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[12]Abstract (Purpose, method, results, conclusions)

This study is an extension of the project, "Recycling of Sewage Effluent by Irrigation: A Field Study on Oahu," completed in July 1975. The major objective of this portion was to determine the dilution with Waiahole Ditch water necessary for optimal sugar yield when chlorinated, secondarily treated sewage effluent was used for furrow irrigation of cane. Hawaiian sugarcane variety 59-3775 was planted in October 1976 to a random-block design of treatments with six replicates in Oahu Sugar Company's Field No. 246 in central Oahu near the Mililani Sewage Treatment Plant. The five irrigation treatments for the 2-yr cane cycle were (1) ditch water; (2) 12.5%; (3) 25%; (4) 50% effluent diluted with ditch water; and (5) effluent the first year and ditch water the second year. The ripener "Polaris" was applied prior to harvest which was completed in October 1978. Crop logs monitored the cane growth and test plots were hand harvested for assessment of cane and sugar yield. Porous plastic tubes were used to sample soil water percolate for chemical analyses. The sewage effluent and the percolate were checked for the presence of human enteric viruses. Sugar yields for effluent concentrations up to 25%, or for effluent the first year and ditch water the second year, were equal to those from conventional ditch-water irrigation. There was a significant loss in juice quality and sugar yield for the 50% effluent concentration. The correlation coefficient between effluent concentration and cane yield was +0.66; between effluent and juice quality, -0.99; and between effluent and sugar, -0.86. The irrigation was equavalent to an annual average of approximately 2.03 m (80 in.)/yr and would thus require 6.8×10^5 m^2(167 acres) for each 0.04 m^3/s (1 mgd) of undiluted output from the Mililani plant. Immediately after each application of fertilizer and also with effluent concentrations of 50 to 100%, the nitrate nitrogen concentrations in the percolate exceeded the critical level of 10 ppm for potable water. An estimated 55% of the irrigation percolated beyond the root zone and from 0.008 to 0.028 kg/m^2 (69.3-254.3 lb/acre) of nitrate since the total applications far exceeded the ability of the sugarcane to take up nitrogen. An unexplained nitrogen deficit of 0.013 to 0.038 kg/m^2 (115-338.6 lb/acre) was assigned to gaseous nitrogen loss. No virus was recovered from the test plots, although 40% of the samples from the effluent reservoir were positive. At least 96% of the virus was inactivated after 1 day of storage.

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RECYCLING OF SEWAGE EFFLUENT BY SUGARCANE IRRIGATION: A DILUTION STUDY OCTOBER 1976 TO OCTOBER 1978 PHASE II-A

Technical Report No. 130

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March 1980

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ABSTRACT

This study is an extension of the project, "Recycling of Sewage Effluent by Irrigation: A Field Study on Oahu," completed in July 1975. The major objective of this portion was to determine the dilution with Waiāhole Ditch water necessary for optimal sugar yield when chlorinated, secondarily treated sewage effluent was used for furrow irrigation of cane. Hawaiian sugarcane variety 59-3775 was planted in October 1976 to a random-block design of treatments with six replicates in Oahu Sugar Company's Field No. 246 in central O'ahu near the Mililani Sewage Treatment Plant. The five irrigation treatments for the 2-yr cane cycle were (1) ditch water; (2) 12.5%; (3) 25%; (4) 50% effluent diluted with ditch water; and (5) effluent the first year and ditch water the second year. The ripener "Polaris" was applied prior to harvest which was completed in October 1978. Crop logs monitored the cane growth and test plots were hand harvested for assessment of cane and sugar yield. Porous plastic tubes were used to sample soil water percolate for chemical analyses. The sewage effluent and the percolate were checked for the presence of human enteric viruses. Sugar yields for effluent concentrations up to 25%, or for effluent the first year and ditch water the second year, were equal to those from conventional ditch-water irrigation. There was a significant loss in juice quality and sugar yield for the 50% effluent concentration. The correlation coefficient between effluent concentration and cane yield was +0.66; between effluent and juice quality, -0.99; and between effluent and sugar, -0.86. The irrigation was equivalent to an annual average of approximately 2.03 m (80 in.)/yr and would thus require 6.8×10^5 m^2 (167 acres) for each 0.04 m^3/s (1 mgd) of undiluted output from the Mililani plant. Immediately after each application of fertilizer and also with effluent concentrations of 50 to 100%, the nitrate nitrogen concentrations in the percolate exceeded the critical level of 10 ppm for potable water. An estimated 55% of the irrigation percolated beyond the root zone and from 0.008 to 0.028 kg/m^2 (69.3-254.3 lb/acre) of nitrate since the total applications far exceeded the ability of the sugarcane to take up nitrogen. An unexplained nitrogen deficit of 0.013 to 0.038 kg/m^2 (115-338.6 lb/acre) was assigned to gaseous nitrogen loss. No virus was recovered from the test plots, although 40% of the samples from the effluent reservoir were positive. At least 96% of the virus was inactivated after 1 day of storage.

