BIOLOGICAL, MORPHOLOGICAL, AND CHEMICAL CHARACTERISTICS OF WAILUKU RIVER, HAWAII

By Johnson J. S. Yee and Charles J. Ewart

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 86-4043

Prepared in cooperation with the

U.S. DEPARTMENT OF THE ARMY

PACIFIC OCEAN DIVISION

CORPS OF ENGINEERS

Fort Shafter, Hawaii

Honolulu, Hawaii

April 1986

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Inch-pound units have been used in this report. To convert to International System units, the conversion factors are listed below.

Concentration units for chemical data are given in milligrams per liter (mg/L), or micrograms per liter (µg/L). Specific conductance is expressed as micromho per centimeter at 25 degrees Celsius (µmho/cm at 25°C).

Multiply	By	To obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (ac-ft)	1,233	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon (gal)	3.785	liter (L)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

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ABSTRACT

Biological, morphological, and chemical data on Wailuku River were collected to assess its water-quality characteristics. Biological measurements included evaluation of benthic invertebrates, periphyton, phytoplankton and coliform bacteria. Morphological measurements consisted of channel surveys and particle-size determination of bed materials. Chemical-quality measurements, made monthly at two sampling stations, included water temperature, pH, specific conductance, dissolved-solids concentration, turbidity, dissolved oxygen, nitrogen, phosphorus, and minor elements.

Biological and chemical data indicate relatively clean water compared to similar streams in conterminous United States. The number and types of benthic organisms are low in Wailuku River. This is due mainly to channel gradient and flow velocities rather than to chemical toxicity. Periphyton data also indicate unpolluted water of low to moderate primary productivity. Diatoms are the dominant organisms observed in the periphyton samples. Coliform bacteria densities are typical of mountain streams in Hawaii that are essentially unaffected by human activities.

The streambed is formed of lava flows from Mauna Loa volcano, and the stream channel is characterized by a series of plunge pools and waterfalls. The longitudinal slope ranges from five percent at midreaches to eight percent at the headwater regions. There is no broad flood plain at the mouth of the stream. The stream channel is generally a narrow steep-sided trapezoid with an irregular base. Streambanks are composed of fine- to very coarse-grained material. Channel depth increases from 6 ft (feet) at the headwaters to 40 ft at Hilo. The width also increases from 60 ft at the highest study site to 220 ft at the Hilo site near the mouth of the river.

Bed materials that move as bedload ranged in diameter from 4 to 90 mm (millimeters). The percentage of smaller size materials is higher in the headwater areas that drain barren cinder land. Boulders, larger than 256 mm in diameter, are common in the streambed at lower elevations.

Suspended-sediment discharges into Hilo Bay are highest during storm runoff. Sediment discharge during a storm 4 months after the study period, on February 20, 1979, was 24 percent of the total sediment discharge over a 31-month period. The percentage of sand-size particles in the Wailuku River is larger than that observed in Oahu streams.

The chemical quality of Wailuku River is excellent. Average water temperature increased 1.4°C (degree Celsius) between the 4,250-foot elevation and near sea level. The pH ranged from 5.0 to 8.5 units. Dissolved-solids concentrations of the water did not exceed 62 mg/L (milligrams per liter). Calcium, magnesium, sodium and bicarbonate are the major ions in the water. Dissolved-oxygen concentrations ranged from 88 to 113 percent saturation. Nitrogen and phosphorus concentrations ranged from 0.00 to 2.0 mg/L. Minor element concentrations seldom exceed U.S. Environmental Protection Agency's drinking water standards.

INTRODUCTION

In cooperation with U.S. Army Corps of Engineers, (USCE), Honolulu District, the U.S. Geological Survey (USGS) made an assessment of the biological, morphological, and chemical characteristics of the Wailuku River on the Island of Hawaii. This report presents the results of the investigation.

This assessment is based mainly, but not entirely, on information collected in water year 1978 from six sites shown in figure 1. Table 1 shows the types of data collected or available for this report.

The six sampling sites, are:

Station A. Wailuku River near Pua Akala. The station is at 6,840-foot elevation on Keanakolu Road, 2.4 miles southwest of Pua Akala, and 18 miles west of Hilo. The station has a drainage area of 10.2 mi^2.

Station 16701750. Wailuku River near Humuula. The station is at 4,250-foot elevation, 10 miles east of Humuula, and 14 miles west of Hilo. The drainage area is 34.8 mi^2.

Station 16701800. Wailuku River near Kaumana. The station is at 3,520-foot elevation, upstream of Waipahoehoe Gulch and 8.4 mile west of Kaumana. Drainage area is 43.4 mi^2.

Station 16704000. Wailuku River at Piihonua. The station is at 1,090-foot elevation, 0.9 mile from Piihonua. Drainage area is 230 mi^2.

Station B. Kapehu Stream at Piihonua. The station is at 880-foot elevation, approximately 1,000 yards upstream from its confluence with Wailuku River.

Station 16713000. Wailuku River at Hilo. The station is at 80-foot elevation, about 0.2 mile west of Hilo Post office. It is the lowest downstream station. Drainage area is 256 mi^2.

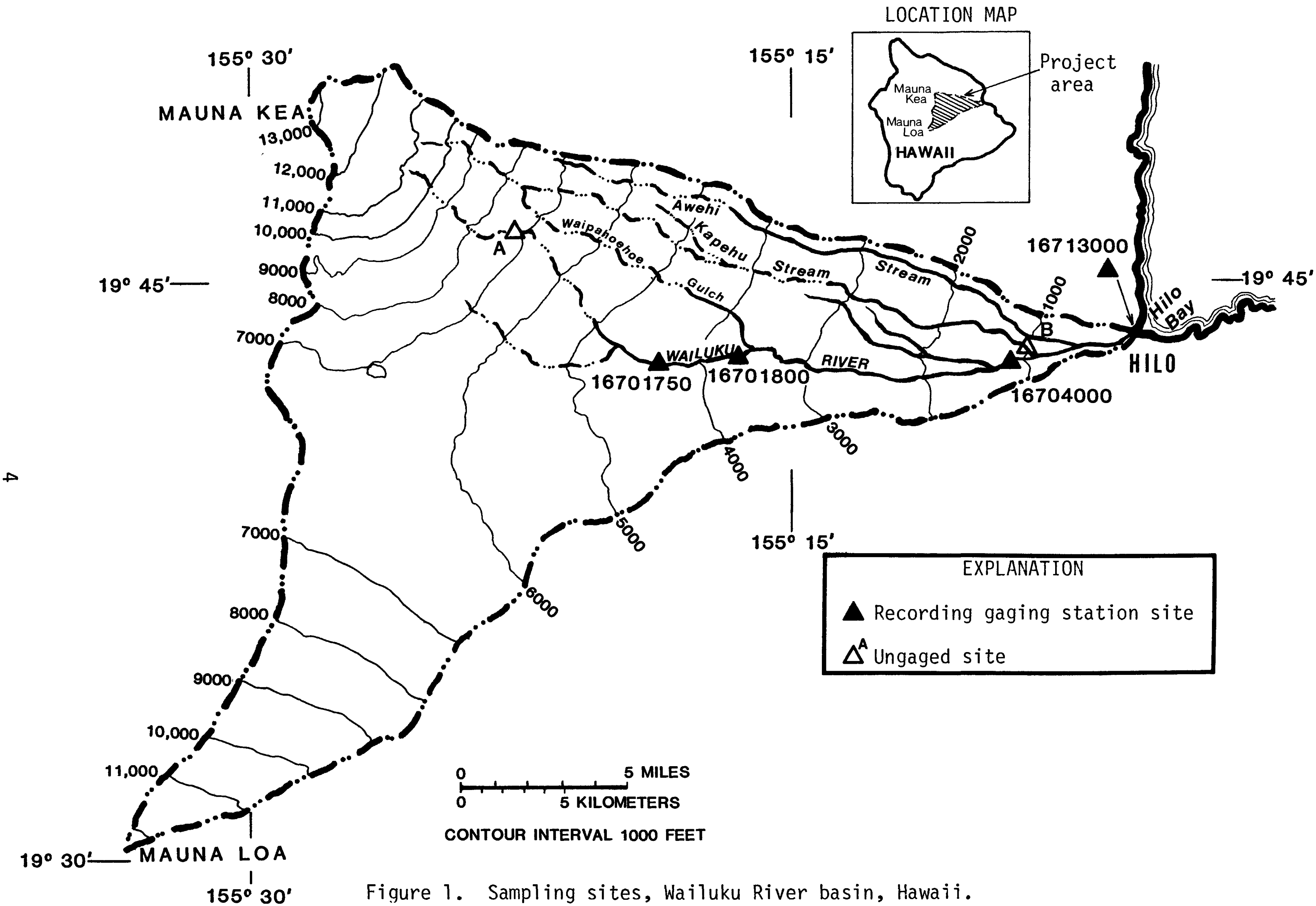


Figure 1. Sampling sites, Wailuku River basin, Hawaii.
Base from U.S. Geological Survey.

Table 1. Types of data collected (x) or available (a) at each station

Data	Station					
	A	16701750	16701800	16704000	B	16713000
Biological						
Benthic invertebrate -------	x	x	x	x	x	x
Periphyton -----------------		x	x	x		x
Seston ---------------------			x	x	x	x
Total coliform -------------			x	x	x	x
Fecal coliform -------------			x	x, a	x	x, a
Fecal streptococcus --------			x	x, a	x	x, a
Phytoplankton --------------				a		
Morphological						
Cross-section survey -------	x	x	x	x	x	x
Bed-material size ----------	x	x	x	x	x	x
Suspended sediment						a
Chemical						
Temperature, pH, specific conductance --------------		a	a	a		a
Common constituents --------		a	a	a		a
Major nutrients ------------				x, a		x, a
Minor elements -------------				a		a
Dissolved oxygen -----------				x, a	x	x, a
Surface water --------------		a	a	a	x	a

Acknowledgments

Keith V. Slack, research biologist from the Geological Survey's Western Regional office in Menlo Park, California, provided guidelines for collection of biological samples. His research laboratory processed and identified the benthic invertebrate samples.

Hawaii's State Department of Land and Natural Resources, Division of Water and Land Development provided funds for the operation of streamflow stations from which surface-water data were collected and used in this report. The surface-water data network is a part of the continuing cooperative program between the U.S. Geological Survey and Hawaii's State Department of Land and Natural Resources.

HYDROLOGIC SETTING

Of all the streams in the State of Hawaii, the Wailuku River has the greatest length and the largest drainage area. It is on the northeastern side of the Island of Hawaii. Its headwater is at an elevation of about 11,000 ft near the summit of Mauna Kea and its length from headwater to mouth is about 26 miles. It drains approximately 256 mi^2 (square miles) of forest reserve, agricultural and urban lands.

Rainfall in the Wailuku River basin ranges from 8 inches per year on the summit of Mauna Kea (State of Hawaii: Data Book, 1981) to more than 300 inches per year at intermediate elevations. The maximum rainfall area is located about 10 miles west of Hilo at an elevation of 2,000 to 3,000 ft. Near sea level, the annual rainfall is about 130 inches. Figure 2 shows the mean annual rainfall distribution for the Wailuku River basin.

Land uses in the Wailuku River basin are: forest reserve 76.5 percent, pasture 20 percent, sugarcane and diversified crops 2.5 percent, and urban 1 percent (U.S. Department of Agriculture, 1976). The forest reserves include barren lava and cinder land in conservation areas. These conservation lands are on the upper and middle slopes of Mauna Kea and Mauna Loa. Pasture lands, used mostly for cattle grazing, are located generally between the 5,000- and 8,000-foot elevation. Sugarcane lands extend to about the 2,000-foot elevation. Figure 3 shows the general land-use pattern for the Wailuku River basin.

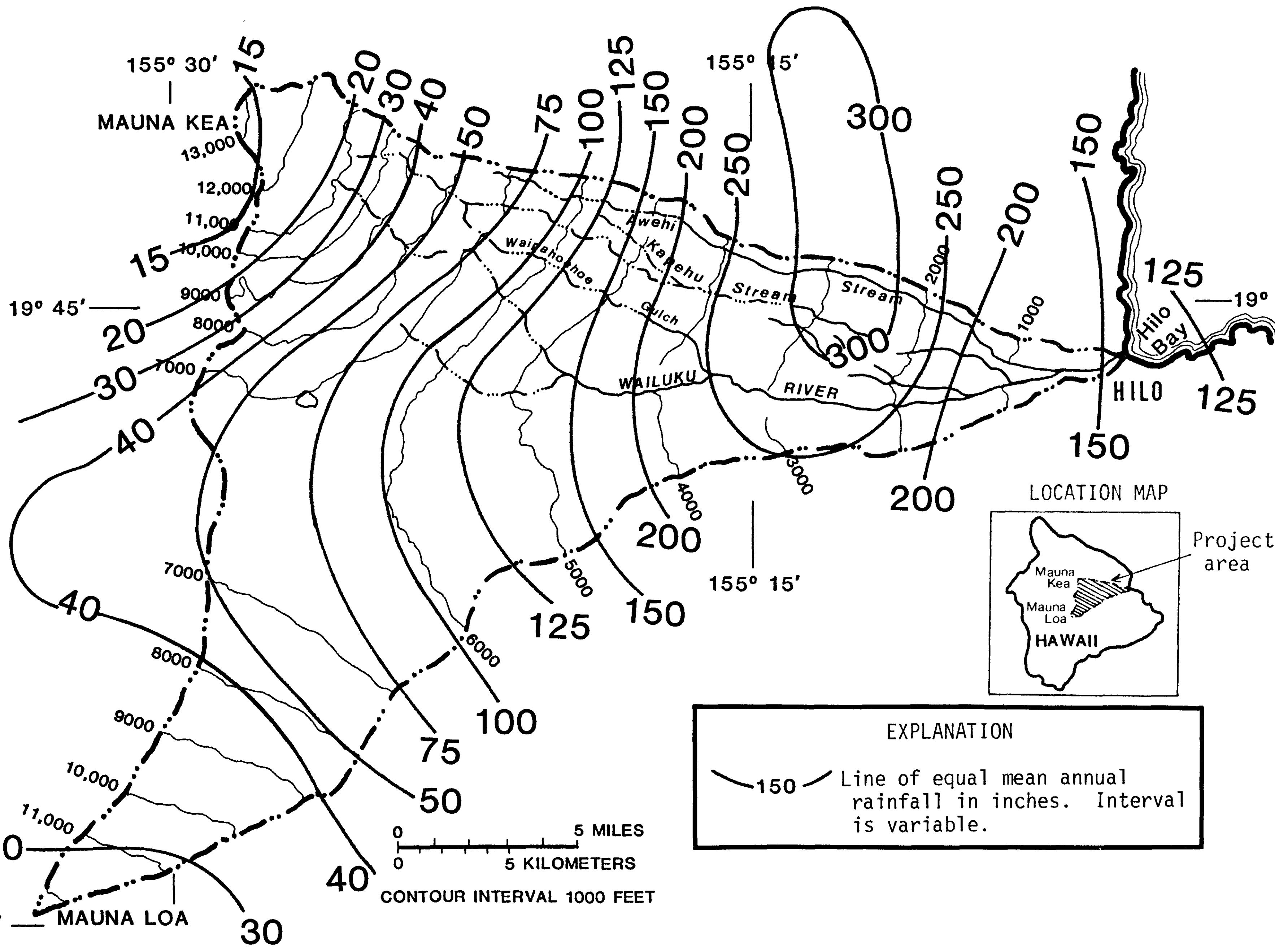


Figure 2. Mean annual rainfall in Wailuku River basin, Hawaii. Base from U.S. Geological Survey; rainfall data from National Weather Service.

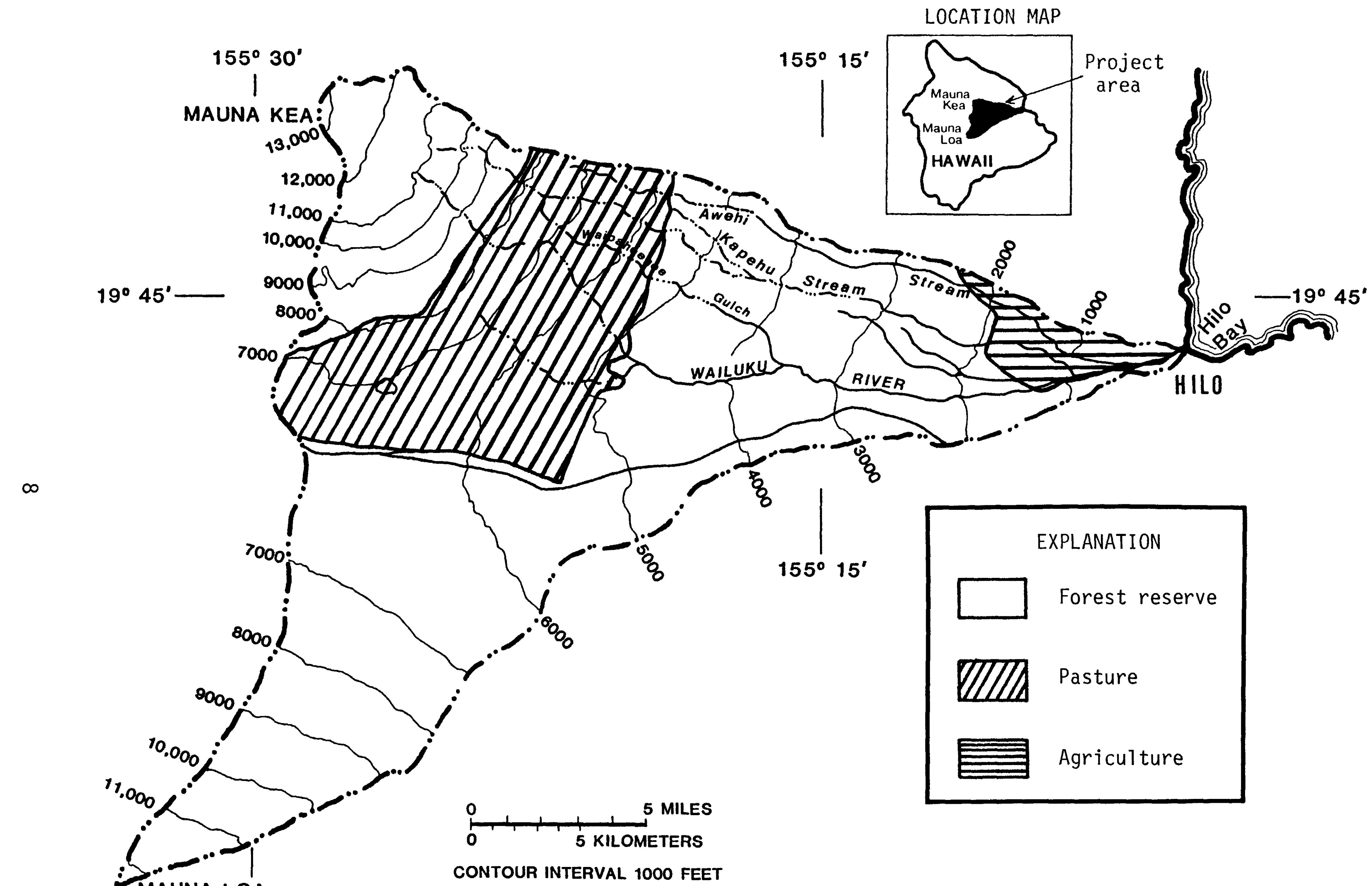


Figure 3. General land use, Wailuku River basin, Hawaii. (Land use data from U.S. Soil Conservation Service, 1976).

STREAMFLOW RECORDS

The U.S. Geological Survey began measuring streamflow in the Wailuku River basin in 1911. Since that time, measurements have been made at 12 locations within the basin. Two gaging stations now monitor continuous streamflow on the main stem. The locations of existing and discontinued stations are shown in figure 4. Table 2 lists the name and period of record for the stations in the Wailuku River basin.

All streamflow records are published regularly by the Geological Survey. Records for the period 1911-60 are published in the Water-Supply Paper series listed under the Selected References (U.S. Geological Survey, 1913-60). Subsequent records are published annually in "Water Resources Data for Hawaii and Other Pacific Areas" (U.S. Geological Survey, 1961-83).

Gaging station 16704000, located at elevation 1,090 ft, has 52 years of streamflow record. A flow-duration curve derived from this record is shown in figure 5. It shows the distribution of the daily discharge and the percentage of time within the period of record when a specified discharge was equaled or exceeded. The highest daily mean discharge, 22,200 ft^3/s (cubic feet per second) was on January 8, 1975, and the lowest, 0.31 ft^3/s, persisted for several days in February 1963.

The downstream gaging station, 16713000, in Hilo had a peak discharge of 65,500 ft^3/s on November 17, 1979. Although the period of record for this station is too short to evaluate the flood frequency, the data for station 16704000 upstream suggest an average recurrence interval of 40 years (0.025 percent probability).

The Wailuku River discharges an average of about 450 ft^3/s annually into Hilo Bay. About 2 percent of the flow is diverted for domestic use, and nearly 15 percent is used for hydroelectric power for the City of Hilo. The water for the power plant, however, is returned to the river near the mouth, just below gaging station 16713000.

During dry periods, no flow is recorded above the 3,500-foot elevation. Below this elevation, flow appears from springs and seeps along the banks. Streamflow increases gradually downstream due to discharges from springs and tributaries. The largest of the springs are Waterhole Spring at an elevation of 2,360 ft, Kapehu Spring at 2,040 ft, Olaa Flume Spring at 1,960 ft, Lyman Spring at 1,620 ft, and Kaumana Spring at 410 ft.

