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WATER RESOURCES OF THE VIRGIN ISLANDS, A PRELIMINARY APPRAISAL, 1963

by

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Summary

Rainfall in the Virgin Islands averages about 44 inches per year, yet fresh water is in short supply, and the general impression of the islands is one of dryness. Land slopes are steep and runoff from rainstorms flows rapidly to the sea in the numerous, short, steep stream courses. During most dry seasons only a few streams maintain flow along any part of their course. Guinea Gut, the only stream in St. John known to have had continual flow during the first half of 1963, had a minimum flow of 3,500 gallons per day (gpd). The flow of Turpentine Run, the largest stream in St. Thomas, dropped to 15,000 gpd during the same period, and the flow of River Gut, the largest stream in St. Croix, dropped to about 70,000 gpd. In past years the flow of the streams has been less at times; in fact, Turpentine Run reportedly did not flow during part of 1923 and probably it has been dry at times since then. The streams thus are not reliable sources of large water supplies unless storage is provided. The building of reservoirs has been discouraged by several factors including the apparent scarcity of good sites, the lack of appreciable stream flow most of the time, and the large amount of sediment carried by the streams during floods.

The water making up the low flow of the streams has a chloride content of about 300 parts per million (ppm) and total dissolved solids of about 1,000 ppm. The chemical quality of storm runoff is more dilute, but the amount of suspended sediment is great.

The availability of ground water for present and future needs is determined largely by the occurrence and character of the water-bearing rocks. Most of the rocks have low permeability and most water-bearing units are of small areal extent. This means that well yields are relatively small, and even if large drafts were possible the water in storage likely would be depleted during drouths. The largest and most productive water-bearing units in the Virgin Islands are in St. Croix where wells generally yield from 1 to 30 gallons per minute (gpm) of potable water, and in a few places yield as much as 50 to 100 gpm. Wells can be located in many parts of St. John and St. Thomas that will yield from less than 1 to 15 gpm of potable water. Larger yields are possible in a few localities, but the average yield of all wells in the Islands will be less than 5 gpm.

The quality of the ground water varies from place to place and with depth. The chloride content ranges from less than 100 to a few thousand ppm, depending largely on the depth of the well, the proximity to the ocean, and the rate at which the well is pumped. Generally, wells should not be bottomed below sea level, and should be pumped at rates sufficiently low to prevent drawing in salty water from water-bearing rocks lying at lower elevations or from the sea. Because wells very near the coast are particularly susceptible to sea-water encroachment, pumping levels should be maintained as high above sea level as possible.

With proper development and management of the water resources of the Virgin Islands, some of the present water-supply problems can be relieved or eliminated. Not only can domestic supplies be obtained from wells in most parts of the islands, but also small public supplies can be obtained in some areas, particularly in major drainage basins. Detailed studies of basins, including Turpentine Run in St. Thomas, Guinea Gut in St. John, and River, Jolly Hill, and Creque Guts in St. Croix should be made to determine the water potential and the best method of development. Batteries of shallow wells near the centers of some of the valleys probably would produce enough potable water for small community supplies.

In order to prolong or increase the yield of a water-bearing zone, the recharge needs to be increased or the natural discharge needs to be decreased. A possible way to increase the recharge is to spread stream runoff over larger areas, preferably slowly, to allow as much water as possible to percolate down to the ground-water reservoir. In some places small retention dams could be constructed to store water temporarily for recharging the ground-water reservoir during dry periods. Natural discharge could be decreased by judicious placement and use of batteries of small wells.

An example of how water can be added to ground-water storage is well illustrated by conditions at a reservoir on Creque Gut, in western St. Croix. In July 1963, leakage from the reservoir apprximated the flow of the stream entering the reservoir. The leakage disappeared into the alluvium a short distance downstream from the reservoir. This water could be salvaged from the alluvium by installing a series of shallow wells or by excavating a trench the full width and depth of the alluvium and constructing some type of collector systems. As the alluvium is narrow and thin these methods are feasible. If at times during the dry season the water demand exceeded that seeping from the reservoir, water could be released at a controlled rate from the reservoir, thus furnishing more water to the alluvium. The supply in the reservoir would be replenished later from storm runoff.

Advantages of this type of supply over surface storage are that water stored in the ground is free of turbidity, and unless the water table is very near the surface the evaporative loss is less.

In addition to developing the ground-, and surface-water supplies, more water can be obtained by constructing additional rain catchments, by installing sea-water converters, and by increasing barging operations. The choice among these is largely a matter of economics. Before the decision is made the ground-, and surface-water potential should be investigated thoroughly because water from these sources is likely to be less costly than that obtained by other means.

Adequate water records are essential to proper development, utilization, and management of water. This includes accurate records of the quantity of water used from all sources. For example, in the case of a well supply, records should be kept of pumping rates, pumping patterns, total pumpage, and static and pumping water levels. The water should be analyzed periodically for chemical content, especially chlorides. A rise in the concentration of chlorides in ground water generally indicates sea-water encroachment. If detected soon enough, correctional measures can be made before encroachment becomes very serious. Some wells in the Kingshill Marl in St. Croix are producing water with a chloride content well above the taste threshold. As more water is taken from these rocks, the chloride concentration may become even greater; therefore, a program of chloride monitoring should be initiated as soon as possible.

Description of the islands

Location and extent

The U. S. Virgin Islands consist of more than 40 islands and cays located about 1,400 miles southeast of New York. The islands form part of the Antilles Island Arch which separates the Caribbean Sea from the Atlantic Ocean. The three largest and most important islands are St. Croix, St. Thomas, and St. John, whose respective areas are approximately 80, 32, and 20 square miles (fig. 1). The smaller islands range in area from slightly less than one square mile to a few hundred square feet.

Topography

The Virgin Islands are generally rugged. The surfaces of St. Thomas and St. John commonly have slopes exceeding 35 degrees. The slopes are dissected by numerous stream courses of steep gradient. The general appearance is a panorama of steep interstream spurs and sharp peaks. Most of the flat land on St. Thomas, is confined to the Charlotte Amalie area and a few narrow beach areas. Some areas of relatively gentle topography exist, such as in the lower Turpentine Run valley. St. John is similar to St. Thomas, but has even less flat land, confined mostly to the Coral Bay area on the eastern end of the island. The northwest part of St. Croix is a rugged mountainous area with deeply incised valleys and is bounded on the south and west by gently undulating lowland. In the central part of the island, the lowland is marked by rounded hills and broad valleys. Adjoining the lowland to the east, and comprising the eastern part of the island, is mountainous terrain characterized by gentler slopes than those in the western part of the island, rounded ridges, and alluviated, moderately incised valleys.

