were enacted to extend some of the regulatory aspects of the 1972 FIFRA amendments and to enlarge the advisory mechanism used to promulgate pesticide regulations. The major new requirements include:

1. An analysis of the impact on the agricultural economy of the cancellation or change in classification of a pesticide, prior to its cancellation or change in classification;

2. The publication in the Federal Register of all proposed and final regulations for pesticides;

3. The allowance of sufficient time for the Secretary of Agriculture and the appropriate House and Senate Committees to comment on the proposed and final regulations;

4. The notification of the Secretary of Agriculture, the Senate Committee on Agriculture and Forestry and the House Committee on Agriculture of the intent to announce proposed or final regulations;

5. The establishment of scientific advisory panels to comment on the impact of proposed and final regulations on health and environment;

6. The redefinition of the term "pesticide," stating exemptions;

7. The inclusion of instructions in integrated pest management techniques as part of applicator certification requirements; and

8. The registration or reregistration of pesticides using data obtained from tests conducted after October 21, 1972.

iii. The Federal Food, Drug and Cosmetic Act: The second major piece of legislation that has affected pesticides was initially enacted as the Federal Food, Drug and Cosmetic Act of 1938. Of more interest to pesticide regulation than the original act are the amendements passed in 1954, 1958 and 1960.

The 1954 Amendment first established the use of the term "pesticide chemical." It established regulations concerning the tolerance levels for pesticide chemical residues in "raw agricultural commodities." The amendment of 1960 required petition and certification for pesticide chemical use and established a fee system for certification application.

The 1954 Amendment provided that the Secretary of Health, Education and Welfare establish pesticide tolerance levels as needed for economic poisons (as defined by the Federal Insecticide, Fungicide and Rodenticide Act of 1947) used on raw agricultural commodities. Under this law, an applicant for pesticide regulation (under the 1947 FIFRA) could suggest a pesticide tolerance level. A pesticide application now had to contain:

1. The name of the pesticide;

2. Its chemical identity;

3. Its composition;

4. The amount, frequency and time of application;

5. Reports of investigations made on the chemical's safety;

6. Analytical methods used and results of residue tests made;

7. Methods to remove residues exceeding the proposed tolerance level;

8. (Optional) A proposed tolerance; and

9. Reasons stating why registration should be granted.

Within 90 days after a certification of usefulness by the Secretary of Agriculture, the Secretary of the Department of Health, Education and Welfare was required to either establish a tolerance for the pesticide (for the purposes for which it is certified for use) or exempt the pesticide from a tolerance. Thus, pesticide regulation was jointly shared by the Secretary of Agriculture, who had to decide usefulness, and the Secretary of the Department of Health, Education and Welfare, who had to decide if the public health was endangered by the use of the pesticide.

iv. National Environmental Policy Act of 1969: A subtle, but important shift in pesticide regulation developed as a result of the articulation in this legislation of a national policy for the environment. This Act established the Council on Environmental Quality and became important in all federal legislation and federal projects. Ultimately, it was used to shift the burden of proof to manufacturers, who now had to prove that their products were safe, whereas before the burden of proof rested with regulatory agencies, who had to prove that a product was hazardous.

v. Federal Plant Pest Act: Of particular interest to regulating certain biological pest control methods is the Federal Plant Pest Act of 1957. This legislation incorporates, but does not amend much of the legislation contained in the Insect Pest Act of 1905 (33 Stat. 1269), the Plant Quarantine Act (37 Stat. 315) and the Mexican Border Act (56 Stat. 40). The Federal Plant Pest Act is concerned primarily with regulating, controlling and eradicating plant pests, both domestic and foreign. It pays particular attention to preventing dissemination of a plant pest to an area where it does not normally occur.

vi. Other pertinent legislation: Although pesticides are not specifically identified, their manufacture and transportation are subject to regulations pertaining to other environmental pollutants or hazardous materials under provisions of the Clean Air Amendments of 1970 to the National Air Pollution Control Act of 1955, the Solid Waste Disposal Act of 1965 (as amended in 1970), Oil Pollution and Hazardous Substances Control Act of 1968, the Refuse Act of 1899, and regulations of the Department of Transportation. In addition, pesticide manufacturers have been required for more than 25 years to report annually to the United States International Trade Commission (formerly the U.S. Tariff Commission) the quantities of organic pesticides produced.

The Federal Trade Commission has the authority to regulate advertising of products of all kinds, and has exercised this authority in a few instances that involved pesticides.

The Technology Assessment Act of 1972 also has the potential to impact on pesticide regulation. The Office of Technology Assessment, part of the legislative branch of the federal government, is responsible for overseeing federal efforts to promote new technology. The potential impact of this Act on chemical and biological pesticide regulation is unknown, but it could be significant.

A Toxic Substances Control Act was passed in late 1976. Regulatory authority under this legislation is centered in the EPA Office of Toxic Substances. Although its thrust is on industrial chemicals, its potential impacts on pesticide regulation could be significant.

b. Processing plant regulations: The framework within which siting and constructing a guayule rubber processing plant would occur is a collection of federal, state and local environmental laws, regulatory programs and judicial reviews. OF primary concern are those regulations concerned with water and air waste discharges.

i. National Environmental Policy Act (NEPA) of 1969: Section 102(2) (C) of NEPA requires that any agency of the federal government proposing to undertake an action "significantly affecting the quality of the human environment" file an impact statement with the Council on Environmental Quality. Constructing a guayule processing plant with federal funds would require a statement describing the action, its impact and the alternatives considered. Before filing, the statements must be circulated to the public and to appropriate federal, state and local environmental agencies by the lead agency. Comments received on the draft statement become part of the public record along with the final statement, which should reflect the comments.

Private projects that involve federal permits, funds or other federal actions will be subject to NEPA requirements. Development and use of impact assessments affects provision of agency funds, granting agency permits, siting or design of a guayule processing facility and implementing construction programs.

NEPA does not provide a veto power to any official, but it does provide new information to the public that exposes agency performance in determining and measuring possible environmental effects, agency consideration of feasible project alternatives in terms of site and design, and enlarges the record for judicial review of agency decisions.

Constructing a guayule processing facility on private land with non-federal funds is exempt from NEPA requirements, but would be required under similar state assessment procedures in California.

Within the four-state guayule growing region, only California has an environmental quality act requiring an assessment of public actions.

ii. Federal Water Pollution Control Act Amendments (FWPCA) of 1972: The Federal Water Pollution Control Act Amendments of 1972 that amended the Federal Water Pollution Control Act of 1968 requires EPA to establish national effluent standards for all point sources of water pollution and to ensure compliance with such standards by means of a national permit program.

Type of Regulation	Categories of Guayule Processing Effluent					
	1	2	3	4	5	etc.
National New Source Performance Standards, for each source type (S.306)						
National Standards for Specified Toxic Pollutants (S.307)						
Special Consideration for Thermal Discharges (S.316)						
Special Limitations to Ensure Achievement of Water Quality Standards (S.302)						
Special Pretreatment Requirements for Discharge into Public Treatment Works (S.307)						
Special Permit System for Discharge of Dredged or Fill Material (S.404)						
State Management Program for Regions with Substantial Water Quality Problems (S.208)...to be developed						

Scope of Discharge Permit (S.402)

Figure III-38. Major elements of FWPCA-72 applicable to the siting, construction and operation of a guayule processing facility. (Reference to sections of FWPCA-72 and subsequent regulations appear in parenthesis).

TABLE III-28

SUMMARY OF POTENTIAL PROCESS-ASSOCIATED-WASTE WATER SOURCES FROM A SALTILLO-TYPE GUAYULE PROCESSING FACILITY

Plant Process	Purpose	Nature and Origin of New Point Source Waste-Water Contaminants
1. Parboiling	Defoliation, dirt removal	Leaves containing copper, manganese and resin compounds
2. Milling	Convert plant to pulp	Caustic soda (sodium hydroxide)
3. Rubber separation	Separate rubber from bark	Bagasse, surfactant, caustic soda
4. Deresination	Remove resins from rubber	Acetone (non-recovered), resins
5. Solution-coagulation	Rubber purification	Hexane (non-recovered), cork fiber and dirt

Implementation of the Act will affect siting a guayule processing facility significantly; the design of such a facility if the operation will produce objectionable effluent; the construction process; and the subsequent operation.

The following matrix of waste-water discharge regulations is presented for the case of a new guayule processing facility (See Figure III-38) requiring a discharge permit. The scope of the system includes discharge of toxic pollutants and thermal waters; limitations to ensure achievement of water quality standards; pretreatment before discharge into public treatment works; and a water quality management program.

Table III-28 presents a review of the potential waste-water sources using the Government of Mexico's pilot guayule processing mill at Saltillo, Coahuila. This process involves six steps consisting of parboiling, milling, separating, deresinating, solution coagulating, and drying and packaging (Guayule, An Alternate Source of Natural Rubber, 1977).

The deresination process using acetone produces volatile and non volatile terpenoids, wax, shellac-like gum, drying oils, and cinnamic acid which remain in the water. Taylor (1946) briefly discussed effluents in the mill extraction of guayule rubber. He reported that in milling, some of the plant material is dissolved. An additional portion is reduced to a near colloidal condition and is held suspended in the water. At the time no attempt was made to remove the solids or reuse the waste water.

An alternative for rubber extraction is the direct solvent extraction method; however, more research is required before it can be considered an alternative method of processing (Glymph, 1979).

iii. The Clean Air Act and Amendments through 1977: The Act sets national primary and secondary ambient standards and the ongoing review and approval of state implementation plans. Figure III-39 illustrates those features of the program as they relate to land use and development of a new guayule processing facility.

The EPA has set ambient air quality standards for six pollutants: carbon monoxide, hydrocarbons, photochemical oxidants, nitrogen oxide, particulates, and sulfur oxide. Each state must develop an implementation plan to ensure attainment and maintenance of primary or secondary standards, including but not limited to, land use and transportation controls.

Air pollutants that could be emitted from a commercial guayule processing plant are unknown at this time; however, compliance with state regulations adopted for attainment of standards must be accomplished.

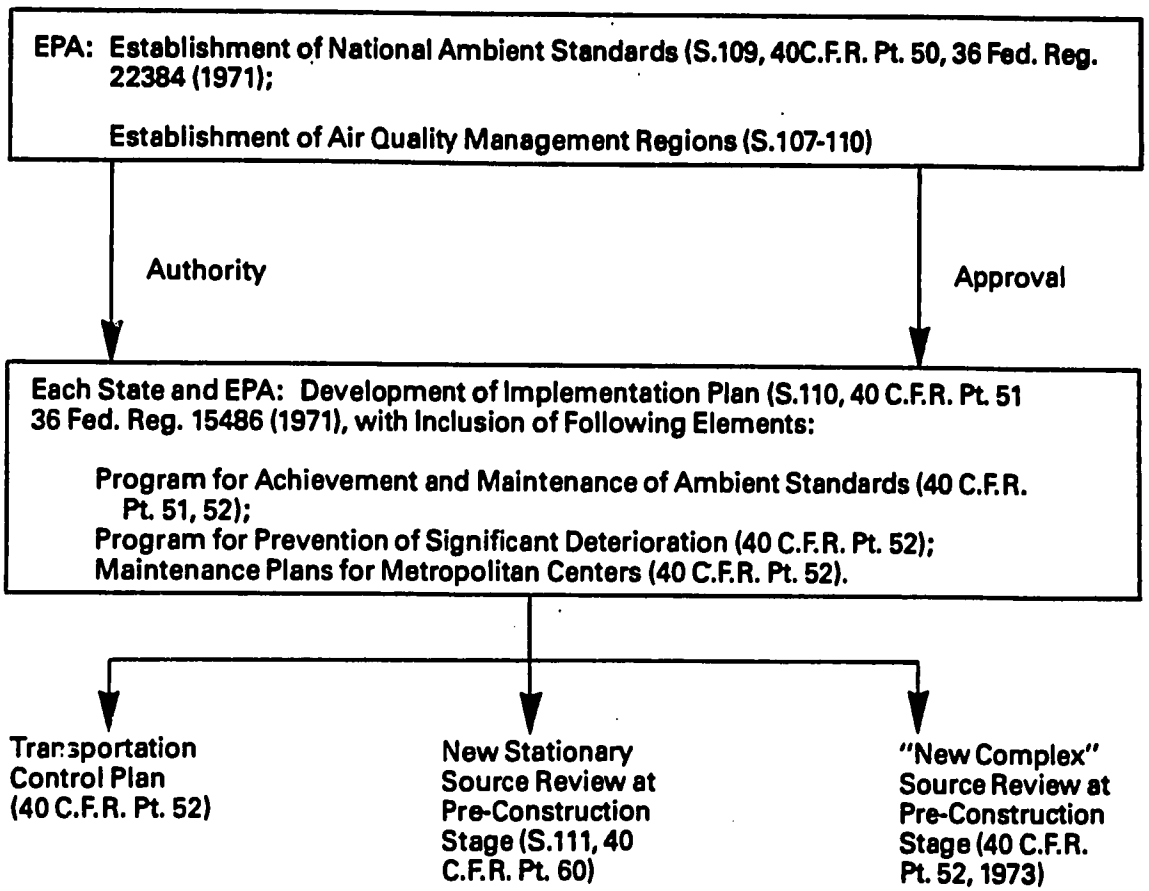


Figure III-39. Major elements of the Clean Air Act applicable to the siting, construction, and operation of a guayule processing facility. (References to sections of Act and subsequent regulations appear in parentheses).

iv. The Solid Waste Disposal Act as amended, 1970: Although the Solid Waste Disposal Act, as amended in 1970, gives EPA the responsibility for recommending guidelines, there are to date no federal regulations for controlling solid waste. However, the EPA has taken an active role in helping state and local governments find the most efficient, practical and environmentally suited methods of controlling and disposing of solid wastes. As specified in Title 36, Arizona Revised Statutes for example, the owner or occupant of any business establishment or industry is responsible for storing and disposing of all refuse. Plans and specifications for disposing of industrial wastes must be submitted to the appropriate county health department.

Although industrial process wastes and toxic substances generally are considered unacceptable for routine collection, they may be so disposed of at the discretion of the collection agency. Landfills must be approved by health departments before operations begin, and if incineration is to be used, plans and specifications must be submitted, including plans for an approved method of disposing of non-combustible refuse.

The rubber separation process generates quantities of bagasse in a slurry. Recycling water and resultant drying of the pulp material will create a source of solid waste for either disposal or energy generation at the plant site.

c. Framework for guayule processing facility siting at state level: Planning and constructing a guayule processing plant will be implemented in several sequential stages of conception, planning, siting, design, construction, and operation. The facility brings about social, environmental and other effects that can be designated as direct, indirect, primary and secondary, beneficial, and detrimental.

Four basic classes of effects from construction and facility operation stages are described in the following paragraphs.

1. Ecological: Sedimentation, erosion, landscape change, wildlife habitat change, and air and noise pollution.

2. Economic: Private property values, taxes, insurance rates, and local and regional community jobs, commerce, services, and tax base.

3. Regional and community quality of life: Esthetics, congestion, traffic, population migration, recreation, and human health.

4. Social and political factors: Changes in residents and lifestyles, changes in social opportunities, and change in municipal systems for education, water supply, energy and solid waste disposal.

Figure III-40 is a flow chart for project planning.

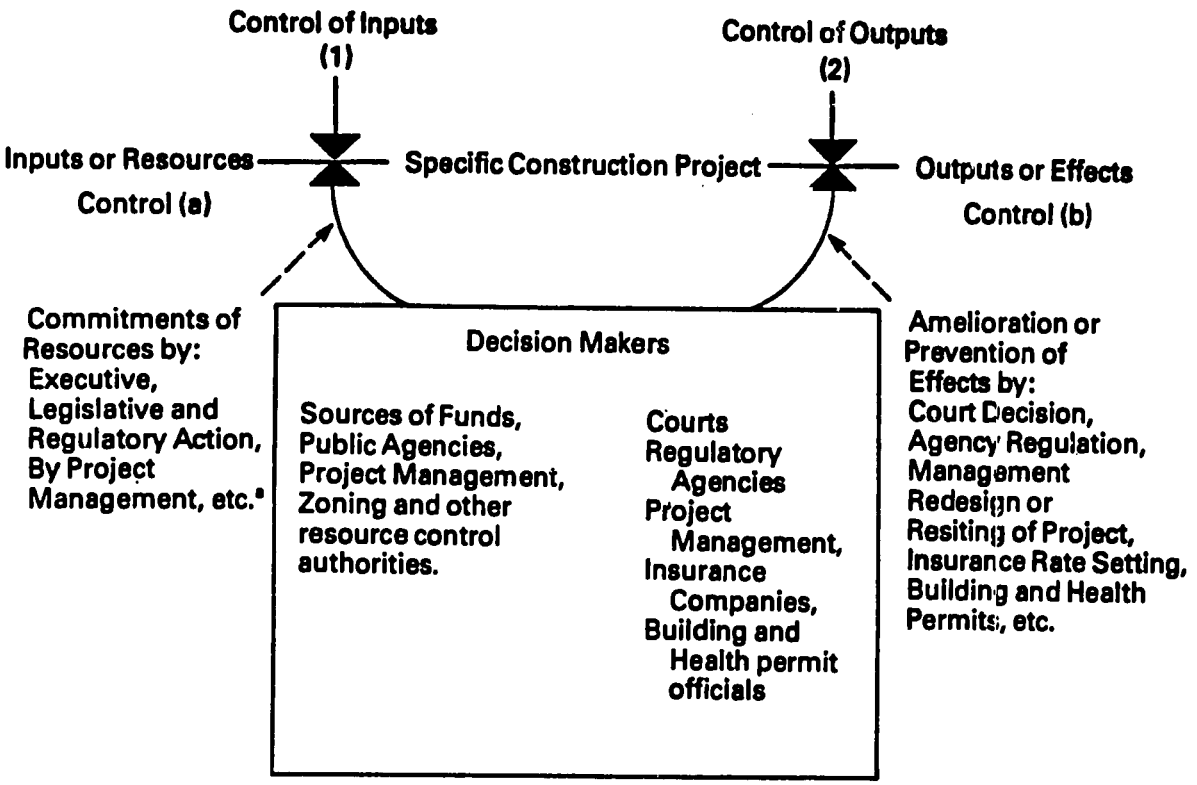
FIGURE III-40

FLOW CHART FOR PROJECT PLANNING

Impacts on Resources	Plant Construction	Outputs or Effects
Natural, Human and Fiscal Resources	Sequential Project Stages	Primary and Secondary Effects
Funds	Conception	Ecology
Manpower	Planning	Economy
Time	Siting	
Facilities and Equipment	Design	Regional and Community Quality of Life
Materials	Construction	Social and Political Changes
Natural Resources (air, water, land)	Operation	

Implementing a guayule rubber processing facility will depend on various decision makers in the public and private sectors and at the local, state, regional and federal levels. These decision makers function as controls as shown in Figure III-41: 1) by controlling inputs of resources, e.g. public agencies and private sector sources of manpower and funds for planning, design and construction; zoning and other land use or natural authorities; federal and state legislatures whose enactments may be essential to the availability of other project resource inputs; project management; and 2) by controlling the effects or outputs, e.g. the courts by means of preliminary or permanent injunctions or awards of compensatory damages; federal agencies and state counterparts that engage in standard setting, regulation and enforcement; the courts again as judicial reviewers of such agency determinations and building and health authorities.

California Environmental Quality Act of 1970: California is the only state in the four-state guayule growing region that requires an environmental impact report to identify the significant effects of a project on the environment. California public agencies at all levels are required to develop standards and procedures necessary to protect environmental quality.



*NEPA impact Assessments by federal and some state agencies when inputs may bring about subsequent environmental effects.

Figure III-41. Decision makers as project controls.

d. Health and safety of workers, Occupational Safety and Health Act of 1970: The intent of this legislation was to establish health and safety standards for workers, and it has had significant influence on developing increased awareness of the dangers of working with hazardous equipment and toxic substances, including pesticides. The Act probably will have significant impact on applicator certification programs and on setting exposure tolerances for agricultural field workers, pesticide manufacturing and formulating workers and guayule processing facility operators.

Several recent studies focused on occupational health of workers in the rubber industry. Rubber World (1975) reported on two studies of health conditions in the industry. The examined cases showed several cancer mortalities, some of which were associated with specific job categories, including lung, colon-rectal and bladder cancers among calendering operations; lung and stomach cancers among extruder operators; stomach and bladder cancers among curingroom workers; and prostate cancer among preparers of rubber compounds and cements. McCormick(1972) conducted a comprehensive survey of the 46 antioxidants and antiozonants available. The toxicity of each was reviewed. McCormick (1971) also identified health hazards in reference to production and processing of styrenebutadiene rubber, nitrile, Neoprene ethylene-propylene, butyl rubbers and urethane elastomers. Carbon black, siliceous dust and organic solvents were reported to be hazardous materials.

2. Institutional and governmental considerations: Since World War II international trade has trended toward liberal economic relations; tariffs have been reduced and foreign investment has grown rapidly. Among the results have been a growing interpenetration and interdependence among national economics because foreign trade and foreign investment have grown much more rapidly than national production income.

Legislation dealing with various aspects of international trade date to the 1930s. A historical review of the development of legislation impacting upon international trade is presented. In addition existing trade agreements with the United States, Hevea rubber exporting countries and Mexico as it specifically relates to guayule development are discussed.

a. International trade agreements and tariffs:

i. Smoot-Hawley Tariff Act 1930: After World War I, each country sought to protect its interests. Currencies were devalued, tariffs raised, imports curtailed and exports sold through force. The Smoot-Hawley Tariff Act raised tariffs in the United States to their highest level. The United States was in the first stage of the depression and sought internal economic recovery. However by the end of the 1931, 26 other countries imposed quantitative and exchange restrictions.

ii. Trade Agreement of 1934: The 1934 Act empowered the president to enter into trade agreements with foreign governments and to reduce tariffs. The Act also laided the foundation for a future U.S. reciprocal trade policy.

iii. 1947 General Agreement on Tariff and Trade (GATT): The GATT is a multilateral agreement written and signed by 23 countries and represents a uniform international trade code. It sets forth as a principle the idea that world trade should be free of restrictions. The GATT also recognized the imperfections of world commerce. It sets the terms of which member countries may erect trade barriers to protect balance of payments; provides the means by which countries can protect against unfair trade practices; determines what type of action will be taken against dumping, and against subsidized imports; and sets standard procedures for redressing another country for violation. As of 1974, 87 countries had signed the Agreement.

iv. 1948 Trade Agreement Act: This Act renewed the 1934 Act but was extended only until 1949. The 1948 enactment was appealed in 1949 and the trade agreement was extended retroactively from 1948 to June 1951. It was felt by President Truman and Congress that a trade policy revision should be developed. Two major elements that dictated American diplomacy and trade were Soviet control of the Eastern Block and the depressed economic situation of Western Europe.

After World War II, the United States was the only country that could produce enough exports for the rest of the world due to destruction in the other major industrial countries. By 1948 the United States produced more than 41 percent of the world's goods and services and accounted for almost half the world's industrial output (Potter, 1960). More than 42 percent of American produced goods were shipped to Europe. But the United States was exporting without receiving imports. Also, between 1945 and 1947, even though the United States had lower tariffs, trade negotiations were bilaterial. There was a fear of a recession and the only way to create a healthy foreign trade policy was by helping to reconstruct the European market. The Marshall Plan was conceived during summer 1947, and would serve two purposes: 1) help the European economy recover; and 2) eliminate possibility of communist influence in Western Europe. The Marshall Plan was successful in opening up multilateral negotiations to give access to raw materials and to establish a sound basis for world economy.

v. 1951 Trade Extension Act: The Peril Point System was adopted. The president submitted to the Tariff Commission a complete list of products for which he intended to negotiate duty reductions. The Commission analyzed the list and recommended either a reduction or an increase on each commodity, with the rationale of not causing injury to the domestic industry.

vi. The Reciprocal Trade Act of 1962: This Act was the final step in reducing tariffs set in 1930. It also emphasized new aspects of trade, agriculture, and non-tariff trade barriers with

developing countries. The Act also created new concepts and methods to negotiate tariffs and reduce other trade barriers as well as established the post of the president's Special Representative for Trade Negotiations. The special representative is responsible to the President for: 1) basic policy issues arising in administering trade agreements; and 2) action the President should take with respect to foreign imports. The special representative is the chief representative of the United States in negotiating trade agreements under the Act.

vii. Trade Act of 1974: The Act allows the president five years to negotiate trade agreements providing for: 1) reducing tariff rates effective January 1, 1975, by as much as 60 percent; 2) harmonizing, reducing or eliminating non-tariff trade barriers; and 3) prohibiting or limiting imposing such barriers.

Since the 1974 Trade Agreement trade policies have regressed. Several factors account for these trade difficulties: emergence of newly industrialized nations that are competing to gain a portion of the market for industrial goods; shifts in the patterns of world consumption and production; greater skepticism about functioning of the international market trading system; and the current trade deficits following the oil price increase in 1973. Accordingly, individual nations have taken measures to safeguard economies and to offset price fluctuations.

