A report recommending continuing, comprehensive study of the water resources of Hawaii

Warne
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recommending continuing comprehensive study of the

WATER RESOURCES
OF THE TERRITORY
OF HAWAII
1951

by WILLIAM E. WARNE
Assistant Secretary of The Interior for Water and Power Development
A Report

recommending

Continuing, Comprehensive Study of the Water Resources

of the Territory of Hawaii

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William E. Warne
Assistant Secretary of the Interior
for Water and Power Development
A report recommending a comprehensive study of the water resource of the territory of New Zealand.
Diamond Head and Honolulu, the metropolis of the Territory of Hawaii
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Photographs by the Author
SUMMARY AND CONCLUSIONS

The Hawaiian Islands are united politically, economically, and socially with the United States mainland. The economic ties, the highly specialized economy, and world events have resulted in certain difficulties for the Islands.

To overcome these difficulties and to make the Islands more nearly self-sufficient in the face of the present world crisis and for possible future crises, Hawaii must find a means of achieving a better economic balance, ways to make the Islands more nearly self-sustaining. Comprehensive development of the water resources of the Islands can do much to meet this situation. Although the time is past when large amounts of water could easily be obtained for irrigation purposes and municipal water supply in the Islands, there is still much water available for further development. Moreover, additional land could be used intensively if supplied with irrigation water and a much needed diversification in agricultural production could be achieved thereby providing assistance to small farmers in the process. The important problems are the selection of feasible projects and the provision of engineering skills to provide projects which make optimum use of Hawaii's water resources.

Unemployment at times is a serious problem. The problems of Hawaii must be solved within the borders of the Islands. There is little opportunity for shifts in population as have been experienced on the mainland because of the wide ocean isolating the Islands. The introduction of small farms would aid stability. The problem of the concentration of much land in a few ownerships would be alleviated by an appropriate irrigation program.

Private capital has done much to meet the need for water. However, as has been the experience in the western United States, the time has come when few water projects remain that may be readily and cheaply developed. Under such conditions, there is required a thorough analysis of the problem in order that water may be provided on a sustained basis and in a manner that does not unwittingly deprive one sector to provide water at some other place where it is needed.

River basin development on a comprehensive scale has become the accepted method for achieving the most effective use of water and related land resources on the mainland of the United States. Though extensive river basins are not found in the Territory of Hawaii, each major Island offers an opportunity for unified, comprehensive treatment of its water resources, utilizing many of the basic concepts and techniques which have been applied to river basin development on the mainland. Comprehensive island-wide investigations are needed to make sure that each Island's water resources are put to the best available use just as comprehensive river basin surveys on the mainland serve the same objective.
The obvious answer in these circumstances is a continuing thorough study of the water resources of each Island. The Federal Government has participated in the past in specific project studies in the Islands, but these studies have lost much of their value through lack of continuity.

The Department of Interior is admirably fitted to make the comprehensive, island-wide investigations which are needed. On the mainland, the Department has had a century of experience in the investigation and management of natural resources. In Hawaii, the Geological Survey of the Interior Department has made surface and ground-water studies for many years. Through its Water Resources Division, it is best able to carry out the hydrologic investigations and obtain the basic data necessary to the solution of Hawaii's problems. The Bureau of Reclamation has the technical skills and experience necessary to appraise the land and water resources and to design the proper engineering works. It has the engineering skills and know-how to solve the unique problems that will be encountered.

I recommend continuing study of the complex water problems of the Hawaiian Islands. This evaluation should be made on an island-wide basis to the end that comprehensive surveys of each Island are obtained. In so doing, the people of the Territory of Hawaii can be assured that optimum and equitable use of their water resources can be achieved. These studies should be reported upon and specific proposals of projects to meet the needs of the Islands should be recommended to the Congress as they are developed.

Maui is the crescent of the Pacific. The distances in nautical miles from Maui to other parts of the Pacific are: San Francisco, 2,300; Sydney, Australia, 4,020; Hong Kong, 4,961; Honolulu, 3,445; and Panama, 4,668.

The main portion of the Hawaiian group consists of the Islands of Hawaii, Maui, Kauai, Lualualei, Moloka'i, Moloka'i, Kauai, and Ni'ihau (Fig. 1). The Islands are the remnants of a range of lofty volcanic mountains rising from the ocean floor. Some of the Islands are old and eroded; others like Hawaii Island are still being formed by lava flows from active volcanoes. Through the ages, coastal cliffs have formed around many of the shores of the Islands. In general, the more southerly sides of the main Islands are mountainous and rougher with steep cliffs which drop away to narrow coastal plains or flat directly into the sea. The mountainous interior consists of high plateaus or ranges covered with forests and tropical vegetation, and relatively free of the encroachment of the sea.
NEED FOR WATER RESOURCES INVESTIGATIONS IN HAWAII

Authority for the report

On page 141 of the report (Calendar 1944, Report No. 1951, 81st Congress, Second Session) of the Senate Committee on Appropriations, on the General Appropriation Bill for 1951, it was recommended that the Department of the Interior prepare a report to Congress setting forth a program for the Bureau of Reclamation to carry out in Hawaii. The following is a report describing the Islands, the problem, and what should be done to initiate a program of sound water resource development. This report has been developed from information in the files of the Department and its agencies, from a personal visit to the Islands made by the writer, and by visits of others within the Department, as well as from information contributed at hearings held during my visit to the Islands by individuals and agencies in the Islands.

Description of the Territory

Hawaii's present economic, social and political situation is in large measure dictated by her geographic position which has determined her position with relation to the United States, her climate, crops, population, and industry.

The Territory of Hawaii is a chain of Islands, atolls, rocks, reefs, and shoals in the North Pacific Ocean lying between 154° 49' and 178° 30' West longitude and between 18° 55' and 28° 28' North latitude. They stretch more than 1,910 statute miles from the Islands of Hawaii in the southeast to Kure (Ocean) Island in the northwest.

Honolulu is the crossroads of the Pacific. The distances in nautical miles from Honolulu to other ports of the Pacific are: San Francisco, 2,100; Sydney, Australia, 4,424; Hongkong, 4,961; Yokohama, 3,445; and Panama, 4,665.

The main portion of the Hawaiian group consists of the Islands of Hawaii, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, and Niilau (Fig. 1). The Islands are the summits of a range of lofty volcanic mountains rising from the ocean floor. Some of the Islands are old and eroded; others like Hawaii Island are still being formed by lava flows from active volcanoes. Through the ages, coral reefs have formed around many of the shores of the Islands. In general, the northeastern sides of the main Islands are mountainous and rugged with steep cliffs which drop away to narrow coastal plains or fall directly into the sea. The mountainous interior of most of the Islands is largely covered with forests and tropical vegetation. On the southwestern sides the mountains stretch to the
sea in long gentle slopes, broken here and there by gulches and canyons. There are many small streams and pools on the larger Islands, but there are no large lakes or rivers in the territory.

The prevailing trade winds and the rugged terrain combine to make the Islands a place of extremes of climate and of opportunities for agriculture. On the windward side of the mountains, the rainfall may be excessive, while on the leeward side of the same mountain the rainfall may be deficient. This is illustrated near Honolulu where the mountain areas experience rains averaging a total of 150 inches per year while a little over five miles away the average is 15 inches per year. On Kauai, the average varies from about 450 inches per year to 20 inches within slightly more than ten miles. The larger figure is greater than the average precipitation received at any other point in the western Hemisphere.

Seasonal variations occur so that a comparatively wet area may not have precipitation at all times when it is needed. There are variations related to the elevation, so that horizontal bands of rainfall variations appear.