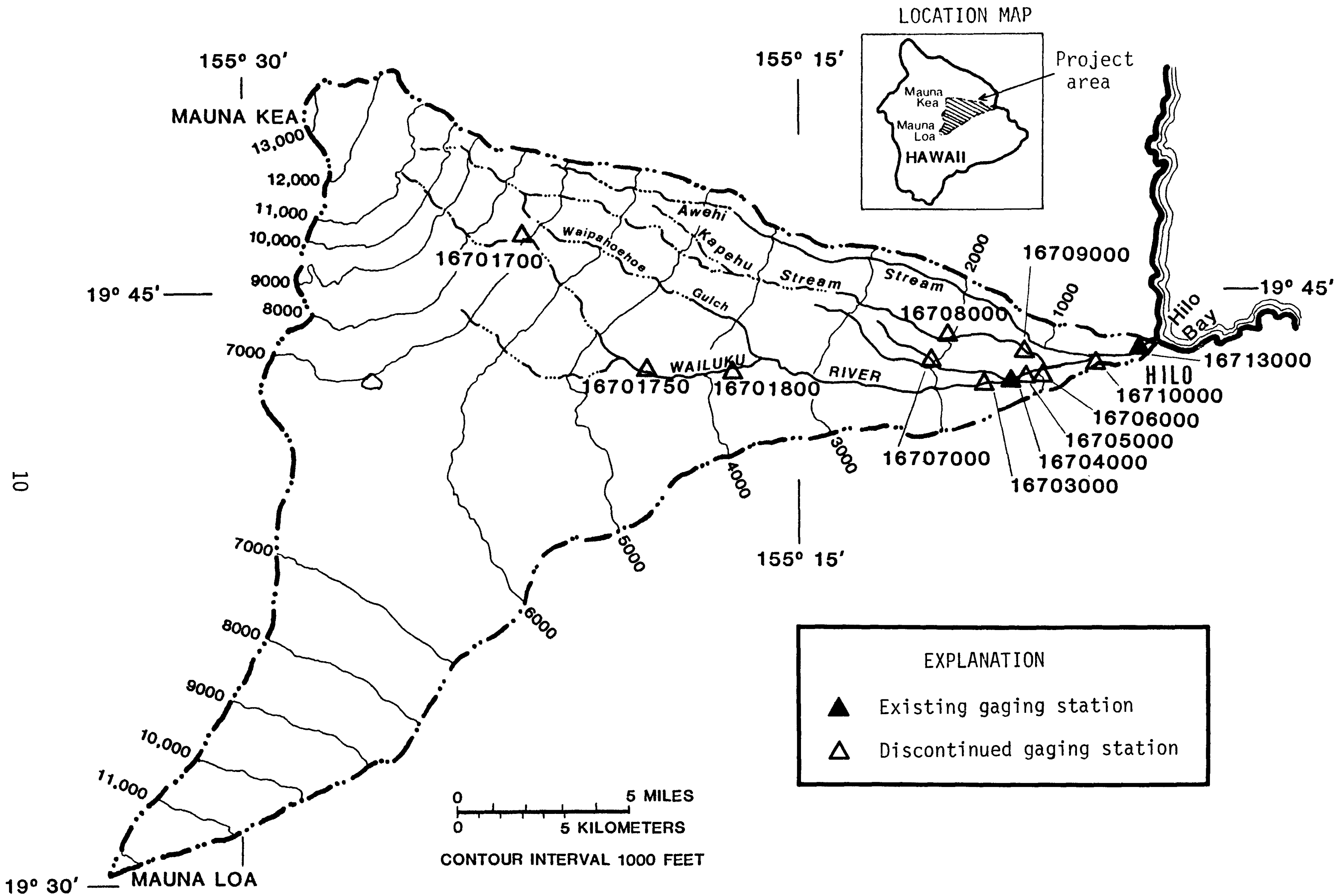


Figure 4. Locations of existing and discontinued gaging stations, Wailuku River basin, Hawaii. Base from U.S. Geological Survey.

Table 2. Gaging stations and period of record, Wailuku River basin, Hawaii

Station No.	Name	Period of record
16701700	Wailuku River near Pua Akala	1964-65.
16701750	Wailuku River near Humuula	1965-83.
16701800	Wailuku River near Kaumana	1966-83.
16703000	Wailuku River at Pukamaui	1923-40.
16704000	Wailuku River at Piihonua	1928-present.
16705000	Hilo Boarding School ditch at intake, near Hilo	1931-40.
16706000	Hilo Boarding School ditch near Hilo	1918-19.
16707000	Kapehu ditch diversion near Hilo	1954-62.
16708000	Kapehu ditch near Hilo	1938-62.
16709000	Kapehu Stream near Hilo	1928-36.
16710000	Wailuku River near Hilo	1911-13, 1918-19.
16713000	Wailuku River at Hilo	1977-present.

The mean discharges recorded during water year 1978 at four gaging stations on the Wailuku Rivers were:

Station No.	Location	Elevation (feet)	Discharge (cubic feet per second)		
			Mean daily	Maximum	Minimum
16701750	Near Humuula	4,250	0.29	15	0.0
16701800	Near Kaumana	3,520	5.6	150	0.0
16704000	At Piihonua	1,090	164	3,260	1.8
16713000	At Hilo	80	286	4,920	6.9

Figure 6 shows a hydrograph of the monthly mean discharges recorded during the 1978 water year.

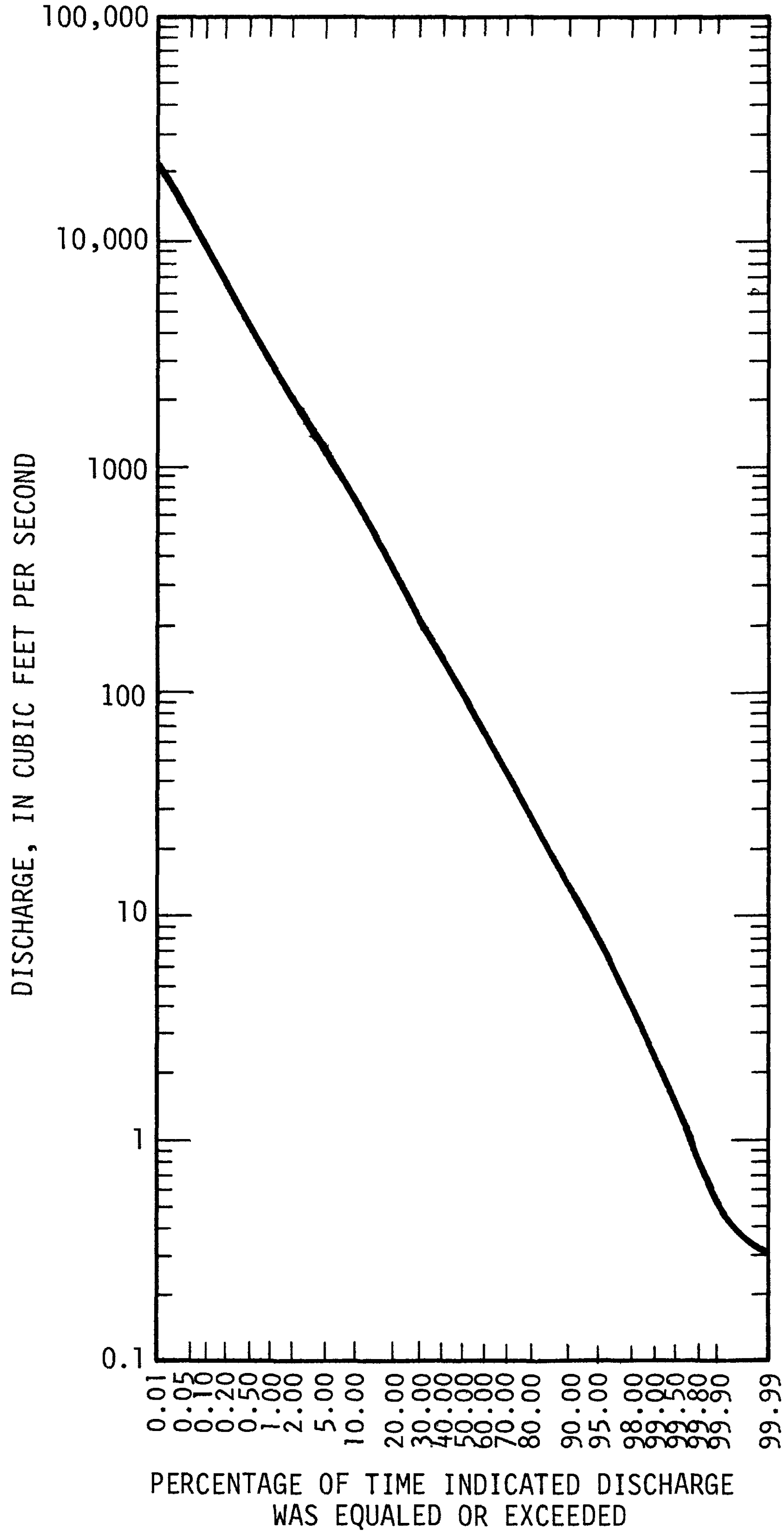


Figure 5. Duration curve of daily flow, station 16704000, Wailuku River at Piihonua, Hawaii, 1929-79.

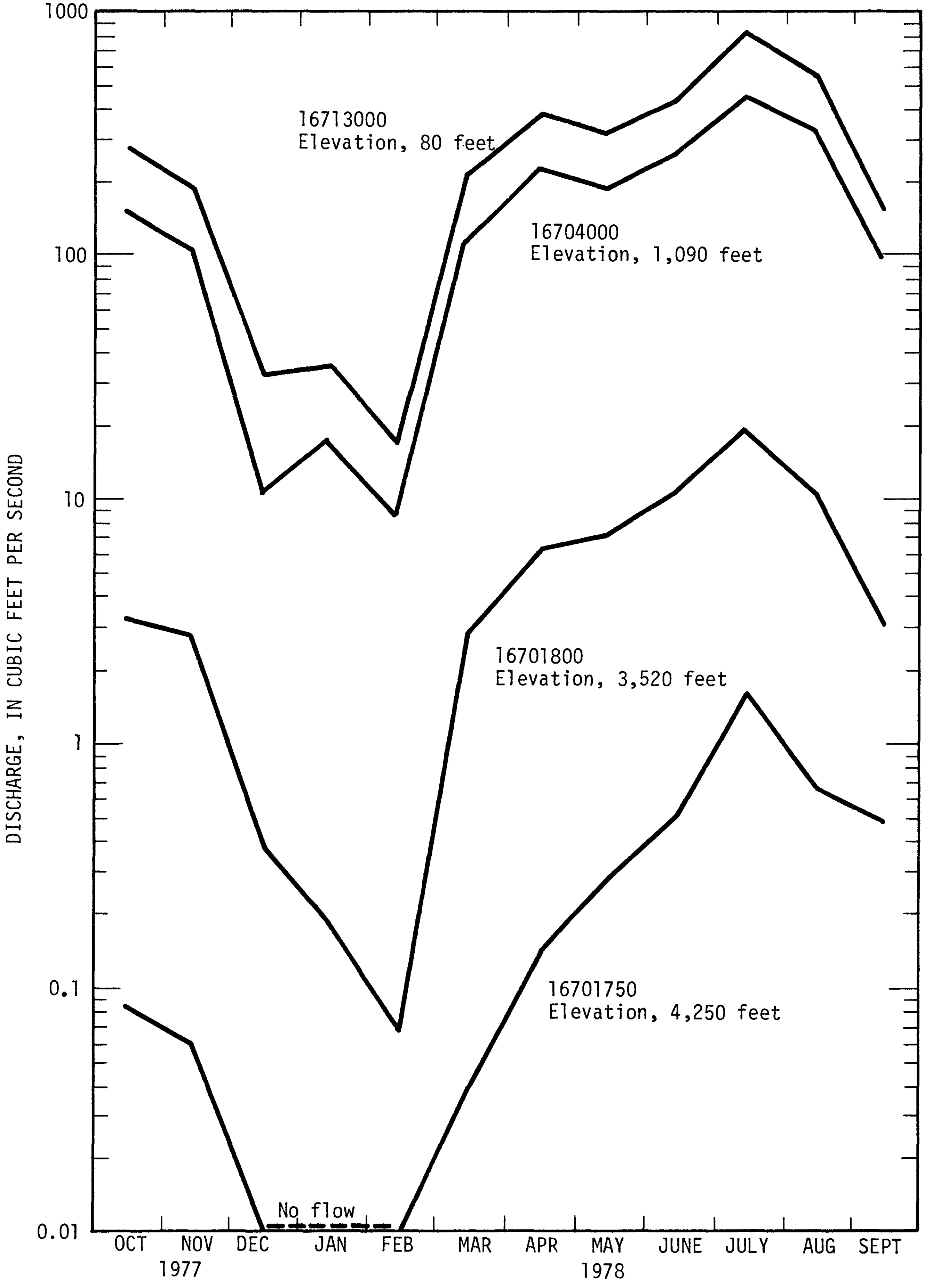


Figure 6. Mean monthly discharge for four gaging station sites, Wailuku River, Hawaii.

SAMPLE COLLECTION AND ANALYSIS

Standard U.S. Geological Survey methods for sample collection and analysis were used. Samples were collected, preserved, and shipped to the laboratory using the guidelines described in Techniques of Water Resources Investigations series of the United States Geological Survey (Skougstad and others, 1978; Greeson and others, 1977).

Benthic invertebrate samples were identified at the Geological Survey research laboratory in Menlo Park, California. Periphyton and phytoplankton samples were analyzed at the Survey's National Water-Quality Laboratory in Atlanta, Georgia. Bacteria determination were made at the Hilo field office. Bed-material samples were analyzed on a Zeiss[*/] particle-size analyzer at the Geological Survey's California subdistrict office in Sacramento, California. Temperature, pH, specific conductance, and dissolved oxygen readings were taken at the sampling sites. Other chemical determinations were made at the Geological Survey's Denver National Water-Quality Laboratory. Table 3 gives a summary of collection methods, equipment used and TWRI references.

[*/] Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 3. Summary of collection method, equipment and TWRI reference

	Collection method	Equipment	TWRI reference
Biological samples			
Benthic invertebrate	Artificial substrate	Jumbo multiple-plate sampler	Greeson and others, 1977.
	Dip net	D-shaped net, Turtox 73-412	Do.
	Drift net	Stream drift net, Wildco No. 15	Do.
Periphyton	Artificial substrate	2x6 in., polyethylene strip	Do.
Seston	Glass-fiber filter	Depth integrating samplers, filtration units	Do.
Phytoplankton	Depth-integrating single point tranverse	1 liter polyethylene sample bottle	Do.
Bacteria	Membrane filtration	Milipore filtration kits	Do.
Morphological data			
Cross section	Transit-stadia surveys	Engineer's transit	Benson, M.H., and Dalrymple, D., 1967.
Particle-size bed material	Optical	Camera, Zeiss particle-size analyzer	Ritter, J. R., and Helley, E. J., 1969.
Suspended sediment			
Suspended sediment	Automatic sampler	PS-69, stage-time activated sampler	Federal Inter-Agency Sedimentation Project, 1970.
Chemical-quality data			
Chemical	Depth-integrating single transverse	Depth-integrating sediment sampler, polyethylene bottles	Skougstad and others, 1978.
Conductivity	Electrometric, Wheatstone bridge	Beckman RB3-338	Do.
pH	Electrometric glass electrode	Leeds and Northrup model 7417	Do.
Dissolved oxygen	Titrimetric, Winkler	Titration glassware	Do.
	Electrometric, polarographic probe	Yellow Springs Instrument, model 54 with recorder	Do.

RESULTS AND DISCUSSIONS

Biology

Benthic invertebrates

Benthic invertebrate samples were collected from five stations on the Wailuku River and from one location on Kapehu Stream, a major tributary of the river. Each station was sampled during a survey conducted over a 30-day period in November 1977. A second survey, spaced over 60 days during July-September 1978, sampled all stations except station A. This site is dry most of the year with flow only during periods of heavy rainfall.

The number and kinds of organisms collected at all stations and dates are shown in table 4. The number of organisms and the number of taxa at the sampling sites are very low when compared to similar streams in conterminous United States. This is due, in part, to the channel morphology and the flow regime in the stream. The channel gradient is steep. The stream velocities are high in riffle areas, and slow in pool areas. The flow and the velocity often undergo large changes within a short period of time. These intermittent high velocities scour most of the benthic invertebrates from the streambed and wash them to the ocean. The geographical location of Hawaii, away from other large land masses, also contributes to low numbers of stream taxa.

Biological factors also control the number and diversity of organisms in this stream. Competition and predation are very intense amongst native and introduced aquatic organisms. This interaction has resulted in the loss of many native species. Timbol and Maciolek (1978) reported finding very few native insects at the lower reaches of Wailuku River. The stream may be too low in primary productivity to support high secondary productivity. From visual observation, there is very little periphyton on the natural substrate at the sampling sites, except at station 16713000 where there appears to be a moderately high standing crop.

A disease characterized by necrotic lesions of the exoskeleton is prevalent amoung the Opae kala'ole (freshwater shrimp), Atya bisulcata, found in the Wailuku River. Chan (1978) suggested that these lesions are related to the physical-chemical characteristics of the stream. The relatively high velocity and silt load in the Wailuku River create an abrasive environment which could lead to the formation of lesions.

Table 4. Benthic invertebrates

(Collection method: H, hand sampled; M, multiplate; D, drift net; d, dip net)

Division .Class ..Order ...Family ....Genus, Species	Common name	A	16701750		16701800		16704000		B		16713000	
		11/3/77	11/4/77	9/14/78	11/1/77	7/28/78	11/30/77	9/12/78	11/2/77	7/25/78	11/30/77	7/27/78
		H	H	H, M	H,M,D,d	H,M,D,d	H,M,D,d	H,M,D,d	H,D,d	H,M,D,d	H,M,D,d	H,M,D,d
Annelida												
.Oligochaeta		1	1	225	3	16	1	4	3	108	3	73
.Hirudinea	Leeches					1	1	2	1	3		
.Turbellaria						45				1		
Arthropoda												
.Crustacea												
..Ostracoda	Seed shrimp		4				2	30		2		
..Copepoda			4		2	5	3	5		4		1
..Isopoda												
...Cirolanidae		1							5	30		
..Amphipoda												
...Talitridae												
....*Hyallela azteca*								2	8	18		
..Decapoda												
...Atyidae												
....*Atya bisulcata*	Opae kala'ole						247	10	6	3	5	
.Arachnoidea												
..Acarina	Water mites											
...Cryptostigmata												
....*Nothroidea*				1	2	1						
....*Hydrozetes*		1		8	9	240		20		1		17
....*Trhypochthenius*				3	2	83		17		9		12
....*Ceratozetoidea*					8	5						2
....*Limnozetes*						2		2		1		2
.Insecta												
..Trichoptera												
...Hydroptilidae												
....*Oxyethira*			1	2	13	18	15	42		24	3	
...Hydropsychidae												
....*Cheumatopsyche analis*	Caddisfly				1		8	4	88	127	18	1
..Odonata												
...Aeshnidae	Dragonfly			1								
...Coenagrionidae	Damselfly				3	3		2		5		
..Hemiptera												
...Veliidae												
....*Microvelia*			3		19	2		1				
..Coleoptera												
...Dytiscidae	Water beetle											
....*Hydroporus*		1	1									
....*Rhantus*		3										
..Diptera												
...Ephydridae												
....*Scatellinae*						9		1	39	5	37	15
...Chironomidae	Midges											
....*Tanytarsus*		2		1		12	3	20		35		15
....*Chironomus*				1		1						
....*Eukiefferiella I*					43	207	5	18	20	530	53	31
....*Cricotopus I*					15	81	1	26	19	459	24	255
....*Eukiefferiella II*						1				12		
....*Cricotopus II*						3		1		5		
...Tipulidae	Cranefly											
....*Geranomyia*						4		2	1	17	1	
...Ceratopogonidae												
....*Forcipomyia*						3				1		
..Collembola	Springtails											
...Poduridae					2	1		3		5		1
...Entomobryidae					1	1		1	1	1		3
...Sminthuridae						1						1
Mollusca												
.Gastropoda	Snails											
..Basommatophora												
...Ancylidae												
....*Ferrissia*			4	20		4						
...Planorbidae												
....*Gyraulus*		15	6	8	7			5	2	1		2
...Lymnaeidae												
....*Lymnaea*								2		2		
..Rhipidoglossa												
...Neritidae												
....*Neritina granosa*	Hihiwai										12	2
.Pelecypoda	Freshwater clams						3		1			
Taxa per collection		7	8	10	15	26	10	24	12	26	9	16
Taxa at station		7	14		28		24		26		19	
Number of organisms		24	24	270	130	752	286	221	193	1409	156	433

There are no data that indicate chemical toxicity on the benthic invertebrate populations in Wailuku River. No significant concentration of toxic trace metals or pesticides were detected.

The benthic invertebrate analyses also show that two of the most common groups of organisms in unpolluted streams, mayflies (Ephemeroptera) and stoneflies (Plecoptera), are absent in the Wailuku River as are in other Hawaii streams (Timbol and Maciolek, 1978). Some insects such as Lepidoptera, Pyralidae, and Nymphalidae, common in many Hawaii streams, were not found probably because of limitations of the sampling methods. The relative percentages of the major groups of organisms differed markedly among the six sampling stations (fig. 7).

Considering only the presence or absence of benthic taxa at different stations, the two headwater stations, A and 16701750, appear to have a fauna different from that of the lower four stations. To test this hypothesis, Jaccard similarity coefficients were calculated and used to evaluate degrees of similarities for all pairs of stations (table 5). Jaccard coefficients range from zero for no similarity to one for complete similarity. For the Wailuku River, the coefficients ranged from 0.13 to 0.79. Higher coefficients denote greater similarity.