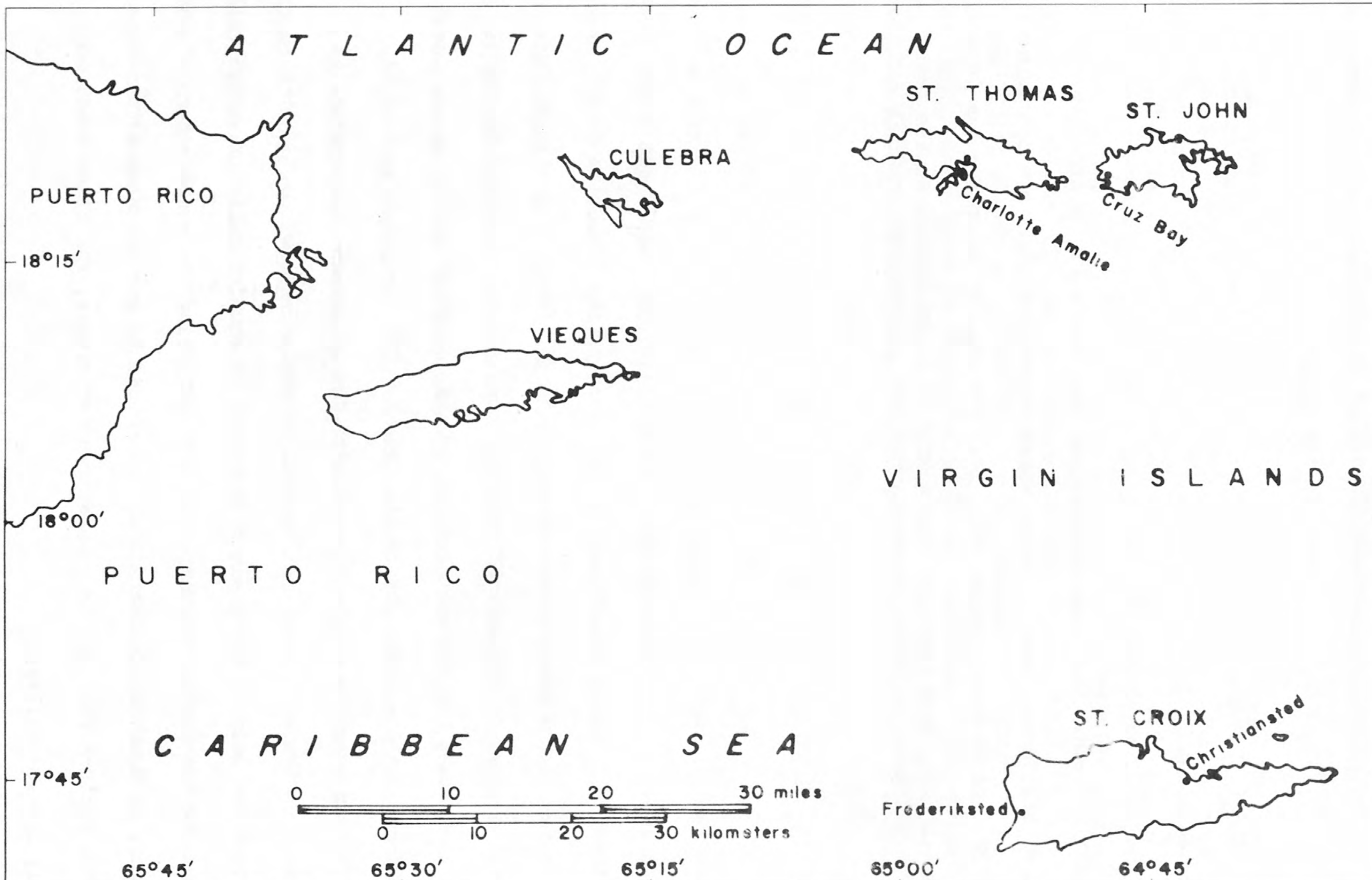

Figure 1.-- Map showing the location of the Virgin Islands.

The water situation up to 1963

A severe shortage of fresh-water supplies continues to plague the Virgin Islands. Rarely have supplies been adequate for irrigation, municipal, industrial, or even domestic purposes. The water situation in St. Croix is better than in St. Thomas or St. John, but even there the water story has been one of shortages, and no source has been developed that will allow for irrigation of sugarcane, the principal agricultural crop. The shortage of fresh water is not new to the islands. In 1936 an ordinance was passed requiring that buildings be equipped so that rain could be collected from roofs. This ordinance, though somewhat modified, remains in effect today. The ordinance states that 4 1/2 gallons of storage must be provided for each square foot of roof area, but most persons provide at least 10 gallons of storage.

Persons residing in Christiansted, Frederiksted, Charlotte Amalie, and Cruz Bay are partially served by the inadequate public-supply systems. Public watering points, consisting of dug and drilled wells or of hillside rain catchments, are available to residents in a few areas. A booming business is enjoyed by water haulers who transport water from water points and public systems to private residences. Water for the public system in Charlotte Amalie, St. Thomas, is obtained from catchments, a sea-water conversion plant, and from barges bringing water from Puerto Rico. The supply for Christiansted and Frederiksted, St. Croix, is from wells, and the supply for Cruz Bay, St. John, is from a small hillside catchment. In the towns, water used for fire-fighting and much of that used for sanitary purposes is sea water.

The small amount of fresh water used, and the limited water facilities of private dwellings, are indicators of the water scarcity in the Virgin Islands. For example, the daily per capita consumption of fresh water in St. John is estimated to be only about 5 gallons per day. Based on the 1960 census, only about 25 percent of the houses in the Virgin Islands had running potable water and less than half of the houses had flush toilets and many of these used salt water. If the water were available in all parts of the Virgin Islands, and were reasonably priced, the per capita and total water use would increase tremendously.

Rainfall as related to water supplies

A prerequisite to the understanding of the water resources of the Virgin Islands is knowledge of the rainfall, the only natural source of fresh water in the Islands. On the average about 44 inches of rain falls on the Islands annually, yet the prevailing impression of the climate is one of dryness. There are pronounced wet and dry seasons, and the climate, though wet enough during the wet season to produce abundant vegetation, is very dry during the dry season. During the dry season ground-water levels decline, stream and spring flows dwindle to a trickle or stop, and vegetation takes on a gray-green to brown appearance.

In most continental areas, 40 inches of rainfall is enough to insure large water supplies and to allow for the growing of a wide variety of crops. There are several reasons why this is not the situation in the Virgin Islands. One of the chief reasons is that a large part of the water is lost by evaporation and transpiration resulting from the year-round warm temperature and relatively high wind movement. Noteworthy also is the fast runoff caused by steep slopes, thin soil cover, and poorly absorptive rocks.

Although the annual rainfall ranges widely, extreme years are relatively few. The annual rainfall at Charlotte Amalie. for the period 1918 through 1961, averaged about 45 inches and ranged from 72 to a little less than 32 inches. In three out of four years, the rainfall was 40 inches or more, not notably less than the annual average (fig. 2). Four times during the period of record the annual rainfall was less than 40 inches for two consecutive years. At no time was there less than 40 inches for three consecutive years, although the rainfall was below average for the 10-year period 1934 through 1943. Possibly of more significance is rainfall variation within the year. Almost 40 percent of the rain falls during October and November, whereas only a little more than 20 percent falls during the five-month period, February through June, when the rainfall averages slightly less than two inches per month. The remainder of the rainfall is fairly evenly distributed among the other five months.