The volcanic origin of the Islands produces soils and sub-soil conditions that will absorb water at very high rates so that little water runs off on the surface. In many areas, the surface flows are entirely in the form of floods. The erratically distributed precipitation coupled with porous soils and rocks tends to make agriculture impractical in many areas, without the help of artificial water supplies. The soils are progressively more porous from Kauai to Hawaii, just as the Islands are believed to progress from older to younger in the same order.

A description of each of the major Islands is contained in the Appendix.

Historical Background

No other Island area has developed a modern civilization in so short a period. The Pacific was crossed as early as 1521, and the "Manila galleons" plied between the Philippines and Mexico for two centuries without once sighting the Hawaiian Islands. Because of this accident of history, Hawaii was the last important Pacific Island area to be discovered (1778); yet, because of its strategic position, it is the first to achieve a state of civilization on a par with the rest of the Western world.

The story of this change is a history of sandalwood, whales, sugar, pineapples, and tourists, accompanied by an ever-increasing dependence upon the American mainland. The change was also accompanied by a decline in the native population from 300,000 in 1778 to 10,831 in 1947, and by the influx of a complex mixture of races which has grown to a population now numbering nearly half a million.
Population

Population of the Hawaiian Islands for selected years is shown in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Population</th>
</tr>
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<tbody>
<tr>
<td>1832</td>
<td>124,449</td>
</tr>
<tr>
<td>1850</td>
<td>84,165</td>
</tr>
<tr>
<td>1872</td>
<td>56,897</td>
</tr>
<tr>
<td>1890</td>
<td>89,990</td>
</tr>
<tr>
<td>1900</td>
<td>154,001</td>
</tr>
<tr>
<td>1910</td>
<td>191,909*</td>
</tr>
<tr>
<td>1920</td>
<td>255,912*</td>
</tr>
<tr>
<td>1930</td>
<td>368,336*</td>
</tr>
<tr>
<td>1940</td>
<td>423,330*</td>
</tr>
<tr>
<td>1941</td>
<td>465,339**</td>
</tr>
<tr>
<td>1944</td>
<td>492,379**</td>
</tr>
<tr>
<td>1945</td>
<td>502,122**</td>
</tr>
<tr>
<td>1946</td>
<td>519,503**</td>
</tr>
<tr>
<td>1947</td>
<td>525,477**</td>
</tr>
<tr>
<td>1948</td>
<td>540,500**</td>
</tr>
<tr>
<td>1949 as of Feb.</td>
<td>541,853**</td>
</tr>
<tr>
<td>1949 by July 1</td>
<td>530,891**</td>
</tr>
<tr>
<td>1950 (prelim. Apr. 1)</td>
<td>493,437*</td>
</tr>
<tr>
<td>1951 (Apr. 1)</td>
<td>463,713§</td>
</tr>
</tbody>
</table>

* U. S. Census
** Annual Report of the Governor of Hawaii
§ Board of Health estimate

Note the significant decrease in population beginning in 1949. This was a result of outmigration due in large part to lack of sufficient employment opportunities in the Islands. The outmigration totalled 13,000 persons in calendar year 1950 alone.

The population of the major Islands in 1950 was as follows:

- Oahu (Principal City, Honolulu 245,612) 347,529
- Hawaii (Principal City, Hilo 27,019) 67,683
- Maui 29,625
- Molokai 40,317
- Lanai 4,939

Source: U. S. Census (preliminary)

All of the major Islands except Oahu and Molokai lost substantial numbers of people between 1940 and 1950.
Economy

The Territory of Hawaii today is closely tied economically to the United States. Because of this, the population and the standard of living are heavily dependent on the volume of mainland dollars the economy can earn. The Territory today is not earning enough mainland dollars.

The economic life of the Territory has been channeled toward a specialization in sugar and pineapples, toward agricultural mass production, and toward increasingly close commercial ties with the mainland United States. To obtain construction materials, clothes, shoes, motorcars, industrial equipment, and other items necessary to the maintenance of present standards (including 65 per cent of the food consumed in the Territory) Hawaii has four major economic activities: (1) sugar, (2) pineapples, (3) services to the armed forces and to tourists, and (4) fish and other marine products. Barring some unexpected technical development, these and only these, are available to maintain or increase present standards. The first three activities mentioned above represent over nine-tenths of the power of the Territory to buy mainland products and services.

Agriculture

Sugar—Agriculture is Hawaii's greatest industry and the foundation of her economic structure. Sugar is king of all agricultural crops in Hawaii. From a beginning of 2.1 tons in 1835, production reached a million tons a century later. The Hawaiian sugar industry today, represented by 28 separate plantation corporations, has been granted an annual production quota of 1,052,000 short tons of sugar under provisions of the Sugar Act of 1948, as passed by the Congress of the United States. This is the principal marker which the industry has to gauge its economic development program.

Hawaii has some 220,000 acres of cane land under cultivation. This represents slightly less than 6 per cent of the total land area of the Territory. Approximately 22,000 persons are employed in the sugar industry on a year-around basis.

Pineapples—Pineapples come second on the list of Hawaii's agricultural products, constituting approximately 75 per cent of the world's supply. It is America's second most important canned fruit. From its beginning in 1903 when 1,893 cases of pineapples were packed, the industry has grown by leaps and bounds. Total production of canned pineapple in 1950 was 23,852,847 cases.
In 1950, there were ten pineapple companies operating 14 plantations and nine canneries in Hawaii. At that time, about 70,700 acres of land in the Territory were used for pineapple production, and about 10,000 persons were employed the year around in growing, harvesting, and canning the crop plus seasonal employment of another 10,000.

Other Agriculture—Coffee growing is on a much smaller industrial scale than sugar and pineapples, but it ranks third in the Territory's exports. Commercial production, confined to about 3,500 acres of the Kona coast on Hawaii, resulted in a crop in 1950 of 4,300,000 green pounds valued at approximately $1,793,000. Most of this crop is exported for blending purposes.

Cattle raising, beginning in 1793, has become significant in the field of diversified agriculture in Hawaii today and goes a long way in reducing dependence on imported meat supplies. However, the total beef production has increased relatively little in the past 40 years, although the competitive position of Hawaii's beef producers can be improved. The primary need is for a cheap, locally produced stock feed to replace feeds imported from the mainland.

Vegetables are grown solely to fill local demands, but total production is far short of the Territory's needs, and vast quantities of fresh and canned vegetables are imported annually.

About 65 per cent of the food consumed in Hawaii is imported. With additional water resource development, directed toward increased local production of vegetables, less food would need to be imported with the result that the Territory's economic position would be improved.

Services

As noted above, services are one of the three principal items representing over nine-tenths of the power of the Territory to buy mainland products and services. In 1949, the Territory sold goods and services in Hawaii for mainland dollars amounting to approximately $205,000,000. Of this, expenditures of the Federal Government accounted for over $174,000,000, of tourists $25,000,000, and of shipping, airlines, and other mainland concerns in Hawaii over $5,000,000. This $205,000,000 is almost half of the total income of the Territory in mainland dollars.

Military—Military establishments of the United States in the Hawaiian Islands provide a source of income for the Territory that is exceeded only by sugar and pineapples. Thousands of service personnel are stationed in the Islands, even during peacetime. The payrolls of the military establishments represent a significant part of the market for the goods and services provided by Hawaiian business enterprises.
Tourist—The tourist industry has become one of the principal bulwarks of the Hawaiian economy during recent years. Tourist arrivals of 9,676 in 1922 nearly doubled by 1930, reaching 18,651 in that year. In 1940, the figure was 25,373. The industry disappeared during World War II, of course, but came back strongly in the postwar years.