The matrix of Jaccard similarity coefficients is graphically presented in a dendrogram to show similarity relationships between Wailuku River stations (fig. 8). The dendrogram shows two distinct groups of stations on the basis of presence or absence of the benthic taxa. Stations A and 16701750, designated subsequently as A-16701750 have low within-group similarity and perhaps should be considered two groups. More intensive sampling would be needed to clarify this. In any case, the A-16701750 cluster is distinct from the cluster of four downstream stations which have high within-group similarity. The fauna at stations 16704000 and B are similar, and that of station 16713000 is least similar to the other stations in this group. The fauna at station 16713000 may be more affected by marine influences than the other sites.

Periphyton

Periphyton (the community of microorganisms that are attached to or live upon submerged surfaces) samples were collected at four sites on the Wailuku River. Biomass, chlorophyll a, and chlorophyll b values were determined from these samples (table 6).

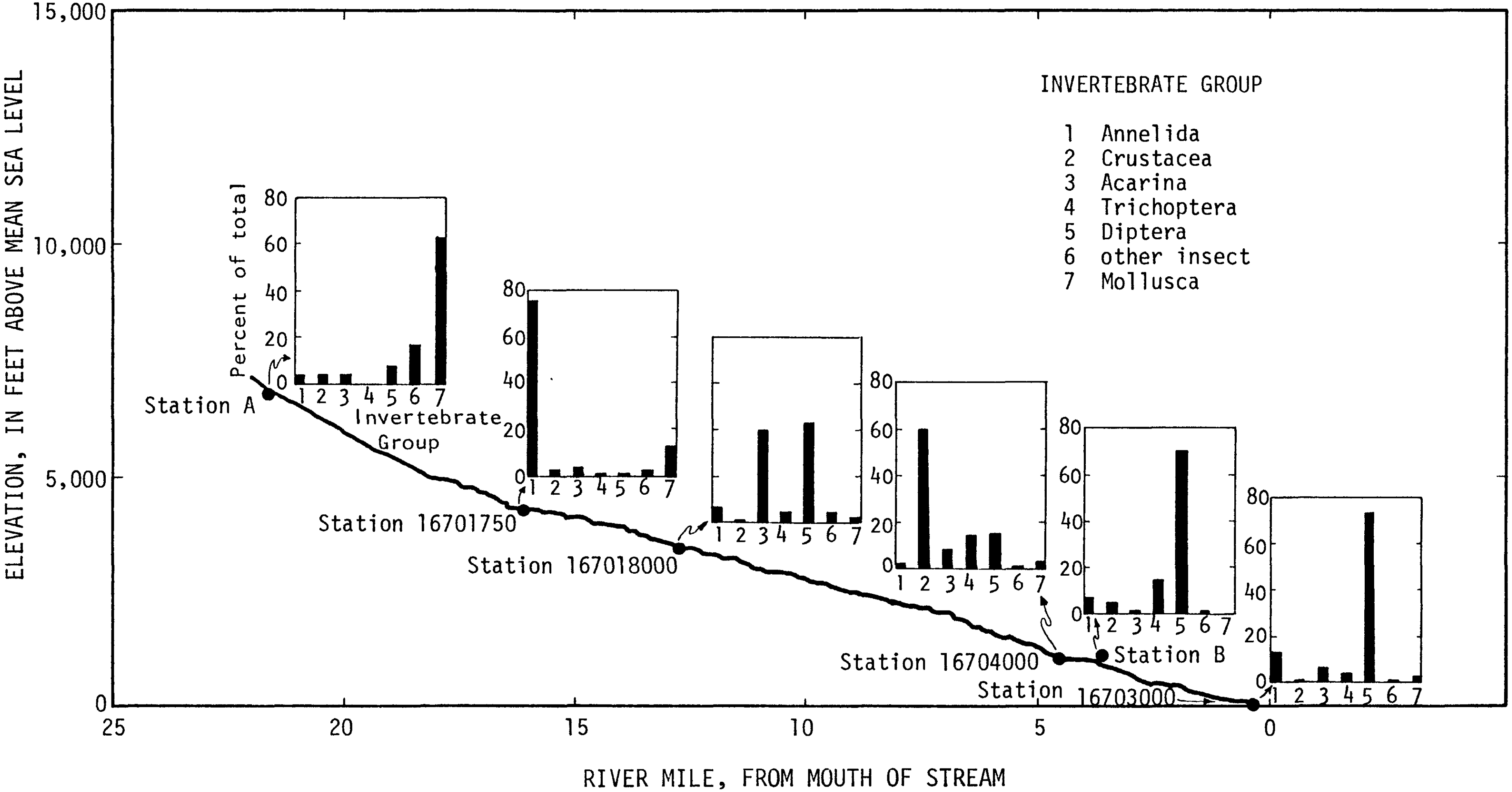


Figure 7. Percentage of the major invertebrate groups at the six sampling stations, Wailuku River, Hawaii.

Table 5. Matrix of Jaccard similarity coefficients for benthic invertebrate samples from six stations in the Wailuku River basin, Hawaii

	A	16701750	16701800	16704000	B	16713000
A	1	0.31	0.13	0.15	0.18	0.18
16701750		1	.35	.31	.25	.27
16701800			1	.62	.64	.57
16704000				1	.79	.59
B					1	.55
16713000						1

S_j (Jaccard similarity coefficient) $= \frac{a}{a+b+c}$

where a = number of taxa found at both of two stations being compared;
b = the number of taxa found at first station, but not second;
c = the number of taxa found at second station, and not at the first;

Example: Comparing stations A and 16701750 using data from table 4:

a = 5; b = 2; c = 9

$$S_j = \frac{5}{5+2+9} = 0.31$$

Table 6. Biomass, chlorophyll a, chlorophyll b and autotrophic index on the Wailuku River, Hawaii

Station	Date collected	Length of exposure in days	Biomass: Dry weight (mg/m^2)	Biomass: Ash weight (mg/m^2)	Biomass: Organic weight (mg/m^2)	Chl a (mg/m^2)	Chl b (mg/m^2)	A.I.
16701750	09/14/78	125	1180	530	650	0.05	0.08	13000
	11/04/77	28	945	472	473	1.03	.36	459
16701800	07/26/78	81	630	394	236	.90	.34	262
	12/01/77	41	2050	1180	870	.36	.15	2420
16704000	09/12/78	127	1180	551	629	4.16	.27	151
	05/08/78	50	630	236	394	4.54	.63	87
16713000	12/13/77	28	3780	1970	1810	14.5	5.60	125

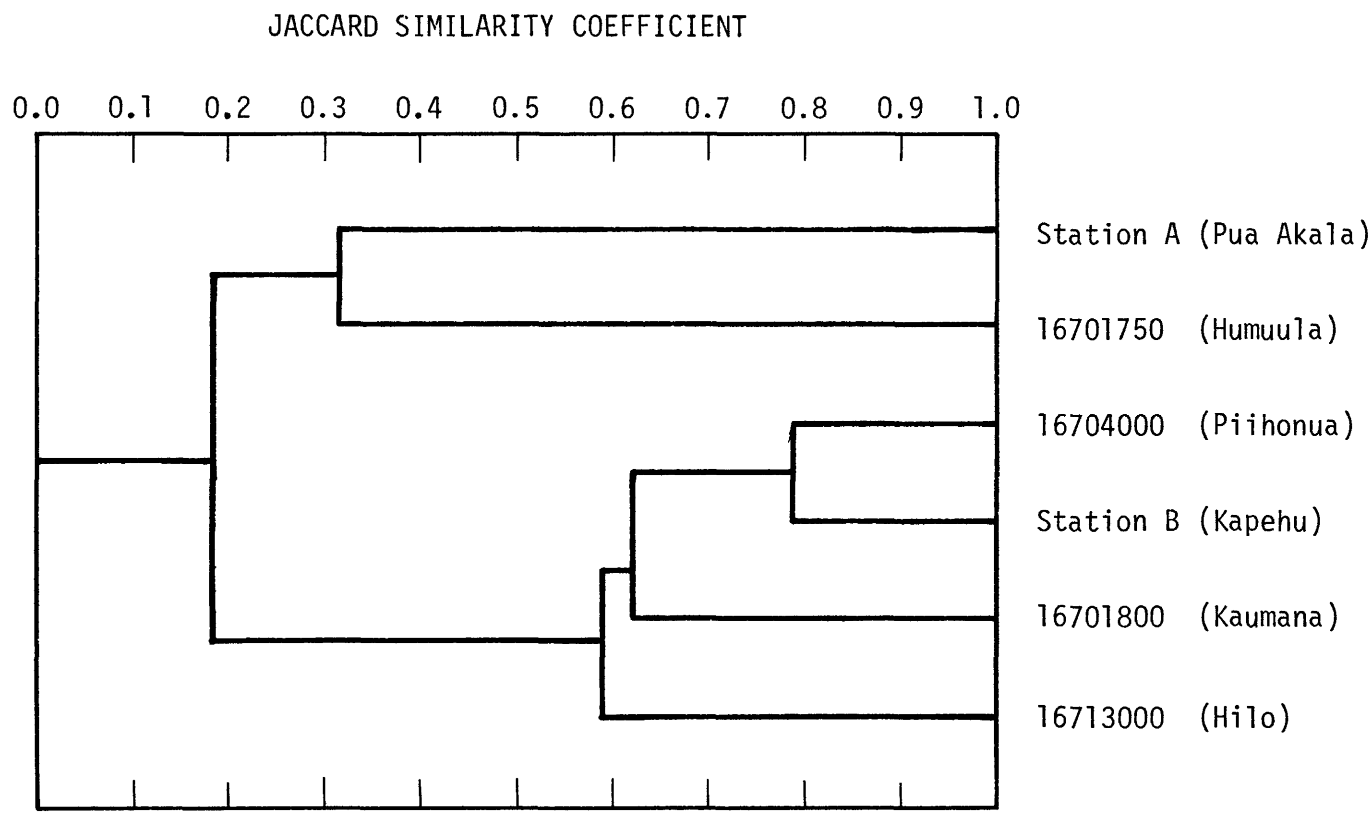


Figure 8. Dendrogram prepared from cluster analysis of the matrix of Jaccard similarity coefficients.

Biomass is defined as the amount of living matter present in any given time. For the data listed on table 6, the biomass values represent the amount of plant growth per unit area of stream habitat. The values are expressed as milligrams of dry weight, ash weight and organic weight per square meter. Dry weight represents the total amount of plant growth, and ash weight represents the inorganic or mineral content of the plants. Organic weight, calculated by difference, is also referred to as ash-free weight of organic matter.

Chlorophyll is the primary photosynthetic pigment in most algae and other plants. The amounts of chlorophyll in the periphyton samples serve to indicate the biological productivity of the plant community.

Table 6 also shows the autotrophic indices for the periphyton samples. The A.I. (autotrophic index) is the ratio of biomass organic weight to chlorophyll a. It is used as a means to evaluate the trophic nature of the periphytic community. Low values indicate a community with predominately autotrophic (food producing) organisms, whereas a high value indicates a heterotrophic (consuming) community. The values for chlorophyll, biomass, and the autotrophic index are within the range expected for clean unpolluted streams with low to moderate primary productivity. Of all the periphyton organisms found at four stations on the Wailuku River, (table 7), diatoms (Navicula, Tabellaria, Eunotia, Flagilaria) appear to be the most common, followed by the green algae (Gloeocystis, Oedogonium, Spirogyra), and smaller numbers of blue-green algae, euglenoids, and fire-algae. The predominance of diatoms is also indicative of relatively clean water with little organic enrichment.

Seston

Seston (suspended particulate matter in the water) values from four sites in the Wailuku drainage area are shown in table 8. The values are very low, near the limit of detection. No conclusions about seston can be drawn from these values and small number of samples. The high percentage of organic matter in the seston indicates that the particulate matter consists of organic detritus or drifting algae, or both. A high percentage is frequently measured when periphyton is dislodged from the streambed.

Table 7. Periphyton species found at four stations on the Wailuku River, Hawaii

(X - Organism observed; E - estimated dominant organism; parentheses denotes common name)

	16701750		16701800		16704000	16713000
	11-04-77	09-14-78	12-01-77	07-26-78	12-13-77	12-13-77
Chlorophyta (green algae)						
.Chlorophyceae						
..Chlorococcales						
...Characiaceae						
....Characium				x		
...Oocystaceae						
....Ankistrodesmus		x	x			
...Scenedesmaceae						
....Scenedesmus		x				
..Cladophorales						
...Cladophoraceae						
....Cladophora				x		
..Oedogoniales						
...Oedogoniaceae						
....Bulbochaete				x		
....Oedogonium	E		x	x	x	
..Tetrasporales						
...Palmellaceae						
....Gloeocyctis			E			
....Sphaerocystis		x		x		
..Ulotrichales						
...Ulotrichaceae					x	
..Zygnematales						
...Desmidiaceae (placodem desmids)						
....Cosmarium				x		
....Closterium			x			
....Euastrum				x		
...Mesotaeniaceae (saccoderm desmids)						
....Netrium				x		
...Zygnemataceae						
....Mougeotia				x		
....Spirogyra					x	E
Chrysophyta						
.Bacillariophyceae (diatoms)						
..Pennales (pennates)						
...Achnanthaceae						
....Achnanthes			x	x		x
....Cocconeis		x				
...Cymbellaceae						
....Cymbella			x			x
....Epithemia				x		
....Rhopalodia			x			
...Eunotiaceae						
....Eunotia	E			x		
...Fragilariaceae						
....Fragilaria						E
....Synedra				x	x	x
...Gomphonemataceae						
....Gomphonema	x		x	x	x	x
...Naviculaceae (naviculoids)						
....Caloneis				x		
....Frustulia			x	x		
....Navicula	x	E	E	E		E
....Pinnularia				x		
...Nitzschiaceae						
....Nitzschia				x		
...Tabellariaceae						
....Tabellaria	E	E	E	x	x	x

Table 7. Periphyton species found at four stations on the Wailuku River, Hawaii--Continued

	16701750		16701800		16704000	16713000
	11-04-77	09-14-78	12-01-77	07-26-78	12-13-77	12-13-77
Cyanophyta						
(blue-green algae)						
.Cyanophyceae						
..Chroccoccales						
(coccoids)				x		
..Hormogonales						
(filamentous)						
...Nostocaceae						
....Anabaena			x			x
....Nostoc	x					
...Rivulariaceae						
....Calothrix	x					x
Euglenophyta						
(Euglenoids)						
.Euglenophyceae						
..Euglenales						
...Euglenaceae						
....Trachelomonas		x				
Pyrrhophyta						
(fire algae)						
.Dinophyceae						
(dinoflagellates)						
..Peridiniales						
...Peridiniaceae						
....Peridinium	x					
Taxa per collection	8	7	12	21	6	10
Taxa at each station	13		27		6	10

Table 8. Seston values in the Wailuku River Basin, Hawaii

Station	Date	Dry weight (mg/L)	Ash weight (mg/L)	Organic weight (mg/L)	Organic weight (percent)
16701800	07/26/78	1.375	0.429	0.946	69
16704000	09/12/78	1.150	.236	.914	80
Station B	07/25/78	1.050	.710	.340	32
16713000	07/27/78	1.136	.526	.610	54

Phytoplankton

Phytoplankton, commonly known as algae, are free-floating plants. They are microscopic and their growth depends on solar radiation and nutrient materials. Phytoplankton are primary producers, and are food for higher aquatic organisms. In large numbers, phytoplankton form a nuisance growth that causes clogging, taste, and odor problems in water. Phytoplankton concentrations are expressed as number of cells per milliliter (cells/mL).

Compared to other Hawaii streams, phytoplankton concentration in Wailuku River is low. Data collected from six National Stream Quality Accounting Network (NASQAN) stations throughout the state showed that Wailuku River had the lowest values. The range in average concentration values for all NASQAN stations was 249-2075 cells/ mL. Concurrently, the nutrient content of the water, in terms of total nitrogen and total phosphorus concentrations, is also lowest at Wailuku River.

Within Wailuku River, phytoplankton concentration increased from 249 to 285 cells/mL between stations 16704000 above the city of Hilo and 16713000 at Hilo. This increase can be attributed to higher nutrients in the water as shown on Table 13. Phytoplankton concentrations are higher from June through November than from December through May (fig. 9). The higher concentrations coincide with the optimum growing season of summer and fall when solar radiation is maximum, primary productivity is highest, and the streamflow is relatively low and steady.

Navicula, a large grouping of diatoms with many species, occurs in both freshwater and saltwater, is the dominant phytoplankton identified in samples collected at station 16704000 (fig. 10).

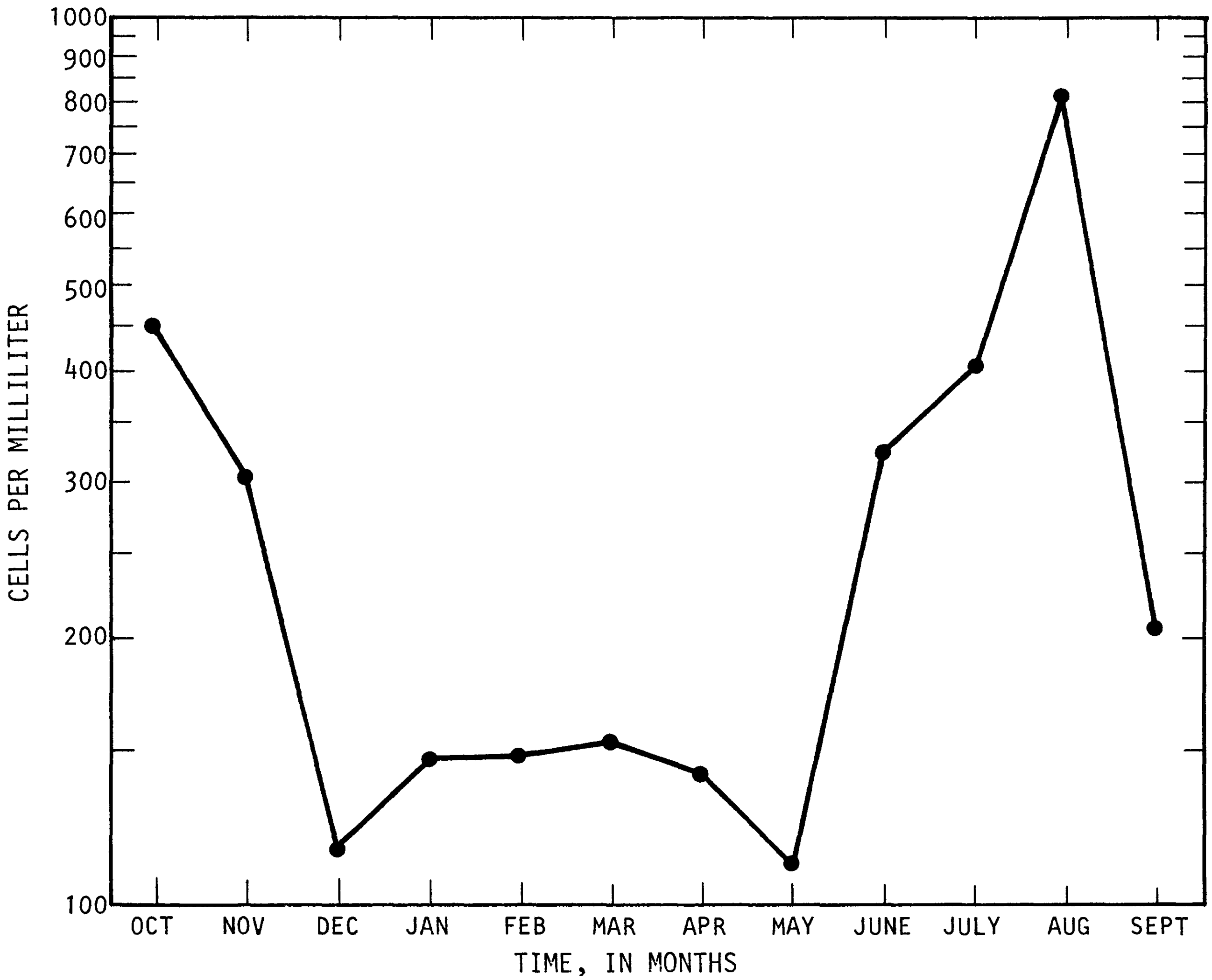


Figure 9. Mean monthly phytoplankton concentration, 1974-1979, for Wailuku River at Piihonua, Hawaii, station 16704000.