Streams

There are numerous small streams in the Virgin Islands, not one of which is perennial in the usual sense. In a few of the larger drainage areas are spring-fed pools in which there is a trickle of water most or all of the time. Except possibly for River Gut in St. Croix, no stream is known that maintains a perennial flow across the coastal plain into the sea. The streams head in the volcanic uplands where the land surface is dissected into a panorama of rugged peaks, knobs, and ridges. Here the valleys are steep-sided and the contained stream courses have steep

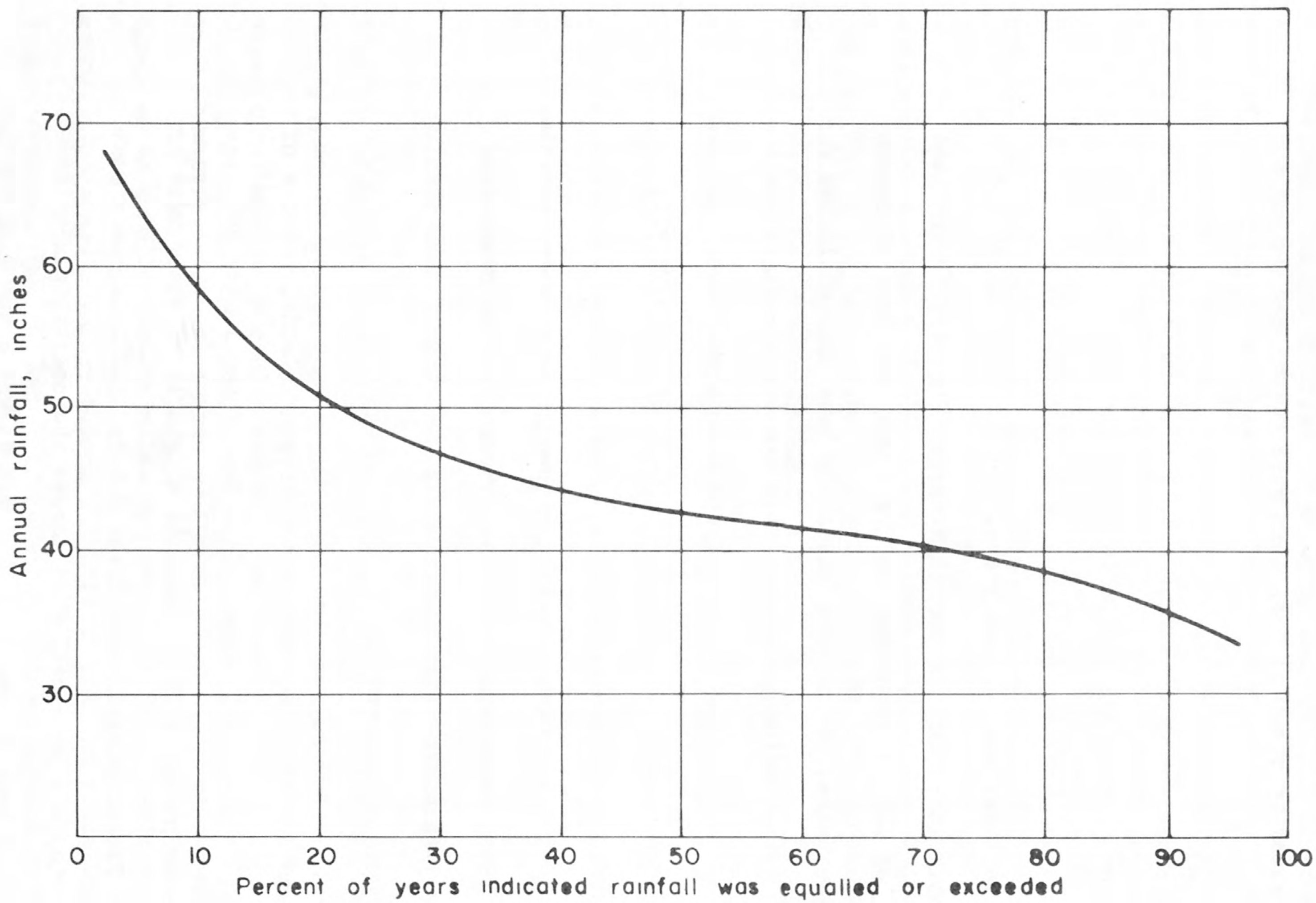

Figure 2.-- Duration curve of annual rainfall at Charlotte Amalie 1918-61. (Based on records of U.S. Weather Bureau).

gradients and commonly are strewn with boulders ranging widely in size. In contrast, the stream gradients on the coastal plains are gentle, the valleys broaden, sand and gravel deposits are more abundant, and boulders are scarce.

A large part of the streamflow is direct runoff from rainfall; consequently, the flow has wide seasonal fluctuations. The dry-season flow is only a small fraction of the average flow, and most of the streams cease to flow soon after rainfall stops. Because of the wide seasonal fluctuations of flow, the streams are not sources of dependable large supplies of water, except where the flow can be regulated by dams and reservoirs. Because of several discouraging factors, there has been little development of surface reservoirs. Good sites for reservoirs are scarce and generally speaking there is not enough water to keep them full through long drouths. Many of the small reservoirs have tended to fill up quickly with sediment, and water loss from evaporation is high, perhaps in the magnitude of 5 or 6 feet annually.

Land use as related to water supplies

The use of land, whether in forest, under cultivation, or for communities affects the water regimen. If land use is changed, the effect may be large or small, detrimental or beneficial; the effect may take place almost immediately or there may not be a noticeable change for years. The magnitude and rapidity of change is dependent upon many factors, including the former use of the land and the extent of change.

At one time almost all land in the Virgin Islands, including steep slopes, was under cultivation, primarily for growing sugarcane and cotton.

In recent years, however, agriculture has declined almost to extinction except in parts of St. Croix. The land has been allowed to revert, naturally, to brush and secondary forest. How this has affected the water situation is not known, but limited observation, the word of older residents, and historical records, indicate that some streams that are now dry were once perennial, and some of the old dug wells which reportedly supplied water during even the most severe drouths now are dry. These changes could be the result of the major change of land use, because, based on rainfall data dating back to 1828, there have been no noticeable climatic changes.

Changes in land use probably will accelerate for the next several years and the effect on water supplies may be considerable. Land is continually being taken over for such things as urbanization, private dwellings, and roads, which deprives the soil of much of its protective cover of vegetation. Removing the vegetation will promote more rapid storm runoff and increased silt in the streams and ponds.

Rocks as related to water supplies

The rocks making up the Virgin Islands control to a large degree the amount and quality of water available for use. Rocks are the source of sediment carried by streams and deposited in ponds, and rocks are the source of most dissolved minerals in both surface and ground water unless the water is contaminated by wastes or by sea water. The amount of streamflow is also affected by the permeability of the near-surface characteristics of the rocks. Rocks are the storage reservoirs for underground water which supplies wells and springs, and which maintains streamflow during times of no rainfall. To a large degree, rocks control the shape of the land and the courses of the streams.