Quoting from the Research Bulletin of the Hawaii Employers' Council, October 6, 1950: "The tourist business has continued to be a source of support to the economy, with the summer season holding to the record levels set earlier in the year and the late-summer slump being no more severe than might be considered normal. Despite the upsetting effect of a war in the Orient, it still appears likely that tourists to Hawaii may number some 60,000 in 1950, compared with 45,000 in 1949."

Fishery

Although many fish abound in the waters of the Pacific, in past years the Hawaiian catch was largely for local consumption. By 1940, fishing had developed into a million dollar industry. Wartime conditions, however, virtually brought the industry to an end, but by 1950, it had a value of $3,509,000. Hawaii is now increasing operation of the fishing boats and has a growing interest in the development of tuna fisheries in the reaches of the western Pacific, thought to be the largest potential source of seafood in the world.

A program of research, experimentation and exploration in Pacific Ocean fisheries has been undertaken by the Fish and Wildlife Service of the Interior Department with headquarters in the Hawaiian Islands. The program is designed to provide scientific and technical information for commercial fisheries in the tropical and subtropical waters of the Pacific Ocean.

The Economic Problem

Hawaii enjoyed a favorable "balance of trade", insofar as exports and imports of actual commodities are an indication, until the late '30's. This excess of income over expenditure produced a rise in assets and in capital investment in Hawaii.

In 1938 the total value of the goods imported into the Territory began to exceed the value of the Hawaiian products exported to the mainland. The added imports were due to the expansion of defense installations in Hawaii. By 1944 the value of imported goods was more than twice the value of the export of Hawaiian products. Although the importation of defense materials declined sharply after the end of the war, the volume of goods imported into Hawaii during the postwar years of 1946 to 1948 was well above the average for the war years. The reason for this sharp rise was the large accumulation of consumer buying power (combined with shortages during the war years) which created a pent-up demand. Consequently, there was a marked rise in the purchase of mainland products as soon as war restrictions were lifted.
In 1949, the Hawaiian Islands spent $76,000,000 more for mainland goods and services than was earned by the Hawaiian economy.

If this unfavorable balance of trade continues over a period of years, a reduction of living standards in Hawaii would inevitably result. The obvious solution to the problem is the building up of the Territory's economy.

Employment Problems—For various reasons, the economy of the Territory did not have to face the basic problems of postwar economic readjustment until after the beginning of 1948. From that time to the outbreak of the Korean War, there were sharp cutbacks in civilian employment by the armed forces. The return of consumer demand and construction to more normal levels tended to reduce the volume of employment. According to estimates of the Territorial Employment Service as of February 1, 1950, unemployment in Hawaii was 33,451. The Business Research Department of the Bank of Hawaii reports that unemployment in the Territory reached an all-time high between November 1949 and March 1950.

Economic developments in Hawaii during the third quarter of 1950 were dominated by the Korean War. As on the mainland, the tempo of business activity quickened—with rising prices, greater production, more employment, and greater trade volume. Unemployment fell from over 34,000 to less than 17,000 in the first three quarters of 1950.

According to the Research Bulletin of the Hawaii Employers' Council for October 6, 1950, "Improved business conditions which are the direct or indirect result of the Korean War and the national mobilization program are inevitably temporary. Their great drawback is that they serve to interfere with the necessary basic adjustments which are essential if Hawaii is, in the long run, to prosper and to provide jobs for its labor force. It is to be hoped that this interference with developmental and research projects that are now under way can be kept to the minimum so that the withdrawal of today's temporary props to the economy will not result in another serious unemployment and relief problem."

Need for Water Resource Development

There is clear need for a fundamental strengthening of the economy of the Hawaiian Islands, based on their own resources. Development of the Islands' water resources is the principal means in sight by which the increased production of goods and services in the Territory on the required scale can be brought about.

For years the economy of the Islands has been hampered by restricted water. Valiant efforts of individuals, large companies, municipalities and the Territorial Government have done wonders to meet the growing domestic needs and to expand agriculture. Even with such effort, additional development is badly needed. Many cities and
towns have strained their facilities to meet past and present needs for domestic water; assistance is needed to forestall future problems. Unemployment in the Islands has become a problem and the development of additional farms could do much to relieve this condition. Additional farms, however, cannot be developed without additional water. A great bulk of the fresh vegetables used in Hawaii is now brought by ship from the mainland. With assured water supplies and with careful planning of the crops to meet the local market, a portion of this produce could be raised in the Islands. Under the present conditions of uncertain supply, the wholesalers and retailers cannot trust local grown crops because they have no assurance that the produce will be available when needed.

Planned water development, island by island, can do much to create a balanced agricultural program. Due to the wide ranges of elevation, precipitation and exposure, the climate of the Islands will permit a variety of crops at all seasons. During normal times, Hawaiian produce can be planned to supplement produce grown on the mainland.

Electrical power is a needed, but expensive item in the economy of the Islands. No natural fuels are available in Hawaii, so oil, coal, diesel or other fuels must be brought in by ship. A few small hydroelectric plants have been installed but they are so rare as to be a novelty. Any water development program should be carefully considered to determine whether it can be made to provide electricity as well as to meet the needs for water. Large spectacular projects are, of course, out of the question but careful attention to the potentials of rugged terrain and the available small quantities of water, may do much to meet a real need. There may be attractive power sites on the Island of Kauai.

Industrial development is restricted by lack of mineral raw materials. Nevertheless, a few possibilities exist for industrial expansion, notably the increase in cement production and in facilities for processing of sugar cane by-products. Investigation of water resource development in the Islands should take into account the potential water requirements of such industrial expansion.

Arable land and usable water which are not now geared to the economic machinery of the Islands are clearly the major unused natural resources of the Islands. The interests of the business man and the laboring man in the Territory demand that these idle resources be put to work in order to avoid continued worsening of Hawaii's long-run economic situation.

The interests of the Nation as a whole demand a vigorous economy in Hawaii. The strategic importance of the Islands to the United States is thoroughly established. The stronger the economy of the Islands, the stronger will be the Territory as a bastion in the Nation's defense system.
As already noted, food production in the Islands is far below the needs of their residents. An increase in local food production through development of water resources would be of substantial benefit in bringing the Islands closer to a self-sustained basis. It would release vital shipping space in times of international emergency from the carrying of food for the people of Hawaii for use in the transportation of the implements of defense.

Hawaiian leaders urge the development of water resources by the Federal Government. Quoted below are excerpts from materials presented at Public hearings which the writer attended in the Territory in December 1950:

W. N. Jacobson

An indication of the value of irrigation in the production of pineapples was provided at a hearing in Kaunakakai, Molokai, on December 4 by Mr. W. N. Jacobson, plantation manager. His statement, in part, was as follows:

"* * * We have experimented to some extent in the irrigation of pineapples, and I might say that we still have a long way to go, but we have established this fact that with water we can grow pineapples where they can't be grown without water. That sounds like a useless statement to make, and yet there are things in the Hawaiian Islands that will not grow under the arid and hot conditions even with water in some places at some times of the year.

"Our experiments point to the fact that perhaps water at the rate of an inch and a half per acre per month over, say, a six or eight-month period will carry the plants along very nicely. * * *"

"I would say there is definitely room for irrigation of pineapples on Molokai and, of course, to back that up is the fact that we think enough of it to put in our own well."

William H. Chun

Mr. William H. Chun, Manager-Engineer of the Board of Water Supply of the County of Hawaii, had this, in part, to say at a public hearing in Hilo on December 7.

"The need is great for Federal aid in the development of Hawaii County's water resources for domestic purposes in the rural areas.