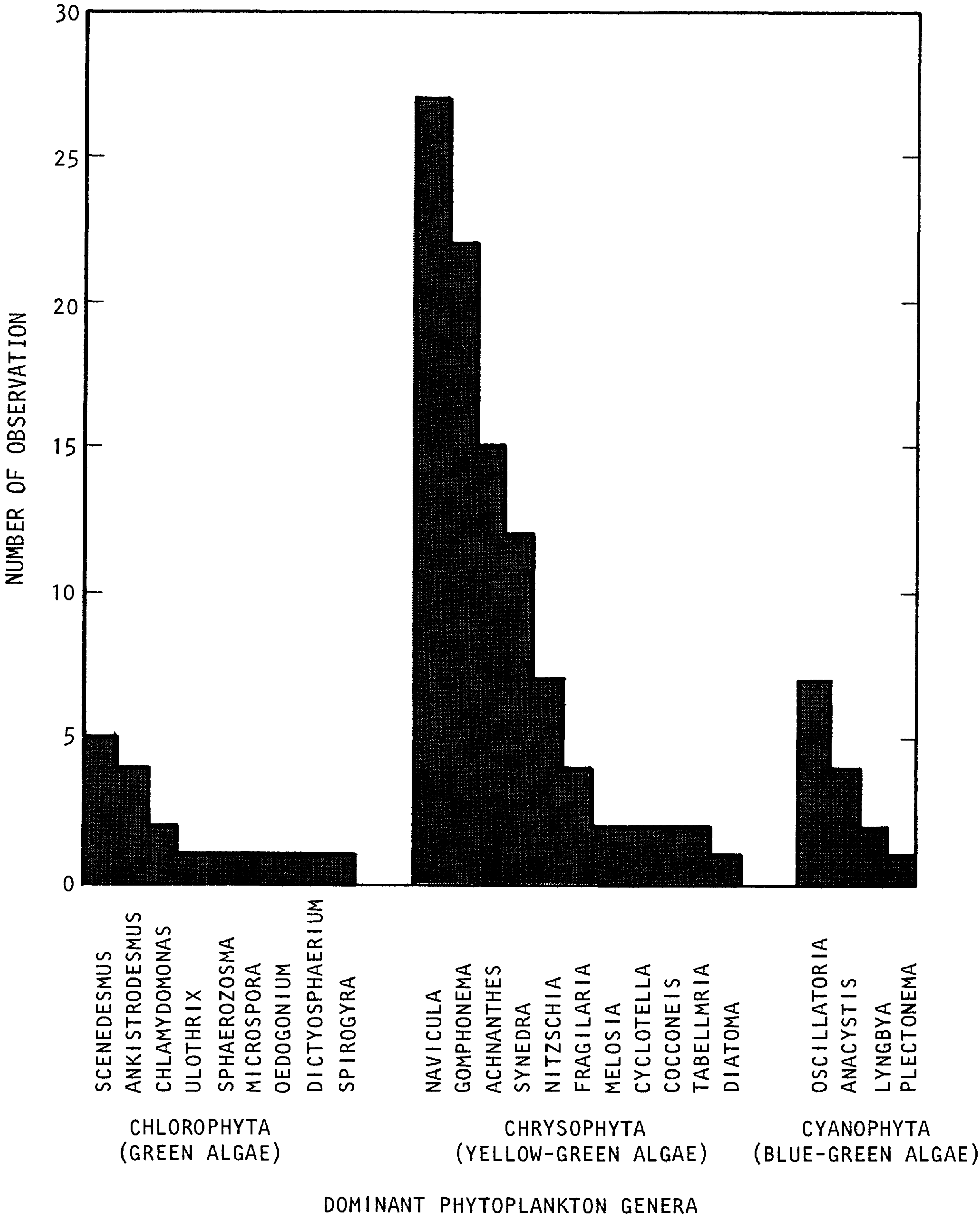


Figure 10. The dominant phytoplankton genera and the number of observation for station 16704000, Wailuku River at Piihonua, Hawaii, 1974-1979.

Other genera most frequently observed are: Gomphonema, Achnanthes, Synedra, Nitzschia, Oscillatoria, and Scenedesmus. Phytoplankton data from monthly samples collected from the Wailuku River are published annually in "Water-Resources Data for Hawaii and Other Pacific Areas", (U.S. Geological Survey, 1961-80).

The taxonomy of Wailuku River's phytoplankton community is similar to that of the periphyton community. This similarity suggests that the plankton organisms are of periphytic origin and were dislodged from rocks and other submerged objects by the fast-flowing water.

Bacteria

Total coliform, fecal coliform, and fecal streptococcus bacteria are used as indicators of pollution from human and animal waste. The number of coliform bacteria found in the Wailuku River above Hilo is typical of mountain streams in Hawaii that receive little or no human influence (table 9). In the upper reaches of the Wailuku River, the land adjacent to the stream is used for range land and pasture for cattle. Except for the Hilo vicinity, the lower reaches of the river are, for the most part, underdeveloped and relatively unaffected by human activities.

Hawaii's water-quality standards establish only the fecal coliform criteria for inland recreational waters. The criteria state, in part: "***fecal coliform content shall not exceed a geometric mean of 200 per 100 mL in ten or more samples collected during any 30-day period and not more than 10 percent of the samples shall exceed 400 per 100 mL in the same period***", (Hawaii State Department of Health, 1982). Although not collected within the State standard criteria for the specified time period, the monthly values in table 9 do indicate low fecal coliform densities. Nearly all values are within the State's water-quality standards. The geometric mean of the monthly samples was 28 and 116 fecal coliform colonies per 100 mL at stations 16704000 (Piihonua) and 16713000 (Hilo), respectively. Fecal coliform density did exceed the 400 per 100 mL limit once at the Hilo station. Higher fecal coliform densities at the Hilo station are attributed to increased urban activities which are located at the lower basin around Hilo.

Table 9. Total coliform, fecal coliform, and fecal streptococcus in three stations on the Wailuku River and Kapehu Stream tributary

(E - Estimated count based on non-ideal colony counts)

Station	Date	Time	Discharge (ft^3/s)	Total coliform (colonies	Fecal coliform per 100	Fecal strepto-coccus milliliter)
16701800	11/01/77	1500	2.8	200	11E	29
	07/26/78	1200	6.8	770	150	88
			Geometric mean	392	41	51
16704000	10/25/77	0900	290	--	65	780E
	11/28/77	1015	20	160	20	630E
	12/13/77	0915	6.6	--	17	500
	01/25/78	0845	32	--	58	800
	02/27/78	1330	5	--	78	250
	03/28/78	0945	51	--	7	54
	04/25/78	0830	73	--	24	480
	05/23/78	0845	99	--	17	720
	06/12/78	1000	41	--	29	270
	07/28/78	0900	176	330	35	470E
	08/29/78	1345	190	--	10E	320
	09/12/78	1330	72	370	87	450
			Geometric mean	269	28	392
16713000	10/25/77	1015	490		190	1700E
	11/28/77	1100	29	1800	110	640
	12/13/77	1045	18	--	94	580E
	01/25/78	1015	60	--	140	160
	02/28/78	1000	12	--	110	780
	03/28/78	1015	66	--	230E	170
	04/24/78	1315	87	--	46	490
	05/23/78	0930	104	--	660	1300
	06/27/78	0915	455	--	38	310
	07/27/78	1130	298	1400	130	100
	08/29/78	1145	331	--	27E	140
	09/13/78	0830	106	--	220	390
			Geometric mean	1590	116	395
Station B	11/02/77	1230	122	470	310	4800
	07/25/78	1230	60	180	91	1500
			Geometric mean	291	168	2680

Morphology

Stream profile

The Wailuku River follows the approximate boundary between Mauna Loa and Mauna Kea volcanoes. The streambed consists of lava flows from Mauna Loa, which overlapped older Mauna Kea flows. With headwaters originating at about the 11,000-foot elevation, the stream is characterized by a series of plunge pools at the higher elevations and by numerous waterfalls at elevations below 2,200 ft. Most of the runoff to the stream originates in the north or the Mauna Kea side of the river. Only a small portion of the total surface flow comes from the area south of the river because rainfall infiltrates rapidly into the fresh lava flows on the slopes of Mauna Loa. There is no broad flood plain at the stream terminus.

The longitudinal slope of Wailuku River ranges from five percent at the middle reaches to eight percent at headwater regions. These relatively steep slopes significantly affect peak flows, size of material transported, and the habitat of stream biota. The profile of the Wailuku River is shown in figure 11.

Cross section

The cross-section configuration of the stream channel, in general, is a narrow steep-sided trapézoid with an irregular base. Two surveys made at the six study sites during November 1977 and July-September 1978 revealed no noticeable change in the river channel. This channel stability is due primarily to a stable lava streambed.

The streambanks are composed of fine to very coarse material and support dense vegetal growth. The channel depth increases gradually from 6 ft at the headwaters to 40 ft at Hilo. The width also increases from 60 ft at the highest study site to 220 ft at the downstream site near the mouth of the river. Figures 12-17 are photographs of the channel, streambed material, and the cross-section profiles at each station. As many as three profiles are presented for stations that have no uniform configuration within a 300-feet stream segment. The profiles, designated as cross-sections 1, 2, and 3, are about 150 feet apart and in downstream order. They depict the irregular bed of Wailuku River.

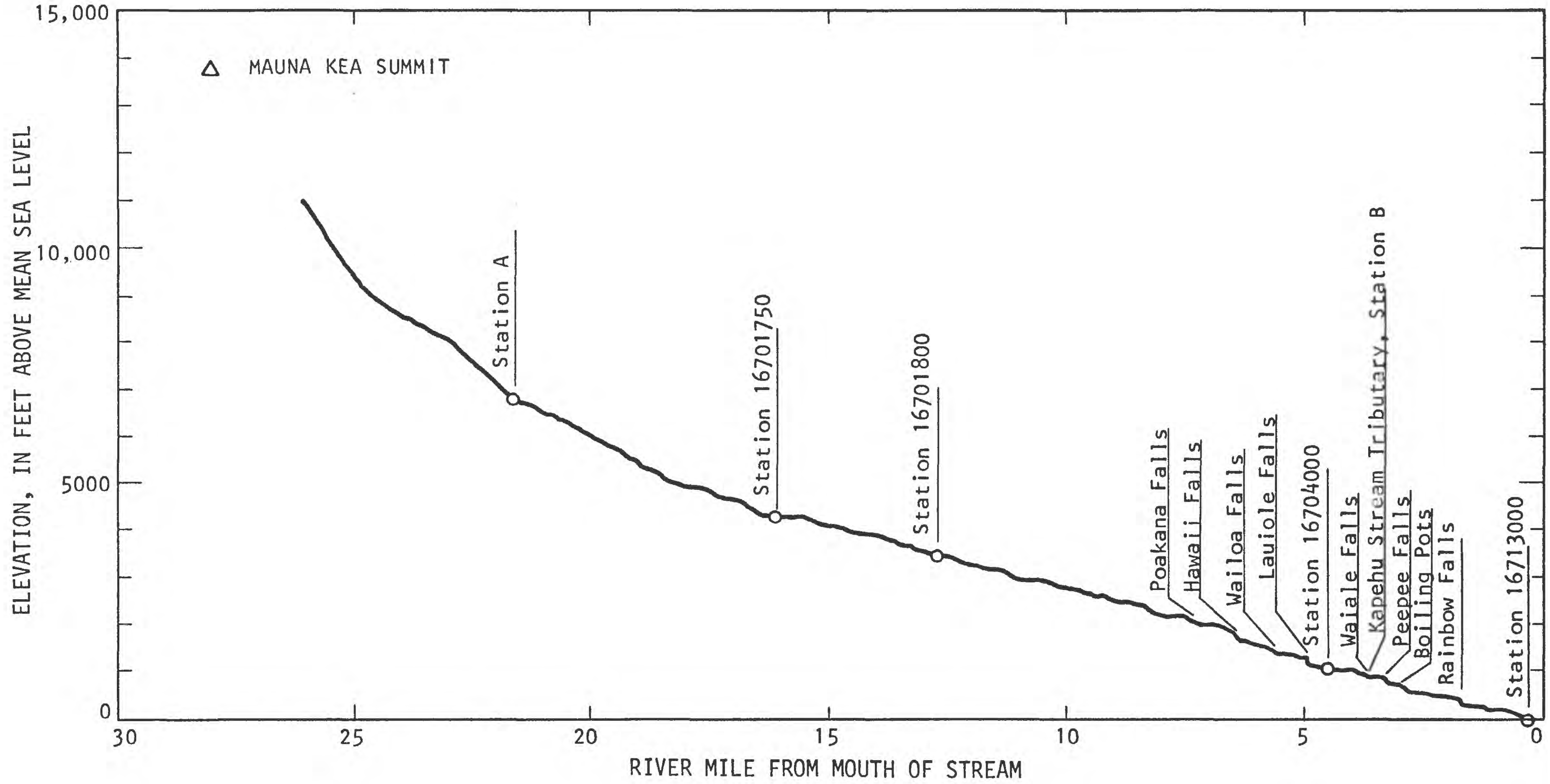
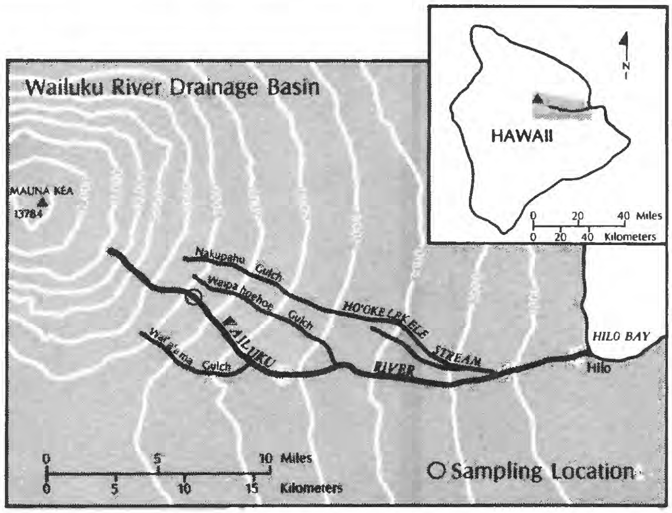


Figure 11. Downstream river profile, sampling stations and selected waterfall locations of Wailuku River, Hawaii.



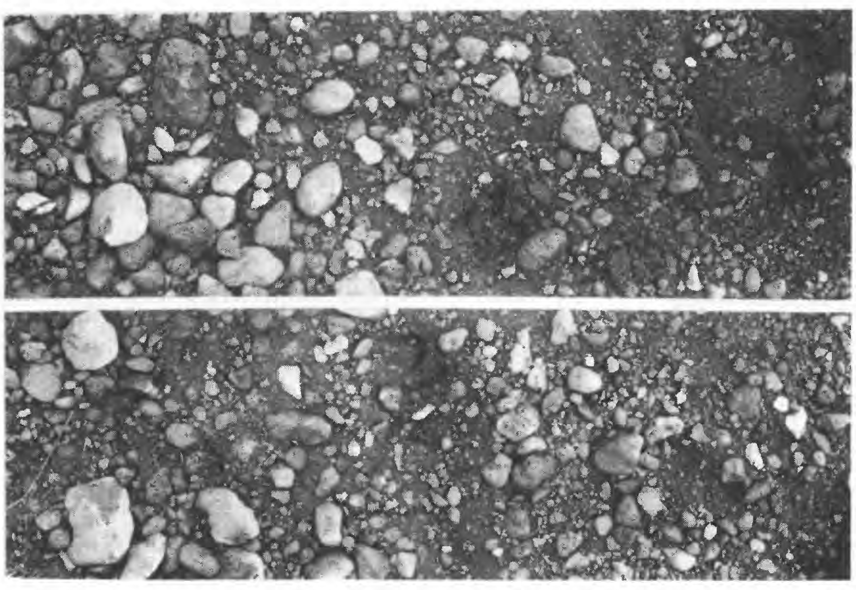


Figure 12. Cross-section and streambed at station A, Wailuku River near Pua Akala, Hawaii.

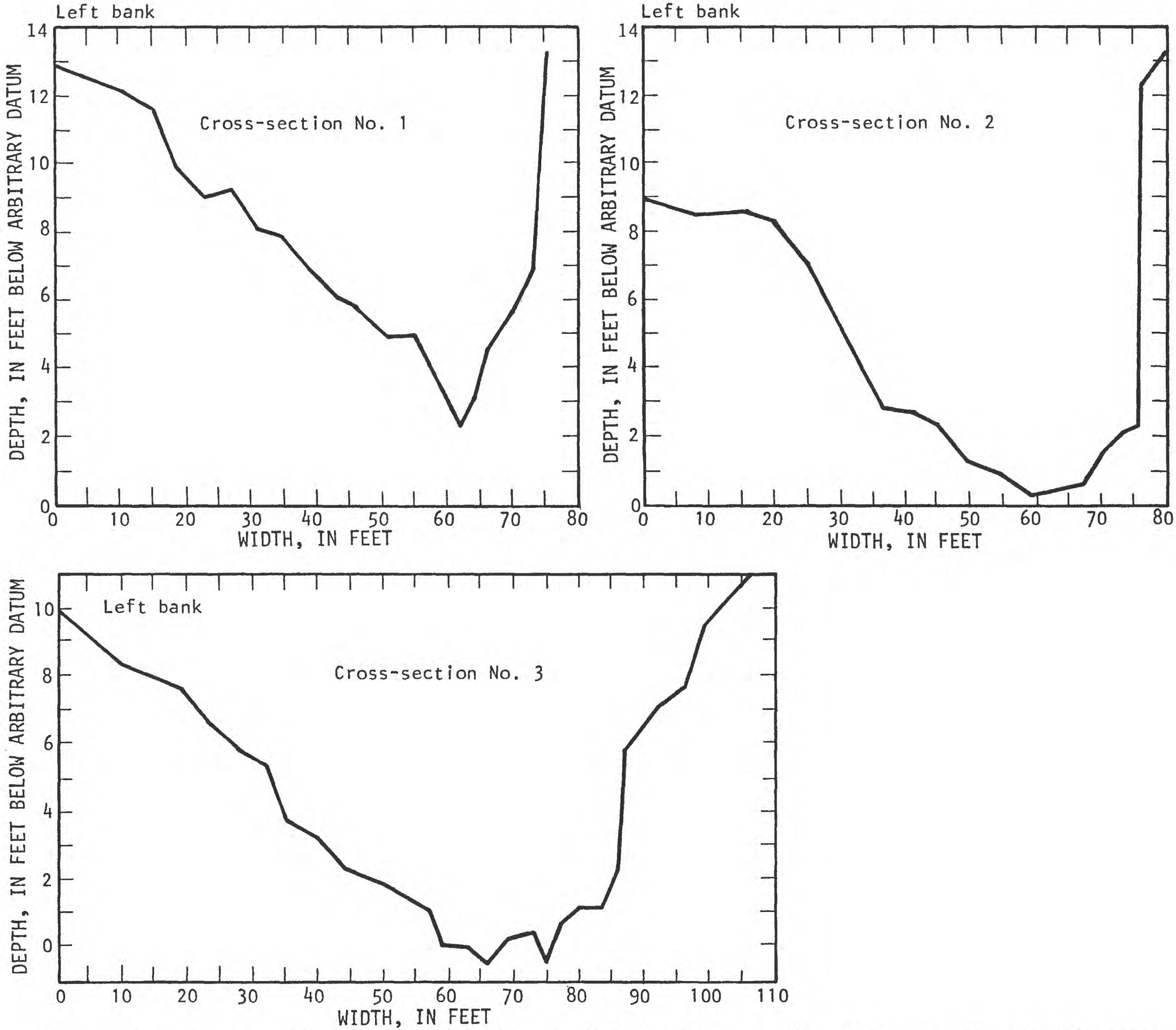


Figure 12a. Cross-section profile at station A, Wailuku River near Pua Akala, Hawaii, July 28, 1978.

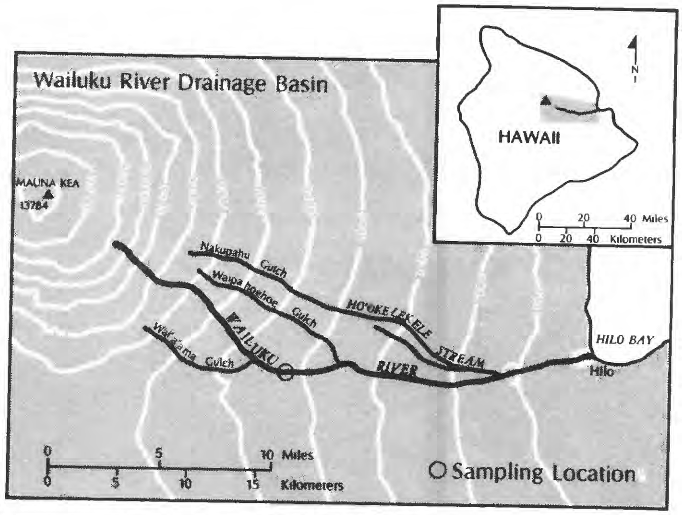


Figure 13. Cross-section and streambed of Wailuku River near Humuula, Hawaii, station 16701750.

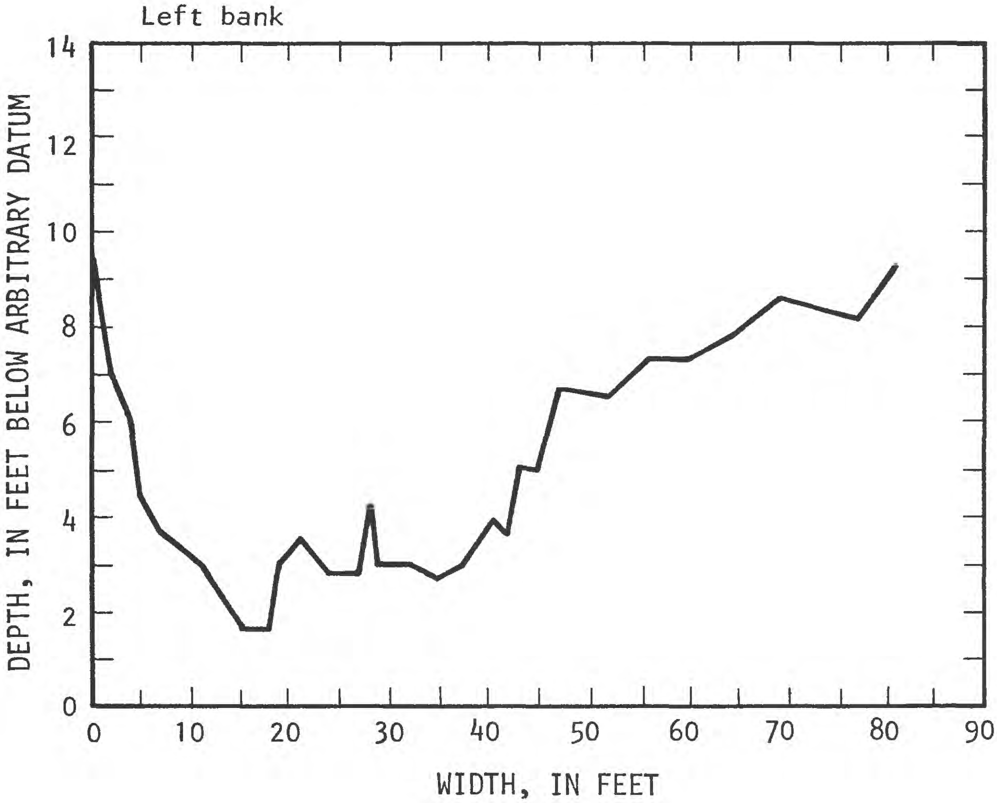


Figure 13a. Cross-section profile of Wailuku River near Humuula, Hawaii, station 16701750, September 14, 1978.