In response to these recent problems, the United States, along with other major industrial countries has become committed to promoting free trade and reducing protectionist pressures around the world.

viii. 1978 Multilateral Trade Negotiations-Tokyo Round: The objectives of these multilateral negotiations have been to re-establish tariff and non-tariff barriers and to formulate rules for fair trade and codes of fair conduct.

Late in 1978, these objectives nearly had been reached with a general agreement on tariff and non-tariff barriers to trade. It is still subject to final agreement and legislative approval. The trade package contained codes on subsidies, government procurement, standards, customs evaluations and licensing. The United States has agreed to a 30 percent reciprocal cut on tariffs with its trading partners. In addition it was agreed to remove several particular industrial and agricultural barriers.

There were also measures in the agreement to improve the General Agreement on Tariffs and Trade (GATT) framework to address agricultrual trade issues with developing countries, balance of payments, export restrictions, and general management of trade disputes.

This tentative agreement on the Multilateral Trade Negotiations represents the first time since the 1960s that the international community has covered such a broad spectrum in reducing tariff and non-tariff barriers.

ix. The National Export Policy, September 26, 1978: The National Export Policy is in conjunction with the Multilateral Trade Negotiations. The Policy was initiated in the light of the weakened dollar and decline of U.S. manufactured exports.

The administration has taken the position of assuring a strong export industry for U.S. businesses and an environment for fair competition from imports.

The Policy also will provide: 1) increased size and flexibility of the Eximbank's activities;2) commitment from the Small Business Administration to channel up to $100 million of its loan guarantees to small export businesses; 3) $20 million of the Commerce and State Departments budgets has been earmarked to provide assistance to small and medium businesses to help marketing efforts abroad; 4) increased level of short-term agricultural exports by almost $1 billion; and 5) clarification by the Justice Department on enforcement of the Foreign Corrupt Practices Act and application of U.S. antitrust laws on an international basis.

b. Trade agreements with rubber exporting countries: To gain access to raw rubber supplies, the United States has negotiated bilateral trade agreements with each rubber producing country. These agreements are referred to as Economic and Technology Cooperation. Each agreement is discussed below for the purpose of defining the agreement by the two countries, and to ensure that the economic and technology exchanges are included in the framework of the bilateral agreement.

The United States may guarantee aid in the form of education, food, military assistance, or industrial equipment in exchange for natural rubber.

i. Mexico: Mexico and the United States recently renewed the Economic and Technology Cooperation Agreement after a meeting between President Carter and President Lopez Portillo, in Mexico City, during February 1979. As part of the agreement cooperation between the two countries for managing the semiarid and arid lands of Mexico and the U.S. Southwest was acknowledged.

Guayule has been of interest to both countries during the past few years and has led to cooperative research, and constructing a guayule pilot processing facility at Saltillo by the Mexican government. This renewed agreement with Mexico provides a stronger bond of guaranteed cooperation between the two countries in the development of guayule (Long, 1979).

ii. Malaysia: The major producer and exporter of rubber since the end of World War II has been Malaysia. During the past three years Malaysian shipments to the United States have constituted a third to a half of the total rubber produced.

RUBBER EXPORTED TO UNITED STATES

(metric tons)

1975	1976	1977
435,193*	514,388	495,075
RUBBER EXPORTED TO OTHER COUNTRIES		
981,807	949,612	1,037,925

*Includes crude, latex and dry forms of rubber
Source: U.S. Department of Agriculture, 1976-1977.

Since producing rubber involves more than 75 percent of the country's agricultural industry, the Malaysian government taxes the export of rubber (Koh and Yong, 1978). The export tax is paid by the rubber producers, and depends on the price of rubber. In 1976, the surcharge and export tax provided the largest source of revenue for the government, more than 51 percent of the total revenue income, and amounted to $519.1 million.

The system of tax is aggregated, and has caused producers to decrease production acreage from a postwar high of two million acres to 1.4 million acres in 1978 (Koh and Yong, 1978).

Recently the government recognized that the larger rubber plantations were decreasing acreages, while smaller rubber producers were increasing acreages. However the government believed that the smaller producers could not compensate for the loss in production caused by the larger plantations. To reverse this trend a restructuring of the export tax was initiated by the government in 1978 and features:

1. No export duty is to be levied when the price of rubber is below 110 ct. per kilogramme; and

2. A surcharge which was operative when the price exceeded 137.8 ct. per kilogramme is now incorporated into the export duty.

Although the new export duty is lower, it is not expected to bring immediate savings. It could take five or more years to reap the benefits from the new tax system.

The producers also would like the government to revise the tax system for calculating the export duty on several grades of rubber,

e.g. RSS.1, .2 and .3, and SMR.20. Presently the tax is calculated on RSS.1 alone (Koh and Yong, 1978).

The United States and Malaysia formed formal diplomatic relations in 1963 when Malaysia was granted independence from the British Commonwealth. The United States originally had signed an Economic and Technology Cooperation agreement with Britian in 1948, however, Malaysia still was a colonial possession at that time. In 1963, all agreements and treaties automatically transferred in full force to Malaysia.

Part of the 1948 agreement specifically spoke of close consultation between both countries on disposing of surplus rubber stockpiles. This program still exists. The United States has consistently sought to carry out its disposal programs in a way that would avoid serious effects on the economies of Malaysia and other rubber producing countries.

U.S. friendship and support for Malaysian development are demonstrated through the Peace Corps ($3.2 million), Public Law 480, Food for Peace Program ($100,000), military assistance grant program ($200,000), and military assistance credit sales ($18.8 million). The military assistance program provides training for Malaysians in the United States. There also is a Fulbright education exchange program. In 1974 the total American aid received by Malaysia was $22.3 million (U.S. Department of State, 1976b).

The United States is among the leading sources of foreign private investment in Malaysia. Current estimates place U.S. private investment at more than $461 million in fields ranging from oil exploration and timber processing to manufacturing sophisticated electronic components. Investors in Malaysia now must take into account the 1975 Industrial Coordinations Act, which requires manufacturing companies in Malaysia to obtain a license from the government. The government wishes to assure the employment of indigenous Malay citizens in manufacturing and other firms.

Relations between the United States and Malaysia are fruendly and respectful. Malaysia has adopted a neutral philosophy in dealing with all Southeast Asian countries. In 1967 Malaysia was one of the main representatives in forming the Association of Southeast Asian Nations (ASEAN). ASEAN, composed of Indonesia, Malaysia, the Philippines, Singapore and Thailand, is based on economic cooperation among the member nations. The United States views ASEAN as a contribution to stabilization and growth in Southeastern ASIA (U.S. Department of State, 1976b).

iii. Singapore: Singapore lies at the southern extremity of Asia at the tip of the Malaya Peninsula and is considered the crossroads for Southeast Asia in international trading. It is the clearinghouse for transporting and shipping natural rubber produced in Malaysia, Thailand and Indonesia. As the third largest port in the world, shipping has become a major factor in Singapore's economic growth. In 1976 Singapore handled more than 58 million freight tons. The data below show the quantity of natural rubber shipped from Singapore for a three-year period.

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
128,031	87,114	101,935

(Includes allied gums, crude, latex and dry forms of rubber) Source: U.S. Department of Agriculture, 1976 and 1977.

Formal diplomatic relations with Singapore have been maintained since 1965 when Singapore severed relations with the Federation of Malaya. Before the Malaya association, Singapore was a British Crown Colony. Singapore's effort to maintain economic growth and political stability is considered in harmony with U.S. policy.

Since Singapore is a country with few natural resources, and must rely heavily on trade, the government has sought to expand the manufacturing sector in the last few years. The United States provides about 12.6 percent of Singapore's imports. The imports to Singapore from the United States are mainly machinery and other manufactured goods. U.S. imports from Singapore are mainly crude rubber, electrical machinery and textile products.

In February 1978, Singapore and the United States signed a four-year bilateral textile agreement. The United States also entered into a civil aviation agreement which will enhance air transportation between the two countries (U.S. Department of State, 1978b).

The United States has no formal program of assistance to Singapore, although an investment guarantee agreement is in effect.

U.S. private investment is playing an increasingly important role in Singapore's rapid economic expansion in petroleum, general manufacturing, electronics and in modernizing regional distribution facilities. U.S. firms also are active in shipping, banking, hotels, insurance, and importing and exporting. The U.S. investment, believed to exceed $1.2 billion, has grown with the increasing number of U.S. citizens living and visiting in Singapore and has enhanced communications between both countries.

Singapore has maintained a non-aligned position with respect to world powers and seeks cordial relations with all nations. Singapore also is a member of ASEAN (U.S. Department of State, 1978b).

iv. Indonesia: Indonesia is a country rich in natural resources, but is short on modern technology and education for development. The United States traditionally has taken 20 percent to 30 percent of Indonesia's exports, mainly in crude oil (70 percent) and natural rubber (8.2 percent). Each year there has been a gradual increase of 4 percent in the amount of natural rubber shipped to the United States.

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
988,825	1,168,748	1,219,053

(Includes allied gums, crude, latex and dry forms of rubber)
Source: U.S. Department of Agriculture, 1976 and 1977.

The United States was an early supporter of Indonesian independence, and for many years the two nations enjoyed good relations. However, the change of Indonesia's international position shifted from non-alignment to outspoken opposition to policies of the United States and its allies. This adversely affected relations between the two countries from 1963 to 1965. There also were serious difficulties resulting from Indonesian action against public and private U.S. interests in Indonesia.

During the early 1960s President Sukarno imposed an authoritarian regime. Concurrently he alligned Indonesian foreign affairs with that of Asian Communist states. President Sukarno lost power after a civil war in October 1965. The Indonesians had retaliated against the communist forces. His power eroded as evidence of mismanagement and misconduct become apparent. Executive power was transferred to General Suharto in 1966 who returned the government to a democratic policy.

Today, however, the United States is playing an important role in supporting Indonesia's effort to begin moving toward self-sustaining development. In 1966 the United States, Japan, the Netherlands, Belgium, France, Australia, the Federal Republic of Germany, Italy and the United Kingdom formed the Inter-Governmental Group on Indonesia (IGGI). Switzerland, Canada and New Zealand also have become members.

In 1976-1977 the IGGI countries committed $1.2 billion in foreign assistance to Indonesia. The amount for 1977-1978 was about $1.1 billion.

Indonesia received U.S. aid from the P.L. 480 (Food for Peace Program) plus about $156 million during FY 1977. U.S. assistance is primarily for agricultural and population programs. There is a modest military assistance program which focuses on developing Indonesia's internal defense capabilities, training skills and management.

The United States and other countries want Indonesia to grow and stabilize itself and to eliminate the communist-dominant philosophy of the early 1960s. Indonesia is another member of ASEAN. Indonesia has large oil reserves that are being developed and are members of OPEC (U.S. Department of State, 1978a).

v. Thailand: This a country that has enjoyed independence since 1826. Since the end of World War II Thailand has enjoyed relative peace; however, during the 1960s and 1970s communist and antigovernment propaganda grew. To meet this challenge the Thai government accelerated its program of economic and social development to avert communist influence among the people.

Agriculture represents about 50 percent of the economic income for the Thai GNP. Only a small part of this is devoted to growing and producing natural rubber, as shown below.

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
61,246	130,492	230,301

(Includes crude, latex and dry forms of rubber) Source: U.S. Department of Agriculture, 1976 and 1977.

Thailand also has experienced substantial balance of payment deficits during the last few years despite foreign borrowing. Thailand export earnings have been down resulting in inflation. The Thai government has made several positive decisions to improve this imbalance by financing $4 billion in foreign currency and investments of $31 billion. These investments are expected to improve the rural-urban disparties, diversify agriculture and improve agricultural production. Natural gas also was discovered off shore, but will not be developed until the 1980s. The Thai economy is relatively free of controls and relies primarily on private rather than public enterprise, which has enhanced Thailand's ability to obtain foreign loans (U.S. Department of State, 1978c).

The United States and Thailand have had diplomatic relations since 1933. In the post-World War II era of rapid international communication the United States and Thailand developed closer relations in many fields and have participated in many multilateral activities and agreements through the United Nations. In 1966 a new Treaty of Amity and Economic Relations was signed by both countries. Other agreements cover air, transportation, civil uses of atomic energy, sale of agricultural commodities, cotton textile exports to the United States, investment guarantees, and military and economic assistance (U.S. Department of State, 1978c).

U.S. economic assistance to Thailand under various programs from 1947 to 1977 totaled $860 million. The programs included rural development, health, family planning and education. There are approximately 150 Peace Corps volunteers in Thailand.

Since 1950 Thailand has received U.S. military equipment, essential supplies, training and assistance for constructing and improving key facilities and installations. Also there is a small group of military advisors present. The level of military assistance is being reduced gradually.

Thailand is an active member of international and regional organizations. As a member of ASEAN it has exhibited an attitude of cordial relationships with all nations (U.S. Department of State, 1978c).

vi. The Philippines: The Philippine Islands are the last link in Southeast Asia as an area of production for natural rubber. Most natural rubber produced in the Philippines is used by industries within that country. Agriculture contributes 36 percent of the domestic economy and forestry represents 12 percent of total exports. The Philippines has extensive proven and potential metallic reserves. Mining exports represent 19 percent of total exports. Manufacturing accounts for 25 percent of total exports. However, economic problems are extensive; large trade deficits and investment capital shortages have stagnated growth.

Foreign investors will not extend credit to the Philippines unless there is improvement in transportation and adequate power supply.

The United States imports more than 22 percent of the total Philippines export which was $754 million in goods in 1976(U.S. Department of State, 1977d).

Under the Laurel-Langley Agreement each country enjoys certain tariff preferences. Investors of both countries receive national treatment or "parity" in the territory of the other. Economic relations between both continue to be close and mutually beneficial.

Since 1946 the Philippines has received $2.5 billion in economic and military assistance, including $257 million in post-war relief and $1.4 billion in development assistance and emergency relief. The United States also provided $74 million for flood rehabilitation after the floods in 1972. The United States also operates Clark Air Base and Subic Naval Base under the 1947 Military Bases Agreement (U.S. Department of State, 1977d).

The U.S. investment is estimated at more than $1 billion as of 1975. The Philippine government has committed itself to a policy of encouraging foreign investment as a basis for economic development subject to certain guidelines and restrictions in specific areas.

vii. Sri Lanka-Ceylon: Sri Lanka is a strong democratic republic and has maintained its independence since 1948. Rubber is among its most important agricultural export commodities accounting for about 45 percent of all exports. In 1974 more than $110 million worth of rubber was exported.

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
16,193	16,389	12,913

(Includes crude, latex and dry forms of rubber) Source: U.S. Department of Agriculture, 1976 and 1977.

Sri Lanka traditionally has relied very heavily on exports for financing; however, in the last few years, to stimulate internal growth, the government has imposed restrictions on the amount of imports.

Government policy during the 1970s created national, foreign and domestic assets. Extensive land reform in the rubber plantation sector occurred from 1972 to 1975. Most large estates, foreign and locally owned, were acquired by the state (U.S. Department of State, 1976c).

A fundamental weakness of the economy has been the failure to achieve food self-sufficiency, resulting in a dependence on food importation that consumed up to 75 percent of its export earnings. When the oil prices of the early 1970s increased, the trade deficit grew from $4 million in 1973 to $112 million in 1974.

Since 1974 U.S. aid has been at a level of $32 million. Finally there are developmental loans for agricultural development that are used to finance the purchases of commodities from the United States (U.S. Department of State, 1976c).

viii. Liberia: Liberia's economy is based upon three natural resources: rubber, iron ore and timber. Rubber production was first introduced in 1926 by Firestone Rubber Co., which presently manages the world's largest plantation there. Since World War II, Firestone has been joined by Goodrich and UniRoyal. These large concessions, along with numerous private Liberian growers, make rubber plantations the largest employers in the country.

The United States is Liberia's pre-eminent trading partner and is expected to continue as a leading source of capital and technical assistance. At present the United States receives about 5 percent of its total rubber import from Liberia.

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
228,805	220,507	198,797

(Includes crude, latex and dry forms of rubber) Source: U.S. Department of Agriculture, 1976 and 1977.

Liberia was recognized by the United States in 1862. Relations between the two countries are friendly and are based on the desire to maintain and strengthen close ties.

The United States continues to give assistance and support to Liberia's efforts to improve welfare and to strengthen its representative government. These are represented by the Peace Corps ($29 million), Food for Peace ($12.6 million), bank loans ($111.3 million), and military assistance. Total aid from 1946 to 1975 was $233.6 million. In 1975 aid was $183.4 million (loans $85.1 million, grants $98.3 million). Additional support is received from private business, missionary and educational organizations (U.S. Department of State, 1977b).

Political stability, continued support for "open door" investment and accepting a free market system has attracted a significant number of private investors. Other U.S. enterprises are Bethlehem Steel, Getty Enterprises, First National City Bank, Manhattan Bank, Chemical Bank and International Bank of Washington.

When Firestone initiated its first agreement in 1926 to develop rubber, it established a long-term commitment for economic growth. This agreement was renewed in 1976 and extends until 2025. Firestone operates a rubber-growing plantation of 90,000 acres (Firestone, 1977).

During the early 1970s, Liberia was interested in a regional economic organization and was the driving force behind the formation of the Economic Community of West African Nations (ECOWAS), founded in 1975. Its main priority was to propose a uniform code on tariffs between the member nations and to promote industrial and agricultural policies (U.S. Department of State, 1977b).

ix. Zaire: Zaire is a country with a strong centralized presidential party government. Zaire was granted independence from Belgium in 1960. At the time of independence, it was highly developed and diversified. Rubber has constituted only a small part of its exports. The main commodities are copper, cobalt, diamonds, manganese and coffee. Of the rubber produced in the last few years the United States has received the amounts shown below (U.S. Department of State, 1978d).

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
12,745	6,256	6,819

(Includes crude and dry form of rubber) Source: U.S. Department of Agriculture, 1976 and 1977.

Due to internal tensions during the last 10 years, Zaire has suffered severe economic and financial disorder. By 1975 the external debt rose from $736 million to $2.8 billion and the country fell behind in its repayment to both private and external

agencies. The government nationalized most private enterprises; but American-owned businesses were spared.

As of 1976, Zaire had been granted a $250 million loan by private creditors to help pay outstanding debts. The government also has devised a plan, the Mobutu Plan, for developing agricultural land and transportation sectors. Agriculture represents about 75 percent to 80 percent of the economy (U.S. Department of Agriculture, 1978d).

Relations between the United States and Zaire are excellent. The two countries share an interest in promoting economic growth and peaceful political development (U.S. Department of State, 1978d).

Total U.S. economic and military assistance through fiscal year 1977 was about $650 million. Current aid programs are concentrated in the fields of health, nutrition and agriculture. Approximately $500 million in direct loans and guarantees have been made by Eximbank in support of U.S. trade and investment in Zaire.

Private foreign investment is welcomed, but continuing economic difficulties have discouraged prospective investors.

In order to encourage investment, a new code was devised in 1969 which provided a tax holiday and other benefits. At the end of 1975 American investment totaled between $150 million and $200 million. During the Zairian nationalization of 1973-1974, American firms were protected by the business code. Repatriating profits from business operations in Zaire have not been possible for several years due to the country's chronic foreign exchange shortfall (U.S. Department of State, 1978d).

Internationally Zaire promotes a policy of non-alignment between East and West and seeks to promote economic interest of the developing African nations.

x. Nigeria: During the late 1960s and early 1970s a great deal of internal dissention split the country. The internal dissent between the tribes in the north and east of Nigeria led to the secession by the three eastern regions, declaring their independence as the Republic of Biafra. A civil war between the two regions existed from 1967 until 1970. Since the end of the civil war, economy has grown at a steady pace but the agricultural sector has lagged behind in development.

Rubber remains Nigeria's largest major export product.

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
31,617	3,276	2,471

(Includes allied gums, crude and dry forms of rubber)
Source: U.S. Department of Agriculture, 1976-1977.

The U.S. took the position of non-involvement during the Nigerian civil war. It has vigorously supported peace efforts and has contributed heavily to wartime and postwar relief. Public and private contributions during that time totaled more than $140 million.

The United States is the major foreign market for Nigeria's crude oil. Nigeria ranks second to Saudi Arabia as the most important foreign supplier of oil to the United States.

U.S. economic aid to Nigeria through 1974 has been $456.1 million. In 1974 aid totaled $5.4 million, $700,000 for development loans and $4.7 million for technical assistance. The United States has not made any new loans or grants since 1974 due to Nigeria's oil wealth (U.S. Department of State, 1977c).

Nigeria has welcomed private U.S. investment as a means of obtaining managerial and technological talent and training. Trade has increased steadily between both countries.

In 1976 the United States exported about $750 million worth of goods and services to Nigeria and has imported goods, mostly oil, worth $4 billion (U.S. Department of State, 1977c).

After the civil war Nigeria's foreign relations returned to normal. Nigeria is also a member of ECOWAS and has entered into a number of bilateral agreements with other West African nations to promote economic projects.

xi. Ivory Coast: Since independence in 1958 the Ivory Coast has enjoyed a steady development pace. The Ivory Coast is predominantly agricultural. The country is making a transition from producing coffee, cocoa, tropical woods and bananas to more productive and higher quality crops, including rubber and palm oil.

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
4,137	4,480	2,225

(Includes allied gums, crude and dry forms of rubber)
Source: U.S. Department of Agriculture, 1976 and 1977.

Ivory Coast leaders tend to follow a policy of economic liberalism, based on a fundamental belief in private enterprise. The policy has been followed faithfully and periodically re-emphasized.

The third five-year development policy, covering 1971 to 1975, called for public investment of $900 million and $80 million in foreign investment. The plan, structured toward economic and agricultural development, was designed to provide a growth rate of 7.7 percent (U.S. Department of State, 1976a).

United States relations with the Ivory Coast are friendly and close with an emphasis on economic development and expressed satisfaction with its moderate stance on international issues.

The U.S. Agency for International Development (AID) sponsors several regional projects in the Ivory Coast including road construction, livestock production and marketing. The Peace Corps is active in education and agriculture (U.S. Department of State, 1976a).

Ivory Coast foreign policy has been oriented toward the West. The government broke diplomatic relations with the Soviet Union in 1969 reaffirming its anti-Communist stance.

The Houphouët-Biogny government has favored a step-by-step approach to the question of African unity. The Ivory Coast maintains close ties with its French speaking neighbors in the Council of the Entente. The Entente countries cooperate to harmonize economic policies and to promote regional economic development.

xii. Brazil: Brazil is an independent country with a governmental system similar to that of the United States. In the last 15 years Brazil's economy has been troubled by runaway inflation, and an excessive trade deficit. The policy of the 1970s has been restrictive in trying to ease inflation and to balance the trade deficit.

The agricultural sector produces 15 percent of Brazil's GNP and 60 percent of its exports. The government is working toward improvement in the agricultural sector by introducing new crops which will bring higher prices on the export market (U.S. Department of State, 1977d).

Rubber was first discovered in the Amazon Basin of Brazil in 1735 by Frenchman Charles Marie de la Condammine. The most important geographical source of rubber in the 19th and 20th centuries was in the Amazonian forest of Brazil. Polhamus (1962) notes an Amazon exploration trip of Lt. William L. Herndon for the U.S. Navy in 1851-1852. According to Lt. Herndon, "rubber was being tapped and used by the tappers and their families."

Exports of unvulcanized rubber included shoes, balls, and toy figures. The annual production of rubber had reached 1,500 tons in the 1850s. A maximum of 34,000 long tons of wild Hevea rubber was harvested in 1914 (Polhamus, 1962).

After Charles Goodyear discovered how to vulcanize rubber in 1839, rubber plantation propagation of Brazilian Hevea was begun (Firestone, 1977). The earliest known plantations were in Brazil and

Mexico, but due to the rapid spread of South American leaf-blight among the newly planted saplings, the South American rubber-plantation effort virtually was abandoned until the 1970's. In late 1978 a fungicide had been developed which could control the South American leaf-blight (Bonner, 1979). Hevea trees will be planted and grown again in Brazil in the near future.

Some older rubber plantations still are being operated in Brazil but the annual tonnage is very small. In the last few years the United States has received mostly allied gums from Brazil.

RUBBER EXPORTED TO THE UNITED STATES

(metric tons)

1975	1976	1977
960	370	370

(Includes allied gums)
Source: U.S. Department of Agriculture, 1976 and 1977

Relations between the two countries are close. Agreements include a treaty of peace, joint participation on communications satellieties, scientific cooperation and a wide range of commercial and military concerns.

Brazil is the United States' 11th amongest its trading partners with $4.7 billion in trade in 1976. Numerous problems have arisen in agricultural commodities trade between the two countries, but these issues have been dealt with through negotiations with a minimum of disruption in trade.