Rock characteristics have an appreciable effect on the flow of streams, especially on the low flow. Some of the water falling on the surface of the land as precipitation, percolates downward into openings in the rocks to replenish the ground water. When the streams flow the openings in the rock may receive some water from the streams by seepage. Regardless of where it enters the ground, the water moves by gravity to lower altitudes, generally to the stream courses. Obviously, if the physical chacteristics of the rocks are such that they cannot store and transmit much water, they contribute only limited quantities of water to the streams. This is the situation in the Virgin Islands; in fact, in places the rocks contain so little water that soon after a rain they are drained to the level of the stream channels and the streams cease to flow.

Discussed below are the three principal rock types comprising the greater part of the Virgin Islands. For more specific information concerning rocks refer to discussions of the individual islands and to the geologic maps (figs. 3 and 4).

Volcanic and associated noncalcareous rocks

The volcanic and associated noncalcareous rocks that make up most of St. Thomas and St. John and a considerable part of St. Croix, have low permeability and are poor water-bearing materials. The rocks yield water slowly to wells and because of the low permeability the water table commonly stands high above sea level. Most of the recoverable ground water is contained in fractures and in weathered zones. making it difficult or impossible to predict well yields. Productive weathered zones probably are not developed below 100 feet below the surface and open fractures decrease with depth. The water from the volcanic rocks commonly contains 200 to 400 ppm of chloride, around 1,000 ppm of total dissolved solids, and the hardness ranges from about 250 to 350 ppm.

Calcareous rocks

Except on St. Croix, calcareous deposits are not extensive. The only calcareous rocks of significance on St. Thomas and St. John comprise the Outer Brass Limestone of Donnelly (1959). These rocks are confined to a narrow band paralleling the northeast coast of St. Thomas and part of the north coast of St. John. Two dug wells in St. Thomas that reportedly produced 2 to 5 gpm probably penetrated the limestone. No other information is available at this time concerning water in the Outer Brass, but exploration is warranted.

The Kingshill Marl, a complex of calcareous deposits, underlies much of central and southwestern St. Croix. These deposits comprise the most extensive and most productive ground-water reservoir in the Virgin Islands. The rocks are not of uniform permeability and wells will yield from a few to about 100 gpm of water of unpredictable quality.

Alluvium and beach deposits

Valley alluvium commonly is not extensive, and being thin and clayey, is not a source of large ground-water supplies. Relatively extensive areas in St. Croix are covered with alluvium but much of it is too thin to contain usable quantities of water. A few gallons per minute is the most that wells generally can be expected to yield, except in a few areas. In most places, not enough water is stored in the alluvium to allow sustained yields of more than a few gallons per minute, especially during drouth periods. The effect of alluvium on water quality is probably slight.

Sandy beach deposits, particularly in bay areas, contain small amounts of fresh water overlying salty water. Supplies of 1 gpm or less can be obtained from shallow wells in some areas, but higher pumping rates likely will result in sea-water encroachment. Collection galleries that skim the fresh water above sea level may yield somewhat larger supplies.

Developed and potential water supplies

The following sections of this report discuss the water resources by individual islands. Because the first gaging station was not installed until November 1962 the discussion of streamflow is based on only a few months of record. A little additional information was obtained from published and unpublished reports.

The division of the islands into ground-water areas (figs. 5 and 6) is based on known and inferred ground-water conditions. The description of the areas gives the general availability and quality of the water. The boundaries of most of the areas are approximate. In some areas, especially in St. John and St. Thomas, precise definition is not possible, and in some parts of the islands the transition from one area to another is gradual.

St. Croix

Developed supply

Potable water for the cities of Christiansted and Frederiksted is obtained from wells, whereas water for fire protection and to some extent for sanitary services is obtained from the sea. In both cities additional water is obtained from individual roof catchments and some water, although often brackish, is taken from dug wells for small private supplies.

Potable water for Christiansted is from five wells drilled in limestone along Salt River. The quantity of water pumped is about 100,000 gpd (fig. 7). Prior to the development of the well field, the public water-supply system consisted of a 30,000 square-foot hillside catchment and dug wells.

Potable water for Frederiksted is from three wells drilled in volcanic rock three-fourths of a mile north of the city. About 100,000 gpd is pumped from this well field (fig. 7), but much of the water is lost through leaky water mains. Before the well field was developed, the public water-supply system consisted of dug wells and a 9-million gallons reservoir on Creque Gut. The water from the reservoir often was turbid and was not used for drinking. During times of drouth the reservoir reportedly went dry. Siltation and apparent leakage of the dam has led to abandonment.

Rural residents obtain water from more than 100 drilled wells, a few dug wells, two hillside catchments, and roof catchments. In addition, about 25 dug or drilled public wells individually serve from a few to several hundred persons.

The Virgin Islands Corporation (VICORP) supplies water to about a dozen rural communities. These communities are served either by individual wells or by a distribution system supplied by two well field along River Gut.

The major industrial water users are the VICORP sugar mill, which obtains water from the well fields along River Gut and several individual wells, and two distilleries, which obtain water from 5 wells. Industrial water use is estimated to average about 150,000 gpd.

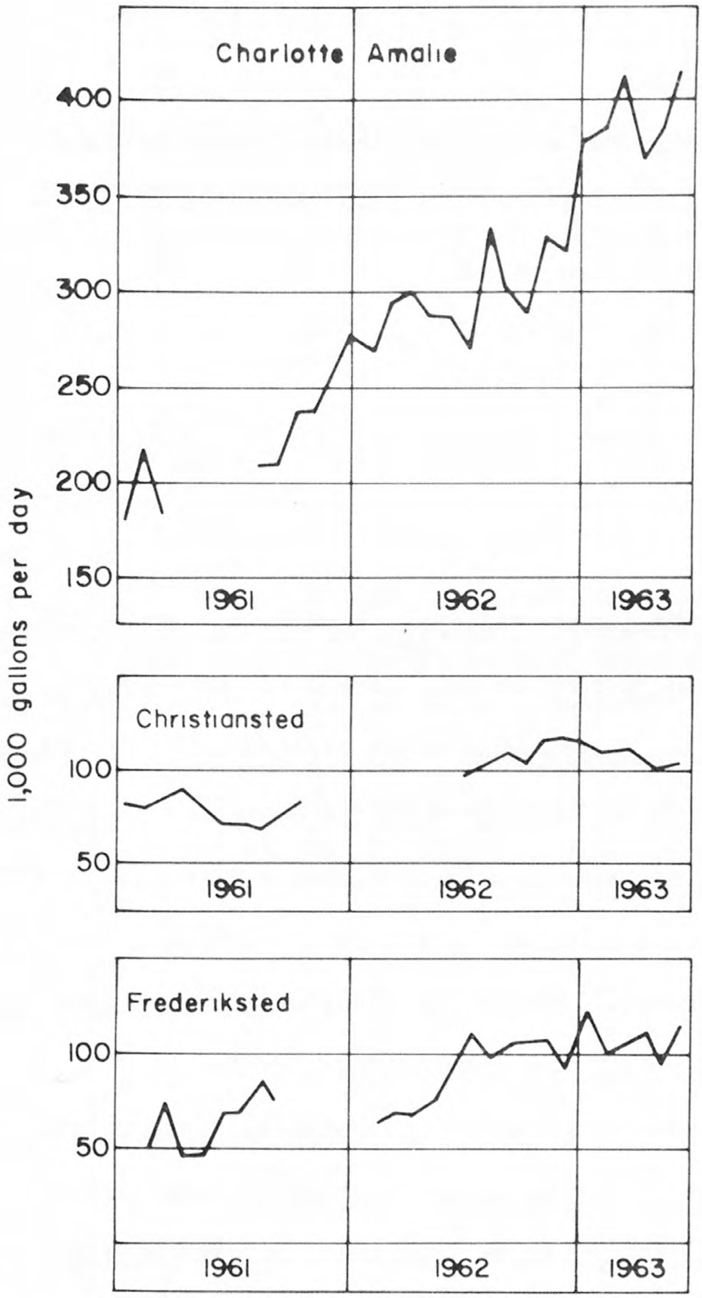

Figure 7.-- Approximate use of potable water in Charlotte Amalie, Christiansted, and Frederiksted, 1961-63.