* * *
"Hawaii County, with its great area and possible potentialities in the increase of more acreage for agriculture, small home-farms and home sites, by the adequate development of its water resources, can improve our island economy for a growing population by natural increases and by the return of our soldiers and former residents to their home island from military service, from Honolulu, and elsewhere.

"The plantations and certain others are trying to meet the need to provide homesites for their workers and tenants to create a permanent population and a stable citizenry. The ownership of land thus made available to our people will preserve our self-sufficiency and the economy of our island. However, this trend will create many problems for the Board of Water Supply because these new home or farm owners will demand water supply services. Under the present laws, the Board of Water Supply cannot cope with the situation so created by floating revenue bearing bonds to finance such projects where such sparsely populated areas do not have the consumers' potential to sustain such improvement program when the present construction cost has increased 55 per cent over 1946 figures and material cost has increased an average of 34 per cent over the 1946 price level. * * * *

"We hope that this brief presentation of our problems supported by concise facts will merit your sympathetic consideration and possible inclusion in your recommendations to the Senate Appropriation Committee for a survey and possible financial aid for the ultimate construction of the necessary water improvement projects."

Dan Ainoa

At the same hearing, Mr. Dan Ainoa, Executive Secretary of the Hawaiian Homes Commission, said, in part:

"How we feel water development in this area for the Hawaiian Homes Commission and also the other areas is very, very important in order to insure the continuation of production of crops. One of the problems of the farmers we put up there, if they didn't have sufficient water, would be the marketing problem. Any farmer that goes up into that area without adequate water will not be able to supply the jobbers in Honolulu with a continuous supply when these jobbers require these supplies to be produced, but with the development of water a continuous supply of crops, that is a continuous growing of crops could be assured, which, in my opinion, would eliminate this problem of marketing."
Richard Penhallow

At the Hilo hearing, Mr. Richard Penhallow, Assistant Manager of a large ranch on the Island of Hawaii, spoke of the importance of irrigation in increasing the supplies of locally-produced beef. He also pointed out the need for a comprehensive water-resource study. He said, in part:

"** It is a fact that the Territory of Hawaii is far from being self-sufficient in beef, producing in the neighborhood of 45 per cent of the fresh beef which is consumed in Hawaii. The point we would like to make in connection with water for grazing animals is that these supplies are relied upon for present operations and must be kept intact if grazing operations are to continue. Also there are some areas in which grazing could be increased, not only areas controlled by Parker Ranch, but also areas which are operated by independent ranchers on which grazing could be increased if the necessary water for stock purposes were conveyed to these areas. That water, we should like to make the point, should also be reserved and guaranteed for future expansion. There is also an opportunity on the lower slopes of South Kohala and also in part of North Kohala to bring into grazing borderline, semi-arid lands if irrigation is available for pasture. **

"** With all this potential expansion in mind and added to the ones already enumerated of raising vegetable crops on present and future potential lands, we will have, as the economy expands, increased need for domestic water by the naturally increased population that such an economic expansion will cause. That puts another drain on this general water table that must be borne in mind. I mention all these things to call to your attention some of these points and the necessity for the carefully detailed study of the overall picture of water usage from this rather limited watershed area, and we feel that there is a need for a very careful study, survey if you wish to call it so, of the actual water available, and an allocation on a pro-rata or fair basis toward a possible future expansion, bearing in mind those which have the greatest chance for success and the greatest bearing on the successful economic expansion of the region.

"Any expansion of basic crops like beef, or of crops which have an important bearing upon the economy and
employment opportunities of the region, like sugar and pineapples, will be limited by the availability of water. The development of a source to facilitate any such expansion will be sound and backed by experience. **

"In view of the complexity of, and lack of information available concerning the entire problem, a thorough survey is deemed necessary before creating a project which will exploit and develop to a greater degree than at present, the water resources of the Kohala Mountains productively and constructively."

Shozun Yamauchi

Mr. Shozun Yamauchi, vocational agriculture teacher at Honokaa High School, emphasized the value of irrigation in establishing of family-size farms and in producing foodstuffs of the kinds particularly needed in the Territory. At the Hilo hearing, he stated:

"In my opinion, this upper Hamakua District is potentially one of the most productive agricultural lands held in fee simple title by homesteaders in the Territory.

"The sugar cane grown by adherent planters in the Kalopa Homestead represents a major portion of the total area cultivated in cane in one of the three plantations mentioned above. Beef cattle production is another profitable enterprise for the homesteaders throughout the district.

"Furthermore, the elevation, the top soil, the rainfall, and the contour of the lands make it an ideal area for the successful establishment of family-size diversified farms. And the farm products that can be produced economically in this district are those that are imported in large quantities from the mainland, such as:

"Irish potatoes—approximately 16 million pounds imported annually,

"Carrots—2 million pounds imported annually,

"Peppers—150 to 200 thousand pounds imported annually,

"Corn—to replace some of the imported grain feedstuffs, and"
"Eggs—more than 2 million dozens imported annually.

"These lands are also well adapted for the production of poultry, dairy cattle, macadamia nut, tropical fruits, and swine.***

"The homesteads, many of them originally were about 20 acres in size, but others have acquired homesteads and some of them run up to about 3 or 400 acres. The small ones are around 5 to 10 acres in size."

Kazua Kikuta

At a public hearing in the Senate Chambers, Iolani Palace, Honolulu, on December 12, Mr. Kazua Kikuta, President of the Hawaii Farm Bureau Federation, summarized his view of Territorial water resource problems as follows:

"1. Water used by the diversified farmers in Hawaii has not been subjected to a critical survey or study. There seems to be a definite need for a survey.

"2. Land area used by diversified crops is a small fraction of the total land area. There seem to be a possibility of utilizing additional land for diversified crops if reclamation projects are planned.

"3. Water and land must be made available to balance our economic budget. We must grow a larger proportion of our crops used in the Territory and we should be able to maintain a larger number of farm enterprises.

"Our only hope in solving these problems is a realistic study of our land, water, and economic conditions by some Government agency. We sincerely hope that your Department will recommend some solution to our diversified farm problems."

F. Ohrt, C. Wentworth, H. A. Wadsworth

One of the most difficult water problems in the Territory is the diminution in the reserve supply which serves Honolulu and environs. Honolulu draws its supply from a lens of fresh water lying on top of salt water underneath the plain on which the city is situated. Artesian water formerly supplied the bulk of the requirements, but this source is a constantly diminishing one.
The problem was presented at public hearings in Honolulu on December 4 and 12, 1950. Frederick Ohrt, Manager of the Honolulu Board of Water Supply; Chester Wentworth, Geologist for the Board, and Dean H. A. Wadsworth of the College of Agriculture, University of Hawaii, made the following statements, among others, at the hearings:

Dr. Wentworth

"** the water level has gone down—the artesian head has gone down from 42 feet to not much more than half of that. **

"** within about a hundred or perhaps 110 or 115 years after the drilling of the first artesian well on this island it is probable that there will be no important use of water from artesian wells; they will all be sealed or put out of commission and we may regard it as a phase in the history of water development—a useful phase of exploration but one due to be ended. **

"** probably 7 or 8 million gallons a day for the last 60 years has been coming from the shrinking of this lens and very likely not from the rainfall of the present years. Now that is an amount in a rough off-hand way—it is around 15 or 20 per cent of the total—and the sad thing about that is that after this shrinking of this lens has been accomplished—after this head has leveled off perhaps in a few years—then we won't be getting that advantage any more, just like the advantage that we got from the holding down of use by consumers. That won't come again—the trust fund has run out and what the rich old uncle left us is gone—we have to live on our income."