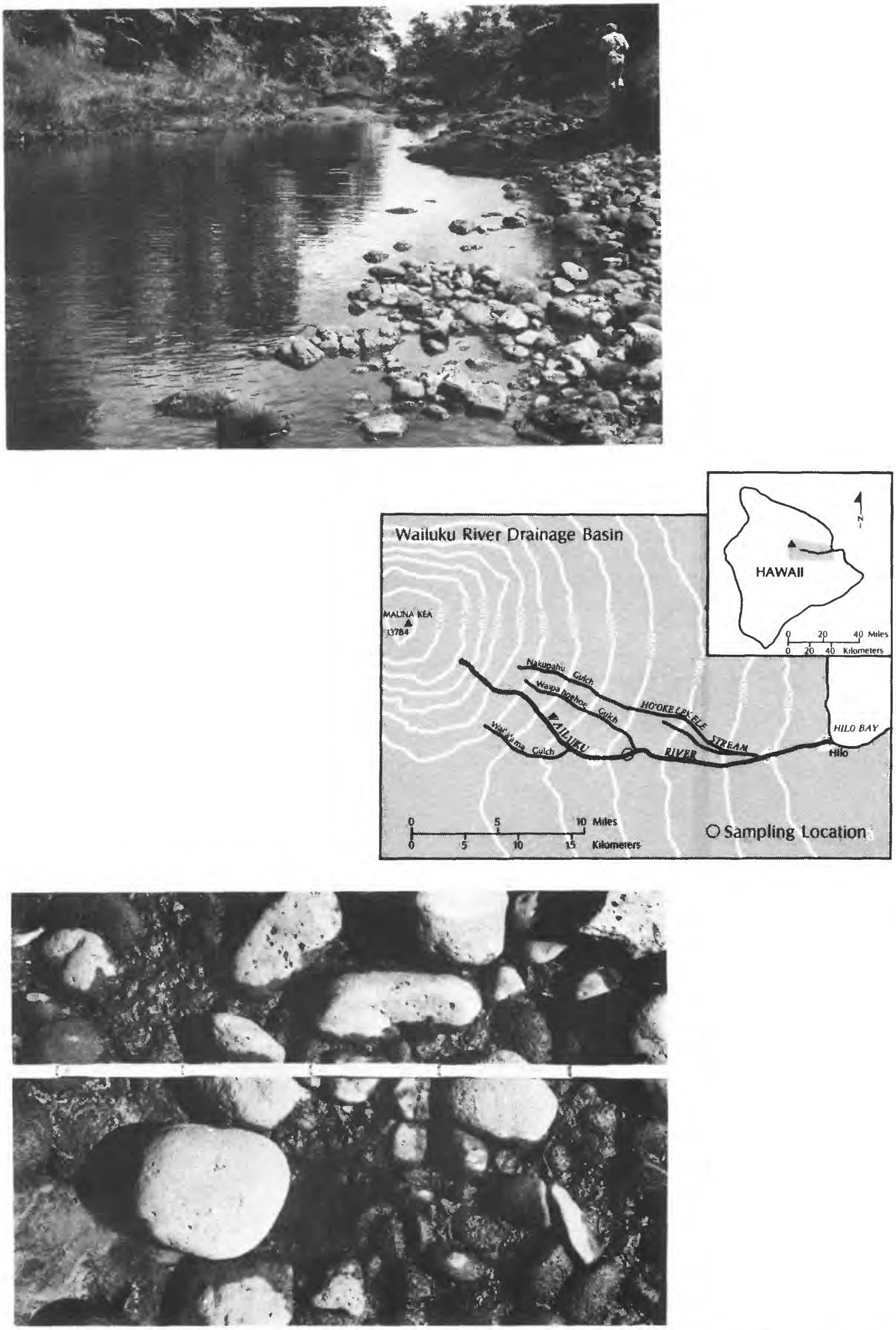


Figure 14. Cross-section and streambed of Wailuku River near Kaumana, Hawaii, station 16701800.

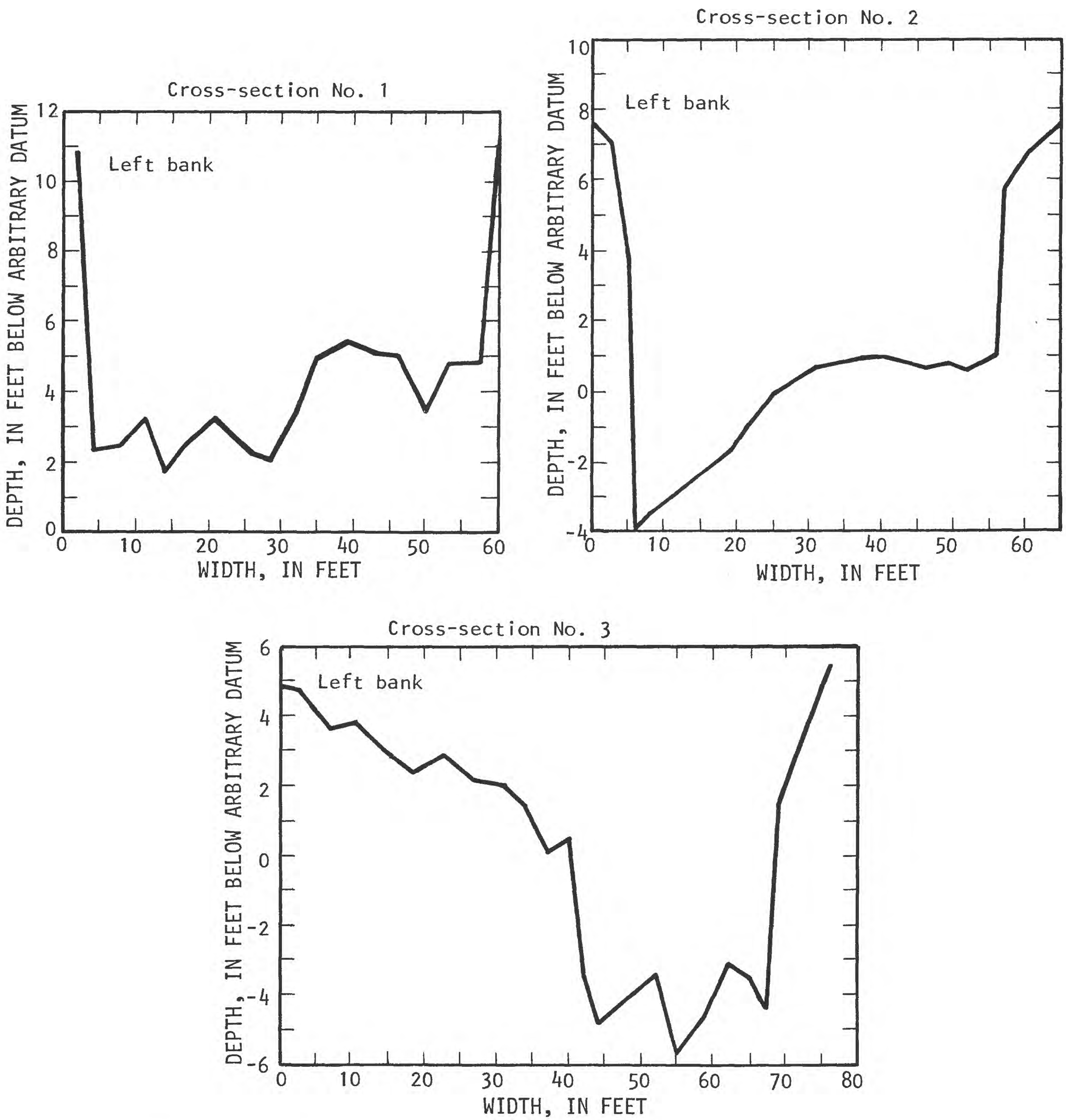


Figure 14a. Cross-section profile of Wailuku River near Kaumana, Hawaii, station 16701800, July 26, 1978.

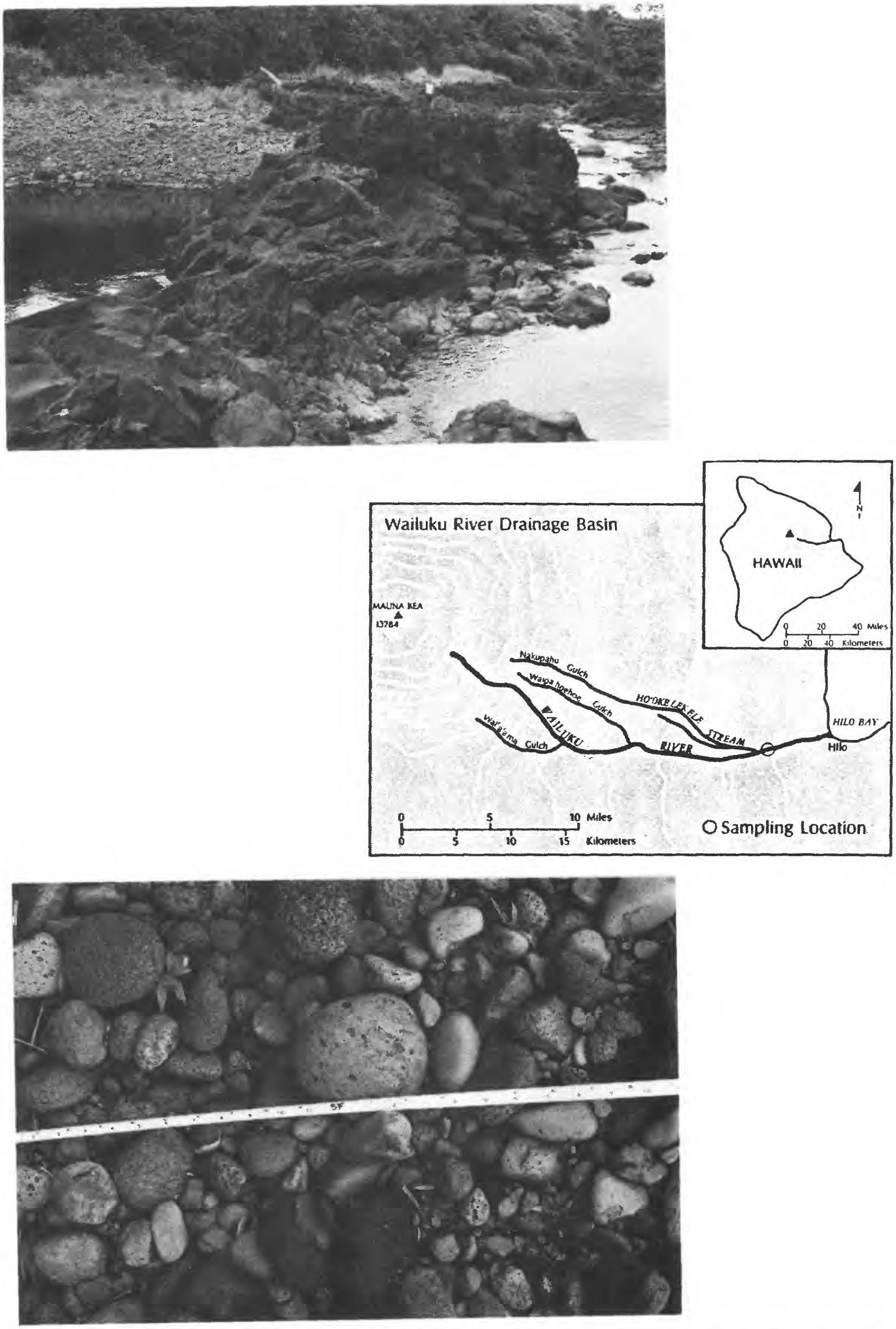


Figure 15. Cross-section and streambed of Wailuku River at Piihonua, Hawaii, station 16704000.

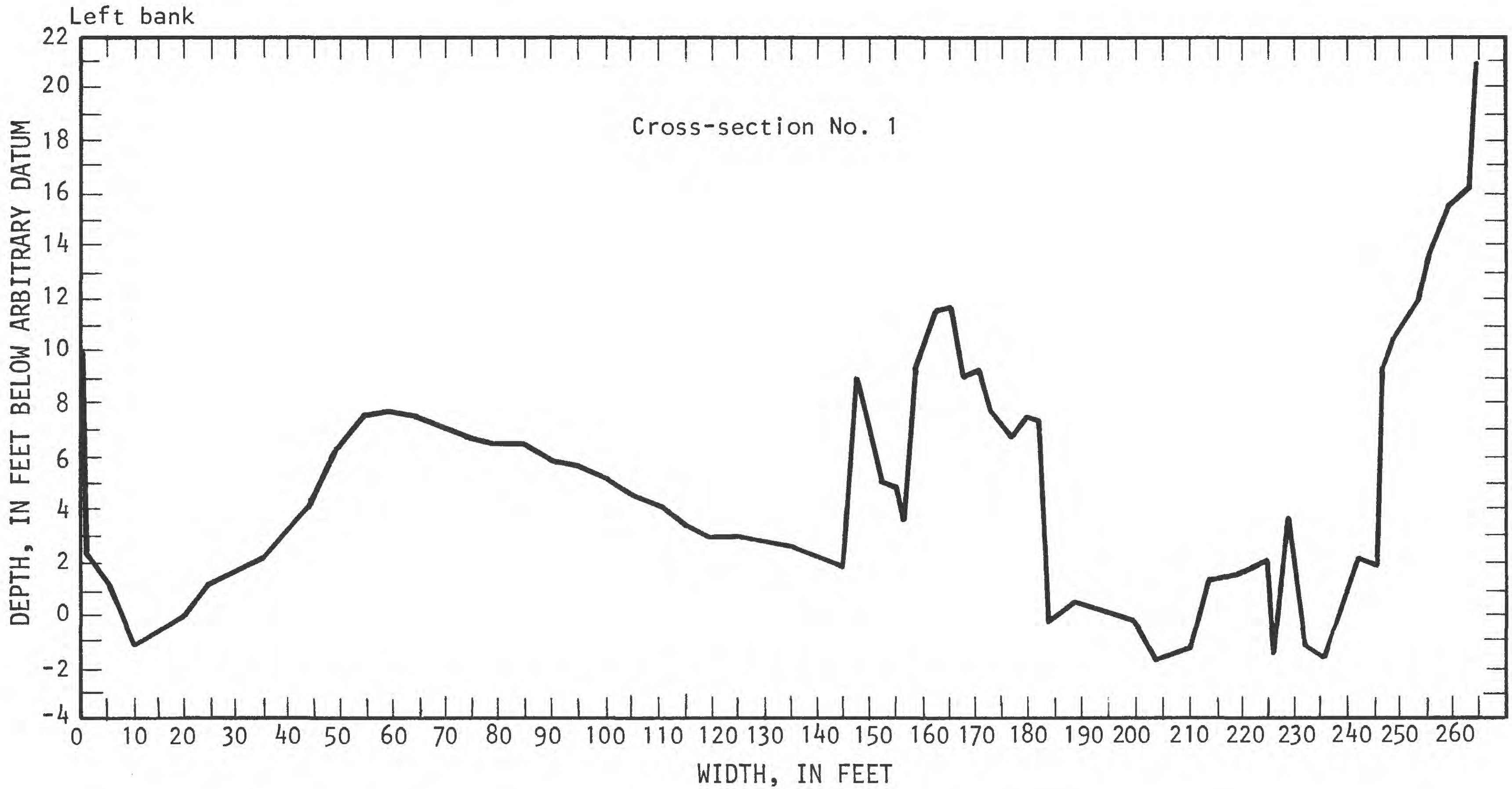


Figure 15a. Cross-section profile of Wailuku River at Piihonua, Hawaii, station 16704000, September 13, 1978.

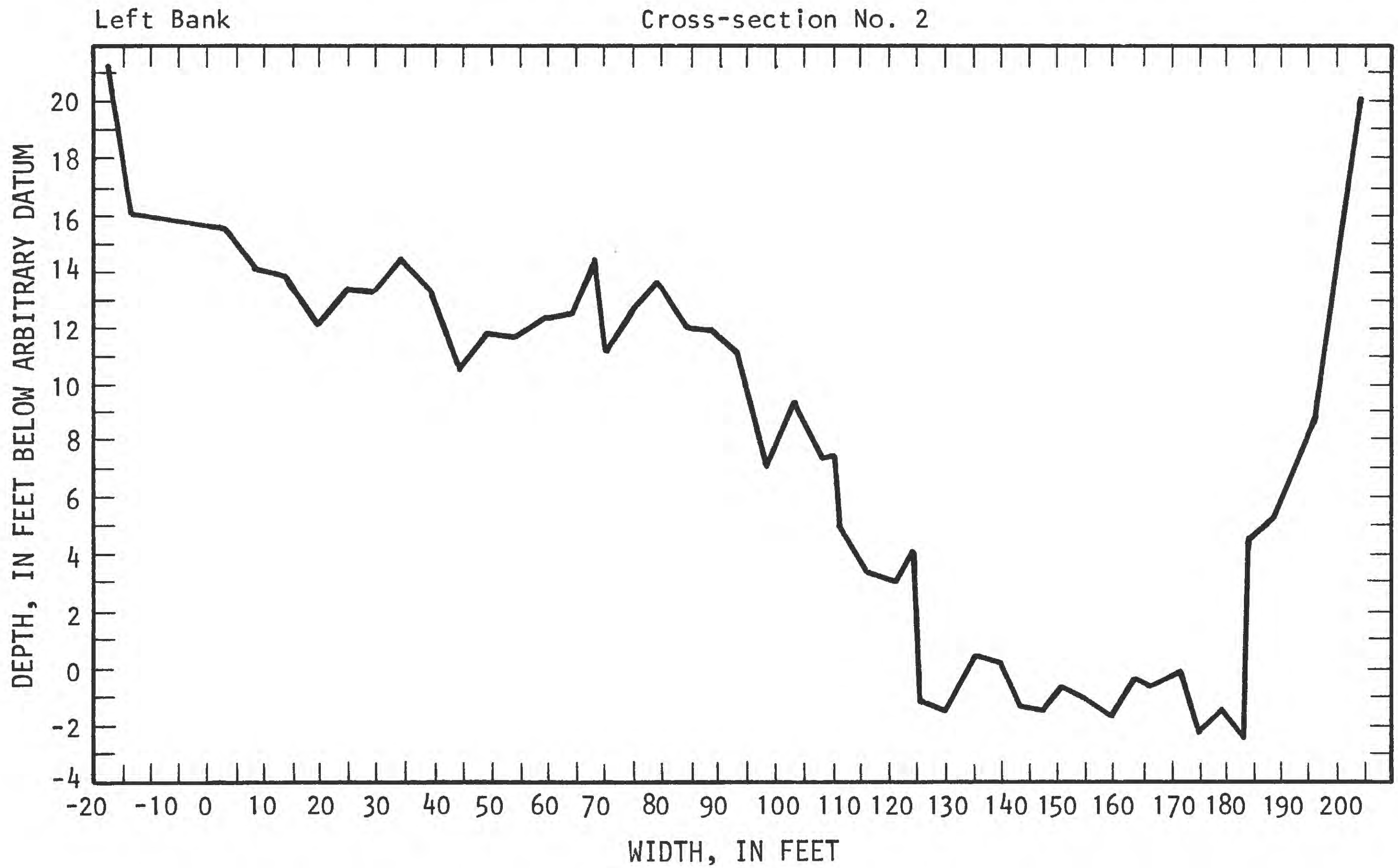


Figure 15b. Cross-section profile of Wailuku River at Piihonua, Hawaii, station 16704000, September 13, 1978.