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INTRODUCTION

Phase II-A is an extension of the recently completed 4-yr project (Lau et al. 1975), "Recycling of Sewage Effluent by Irrigation: A Field study on Oahu" (Phase I). In Phase I, secondarily treated sewage effluent from the Mililani Sewage Treatment Plant (STP) was applied to thirty 404.7 m^2 (0.1 acre) test plots of sugarcane in Oahu Sugar Company's (OSC) Field No. 246 in central O'ahu, Hawai'i. The results showed that sewage effluent used for irrigation during the first year and with Waiāhole Ditch water during the second year of the 2-yr sugarcane crop cycle increased the sugar yield by 6% over control plots, whereas sewage effluent applied during the full 2-yr cycle decreased the sugar yield to 6% below the control plots. Sewage-borne viruses and coliform bacteria in the applied sewage effluent were inactivated within the shallow root zone, and salts, including nitrogen (N), did not leach below the root zone in any greater quantities than in the companion ditch-irrigated plots.

Phase I originated as a result of concurrent resolutions by the House (H.C.R. No. 67) and the Senate (S.C.R. No. 46), and House Resolution No. 22 of the Sixth Legislature of the state of Hawai'i (1971). The House and Senate Concurrent Resolutions requested the City and County of Honolulu to "broaden the scope of the present sewage and water control study to include studies on the feasibility of recycling of sewage...;" H.R. No. 22 requested the Department of Land and Natural Resources, with the cooperation of the county Boards of Water Supply, "to conduct a study to determine the feasibility of reclaiming sewage and waste water for agricultural use...."

Phases I and II have been jointly funded by the Board of Water Supply and the Department of Public Works of the City and County of Honolulu, and conducted under the direction of the Water Resources Research Center of the University of Hawaii, with the Hawaiian Sugar Planters' Association and the Oahu Sugar Company as cooperating agencies.

This report was prepared and presented for management decisions rather than as a purely scientific research document. Enough scientific data, which could be used to explore many areas beyond the direct intent of this report, were gathered. The basic data generated for this report are condensed in the Appendix section.

Need for Study

Surrounded by the Pacific Ocean, the Hawaiian Islands are limited in their natural freshwater resources. Each major island has its characteristic leeward, high temperature, low rainfall, cultivated and/or urban-resort areas that are susceptible to seasonal water shortages especially as the water demand increases. O'ahu accommodates over 700,000 residents, or 80% of the state resident population, receives the majority of the 3.5 million annual influx of tourists, and is the home of most of Hawai'i's military and associated personnel. Thus, the water situation on O'ahu could be potentially more serious on an island-wide basis than on the other islands.

Approximately 85% of the 1977 total freshwater use on O'ahu, 20.59 m^3/s (470 mgd), is from groundwater sources with an estimated 21.03 to 27.6 m^3/s (480-630 mgd) available for a sustainable groundwater yield. Of the total fresh groundwater used in 1977, 10.51 m^3/s (240 mgd) is allocated for sugarcane culture, 5.7 m^3/s (130 mgd) for municipal consumption, 1.75 m^3/s (40 mgd) for military use, and 2.63 m^3/s (60 mgd) for industrial and other uses (State Water Commission 1978). Based on current trends, the year 2000 has been projected by the State Water Commission (1979) to be when the water demand, estimated to be 25 m^3/s (570 mgd), will approach the near median estimate of the sustainable groundwater yield. Thus, by that time supplemental water sources must be found and/or conservation measures initiated.

Now and in the foreseeable future, desalting even brackish groundwater and especially ocean water is not considered economically feasible for a large-scale water supply, especially in view of recent increased energy costs. The catchment of streamflow present multiple problems in Hawai'i, including a limited number of large perennial streams, shortage of reservoir storage space due to limited land area, necessity for extensive water treatment—if used for potable supplies, and uncertainty in stream-use requirements and water rights.

The only other practical supplemental water source is municipal waste water effluent, which is a readily available and dependable resource, has fertilizer value, and may possibly be used for irrigation by the furrow method if its use does not result in groundwater pollution and/or a decrease in crop yield.