Mr. Ohrt

"** during the war we had a 7-year drought, ** and if we hadn't had the artesian head built up there, we probably would have been up against a real water problem here. But fortunately we had our reserve prettywell built up at the beginning of this dry period, the 7-year drought, so we weathered the thing. **

"Several times it has been critically demonstrated that our 'water problem' is due to the sensitiveness of the fresh water-sea water balance. Periods of subnormal rainfall or of excessive draft, or a combination thereof, result in increased chloride content because of the diminishing level of the water table and the consequent shrinking of the lens of fresh water and intrusion of sea water into aquifer zones tributary to municipal water sources. There is adequate proof to support
the conclusion that, although deterioration of water quality may be checked to some extent, the trend to increased chloride content is inexorable.  

"It is estimated that the four recharge projects now contemplated would result in the addition of approximately ten million gallons daily to our underground water supply so the possible importance of such projects will be readily apparent. Technical difficulties may arise, however, and it is quite probable that experts of the Bureau of Reclamation will be able to assist us materially when our planning has advanced somewhat further."

Dr. Wadsworth (speaking of the Honolulu problem as well as the Territorial water problem generally)

"The easiest developments will be produced first, and then each one becomes more difficult and expensive. We have gone through that same picture, and now we are at the point where development of any more water for any purpose would be such a costly venture that it is going to demand the cooperation that we did not need before. Now is the time possibly when we turn to an outside agency such as the Reclamation Service to help us over the next step which is going to be the most costly one of all."

At the hearing in Honolulu on December 12, Dr. Wadsworth had this to say, in part, about the need for irrigation in the Territory:

"We need irrigation facilities, it is true. But we need to have them designed for our local economic and environmental pattern. It is perhaps safe to say that in the local scene, long-scale economic planning is more important in the design of new irrigation projects than is the engineering involved.

"In this task of planning, evaluation and allocation, the great resources of the Reclamation Service can be of utmost value to the agriculture of Hawaii."

Colin G. Lennox

Mr. Colin G. Lennox, President of the Board of Agriculture and Forestry in Hawaii, who accompanied the writer at all the public hearings in Hawaii, summed them up at the hearing in Honolulu on December 12 by saying, in part:
"** Fundamentally I know you are fully aware by this time of our insular situation, with the sea as its limits and a population which is growing rapidly, which is still feeling the normal upswing that populations feel in a newly settled country, that we are rapidly approaching a situation where gainful employment is important to plan for.

"The soil has been and it still is the principal resource of Hawaii. However, there are certain problems, and I know you already put your finger on them in your public utterances, that are limiting the expansion of this resource. Now, outside of the matter of markets for what we could raise on these lands, and our land use problems, and our water law with its complications, these are things that we should be able to solve in time. I would like to highlight what possibly are limiting in some of the areas toward developing our lands further simply from the point of view of water deficiency. We start with the southern island, and over in Kona we found water was limiting there for residential and tourist development, for a more complete use of highly developed pastures for cattle, and that in this area we have one of the potential areas for orchard increases, macadamia nuts, oranges and avocados, for which we hope we will find mainland markets, but again water is limited there for orchard operations.

"From there we moved over to the North Kohala District and in that old geologic formation found a certain amount of firm water being obtained at the present time, and has been for many years. We also saw that there is a great quantity of land in that area that could be developed if more water could be obtained from these Kohala Mountains.

"Then we went on around to the area above Hilo, the Olon-Volcano region, and there you saw an example of what can be done with picking up surface water under this more or less continuous rainfall where surface water does not stand or run in streams, but filters into this relatively new geologic formation of Mauna Loa.

"** We spent a day on Molokai, and there we saw and reviewed the two surveys that have been made, and saw the possibilities of expanding irrigated pastures as a means of increasing the beef supply for a market which is already importing a great deal from the mainland. We also saw a very important possible development, and that is the potential use of such water for irrigating the pineapples. We were told by the pineapple people that they get as much as 50 per cent of their normal crop in some years of dry weather. We were also shown and told that in some preliminary experiments as low as 8 acre inches will give a maximum crop in a
dry period for pineapples. In other words, with this crop for which we have an established market, we can see needs for a high value use for this water that is now running to waste, which has been so carefully engineered and evaluated for an irrigation project for Central Molokai.

"Now, the Oahu picture * * *. There is this competition for the ground water on the leeward side, both in the Pearl Harbor Basin and in the Honolulu Basin. There is competition between agencies, both those supplying domestic water and to the Services and to the plantations. * * * all of which points up to a point made a couple of times this morning with regard to overall planning for the use of these limited water supplies on this Island. This Island may be more acutely in need than some of the others. You have emphasized the need for planning on all the Islands, and there is no question that that is coming eventually.

"The last island we visited was Kauai, and there we saw what we have visualized as a multiple purpose opportunity to develop irrigation, hydroelectric power, and possibly some flood control in these tributary streams to the Waimea River. * * *"
**Water Resources**

Hawaii has vast water resources. The extremely heavy precipitation on the mountains of the Territory provides large quantities of water which are potentially usable for irrigation, domestic requirements, and other purposes. Putting these water resources to use presents many difficult and unique problems. Private and local public developments, however, have demonstrated that these problems can be effectively solved by competent engineers.

Some of the unique characteristics of Hawaiian water resources as compared to those of the mainland were highlighted by Dr. Wadsworth at the Honolulu hearing on December 4 when he had this, in part, to say:

"One rule that is important is that everywhere in Hawaii the weathered material, that is, the sand or gravel (what we call sedimentary rock on the mainland) is a tight impervious material and the bedrock or native rock which is porous thin lava flows is the loose, permeable open-textured material which holds the water. That is exactly the opposite of what is usual on the mainland. On the mainland the natural rock is very tight, very solid, and on the other hand the gravel and sand, particularly lying in the floor of the valley, is the open-textured material where the water is stored. On the mainland water is commonly sought in valley bottoms, flood plains, etc., which is a matter of considerable confusion to well drillers when they first come to this part of the world."

**Ground Water**

Ground water is the source of almost half of the Territory's water supply. As earlier noted, the terrain of the Islands is uncommonly porous. Precipitation tends to sink into the surface rapidly to join the waters below.

The largest bodies of fresh ground water are contained in the so-called basal waters. These basal waters float upon the salt water, which saturates at greater or lesser depths the rock structures under all of the Islands. The basal fresh water remains on top because of its lesser specific gravity. Fresh and salt water lie mixed in a zone separating the basal water from the lower-lying salt water.

Artesian waters, stemming from the basal supplies, occur at places along the coasts of Oahu and Kauai. The artesian action results from caprocks which confine the basal water in the lava rock under pressure.

The second largest body of ground water is that which occurs in the dike complexes which characterize the core of each volcanic mountain. The vertical-trending dikes are sheets of materials which ascended from...
the depths during periods of volcanic action. These materials solidified in impervious masses near the end of the volcanic activity. Literally hundreds of dikes underlie each surface zone—the rift zone—where volcanic material was at one time expelled.

The pervious material surrounding the dikes may be saturated with fresh water. Such ground water frequently occurs at relatively high levels. Lateral movement is restricted by the impervious dike walls, and downward movement is hampered by the relative slowness by which water can pass through the underlying rock structure. The dikes may be likened to a bundle of giant tubes confining water and holding it above the level it would otherwise seek.

A considerable portion of the existing water resource development depends on the tapping of water confined in these dike complexes by extensive tunnels.

A typical occurrence of basal ground water and water confined by dike complexes is shown diagrammatically in Figure 2.

Other ground waters are perched on ash or tuff beds, soil beds, and on alluvium.