About half the rural hotels and resorts have wells. The others rely on roof catchments and cisterns, supplemented by water hauled from other sources.

The only two commercial irrigation projects probably use no more than 1,000 gpd. A citrus nursery uses a pond as a water source, and a citrus orchard uses a well.

Potential

Potable ground water is obtainable in most parts of St. Croix (see fig. 5 and table 1). Depending on the location, wells will yield from less than 1 gpm in the volcanic rock, to 100 gpm in the alluvium and limestone in the larger valleys. A well that would yield 25 gpm of potable water would be considered a very good one.

Surface water.--The major streams in St. Croix, namely Creque, Jolly Hill, and River Guts, head in the mountains in the northwest part of the island. Creque and Jolly Hill Guts are perennial only at intervals along their courses. River Gut maintains flow over most of its length during the dry season. About half the year there is flow in Bethlehem and Caledonia Guts. All other stream channels in St. Croix are dry most of the time except during periods of relatively heavy rainfall. Observations of runoff and comparison with rainfall records indicate that storm runoff will occur in any given area about 6 times a year. The records also indicate that after a period of several weeks with no rainfall, an inch or more of intensive rainfall is necessary to cause appreciable storm runoff.

The only known streams that had continuous flow in at least part of their course throughout the first half of 1963 were Creque, Jolly Hill, and River Guts. Gages have been installed on Jolly Hill Gut near Jolly

Hill and on River Gut at River and at Golden Grove. Miscellaneous measurements have been made of a few streams. The low flow and chloride content of the water at selected sites are given in table 2.

The streams in the past have been sources of water for public supply, industry, and irrigation, but without sufficient storage they are not reliable sources of water. Indications are, however, that small supplies can be taken from the streams shown in table 2 most of the time. Surface storage immediately raises the problems of evaporation and sedimentation. The average annual evaporation from an open pan about 2 miles southwest of Christiansted is about 70 inches per year, which indicates that evaporation losses from a reservoir will be appreciable. The streams carry very little sediment during low flow, but considerable material is transported during high intensity storm runoff. In addition to the coarser sediments, storm runoff water contains large amounts of very fine material which will remain in suspension for long periods of time when trapped in reservoirs.

Ground water.--The development of major ground-water supplies generally has been confined to the limestone and alluvial deposits in the south-central part of the island where yields of 30 gpm or more have been obtained. Additional wells can be developed in a few areas that will produce 30 gpm or more from alluvium along Bethlehem and River Guts and from alluvium and limestone in other major valleys. Domestic supplies can be developed throughout these areas.

The ground water in the volcanic and intrusive rocks forming the mountainous areas of the island is essentially untapped. Yields of 5 to 10 gpm generally can be obtained from fractured and weathered zones in these rocks in the valleys of the Northside Range. Several of the larger valleys, such as those of Creque and River Guts, offer excellent possibilities for the development of wells yielding 30 gpm or more. Yields of wells in similar rocks in the Eastend Range probably will not exceed 10 gpm. Here, the valleys seem to follow zones of weakness in the rocks which generally are water bearing.

The limestone and alluvium along the south and southeastern flank of the Northside Range and extending across the north-central part of the island to Christiansted have a poor ground-water potential. The rocks have a low permeability and much of the water they contain is highly mineralized.

One of the principal problems in developing ground water is the poor chemical quality. For example, the chloride content of the water in the Kingshill Marl, the most extensive water-bearing unit on the island, ranges from about 400 to 1,000 ppm. In general, the chlorides increase with depth. Several wells have been drilled to depths considerably below sea level in efforts to obtain higher yields. The general result is the production of high-chloride water. Wells very near the coast likely will produce salty water unless the wells are shallow and the pumping level is maintained above sea level.

Table 1 gives information on developed and potential ground water supplies as related to geologic formations. The distribution of the rocks is shown on the geologic map (fig. 3). and the ground-water potential in different areas is shown on fig. 5.

St. Thomas

Developed supplies

Charlotte Amalie.--The public water system in Charlotte Amalie is a dual system, one part for fresh water and one part for salt water. The fresh water is used for drinking and general household use and the salt water is used for sanitary and fire-control purposes. The fresh-water supply, obtained from hillside rain catchments and a salt-water distillation plant, is supplemented by water barged from Puerto Rico.

Nearly all buildings, both private and public, in Charlotte Amalie have roof catchments and cisterns. In 1926, prior to the establishment of a public water system, there were about 200 private and 17 public dug wells in use in the urban area. Since then the majority of the wells have been abandoned because of sewage and salt-water contamination. Some of the salty water was pulled into the wells from the sea as a result of overpumping and some of it entered the wells from leaky salt water pipes. A few wells still are used occasionally for non-driking domestic supplies and for construction purposes. In recent years, wells have been dug in eastern Charlotte Amalie as a supplemental water supply for the two public housing projects. A number of wells have been dug in the same general area for non-drinking domestic use.

Since 1926, 18 public hillside rain catchments have been constructed. Of these, 14 are connected to the urban water distribution system. Water is hauled from the remaining four catchments by individual users or by water haulers. The total catchment area of the public catchments is estimated to be about 24 acres and the storage is estimated to be about 14 million gallons. Reliable figures are not available on the amount of water used from any of the catchments. In addition to the public catchments, four privately-owned catchments are in the urban area.

A system was built whereby rain water from the airport runway could be used to recharge the ground water, but the 1,700 foot collection gallery from which the water was to be taken is not used.

A recent rise in the demand for water is due in part to an increase in population and to a rise in living standards, but some of the increase in demand is due to an increase in the number of tourists who generally bring their habits of high water use with them. As an emergency measure. the U.S. Navy began in 1955 to barge water on a regular basis from Puerto Rico to St. Thomas. The Virgin Islands Government took over the barging operation when it became evident that if barging were stopped a severe water shortage would result. The quantity of water being barged is estimated to have been about 170,000 gallons per day in mid-1963.

A salt-water distillation plant was put into operation on January 11, 1963, and water was pumped to the public distribution system. The plant was designed to produce 275,000 gpd and in mid-1963 was producing about 325,000 gpd of water with a chloride content of less than 5 ppm. The chloride content is unnecessarily low; in fact, it probably is lower than that contained in the water collected from the rain catchments.