If the effluent is not reclaimed and reused for irrigation, the remaining disposal alternatives are groundwater recharge, discharge into freshwater streams, with advanced treatment being required in most situations—which may not be economically viable, or ocean disposal through a long pipeline which is not only costly, but results in the loss of the resource.

In summary, the need is real and urgent to seriously consider the reuse of municipal and domestic sewage effluents for irrigation in Hawai'i from the standpoint of water conservation and waste water management.

Previous Project Findings

Phase I established the basic concept that sugarcane can be successfully furrow irrigated with secondarily treated sewage effluent. Thus, irrigation with sewage effluent could serve as a waste water management alternative and water conservation measure for O'ahu.

During Phase I under experimental conditions, the percolate quality from effluent-irrigated sugarcane soil was of acceptable concentration from the standpoint of potable groundwater quality protection (U.S. Public Health Service 1962; Department of Health, State of Hawaii 1977, chap. 49) for all water quality parameters studied, except for nitrogen (N) during the first 6 mo of growth. However, the concentration of N was also exceeded in the control plots irrigated only with ditch water. Human enteric viruses were present in the majority of the effluent samples even after chlorination, but no viruses were detected in the percolate samples below the root zone throughout the entire 2-yr crop cycle. Thus, the possibility of viral contamination of deep groundwater sources appears to be virtually nonexistent. There should also be no problem with pesticide residues and heavy metals inasmuch as the levels of these constituents were barely detectable or below detection levels in the Mililani Sewage Treatment Plant's treated sewage effluent.

Application of sewage effluent for the first year of a 2-yr sugarcane crop, followed with ditch water thereafter, increased the sugar yield by about 6% compared with the control plots. However, when sewage effluent was applied for the entire 2-yr crop cycle, sugar yield decreased by approximately 6%, which was the result of the juice quality dropping by about 15% even though the total cane yield increased by about 11%. There was no evidence of significant clogging of the soil surface and/or impairment of the soil's physical and/or chemical properties as a result of the application of sewage effluent for irrigating during the full 2-yr crop cycle.

Some major summary recommendations resulting from Phase I include: (1) disinfected secondary sewage effluent of similar composition to the Mililani STP effluent may be used for irrigation of sugarcane in the first year followed thereafter by irrigation with ditch water; however, effluent irrigation for the entire 2-yr crop cycle is expected to result in reduced sugar yields; (2) additional research on various dilutions of treated sewage with ditch water and with the application of chemical ripeners prior to harvest to enhance sugar yields was recommended; and (3) an essential part of recycling effluent by irrigation should include a virus monitoring and quality control program.

Objectives of Study

The main objective of Phase II-A was consistent with the Phase I recommendation of determining sugar yields under field conditions (using chemical ripeners) that result from the application of various dilutions of secondary sewage effluent and ditch water for both years of the crop cycle. Secondary objectives include the estimation of the amount of N that leaches beyond the root zone and the efficiency of virus inactivation at the STP and by the dilution technique employed.

Nature and Rationale of Study

As stated previously, the Phase I results indicated that the use of treated sewage effluent for the irrigation of sugarcane during the first year of growth and of ditch water thereafter increased the sugar yield over conventional irrigation practices, whereas the use of sewage effluent for the entire 2-yr irrigation cycle decreased the yield. However, the practical means of distributing separate, effluent and ditch-water flows poses considerable management problems with the present single-distribution system used for ditch water.

Providing dual systems is a solution, but this may not be economically advantageous under present conditions, particularly as the distance from the sewage treatment plant increases. Thus, the need to determine sugar yield for various dilutions of treated sewage effluent and ditch water for the present distribution system is obvious.

The potential amount of treated sewage effluent that would be available, within economical distribution distances, for sugarcane irrigation is not precisely known at this time, since it will depend to some extent on the land-use policies of the state of Hawai'i and the City and County of Honolulu, and on the amount of sewage effluent that can be used for irrigation. To accommodate the projected resident population, certain rezoning actions will be required. The population projections for central O'ahu and development areas consist of the following:

DEVELOPMENT	AREA (acres)*	2020 POPULATION
Waipio Acres	100	2,500
Melemanu Woodlands	340	12,000
Mililani Town	3600	56,300
TOTAL	4040	70,800

SOURCE: Dept. of Public Works (1977*a*).
*Acre × 4 047 = m^2.