The United States has given Brazil $1.4 billion in financial and technical assistance since the end of World War II. During the last few years there has been a shift in Brazil's economic performance that enabled Brazil to obtain loans from multilateral sources. U.S. aid now is concentrated on selected sectors, such as health, education and agriculture. In 1976 aid totaled $9 million. All military aid was terminated in 1977 by mutal consent by both governments. This also is a cooperative exchange between unviersities of the two countries. (U.S. Department of State, 1977d)

Brazil has been an ally of the U.S. community since the late 1800s. Brazil has played an important role in the security of the Western Hemisphere, contributing forces in both World Wars. Brazil also assigns forces to U.N. peacekeeping efforts.

Brazil is a member of the Latin American Free Trade Association (LAFTA), which stems from the Motevidion Treaty of 1962. LAFTA provides closer policy coordination on tariffs, industrialization, farm products

marketing and foreign investments. The member countries are Argentina, Chile, Mexico, Paraguay, Peru, Uruguay, Colombia and Ecuador. Brazil also is a member of the General Agreement on Tariffs and Trade (GATT) and the Committee of Twenty of the International Monetary Fund (IMF). (U.S. Department of State, 1977d).

c. Balance of trade: The United States shows a growing trade deficit and dependence on natural rubber and on oil importation for producing synthetic rubber to maintain national defense and living standards. Throughout the last decade there have been fundamental changes in the international economic system. Financial markets have become more integrated internationally and have adapted to the task of recycling unprecedented flows of funds from surplus to deficit countries.

Third World Countries have experienced rapid export growth, larger importation of heavy manufacturing equipment from the industrial countries and a rapid rise in income growth and production. The entrance of these countries into industry will continue to promote demands of natural rubber from Southeast Asia.

i. Current U.S. deficit transition: Throughout the postwar period the growth of U.S. imports tended to be greater in relation to domestic growth than the growth of exports in relation to growth abroad. Until 1975, a balance between import and export growth was maintained by the fact that growth abroad tended to exceed U.S. growth. From 1975 through 1978, however, growth in the United States surpassed the average growth abroad. As a result, the current U.S. account shifted sharply. In 1977, U.S. economic growth exceeded that of its trading partners by about 1.5 percent and the U.S. current account shifted by almost $20 billion, from a surplus of $4.3 billion to a deficit of $15.3 billion. Three-fourths of this amount is accounted for by the growth of imports.

With the increase in oil imports during the early 1970s, a recovery in private investments was necessary to sustain non-inflationary growth. Without it, private savings would remain excessive and aggregate demand growth inadequate. For a time, this gap was plugged by disavings (government expenditure exceeding tax revenue).

Following the modest 1975-76 recovery from the economic slump, inflation stopped falling. Private investment showed few signs of a comeback. At the time, it seemed that the demand stimulations were at an end and another recession would occur. If another recession occurred, it would start from record levels of unemployment and idle capacity. In the absence of any effective international balance of payments adjustment mechanism, other than through deficit countries stagnating more than their competitors, most would be forced to retreat behind trade barricades.

In mid-1977 there was an industrial minislump which hit Europe and Japan. It caused a marked improvement in terms of industrial country trade; a sharp break in inflation occurred during the second half of the year and the dollar valuation declined. Production fell in Australia, Belgium, France, Germany, Italy, the Netherlands and Britain. It stagnated in Japan and Canada. Only in the United States did it continue to expand (Reading, 1978).

In 1978 rates of inflation declined almost everywhere (Table III-29).

TABLE III-29

CHANGES IN CONSUMER PRICES IN MAJOR INDUSTRIAL COUNTRIES, 1976-78

(Percent[1])

Country	1976	1977	1978[2]
United States	5.8	6.5	7.6
Japan	9.3	8.0	3.9
Germany	4.6	3.9	2.7
France	9.6	9.5	9.2
United Kingdom	16.6	15.8	8.3
Canada	7.5	8.0	9.0
Italy	16.8	17.0	12.2

1 Changes measured from year average to year average.
2 Estimate.

Sources: Department of Labor, Board of Governors of the Federal Reserve System, and Council of Economic Advisers.

ii. Growth and inflation: The 1978 pattern of changes in growth and inflation rates was influenced heavily by the marked decline of the dollar and the consequent appreciation of most other major currencies. In countries where exchange rates appreciated, GNP growth lagged behind the growth of domestic demand and inflation rates declined. In this environment fiscal policy became more expansionary during the course of the year.

In the United States a weak external sector, accelerating inflation, rapidly declining unemployment, and a depreciating currency made it necessary to shift toward a more restrictive fiscal and monetary policy. There is a need to realign and coordinate economic policies, to promote a consistent pattern of adjustment between all countries. In the course of meetings that culminated in the Economic Summit at Bonn in July 1978, a significant degree of coordination was realized. At the Bonn meeting the leaders of the seven largest industrial countries discussed the major goals and problems in the world economy and a concerted action program was devised in which each country made appropriate specific commitments.

The Bonn Summit marked a turning point, particularly for the United States. The United States noted that curbing inflation has become the top priority of economic policy. The president therefore

pledged to take specified actions to reduce the U.S. inflation rate, to obtain a more rapid reduction in U.S. current account deficit, and to adopt an energy policy which would cut U.S. imports of petroleum by 2.5 billion barrels per day by 1985.

In addition, Germany and Japan proposed steps to increase growth and thus reduce external surpluses. Germany proposed to provide additional fiscal stimulus totaling 1 percent of GNP. Japan proposed to achieve a 7 percent growth in real GNP between March 1978 and March 1979. The other participating countries--France, Italy, the United Kingdom and Canada had high rates of inflation provided less scope for specific action--made broadly complementary commitments. At the same time, each country recognized the overriding importance of not allowing sluggish growth, sectoral difficulties, or trade imbalances to serve as pretexts for actions that would undermine the framework of free trade among nations.

iii. Devaluation: The value of the U.S. dollar changed dramatically in 1977 as shown by Figure III-42. From September 1977 through March 1978 the dollar fell by 8.7 percent on a weighted average basis against other currencies. During this period the markets tended to focus on the rapidly widening U.S. trade and current account deficits and their expected persistence. Even through a substantial portion of the deficits could be accounted for by the cyclical position of the United States relative to its major trading partners, growth forecasts suggested that this cyclical divergence would not be eliminated soon.

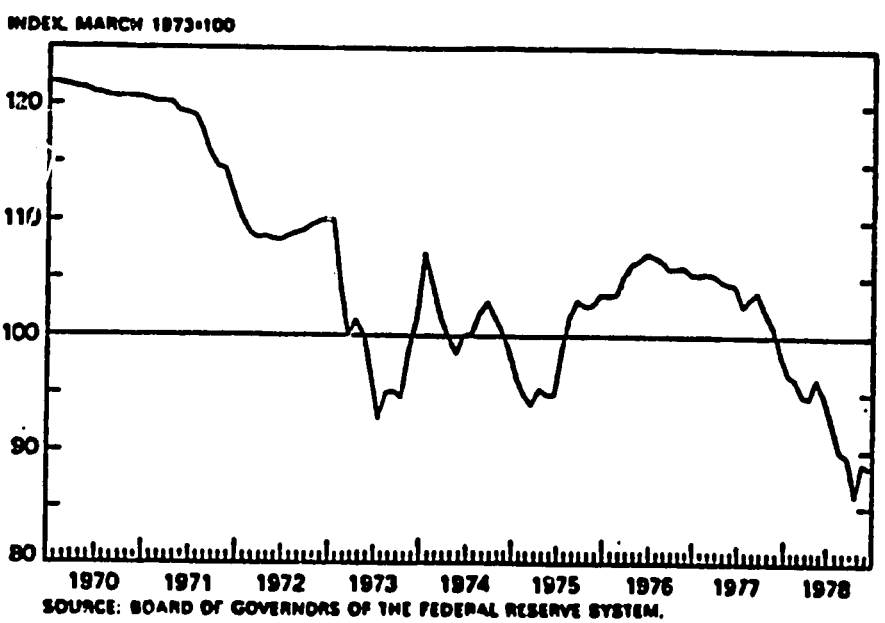


Figure III-42. Weighted-average exchange value of the U.S. dollar.

There was a brief leveling off period in April and May 1978; however, in early June 1978 the U.S. dollar again began a decline that lasted until the end of October. Some of this renewed decline can be accounted for by the accelerated and persistent U.S. inflation, which aroused much concern in international financial circles . Unitl November 1978, financing of this deficit was left almost entirely to foreign central banks or private financial transactions, thus leading to unjustified changes in exchange rates.

For some time foreign central banks tried to guide the external value of the dollar by purchasing excess supplies of dollars on the exchange markets. But it became clear that foreign central banks abandoned much of their intervention in utter discouragement, thus causing even more rapid movements in exchange rates (deVries, 1979). The deficit for 1978 was estimated to be $38 billion (President's Economic Report, 1979).

iv. Policy guidelines: On November 1, 1978, two measures aimed at anti-inflation were announced: 1)a sharp increase in the Federal Reserve discount rate, the rate charged to commercial banks when they borrow from the Federal Reserve System; and 2) conclusion of arrangements which provided the United tates with facilities totaling $30 billion in the currencies of Germany, Japan and Switzerland, which U.S. authorities could use for intervention on the exchange markets, thus financing part of the U.S. deficit for an intermediate period.

The $30 billion consists of:

1. U.S. transactions with the International Monetary Fund in the amount of $5 billion;

2. Credit lines of $15 billion; and

3. Foreign currency denominated securities issued in the amount of $10 billion.

In addition, the U.S.treasury announced that it would increase its gold sales to at least 1.5 million ounces monthly. This action is expected to improve the U.S. trade balance by $6 billion.

Although the U.S. Treasury is doing so in coordination with other central banks, the new policy means that the United States has assumed responsibility for the external value of the dollar. This is a shift in position of historic importance for international monetary relations.

In addition, significant psychological factors are at work. It was precisely the U.S. refusal to take any responsibility for the

external value of the dollar and the policy of leaving this value to be established by the free play of market forces, that led to a massive lack of confidence in the dollar and to vast dollar sales. The changed policy is likely to lead to a greater willingness of private financial markets to finance part of the U.S. deficit.

Moreover, the tightening of monetary policy is likely to have important effects. This excessive creation of money meant that new dollars were steadily becoming available for sale on the exchange market. The more restrictive monetary policy will correct this situation.

Also, it will have an effect on the U.S. domestic economy, thus slowing down growth.

v. Impact of rubber imports on balance of trade: In 1977, rubber imports represented 2.3 percent of U.S. overseas trade. In tons and dollars, this was 792.4 thousand tons valued at $726.5 million (Commodity Research Bureau, 1978).

Forecast world production and consumption of natural rubber and synthetic rubber is expected to have doubled by 1990 over the 1977 volume (D'Ianni, 1978). The probability of world demand for both synthetic and natural rubber exceeding supplies has been discussed by Miller (1978). Factors that impinge upon the rubber supply/demand ratio include the price of crude oil, availability of petrochemicals and inflation.

The U.S. consumes more than 25 percent of the natural rubber produced. With the U.S. completely dependent on Hevea rubber imports for its natural rubber supply, shortfalls could severly disrupt the U.S. economy, particularly the industrial sector.

The United States is now in a position of trying to balance its trade deficit. Our complete dependence upon the rubber producing countries is causing an imbalance in trade with these countries. For example, our 1976 trade with Malaysia included U.S. $940 million of imports and exports of $536 million, leaving a trade deficit of $404 million. In 1977 this figure grew to a disproportionate $761 million (U.S. Commerce Department, 1978).

A realistic appraisal of the natural rubber market and the political stance of the Third World countries is necessary to maintain economic stability for the U.S. Guayule production could provide domestic natural rubber to industry, helping to curtail the excessive trade deficit with rubber producing countries. Such obvious trade deficit advantage, however, must be considered within the context of overall U.S. relations with these Third World nations.

d. Antitrust: From medieval times tothe present, trusts have been recognized as monopolies. Toward the end of the 1800s, during the American Industrial revolution, businesses sought to control entire industrial sectors by forming monopolistic environments. States tried to combat business combinations by enacting antitrust laws. But these laws were ineffective in the absence of unanimity among the states.

Since 1890 federal law has dealt with trusts. The overall intent is to ensure an unimpeded flow of interstate commerce and to ensure that trusts are not used to destroy or restrict competition. The producing, fabricating and selling of guayule rubber products by industry must operate within this framework.

Rubber industry activities are regulated under several important antitrust laws. The discussion of these laws is presented in chronological order.

The Sherman Act of 1890 : The first legislation dealing with antitrust regulation, the Sherman Act of 1890, was written with the intent to assure that combinations controlling production and trade and breaking down competition did not occur.

Section 1 of the Sherman Act states that every contract, combination or conspiracy in restraint of trade is illegal. In the Standard Oil Case, 1911, the Supreme Court adopted the "rule of reason" and held that only unreasonable or undue restraints on trade were meant to be included (31 S.Ct. 502). Section 2 of the Act was aimed at monopolizing. In the Second American Tabacco case (328 U.S. 781), 1946, the Supreme Court state that this section is violated when one company or a combination of companies possesses monopoly power to fix prices or to exclude competitiors, coupled with the intent and purpose to exercise this power.

The Clayton Act of 1914 : The Clayton Act of 1914 declared four restrictive or monopolistic acts illegal: 1) price discrimination; 2) tying and exclusive dealing contracts -- sales on condition that the buyer stop dealing with the seller's competitor; 3) corporate mergers -- acquiring competing companies; and 4) interlocking directorates -- having common board members among competing companies. In each instance, the prohibition was qualified by the general condition that the specified practice was illegal only when the effect may substantiallly lessen competition or may tend to create a monopoly in any line of commerce.

The Federal Trade Commission Act of 1914 : The Federal Trade Commission Act of 1914 represents the last major antitrust law in the United States, and may be classed as an antitrust statute in a general sense. This act created the Federal Trade Commission with powers to prevent persons and corporations, with certain exceptions, from using "unfair methods of competition in commerce and unfair or deceptive acts or practices in commerce." Such unfair methods of

competition have been held to include acts contrary to the Sherman and other antitrust laws.

The Wilson Tariff Act of 1930: The Wilson Tariff Act contains antitrust provisions particularly relating to foreign commerce. Section 73 of this act, in brief, declares that every combination, conspiracy, trust, agreement or contract made by or between two or more persons, either of whom is engaged in importing any article from a foreign country into the United States is illegal and "void" when intended to operate in restraint of lawful trade or to increase the market price of any imported articles in any part of the United States or of "any manufacture into which such imported article enters or is intended to enter."

The Revenue Act of 1916: The Revenue Act of 1916 contained so-called "antidumping"provisions. This act made it unlawful to import or to sell articles from abroad at prices substantially less than the actual market value or wholesale price of the article at the time of their exportation (after adding the necessary expenses of importation and sale in the United States) if done with intent: 1) to destroy or injure an industry in the United States; 2) to prevent establishing an industry in the United States; or 3) to restrain or monopolize any part of the trade or commerce in such articles in the United States.

The Tariff Act of 1930: The Tariff Act of 1930 contained provisions relating to unfair practices in import trade. It authorizes the Tariff Commission to investigate unfair methods of competition or unfair acts in the importation of articles into the United States or in their sale in the United States, the effect of which is to destroy or substantially injure an industry efficiently operated in the United States, to prevent the establishment of such an industry, or to restrain or monopolize trade and commerce in the United States. The findings of the Commission are to be transmitted to the President, who is directed to exclude articles whenever the existence of such unfair methods or acts is established to his satisfaction.

Webb-Pomerene Export Trade Act of 1952: The Webb-Pomerene Act makes an exception to the Sherman Act with respect to an association entered into for the sole purpose of engaging in export trade and actually engaging in such export trade, and to acts done or contracts made by such association in the course of such export trade, if not in restraint of trade within the United States and not in restraint of the export trade of any domestic competitor of such association provided also that the association does not do anything to artificially or intentionally enhance or depress prices of the same class of goods in the United States or to substantially lessen or to otherwise restrain trade in the United States.

Miscellaneous antitrust statutes: Other statutes with antitrust provisions covering foreign trade include the Shipping Act of 1916, the Marine Insurance Act, the Communication Act of 1934, the Panama Canal Act and the Civil Aeronautics Act.

i. Horizontal and vertical restraints: Two trust structures sought to be controlled by the Sherman Act commonly are referred ta as "horizontal and vertical restraints." Horizontal restraints tend to eleminate competition between businessses in the same industry. This normally involves anticompetitive practices such as agreements among competitiors to fix prices, to restrict output, to divide markets or to exclude other competitors. Prices can be controlled not only by direct price-fixing agreements, but also indirectly by agreements among firms not to compete with one another. Withdrawing supplies from a market raises the equilibrium price of a product. Market division agreements eleminate competitors. By eleminating competitors, the single remaining market occupant of a limited territory has a monopoly and is freed of competition not only with respect to prices but also with respect to service, quality and innovation.

The vertical restraints considered here can be classified into two categories; 1) those restricting production and product distribution; and 2) those excluding or foreclosing competing firms from a market.

Restricting the distribution of a product is generally undertaken by three mechanisms; resale price maintenance; consignment and distribution through agents; and territorial and customer restrictions. Resale price maintenance (RPM) involves efforts by manufacturers to set prices below which retailers subsequently could not resell their products. RPM agreements between a manufacturers and its dealers may serve several functions. For example, retailers may have formed a cartel, fixing the prices at which they would sell the product and pressuring the manufacturer to enforce it for them. Or RPM may have been imposed by the manufacturer on its dealers in order to assure adherence to a price-fixing conspiracy among the amnufacturers.

Consignment and distribution through agents involves selling products by agents while the manufacturere retained title to the product. Could the manufacturer then set the retail price? Yes. In United States vs General Electric Co., 272 U.S. 476 (1926), the U.S. District Court of Northern Ohio answered that "where it is clear that the arrangement is legitimate and that the manufacturer both retains title and bears risk of ownership, the antitrust laws do not prevent him from dictating the terms of sale including retail prices."

Territorial and customer restrictions relate to a manufacturer's wish to insulate appointed dealers from competition from others also selling his product.

Exclusive dealing, the second category of vertical integration, provides the manufacturer the opportunity to offer a sales contract conditioned upon the agreement by the buyer not to deal in the goods of a competitor.

ii. Attempts to control price of rubber: Internationally two known attempts have been made to vertically control the price of natural rubber through plantation output, the Stevenson Scheme and the International Rubber Regulation Agreement (Allen, 1972).

The Stevenson Scheme: Prices for natural rubber had reached their peak in 1910. Throughout World War I there was a steady decline for natural rubber. Even though production was at a high level, an excess supply started to develop. In 1922 the British government became greatly alarmed and initiated a program of compulsory restriction of output to British-controlled producing countries, Malaya and Ceylon. The price rose from 1924 to 1926. Many rubber consumers became annoyed by the program, especially the United States. The U.S. Rubber Industry began establishing plantations in other countries and a renewed interest in synthetic rubber also occurred.

The Stevenson Scheme was terminated by the British.

International Rubber Regulation Agreement: After the Stevenson Scheme terminated, the price of natural rubber plummeted once again. By 1932, the price for rubber again was at a low; however, this time industry, with the producing countries, devised the International Rubber Regulation Agreement. It was a quota program designed to give each country an allotted export quota. Determined by a complex procedure via a statistical committee, limitations also were placed on establishing new plantations and replanting old ones. This remained in effect until 1943 and the demand for rubber soared because of World War II.

United States vs B.F. Goodrich Company: Under the direction of the U.S. Attorney General, in 1978, the United States brought civil action against B.F. Goodrich Company under Section 4 of the Sherman Act. The complaint alleges that B.F. Goodrich, by the sale of company produced passenger tires through its company owned stores, independent retailers and wholesalers, has attempted to maintain prices artificially in the western states of California, Nevada, Washington, Arizona, Colorado and Oregon. The states of Arizona and California have filed similar suits on their own behalf alleging antitrust violations.

iii. Potential for control of guayule production: Two types of growers of guayule are forseen, the private farmer and the rubber companies. The following discussion describes operational alternatives and possibilities for antitrust violations.

The rubber industry: Growing guayule for a rubber supply by those companies currently involved in Hevea production could be construed as an extension of vertical integration to control rubber production. Producing guayule rubber at a cost commensurate with hevea would provide rubber companies with a source of domestic rubber free from certain charges such as oceanic transportation costs, post duties and broker fees. Such a rubber source would allow rubber companies to be less dependent on foreign sources and to have a greater flexibility in controlling rubber prices when impacted by foreign decisions altering the current price structure through new labor or production agreements.

Two alternatives exist for the rubber companies to grow and produce guayule rubber. These are developing industrial land holdings with company management or contractual arrangements with private farmers. Private farmers would focus on yield production, and the rubber companies would develop markets and processing facilities. As with crops such as cotton, the rubber companies also could provide farm loans to induce guayule production. The farmer would repay the loan with guayule.

During the 1960s there was direct entry and integration of many large industries into farming (Harris, 1972). This is viewed as a possible trend of the future for controlling guayule production and processing.

The following table shows the extent of vertical integration of various industry-dominated enterprises in the agricultural field. The table includes company-owned and cooperative integration as well as contract farming.

Predicted Scope of Vertical Integration

Integration	Enterprises *
76 to 100 percent	Broiler chickens, hatching eggs, market turkeys; vegetables for canning-freezing; sugar crops, certain kinds of tobacco; seed production; popcorn; castor and soy beans; safflower; table eggs.
51 to 75 percent	Citrus; tree nuts; potatoes;

* Matter, 1958

Integration	Enterprises
51 to 75 percent (continued)	dry peas; fresh vegetables; milk marketing.
26 to 50 percent	Deciduous fruits; dry beans; alfalfa; sheep and lambs; beef and hog feeding.
1-25 percent	Corn; wheat; rice; cotton; forest products; tung nuts; peanuts; tobacco.

Rubber cooperatives: Under the antitrust law of the United States the farming industry has been given an exempt status. Section 6 of the Clayton Act of 1914 states that:

"Nothing contained in the antitrust laws shall be constituted to impede the existence and operation of labor, agricultural, or horticultural organizations instituted for the purpose of mutual help and not having capital stock or conducted for profit."

One tool at the farmer's disposal is the cooperative, which enables farmers to have bargaining power in the market place and to sell their products at the highest possible price. They also provide services for the group by purchasing supplies for members,and negotiating marketing contracts with a processor or distributor. Cooperatives range from local associations to federations, each level providing needed services from marketing to research (Rust, 1978).

Farm cooperatives are regulated under several important laws. A discussion of these is presented below.

The Copper-Tolstead Act of 1922 : The act approved corporate cooperatives, authorized them to deal in products of non-members provided that "such associations may have marketing agencies in common." The act also extended this exemption to capital stock needed for maintaining the cooperative. The stock is bought by members only and does not pay dividends unless elected by the membership and this is limited for eight percent per annum (Hubbert, 1970).

'The Cooperative Marketing Act of 1922' : The Act authorized a cooperative to acquire, exchange, interpret and disseminate past, present and perspective crop market.

'The Agricultural Marketing Agreement Act of 1937' : The Act attempted natural marketing policy coordination through marketing agreements entered into by the Secretary of Agriculture.

This deals only with the marketing phase of a product. The Secretary also has the power to impose price control. Marketing agreements negotiated by the Secretary usually are more effective than agreements sponsored by a cooperative or another producing agent.

Farming cooperatives have been granted great leeway in operating so as to achieve higher incomes, lower costs and more efficient and dependable services for the farmer.

Cooperatives are formed under a state granted charter, as non-profit corporations. These corporations must deal exclusively with agriculture or horticultural activities. For the cooperative to be recognised it must submit a charter and bylaws so that the state can judge if those bylaws come under those of a non-profit corporation dealing in agriculture (Neely, Hubbert and Kemper, 1976). One or more cooperatives may merge to have a common marketing agency and to comply with all the conditions of the Copper-Tolstead Act.

They may not enter into abnormal transactions such as price-fixing or other agreements with third persons which are contrary to antitrust laws. If they are found in violation, the Department of Justice will file proceedings against them (U.S. vs. Borden Company 308 U.S. 188).

e. Oligopoly: The basic characteristic of an oligopoly is the postulate that because there are only a few sellers in the rubber market, all sellers recognize that they are interdependent to a substantial degree. Therefore, each seller takes into account the reactions of rival sellers when making output and pricing decisions. This means that firms in oligopoly markets will not reduce prices to increase sales because any gains will be cancelled immediately when rival sellers retaliate with similar price reductions.

Indirect competition exists through improved product quality, credit terms, delivery, service and advertising.

The primary theoretical difference, then, between oligopoly and competition and monopoly (and even monopolistic competition) is that in oligopoly markets, price and output decisions are made while anticipating the reactions of the identified rivals. Neither the competitive firm nor the monopolist considers the reactions of others; the competitive seller has no impact on his rivals and the monopolist has no close rivals. On the other hand, coordination among oligopolists is unlikely to be perfect; cost curves may differ, and more efficient firms have a strong incentive to engage in disguised price cutting in order to capture additional sales above (or at) their marginal cost. Oligopoly theory does not assume that output and pricing decisions in oligopoly are identical to those in monopoly. Rather, the expectation is that each is somewhere between predicted competitive and monopoly levels.