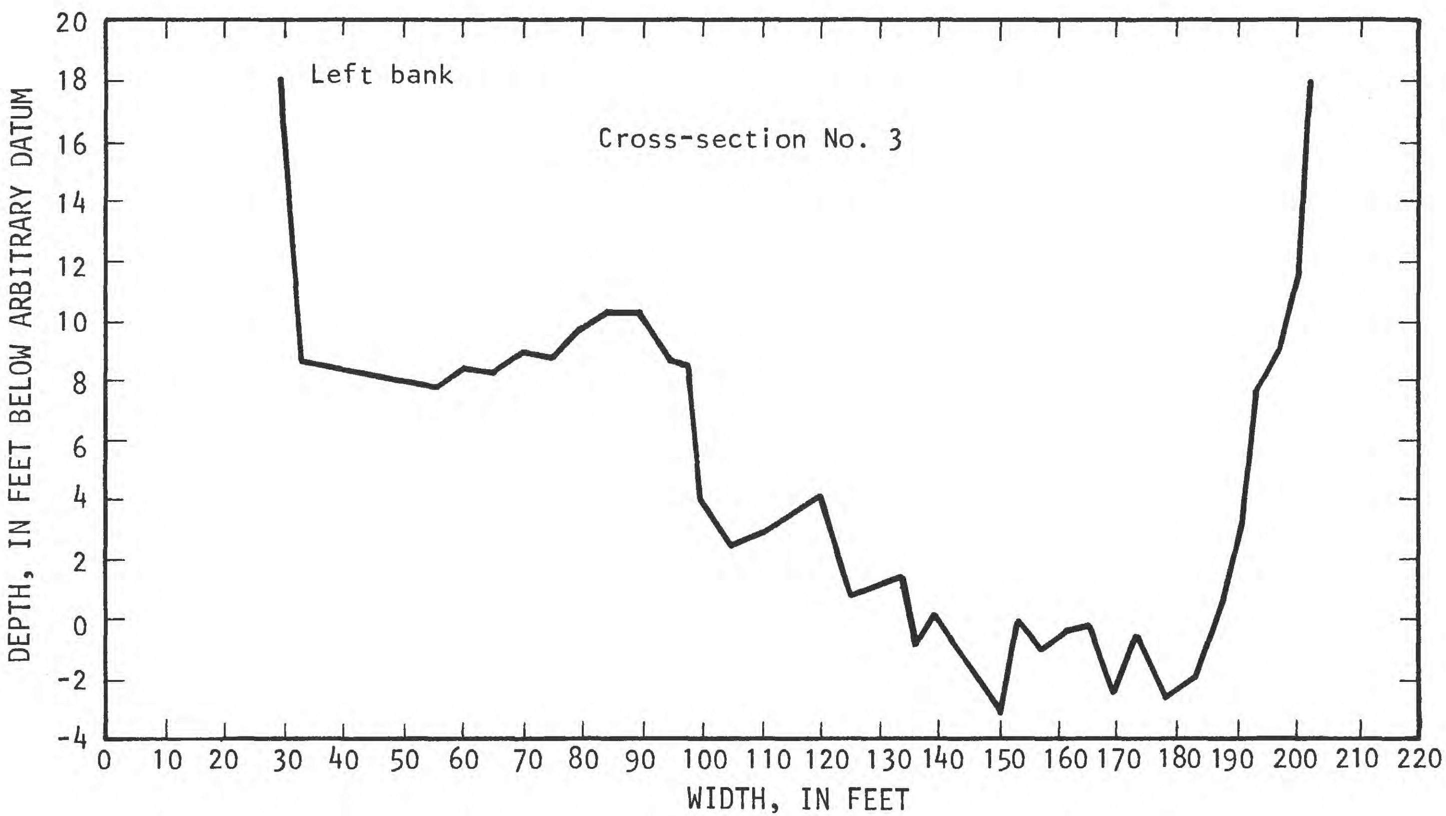


Figure 15c. Cross-section profile of Wailuku River at Piihonua, Hawaii, station 16704000, September 13, 1978.

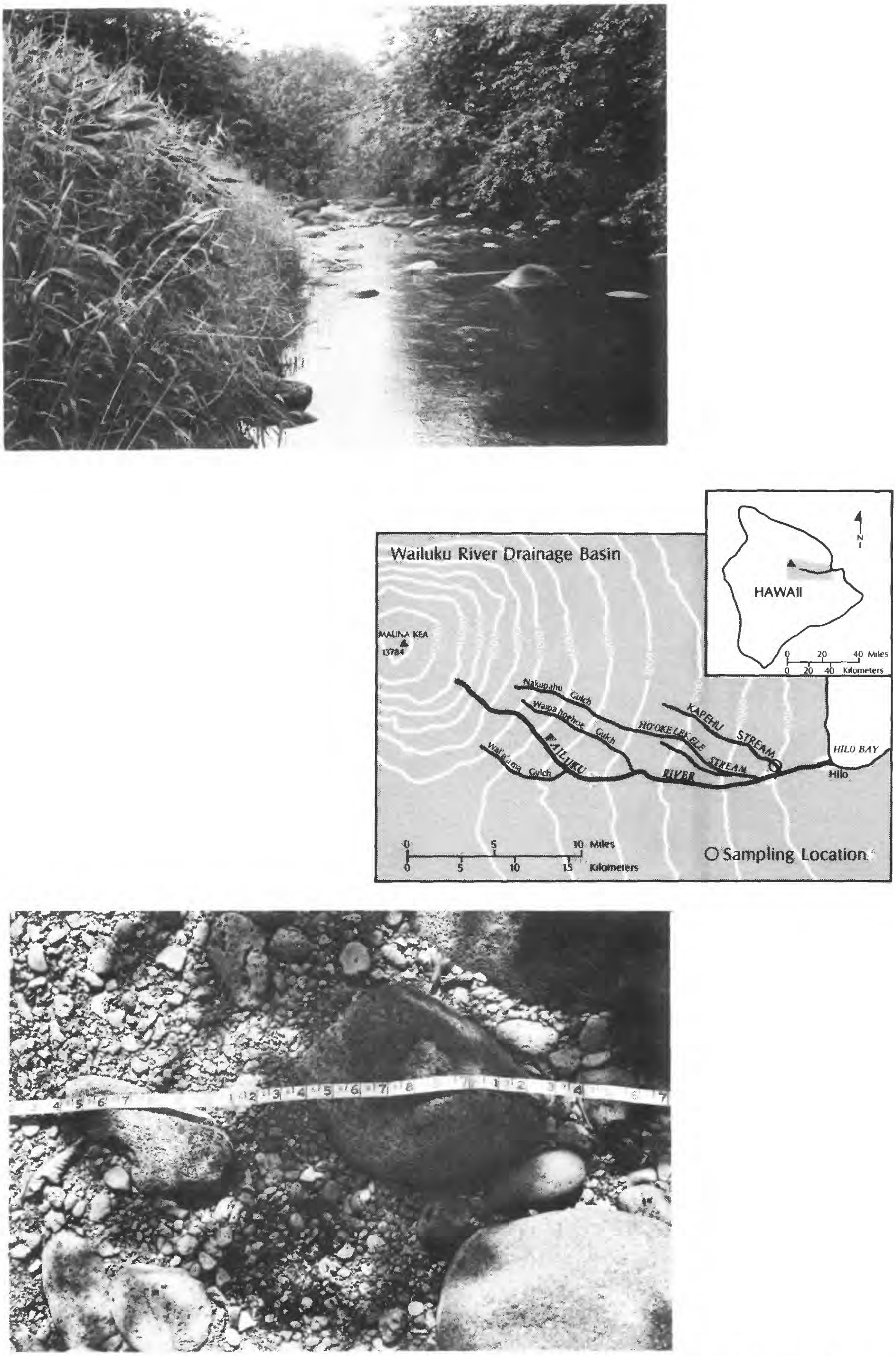


Figure 16. Cross-section and streambed of station B, Kapehu Stream tributary, near Hilo, Hawaii.

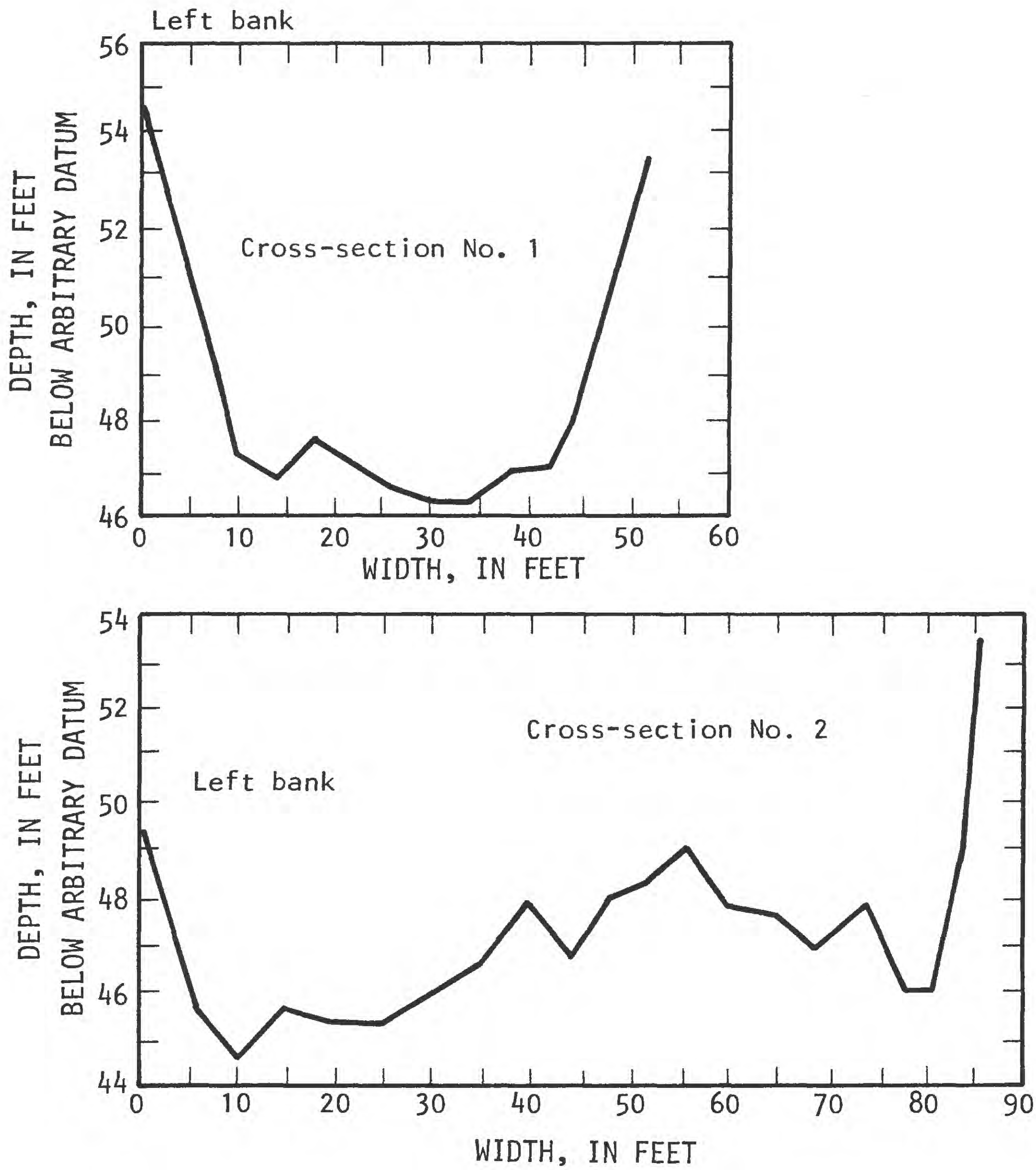


Figure 16a. Cross-section profile of station B, Kapehu Stream tributary, near Hilo, Hawaii, July 25, 1978.

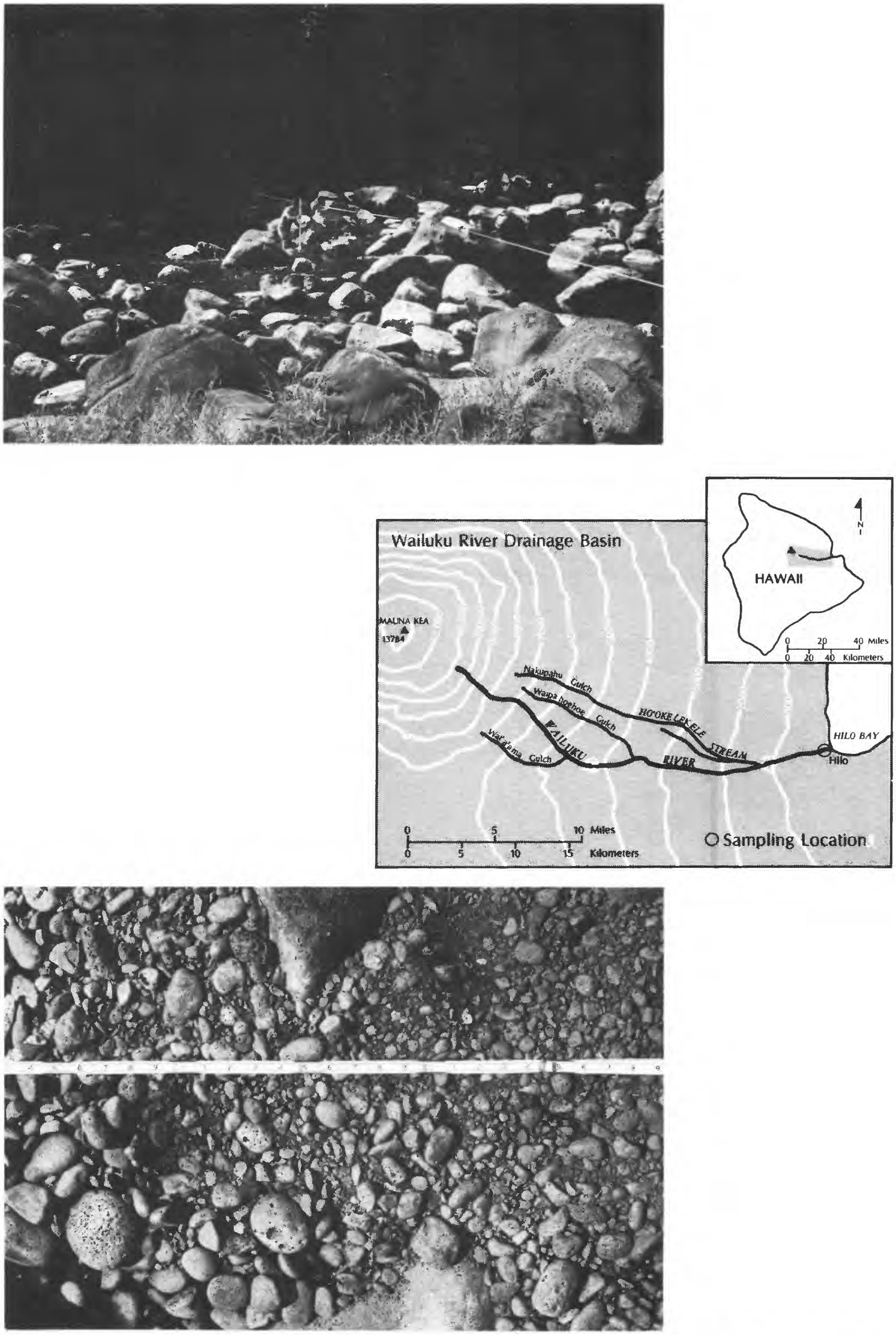


Figure 17. Cross-section and streambed of Wailuku River at Hilo, Hawaii, station 16713000.

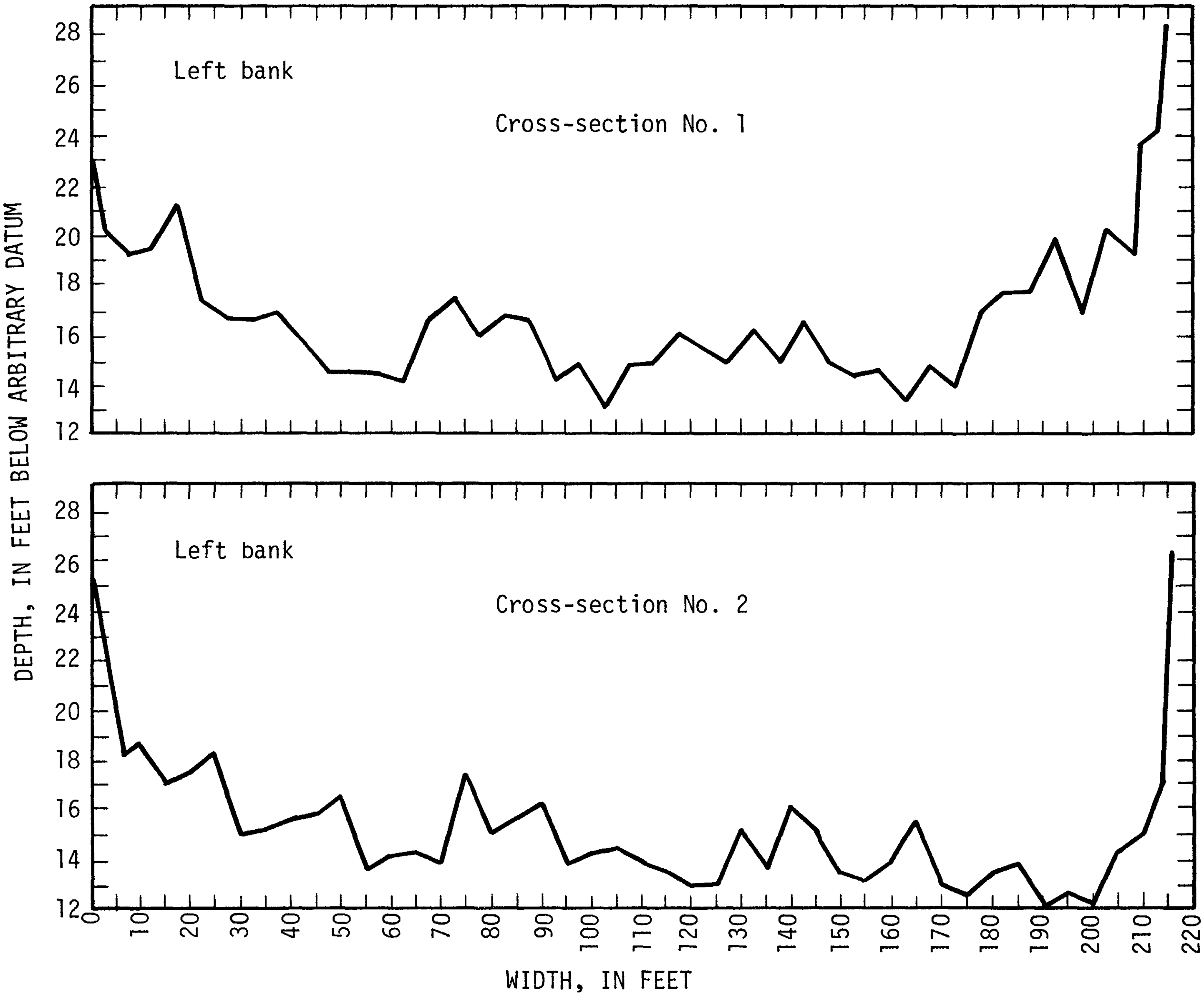


Figure 17a. Cross-section profile of Wailuku River at Hilo, Hawaii, station 16713000, July 27, 1978.

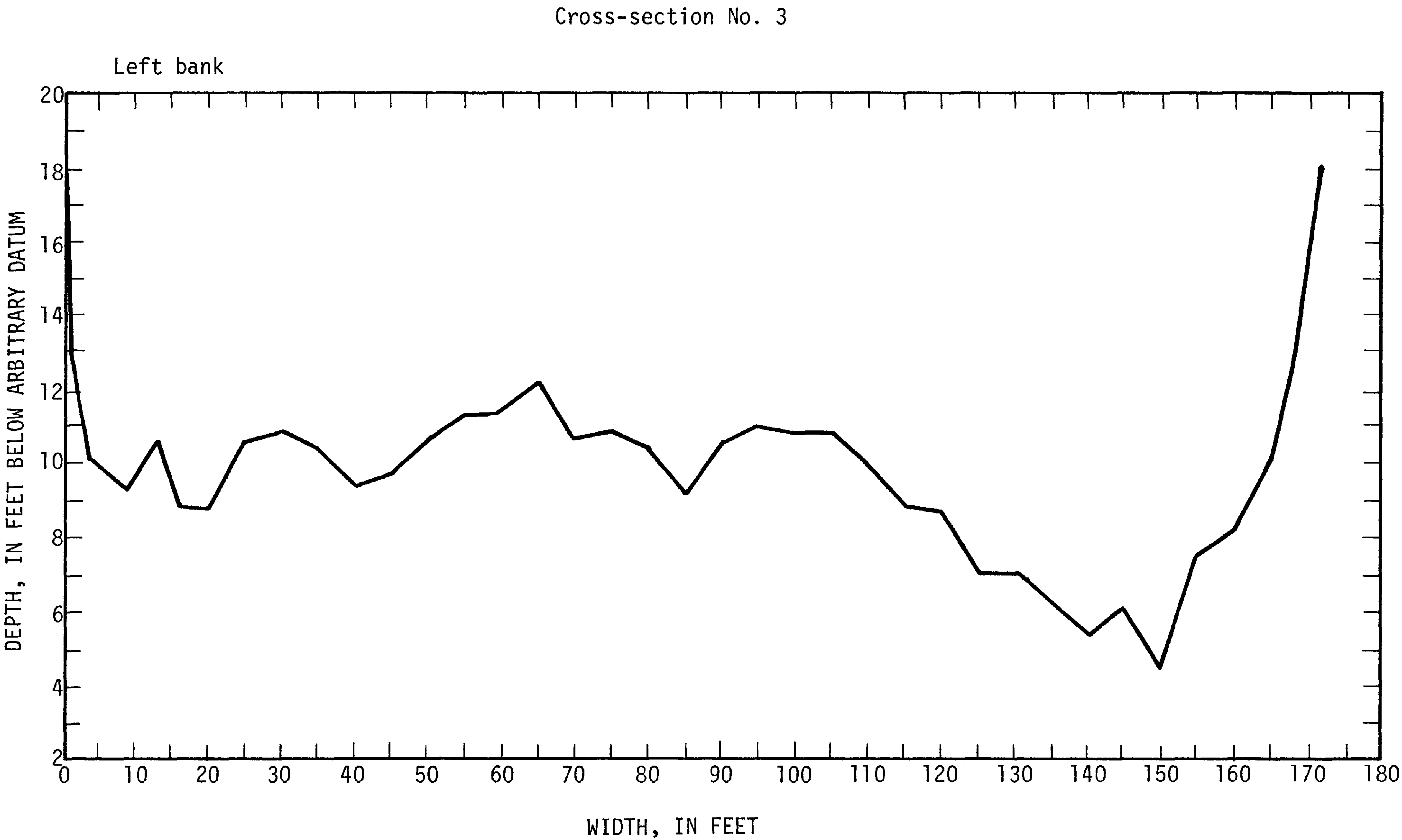


Figure 17b. Cross-section profile of Wailuku River at Hilo, Hawaii, station 16713000, July 27, 1978.