On the basis of these population projections, approximately 4.9×10^6 m^2 (1200 acres) of adjacent agricultural lands would be reclassified to urban use, and housing units for approximately 32,000 people would be built on the rezoned lands. These matters were partially clarified on 3 June 1977, when the State Land Use Commission reclassified 2.388×10^6 m^2 (590 acres) of agricultural land to urban use. On these lands, Mililani Town will be expanded to accommodate about 3600 dwelling units for a population of about 11,500. Assuming the full development within the present state urban boundaries, including the recent rezoning action, the total urban area of 10.239×10^6 m^2 (2530 acres) could provide housing units for up to 50,700 residents by the year 1995. However, because of population growth restrictions by the City Council's (1977) *Oahu General Plan* and their proposed Development Plan (to be adopted in late 1980), the projected population for the year 2000 is 37,900. The June 1978 population for Mililani-Waipio was approximately 21,000.

The average daily secondary sewage effluent flow from the Mililani STP for June 1978 was 0.071 m^3/s (1.61 mgd), which for a population of approximately 21,000 would be about 3.4×10^{-6} m^3/capita/s (76.6 gal/capita/day). Based on the 37,900 population projection and using the city's current design criteria of 3.7×10^{-6}/capita/s (85 gal/capita/day), sewage flows would be 0.197 m^3/s (4.49 mgd) for the year 2000. These flows include 0.14 m^3/s (3.22 mgd) from residential units, 0.047 m^3/s (1.08 mgd) from commercial establishments, and an allowance of 0.008 m^3/s (0.19 mgd) for dry weather infiltration. The original Mililani STP design and project preplanning used an average per capita flow of 4.381×10^{-6} m^3/s (100 gal/capita/day)*.

The City and County of Honolulu's National Pollutant Discharge Elimination System (NPDES) permit for the Mililani STP requires that the effluent discharge to Kīpapa Stream, which flows into Waikele Stream and into the West Loch of Pearl Harbor, must cease. Several alternatives that were considered for the disposal of the Mililani STP effluent are listed in Appendix A (Division of Sewers 1977*b*). However, the recommended alternative by all agencies and institutions affected (Hawaii State Department of Health; City and County of Honolulu, Department of Public Works [Division of Wastewater Management], and Board of Water Supply; and Oahu Sugar Company, Ltd.) is the reclamation-reuse of the Mililani STP effluent for sugarcane irrigation.

Water that is potentially available to OSC is related, to a certain degree, to policy goals stated in the Board of Water Supply's *Oahu Water Plan* (1975), and the *Hawaii Water Resources Plan* [HWRRS] 1979). The BWS plan would involve the exchange of basal spring and perennial streamflows into the Pearl Harbor basin, and waste water effluent from the Mililani and Honouliuli treatment plants for the high quality irrigation water used presently by the OSC. Details of the exchange proposal are presented in the BWS (1975, pp. 53-56) *Oahu Water Plan*.

Future water needs for sugarcane irrigation by OSC will depend, in part, on the amount of land presently in sugarcane cultivation that is converted to urban development or nonagricultural use. Equally important is the future profitability of sugarcane operations. However, the paramount action which could affect the large-scale use of sewage effluent for sugarcane irrigation is the recent decision by OSC to convert to drip irrigation for economic reasons.

Whether sewage effluent, after posttreatment, can be successfully used for drip irrigation under field conditions will be partially answered from the results of the concurrent companion Phase II-B study. The final project report of the study is in preparation.

Several alternatives involving the reuse of treated sewage effluent for furrow irrigation were developed; however, OSC has recently indicated that

*Based on Dept. of Public Works, City and County of Honolulu calculations.

these alternatives are no longer feasible because of their decision to convert to drip irrigation in the areas designated originally for sewage effluent irrigation. In view of this change, the City and County of Honolulu plans to build a diversion line from the Mililani STP to OSC's Field 215 for furrow irrigation with a bypass through the Barbers Point Ocean Outfall via the Waipahu Sewage Pump Station during periods of nonirrigation due to heavy rains and extended sugar labor strikes.

The overall desirability of reclamation-reuse of secondary sewage effluent for irrigation, rather than some other means of disposal, can be summarized as follows:

1. The statutory goal of "zero discharge" of Public Law 92-500, the federal Water Pollution Control Act Amendment of 1972, is met
2. The mass emission of pollutants into receiving waters is reduced
3. O'ahu's water supply is conserved.

Organization of Study

The overall responsibility and direction of the project was delegated to the principal investigator, L. Stephen Lau, Director of the Water Resources Research Center. He was assisted by an Executive Group of University of Hawaii faculty from various departments and the staff of the Water Resources Research Center; engineers from the Board of Water Supply and the Department of Public Works of the City and County of Honolulu; and agronomists and engineers from the Hawaiian Sugar Planters' Association, and from the Oahu Sugar Company, Limited. The Executive Group and members of the participating staff from the cooperating agencies met on a regular basis, approximately once a month, to review and discuss progress, and to conduct detailed planning and coordination of the research.