The oligopolistic firm is not unique in its dependence on the actions of other firms since even a monopolist's demand curve is affected by the prices of substitute products. What is different about the oligopolist is that the actions of rival firms both affect him and are affected by the oligopolist.

3. Regional sector: Full-scale guayule commercialization would imply trade-offs of resources from one product development to another. In general, commiting agricultural land, water and labor to guayule would be at the expense of producing certain other field crops.

a. Land and water trade-offs for food and fiber: As a relatively low-water-demanding crop, guayule cultivation may save water and energy in areas of irrigated agriculture. Potentially, guayule could be brought into production: 1) as a non-irrigated crop where traditional crops require some supplemental irrigation; 2) as a non-irrigated crop where precipitation and/or irrigation water are insufficient for traditional crops; 3) as an irrigated crop where water costs are too high for producing traditional crops (idled farmland); or 4) as an irrigated crop replacing traditional crops where irrigation costs are rising.

Conserving scarce water resources or reintroducing idled farmland into production are positive incentives for guayule introduction. However, constraints on introducing guayule might include food and fiber needs of the nation making field crop trade-offs unfavorable for guayule. Table III-30 shows average production of the 14 major field crops grown in the potential guayule growth area. It is unlikely that guayule will replace either orchard crops or vegetables in the foreseeable future.

Extensively developing guayule production could result in significant reductions of the nation's cotton production. Declines also could be felt in the nation's sugarbeet, barley and sorghum production should guayule be introduced in large acreages. Of these four crops, barley, cotton and sugarbeets all require at least twice the precipitation and/or irrigation water necessary for guayule production. Sorghum requires approximately one-and-a-half times as much water as guayule.

Although guayule is a lower water using crop compared with to more conventional crops, there are conditions under which introducing guayule would constitute an additional depletion of diminishing water supplies. In Arizona, New Mexico and western Texas, developed irrigated farmland is predicted to be idled due to declining water resources and increasing competition from other water-demanding sectors of the economy. In those instances where the water savings inherent in guayule production relative to other crops would be sufficient to

TABLE III-30

AGRICULTURAL PRODUCTION OF SELECTED FIELD CROPS FOR THE POTENTIAL GUAYULE GROWTH REGION AND FOR THE NATION

Average for crop years 1975 through 1977

Crop	National[1/] Production	Regional[2/] Production	Percent of National
Cotton[3/] (1000 bales)	11,091	3,838	35
Sugarbeets (1000 tons)	28,068	7,989	28
Rice[4/] (1000 cwt)	114,436	22,204	19
Barley (1000 bushels)	387,550	62,026	16
Sorghum (1000 bushels)	754,503	99,134	13
Hay (all types) (1000 tons)	127,758	8,196	6
Peanuts (1000 lbs)	3,778,004	138,280	4
Wheat (1000 bushels)	2,096,871	84,743	4
Sugar Cane (1000 tons)	38,040	1,202	4
Flaxseed (1000 bushels)	13,154	296	2
Corn (1000 bushels)	6,150,9[illegible]	60,432	1
Oats (1000 bushels)	645,424	5,672	1
Soybeans (1000 bushels)	1,517,092	126	-
Rye (1000 bushels)	15,969	1	-

1/ Source: U.S. Department of Agriculture, Agricultural Statistics 1978

2/ Source: Sums of totals for the potential guayule growth regions of Arizona, California, Nevada, New Mexico and Texas.

3/ The guayule region grows virtually all of the Nation's American Pima Cotton

4/ Rice and guayule are grown in virtually antithetical microclimatic conditions. Little if any, impact on rice production is anticipated.

warrant bringing these idled acreages back into agricultural production, this introduction may be prohibited due to allocations of the water resource.

The extent to which guayule development potentially could impact the agricultural land base in the U.S. Southwest is shown in Figure III-43. Bar 1 shows harvested acreage in the potential guayule growth region in the mid-1970s (10.7 million acres) as reported by the respective state crop and livestock reporting services and the Bureau of Indian Affairs (BIA, 1976). Bar 2 represents the 14.9 million potential acres where guayule might be grown in 1980. This includes non-Indian irrigated acreage in the five-state potential guayule growth region, two million acres of potential dryland guayule cropping in Texas and 250,000 acres of Indian lands.1/

Bar 3 shows the acreage that would be required to satisfy all U.S. natural rubber demand with guayule as projected for 1980 (3.6 million acres). This acreage assumes a 500-pound per year production level. To supply half of the U.S. natural rubber demand would require half the acreage, or 1.8 million acres.

The 15.6 million agricutlural acres projects for the year 2000 are shown in Bar 4 using the same assumption as in 1980, but doubling Indian agricultural land to 500,000 acres. 1/

Bar 5 represents the 6.3 million acres that would be required to meet all the natural rubber demand of the U.S. in the year 2000 with domestic guayule. Bar 6 represents acres required to meet all of the U.S. rubber demand in the year 2000 if efficiencies of guayule rubber field production were doubled, 3.2 million acres.

As can be seen from Figure III-43, to use guayule to produce all the natural rubber required by the United States would take 24 percent in 1980 and 40 percent in 2000 of the total agricultural land in the potential guayule growth region of the U.S. Southwest at 1979 production levels. This includes two million acres in Texas that might produce guayule with dryland farming. Excluding these dryland acreages would raise the relative guayule demand to 28 percent and 46 percent of agricultural lands for 1980 and 2000, respectively.

To supply half the U.S. natural rubber demand would require 12 percent and 20 percent of agricultural lands in the area, respectively, for 1980 and 1990. If guayule production efficiency could be doubled, as many researchers think possible, then acreage demands could be reduced by half.

1/ Estimates of future agricultural development for the reservations in question range from 200,000 to 1.4 million acres. Until Winters Doctrine negotiations have been completed, only rough estimates of Indian agricultural acreages can be made.

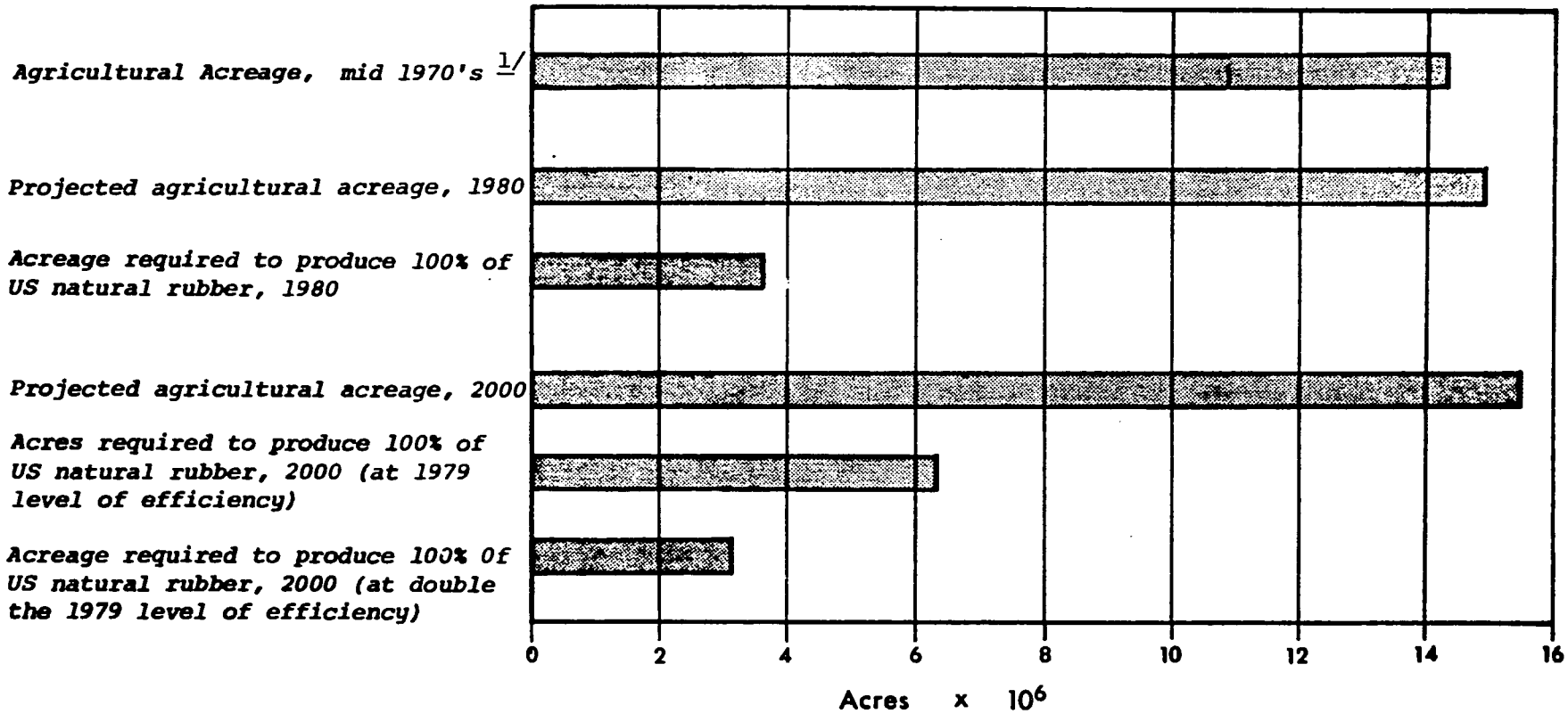


Figure III-43. Relationship between acreage necessary to supply U.S. natural rubber needs with guayule to agricultural acreage in the potential guayule growth region.

1/ Rows 1, 2 and 4 include irrigated agriculture in the 5-state potential guayule growth region plus 2 million acres of potential guayule dryland farming in Texas.

b. Sociocultural consideration: Analysis of baseline data which describe the existing environment suggest that the magnitude of agricultural employment within the study is highly variable. Four observations can be made: 1) the absolute number employed in agriculture is usually relatively small; 2) a large share of those employed in agriculture are temporary rather than permanent workers; 3) agricultural employment is usually only a small portion of total employment; and 4) payrolls usually are modest.

i. Agricultural employment figures: The most complete source of data which describe agricultural employment is the Census of Agriculture (1974). Data from this source are presented on Tables III-31 through 35; they describe both the baseline employement structure (for 1974) and allow for evaluating change in employment during the 1969-1974 period.

Because of variable county size, employment comparisons must be made with care. However, data clearly show that in terms of employment, California counties are in the lead. There are some 778,000 agriculture workers in California's potential guayule counties; Fresno County alone has almost one-fifth of this number. The potential guayule counties in Texas have 56,000 agricultural workers; the largest number, 11,304, is in Hidalgo County. Figures for Nevada, Arizona, and New Mexico are lower --- 296, 469,699, and 8,468 respectively. Three Arizona counties have conspicuously high counts. Yuma County has 19,731 agricultural workers, Maricopa has 17,459 and Pinal has 6,769. Still, California is the big employer. It has 14 counties each having 20,000 or more agricultural workers.

ii. Permanent Workers: Even though agriculture employment figures are sometimes high, it must be remembered that a) many of these workers are only employed on a part-time or seasonal basis and that b) many of a county's agricultural workers may not be permanent residents of the county in which they are employed. This latter point is significant! 1) migrant workers can be expected to have only minimal economic impacts in the producing region; and 2) there may be some "double counting." Double counting will occur if a migrant worker is employed in two (or more) counties.

In any case, the agricultural workers who will contribute most significantly to the sociocultural and economic life of an area are the permanent ones. In most counties, permanent workers make up only 20 percent or 30 percent of the agriculture work force. This is a small number in relative terms and, in most cases, in absolute terms. In California, only one of 34 counties shows permanent workers as 50 percent or more of total agricultural employment and only three counties have 40 percent or more in the permanent category. In Texas the percentage of permanent agricultural workers exceeds the 50 percent mark in only two of 38 counties and only four counties top the 40 percent mark. No New Mexico county has more than 21 percent of its agricultural workers in the permanent category. In Arizona, only one of nine counties has more than 40 percent of its agricultural workers in the permanent category. One county in Nevada has 296 agricultural workers including 173, 58 percent who are permanent.

In short, the permanent agricultural workforce that will be focused on in the impact analysis phase of this study is usually a small group in numerical terms.

iii. Agricultural employment as a share of total employment: In many cases, agricultural employment is small compared to aggregate employment figures. Comparable figures are difficult to obtain, but available data suggest that figures are frequently very low. In terms of state aggregates, California and Nevada have about 2 percent of the work force in agriculture. The figure for Arizona is 3 percent. In Texas and New Mexico the figures are both 4 percent. At the County scale figures may be larger and they will certainly be more variable. For example, in Yuma County, Arizona 21 percent of all workers are employed in agriculture. Counties such as this will be of special importance in subsequent phases of this project.

iv. Agricultural payrolls: The agricultural workers earnings are usually not great when compared to payrolls of many other sectors. Their localized significance is often greatly diminished if a large portion of the workers are migrants who carry their earnings out of the county in which they were paid. In all, 21 counties have agricultural payrolls of less than $1 million. Thirty-four counties have payrolls of $1 million to $10 million and 31 counties have payrolls in excess of $10 million. All but four of the counties in the "over $10 million" category are in California; only two counties, both in California, have agricultural payrolls in excess of $1 billion.

TABLE III-31

TEXAS FARM LABOR STATISTICS, POTENTIAL GUAYULE GROWTH AREA

County	1974 Number of Agricultural Workers	1974 Percent (150 day/yr or more)	1974 Payroll (thousands of dollars)	1969 Number of Agricultural Workers	1969 Percent (150 day/yr or more)	1969 Payroll (thousands of dollars)
El Paso	2,450	26	3,747	2,966	32	3,914
Hudspeth	1,153	18	1,006	771	21	787
Reeves	953	43	2,642	1,409	31	2,216
Pecos	1,285	22	1,684	1,419	21	1,494
Brewster	431	26	578	436	26	479
Culberson	478	18	645	416	17	320
Jeff Davis	286	33	437	440	35	530
Presidio	1,147	14	931	833	19	737
Maverick	486	47	1,311	635	39	1,080
Starr	2,672	28	3,258	2,691	19	1,773
Webb	2,366	15	1,824	3,154	18	1,729
Zavala	1,832	28	3,535	1,411	27	1,790
Frio	1,547	23	2,219	2,135	17	1,894
Atascosa	1,999	15	1,823	2,486	14	1,358
Dimmit	542	38	1,083	971	23	940
La Salle	698	25	853	861	26	703
McMullen	415	19	354	562	14	293
Live Oak	820	18	685	1,118	13	547
Bexar	1,912	27	2,568	2,345	30	2,601
Goliad	535	17	387	846	15	449
Karnes	805	11	423	1,345	10	518
Wilson	1,105	20	1,093	1,599	14	816
Guadalupe	1,212	17	1,055	1,233	14	727
De Witt	1,205	15	766	1,566	15	802

(continued)

TEXAS FARM LABOR STATISTICS, POTENTIAL GUAYULE GROWTH AREA

County	1974 Number of Agricultural Workers	1974 Percent (150 day/yr or more)	1974 Payroll (thousands of dollars	1969 Number of Agricultural Workers	1969 Percent (150 day/yr or more)	1969 Payroll (thousands of dollars
Duval	1,586	11	792	1,195	18	788
Jim Wells	1,337	23	1,533	1,548	32	1,750
Nveces	2,100	29	3,023	2,362	31	2,534
Kleberg	1,114	87	2,284	1,357	57	1,408
Jim Hogg	404	30	585	520	25	526
Brooks	670	15	521	568	23	445
Kenedy	152	80	393	280	41	366
Hidalgo	11,304	24	13,879	10,443	22	8,752
Willacy	1,383	29	2,266	1,612	27	1,772
Cameron	4,739	23	5,942	5,815	20	4,568
Bee	1,041	18	943	1,252	20	784
Refugio	700	34	1,234	494	34	614
San Patricio	1,545	29	2,436	2,027	28	2,134
Aransas	31	29	61	32	50	46
TOTALS	56,440		70,799	63,153		54,984

TABLE III-32

ARIZONA FARM LABOR STATISTICS, POTENTIAL GUAYULE GROWTH AREA

County	1974 Number of Agricultural Workers	1974 Percent (150 days/yr or more)	1974 Payroll (thousands of dollars)	1969 Number of Agricultural Workers	1969 Percent (150 days/yr or more)	1969 Payroll (thousands of dollars)
Graham	1,095	21	1,339	1,305	22	1,423
Greenlee	224	12	242	331	14	211
Cochise	2,037	21	2,951	2,295	15	1,802
Santa Cruz	192	51	467	245	38	336
Pima	1,634	39	3,825	3,522	17	3,460
Pinal	6,769	31	14,262	13,341	17	11,955
Maricopa	17,459	30	37,012	26,242	22	27,371
Yuma	19,731	18	25,147	17,826	26	15,591
Mohave	458	27	709	415	19	455
TOTALS	49,699		85,954	65,522		62,604

TABLE III-33

NEVADA FARM LABOR STATISTICS, POTENTIAL GUAYULE GROWTH AREA

County	1974 Number of Agricultural Workers	1974 Percent (150 days/yr or more)	1974 Payroll (thousands of dollars)	1969 Number of Agricultural Workers	1969 Percent (150 days/yr or more)	1969 Payroll (thousands of dollars)
Clark	296	58	827			

TABLE III-34

NEW MEXICO FARM LABOR STATISTICS, POTENTIAL GUAYULE GROWTH AREA

	1974			1969		
County	Number of Agricultural Workers	Percent (150 days/yr or more)	Payroll (thousands of dollars)	Number of Agricultural Workers	Percent (150 days/yr or more)	Payroll (thousands of dollars)
Dona Ana	6,255	21	7,434	4,275	30	4,714
Luna	1,021	21	1,170	919	23	897
Grant	407	18	339	532	21	500
Hidalgo	785	18	792	792	18	608
TOTALS	8,468		9,795	6,371		6,719

TABLE III-35

CALIFORNIA FARM LABOR STATISTICS, POTENTIAL GUAYULE GROWTH AREA

County	1974 Number of Agricultural Workers	1974 Percent (150 days/yr or more)	1974 Payroll thousands of dollars)	1969 Number of Agricultural Workers	1969 Percent (150 days/yr or more)	1969 Payroll (thousands of dollars
Riverside	29,450	18	43,777	27,782	77	27,415
San Bernadino	9,156	29	19,457	11,065	22	14,503
Imperial	25,211	21	46,880	26,865	17	28,140
San Diego	23,396	40	39,027	16,055	36	26,222
Orange	15,789	21	28,026	11,902	27	14,278
Los Angeles	8,384	40	24,446	10,135	34	18,248
Ventura	27,185	27	50,526	18,188	30	28,458
Kern	70,831	18	102,841	47,710	17	48,241
Santa Barbara	10,265	35	21,007	8,034	36	12,356
San Luis Obispo	5,827	31	11,457	6,495	22	7,636
Kings	16,521	17	24,301	11,411	19	12,116
Fresno	149,502	8	108,977	125,046	7	64,582
Tulare	69,784	14	62,143	56,979	12	39,742
San Benito	7,957	10	7,280	9,815	7	5,756
Santa Clara	19,097	16	20,038	28,256	9	15,572
Santa Cruz	13,539	16	13,701	14,130	15	9,989
San Mateo	3,082	52	9,309	2,667	53	6,356
Merced	30,368	19	50,763	29,444	12	21,426
Stanislavs	42,490	10	37,043	41,460	11	31,893
Madera	22,565	9	18,256	19,289	9	11,126
San Jovaquin	55,954	9	48,505	56,167	8	32,817
Alameda	5,005	39	11,316	6,653	27	10,824

CALIFORNIA FARM LABOR STATISTICS

(continued)

County	1974 Number of Agricultural Workers	1974 Percent (150 days/yr or more)	1974 Payroll thousands of dollars)	1969 Number of Agricultural Workers	1969 Percent (150 days/yr or more)	1969 Payroll thousands of dollars
Sacramento	20,053	7	13,883	10,021	12	8,913
Contra Costa	6,412	16	7,807	7,350	10	5,163
Solano	10,016	13	12,053	9.294	9	6,506
Yolo	22,115	11	23,962	13,345	12	13,348
Colusa	7,340	17	10,517	7,182	10	6,617
Sutter	21,445	9	18,829	21,155	17	11,809
Glenn	5,537	15	8,085	4,695	14	4,584
Butte	11,347	11	11,270	15,677	7	8,506
Yuba	5,483	13	6,284	7,551	8	5,460
Tehama	4,718	12	3,854	5,918	7	3,074
Placer	2,087	13	2,154	2,358	15	2,052
TOTALS	777,911		917,744	690,092		563,733

IV. ALTERNATE ELASTOMER TECHNOLOGIES

This section of the report discusses alternate elastomer technologies and includes changes in natural and synthetic rubber supplies, changes in consumption patterns, and elastomer substitutes and prospects of reclamation.

A. Changes in Elastomer Supply

Natural rubber is derived from various plant species native to tropical, semi-tropical, and in the case of guayule rubber, arid regions of the world. Synthetic rubber is ultimately derived from crude oil which is available in varying quantities around the world. This subsection examines other natural rubber plants, the prospects of rubber plantations in Brazil and Africa, other sources of crude oil, and synthetic cis-1,4-polyisoprene.

1. Alternate sources of natural rubber: Natural rubber is obtained as latex, a milky sticky fluid, from various plants and trees by cutting the tree surface and allowing the latex to bleed away. Wild species of latex producing plants include:

Hevea brasiliensis (Amazon River Basin);

Manihot glaziovii (Central and South America);

Castilloa elastica (Central America and Brazil)

Ficus elastica (India, Burma, Java)

Landolphia (African Congo region)

Parthenium argentatum, or guayule (Mexico and Texas)

Of these, commercial success has been achieved by *H. brasiliensis* cultivated principally in Malaysia, Thailand, and other parts of Southeast Asia. In the United States and Mexico, guayule remains a potential commercially important source of natural rubber.

a. *H. Brasiliensis* rubber tree-diseases and control: Early in this century, *H. brasiliensis* stands in South America were decimated by South American leaf-blight, *Dothidella*. Cross-breeding of several types of high productivity Hevea clones has not been particularly successful in developing trees resistant to *Dothidella*. Some trees resistant to leaf-blight have been grown in Costa Rica, but are of low productivity. *H. brasiliensis* trees in Southeast Asia are also susceptible to this disease.

Dothidella is controlled by sulfur, fungicides containing copper, or, more recently, by benomyl (Benlate^{tm}), a carbamate fungicide. Benomyl is applied near ground level with an aerosol "fogging" generator that is able to project fine droplets of the fungicide formulation to heights of 50 to 70 feet to contact the leaves (Bonner, 1979).

Another method of combatting leaf blight involves grafting a disease-resistant crown to the trunk of a high productivity clone. This technology is practiced in Malaysia and is effective in combatting similar diseases.

Root diseases such as dry root rot and Fomes lignosus are also prominent. Young trees are often attacked by fungi. Decaying stumps may promote fungal spore formation. Root diseases are controlled by application of pentachloronitrobenzene, a common soil fungicide.

b. Prospects of the rise of Brazilian rubber tree stands: A new strain of H. brasiliensis has been developed in South America that is immune to leaf blight. A new immune crown is grafted when trees are about 10 feet tall, about 1 year after planting. The old susceptible crown is eventually pruned after the graft is successful (Bonner, 1979).

At present it is possible only to speculate on the possibility of the reestablishment of large stands of H. brasiliensis in the Amazon River Basin based on strains immune to leaf blight. Opinions vary from significant potential to skepticism about the rise of a new Brazilian agribusiness.

Whatever level of development does occur, it must be supported by the Brazilian government, including credit and tax incentives, land and water allocations, skilled and semi-skilled labor sources, and research and development. U.S. companies such as the Goodyear Tire and Rubber Company, the Firestone Tire and Rubber Company, and the Michelin Company of France can assist in this development, but the final decision, level of effort, and timing of events properly lies with the Brazilian government.

Present production levels of natural rubber in Brazil are estimated at 45 to 55 million pounds annually, which represents only 0.6 percent of the world's total annual production of natural rubber. In order for Brazilian stands to be of economic importance, supplying perhaps 10 percent of the world's annual needs for natural rubber, a massive and sustained development program of at least 10 to 15 years would be required. Such a program is not planned by the Brazilian government at this time (Klein, 1979).

c. Other developments in rubber plantations by U.S. firms: The Firestone Tire and Rubber Company announced in early 1978, that it would increase its natural rubber operations by an additional

22,500 acres in Liberia and 7,500 acres in Ghana. Total present holding by Firestone amount to 130,000 acres around the world, including Africa, Brazil, the Philippines and Guatemala, and will be expanded to 180,000 acres by 1992 (Anon., 1978a). Goodyear Tire and Rubber Company recently expanded its rubber-growing capacity near Belem, Brazil, and is acquiring an 11,000-acre plantation in Sumatra.