Particle size and bed material

Bed material is the sediment mixture of which the streambed is composed. Some of this bed material is transported in the stream channel by rolling or sliding on and near the streambed. This material is called the bedload, which includes boulders, cobbles, gravel, and coarse sand. The quantity of bedload transported depends on channel hydraulics as well as on the size, shape and weight of material. Data on bed-material size are important for evaluating hydraulic properties and for describing stream habitat.

Table 10 shows the particle-size distribution of bed material at the six study sites. Because of large particle sizes, the optical method, as described by Ritter and Helley (1969), was used to determine size-distribution in the range of 4 to 256 mm.

The particle size of bed material in the Wailuku River ranged mostly from 5.7 to 91 mm. A higher percentage of the smaller size material occurred at station A, near Pua Akala, than at any of the lower stations sampled. This is due primarily to the lack of perennial and flood flows at the station. Also, the site drains mostly lava and cinder land. Boulders larger than 256 mm were observed at all the sample sites but these were not considered in the tabulation.

Table 10. Particle size of bed material at six study sites, Wailuku River, Hawaii

(Volumetric analysis by optical analyzer)

		Percent finer than the size (in millimeters) indicated												
Station	Date	4.0	5.7	8.0	11	16	23	32	45	64	91	128	181	256
A	11/3/77	--	14	19	28	36	50	72	89	100				
16701750	11/4/77	--	6	8	12	16	23	36	48	64	100			
16701800	11/1/77	--	10	10	10	11	13	17	29	61	100			
16704000	11/30/77	7	7	8	8	9	12	18	38	71	100			
B	11/2/77	--	--	1	1	1	2	3	4	6	11	16	24	100
16713000	11/30/77	--	2	5	9	16	29	58	77	89	100			

Suspended Sediment

A sediment station was established in 1977 at Wailuku River at Hilo, station 16713000. Daily sediment records were collected to monitor the suspended-sediment load discharging from the basin into Hilo Bay. The station was in operation from March 1977 to October 1979. It was destroyed during the flood of November 17, 1979, was rebuilt, and has been operating since June 1980. All sediment data are published annually in the U.S. Geological Survey's "Water Resources Data for Hawaii and Other Pacific Areas" (1977-1983).

Based on records for 31 months during 1977-79, Wailuku River discharged a total of 58,000 tons of suspended sediment into Hilo Bay. On February 20, 1979, 14,100 tons were recorded; an equivalence of 24 percent of the total suspended load for the 31-month period. For the same period of record, the instantaneous suspended-sediment concentrations were used to develop a general relation between water discharge and suspended-sediment discharge (fig. 18). The points on this curve represent the suspended-sediment discharge of the stream at the time of sampling, the results being expressed as though the cited discharge had persisted for a full day.

Suspended-sediment concentrations ranged from 1 to 3,000 mg/L. Concentrations greater than 20 mg/L seldom occurred when the streamflow was less than 200 ft^3/s. The sediment concentration did not exceed 10 mg/L for all samples collected when the discharge was less than 80 ft^3/s, which occurred about 50 percent of the time. Compared with streams on Oahu, the Wailuku River (16713000) carries less than half the suspended-sediment concentration at similar flows.

Hawaii's water quality standards do not contain any criteria for suspended-sediment. However, for total nonfiltrable residue (suspended solids), the criterion for stream water is:

	Geometric mean not to exceed (mg/L)	Not to exceed more than 10 percent of the time (mg/L)	Not to exceed the given value (mg/L)
Wet season Nov. 1-Apr. 30	20	50	80
Dry season May 1-Oct. 31	10	30	55

Equating suspended-sediment values to suspended-solid values, the Wailuku River did not exceed water-quality standards except during periods of heavy runoff, which occur less than 10 percent of the time. The 80 mg/L limit was exceeded 5 percent of the time for the period 1977 to 1979 during storms when streamflow was greater than 1,000 ft^3/s.

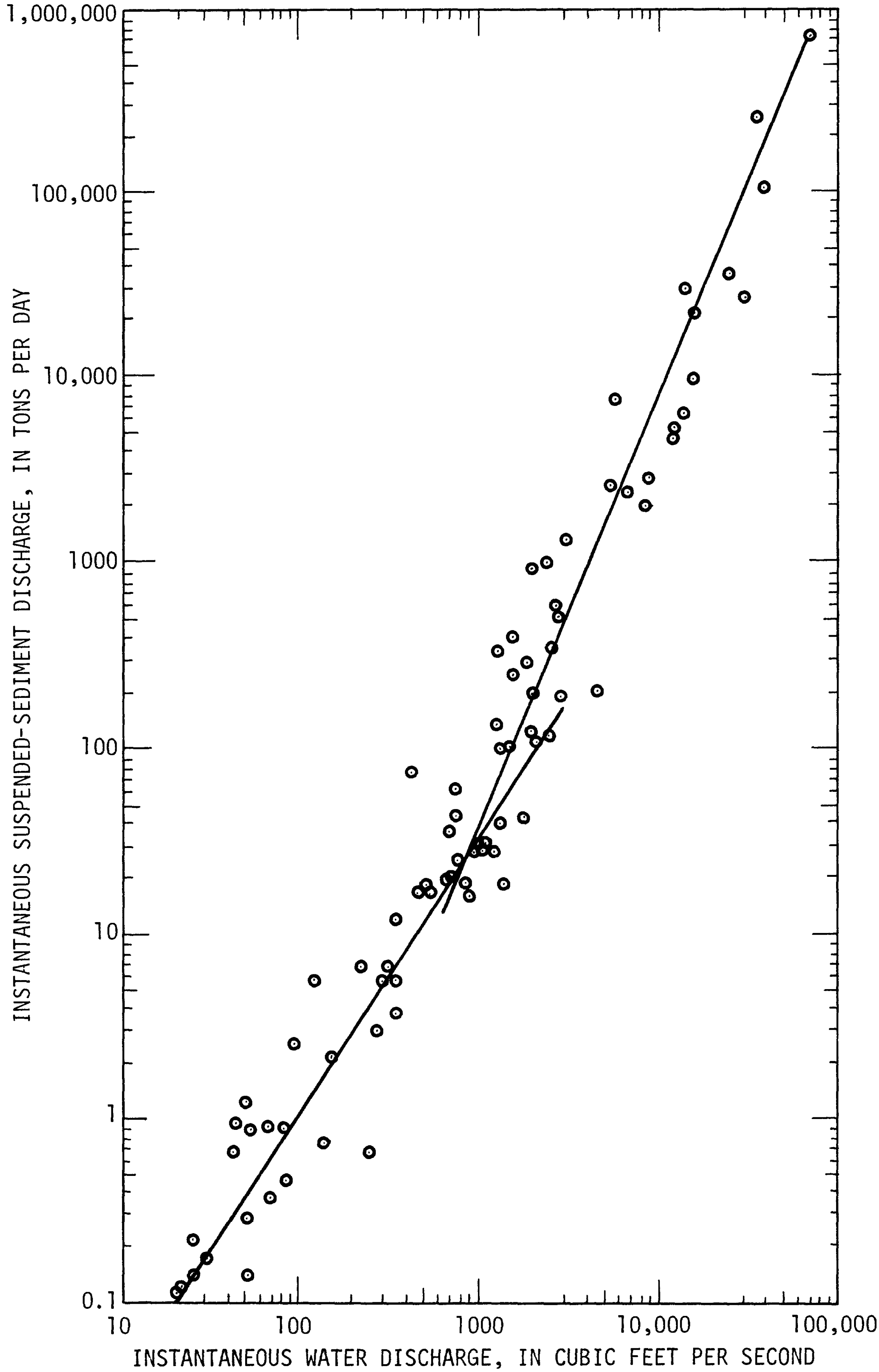


Figure 18. Instantaneous water and suspended-sediment discharge curve, station 16713000, Wailuku River at Hilo, Hawaii.

Particle-size analyses of storm samples indicated that 25 to 48 percent of the suspended sediment was in the sand-size range (0.062 to 2.0 mm), a higher percentage than observed for streams in Oahu (Jones and others, 1971). The sand is from outside the stream channel, derived mostly from weathering of basalts and volcanic cinder cones. It moves out of the basin with each flood and contributes to the "black sand" beaches in the Hilo Bay area. Particles in suspended-sediment samples collected during normal flow are in the silt-clay size (0.002 to .062 mm) ranges. For example, the particle sizes of all monthly samples collected from May 1975 to October 1982 from station 16704000 for NASQAN were less 0.062 mm.

Chemistry

The water chemistry of Wailuku River is presented in terms of physical and chemical measurements taken at four gaging-station sites. Frequency of measurements varied with the type of constituents or characteristic determined and with the station operation. Physical constituents such as temperature, pH, specific conductance, were measured quarterly for Humuula station, 16701750; eight times per year for Kaumana station, 16701800; and monthly for stations at Piihonua, 16704000 and at Hilo, 16713000. Chemical constituents were measured periodically for the Humuula and Kaumana stations, and monthly for the Piihonua and Hilo stations. All water-quality data are published annually in "Water-Resources Data for Hawaii and Other Pacific Areas", (U.S. Geological Survey, 1961-83.)

Stream temperature

Stream temperature in the Wailuku River does not vary significantly along the stream course. The mean water temperature increased by only 1.4°C between the Humuula station at the 4,250-foot elevation and Hilo station near sea level. Water temperature fluctuates with ambient conditions, and ranged between 14.0-23.0°C. Figure 19 shows the maximum, minimum, and mean temperatures recorded at the four gaging-station sites.

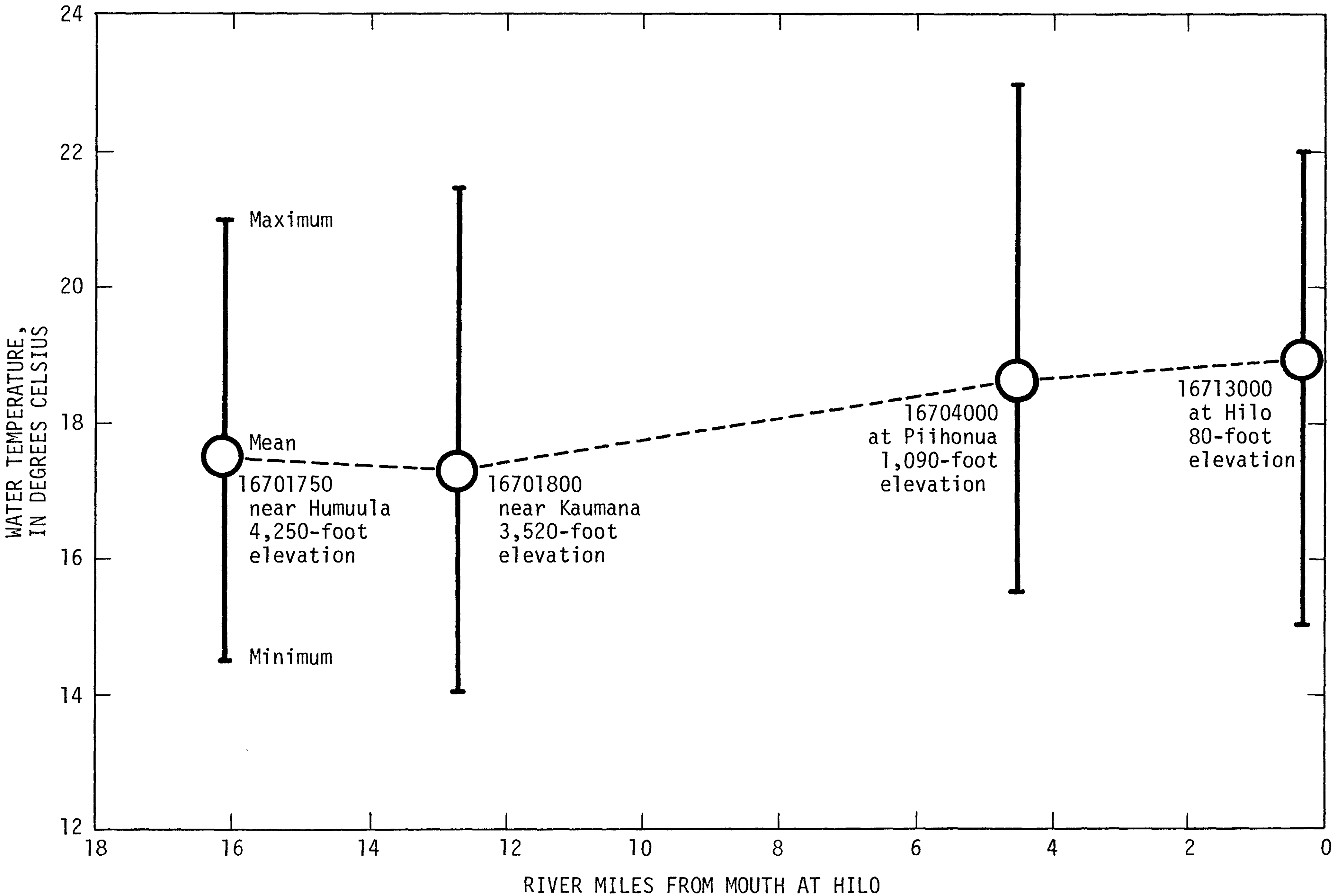


Figure 19. Water temperature of Wailuku River, Hawaii.

pH values

The pH value is a measure of acidity or basicity, and is defined as the negative logarithm of the hydrogen ion concentration. A neutral solution has a pH of 7. Values higher than 7 indicate basic solutions, and values lower than 7 indicate acidic solutions. In the Wailuku River, pH values measured at four stations, ranged between 5.0 and 8.5. Slightly lower values were recorded at the 4,250-foot elevation than at the Hilo station near the mouth of the river. The low values indicate slight acidity and are attributed mostly to rainfall runoff and its interaction with the volcanic rocks. Low mineralization and lack of alkalinity to serve as a buffering agent also contributes to the low values. The pH tends to increase in downstream reaches as alkalinity increases. The pH of the water is not likely to have significant detrimental effects or to directly harm freshwater aquatic life. Figure 20 shows the pH ranges of the water in the Wailuku River.

Specific conductance and dissolved solids

Specific conductance is a measure of the ability of water to conduct an electrical current and is directly proportional to the amount of dissolved solids in water. The dissolved-solids concentration can be estimated from specific conductance values by the following relationship: dissolved solids (mg/L) = specific conductance (μmhos) x A (a conversion factor). In Wailuku River water, the regression line is not linear. The conversion factor A was found to range from 0.57 to 1.1.

The specific conductance of Wailuku River ranged from 16 to 85 micromhos. The values are very low when compared with values from similar streams in conterminous United States and many streams on Oahu. The principal reason for the low specific conductance values is the high rainfall over a terrain of fresh volcanic rock.

As indicated by its low specific conductance values, the water in the Wailuku River contains very little dissolved solids. The highest dissolved-solids concentration measured was 62 mg/L, which occurred at station 16713000 at Hilo. Average concentration for monthly samples analyzed at stations 16704000 and 16713000 was 33 mg/L and 41 mg/L, respectively. Slightly lower values were found for the waters at higher elevation.

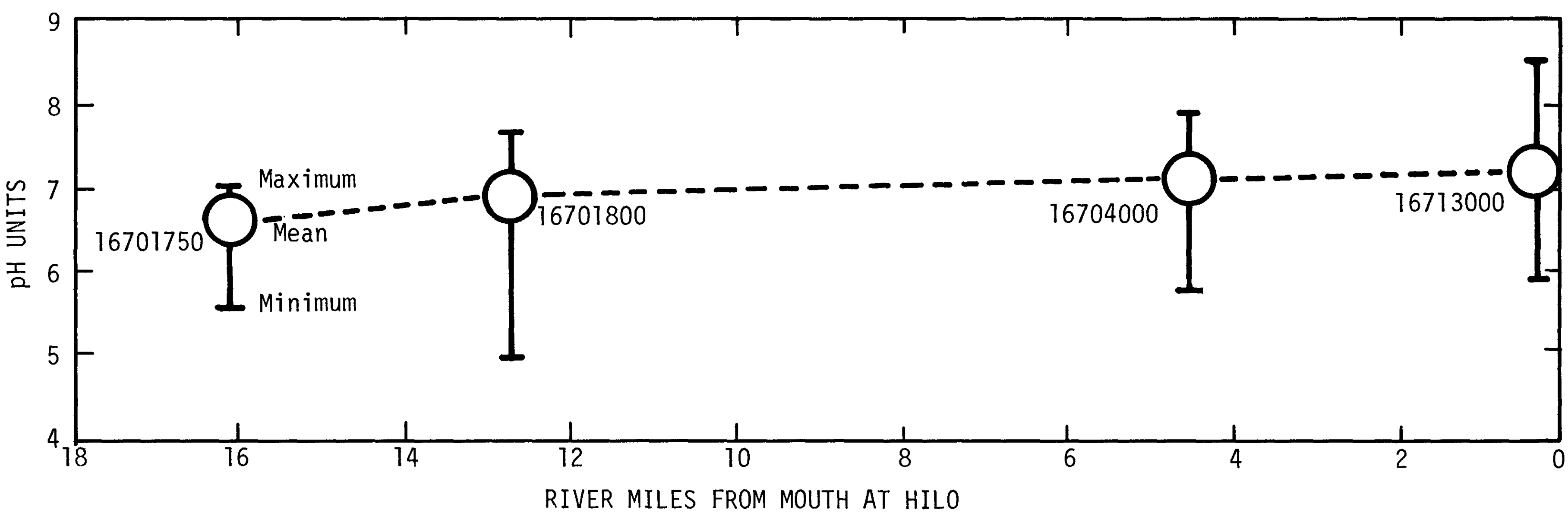


Figure 20. pH of water in Wailuku River, Hawaii.

Specific conductance also correlates with the concentration of individual dissolved constituents in the water. The relationship can be expressed as:

Constituent concentration = (R) x (Specific conductance) + B.

Concentration is in milligram per liter, R is the regression coefficient, and B is the regression constant. A summary of the above relationship between selected chemical constituents and specific conductance for Wailuku River stations at Piihonua and Hilo is provided in tables 11 and 12. The summary shows relationship between specific conductance and concentrations of bicarbonate, hardness, calcium, magnesium, sodium, silica, and dissolved solids.

Ionic composition

The ionic composition of water in the Wailuku River is predominantly calcium, magnesium, sodium, and bicarbonate. The water contains no single cation which amounts to 50 percent or more of the total cation. Calcium, magnesium, and sodium are all present in relative proportions but neither of the three equal to 50 percent of the total cations. Bicarbonate is the most dominant anion and amounts to more than 50 percent of the total anion.

Ion-concentration diagrams for Wailuku River water at stations 16704000, Piihonua, and 16713000, Hilo, are shown in figure 21. Each circular diagram represents the mean value of all monthly samples collected at the two stations. The cation-anion equivalents for the two sites are similar.

Turbidity

Turbidity in water is caused principally by fine colloidal sediments, such as clay and silt, and by minute organisms and plants that are held in suspension. As expected, turbidity in the Wailuku River is highest during periods of heavy rainfall. During base-flow conditions, turbidity values seldom exceed five NTU[1/] (Nephelometric Turbidity Units). A maximum value of 45 NTU was recorded for one sample collected from the Hilo station during a storm flow of 2,300 ft^3/s. The 45 NTU value is low compared to Oahu streams, where turbidity values greater than 200 NTU are common during storm runoffs. The relatively low turbidity in the Wailuku River is attributed to a stable streambed, well vegetated streambanks, and small percentage of agricultural land use within the basin.

1/ Turbidity values reported as JTU (Jackson Turbidity Unit) in earlier analyses are considered equivalent to NTU for this report.