The water distribution system is operated as two interconnected, but separate systems. VICORP operates one system and the Public Works Department of the Virgin Islands Government operates the other. The housing area north of the airport and the airport use water from two catchments operated by VICORP. Occasionally the supply is supplemented with water purchased from Public Works. VICORP operates the distillation plant and uses the storage facilities of one of the hillside catchments for temporary storage, from which the water is pumped to the storage tanks at the treatment plant at the airport. Public Works operates the treatment plant and the distribution system for Charlotte Amalie.

The quantity of water entering the treatment plant is metered and it amounts to about 400,000 gpd (fig. 7). This does not account for all the fresh water used. For example, the water from the rain catchments is not metered, and undoubtedly some of the barged water and some of the water from the distillation plant is distributed without metering. All the water from all sources should be metered to determine, among other things, the amount of water lost by leaky pipes, which probably is large. As a conservation measure, leakage surveys and repairs of mains should be made.

Rural St. Thomas.--Most rural residents depend upon rainfall collected from rooftops for drinking and general household use. Privately-owned water supplies include several dug and three drilled wells, and two springs. Only one well is known to be used as a source of drinking water. Public rural supplies consist of 3 small hillside catchments and 10 dug wells. The water from these sources is used for general domestic purposes except that the well water generally is not used for drinking.

Most stock is watered from more than 30 small man-made ponds, a few dug wells, Turpentine Run, and a few small springs.

The only significant irrigation is at the Agricultural Experiment Station where water is diverted from Bonne Resolution Gut. In June 1963 the diversion amounted to 8,500 gallons every other day, but greater amounts have been used at times in the past.

Potential

Ground-water supplies can be obtained in several areas for domestic use and small communities from wells that will yield up to 15 gpm or more (see fig. 6 and table 3). Even in high mountainous regions domestic supplies probably can be obtained from wells drilled in the hard, fractured volcanic rocks. Recently. three wells have been drilled in these rocks, with estimated yields of about one gpm each. The initial yield of two of the wells was reported as 7 and 11 gpm, but since completion the yields are reported to have declined to an estimated one gpm each. From these figures it can be surmised that dewatering of the rocks in the vicinity of the wells has occurred.

Surface water.--Turpentine Run drains the largest basin in St. Thomas. Most of the time there is streamflow in the vicinity of Mt. Zion, but it is reported that there was no flow in that area from January 21 to September 23, 1923, and from November 29 to December 31 of the same year. From January through June 1963, the lowest flow observed at the gaging station near Mt. Zion was about 15,000 gpd. The average flow for that period is estimated to be about 35,000 gpd. Following a rainless period of several weeks, rainfall of an inch or more usually is required to produce a notable increase in streamflow. As runoff is fairly rapid, the stream returns to near low flow only a few hours after peak discharge.

The water, during low flow, usually contains 300 to 400 ppm of chloride and 1,000 ppm or more of dissolved solids.

The only other stream that has a low flow of any consequence is Bonne Resolution Gut, which may be perennial. The origin of the low flow is a series of small seeps issuing from weathered volcanic rocks of the Louisenhoj Formation. During the period November 17, 1962, through June 1963, the lowest flow was estimated to be 7,000 gpd and the average flow to be about

15,000 gpd. The flow of this stream disappears into the alluvium and beach sand before reaching the ocean, except during storm runoff. The chloride content of the water during low flow is about 250 ppm.

Little water can be taken from the streams the year round unless water is impounded during periods of storm runoff and stored for use during dry periods. But if supplies of 7,000 and 15,000 gpd are wanted that are easily available most of the time, the streams should not be overlooked as a potential source of water supply.

Ground water.--Most of the available ground water in bedrock is confined to fractured and weathered zones, which likely do not extend to depths below 100 feet. A trench was dug in the bottom of a tributary of Turpentine Run near Tutu, to a depth of about 25-30 feet in volcanic rocks. The trench, dug when the tributary was dry, cut across a fractured zone and at a depth of about 20 feet water begun seeping from the fractures. After excavating a few feet below the water table, water was pumped from the ditch at an estimated rate of 8 gpm for 24 hours. Additional supplies likely can be developed in other areas from similar trenches and dug wells located in stream courses.

Ground water can be obtained from alluvium in some of the valleys from shallow wells and collection galleries. The expected yield of wells will range from 1 to 15 gpm with average yield less than 5 gpm. The chloride content of the water will be 200-500 ppm except very near the coast where the chlorides may be higher. Much of the alluvium in the Charlotte Amalie area is polluted from sewage and leaky salt-water mains.

Small quantities of water can be taken from beach deposits but pumping levels must be kept above sea level to prevent sea water encroachment. Dug wells in the beach deposits probably will produce about 1 or 2 gpm.

St. John

Developed supplies

Three hillside rain catchments are the only public water supplies on St. John. Water from the catchment at Cruz Bay is piped to several public faucets in the village of Cruz Bay. The other public catchments are in rural areas where no distribution facilities are provided. Although most residents obtain drinking water from roof catchments, many persons supplement their supply by hauling water from the public catchments during periods of low rainfall.

The tourist resort at Caneel Bay utilizes a privately-owned hillside catchment, roof catchments, and a small sea-water distillation plant. The plant can convert sea water to fresh water at a rate of 30,000 gpd. At times the plant reportedly does not meet the demand and water must be used from storage.

The present fresh water use in St. John is not known, but it is estimated to be roughly 5,000 gpd, excluding the use at Caneel Bay. Using this figure and the population for 1960, which is 925, the per capita consumption is about 5 gpd. For contrast, the per capita consumption of fresh water at the Caneel Bay resort is estimated to be 100 gpd.

Potential

Small water supplies are obtainable from underground sources in many places in St. John (see fig. 6 and table 4). Indications are that dug wells and pits will produce from less than one to 5 gpm from alluvium. Larger yields may be expected in a few places. A test well dug to a depth of 30 feet in clayey alluvium inland from Coral Bay, was pumped for about 50 minutes at rates ranging from 9 to 84 gpm, essentially drying up the well.

The chloride content of the water remained below 400 ppm. The sustained yield of the well probably would be 5 gpm or less. Another test well was dug to a septh of 30 feet in clayey alluvium about 2,000 feet upstream from the beach at Reef Bay. The chloride content was less than 200 ppm. The yield is unknown, but it probably would be sufficient for a domestic supply. Several old dug wells exist but adequate tests have not been made to draw conclusions, except that some of them near the coast are too brackish to be used for drinking. The water in the few dug wells at higher elevations and away from the coast is potable and the wells are not subject to salt-water contamination.

Wells drilled in volcanic rocks in many upland areas probably will yield from a few hundred to several thousand gpd of potable water. Similar supplies may be obtainable by digging or excavating wells into volcanic rock in streambeds. It seems that most water contained in the volcanic rocks is confined to cracks and fractures; therefore, the best chances of constructing a successful well are in areas where the rocks are extensively broken and fractured. As a general rule wells should be bottomed above sea level to lessen the chances of salt-water encroachment.

Data from well points installed within a few hundred feet of the sea in beach areas on the north coast suggest that small amounts of potable water can be taken from the alluvium.