2. Alternate sources of synthetic rubber: This subsection of the report discusses additional sources of oil from Alaska, Mexico and China and closes with a discussion of synthetic cis-1, 4-polyisoprene.

a. Oil from Alaska: In mid-1977 the port of Valdez, Alaska, began receiving North Slope crude oil from fields near Prudhoe Bay via the famed trans-Alaskan pipeline. By the end of 1977, oil flow reached 1.2 million barrels per day and continues at this level. Tankers transport 70 percent of the crude oil to the West Coast and 30 percent to Gulf Coast for refining and distribution. The result has been an oil glut on the West Coast and a continuing threat of severe oil shortages in the Midwest.

Alaskan oil is characterized as being "sour and heavy." It is sour because it contains a relatively high sulfur content (1.04 percent by weight) and it has a relatively high specific gravity (26.8 API or specific gravity 0.893) (Weismantel, 1977). Because North Slope Crude oil is high in sulfur, refineries must have existing desulfurization units or add them to comply with governmental emission standards for oxides of sulfur, hydrogen sulfide, and other noxious components as required by the Clean Air Act. Desulfurization units remove sulfur components, e.g., thiophene, by reaction with hydrogen gas in the presence of a platinum catalyst to form hydrogen sulfide and butanes. Hydrogen sulfide is usually recovered in mono- or diethanolamine reactors for later conversion to sulfur or sulfuric acid.

Principal West Coast refineries having the ability to process sour oil are located in Cherry Point, Washington, the San Francisco Bay region and the Los Angeles-Long Beach region. Even so, approximately 30 percent of North Slope Crude oil must be shipped to Houston refineries for processing and distribution to the Midwest via existing pipelines.

In 1974 Standard Oil of Ohio (Sohio) proposed a 30-inch pipeline to transport North Slope Crude oil from Long Beach to Midland, Texas, a distance of 1,025 miles. At Midland the proposed pipeline would join existing pipeline networks to transport the oil to the Gulf Coast, the Midwest and the East. Sohio secured agreements from El Paso Natural Gas Company and Pacific Lighting Company to use 795 miles of existing pipeline as part of the proposed system. Thus, only 230 miles of new pipeline would be required. Additional tanker facilities at Long Beach were to be constructed. The completion date was to have been mid-1978. By early March 1979 the California Air Resources Board

had not approved the project and stated that Sohio could not use the port of Long Beach as a tanker terminal. Concern over potential hydrocarbon emissions at the point of transfer and their impact on Southern California is said to be a major factor in this decision.

On March 13, 1979, Sohio announced abandonment of the proposed pipeline citing prolonged delays in obtaining the necessary state agency approvals (Wall Street Journal, 1979a). Sohio's decision to abandon the pipeline has caused concern among government officials. Key votes by the California Air Resources Board District and by the California Coastal Commission were to be taken by late March and approval by both agencies was said to be almost certain (Wall Street Journal, 1979b). California Governor Edmund G. Brown, Jr. has called for a congressional investigation and charged Sohio with creating "a carefully contrived publicity circus. They knew the permits were days away. They pulled out in the middle."

Meanwhile, negotiations between the eight owners of the trans-Alaskan pipeline* and the U.S. Department of the Interior to construct a pipeline to the upper Midwestern states are apparently proceeding smoothly. Northern Tier Pipeline Company which includes U.S. Steel Corporation, Burlington Northern Inc., and Westinghouse Electric Corporation, plans to construct a 1,550-mile pipeline from Port Angeles, Washington, to Clearbrook, Minnesota, which will serve the northern tier of states and the Midwest where critical oil shortages may occur in the near future.

Other proposals for bringing Alaskan oil to the lower 48 states include: a) construction of oil and natural gas pipelines from Skagway, Alaska to Edmonton, Alberta and then south and east to Chicago, Illinois, utilizing existing Canadian pipelines, and b) construction of oil and gas pipelines from Kitimat, British Columbia to Edmonton, Alberta.

At present, Alaskan oil is not available to the Japanese who continue to buy oil from the Arabian Gulf region. Trade negotiations are under way in Congress to allow up to 100,000 barrels per day to be sold to Japan. In turn, the United States would buy an equal quantity from Mexico which would then be shipped to the Gulf Coast for refining and distribution. An estimated net savings of $2.00 per barrel in transportation costs would accrue to the United States in this exchange (Jenny, 1979).

b. Oil from Mexico: When President Carter met with President Jose López Portillo in mid-February in Mexico City to discuss mutual economic and social problems, the atmosphere was strained.

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*Sohio owns approximately 50 percent of the oil presently flowing in the Alaskan pipeline.

Previous failures in trade negotiations regarding Mexican oil and natural gas coupled with the continuing illegal immigration of Mexicans to the United States had soured formal relations between the two nations. At stake was the potential role that Mexican oil and gas could play in meeting American energy needs, and in meeting Mexican goals of economic growth and development and the social needs of the Mexican people. In recent months, proven reserves of oil and gas in the southeastern state of Tabasco and in the Gulf of Mexico have ranged from 20 billion to 40 billion barrels and potential reserves have been estimated at more than 200 billion barrels. Present production is near 1.5 million barrels per day, and according to Pemex, the government oil and gas moncpoly, it is expected to rise to 2.5 million barrels per day by 1980. The United States imports approximately 9.1 million barrels per day, and in principle, Mexico could supply approximately 10 percent of this amount. Thus, Mexican oil and gas could delay the projected shortfall in U.S. crude oil supply from the late 1980s to the early 1990s,according to energy experts.

Although both nations have much to gain through successful negotiation, many obstacles must be overcome. Pemex needs technology capital, and organizational skills to develop the newly found oil fields. Mexican leftist groups oppose rapid development and the export of oil and gas to the United States. Other groups, particularly Mexican officials and the wealthy upper class, fear potential social problems arising from sudden oil-based wealth.

The U.S. trade position has not been constructive. The Mexican government became annoyed and then angered when, in December 1977, Energy Secretary James Schlesinger stated his view to Foreign Minister Santiago Roel and Petroleum Chief Diaz Serrano in Washington that Mexico's price for natural gas $91.60/m^3$ ($2.60/mcf) was too high and he refused to make a counter-offer.

In January 1979, Secretary Schlesinger again repeated his view that the Mexican price was too high compared to Canadian natural gas at $76.00/m^3$($2.16/mcf)or the U.S. ceiling to American producers at $61.60/m^3$($1.75/mcf). This reiteration is said to have "infuriated" President Carter, who was then planning to reopen trade negotiations with Mexico. Many ill feelings also exist between the two countries over the increase in illegal Mexican immigration in the U.S. Southwest.

President Carter's trip in mid-February did not produce a trade agreement. Instead, President López Portillo accused the United States of "surprise moves and sudden deceit or abuse that sooner or later have a reverse effect." Leftist demonstrators shouted anti-Carter slogans and burned "Uncle Sam" in effigy. President Carter later told President López Portillo privately that it was "counter-productive to over-emphasize differences, particularly historical differences, as opposed to our commitment to efforts to resolve them." At present, the two nations have formally agreed to begin negotiations concerning oil and natural gas and illegal immigration. The United States also has signed scientific and technological agreements to help improve housing and agriculture in Mexico.

Although both nations have much to gain through negotiation and cooperation, the role of Mexican oil and gas is not clear in supplying U.S. needs for crude oil and gas and subsequently in responding to the needs of the synthetic rubber industry. The total U.S. demand for rubber presently hinges upon natural Hevea rubber and crude oil. If these are in short supply for whatever cause, the case for commercialization of domestic guayule rubber is strengthened.

c. Oil from China: Beginning in early 1979 oil from the People's Republic of China will be available on the West Coast. Coastal States Gas Corporation of Houston and the China National Chemical Import and Export Corporation of Peking negotiated the shipment of 3.6 million barrels of Chinese crude oil valued at $50 million over a six-month period. Chinese medium and heavy grade crude oil is low in sulfur and is expected to be converted to fuel oil at the Coastal refinery at Hercules, California. Although 3.6 million barrels over a six-month period represents about 1 percent of the crude oil demand in California, Coastal representatives are hopeful of a continuing and perhaps expanding crude oil agreement with China (Anon., 1978b).

Oil from Alaska, China and Mexico represents a domestic source of oil that is operating at capacity and two additional foreign sources of oil. The flow of oil from Alaska could be increased from 1.2 million barrels to 1.5 million to 1.6 million per day, according to experts. At the higher flow rates, proven Alaskan oil reserves of nine billion barrels would last only until 1995-2000 (Jenny, 1979). Although China and Mexico may supply a significant portion of the oil imported by the United States in the future, this is by no means certain. The United States will continue to depend primarily on oil from the Arabian Gulf region unless restrictions are imposed by the Arab leaders. The U.S. synthetic rubber industry, including synthetic cis-polyisoprene, remains vulnerable to changing political, social and economic conditions in the Third World. Thus, the prospects of guayule commercialization are strengthened.

d. Synthetic cis-1, 4-polyisoprene (polyisoprene): Polyisoprene is a synthetic elastomer designed to resemble as closely as possible natural Hevea rubber*. The only current domestic producer of polyisoprene is Goodyear Tire and Rubber Company at Beaumont, Texas. B.F. Goodrich Chemical Company has placed its polyisoprene plant at Orange, Texas, in "mothballs" in case it is needed in the future. Domestic consumption of polyisoprene is approximately 150 million to 160 million pounds annually. The product is an acceptable substitute for Hevea rubber and is derived from crude oil. In the past the economics of domestic production of polyisoprene has been

*Other polyisoprenes include trans-1,4- and 1,2- and 3,4- enchained polymers.

unfavorable compared to natural Hevea rubber. However, as the price of natural rubber rises to U.S. $ 0.60 per pound or more, domestic polyisoprene may become economically viable (Anderson, 1979).

Synthetic cis-1, 4-polyisoprene is nearly the same composition as natural Hevea rubber but may differ in average molecular weight, molecular weight distribution, degree of crystallinity, gel content, non-rubber content and cure properties. It is produced by solution polymerization of isoprene or 2-methyl-1,3-butadiene utilizing stero-specific catalysts*. Isoprene is obtained from crude oil under severe cracking conditions.

Foreign sources of polyisoprene include Canada, France, Italy, the Netherlands, Rumania, USSR and Japan. World capacity of cis-1,4-polyisoprene, trans-1,4-polyisoprene and other 1,2- and 3,4-enchained polymers is near 1.6 billion pounds. In general, the centrally planned economy countries are developing cis-1,4-polyisoprene plants in an effort to become independent from imports of Hevea rubber. Countries that are moving in this direction include Bulgaria, Czechoslovakia, Poland and USSR.

B. Changes in Elastomer Demand

Changes in elastomer demand include recent competitors of natural rubber, new rubber technology and shifts in U.S. consumption patterns of elastomers.

1. Present market for elastomers: Following is a tabulation of various kinds of elastomers and their relative world market importance (Allen, et al., 1975).

Elastomer Type	Estimated World Market Share in 1975 (%)
Natural polyisoprene	30
Synthetic polyisoprene	5
Styrene/butadiene and polybutadiene	50
All others, including polychloroprene, ethylene/propylene co- and terpolymers, butyl and specialty varieties	15
	100

The primary use of these materials is for tire treads, sidewalls and inner tubes. Other uses include automotive, industrial and appliance

*Catalysts include butyl lithium and Ziegler-Natta types as titanium tetrachloride with butyl aluminum.

components.

The specific elastomers are best suited for specific applications. Thus 72 percent of all natural rubber imported to the United States is consumed in making tires. The remaining 28 percent is used to make various rubber products, including rubber bands, shoe soles, carpet backing, adhesive bandages, baby bottle nipples, garden hose, windshield wipers, door gaskets, brake diaphragms, and bumper moldings (Anonymous, 1978a).

Styrene/butadiene is used mainly in tire treads and tire fabrication as sidewalls and carcasses. Polybutadiene usually is blended with styrene/butadiene and natural isoprene, and in the United States approximately 95 percent of it is used in tires.

Polychloroprene or Neoprene® is used in the white sidewalls of tires but the main areas of consumption are automotive and industrial components, wires, cables and adhesives. Ethylene/propylene co- and ter- polymers generally are not used in tires; instead, these polymers are used in automotive and appliance components, cables, etc. Butyl rubber is mainly used in inner tubes due to its very low permeability to gases.

2. Recent market competition for natural rubber: Recent competitors for natural rubber include new kinds of elastomers, new elastomer technology which would decrease the overall consumption of rubber, and the general replacement of natural rubber by plastics. New elastomers include polypentenamer (Bayer AG Farbenfabriken of West Germany), polypropylene oxide, and butadiene copolymer with propylene. Industry representatives support the view that such new elastomers will not be serious threats to natural rubber markets in the near future due to unfavorable production costs. However, the possible future perfection and availability of a cast tire would affect the demand for natural rubber. Several companies are currently doing research toward developing a cast tire and two have announced tests for experimental tires. LIM-Holding S.A. of Luxembourg has developed a polyair cast tire, and Phoenix Gummiwerke of Germany has developed a steel-belted, polyurethane, nonpneumatic cast tire (Scroggy, 1979; Norbye and Scroggy, 1978).

At present, tires are manufactured by "building." Different materials such as fabrics, steel belts and rubber are layered together to form a tire through a relatively labor-intensive process. Casting, where a liquid raw material is injected into a mold to form a tire requires much less labor. Predictions have been made that cast tires would use fewer hydrocarbon materials and energy. One source estimates it takes 7 gallons of crude oil to produce a conventional rubber tire compared to 1 gallon for a cast tire (Scroggy, 1979). Plastic cast tires could be easily recycled, further reducing raw material demands. Thus, widespread use of pourable synthetic liquid rubber or plastic to prepare a cast, cordless tire could have a significant negative impact on the demand for natural rubber and the synthetic rubbers currently used in tire building (Alliger,et al , 1971).

Three other advantages of plastic cast tires also may be cited. Cast tires have a much longer life, give as much as 10 percent less rolling resistance than conventional radial tires and are able to run when flat (Wall Street Journal, 1978). Despite the promise of advantages, experimental cast tires have not yet been able to measure up to the performance of conventional tires. They have problems of heat build-up and a tendency to go out of round. In addition the low coefficient of friction which helps to provide the low rolling resistance hinders effective acceleration and braking. In spite of the announcement in 1971 by the Firestone Tire and Rubber Company of the development of a low-cost, cast, cordless tire, it is not yet commercially available.

In the immediate future, the market for cast tires will probably be limited to tires for small-to medium-size equipment such as lawn/garden equipment, golf carts, farm implements and forklift trucks, which do not require the high performance characteristics of radial tires such as excellent cornering and handling ability, wear resistance and better gas mileage due to less rolling resistance (Klein, 1979).

Plastics continue to replace rubber in applications where the full range of attributes of natural rubber is not required. Examples include:a) polyvinyl chloride in flooring, footwear, cables, and garden hose; b) polyurethanes/polyethers in footwear, foam, thread, mattresses, and cushions; and c) thermoplastic rubbers that possess rubber properties at normal temperatures and are processed as plastics at compounding temperatures. The main uses of thermoplastic rubbers include adhesives, plastics modifiers, footwear and sheeting (Mawer, 1972). These materials are about twice as expensive as natural rubber.

Future natural rubber competition in the marketplace will undoubtedly include other elastomers and plastics which offer fabrication and compounding advantages. These include thermoplastics and powdered, pourable and castable rubbers. The principal markets for natural rubber will remain tires and industrial belting.

3. Recent changes in U.S. consumption of natural rubber: The following is a tabulation of recent trends in U.S. consumption of natural rubber:

Changes in automotive design;

Changes in flammability standards for automotive upholstery;

Changes in automobile tire size;

Changes in consumer driving habits; and

Changes in general rubber consumption as reflected by the Gross National Product (GNP).

Each of these sectors is described briefly below.

Changes in automotive design can have powerful impacts on natural rubber consumption. Anti impact bumpers are now manufactured by the Ford Motor Company and use approximately 20 million pounds of natural rubber annually (Lindley, 1970). On the other hand, due to increased engine operating temperatures, the continued use of natural rubber as engine mounts is in jeopardy. The estimated market at stake is only approximately two million pounds annually.

Changes in flammability standards for automotive upholstery as promulgated by the Department of Transportation have caused an increase in the use of natural rubber as a backing material for fabric.

Changes in automobile tire size, lowering of legal speed limits, and changes in consumer driving habits have reduced the growth rate of natural rubber in the tire market. Tire sizes have become smaller with the growth in the sales of compact and sub-compact cars. Further, tires will be lasting longer since consumers will be driving less as the price per gallon of gasoline rises to $0.70 to $0.80 per gallon of lead-free gasoline in mid-March 1979. The legal speed limit of 55 miles per hour also tends to lengthen tire life.

4. Consumption patterns forecast for elastomers: Real growth rates of the GNP of 3 percent to 5 percent are forecast for the near future, and it is expected that natural rubber growth in the industrial sector will be approximately that or real GNP growth.

U.S. consumption of natural and synthetic rubbers will increase over the next 10 years, but the growth rate will decrease compared to the last 10 years. Table IV-1 indicates natural and synthetic rubber demand by major end-use in the United States and Canada from 1965 to 1990 as predicted by the World Bank (1978). Tire uses for elastomers are expected to double by 1990 compared to 1965 but the growth rate will probably fall from 4.1 percent to 1.9 percent per year. Non-tire uses will have essentially tripled by 1990 compared to 1965 and the growth rate will probably be 3.6 percent to 5.4 percent or approximately the real GNP growth rate. The total elastomer demand will have increased from 2.2 million metric tons in 1965 to 5.3 million metric tons in 1990. The five-year average growth rates for this period vary from 3.1 percent to 3.9 percent per year. Based on World Bank projections, the future supply of both natural and synthetic rubbers may be hard pressed to meet demand in North America due to new technology and growing industrial and consumer markets.

C. Elastomer Substitutes

Substitutes for rubber include silicone elastomers; rigid, semirigid and flexible plastics; and leather goods.

Silicone elastomers and plastics ultimately depend on crude

TABLE IV- 1

ELASTOMER DEMAND IN THE UNITED STATES AND CANADA BY MAJOR END-USES

	1,000 Metric Tons						% Per Annum Growth Rates				
	Estimated			Projected							
	1965	1970	1974-76	1980	1985	1990	1965-70	1970-75	1975-80	1980-85	1985-90
Tire Uses											
Original equipment tires	393.0	380.0	482.0	555.0	640.0	720.0	- 0.7	4.9	2.9	2.9	2.4
Automobile[a]	243.0	198.0	251.0	280.0	310.0	340.0	- 4.0	4.9	2.2	2.1	1.9
Commercial vehicle[b]	150.0	192.0	231.0	275.0	330.0	380.0	5.1	3.8	3.6	3.7	2.9
Replacement tires	734.0	1,092.0	1,166.5	1,405.0	1,550.0	1,670.0	8.3	1.3	3.8	2.0	1.5
Automobile[a]	452.0	704.0	708.5	795.0	820.0	850.0	9.2	0.2	2.3	0.6	0.7
Commercial vehicle[b]	282.0	391.0	458.0	610.0	730.0	820.0	6.8	3.2	5.9	3.7	2.4
Other tires[c]	90.5	119.0	136.0	165.0	200.0	240.0	5.6	2.7	3.9	3.9	3.7
Exports of loose tires	26.5	20.5	53.0	42.0	51.0	60.0	- 5.0	21.0	- 4.6	4.0	-3.3
Automobile	10.3	8.3	32.0	15.0	18.0	20.0	- 4.2	31.0	-14.2	3.7	3.2
Commercial vehicle	12.0	7.0	15.0	20.0	25.0	30.0	-10.2	16.5	5.9	4.6	3.7
All others	4.2	5.2	6.0	7.0	8.0	10.0	4.4	2.9	3.1	2.7	4.6
Other tire uses	183.0	136.0	114.0	91.0	85.0	80.0	- 5.7	- 3.5	- 4.4	- 1.4	- 1.2
Subtotal	1,427.0	1,747.5	1,951.0	2,258.0	2,526.0	2,770.0	4.1	2.2	3.0	2.3	1.9
Nontire Uses											
Subtotal	801.0	955.0	1,229.5	1,600.0	2,000.0	2,500.0	3.6	5.2	5.4	4.6	4.6
Total Rubber											
Demand	2,228.0	2,702.5	3,180.5	3,858.0	4,576.0	5,270.0	3.9	3.3	3.9	3.2	3.1

Source: The World Rubber Economy: Structure, Changes, Prospects, The World Bank, Washington, D.C., June 1978, p. 119.

a/ Including snow tires.
b/ Including light trucks.
c/ Farm, aircraft and industrial tires.

oil and offer little or no physical or economic advantages over natural or synthetic rubbers. Silicone elastomers are approximately six times more expensive than rubber. The leather goods industry ultimately depends on the beef cattle industry for hides and imports of raw and finished leather. Cattle hides are used for shoe soles, belting, upholstery, harness, and industrial applications. Other sources of larger hides include dairy cows and horses. Calf skin is a source for smaller hides. Also, leather goods use hides from sheep, pigs, goats, seals, ostriches, reptiles, sharks. It is not realistic to expect that the leather goods industry could replace a significant portion of 5 percent to 10 percent of the natural and synthetic rubber market.

D. Prospects of Elastomer Reclamation

In the past, reclaiming of rubber has provided some rubber and carbon black, and much future potential exists in both these areas. Interest in reclamation has increased recently as the price of the raw materials for both natural and synthetic rubber has increased. New ideas are being developed and tested for reclaiming the two major sources of scrap rubber, in-house rubber scrap and used tires. In-house rubber scrap represents the trimmings, sprues and scrap created during the general rubber goods manufacturing process. It is estimated that there are at least 200 million pounds generated annually (Frable, 1976).

The two methods of reclaiming rubber are devulcanization and the recycling of ground rubber. Devulcanization involves mechanically and chemically reducing rubber to its original state and then blending it with virgin raw materials for reuse. Since devulcanized rubber loses some of its original properties, it can be substituted at only a 5- percent level. Recycling ground rubber involves grinding scrap in as small particles as possible and blending this with virgin rubber. In the past, ground rubber affected the surface appearance and physical properties of the rubber product and so was limited in use. Now a new process has been developed which grinds the scrap into small enough particles that even when added at levels of 30 percent, it will not reduce the rubber quality (Anon., 1977; Frable, 1976).

The reclamation of tires presents some problems. First, the tires may contain fiberglass or steel, which must be separated. Second, the tires are widely dispersed and collection can be costly. However, some reclamation of tires is being done on a small scale. Several companies are reclaiming carbon black from tires and using it in new tire manufacture. Recovery rates for carbon black of 30 percent to 50 percent are making it very economical to recover; presently, the rubber itself is not recovered from tires but is being burned as fuel and the ash converted to carbon black. One company is reported to be developing a process to separate the rubber out of tires and grind it for reuse. There is great potential for this process if it works; approximately 200 million tires containing eight billion pounds of rubber are discarded annually in the United States.

As present the contribution of reclaimed rubber to the total rubber supply is probably limited to using ground in-house scrap. This seems to be feasible and economical, and several companies are reported to have entered the field. Tires presently contribute only carbon black and fuel when processed, but a breakthrough in recovering tire rubber would make available a significant amount or reusable rubber.

V. CONCLUDING REMARKS

The future prospects for natural rubber will determine the future of guayule. If natural rubber demand rises sharply, the opportunity for successful guayule rubber production will be present. Considering the world elastomer supply and demand situation, there are five factors which favor this development.

First, there is no technical basis for the disproportionate control which synthetic rubber now has on the world elastomer market. The fluctuating price and availability of natural rubber in the past allowed synthetic rubber to gain this advantage. On the basis of properties required to satisfy the needs of the various consumers, and assuming an adequate supply, natural rubber could be used to satisfy as much as 70 percent of the total world elastomer demand (Allen,et al, 1975).

Second, recent meetings between the Association of Natural Rubber Producing Countries and 40 consuming countries have paved the way for the possible establishment of an international natural rubber stockpile of approximately 88 million pounds including various grades. This stockpile would be supported by funds from both producing and consuming countries, and it would be managed in such a way as to stabilize prices. Presumably, this arrangement could work to the advantage of both producers and consumers (Ruebensaal, 1978). However, at least one of the major U.S. tire manufacturers is opposed to U.S. involvement in the agreement (Klein, 1979).

Third, although the demand for vehicle tire rubber may be leveling off in the developed nations, the potential demand in the emerging nations of the world is just beginning to materialize. The use of automobile, truck and tractor tires has trememdous room for growth in Asia, Africa and South America.