**Surface Water**

Surface water supplies something over half of the total fresh water now used in the Territory. This represents a large part of the surface water easily and economically applicable to the agricultural development of the Islands. There are many small streams, however, near areas of high water demand that may make substantial contributions to more comprehensive and more efficient water supply systems in those same areas. More data are needed on the many such streams.

Much surface water is wasted in areas remote from suitable agricultural land. Studies have been made of the extent and quantity of some of these remote supplies, but much more investigation is needed for a complete inventory of such streams.

As previously stated, the porous structure of the terrain permits a large part of the rainfall to sink directly into the ground in some areas. In areas where a protecting cap rock or a relatively dense material prevail this water lost to the streams may go into ground water storage. There are many other areas, however, that because of their extremely porous nature, cannot maintain an effective separation of the fresh from the salt water. The result is a heavy loss of the water precipitated. The possibility of carrying surface flow from such areas to be used for recharging ground storage at places where ground storage is possible, is a field for investigation.
DIAGRAM OF TWO PRINCIPAL TYPES OF GROUND WATER OCCURRENCE ON A TYPICAL HAWAIIAN ISLAND

The Heavy Vertical Lines Represent A Dike Complex

The Lens-shaped Body Represents Fresh Ground Water Floating on Salt Water

Note that the Bulk of the Fresh Water Lies Below Sea Level
The drainage areas of the Hawaiian Islands are both short and steep; they occupy narrow basins extending from the crests of the mountains to the sea.

Perennial streams are found on Molokai, Maui, Hawaii, Kauai, and Oahu. They are exceedingly flashy streams. One stream on Kauai, for example, has an average discharge of 133 cubic feet per second. Its maximum recorded flood peak is 45,000 cubic feet per second. The total annual runoff of the same stream has varied from 20,000 to somewhat more than 181,000 acre-feet.

The streams of the Islands are generally small and low in dependable discharge.

Hawaiian Water Rights

The Hawaiian system of water rights is unique. It is based in part on ancient customs and the peculiar Hawaiian system of land titles, tenures, and use, and in part on doctrines borrowed from the mainland. Water rights in Hawaii are intimately bound up with land ownership, whether the owner be Government or private individual. Hawaiian waters are, therefore, essentially private, not public waters.

There is little statutory law governing rights to the use of either surface or ground waters. The governing principles have been established mainly in court decisions. Court cases on surface waters have been numerous and have covered a wide field. Only a few decisions, however, have dealt with rights to the use of ground waters, and these have covered only a limited field.

Legislation, therefore, may be needed for the orderly administration of the ground waters which may be utilized in the overall development of Hawaiian water and land resources. Investigations of the type recommended herein would deal with the problems of water rights, and the reports on them would propose appropriate solutions.

Land Resources

The land resources of Hawaii were described as follows by Mr. Noboru Miyake, a member of the Territorial legislature and a resident of Waimea, Kauai, at a hearing there on December 11, 1950.

" * * * The major islands are Kauai, Oahu, Hawaii, Maui, Molokai, Lanai, and Niihau, containing 4,118,826.80 acres of land. Of this total, 2,362,608.24 acres or 57.36 per cent, is privately owned and 1,756,218.56 acres or 42.64 per cent is owned by the Territory and all the various Government agencies.
Due to its high mountains and steep terrains, only 47 per cent or 1,925,000 acres of its entire land area is suitable for agricultural purposes, of this amount only 7 per cent or 237,000 acres are now used for agricultural crops, such as sugar cane, pineapple and for small farming. The remaining 40 per cent or 1,638,000 acres are used for grazing land. The balance of 53 per cent or over 2 million acres are considered forest reserves, waste land, and for other nonproductive use.

With only 7 per cent of our total land area now used for agricultural crop production, future land resource development becomes an important factor to maintain a stable economy in Hawaii. We must admit that the rapid progress made in Hawaii during the last half a century in our agricultural industries has been largely due to huge capital investments made by corporations and private individuals for the construction of one of the finest chain of irrigation systems ever built by anyone in Hawaii, at the cost of over 50 million dollars. Such large investments by private capital has been the life line of Hawaii's economic system and high standard of living.

The Territory owns 42.64 per cent or 1,756,218.56 acres of land. A great portion of this potential good agricultural land is located in the Wai'anae plateau in the Big Island of Hawaii, the Island of Molokai, our Windward Oahu in the Waimanalo area, and on the Island of Kauai in the Kokee region. Any aid for water resource development in these areas by the Federal Government will be of great value to the Territory of Hawaii, and more particular to the Hawaiian Homes Commission, whose land is largely located within this area.

Existing Irrigation Development

In 1940, about 131,600 acres were under irrigation, almost all in sugar cane (See Fig. 1). Generally speaking, there is at present more surface water than ground water used for irrigation in the Territory. This is true of Maui, Hawaii, and Kauai. The opposite is true on Oahu.

About half of the acreage of sugar cane grown in Hawaii is irrigated. The same ratio might hold for the fruit and vegetable crops in the Territory. Pineapples generally are not irrigated commercially and are grown in areas receiving enough natural precipitation for their production. Their water requirements are relatively low. Commercial irrigation is emerging as a possible operation on a large scale. It is interesting to pineapple growers and all others.
The problem of the sugar industry, which has been responsible for the development of irrigation in Hawaii, has been to capture water in the swift, flashy streams on the windward side and lead it through or around the mountain masses to the dry plains on the lee side. About $45,665,000 have been spent in these works with an average investment of some $300 per acre for the area which is irrigated. This money has been entirely private capital.

Very large quantities of water are required by sugar cane. It is said in Hawaii that "sugar is made of sun and water" and that "it takes a ton of water to produce a pound of sugar." The largest and most productive sugar plantations are irrigated. Two-thirds of the total cane tonnage raised is produced under irrigation. Irrigation water is generally developed by the plantations for their own use, although in a few cases corporate units have taken over water development and distribution.

Water is obtained from two sources, ground water and surface systems that are mainly operated by gravity. Most irrigated plantations obtain water from both sources. Water distribution systems are expensive and usually elaborate. The high value of water demands careful handling of the water and the use of water-saving methods. On Oahu a single plantation has 61 artesian wells with a pumping capacity of over 100,000,000 gallons daily; one plantation on Maui obtains 300,000,000 gallons every 24 hours of which about 100,000,000 are derived from its wells.

Although the time has passed when large amounts of water could easily be obtained for irrigation purposes in Hawaii, there is still much water available for further developments. Moreover, considerable land in Hawaii could be used more intensively, if supplied with irrigation water. The important questions are economic feasibility and engineering skill—new irrigation developments tend to be more difficult and often more expensive than in the past.

Between 1940 and 1949, irrigation on sugar plantations was improved. More ditches were lined to avoid seepage. A new type of concrete flume, the so-called Waialua type, was put into increasing use, enabling increased frequency of coverage, increased irrigated area per man day, and greater flexibility of operations. Several new wells were added, including one with a capacity of 15 million gallons a day on the Wailuku plantation on Maui. Sugar plantations have also been experimenting with overhead irrigation.

A great deal of research is being conducted in the Islands to improve the agriculture. Many private, cooperative and Territorial agencies are working on various problems in order to derive better crops and more efficient methods. Tests in growing pineapple under irrigation are continuing and have shown encouraging results. Extensive experiments in types of fertilizers and means of application are being conducted and excellent progress is evident.
Cane, irrigated, on Kauai.

The reservoir at Wahiawa on Oahu. The biggest in the islands. Deep percolation takes away every year enough water to fill it three or four times.
Recent major developments in the use of water for irrigation purposes have taken three courses: improvements in the irrigation systems of sugar plantations; renewed experiments in growing pineapple under irrigation; and promotion of projects to convert certain larger tracts of Territorial land, now used mainly for grazing, into areas of intensive crop cultivation.