Of the nine known springs and seep areas, none are believed to be perennial except possibly the seep area on Guinea Gut. The seeps maintained the low flow of Guinea Gut from January through June 1963, the period for which records have been collected, but the seeps may dry up during prolonged droughts. The lowest flow of Guinea Gut for the period of record is estimated to be about 3,500 gpd and the average flow is estimated to be about 8,500 gpd. The chloride content of the water during low flow is about 350 ppm. No other streams in the Island are known to have flowed throughout the period January through June 1963.

In summary, small ground-water supplies (1 to 10 gpm) can be developed in many places from both consolidated and unconsolidated rocks. With the possible exception of Guinea Gut, streams cannot be relied on for perennial water supplies unless storage is provided.

Table 1.--Rocks in St. Croix and their relation to ground-water supplies

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
<u>Mount Eagle Volcanics</u> Predominately mudstone and siltstone interbedded with, and grading laterally into, tuff, sandstone, and mudstone. Includes some thin limestones, conglomerates, and breccias. Thickness, exceeds 30,000 ft.	Upper weathered and fractured zone yields 5 to 10 gpm of water, generally of drinkable quality, to several wells in the valleys of the Northside Range. Three wells, north of Frederiksted, yield about 30 gpm each. In east-central part of the island and in the Eastend Range, the general yield of wells is much smaller and the quality is poorer.	Domestic supplies probably can be obtained from wells at many localities. Wells in the east-central area and in the Eastend Range are likely to produce highly mineralized water in some localities. Much of the water is contained in erratically distributed fractures; therefore several test wells may be necessary for each successful well. The productive weathered zone generally is not developed below a depth of 100 feet and open fractures decrease with depth.

Table 1.--Rocks in St. Croix and their relation to ground-water supplies (Continued)

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
<u>Intrusives</u> Major intrusives are a gabbro, in the Northside Range, and a diorite, in the Eastend Range, both of which are coarse-to-fine-grained crystalline rocks. Small dikes of variable composition intrude rocks of the Mount Eagle Volcanics.	A well drilled in weathered intrusive rock in central part of the Northside Range produced 19.5 gpm. Two wells in weathered intrusive rock in the Eastend Range produced 10 gpm each. The chloride contents of the water from the wells were 200 and 300 ppm.	Supplies of a few to possibly 20 gpm can be obtained in several localities from the upper weathered zone.
<u>Jealousy Formation</u> Dark, grayish clay containing a few thin beds of limestone and calcareous conglomerate. Thickness, about 1,400 ft.	No wells are known to produce from these rocks. Only small quantities of highly saline water have been found in test holes.	Domestic supplies might be located at a few places from the basal conglomerate through a program of test drilling.

Table 1.--Rocks in St. Croix and their relation to ground-water supplies (Continued)

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Kingshill Marl Buff-to-white moderately thick-bedded limestone, alternating with soft cream or white marl. Contains some coral rubble, sandy limestone, and gravelly deposits derived from rocks of the Mount Eagle Volcanics. Thickness, about 600 ft.	Numerous productive wells have been completed in this unit. Four of the wells were pumped at rates of at least 100 gpm. Chlorides commonly range from 400 to 1,000 ppm.	Wells in many areas will yield from a few to 100 gpm of water of unpredictable chloride content. Many wells likely will produce brackish-tasting but drinkable water.

Table 1.--Rocks in St. Croix and their relation to ground-water supplies (Continued)

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Alluvium Predominately clay and silt with thin beds of clayey and silty sand and gravel. Includes beach sand in bay areas. Maximum thickness, about 80 ft.	Alluvial sand and gravel yield 40 gpm or more to several wells in the lower reaches of the valley of River Gut. Alluvial deposits supply part of the water pumped from the Christiansted and Frederiksted well fields. The quality of the water in the alluvium in the valleys of the Northside Range and most of the central plains area generally is fair to good. Chlorides range from 100 to 700 ppm.	Domestic supplies probably can be obtained from shallow wells in many localities. Wells with yields up to 20-40 gpm may be located in a few places. Salt water occurs near the coast and at the east end of the island, and may occur along the southeast flank of the Northside Range.

Table 2.--Flow and chloride content of gaged streams in St. Croix on selected dates, February to July 1963.

Stream	Gaging site 1/	Low flow (gpd)	Chloride (ppm)	Date
Creque Gut	A	7,200	90	2-19
Jolly Hill Gut	B	17,000	-	3-26
River Gut	C	85,000	80	7-26
Do	D	40,000	210	7-26
Do	E	90,000	-	4-23
Do	F	85,000	320	7-25

1/ Refers to locations shown on figure 5.

Table 3.--Rocks in St. Thomas and their relation to ground-water supplies

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Water Island Formation 1/ Lava flows, flow breccia, and water-laid tuff, intruded by dikes and plugs. Maximum thickness, exceeds 15,000 ft.	No wells are known to produce from these rocks and no perennial springs are known to flow from them.	It is likely that domestic supplies could be obtained from wells in areas where the rock is weathered and fractured. The water may be moderately mineralized but suitable for domestic use. Larger supplies might be located by test drilling.

Table 3.--Rocks in St. Thomas and their relation to ground-water supplies (Continued)

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Louisenhoj Formation 1/ Water-laid tuff, breccia, and a few thin beds of limestone. Near the base is a conglomerate composed chiefly of rocks derived from the Water Island Formation. Maximum thickness, probably exceeds 14,000 ft.	Two drilled wells reportedly produce enough water for domestic supplies and one dug well near Tutu reportedly yields a few gpm. A well dug into a small seep area near Rosendal is used for domestic purposes. A trench dug in a dry streambed near Tutu was pumped at an estimated rate of 8 gpm for 24 hours. The seemingly perennial base flow of Bonne Resolution Gut is sustained by small springs issuing from the Louisenhoj Formation. Much of the base flow of Turpentine Run is from these rocks. All of the known springs issue from this formation.	Supplies of 5 gpm or less can be obtained from wells, especially where the rock is weathered or fractured. Supplies are obtainable from dug wells near the bottom of small drainageways. Larger supplies of 15 gpm or more can probably be located by test drilling.

Table 3.--Rocks in St. Thomas and their relation to ground-water supplies (Continued)

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Outer Brass Limestone 1/ Thin-bedded siliceous limestone and a few thin beds of tuff. Thickness, 200-600 ft.	Two dug wells reportedly yield 2 to 5 gpm.	The limestone being thin bedded and fractured locally probably will yield enough water to wells for domestic supplies in many locations. Larger supplies may be possible.
Tutu Formation 1/ Fine-to-coarse grained conglomeratic, tuffaceous mixture of rocks derived chiefly from the Louisenhoj Formation. Contains some limestone. Thickness, exceeds 6,000 ft.	No wells are known to produce from these rocks.	The potential probably is low but a few domestic supplies may be obtainable from wells where the rock is fractured or weathered.