Fourth, the price comparison between natural rubber and synthetic rubber may shift in favor of natural rubber. The price of synthetic rubber has traditionally stayed below that of natural rubber (Grilli,et al, 1978). However, the numerous petroleum price hikes that have occurred since 1973 and the recent disruption of Iranian oil production leave the entire petrochemical picture shrouded by uncertainty. One definitive statement that can be made is that the cost of natural rubber production is increasing much slower than the cost of synthetic rubber production.

Fifth, the potential for increasing natural rubber production to the levels required to meet much higher demand is present. There is substantial room for expansion and improvement of Hevea rubber production in Southeast Asia, Africa and, now that the Brazilian leaf blight is under control, South America (Allen,et al, 1975; Bonner, 1979). In addition there is the possibility of developing commercial scale guayule based natural rubber production in Mexico, the United States and elsewhere (Guayule, 1977).

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APPENDIX A

Technology Assessment Team Members

Advisory Committee

Consultants

Chapter II Reviewers

APPENDIX A

Technology Assessment Team Members

Dr. Jack D. Johnson
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona 85719

Dr. Kennith E. Foster
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona 85719

Dr. William G. McGinnies
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona 85719

Mr. Jonathan G. Taylor
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona 85719

Ms. Jean L. Mills
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona 85719

Mr. N. Gene Wright
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona 85719

Ms. Suzanne J. Alexander
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona 85719

Dr. Lay James Gibson
Department of Geography and
Regional Development
University of Arizona
Tucson, Arizona 85721

Mr. David de Kok
Department of Geography and
Regional Development
University of Arizona
Tucson, Arizona 85721

Dr. Ralph R. Wilkinson
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Mr. Fred C. Hopkins
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Dr. Edward W. Lawless
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Ms. Joy L. McCann
425 Volker Boulevard
Kansas City, Missouri 64110

Advisory Committee Members

Dr. Andrew Cowan
United State Department
of Agriculture
Beltsville, Maryland 20705

Mr. Earl Gregg
The B.F. Goodrich Company
Research Development Center
9921 Brecksville Road
Brecksville, Ohio 44141

Dr. Harold Linstone
Portland State University
Department of Systems Science
Portland, Oregon 97207

Dr. David Rubis
Plant Sciences
University of Arizona
Tucson, Arizona 85721

Mr. Stephen T. Semegen
Malaysian Rubber Bureau
15 Atterbury Boulevard
Hudson, Ohio 44236

Mr. Marcelo Fontanoz, Jr.
United States Navy
Naval Air Rework Facility
North Island
San Diego, California

Ms. Kathryn T. Louka
U.S. Department of Commerce
Office of Technical Assistance
Washington, D.C. 20230

Consultants

Dr. George Hanson
Los Angeles State and
County Arboretum
301 N. Baldwin Avenue
Arcada, California 91006

Dr. Donald McIntyre
Institute of Polymer Science
University of Akron
Akron, Ohio

Dr. Enrique Campos-Lopez
Centro de Investigacion
en Quimica Aplicada
Aldama No. 371 Ote.
Saltillo, Coahuila, Mexico

Chapter II Reviewers

The State-of-the-Art of Guayule Chapter was reviewed by the following people and many of their suggestions and comments were included in the final draft.

Guayule Plant Modification and Manipulation

Dr. Reed Rollins
(Geneticist and Plant Breeder, ERP)
Harvard University
22 Divinity Avenue
Cambridge, MA 02138

Dr. David Rubis
University of Arizona

Dr. George Hanson
Los Angeles State and County Arboretum
301 N. Baldwin Avenue
Arcadia, California 91006

Propagation Methods and Alternatives

Dr. Harris M. Benedict
(Chief Scientist, U.S. Bureau of Plant Industry Group on ERP)
P.O. Box 393
South Pasadena, California 91030

Dr. George Hanson
Los Angeles State and County Arboretum

Mr. Kenneth Taylor
(Research and Development Leader, ERP)
P.O. Box 669
Aromas, California 95004

Alternative Agronomic Practices

Dr. Harris M. Benedict
(Chief Scientist, U.S. Bureau of Plant Industry Group on ERP)

Mr. Kenneth Taylor
(Research and Development Leader, ERP)

Dr. Wayne Whitworth
(Post-War Guayule research in Texas)
New Mexico State University
Department of Agronomy
Box 30
Las Cruces, New Mexico 88003

Harvesting Techniques

Mr. James Byrne
(Chief Engineer, ERP)
257 Sharptown So.
Laurel, Maryland 20810

Mr. Henry L. Lobenstein
(Chief of Field Plantations, ERP)
3940 Nordin Avenue
Ogden, Utah 84403

Mr. Kenneth Taylor
(Research and Development Leader, ERP)

Processing Alternatives

Mr. James Byrne
(Chief Engineer, ERP)

Dr. Enrique Campos-Lopez
Centro de Investigacion
en Quimica Aplicada

Dr. E.M. Glymph
Firestone Natural Rubber
and Latex Company
1200 Firestone Parkway
Akron, Ohio 44317

Mr. Kenneth Taylor
(Research and Development
Leader, ERP)

Guayule Rubber Quality and Utilization

Dr. Enrique Campos-Lopez
Centro de Investigacion
en Quimica Aplicada

Dr. E.C. Gregg
The B.F. Goodrich Company
Research Development Center
9921 Brecksville Road
Brecksville, Ohio 44141

Dr. William Mueller
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91103

By-Products Characterization and Utilization

Mr. James Byrne
(Chief Engineer, ERP)

Dr. E.M. Glymph
Firestone Natural Rubber
and Latex Company

Dr. William Mueller
Jet Propulsion Laboratory

Dr. James Bonner
(Cooperating Scientist with ERP)
Professor of Biology
California Institute of
Technology
Pasadena, California 91109

APPENDIX B

Agricultural Statistics for the Potential Guayule Growth Area County-by-County

Texas Agricultural Statistics

Aransas, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Sorghum (bushels)	3,233	3,100	153,133	338.8	37,510
Hay (tons)	NA	467	567	27.4	7,817
Upland Cotton (bales)	300	300	200	47.1	5,616
TOTALS					
1975	4,500	4,800		576.7	60,405
1976	2,300	3,100		276.5	41,695
1977	3,800	3,700		386.8	50,710
X	3,533	3,867		413.3	50,937

Atascosa Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	10,267	5,700	112,400	334.3	44,460
Oats (bushels)	15,033	233	9,867	13.2	1,820
Flaxseed (bushels)	2,567	1,800	17,867	102.5	NA
Sorghum (bushels)	32,433	14,667	475,167	1,061.6	177,467
Corn (bushels)	4,633	2,967	170,533	415.4	31,150
Peanuts (lbs)	22,033	21,442	44,197,667	8,436.6	502,807
Hay (tons)	NA	18,367	26,433	1,285.9	307,642
Cowpeas (lbs)	1,433	933	555,133	NA	NA
Upland Cotton (bales)	517	323	140	33.0	6,046
Soybeans (bushels)	200	200	4,333	23.2	NA
TOTALS					
1975	86,300	70,800		12,332.5	1,110,145
1976	98,200	60,675		11,557.2	989,784
1977	82,850	68,420		11,227.5	1,114,246
X	89,117	66,632		11,705.7	1,071,392

Bee, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	1,067	933	767	188.7	17,453
Wheat (bushels)	3,700	2,300	52,467	150.2	17,940
Oats (bushels)	2,367	333	10,500	15.4	2,600
Flaxseed (bushels)	8,933	7,517	74,667	428.2	NA
Sorghum (bushels)	65,233	57,167	2,318,500	4,866.2	691,717
Corn (bushels)	12,100	11,067	643,267	1,486.9	116,200
Hay (tons)	NA	16,067	28,633	1,396.3	269,117
Barley (bushels)	267	33	1,367	2.3	260
Cowpeas (lbs)	NA	17	5,900	NA	NA
TOTALS					
1975	79,700	75,650		6,449.3	835,515
1976	87,850	90.350		8,232.2	1,001,765
1977	113,450	120,300		10,921.2	1,508,580
X	93,667	95,433		8,534.2	1,115,287

Bexar, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	12,467	8,100	151,500	438.9	63,180
Oats (bushels)	16,900	1,933	75,000	102.5	15,080
Rye (bushels)	200	NA	NA	NA	NA
Sorghum (bushels)	37,433	29,167	1,062,600	2,301.5	352,917
Corn (bushels)	10,567	9,633	678,333	1,618.1	101,150
Peanuts (lbs)	3,683	3,448	4,436,333	845.1	80,864
Hay (tons)	NA	17,733	35,200	1,709.0	297,033
Cowpeas (lbs)	NA	87	30,667	NA	NA
TOTALS					
1975	88,100	76,900		7,560.7	986,830
1976	73,650	60,775		7,163.7	807,344
1977	82,000	72,630		6,320.7	936,497
X	81,250	70,102		7,015.0	910,224

Brewster, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Hay (tons)	NA	367	267	12.5	6,142
TOTALS					
1975	NA	1,100		37.6	18,425
X	NA	367		12.5	6,142

Presidio, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Sorghum (bushels)	333	200	11,467	25.0	2,200
TOTALS					
1976	1,000	600		74.9	6,600
X	333	200		25.0	2,200

Brooks, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Oats (bushels)	567	NA	NA	NA	NA
Sorghum (bushels)	11,900	7,767	261,567	587.3	93,977
Hay (tons)	NA	3,233	5,667	277.1	54,158
Cowpeas (lbs)	267	267	293,333	NA	NA
Corn (bushels)	200	200	8,100	17.8	2,100
TOTALS					
1975	12,400	12,800		1,235.1	166,505
1976	15,800	9,200		697.5	118,380
1977	10,600	12,400		714.3	165,820
X	12,933	11,467		882.3	150,235

Cameron, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	112,767	108,333	99,300	25,354.4	2,025,833
Wheat (bushels)	567	500	12,167	41.1	3,900
Sorghums (bushels)	132,400	124,933	7,330,400	16,758.0	1,511,693
Corn (bushels)	4,967	3,567	295,000	716.8	37,450
Soybeans (bushels)	167	133	4,000	17.2	NA
Sugarcane (tons)	NA	5,200	175,667	NA	NA
Hay (tons)	NA	3,400	6,900	335.6	56,950
Barley (bushels)	167	133	5,433	9.0	1,040
Cowpeas (lbs)	NA	17	7,733	NA	NA
TOTAL					
1975	274,500	265,600		40,518.2	3,421,785
1976	241,800	240,100		46,516.1	3,555,860
1977	236,800	232,950		42,661.8	3,932,955
X	251,033	246,217		43,232.0	3,636,867

Culberson,. Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	1,710	1,710	1,345	314.2	31,977
American Pima Cotton (bales)	233	233	40	15.2	4,363
Wheat (bushels)	2,567	2,333	119,433	294.4	18,200
Barley (bushels)	1,433	1,050	45,800	90.1	8,190
Sorghums (bushels)	1,400	1,267	84,300	175.5	13,933
Hay (tons)	NA	1,067	6,633	324.3	17,867
Corn (bushels)	367	233	23,333	51.3	2,450
Sunflowers (lbs)	667	633	747,667	NA	NA
TOTALS					
1975	6,580	5,880		729.9	76,976
1976	2,700	3,300		595.7	34,690
1977	15,850	16,400		2,469.6	179,275
X	8,377	8,527		1,265.1	96,980

De Witt, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	6,333	3,667	58,867	184.6	28,600
Oats (bushels)	7,567	1,167	33,733	51.8	9,100
Flaxseed (bushels)	400	367	1,667	8.1	NA
Sorghum (bushels)	15,067	10,233	388,667	828.2	123,823
Corn (bushels)	6,867	6,300	209,900	498.3	66,150
Peanuts (lbs)	700	670	627,333	119.7	15,711
Hay (tons)	NA	15,167	30,800	1,478.2	254,042
Sunflowers (lbs)	333	333	276,667	NA	NA
Cowpeas (lbs)	NA	87	30,733	NA	NA
TOTALS					
1975	448,000	48,900		4,314.7	647,995
1976	360,000	33,420		2,495.0	428,934
1977	31,000	31,650		2,697.0	415,350
X	37,267	37,990		3,168.9	497,426

Dimmit Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	2,083	2,050	2,218	531.2	38,335
Wheat (bushels)	2,667	1,933	43,900	128.1	15,080
Oats (bushels)	2,300	NA	NA	NA	NA
Sorghum (bushels)	5,167	4,250	228,600	536.2	51,425
Corn (bushels)	1,467	1,267	101,633	242.6	13,300
Hay (tons)	NA	1,667	2,367	114.6	27,917
TOTALS					
1975	14,750	14,350		2,018.2	179,640
1976	14,300	7,100		812.4	73,990
1977	12,000	12,050		1,827.3	184,540
X	13,683	11,167		1,552.6	146,057

Duval, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	1,467	1,800	16,700	47.7	6,240
Oats (bushels)	3,133	67	3,367	4.4	520
Flaxseed (bushels)	1,400	1,067	7,800	43.9	NA
Sorghum (bushels)	36,433	26,233	789,933	1,741.4	317,423
Corn (bushels)	2,067	1,567	88,967	204.7	16,450
Peanuts (lbs)	837	802	2,147,333	411.3	18,799
Guar (lbs)	167	167	200,000	NA	NA
Hay (tons)	NA	12,233	18,333	886.4	204,908
Cowpeas (lbs)	1,300	1,067	492,467	NA	NA
Upland Cotton (bales)	783	783	500	117.8	14,648
Barley (bushels)	367	83	3,367	5.6	650
TOTALS					
1975	42,810	45,610		4,351.9	606,004
1976	48,300	38,395		2,605.1	467,548
1977	52,750	50,600		3,432.5	665,365
X	47,953	44,868		3,463.2	579,639

El Paso, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	7,300	7,100	9,467	2,385.7	132,770
American Pima Cotton (bales)	13,900	13,300	13,850	5,890.1	248,710
Wheat (bushels)	12,067	11,767	679,567	2,009.5	91,780
Barley (bushels)	2,033	1,700	102,200	199.6	13,260
Sorghum (bushels)	3,333	2,800	144,267	323.1	30,800
Corn (bushels)	433	67	7,167	17.9	700
Hay (tons)	NA	15,667	102,100	4,947.9	262,417
TOTALS					
1975	37,500	51,200		11,369.9	796,055
1976	41,000	55,800		15,489.3	739,075
1977	38,700	50,200		20,462.0	806,180
X	39,067	52,400		15,773.9	780,437

Frio, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	3,417	2,700	2,033	493.2	50,490
Wheat (bushels)	16,667	12,200	336,000	993.9	95,160
Oats (bushels)	13,933	2,167	80,167	110.8	16,900
Sorghum (bushels)	37,600	28,800	1,252,133	2,822.7	348,480
Corn (bushels)	5,800	5,167	301,400	710.3	54,250
Peanuts (lbs)	19,617	19,475	51,754,333	9,887.1	456,689
Hay (tons)	NA	9,100	14,500	705.7	152,425
Cowpeas (lbs)	3,633	3,400	2,063,133	NA	NA
TOTALS					
1975	92,700	85,900		17,408.8	1,216,025
1976	108,600	76,125		13,838.3	1,043,211
1977	100,700	87,000		15,924.0	1,263,945
X	100,667	83,008		15,723.7	1,174,394

Goliad, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	1,033	900	11,900	39.0	7,020
Oats (bushels)	3,433	500	16,667	24.0	3,900
Flaxseed (bushels)	167	133	933	4.5	NA
Sorghum (bushels)	5,800	3,967	130,167	276.4	47,997
Corn (bushels)	5,067	4,600	215,667	494.0	48,300
Hay (tons)	NA	6,033	12,533	611.6	01,058
TOTALS					
1975	14,900	12,700		928.3	154,195
1976	11,900	15,700		1,403.3	213,975
1977	19,700	20,000		2,017.4	256,655
X	15,500	16,133		1,449.5	208,275

Guadalupe, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	18,333	12,300	245,167	727.7	95,940
Oats (bushels)	7,667	633	18,100	27.8	4,940
Sorghum (bushels)	55,467	46,833	2,028,300	4,292.9	566,683
Corn (bushels)	7,467	6,167	256,800	601.3	64,750
Peanuts (lbs)	1,017	938	914,000	174.1	22,004
Hay (tons)	NA	19,200	37,400	1;812.6	321,600
Upland Cotton (bales)	567	517	222	52.2	9,662
TOTALS					
1975	84,950	85,225		7,367.5	1,056,831
1976	84,400	73,150		7,113.6	891,848
1977	102,200	101,390		8,584.4	1,308,058
X	90,517	86,588		7,688.5	1,085,579

Hidalgo, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	70,933	70,333	74,500	18,659.4	1,315,233
Wheat (bushels)	1,967	1,800	35,433	105.3	14,040
Oats (bushels)	967	NA	NA	NA	NA
Flaxseed (bushels)	400	367	6,400	41.9	NA
Sorghum (bushels)	244,533	236,333	12,114,533	26,972.2	2,859,633
Corn (bushels)	18,200	15,267	1,347,900	3,330.9	160,300
Soybeans (bushels)	1,400	1,267	44,000	198.0	NA
Sugarcane (tons)	NA	25,300	867,000	NA	NA
Hay (tons)	NA	5,833	12,067	578.5	97,708
Cowpeas (lbs.)	1,000	883	NA	NA	NA
TOTALS					
1975	399,700	412,500		56,573.8	4,752,500
1976	281,300	355,300		40,663.2	3,713,375
1977	227,200	355,300		52,421.2	4,874,870
X	339,400	357,383		49,886.1	4,469,915

Hudspeth, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	12,033	11,867	12,083	2,988.6	221,907
American Pima Cotton (bales)	2,883	2,583	2,977	1,274.4	48,308
Wheat (bushels)	2,800	2,633	137,100	407.8	20,540
Oats (bushels)	267	33	1,300	2.1	260
Barley (bushles)	4,100	3,333	155,500	292.1	26,000
Sorghum (bushels)	4,533	3,300	192,700	400.5	36,300
Corn (bushels)	1,433	767	42,600	97.6	8,050
Hay (tons)	NA	7,467	44,133	2,137.9	125,067
TOTAL					
1975	19,800	24,350		5,143.5	396,870
1976	30,300	33,550		7,808.1	472,630
1977	34,050	38.050		9,851.6	589,795
X	28,050	31,983		7,601.1	484,432

Jeff Davis, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Sorghum (bushels)	700	467	25,533	58.6	5,133
Wheat (bushels)	333	333	10,167	30.9	2,600
TOTALS					
1975	1,000	800		97.5	8,800
1976	2,100	1,600		171.1	14,400
1977	NA	NA		NA	NA
X	1,033	800		89.5	7,733

Jim Hogg, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Sorghum (bushels)	3,733	2,333	99,300	227.0	28,233
Hay (tons)	NA	333	467	21.9	5,583
TOTALS					
1975	4,900	4,400		511.0	57,890
1976	4,900	2,500		168.2	30,250
1977	1,400	1,100		67.4	13,310
X	3,733	2,667		248.9	33,817

Jim Wells, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	5,117	4,933	2,833	689.7	92,253
Oats (bushels)	3,500	400	15,100	21.6	3,120
Barley (bushels)	200	NA	NA	NA	NA
Flaxseed (bushels)	7,233	4,467	38,700	227.6	NA
Sorghum (bushels)	108,400	91,967	3,530,400	7,618.4	1,112,797
Corn (bushels)	1,500	1,133	45,700	106.3	11,900
Hay (tons)	NA	13,400	32,500	159.0	157,450
Cowpeas (lbs)	533	400	165,467	NA	NA
TOTAL					
1975	128,500	125,600		11,548.1	1,427,445
1976	108,650	84,200		6,155.5	947,335
1977	142,300	140,300		13,060.1	1,767,780
X	126,483	116,700		10,2546	1,377,520

Karnes, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	29,567	14,767	241,900	751.4	115,180
Oats (bushels)	10,000	1,167	35,833	48.3	9,100
Flaxseed (bushels)	8,433	6,300	43,233	243.3	NA
Sorghum (bushels)	30,233	19,567	624,733	1,318.6	236,757
Corn (bushels)	13,233	11,533	269,133	634.1	121,100
Hay (tons)	NA	21,533	53,767	2,610.0	253,017
Barley (bushels)	200	67	2,700	4.5	520
Rye (bushels)	167	100	1,200	2.2	780
TOTALS					
1975	101,800	85,600		5,869.8	814,640
1976	89,300	68,200		6,509.1	640,260
1977	84,400	71,300		4,458.0	754,460
X	91,833	75,033		5,612.3	736,453

Kenedy, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Sorghum (bushels)	533	433	13,800	28.3	5,243
Hay (tons)	NA	233	367	18.1	2,742
TOTALS					
1975	500	400		30.0	4,840
1976	NA	NA		NA	NA
1977	1,100	1,600		109.4	19,115
X	533	667		46.5	7,985

Kinney, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	4,700	3,900	95,600	284.0	30,420
Oats (bushels)	500	33	867	1.3	260
Sorghum (bushels)	3,167	2,467	114,133	243.2	29,847
Corn (bushels)	700	700	62,500	150.7	7,350
TOTALS					
1975	12,000	10,200		1,009.0	91,770
1976	5,500	3,400		410.6	36,150
1977	9,700	7,700		617.9	75,710
X	9,067	7,100		679.2	67,877

Kleberg Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	6,700	6,600	5,867	1,469.7	123,420
Wheat (bushels)	167	67	1,333	4.5	520
Sorghum (bushels)	44,100	41,700	1,614,333	3,372.4	504,570
Hay (tons)	NA	7,367	19,433	944.4	86,558
Cowpeas (lbs)	500	433	140,667	NA	NA
TOTALS					
1975	38,800	43,600		3,385.2	540,370
1976	52,400	58,100		6,224.4	734,630
1977	63,200	66,800		7,763.2	870,205
X	51,467	56,167		5,790.9	715,068

La Salle Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	3,867	3,683	1,867	455.9	68,878
Wheat (bushels)	5,667	3,267	83,433	237.0	25,480
Oats (bushels)	4,067	933	35,733	50.8	7,280
Sorghum (bushels)	39,200	27,833	1,021,000	2,361.4	336,783
Corn (bushels)	1,033	900	46,167	117.4	9,450
Peanuts (lbs)	2,533	2,497	4,067,667	776.4	58,547
Hay (tons)	NA	6,800	7,233	351.0	79,900
Cowpeas (lbs)	500	500	123,800	NA	NA
TOTALS					
1975	85,650	78,950		6,940.3	953,402
1976	39,800	24,090		2,967.0	305,753
1977	45,150	36,200		3,142.3	499,800
X	56,867	46,413		4,349.9	586,318

Live Oak, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	1,733	1,560	1,283	307.4	29,172
Wheat (bushels)	7,967	4,533	68,133	186.6	35,360
Oats (bushels)	2,900	167	4,667	7.0	1,300
Flaxseed (bushels)	4,267	3,200	18,267	103.1	NA
Sorghum (bushels	43,933	34,067	1,677,667	2,371.0	412,207
Corn (bushels)	15,267	14,033	532,300	1,251.8	147,350
Hay (tons)	NA	14,800	24,700	1,203.5	173,900
Soybeans (bushels)	267	233	5,000	26.7	NA
TOTALS					
1975	71,200	76,900		6,275.6	845,315
1976	74,950	58,880		3,395.3	606,206
1977	82,850	82,000		6,700.9	946,345
X	76,333	72,593		5,457.3	799,289

Maverick, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	1,583	1,383	1,063	263.4	25,868
Wheat (bushels)	3,067	2,767	84,533	243.6	21,580
Oats (bushels)	3,533	400	12,333	18.6	3,120
Flaxseed (bushels)	267	167	1,467	9.6	NA
Sorghum (bushels)	6,233	4,250	253,567	592.5	51,425
Corn (bushels)	2,600	1,767	140,933	339.7	18,550
Hay (tons)	NA	7,233	17,333	845.7	84,992
TOTALS					
1975	18,400	24,300		2,575.5	267,210
1976	20,900	15,350		2,192.8	169,010
1977	12,550	14,250		2,171.3	180,385
X	17,283	17,967		2,313.2	205,535

McMullen, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	233	100	2,667	8.1	780
Oats (bushels)	1,533	167	5,667	8.2	1,300
Sorghum (bushels)	8,300	6,333	180,567	398.4	76,633
Hay (tons)	NA	2,300	3,600	174.4	27,025
TOTALS					
1975	10,200	10,500		794.6	124,455
1976	12,200	9,100		471.7	108,330
1977	7,800	7,100		501.2	84,430
X	10,067	8,900		589.2	105,738