A number of efforts have been made from time to time to bring about the development of public irrigation projects. Investigations of individual projects have been made. No such project, however, has yet reached the construction stage.

Records of surface runoff and of precipitation have been, and are still being, compiled. Likewise, studies have been made of various parts of the ground-water problems.

The Geological Survey of the Interior Department is maintaining a program comprising both surface- and ground-water investigations in the Territory of Hawaii. The program is being conducted under cooperative agreement with the Territory of Hawaii, through the Commissioner of Public Lands.

The first general study of the surface-water resources of the Islands was begun by the Geological Survey in 1910. Since that time, records of daily discharge of streams and ditches have been obtained at 565 stations for periods ranging from a few months to 40 years. In addition, hundreds of miscellaneous measurements have been made. At the present time, there are being maintained 127 gaging stations.

The systematic investigation of the ground-water resources of the Territory was begun in 1920. The first detailed study of geology and ground-water conditions was made in the Kau district on the Island of Hawaii. The work was suspended between 1924 and 1930, but has gone on since that time. Many reports have been made covering specific areas where ground-water utilization is of special importance in municipal, irrigation, or military supply.

Such data compilation is a very necessary part of both present and future developments of water utilization projects. The data so far compiled provide a vital part of the future development program, but will need to be expanded to provide records at or near the sites of potential projects or at points where records are needed to complete the full picture of the general pattern. Specific recommendations for expanding the stream gaging, precipitation and ground-water observations in the Hawaiian Islands were made in the report of the Committee on Standards for Basic Data of the President's Water Resources Policy Commission. The implementation of these recommendations would add some 60 new surface water stations, 30 precipitation gages and soil moisture stations, and very considerably increase ground-water studies.
Irrigation is older than written history on the Islands. This is the Menehune ditch on Kauai, so-called because it antedates knowledge of the builders. The Menehunes, or fairies, are credited with its construction.

One of the principal canals on Oahu. It was built by and serves a sugar company.
Special note must be taken of the ground-water lens that underlies and supplies Honolulu and vicinity. Its fortunate location has played a decisive role in the growth of the city. It has been closely studied. There is some evidence of overuse at present. Because of its importance, every effort should be made to measure the safe yield and compare the use to the recharge.

Very little attention has been given to the chemical quality of surface and ground waters in Hawaii except for concentrations of chloride. Because the fresh water lens of ground water floats on sea water, the chloride content of ground water has been the most important index of salt-water contamination. However, a more thorough study of the chemical character of the Islands' water resources should be undertaken in order (1) to follow changes in composition from time to time and from place to place, (2) to determine if salt water originates from sources other than sea water, and (3) to learn if the composition of moderately contaminated water has undergone chemical changes as the result of ion exchange processes. Chemical quality studies might also yield information that would make possible the use of moderately salty water without serious injury to irrigated crops.

Prospects for Future Development

The most economical surface water sources have generally been fully utilized for many years. New developments based on surface sources will be possible but the proposed projects must be carefully studied. Large reservoir storage of flood flows is not practical in most localities because of the porous conditions characteristic of the Islands and because the steep slopes preclude the existence of economical reservoir sites. One reservoir on Oahu, for example, loses through seepage something like three times its regulated yield.

In some areas, notably on the Island of Hawaii, collection facilities and storage tanks, much on the principle of eaves, pipes and cisterns, will be required because of the extremely porous lava. The amount of rainfall at higher elevations, however, makes even this extraordinary type of project promising for agricultural development.

The engineering structures needed in order to make the water physically available for use are somewhat novel when compared with the projects of the western States. However, the novelty lies in the types of structures; all of the basic engineering construction problems have been encountered in projects throughout the irrigated West. The skills that have been developed can be utilized to solve the problems that may seem to be so unusual when casually examined. Many of the problems will be difficult, but past experience and skill are available to solve them. An example of a novel solution for a difficult water problem in an unusual area, is found on the Island of Hawaii where the prison has developed a water supply by going up into the rain forest, running a few short, shallow ditches in herringbone pattern, concreting their bottoms to prevent seepage, and has collected a substantial supply for storage in
Artesian well being demonstrated in heart of Honolulu on city water department property. It is controlled. It illustrates the nature of the Honolulu ground water basin.

Entrance of Honolulu's new horizontal well.
Shed and eaves tanks built to supply water for the National Park hotel and headquarters on the Island of Hawaii at Kilauea crater.

Collection ditches, lined at the bottom with concrete, in the upland rainbelt on Hawaii built to gather water for the tanks serving the prison.
tanks against dry seasons. This method offers promise if studied by imaginative engineers.

For the most part, expenditures by private capital have been made to improve agriculture by the irrigation of sugar cane on large plantations. This development has probably approached an economic limit. There is called for now in the Islands the type of agriculture which is obtained from small, individually owned farms producing diversified crops. These crops, such as carrots, lettuce and other perishable vegetables, would find a ready market and should be competitive with frozen vegetables imported from the mainland. These small farms with diversified crops will help relieve unemployment, aid the population, and bolster the economy.

It must be recognized that such development calls for a full realization of the need for federally-financed projects which can be amortized over extended periods, thus enabling the farmers to pay for them within their ability. In some instances, it may be in the National interest to write off certain features of the cost.

Related to the increased use of water in irrigation is the problem of land ownerships. Many areas will be handicapped in the development of small farm irrigated agriculture by the large land holdings. Several holders of large acreages, however, indicated a willingness to cooperate in making land available for such irrigation development. This was true on Molokai and Hawaii. It is probable that continued work on the water resource problems would assist in orderly solution of the basic land ownership problems and make a double contribution to Hawaiian development.

Consideration must be given to the works to make water available for use and studies must be made of the soils, the crops and the markets. Water cannot just be applied to the nearest piece of land; it is too valuable to use without careful planning. For a crop to be worthwhile, it must be of a good quality and produced at the time when needed, and the supply must be dependable so that the merchants and consumers can trust that it will be available. Many crops can be grown in the Islands at present, but are not because they cannot meet market requirements. A coordinated plan is necessary in order that the water can produce the most profitable and desirable crops and that the water use can be fitted into the other phases of the economy of the Islands. This is just as much of a problem as the engineering structures that must be built to put the water to use.

**Navigation and Flood Control**

During the last two decades, interest has gradually increased in problems of flood control, as communities have grown near the mouths of some of the larger streams. Thus, Waiheea, Hanapepe and Wailua on Kauai; Honolulu and Waialua on Oahu; Kaunakakai on Molokai, and Wailuka
The dry side of Molokai, one of the areas needing irrigation.

The beautiful Kona coast of Hawaii, which needs supplemental water for seasonal droughts. Here coffee and many other crops are grown commercially.
on Maui have all suffered sufficiently from flood damage to want to do something about it. Stream-gaging stations have been installed in all these areas to assist in the solution of their problems, most of them involving some sort of cooperation with the Corps of Engineers of the Army.

Only two of the flood control projects proposed by the Corps of Engineers have been authorized. One of these, the Kaunakakai Project on Molokai has been completed. No appropriations have been made for the other, the Kawainui Swamp Project.

Three rivers and harbors projects proposed by the Corps of Engineers have been authorized since the close of the war. These are: Keechi Lagoon, Honolulu Harbor, 1945 (modification of a seaplane base); channel and harbor work in Honolulu Harbor, 1946; and channel and harbor work in Kawaihae Harbor, Island of Hawaii, 1950. No funds have been appropriated for construction of any of these projects. Small boat harbors are especially needed in several of the Islands. Their lack holds back fishing and recreational developments and subjects the residents to unusual hazards.