Table 11. Statistical summary of water-quality data, Wailuku River at Piihonua, Hawaii, station 16704000

Period of record: October 1, 1971 through September 30, 1980

Statistical summary of sélected dissolved chemical constituents and regression relationships of constituent concentrations to specific conductance

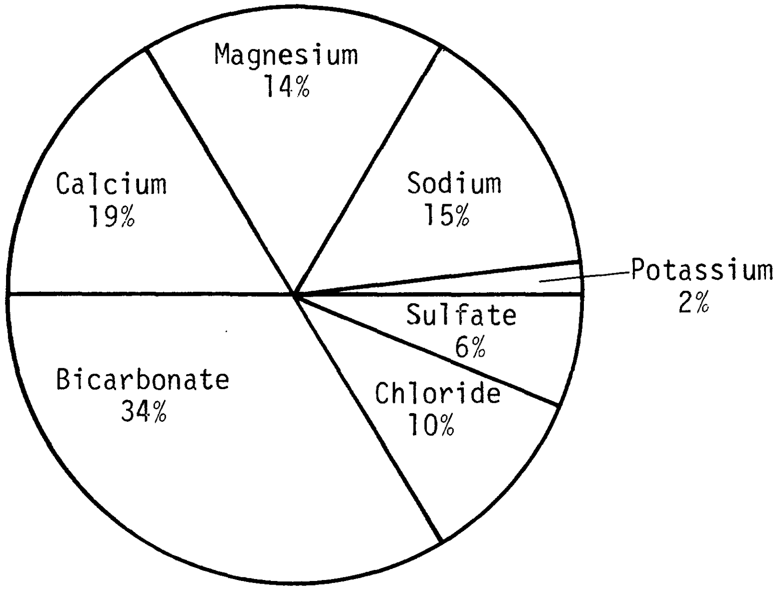
Constituent	No. of samples	Mean (mg/L)	Standard deviation	Range		Regression coefficient R	Constant B	Correlation coefficient	Standard error of estimate
Specific conductance (micromhos)	83	39.25	9.73	20	75				
Bicarbonate ion	51	17.27	5.98	5	33	0.4127	0.9297	0.7575	3.9417
Hardness, total	66	13.52	4.02	5	26	0.2836	2.5451	0.7148	2.8331
Calcium, dissolved	66	3.11	0.93	1.1	5.3	0.0599	0.7888	0.6527	0.7100
Magnesium, dissolved	66	1.39	0.53	0.6	3.1	0.0324	0.1342	0.6197	0.4197
Sodium, dissolved	66	2.76	0.46	1.8	3.9	0.0311	1.5555	0.6839	0.3386
Silica, dissolved	66	11.82	3.76	3.5	22	0.26160	1.6991	0.7048	2.6889
Dissolved solids, residue on evaporation at 180°C	58	32.91	7.67	12	53	0.4454	15.8749	0.5689	6.3671
Dissolved solids, sum of constituents	66	33.29	7.83	15	52	0.5902	10.4587	0.7641	5.0880

Table 12. Statistical summary of water-quality data, Wailuku River at Hilo, Hawaii station 16713000

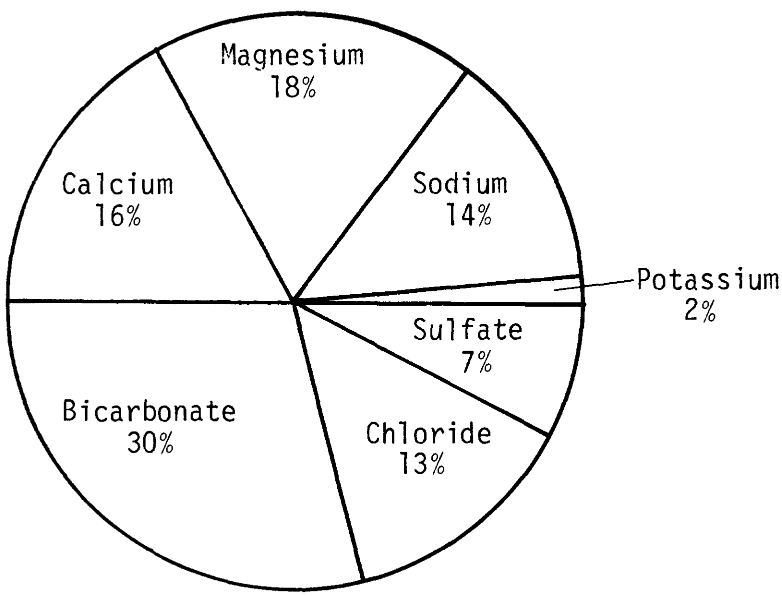
Period of record: February 1, 1977 through September 30, 1980

Statistical summary of selected dissolved chemical constituents and regression relationships of constituent concentrations to specific conductance

Constituent	No. of samples	Mean (mg/L)	Standard devia- tion	Range		Regression coeffi- cient, R	Constant, B	Corre- lation coeffi- cient	Standard error of estimate
Specific conductance (micromhos)	54	50.83	18.08	16	85				
Hardness, total	22	18.55	7.56	3	33	0.4434	-4.7524	0.9515	2.3836
Calcium, dissolved	22	3.58	1.53	0.4	6.2	0.0896	-1.1255	0.9480	0.5002
Magnesium, dissolved	22	2.30	1.03	0.4	4.4	0.0534	-0.5019	0.8415	0.5703
Sodium, dissolved	22	3.17	0.86	0.9	4.6	0.0499	0.5484	0.9358	0.3125
Silica, dissolved	22	11.61	3.76	2.4	17	0.2219	-0.0439	0.9585	1.0983
Dissolved solids, residue on evaporation 180°C	20	41.30	12.91	16	62	0.7518	1.0403	0.9657	3.4464
Dissolved solids, sum of constituents	22	38.18	12.62	10	59	0.7337	-0.3700	0.9439	4.2699



Station 16704000, Wailuku River at Piihonua, Hawaii.



Station 16713000, Wailuku River at Hilo, Hawaii.

Figure 21. Ionic composition based on percentage of total milliequivalents per liter at two stations of Wailuku River, Hawaii.

Dissolved oxygen

Dissolved-oxygen (DO) concentrations in the Wailuku River are high and adequate to support most aquatic organisms in the streams. The high concentrations are due, in part, to the numerous waterfalls in the basin. DO concentrations ranged from 8.4 to 10.2 mg/L for all monthly samples collected at the Piihonua (16704000) and Hilo (16713000) stations. This range represents 88-113 percent DO saturation, which is above the 80-percent minimum criterion established by Hawaii's State Water Quality Standards, Chapter 54 (1982).

A 24-hour recording of dissolved oxygen was made on November 29-30, 1977, and on July 26-27, 1978, at the Hilo site, station 16713000 (fig. 22). Dissolved oxygen levels fluctuated slightly from 8.8 to 9.2 mg/L (95-99 percent saturation) during the November diel measurements. There was no diel variation recorded during the July measurements, when DO ranged only between 9.0-9.2 mg/L (97-99 percent saturation). The difference in diel fluctuations between the two measurements is attributed mainly to streamflow. The discharge was 26 ft^3/s, near base-flow conditions, on November 30, 1977, and 300 ft^3/s on July 27, 1978. The higher flows, cascaded over numerous waterfalls, are well aerated, and thus maintained higher DO content.

Nitrogen and phosphorus

Nitrogen and phosphorus are essential nutrients for plant growth. In the aquatic environment, they play a major role in the process of eutrophication, and they are often considered to be the "limiting factors" in algae production. The enrichment of a body of water with nutrients is normally associated with increase in algal population. Table 13 is a summary of nutrient analyses from Wailuku River at stations 16704000 at Piihonua, and 16713000, at Hilo.

Nitrogen--Several forms of nitrogen are found in natural waters. Most common of these are ammonia, nitrite, nitrate, and organic nitrogen. Samples of unfiltered water were analyzed from Piihonua and Hilo stations. They include both the dissolved and suspended phases, reported as "total nitrogen". In addition, filtered water samples from the Hilo station were analyzed also for the dissolved forms of nitrogen.

Ammonia is a reduced form of nitrogen that is readily oxidized to nitrite and nitrate. It is also the preferred form of nitrogen for algae growth. Ammonia concentration in the Wailuku River is very low. Mean monthly values did not exceed 0.03 mg/L. The low values are due, mostly, to the lack of ammonia input and to the high rate of in-stream oxidation of ammonia to nitrate.

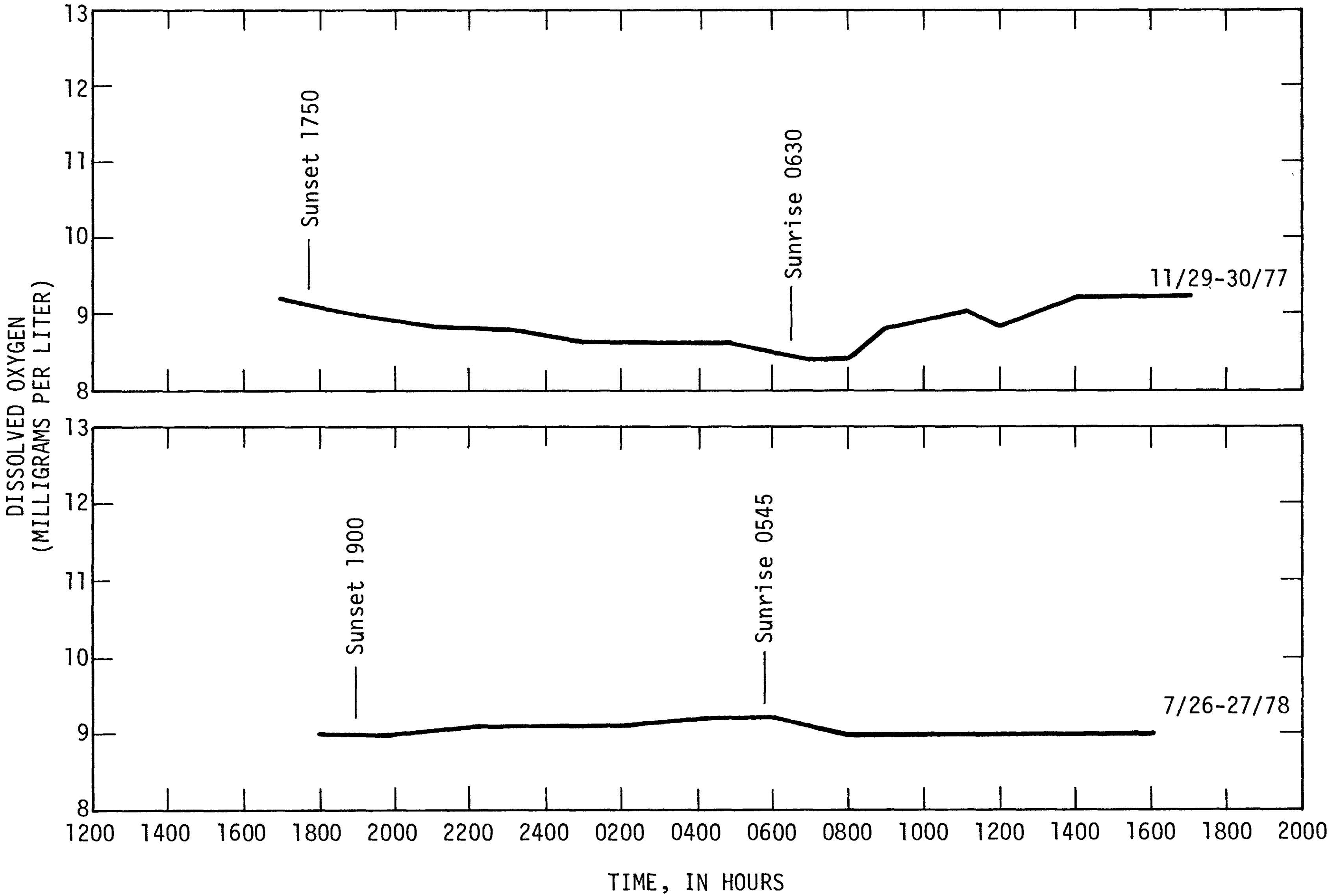


Figure 22. Dissolved-oxygen concentration versus time, Wailuku River at Hilo, Hawaii, station 16713000.

Table 13. A summary of nutrient analyses from two Wailuku River stations, Hawaii

	16704000			16713000		
	No. of samples	Mean (mg/L)	Range (mg/L)	No. of samples	Mean (mg/L)	Range (mg/L)
Total ammonia (as N)	27	0.01	0.00-0.02	53	0.02	0.00-0.18
Dissolved ammonia (as N)	--	--	--	13	0.03	0.00-0.07
Total nitrite plus nitrate (as N)	62	0.09	0.02-0.29	52	0.14	0.03-0.66
Dissolved nitrite plus nitrate (as N)	--	--	--	14	0.14	0.04-0.23
Total ammonia plus organic nitrogen (as N)	57	0.19	0.00-0.91	52	0.34	0.00-2.00
Dissolved ammonia plus organic nitrogen (as N)	21	0.14	0.00-0.46	23	0.28	0.00-0.85
Total phosphorus (as P)	62	0.01	0.00-0.05	52	0.03	0.00-0.29
Dissolved phosphorus (as P)	25	<0.01	0.00-0.02	25	0.01	0.00-0.04
Total organic carbon (as C)	29	2.2	0.6-8.3	43	3.3	0.7-13

Nitrite and nitrate are considered the major inorganic component of nitrogen in the Wailuku River. Nitrite, an intermediate product of aerobic oxidation and decomposition, is extremely low, usually below levels of detection in Hawaiian surface waters. The combined measurement of nitrite and nitrate is reported as a single value of nitrogen (NO_2 + NO_3 as N). The mean value for all monthly samples collected from Wailuku River at Hilo is 0.14 mg/L.

Ammonia plus organic nitrogen, frequently referred to as kjeldahl nitrogen (KJD-N), is the largest component of the nitrogen species in the waters at Wailuku River. Because ammonia nitrogen is usually very low, the KJD-N determination reveals that organic nitrogen is the most abundant form of nitrogen in the river. Kjeldahl nitrogen concentration nearly doubled between Piihonua and Hilo stations. Mean concentrations between the two sites increased from 0.19 to 0.34 mg/L for total KJD-N, and 0.14 to 0.28 mg/L for dissolved KJD-N. The increase is the result of higher input of organic nitrogen material from the watershed from increased runoff. Streamflow is 60 percent higher at the Hilo station than at Piihonua.

Phosphorus--Phosphorus is known to occur in several forms, and those of greater concern in water are dissolved inorganic and organic phosphorus, and particulate organic phosphorus. Dissolved phosphorus generally occurs in the form of phosphate. Total phosphorus includes the dissolved plus the particulate portions that are associated with suspended sediments.

Phosphorus concentration is very low in the Wailuku River. Mean values for all the monthly samples analyzed from Hilo station are 0.01 and 0.03 mg/L for dissolved and total phosphorus, respectively. Phosphorus concentration values are highest during periods of heavy runoff, due to higher particulate concentrations in the water.

Total organic carbon

Total organic carbon (TOC) data provide a gross measure of dissolved and particulate organic materials in the water. The materials include plant detritus, decay products, living cells, organic chemicals and other sources of organic substances. There are no criteria to compare TOC values for acceptability. TOC values for Wailuku River are included in the nutrient summary in table 13. The concentration ranged from 0.6 to 13 mg/L with mean concentration values of 2.2 and 3.3 for Piihonua and Hilo stations, respectively.

Minor elements

Minor elements, often called trace metals, occur in minute concentrations in the Wailuku River. These trace metals are of concern because, even in low concentrations, they may be toxic to humans, plants, and animals.

Twelve minor elements were analyzed from quarterly samples collected at Piihonua and Hilo stations. These elements were arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, selenium, silver, and zinc. Analyses were performed on both unfiltered samples and samples that were filtered through a 0.45-micrometer pore-size membrane filter. Concentration results from the unfiltered samples are reported as total, while results from the filtered samples are reported as dissolved. A summary of total and dissolved minor-element concentrations are listed in tables 14 and 15.

Mean values for several of the minor elements were not computed because many of the true values were not known. Due to interferences and lack of detection limits in some analytical methods, it was necessary to report values as "less than" figures.

Generally, the concentrations of minor elements in the Wailuku River, except iron and manganese, are low. Concentration values seldom exceed the water-quality criteria recommended for domestic water supplies by the U.S. Environmental Protection Agency (1976). Total-concentration values for cadmium, chromium, iron, lead and manganese have occasionally exceeded recommended criteria during periods of high runoff. High concentration values are associated with the suspended solids and do not occur during normal flow conditions.

Table 14. A summary of total minor-element concentration for Wailuku River stations at Piihonua and Hilo, Hawaii

(Mean values denoted by a were not computed because "less than" values were in the data set)

	16704000 1975-1979			16713000 1977-1980		
Minor elements (Total)	No. of samples	Mean (µg/L)	Range (µg/L)	No. of samples	Mean (µg/L)	Range (µg/L)
Arsenic (As)	20	0.6	0-3	19	0.8	0-3
Cadmium (Cd)	18	a	<1-11	20	a	<10-10
Chromium (Cr)	20	3.5	0-40	21	9.1	0-50
Cobalt (Co)	21	a	0-<50	20	a	0-<50
Copper (Cu)	21	a	<1-20	20	a	<1-70
Iron (Fe)	21	191	30-620	21	2000	80-23000
Lead (Pb)	19	a	<1-200	20	a	0-<100
Manganese (Mn)	20	5.4	0-20	21	27	0-180
Mercury (Hg)	20	0.1	0.0-0.9	21	0.02	0.0-0.3
Selenium (Se)	20	1.6	0-30	19	0.3	0-4
Silver (Ag)	9	a	0-<10	21	a	0-<10
Zinc (Zn)	21	a	<10-100	21	27	0-200

Table 15. A summary of dissolved minor-element concentration for Wailuku River stations at Piihonua and Hilo, Hawaii

(Mean values denoted by a were not computed because "less than" values were in the data set)

	16704000 1975-1979			16713000 1977-1980		
Minor elements (Dissolved)	No. of samples	Mean (µg/L)	Range (µg/L)	No. of samples	Mean (µg/L)	Range (µg/L)
Arsenic (As)	20	0.5	0-3	22	0.4	0-1
Cadmium (Cd)	18	a	<1-3	22	a	<1-9
Chromium (Cr)	20	3.5	0-40	22	1.4	0-10
Cobalt (Co)	21	a	0-<3	20	a	0-<3
Copper (Cu)	21	0.9	0-3	22	2.0	0-10
Iron (Fe)	22	67	10-130	20	114	0-930
Lead (Pb)	17	a	<1-13	21	9.1	0-90
Manganese (Mn)	22	1.5	0-10	20	5	0-50
Mercury (Hg)	20	0.02	0.0-0.2	22	0.0	0.0-0.1
Selenium (Se)	20	0.7	0-13	20	0.2	0-3
Silver (Ag)	9	0.0	0	17	0.0	0
Zinc (Zn)	20	a	0-<10	20	a	0-<10

SUMMARY AND CONCLUSIONS

1. The number and types of benthic organisms in Wailuku River are low. Periphyton data indicate unpolluted water that has low to moderate primary productivity. Fecal coliform densities seldom exceed the State of Hawaii's water-quality standards and then only in the lower reaches near Hilo.
2. Physical controls, rather than chemical toxicity, limit the number and type of organisms in the Wailuku River. The streambed is composed of volcanic lava and is characterized by a series of plunge pools and waterfalls. Channel gradient is steep and flow velocities are high. Depending on elevation, the channel depth ranges from 6 to more than 40 ft, and channel width ranges from 60 to 220 ft.
3. Bed material that moves as bedload was found to range in grain size from 4 to 91 mm in the Wailuku River. The percentage of smaller-size material is higher in areas that drain barren cinder land.
4. Suspended-sediment discharges are highest during storm runoff. The particle-size distribution of suspended sediment is approximately 25 percent sand and 75 percent silt and clay.
5. Chemical quality of Wailuku River is excellent. Stream temperature and pH values do not vary significantly and dissolved-solids content measured does not exceed 62 mg/L. Calcium, magnesium, sodium and bicarbonate are the major ions in the water. Dissolved oxygen levels are at or near saturation, and are adequate to support most aquatic organisms. Nutrient concentrations are low, and minor element (trace metals) concentrations seldom exceed drinking-water standards.

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GLOSSARY OF SELECTED BIOLOGICAL TERMS

Algae - members of the plant kingdom containing chlorophyll, unicelluar reproductive structures, and consisting of a single cell, filament, or colony of cells of various organizations but never organized into tissues.

Anaerobic - adjective denoting the absence of free oxygen.

Autotroph - an organism in which organic matter is synthesized from inorganic substances.

Autotrophic index - the ratio of biomass to chlorophyll *a*. It is used as an indication of the relative autotrophy or heterotrophy of a periphyton community.

Benthos - refers to organisms living or attached to the substrate or bottom material in an aquatic habitat; also refers to deep-water life.

Biomass - see standing crop.

Carnivore - an organism that obtains its nourishment by consuming animals.

Chlorophyll - the primary photosynthetic pigment in most algae and higher plants. It occurs in three forms designated chlorophyll a, *b* and *c*.

Dendrogram - a branching diagrammatic representation of the interrelations of a group of items sharing some common factors.

Diadromous - refers to an organism that completes part of its life cycle in freshwater and another part in saltwater.

Endemic - occurs naturally in only one geographic area; in this report, Hawaii.

Exoskeleton - the external skeleton or supportive covering of an invertebrate.

Fauna - the animal life in a particular habitat or area.

Fecal coliform bacteria - that part of the coliform group that is present in the gut of warmblooded animals; they are indicators of possible sewage pollution.

Fecal streptococcal bacteria - a particular group of bacteria found in the gut of warmblooded animals; their presence in waters is considered to verify fecal pollution.

Herbivore - an organism that obtains its nourishment by consuming plants.

Heterotroph - an organism that requires organic material as a source of nutrition.

Indigenous - occurs naturally in the geographic area described (Hawaii) but also occurs elsewhere.

Invertebrate - an animal without a backbone.

Jaccard similarity coefficient - an index of the similarity of two samples.

Larvae - juvenile insect which hatches from the egg in an early stage of metamorphological development and differs fundamentally in form from the adult.

Periphyton - the assemblage of organisms attached to the substrate.

Plankton - the community of suspended or floating organisms.

Primary productivity - the rate at which radiant energy is stored by photosynthetic and chemosynthetic organisms in the form of organic substances.

Productivity - the total amount of living matter produced in an area per unit time.

Pupae - in insects, the resting or inactive stage of organic matter in the heterotrophs of the community.

Secondary productivity - the rate of increase of organic matter in the heterotrophs of the community.

Seston - the total particulate matter suspended in water.

Standing crop - the amount of living matter present at any given time, expressed as the number or weight per unit area or volume of habitat.

Substrate - the physical surface upon which something lives.

Taxon - a category in which a group of organisms are placed which denotes that they have similar genetic and morphological characteristics.