Medina, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	21,933	16,900	397,133	1,206.1	131,820
Oats (bushels)	20,367	9,267	313,633	460.7	72,280
Sorghum (bushels)	62,033	54,133	2,293,400	4,944.7	655,013
Corn (bushels)	15,433	14,467	1,171,467	2,767.0	151,900
Peanuts (lbs)	2,133	2,047	4,471,333	853.1	47,994
Hay (tons)	NA	16,233	27,167	1,320.9	190,742
Upland Cotton (bales)	183	133	73	17.3	2,493
Soybeans (bushels)	333	233	4,333	23.2	NA
TOTALS					
1975	120,000	119,725		12,736.0	1,276,466
1976	118,700	104,675		10,819.7	1,180.699
1977	128,550	116,840		11,223.2	1,299,583
X	122,417	113,413		11,598.0	1,252,243

Nueces, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	51,833	50,667	50,533	12,654.3	947,467
Wheat (bushels)	533	333	3,900	12.6	2,600
Flaxseed (bushels)	4,100	2,700	31,200	188.5	NA
Sorghums (bushels)	295,067	284,867	13,366,867	28,932.9	3,446,887
Corn (bushels	900	733	28,767	69.8	7,700
Hay (tons)	NA	1,800	3,500	169.3	21,150
Cowpeas (lbs)	233	67	19,333	NA	NA
TOTALS					
1975	332,000	318,800		37,295.2	3,970,915
1976	373,600	365,000		45,759.9	4,684,075
1977	362,400	339,700		43,026.9	4,622,420
X	352,667	341,167		42,027.3	4,425,803

Pecos, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	2,433	2,283	2,083	522.9	42,698
American Pima Cotton (bales)	617	467	250	95.3	8,727
Wheat (bushels)	6,600	5,333	197,200	611.6	41,600
Barley (bushels)	5,133	3,900	168,867	328.3	30,420
Sorghum (bushels)	4,050	3,166	188,033	419.4	34,833
Hay (tons)	NA	4,067	22,667	1,103.4	68,117
Sunflower (lbs)	1,100	1,067	1,100,100	NA	NA
Oats (bushels)	600	367	17,533	25.0	2,860
TOTAL					
1975	27,750	28,050		3,335.8	273,685
1976	19,200	17,600		3,396.3	201,145
1977	14,650	16,300		2,585.6	212,935
X	20,533	20,650		3,105.9	229,255

Reeves, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	7,400	7,217	8,733	2,151.0	134,952
American Pima Cotton (bales)	1,183	1,183	666	254.1	22,128
Wheat (bushels)	6,800	5,700	206,833	614.1	44,460
Oats (bushels)	1,400	367	22,733	33.5	2,860
Barley (bushels)	5,833	4,383	183,267	380.7	34,190
Sorghum (bushels)	3,200	2,367	150,000	360.4	26,033
Guar (lbs)	233	200	283,333	NA	NA
Hay (tons)	NA	6,133	38,667	1,881.4	102,733
Sunflowers (lbs)	2,933	2,867	3,170,900	NA	NA
TOTALS					
1975	49,550	46,600		6,717.0	480,430
1976	20,500	23,700		5,387.4	301,115
1977	16,900	20,950		4,920.9	320,525
X	28,983	30,417		5,675.1	367,357

Refugio, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	4,130	3,430	2,867	726.1	64,141
Wheat (bushels)	400	50	467	1.4	390
Oats (bushels)	1,333	NA	NA	NA	NA
Flaxseed (bushels)	2,333	1,867	32,867	196.9	NA
Sorghum (bushels)	83,867	80,767	3,834,667	8,332.4	977,277
Corn (bushels)	2,367	2,167	109,000	240.5	22,750
Hay (tons)	NA	1,567	2,700	131.7	18,408
TOTALS					
1975	70,890	68,490		9,179.1	801,148
1976	113,500	112,350		12,223.6	1,350,500
1977	98,900	88,700		7,484.5	1,097,250
X	94,430	89,847		9,629.1	1,082,966

San Patricio, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	47,467	46,600	54,700	13,602.3	871,420
Wheat (bushels)	700	200	3,133	10.4	1,560
Oats (bushels)	333	33	1,000	1.5	260
Flaxseed (bushels)	2,133	1,467	16,000	91.9	NA
Sorghum (bushels)	213,733	205,233	9,926,000	21,809.6	2,483,323
Corn (bushels)	3,233	2,667	120,767	283.0	28,000
Hay (tons)	NA	2,167	3,300	160.2	25,458
TOTALS					
1975	275,500	267,200		35,936.3	3,362,095
1976	281,300	270,600		35,964.6	3,524,030
1977	247,600	237,300		35,975.9	3,343,940
X	267,600	256,367		35,958.9	3,410,022

Starr, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	767	700	9,800	31.4	5,460
Flaxseed (bushels)	300	300	5,267	34.4	NA
Sorghum (bushels)	54,667	50,333	1,110,100	4,057.1	609,033
Corn (bushels)	1,333	1,033	79,600	198.3	10,850
Hay (tons)	NA	3,900	7,000	336.0	45,825
Upland Cotton (bales)	4,767	4,767	2,867	675.6	89,137
TOTALS					
1975	46,400	46,600		4,009.3	546,825
1976	55,100	54,500		5,611.6	649,130
1977	84,000	82,000		6,377.9	1,084,960
X	61,833	61,033		5,332.9	760,305

Uvalde, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	2,577	2,363	2,490	608.5	44,194
Wheat (bushels)	23,600	18,967	527,667	1,518.4	147,940
Oats (bushels)	18,933	6,867	213,267	308.8	53,560
Sorghum (bushels)	20,100	15,700	759,933	1,652.9	189,970
Corn (bushels)	15,867	15,100	1,382,200	3,264.2	158,550
Soybeans (bushels)	2,800	2,317	53,333	270.6	NA
Hay (tons)	NA	7,567	12,333	602.5	88,908
TOTALS					
1975	82,980	70,590		7,882.2	670,628
1976	74,750	52,150		7,691.0	543,345
1977	93,900	83,900		9,104.3	835,395
X	83,877	68,880		8,225.8	683,123

Webb, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Oats (bushels)	15,33	100	3,933	5.1	780
Sorghum (bushels)	2,767	2,400	109,767	252.6	29,040
Hay (tons)	NA	1,267	2,500	118.0	14,883
Wheat (bushels)	200	167	8,533	19.2	1,300
TOTALS					
1975	6,200	7,900		856.5	94,505
1976	4,300	2,100		188.5	25,165
1977	3,000	1,800		139.5	18,340
X	4,500	3,933		394.8	46,003

Willacy, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	67,733	66,767	74,100	18,635.5	1,248,537
Wheat (bushels)	333	300	7,600	25.7	2,340
Sorghum (bushels)	109,733	107,067	5,648,300	12,567.1	1,295,507
Corn (bushels)	833	800	53,833	129.1	8,400
Sugarcane (tons)	NA	4,600	159,667	NA	NA
Hay (tons)	NA	167	167	7.8	1,958
Cowpeas (lbs)	833	767	656,700	NA	NA
Soybeans (bushels)	233	233	7,000	37.5	NA
TOTAL					
1975	176,800	174,700		24,624.4	2,251,665
1976	187,700	191,200		34,503.6	2,644,380
1977	174,600	176,200		35,080.0	2,774,180
X	179,700	180,700		31,402.7	2,556,742

Wilson, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Wheat (bushels)	22,400	10,933	184,167	553.9	85,280
Oats (bushels)	12,333	467	15,033	22.0	3,640
Rye (bushels	500	NA	NA	NA	NA
Sorghum (bushels)	37,700	28,700	1,087,400	2,266.1	347,270
Corn (bushels)	3,833	3,033	66,300	157.4	31,850
Peanuts (lbs)	17,433	17,132	26,289,333	5,019.4	401,738
Hay (tons)	NA	28,567	57,133	2,777.3	335,658
Cowpeas (lbs)	1,133	533	229,000	NA	NA
Upland Cotton (bales)	367	307	107	25.1	5,735
TOTALS					
1975	102,600	88,300		9,953.6	1,160,170
1976	89,900	81,995		10,829.1	1,144,785
1977	94,600	98,720		11,681.1	1,328,557
X	95,700	89,672		10,821.3	1,211,171

Zapata, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Sorghum (bushels)	6,633	5,767	222,433	504.6	69,777
Hay (tons)	NA	1,067	1,167	56.3	12,533
Upland Cotton (bales)	550	550	700	165.0	10,285
TOTALS					
1975	11,800	13,500		1,227.3	162,650
1976	1,000	1,000		85.2	11,890
1977	8,750	7,650		865.2	103,245
X	7,183	7,383		725.9	92,595

Zavala, Texas Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	9,650	8,650	11,100	2,767.8	161,755
Wheat (bushels)	12,433	7,733	240,400	671.3	60,320
Oats (bushels)	7,300	1,833	89,167	122.8	14,300
Sorghum (bushels)	23,733	19,233	1,060,767	2,404.6	232,723
Corn (bushels)	15,267	14,200	1,308,467	3,156.7	149,100
Hay (tons)	NA	3,233	5,433	263.3	37,992
Soybeans (bushels)	200	200	3,667	19.6	NA
TOTALS					
1975	64,950	58,950		10,480.9	667,780
1976	75,300	49,200		8,497.8	582,645
1977	65,500	5,100		9,239.7	718,145
X	68,583	55,083		9,406.1	656,190

Arizona Agricultural Statistics

Cochise, Arizona Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Upland Cotton (bales)	19,417	19,100	29,847	8,473.5	554,855
American Pima Cotton (bales)	3,333	3,317	4,470	1,985.1	100,163
Hay (tons)	NA	12,133	65,900	4.249.1	230,533
Wheat (tons)	36,767	35,700	73,130	8,713.6	342,720
Barley (tons)	2,533	2,167	3,623	396.1	20,800
Corn (tons)	17,800	15,500	36,433	3,045.0	162,750
Sorghum (tons)	35,200	33,167	74,743	6,908.7	401,317
Sugarbeets (tons)	3,700	3,450	67,533	1,929.9	87,802
Lettuce (1000 cwt)	1,200	1,200	271	2,126.4	190,200
TOTAL					
1975	112,290	119,830		305,395	1,837,410
1976	145,800	146,850		452,959	2,203,228
1977	101,760	110,520		357,169	2,232,784
$\bar{X}$	119,950	125,734		378,274	2,091,140

Graham, Arizona Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Upland Cotton (bales)	6,483	6,383	10,503	2,986.5	185,436
American Pima Cotton (bales)	7,317	7,117	9,103	4,004.4	214,923
Hay (tons)	NA	8,800	51,467	3,324.4	147,400
Wheat (tons)	6,000	5,633	11,570	1,340.5	54,080
Barley (tons)	6,467	5,800	10,317	1,123.9	55,680
Corn (tons)	1,833	800	1,707	140.5	8,400
Sorghum (tons)	20,967	19,433	40,607	3,714.8	235,143
Sugarbeets (tons)	200	120	1,993	85.2	3,054
TOTAL					
1975	50,150	55,110		139,278	832,279
1976	46,450	52,650		177,149	811,215
1977	51,200	54,500		184,324	1,068,855
$\bar{X}$	49,267	54,086		167,202	904,116

Greenlee, Arizona Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Upland Cotton (bales)	417	417	657	188.4	12,104
Hay (tons)	NA	2,300	13,100	844.1	38,525
Wheat (tons)	1,733	1,567	3,013	354.7	15,040
Barley (tons)	133	100	143	15.8	960
Corn (tons)	200	167	350	27.5	1,750
Sorghum (tons)	667	500	923	82.0	6,050
TOTAL					
1975	2,400	4,000		1,024.8	54,665
1976	3,950	5,950		1,898.8	79,927
1977	3,100	5,200		1,623.0	88,695
$\bar{X}$	3,150	5,051		1,512.5	74,429

Maricopa, Arizona Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Upland Cotton (bales)	164,333	163,950	375,833	106,672.0	4,762,748
American Pima Cotton (bales)	6,733	6,683	10,200	4,467.1	201,837
Hay (tons)	NA	103,300	669,467	24,999.0	1,962,700
Wheat (tons)	81,667	75,900	178,397	20,610.0	728,640
Barley (tons)	29,433	27,100	50,197	5,290.3	260,160
Corn (tons)	6,633	1,100	1,373	144.0	11,550
Sorghum (tons)	24,633	23,100	43,887	3,960.3	254,100
Safflower (tons)	6,900	6,900	7,967	2,178.6	89,700
Sugarbeets (tons)	5,110	4,970	127,793	3,181.8	126,486
Broccoli (1000 cwt)	600	600	34	714.1	NA
Cantaloupe (1000 cwt)	2,257	2,257	292	3,590.5	349,783
Carrots (1000 cwt)	1,473	1,473	181	1,749.1	167,960
Cauliflower (1000 cwt)	713	713	41	1,053.7	NA
Lettuce (1000 cwt)	6,220	6,220	1,399	10,813.7	985,870
Dry Onions (1000 cwt)	1,150	1,150	533	3,760.3	1,265,500
Watermelons (1000 cwt)	2,183	2,183	345	1,598.0	244,533
Honeydews (1000 cwt)	280	280	36	372.4	NA
Potatoes (1000 cwt)	6,500	6,500	1,703	9,130.0	325,000

Maricopa, Arizona Agricultural Statistics, 1975-1977 Average

(Continued)

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
TOTAL					
1975	295,440	389,660		177,480.2	9,072,974
1976	356,800	437,800		248,870.2	10,289,970
1977	388,220	475,680		127,321.8	12,429,758
$\bar{X}$	346,818	434,379		221,224.1	10,597,567

Mohave, Arizona Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Upland Cotton (bales)	1,850	1,850	4,207	1,203.2	53,742
Hay (tons)	NA	3,733	18,000	1,131.5	70,933
Wheat (tons)	467	333	477	50.4	3,200
Sorghum (tons)	1,100	367	410	33.2	4,033
TOTAL					
1975	2,250	6,550		2,286.4	135,002
1976	3,000	5,600		2,631.9	119,725
1977	5,000	6,700		2,336.5	141,000
$\bar{X}$	3,417	6,283		2,418.3	131,908

Pima, Arizona Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Upland Cotton (bales)	15,067	15,017	26,873	7,594.1	432,901
American Pima Cotton (bales)	3,283	3,267	4,827	2,118.6	98,653
Hay (tons)	NA	2,700	14,400	928.3	51,300
Wheat (tons)	10,600	10,167	21,130	2,406.6	97,600
Barley (tons)	2,900	2,500	4,623	492.0	24,000
Corn (tons)	400	167	210	24.0	1,750
Sorghum (tons)	5,233	4,767	7,450	685.8	57,677
Lettuce (1000 cwt)	2,977	2,977	647	5,010.5	471,802
TOTAL					
1975	39,280	40,380		15,411.8	1,109,522
1976	43,850	44,550		21,960.6	1,246,045
1977	38,250	39,750		20,407.4	1,351,480
$\bar{X}$	40,460	41,562		19,259.9	1,235,683

Pinal, Arizona Agricultural Statistics, 1975-1977 Average

Crops	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Upland Cotton (bales)	114,283	113,933	228,167	64,897.8	3,309,763
American Pima Cotton (bales)	5,167	5,150	12,040	5,331.7	155,527
Hay (tons)	NA	18,767	106,733	6,890.5	356,567
Wheat (tons)	72,633	70,933	153,070	17,419.2	680,960
Barley (tons)	20,067	17,700	32,260	3,361.2	169,920
Corn (tons)	167	NA	NA	NA	NA
Sorghum (tons)	7,333	6,767	13,087	1,201.5	73,433
Safflower (tons)	9,633	9,633	11,653	3,258.3	125,233
Sugarbeets (tons)	4,693	4,607	91,387	2,633.2	117,240
Lettuce (1000 cwt)	4,503	4,503	979	7,608.3	713,778
Cantaloupe (1000 cwt)	33	33	5	52.2	5,167
Carrots (1000 cwt)	167	167	23	268.9	19,000
Dry Onions (1000 cwt)	100	100	39	224.3	11,000
Watermelons (1000 cwt)	733	733	116	530.0	82,133
TOTAL					
1975	237,690	249,800		90,771.9	5,604,382
1976	256,900	271,900		141,856.5	5,956,897
1977	223,950	237,380		105,769.2	5,900,884
$\bar{X}$	239,512	253,026		113,677.1	5,820,721

Santa Cruz, Arizona Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Hay (tons)	NA	2,067	7,133	460.4	39,267
Barley (tons)	600	433	643	65.5	4,160
Sorghum (tons)	333	267	390	37.1	3,227
TOTAL					
1975	1,000	2,800		480.6	46,680
1976	1,000	2,700		608.8	45,720
1977	800	2,800		599.7	47,560
$\bar{X}$	933	2,767		563.0	46,654

Yuma, Arizona Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Upland Cotton (bales)	53,567	53,433	142,640	40,375.8	1,552,239
American Pima Cotton (bales)	5,067	5,033	8,793	3,826.7	152,007
Hay (tons)	NA	73,367	487,333	31,264.0	1,393,967
Wheat (tons)	73,967	71,833	162,780	19,061.7	689,600
Barley (tons)	3,500	2,700	4,573	477.4	25,920
Corn (tons)	1,100	867	1,150	116.0	9,100
Sorghum (tons)	11,767	10,633	22,180	1,929.2	116,967
Safflower (tons)	1,800	1,800	2,147	604.9	23,400
Sugarbeets (tons)	2,530	2,453	58,627	1,881.9	62,437
Cantaloupe (1000 cwt)	6,643	6,643	901	10,857.2	1,029,717
Califlower (1000 cwt)	440	440	35	908.3	NA
Honeydews (1000 cwt)	1,200	1,200	151	1,563.3	NA
Lettuce (1000 cwt)	23,467	23,467	4,625	35,713.7	3,719,467
Dry Onions (1000 cwt)	283	283	102	814.1	31,167
Watermelon (1000 cwt)	383	383	68	314.1	42,933
TOTAL					
1975	158,720	226,690		126,140.3	8,219,990
1976	216,050	283,000		163,082.8	8,710,943
1977	182,370	253,920		158,019.9	9,615,824
$\bar{X}$	185,714	254,535		149,081.0	8,848,919

New Mexico Agricultural Statistics

Dona Ana, New Mexico Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Barley (bushels)	2,933	2,767	165,100	325.3	21,580
Corn (bushels)	1,543	140	13,033	29.4	1,470
Sorghum (bushels)	4,467	3,633	264,767	566.2	43,963
Wheat (bushels)	8,333	8,300	553,200	1,786.3	64,740
Upland Cotton (bales)	20,967	20,883	27,033	11,611.8	390,518
American Pima Cotton (bales)	8,787	8,502	7,042	NA	158,981
Hay (tons)	NA	15,600	77,560	4,426.6	261,300
Lettuce-Spring (cwt)	917	733	119,500	7,567.9	112,933
Lettuce-Fall (cwt)	3,350	2,757	629,033	NA	449,337
Onions (cwt)	2,900	2,750	915,500	8,291.7	302,500
TOTAL					
1975	56,360	64,970		320,928	1,791,115
1976	54,260	68,230		391,216	1,857,701
1977	51,970	64,995		329,013	1,773,152
$\bar{X}$	54,196	66,065		347,052	1,807,32?

Grant, New Mexico Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Barley (bushels)	290	57	2,533	4.6	442
Corn (bushels)	416	317	21,740	46.3	3,325
Sorghum (bushels)	1,000	940	54,550	121.2	11,374
Wheat (bushels)	703	270	10,890	28.6	2,106
Upland Cotton (bales)	27	27	47	17.3	497
Hay (tons)	NA	1,500	4,573	266.6	17,625
TOTAL					
1975	2,920	3,220		4,916	37,950
1976	2,160	3,331		5,228	37,432
1977	2,230	2,780		4,392	30,730
$\bar{X}$	2,436	3,111		4,846	35,369

Hidalgo, New Mexico Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hour
Barley (bushels)	933	730	42,240	87.7	5,694
Corn (bushels)	2,500	2,467	288,667	615.9	25,900
Sorghum (bushels)	14,233	13,633	1,147,033	2,445.2	164,963
Wheat (bushels)	2,467	2,067	89,133	254.0	16,120
Upland Cotton (bales)	4,047	3,940	4,820	1,437.4	73,678
Hay (tons)	NA	2,983	11,243	658.3	35,054
TOTAL					
1975	24,370	24,450		47,619	299,520
1976	23,270	26,130		50,945	307,960
1977	24,900	26,880		66,391	356,749
$\bar{X}$	24,179	25,820		54,985	321,409

Luna, New Mexico Agricultural Statistics, 1975-1977 Average

Crop	Planted Acreage	Harvested Acreage	Production	Value of Production (1000 dollars)	Man Hours
Barley (bushels)	2,583	2,367	155,333	317.3	18,460
Corn (bushels)	4,567	3,400	349,800	748.4	35,700
Sorghum (bushels)	21,667	20,967	2,195,733	4,759.3	253,697
Wheat (bushels)	3,350	3,200	181,933	568.9	24,960
Upland Cotton (bales)	11,400	11,267	16,347	5,307.5	210,687
American Pima Cotton (bales)	807	763	673	NA	14,274
Hay (tons)	NA	2,600	11,963	696.2	30,550
TOTAL					
1975	45,110	44,090		106,978	563,173
1976	45,610	45,950		124,135	570,528
1977	42,400	43,650		140,815	631,282
$\bar{X}$	44,374	44,564		123,976	588,328

California Agricultural Statistics

Alameda, California Agricultural Statistics, 1975-1977 Average

Crop.	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	4,000	190,659	468.3	38,400
Wheat (bushels)	600	42,017	147.0	5,760
Safflower	458	NA	66.0	5,958
Alfalfa (tons)	962	5,686	394.7	16,108
Wild & Grain Hay (tons)	8,933	17,288	574.3	149,633
Irrigated Pasture	1,128	NA	79.0	NA
Sugarbeets (tons)	1,002	27,373	538.7	25,509
TOTALS				
1975	29,440		3,253.0	411,916
1976	10,402		1,956.8	144,261
1977	11,410		1,594.2	167,929
X	17,084		2,268.0	241,369

Butte, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	10,800	642,996	1,569.7	103,680
Wheat (bushels)	27,667	1,744,527	5,547.0	265,600
Oats (bushels)	6,033	549,921	981.3	57,920
Corn (bushels)	6,910	941,673	2,603.0	72,555
Rice (cwt)	71,600	4,075,353	34,104.0	NA
Sorghum (bushels)	8,467	731,576	1,946.7	93,133
Alfalfa (tons)	6,000	35,542	2,486.7	100,500
Wild & Grain Hay (tons)	4,317	8,283	368.0	72,304
Safflower	1,167	NA	187.3	15,167
Irrigated Pasture	19,800	NA	1,801.7	NA
Dry Beans & Peas	7,467	NA	3,162.0	NA
Sugar Beets (tons)	3,740	102,336	2,133.0	95,183
TOTALS				
1975	189,330		63,942.0	925,731
1976	177,870		54,625.5	932,105
1977	154,700		52,103.4	770,290
X	173,967		56,890.3	876,042

Colusa, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	19,200	1,027,284	2,467.2	184,320
Wheat (bushels)	39,167	2,516,206	7,982.5	376,000
Corn (bushels)	12,167	1,434,136	3,828.1	127,750
Sorghum (bushels)	10,717	758,323	1,922.7	117,883
Rice (cwt)	*119,000	*718,300	48,222.0	NA
Safflower	13,687	NA	3,327.7	177,927
Alfalfa (tons)	3,206	18,975	1,208.3	53,700
Wild & Grain Hay (tons)	1,650	3,195	222.0	27,638
Irrigated Pasture	12,000	NA	900.0	NA
Dry Beans & Peas	7,667	NA	3,050.3	NA
Sugar Beets (tons)	12,743	348,487	7,874.8	324,318
TOTALS				
1975	242,200		96,321.0	1,212,100
1976	237,665		66,335.0	1,330,390
1977	**154,743		80,360.7	1,626,118
X	**211,256		81,005.6	1,389,536

* Two year average

** Due to no acreage reported for rice in 1977

Contra Costa, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	4,170	314,704	758.7	40,032
Wheat (bushels)	3,573	310,706	988.0	34,304
Corn (bushels)	4,933	627,420	1,805.3	51,800
Alfalfa (tons)	1,523	9,006	814.0	25,516
Wild & Grain Hay (tons)	3,191	6,227	210.7	53,455
Irrigated Pasture	7,480	NA	470.0	NA
Sugar Beets (tons)	3,443	94,189	2,181.7	87,633
Sorghum	1,930	173,279	440.0	21,230
TOTALS				
1975	32,190		9,123.0	360,909
1976	26,464		6,804.5	263,682
1977	32,080		7,077.7	317,318
X	30,245		7,668.4	313,970