Needed Framework for Solutions

The solutions to the water problems will need to be considered, primarily, for each Island as a whole. The amount of water that may be obtained for use is limited—misuse at one point may deprive another point of its needed supplies. A thorough blending of ground water and surface water developments will be needed. In some localities catchment works may be necessary to capture the rainfall before it can be absorbed by the ground. Water will need to be recovered from underground by tunnels, wells or galleries. Every opportunity for power production should be utilized.

A few potential projects have already received some direct planning and can be brought up to the construction stage within a relatively short time. These include the Molokai project studied by the Bureau of Reclamation for the Hawaiian Homes Commission, the Waimea Plains project on Hawaii, and others that have received local study. However, the great need is for comprehensive studies of each Island leading to an over-all water development program for each Island that is coordinated with the economic needs of the whole Territory. Such a study will need the skills and experience of agencies of the Department of the Interior such as the Bureau of Reclamation, the Geological Survey and cooperation with the Office of Territories; it will also need the cooperation of local interests and other agencies. The advice of the Hawaiian agricultural interests will be especially valuable. It should be done on a planned and continuing basis.

The future work for water developments should include an intensified program of data collection, a comprehensive study of the water problems, supplies, and potential projects; and the preparation of reports presenting specific plans for developments.
As in any dry area, Molokai is afflicted with flash floods. Here the road is buried with debris swept down from the dry plains by a heavy storm of the type that is occasionally experienced there.

Debris disgorged by a stream in a single storm on Molokai, as seen from the air.
A description of each of eight major Hawaiian Islands is presented in the following paragraphs:

Hawaii.—The Island of Hawaii, the largest of the main group, and the youngest geologically, is at the southeastern end of the group. It is triangular in shape, 87 miles from north to south, and 75 miles greatest width, and is almost twice as large as the rest of the group put together. It has an area of 4,015 square miles. Hawaii is an island of snow-capped mountains, live volcanoes, palm-lined beaches, and forest of ferns. It is dominated by two peaks—Mauna Loa and Mauna Kea—each almost 14,000 feet high. The Island is considered by geologists to have been formed by five volcanoes, two of which (Mauna Loa and Kilauea) are still active.

On the east side of the Island is the colorful Hamakua coast with its many waterfalls and gulches, and lush tropical foliage.

One of the largest private cattle ranches in the United States is located on the Waimea Plateau in the north central part of Hawaii Island. About 45 per cent of the Territory's sugar cane is grown on Hawaii Island along the Hamakua coast in the north of Kohala. Fruits, vegetables, coffee, and macadamia nuts are produced in the beautiful Kona district on the west side of the Island and on the coastal areas of the east side.

Maui.—The Island of Maui, the second largest of the main group, lying 26 miles northwestern of Hawaii Island, is about 38 miles long east and west, and 25 miles wide, with a total area of 728 square miles. It consists of two mountain masses connected by a low, flat isthmus. Maui contains the now dormant crater of Haleakala, which is 10,025 feet high and has a circumference of 21 miles. Sugar and pineapples are grown on the isthmus and narrow coastal plain, and cattle ranching is conducted on the slopes of Haleakala.

Kahoolawe.—This Island, six miles off the southwestern end of Maui, is eighth in size of the main group and is a part of Maui county. It is about 11 miles long east and west and six miles wide. The Island is dominated by Mount Moaula, a brown dome 1,444 feet high. Much of the native vegetation has been destroyed by over-grazing, and the Island is desolate and barren in appearance. It has little commercial importance and is at present uninhabited.

Lanai.—The Island of Lanai, six miles westward of Maui, is roughly fifteen miles long and ten miles wide and has an area of 141 square miles. The Island, sixth in size, is fringed in part by a coral reef about 150 yards off the beach. There are slopes on the easterly and westerly sides and the central portion is a rolling plain. The Island is owned by the Hawaiian Pineapple Company and is populated entirely by employees of the company seat and business center.
company and their families, totaling about 4,000 persons. The company
developed a small harbor and established Lanai City. A little more than
one-sixth of the land area of the Island is in pineapples; much of the
remainder is devoted to cattle ranching.

Molokai.—This Island, lying 7\(\frac{1}{2}\) miles northwest of Maui and 8
miles north of Lanai, is fifth in size with a total area of 260 square
miles. It is rectangular in shape, about 37 miles long (east to west)
and 7 to 10 miles wide. The eastern end of the Island is mountainous,
rising to 4,970 feet (Kamakou Peak). The mountain slopes on the north
are very steep, but on the southern side the slopes are more gradual and
terminate in a narrow coastal plain. The western end of the Island is a
tableland rising gradually to Mount Nana, 1,381 feet high. There is con-
siderable diversified farming on the Island; its pineapples are trans-
ported by barge to canneries on the Island of Oahu. It is the site of
a Hawaiian homestead project developed to encourage landholding by native
Hawaiians. The Kalaupapa leper settlement is also located on this Island
in an area which is accessible only by boat, plane, or foot path. Molokai's
principal port is Kaunakakai.

Oahu.—This Island, which is third in size, with an area of
60\(\frac{1}{4}\) square miles, lies 22 miles westward of Molokai. It is a diamond-
shaped island about 40 miles long at its longest and about 26 miles wide
at its widest point. The entire northeastern coast is paralleled by the
Koolau range with a maximum elevation of 3,150 feet. This range is broken
at the famous Nuuanu Pali (pass) at the head of Nuuanu valley, 1,186 feet
elevation, only 6 miles from Honolulu. The north face is a sheer rocky
cliff nearly 2,000 feet high in places. The Waianae mountains which
parallel practically the whole of the western coast of Oahu are marked
by a number of peaks, the highest of which (Mt. Koala) is 4,025 feet above
sea level. Between the Koolau range and the Waianae mountains lies a great
and somewhat elevated plain, practically all of which is under cultivation.
Here is located Schofield Barracks, Hawaii's largest army post. The south-
ern side of Oahu is a broad coastal plain with Honolulu, the principal port
and largest city of the Islands and the capital of the Territory, situated
toward its eastern end. The famous Waikiki beach lies on the southern coast
between Honolulu and Diamond Head, a secondary tuff crater. To the west of
Honolulu lies the Pearl Harbor naval base with its surrounding yards, shops,
and airfields.

Kauai.—This Island, fourth in size of the main group, is 6\(\frac{1}{4}\)
miles west-northwest of Oahu, and is believed to be the first of the main
group of Islands to have been formed. It is almost circular in shape,
about 25 to 30 miles in diameter, with a total area of 555 square miles
and a central mountain mass that reaches an elevation of 5,170 feet. On
the western and northern sides the mountains have steep ridges; on the
eastern and southern sides there are more gentle slopes. The spectacular
Waimea Canyon on Kauai, a miniature Grand Canyon, is 3,000 feet deep.
The principal port is Nawiliwili harbor, and the town of Lihue is the
county seat and business center.
Waimea Canyon on Kauai contrasts with the topography of Hawaii. These are geologically the oldest and newest, respectively, of the islands. Here is the single opportunity, perhaps, to devise a multiple-purpose project like those in the western states of the mainland.

The rain forest high on Kauai above Waimea Canyon near the wettest place in all the Islands, or perhaps in the world, where 450 inches a year have been recorded.
Niihau.—The Island of Niihau is seventh in size of the main Islands, with an area of 72 square miles. It is about 17 miles long and varies in width from about 3 to 5 miles. The Island is low at both ends with a high tableland near the maximum elevation which is 1,281 feet. It is devoted almost entirely to stock raising and is owned by one family.
## PAMPHLET BINDERS

This is No. 1932

also carried in stock in the following sizes

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