Table 3.--Rocks in St. Thomas and their relation to ground-water supplies (Continued)

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Alluvium Predominately clay and silt, discontinuous, beds of sand and gravel. Includes beach sand in bay areas. Maximum thickness, estimated 30 ft.	Numerous dug wells have produced water from the alluvium in several areas including the airport area east of Charlotte Amalie, and in the lower part of Turpentine Run. Many of the wells near the shore produced brackish water not suitable for drinking but suitable generally for stock.	It is probable that by carefully controlled pumpage, small domestic supplies could be obtained from shallow wells in bay areas and in the lower reaches of the major drainageways. Care must be exercised in installing and using wells in low areas very near the shore to prevent salt-water encroachment.

1/ Geologic names as used by Donnelly (1959).

Table 4.--Rocks in St. John and their relation to ground-water supplies

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Water Island Formation 1/ Lava flows, flow breccia, and waterlaid tuff. Metamorphism has altered much of the rock giving it a slaty appearance. Thickness, probably several thousand feet.	No wells are known to produce from these rocks but they are the source of several small seeps. Base flow of Fish Bay Gut apparently is supported by seepage from these rocks.	Small domestic supplies can be obtained from wells locally where the rock is weathered and fractured.
Louisenhoj Formation 1/ Water-laid tuff, breccia, and a few thin beds of limestone, near the base is a conglomerate composed chiefly of rocks derived from the Water Island Formation. Maximum thickness, may exceed 7,000 ft.	Several dug wells are known to produce a small amount of potable water from these rocks. Several small seeps issue from these rocks, and the low flow of Guinea and Battery Guts is apparently supported by seepage from these rocks.	Supplies of less than 1 to 10 gpm are obtainable in many places from drilled and dug wells, especially where the rock is weathered and fractured.

Table 4.--Rocks in St. John and their relation to ground-water supplies (Continued)

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Outer Brass Formation 1/ Thin-bedded siliceous lime-stone and a few thin beds of tuff. Thickness, 200-600 ft.	No wells are known to produce from these rocks.	It is likely domestic supplies can be obtained from wells, especially where fractured and weathered.
Tutu Formation 1/ Fine-to coarse grained, con-glomeratic, tuffaceous mixture of rocks derived chiefly from the Louisenhoj Formation. Contains some limestone. Thickness, may exceed 6,000 ft.	No wells are known to produce from these rocks.	It is likely domestic supplies can be obtained from wells, especially where weathered and fractured.

Table 4.--Rocks in St. John and their relation to ground-water supplies (Continued)

FORMATION	WATER SUPPLY	POTENTIAL WATER SUPPLY
Alluvium Predominately clay and silt with thin, discontinous, beds of sand and gravel. Includes beach sand in bay areas. Maximum thickness, estimated 30 ft.	Alluvial sands, in the lower reaches of the major valleys, and beach sands yield water in small amounts to dug wells ranging in quality from fresh to salty.	It is probable that by carefully controlled pumpage small domestic supplies can be obtained from shallow wells in bay areas and in the lower reaches of the major drainageways. Care must be exercised in installing and using wells in low areas very near the shore to prevent salt-water encroachment.

1/ Geologic name as used by Donnelly (1959).

References

Cederstrom, D. J., 1950 Geology and ground-water resources of St. Croix, Virgin Islands: U. S. Geol. Survey Water-Supply Paper 1067. 117 p., 6 pls.

A brief description of the geology and physiography. Discusses the sources and use of water. Contains considerable information on ground water including quantity and quality data. Includes a supplement on a drilling program conducted by the National Park Service. Contains a geologic map.

Donnelly, T. W., 1959, Geology of St. Thomas and St. John, Virgin Islands: Unpublished Ph. D. thesis, Princeton University, 170 p., 3 pls., 65 figs. A discussion of the geology including the origin, petrology, and structure of the volcanic and sedimentary rocks. Contains a geologic map.

Gibbs & Hill, Inc., Sheppart, T. Powell, 1946, Potable water supply for Charlotte Amalie, St. Thomas, Virgin Islands: Consultants reports, 41 p., 2 pls., 7 figs.

Summarized the water-supply facilities for Charlotte Amalie. Presents recommendations and cost estimates for constructing rainfall catchments. Shows cost comparison of methods for sea-water distillation.

Grossman, I. G., 1959, Ground water from St. Thomas, Virgin Islands: U. S. Geol. Survey open-file report, 35 p., 1 fig.

Presents data on wells, water levels, and the quality of the water.

Hendrickson, G. E., 1962, Development of the ground water resources of St. Croix, Virgin Islands: U. S. Geol. Survey open-file report, 84 p., 1 fig.

Discusses present and planned development of ground water for public supplies. Discusses the well fields in use and those developed for future use. Contains basic data on many of the wells drilled since 1940. Includes a ground-water availability map.

________________,(1963) Ground water for public supply in St. Croix, Virgin Islands: U. S. Geol. Survey Water-Supply Paper 1663-D, 27 p., 5 figs.

A summary of geologic formations on St. Croix and their relation to ground water. Contains data on wells in the major well fields.

Johnson, A. F., 1936, Water Supply for St. Thomas, Virgin Islands: U. S. Bur. Reclamation, mimeographed report, 26 p., 1 pl.

Recommends public rainfall catchments. Briefly summarizes the water situation. Recommends water-use studies. Includes reports on water supplies by other authors.

____________, 1937, Preliminary report on the water supplies for properties managed by the Virgin Islands Company, St. Croix, Virgin Islands: U. S. Bur. Reclamation, manuscript report, 77 p., 2 pls.

Makes recommendations for developing water supplies for irrigation and for public supplies for villages and labor camps.

diversions on Creque and Jolly Hill Guts and from wells drilled in calcareous rocks in central St. Croix.

Recommends improving the salt-water sanitary systems for both towns.

Tippetts-Abbett-McCarthy-Stratton, 1958, Potable water supply for St. Thomas, Virgin Islands: Consultants report, 55 p., 9 pls.

A summary of the existing water supply. Discusses future needs and possible sources of water.

______________________________, 1959, Potable water supply for St. Croix, Virgin Islands: Consultants report, 61 p., 10 pls.

A summary of precipitation, existing potable water supplies, and demand. Projects future water demands. Discusses development of additional supplies from ground-water and surface-water sources.

Vaughan, T. W., and Kidwell, C. H., 1920, The ground water resources of the West Indian Islands, St. John, St. Thomas, Culebra, Vieques, and of the eastern end of Puerto Rico: U. S. Geol. Survey open-file report, 53 p., 7 pls.

Contains a reconnaissance of the geology and data from more than 200 dug wells on St. Thomas, principally Charlotte Amalie. Discusses the quality and pollution of ground water in wells in Charlotte Amalie.

Van der Lippe, Paul, 1952, Report on the study of economic feasibility of dam sites on the Island of St. Croix, Virgin Islands of the United States: U. S. Bur. Reclamation duplicated report, 56 p., 9 pls.

Discusses potential dam sites for irrigation projects.

Whetten, J. T., 1961, Geology of St. Croix, U. S. Virgin Islands: Unpublished Ph. D. thesis, Princeton University, 102 p., 9 pls., 19 figs.

A discussion of the geology including the origin, petrology, and structure of the volcanic, tuffaceous sedimentary, and intrusive rocks. Contains a geologic map.

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