Fresno, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	223,667	16,720,354	40,161.3	2,147,200
Wheat (bushels)	60,733	3,937,711	12,886.3	583,040
Corn (bushels)	30,467	2,904,927	8,000.3	319,900
Sorghum (bushels)	9,933	682,840	1,815.7	109,267
Rice (cwt)	13,467	765,290	5,848.0	NA
Safflower	11,157	NA	3,302.7	145,037
Alfalfa (tons)	88,333	522,750	39,406.0	1,479,583
Wild & Grain Hay (tons)	9,933	19,028	1,020.3	166,383
Irrigated Pasture	40,000	NA	3,933.3	NA
Cotton (cwt)	297,000	3,057,000	208,742.7	8,627,850
Dry Beans & Peas	6,713	NA	2,442.7	NA
Sugar Beets (tons)	25,533	705,467	19,918.7	649,823
TOTALS				
1975	833,260		332,695.0	13,509,805
1976	831,870		410,950.0	14,804,285
1977	785,680		298,789.0	14,370,160
X	816,937		347,478.0	14,228,083

Glenn, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	7,500	263,754	645.7	72,000
Wheat (bushels)	24,167	1,078,118	3,479.7	232,000
Corn (bushels)	7,333	737,050	2,037.3	77,000
Sorghum (bushels)	6,833	462,153	1,202.3	75,167
Rice (cwt)	53,566	3,048,188	27,494.0	NA
Safflower	1,821	NA	264.7	23,677
Alfalfa (tons)	17,533	103,620	7,106.0	293,683
Wild & Grain Hay (tons)	4,000	7,750	377.7	67,000
Irrigated Pasture	30,000	NA	1,176.0	NA
Dry Beans & Peas	2,134	NA	863.3	NA
Sugar Beets (tons)	6,563	179,469	3,499.3	167,028
TOTALS				
1975	184,187		55,734.0	1,049,167
1976	159,311		45 667.0	918,694
1977	140,854		43,037.0	1,054,806
X	161,451		48,146.0	1,007,556

Imperial, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	4,867	533,764	1,268.3	46,720
Wheat (bushels)	133,033	11,594,910	38,185.7	1,277,120
Sorghum (bushels)	16,400	1,584,512	4,199.3	180,400
Alfalfa (tons)	140,933	833,582	68,389.7	2,677,733
Wild & Grain Hay (tons)	66,500	125,100	12,274.7	1,263,500
Irrigated Pasture	6,333	NA	1,069.3	NA
Cotton (cwt)	86,333	872,120	47,190.7	2,507,983
Sugar Beets (tons)	57,500	1,573,433	41,067.7	1,463,375
TOTALS				
1975	520,800		206,861.0	8,979,580
1976	543,900		256,287.0	9,778,930
1977	471,000		177,788.0	9,491,585
X	511,900		213,645,3	9,416,832

Kern, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	53,333	3,666,044	8,873.3	512,000
Wheat (bushels)	53,333	4,211,008	13,722.0	512,000
Corn (bushels)	1,128	133,776	378.0	11,847
Sorghum (bushels)	20,600	1,495,662	4,053.7	226,600
Rice (cwt)	5,167	295,850	1,091.0	NA
Safflower	2,267	NA	471.7	29,467
Alfalfa (tons)	117,333	694,417	53,705.7	2,229,333
Wild & Grain Hay (tons)	10,700	20,387	2,878.7	203,300
Irrigated Pasture	17,500	NA	2,187.7	NA
Cotton (cwt)	304,333	3,130,507	227,666.0	8,840,883
Potatoes	31,517	NA	55,802.0	1,575,833
Dry Beans & Peas	4,667	NA	2,999.0	NA
Sugar Beets (tons)	21,900	602,030	14,075.0	557,355
TOTALS				
1975	640,035		380,353.0	13,848,807
1976	670,800		435,024.0	15,222,160
1977	620,500		348,334.0	15,024,890
X	643,778		387,903.7	14,698,619

Kings, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	127,300	11,197,956	26,695.3	1,222,080
Wheat (bushels)	75,866	6,874,166	22,645.0	726,080
Corn (bushels)	23,933	2,576,812	7,199.3	251,300
Sorghum (bushels)	12,916	922,369	2,479.0	142,072
Rice (cwt)	1,383	78,831	640.2	NA
Safflower	27,867	NA	8,402.3	362,267
Alfalfa (tons)	56,667	335,200	24,830.3	949,167
Wild & Grain hay (tons)	4,033	7,730	799.7	67,558
Irrigated Pasture	9,400	NA	1,001.3	NA
Cotton (cwt)	196,833	2,024,927	132,162.3	5,718,008
Sugar Beets (tons)	3,181	87,156	2,149.7	80,948
TOTALS				
1975	543,220		214,459.0	9,012,476
1976	537,548		247,062.5	9,569,122
1977	536,669		225,492.0	9,976,842
X	539,146		229,004.5	9,519,480

Los Angeles, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	9,494	238,895	579.5	91,139
Wheat (bushels)	9,367	140,805	447.7	89,920
Alfalfa (tons)	21,537	127,364	9,996.7	409,197
Wild & Grain Hay (tons)	6,677	12,694	816.3	126,857
Irrigated Pasture	1,278	NA	238.0	NA
Dry Beans & Peas	191	NA	40.3	NA
Sugar Beets (tons)	2,363	63,802	1,845.3	60,130
TOTALS				
1975	55,934		12,287.5	783,853
1976	44,103		15,157.3	718,595
1977	52,679		14,446.5	829,279
X	50,905		13,963.8	777,242

Madera, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	400	NA	501.7	21,200
Barley (bushels)	28,033	1,802,890	4,383.7	269,120
Wheat (bushels)	22,633	1,365,543	4,448.0	217,280
Oats (bushels)	1,667	104,670	192.7	16,000
Corn (bushels)	16,333	2,159,914	6,152.7	171,500
Sorghum (bushels)	1,600	123,674	323.0	17,600
Rice (cwt)	533	30,666	226.7	NA
Safflower	67	NA	10.0	867
Alfalfa (tons)	50,667	299,750	20,511.7	848,667
Wild & Grain Hay (tons)	1,733	3,333	254.3	29,033
Irrigated Pasture	41,333	NA	3,466.7	NA
Cotton (cwt)	42,867	437,295	23,608.0	1,245,277
Dry Beans & Peas	2,633	NA	1,219.7	NA
Sugar Beets (tons)	6,100	166,790	4,271.0	155,245
TOTALS				
1975	216,000		64,328.0	2,775,975
1976	216,800		74,991.0	2,913,860
1977	217,000		69,390.0	3,285,530
X	216,600		69,569.7	2,991,789

Merced, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	21,096	1,542,667	3,739.7	202,518
Wheat (bushels)	14,085	939,715	3,059.0	135,219
Oats (bushels)	3,240	170,099	317.9	31,101
Corn (bushels)	51,847	4,939,193	13,751.7	544,390
Sorghum (bushels)	2,972	220,143	601.3	32,692
Rice (cwt)	8,601	488,483	3,720.0	NA
Safflower (tons)	2,842	NA	552.3	36,942
Alfalfa (tons)	55,949	331,189	26,813.3	937,146
Wild and Grain Hay (tons)	18,967	36,047	2,696.0	317,697
Irrigated Pasture	104,333	NA	9,541.7	NA
Cotton (cwt)	48,494	494,986	30,832.3	1,408,760
Dry Beans & Peas	4,959	NA	2,857.0	NA
Sugar Beets (tons)	11,199	307,444	8,156.0	285,006
TOTALS				
1975	350,998		96,294.0	3,662,248
1976	369,111		117,710.0	4,104,839
1977	325,641		105,910.7	4,027,328
X	348,583		106,638.2	3,931,472

Monterey, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	3,512	NA	4,588.0	186,118
Barley (bushels)	35,833	1,880,870	4,676.3	344.000
Wheat (bushels)	1,473	66,474	216.7	14,144
Oats (bushels)	2,193	226,140	429.7	21,056
Corn (bushels)	1,957	486,197	1,283.0	20,545
Safflower	100	NA	13.0	1,300
Alfalfa (tons)	6,658	39,311	3,397.7	111,527
Wild & Grain Hay (tons)	1,300	2,558	132.0	24,700
Irrigated Pasture	1,500	NA	130.0	NA
Dry Beans & Peas	10,317	NA	6,016.3	NA
Sugar Beets (tons)	17,258	474,030	15,411.7	439,224
TOTALS				
1975	93,615		49,964.0	1,293,829
1976	78,415		30,759.9	1,145,667
1977	74,275		28,158.9	1,048,348
X	82,102		36,294.3	1,162,615

Orange, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	6,627	306,706	760.6	63,622
Wild & Grain Hay (tons)	882	1,664	129.7	16,764
Irrigated Pasture	48	NA	8.7	NA
Dry Beans & Peas	1,684	NA	956.3	NA
TOTALS				
1975	11,746		2,742.6	92,747
1976	9,341		1,721.4	88,700
1977	6,638		1,101.8	59,713
X	9,242		1,855.3	80,387

Placer, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	320	13,324	30.1	3,072
Wheat (bushels)	10,100	219,175	710.0	96,960
Oats (bushels)	6,153	374,138	655.0	59,072
Corn (bushels)	449	58,685	162.2	4,714
Sorghum (bushels)	207	12,623	32.6	2,273
Rice (cwt)	10,500	597,017	4,676.7	NA
Alfalfa (tons)	610	3,604	204.3	10,217
Wild & Grain Hay (tons)	5,505	10,648	384.6	92,209
Irrigated Pasture	24,767	NA	1,825.0	NA
TOTALS				
1975	65,405		10,109.2	271,171
1976	57,502		8,411.9	223,195
1977	52,925		7,520.5	311,187
X	58,611		8,680.5	268,518

Riverside, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	6,969	NA	9,531.6	348,467
Wheat (bushels)	41,960	2,787,160	9,302.7	402,819
Barley (bushels)	29,002	2,028,225	4,788.9	278,422
Oats (bushels)	14,779	1,518,480	2,556.3	141,882
Corn (bushels)	1,863	286,150	803.6	19,565
Sorghum (bushels)	2,679	165,206	443.2	29,465
Safflower	70	NA	24.0	914
Alfalfa (tons)	42,532	251,620	18,553.1	808,114
Wild & Grain Hay (tons)	6,670	12,984	1,038.6	126,730
Irrigated Pasture	11,247	NA	2,289.4	NA
Cotton (cwt)	27,534	278,186	15,717.1	799,863
Dry Beans & Peas	1,426	NA	663.7	NA
Sugar Beets (tons)	3,196	88,413	2,113.9	81,338
TOTALS				
1975	173,814		64,539.0	2,714,739
1976	198,778		72,347.3	2,961,665
1977	197,193		66,592.5	3,436,335
X	189,928		67,826.3	3,037,580

Sacramento, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	3,993	358.198	856.0	38,336
Wheat (bushels)	33,400	3,094,903	9,879.3	320,640
Oats (bushels)	3,713	313,206	560.3	35,648
Corn (bushels)	49,000	6,550,635	18,316.3	514,500
Sorghum (bushels)	3,997	488,912	1,288.0	43,963
Rice (cwt)	11,033	627,423	4,992.0	NA
Safflower	6,137	NA	1,878.0	79,777
Alfalfa (tons)	8,433	49,897	4,590.0	141,258
Wild & Grain Hay (tons)	18,233	35,108	2,133.0	305,408
Irrigated Pasture	59,000	NA	4,720.0	NA
Sugar Beets (tons)	5,367	147,203	3,255.7	136,582
TOTALS				
1975	208,470		54,345.0	1,595,917
1976	207,600		56,484.0	1,651,400
1977	190,850		46,577.0	1,601,020
X	202,307		52,468.7	1,616,112

San Benito, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	242	NA	363.7	12,808
Barley (bushels)	7,933	400,383	988.0	76,160
Wheat (bushels)	518	17,489	57.5	4,976
Corn (bushels)	529	49,953	138.8	5,558
Alfalfa (tons)	1,423	8,391	655.0	23,841
Wild & Grain Hay (tons)	17,333	33,400	1,086.0	290,333
Irrigated Pasture	500	NA	90.0	NA
Cotton	327		187.3	9,490
Sugar Beets (tons)	3,341	91,519	2,568.3	85,037
TOTALS				
1975	43,080		8,048.0	654,932
1976	26,094		5,390.0	413,324
1977	27,268		4,966.0	456,353
X	32,147		6,134.7	508,203

San Bernardino, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	2,410	174,203	429.5	23,136
Wheat (bushels)	933	57,585	195.0	8,960
Oats (bushels)	853	93,774	177.0	8,192
Corn (bushels)	1,777	251,572	680.3	18,655
Alfalfa (tons)	18,777	111,007	7,906.2	356,757
Wild & Grain Hay (tons)	15,630	29,711	2,933.0	296,970
Irrigated Pasture	7,510	NA	1,472.6	NA
Cotton (cwt)	462	4,927	214.7	13,411
Dry Beans & Peas	412	NA	121.8	NA
Sugar Beets (tons)	127	NA	62.5	3,224
TOTALS				
1975	46,562		12,624.5	673,878
1976	51,880		17,522.3	793,750
1977	48,230		12,431.1	720,286
X	48,891		14,192.6	729,305

San Diego,California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	600	NA	1,218.3	30,000
Barley (bushels)	7,633	290,493	719.3	73,280
Wheat (bushels)	2,298	83,112	274.7	22,064
Alfalfa (tons)	598	3,536	401.7	11,368
Wild & Grain Hay (tons)	7,932	15,153	1,104.0	150,702
Irrigated Pasture	2,025	NA	196.0	NA
Dry Beans & Peas	1,383	NA	716.7	NA
TOTALS				
1975	20,030		3,730.0	258.125
1976	26,670		5,041.0	335,758
1977	20,710		5,121.0	268,359
X	22,470		4,630.7	287,414

San Joaquin, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	1,926	NA	2,646.0	102,096
Barley (bushels)	35,643	3,092,213	7,441.7	342,176
Wheat (bushels)	33,372	3,266,658	10,677.0	320,374
Oats (bushels)	5,383	269,656	471.0	51,680
Corn (bushels)	88,673	10,866,871	29,789.0	931,070
Sorghum (bushels)	5,137	480,221	1,285.7	56,503
Rice (cwt)	6,816	387,893	3,287.0	NA
Safflower	5,610	NA	1,721.3	72,930
Alfalfa (tons)	53,867	318,687	27,056.7	902,267
Wild & Grain Hay (tons)	26,163	49,744	3,916.3	438,236
Irrigated Pasture	65,933	NA	5,528.3	NA
Dry Beans & Peas	22,485	NA	10,143.9	NA
Sugar Beets (tons)	38,005	1,043,730	25,355.7	967,219
TOTALS				
1975	410,422		142,692.7	4,501,420
1976	393,339		131,707.0	4,340,708
1977	363,280		113,559.0	3,711,524
X	389,014		129,319.6	4,184,551

San Luis Obispo, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	345	NA	469.0	17,267
Barley (bushels)	63,663	1,788,965	4,297.0	611,162
Wheat (bushels)	51,550	951,326	3,074.3	494,880
Oats (bushels)	1,075	80,589	129.5	10,323
Corn (bushels)	1,133	87,925	239.7	11,900
Safflower	3,527	NA	189.7	45,847
Alfalfa (tons)	11,893	70,554	4,806.0	199,208
Wild & Grain Hay (tons)	36,666	69,217	2,29.17	614,167
Irrigated Pasture	3,300	NA	191.7	NA
Dry Beans & Peas	5,184	NA	1,771.4	NA
Sugar Beets (tons)	1,419	39,080	853.7	36,105
TOTALS				
1975	217,537		24,304.3	2,560,656
1976	200,205		18,764.8	2,323.951
1977	121,526		11,872.2	1,237,966
X	179,756		18,313.8	2,040,858

San Mateo, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	67	NA	119.0	3,569
Barley (bushels)	762	31,642	76.9	7,315
Oats (bushels)	1,207	33,658	59.1	11,584
Wild & Grain Hay (tons)	3,823	7,315	257.3	64,041
Irrigated Pasture	414	NA	40.5	NA
Dry Beans & Peas	31	NA	5.5	NA
TOTALS				
1975	6,211		763.8	84,751
1976	6,511		529.1	90,175
1977	6,192		381.9	84,600
X	6,305		558.3	86,509

Santa Barbara California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	1,807	NA	2,455.4	90,333
Barley (bushels)	5,917	199,396	488.4	56,800
Wheat (bushels)	5,133	113,127	357.2	49,274
Oats (bushels)	850	51,895	92.0	8,160
Corn (bushels)	1,056	177,855	490.8	11,084
Alfalfa (tons)	10,028	59,356	5,762.5	167,975
Wild & Grain Hay (tons)	12,557	24,020	1,491.2	210,324
Irrigated Pasture	10,161	NA	500.4	NA
Dry Beans & Peas	9,714	NA	5,870.6	NA
Sugar Beets (tons)	2,428	66,726	1,571.1	61,792
TOTALS				
1975	61,213		18,418.3	678,682
1976	60,187		21,059.8	666,684
1977	57,548		17,760.6	621,861
X	59,649		19,079.6	655,742

Santa Clara, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	861	32,648	76.0	8,262
Oats (bushels)	233	16,667	31.7	2,240
Alfalfa (tons)	273	1,614	85.0	4,573
Wild & Grain Hay (tons)	4,707	8,989	240.0	78,837
Irrigated Pasture	1,500	NA	275.0	NA
Sugar Beets (tons)	1,863	51,216	1,450.0	47,405
TOTALS				
1975	15,930		2,909.5	248,252
1976	7,845		2,191.5	123,682
1977	4,534		1,372.0	52,016
X	9,436		2,157.7	141,317

Santa Cruz, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Wild & Grain Hay (tons)	1,110	2,126	104.0	18,593
Irrigated Pasture	2,800	NA	270.7	NA
Dry Beans & Peas	303	NA	112.7	NA
TOTALS				
1975	4,070		551.0	14,238
1976	4,490		520.0	20,100
1977	4,080		391.0	21,440
X	4,213		487.3	18,593

Solano, California Agricultural Statistics, 1975-1977 Average

Crop.	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	11,367	770,051	1,858.8	109,120
Wheat (bushels)	21,533	1,939,460	6,152.7	206,720
Oats (bushels)	3,333	223,838	390.5	32,000
Corn (bushels)	23,333	3,067,225	8,427.3	245,000
Sorghum (bushels)	4,533	331,799	887.3	49,867
Safflower	2,325	NA	640.2	30,225
Wild & Grain Hay (tons)	9,800	18,852	839.7	164,150
Alfalfa (tons)	12,300	72,772	5,121.9	206,025
Irrigated Pasture	25,367	NA	1,730.7	NA
Dry Beans & Peas	5,893	NA	2,258.2	NA
Sugar Beets (tons)	14,106	375,560	9,828.1	358,998
TOTALS				
1975	146,076		45,036.1	1,646,872
1976	111,790		27,893.0	954,285
1977	143,807		41,477.3	1,605,156
X	133,891		38,135.5	1,402,104

Stanislaus, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	28,333	1,683,182	4,021.0	272,000
Wheat (bushels)	2,173	152,856	494.3	20,864
Oats (bushels)	1,140	79,382	137.1	10,944
Corn (bushels)	24,917	2,366,164	7,009.3	261,625
Sorghum (bushels)	2,177	193,612	508.0	23,943
Rice (cwt)	2,083	117,842	989.7	NA
Alfalfa (tons)	32,600	192,788	13,335.0	546,050
Wild & Grain Hay (tons)	19,967	38,280	2,556.3	334,442
Irrigated Pasture	71,167	NA	6,402.3	NA
Dry Beans & Peas	21,117	NA	11,870.0	NA
Sugar Beets (tons)	4,653	128,249	2,897.0	118,427
TOTALS				
1975	225,870		54,447.0	1,783,208
1976	214,970		49,197.2	1,641,935
1977	190,140		47,016.0	1,339,743
X	210,327		50,220.1	1,588,295

Sutter, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	19,506	1,303,554	3,116.0	187,258
Wheat (bushels)	31,844	2,112,397	6,909.0	305,706
Oats (bushels)	1,385	129,754	228.5	13,296
Corn (bushels)	14,719	2,254,497	6,177.3	154,553
Sorghum (bushels)	19,728	1,485,197	3,873.3	217,004
Rice (cwt)	74,519	4,234,084	35,410.7	NA
Safflower	12,491	NA	3,535.3	162,379
Alfalfa (tons)	9,468	56,049	4,572.3	158,595
Wild & Grain Hay (tons)	26,476	50,712	1,341.0	443,473
Irrigated Pasture	24,000	NA	2,120.0	NA
Dry Beans & Peas	12,020	NA	4,550.7	NA
Sugar Beets (tons)	3,250	86,780	2,061.3	82,721
TOTALS				
1975	256,119		81,145.3	1,608,576
1976	259,712		72,686.2	1,747,849
1977	232,389		67,855.3	1,818,528
X	249,407		73,895.6	1,724,984

Tehama, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	8,867	303,572	725.3	85,120
Wheat (bushels)	12,700	473,984	1,503.7	121,920
Oats (bushels)	2,917	174,090	306.7	28,000
Corn (bushels)	1,015	109,015	303.0	10,657
Sorghum (bushels)	1,518	97,680	256.7	16,702
Safflower	100	NA	15.2	1,300
Alfalfa (tons)	4,400	26,015	1,455.0	73,700
Wild & Grain Hay (tons)	6,333	12,247	534.7	106,083
Irrigated Pasture	32,667	NA	2,367.7	NA
Dry Beans & Peas	1,558	NA	769.3	NA
Sugar Beets (tons)	8,317	236,752	4,648.7	211,659
TOTALS				
1975	69,370		8,650.6	429,790
1976	92,440		20,916.0	999,235
1977	79,365		9,091.0	536,400
X	80,392		12,885.9	655,142

Tulare, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Potatoes	168		239.7	8,417
Barley (bushels)	33,333	2,899,503	7,103.7	320,000
Wheat (bushels)	64,800	5,074,200	16,906.7	622,080
Oat (bushels)	1,347	65,886	124.7	12,928
Corn (bushels)	8,757	1,096,739	3,138.0	91,952
Sorghum (bushels)	25,333	1,758,178	4,747.0	278,667
Rice (cwt)	1,681	95,657	635.0	NA
Safflower	242	NA	68.7	3,150
Alfalfa (tons)	74,900	443,843	33,124.7	1,423,100
Wild & Grain Hay (tons)	3,257	6,204	390.3	61,883
Irrigated Pasture	12,667	NA	981.0	NA
Cotton (cwt)	152,277	1,553,054	95,406.0	4,423,637
Dry Beans & Peas	6,167	NA	2,453.3	NA
Sugar Beets (tons)	5,661	155,260	4,075.0	144,064
TOTALS				
1975	418,237		160,539.0	6,852,905
1976	415,378		192,448.0	7,563,022
1977	338,155		155,194.0	7,753,707
X	390,590		169,393.7	7,389,878

Ventura, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Wild & Grain Hay (tons)	7,833	15,070	918.0	131,208
Dry Beans & Peas	5,737	NA	3,075.8	NA
Sugar Beets (tons)	931	25,639	659.7	23,702
TOTALS				
1975	15,624		4,520.4	175,950
1976	14,149		4,392.2	138,701
1977	13,731		5,047.6	150,081
X	14,501		4,653.4	154,911

Yolo, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	24,667	787,564	1,859.7	236,800
Wheat (bushels)	67,000	4,029,545	12,549.0	643,200
Oats (bushels)	1,533	84,088	159.8	14,720
Corn (bushels)	31,467	3,903,650	10,676.7	330,400
Sorghum (bushels)	21,500	1,592,060	4,289.3	236,500
Rice (cwt)	22,700	1,293,537	10,392.8	NA
Safflower	20,520	NA	4,915.7	266,760
Alfalfa (tons)	28,800	170,673	10,664.3	482,400
Wild & Grain Hay (tons)	4,300	8,362	750.7	72,025
Irrigated Pasture	17,333	NA	1,326.7	NA
Dry Beans & Peas	1,252	NA	361.4	NA
Sugar Beets (tons)	13,798	369,822	9,282.0	351,168
TOTALS				
1975	301,275		91,996.5	3,238,321
1976	215,225		52,078.0	2,048,530
1977	248,110		57,609.4	2,615,067
X	254,870		67,228.0	2,633,973

Yuba, California Agricultural Statistics, 1975-1977 Average

Crop	Harvested Acres	Production	Value (1,000 dollars)	Man hours
Barley (bushels)	1,283	73,835	169.4	12,317
Wheat (bushels)	4,881	219,273	710.5	46,854
Oats (bushels)	1,030	95,330	148.5	9,885
Corn (bushels)	3,275	428,887	1,157.4	34,387
Sorghum (bushels)	1,181	73,473	193.9	12,987
Rice (cwt)	27,897	1,589,224	13,930.9	NA
Safflower	250	NA	43.9	3,250
Alfalfa (tons)	624	3,695	256.1	10,446
Wild & Grain Hay (tons)	3,016	5,773	394.0	50,518
Irrigated Pasture	21,000	NA	1,680.0	NA
Dry Beans & Peas	726		297.2	NA
TOTALS				
1975	64,582		19,029.6	166,666
1976	64,008		16,627.6	183,131
1977	66,893		21,288.4	192,136
X	65,161		18,981.9	180,644