The University faculty were responsible for the following activity areas:*

Paul C. Ekern	Irrigation and Soil Water Quality Analysis
Philip C. Loh	Virology
Reginald H.F. Young	Effluent Quality Analysis
Gordon L. Dugan	Data Systems and Report Preparation

*Refer to Appendix C for specific agency assignments.

Cooperating agencies made the following contributions:

City and County of Honolulu	
• Division of Wastewater Management (Mililani STP, Pearl City Treatment Plant Laboratory)	Effluent, and laboratory and field support
• Board of Water Supply	Laboratory and field support
Hawaiian Sugar Planters' Association	Field and laboratory studies of sugarcane responses, planting, fertilizing, soil analysis, and harvesting and water quality analysis
Oahu Sugar Company, Limited	Sugarcane field site and preparation, reservoir, pipe system, sugarcane, ditch water, irrigation, fertilizer, herbicides, ripener, weather data collection.

RESEARCH DESIGN

Project Site

The project site (Fig. 1) in OSC Field No. 246, at an elevation of approximately 162 m (530 ft), was originally chosen for the Phase I study not only because of its proximity to the Mililani STP, but because the sugarcane in these fields is grown on soils similar to that on which approximately 90% of the sugarcane under cultivation on O'ahu is grown. The predominant Oxisol is the Lahaina silty clay, a Tropeptic Haplustox, which developed on a thick deposit of Ko'olau lava. These soils are readily compacted by conventional sugarcane tillage operations to bulk densities (1.3-1.4) which reduce considerably their infiltration capacity. The general area receives an average annual rainfall of approximately 1.0 m (40 in.), primarily from the winter cyclonic storms.

Mililani STP

The Mililani STP, an activated sludge plant, designed originally for an average daily flow of 0.08 m^3/s (1.81 mgd), was expanded to a capacity of 0.16 m^3/s (3.60 mgd) in December 1976. The original 0.08-m^3/s units used the proprietory Rapid Bloc (Chicago Pump) system; the new biological treatment units are based on the complete-mix aeration system. During the first

Aerial photograph (7789-10; 7 Feb. 1980) by R.M. Towill Corporation.

Figure 1. Aerial photograph of Mililani STP and OSC Field No. 246 test plot project site, O'ahu, Hawai'i

half of 1978 the STP received an average flow of 0.07 m^3/s (1.50 mgd). A schematic flow diagram of the Mililani STP is shown in Appendix Figure E.1.

The capacity of the chlorine contact chamber was increased two-fold by the expansion. The Hawaii State Department of Health (DOH) disinfection standards require a detention time of 15 min for the designed maximum flow with a chlorine residual of 0.5 mg/ℓ; however, actual average detention time is over twice the minimum time since the maximum flow is some 2.4 times the present average flow. In a progress report by Lau (1976), the flow in the chlorine contact chamber, before expansion, was found to be well mixed at that time.

Research Activities

The research activities were grouped into four major areas: (1) Irrigation and Fertilization, (2) Water Quality Analysis, (3) Viral Analysis, and (4) Assessment of Sugarcane Growth and Sugar Yield. Nitrogen is one of the most critical factors in sugarcane growth and sucrose yield, and, as such, governs the feasibility of utilizing secondary sewage effluent as an irrigation source. The effect of time of application and the total amount of N applications were particularly emphasized in Phase I (Lau et al. 1975).

Irrigation and Fertilization

The secondary sewage effluent was pumped through a 0.10-m (4-in.) polyvinyl chloride (PVC) pipe from the Mililani STP for approximately 1 600 m (1 mile) to the effluent reservoir, against a static head of 21.6 m (71 ft). The butyl rubber-lined effluent reservoir, located approximately 122 m (400 ft) from the test plots in the OSC Field No. 246, has a depth of 2.6 m (8.5 ft), a volume of 423 m^3 (14,950 ft^3), and a minimum static head of 3.05 m (10 ft) to the test plots. The ditch-water reservoir, with a capacity of 801 m^3 (28,600 ft^3) at a depth of 3.3 m (10.75 ft), is located adjacent to the effluent reservoir. The ditch-water reservoir, which draws its water by gravity from the nearby Waiāhole Ditch, has approximately the same hydraulic characteristics as the effluent reservoir. A schematic layout of the two reservoirs and piping system in relation to the test plots is shown in Figure 2.

The treated sewage effluent and ditch water from the reservoirs flow through 0.10-m (4-in.) PVC pipes with shut-off and check valves, and meters

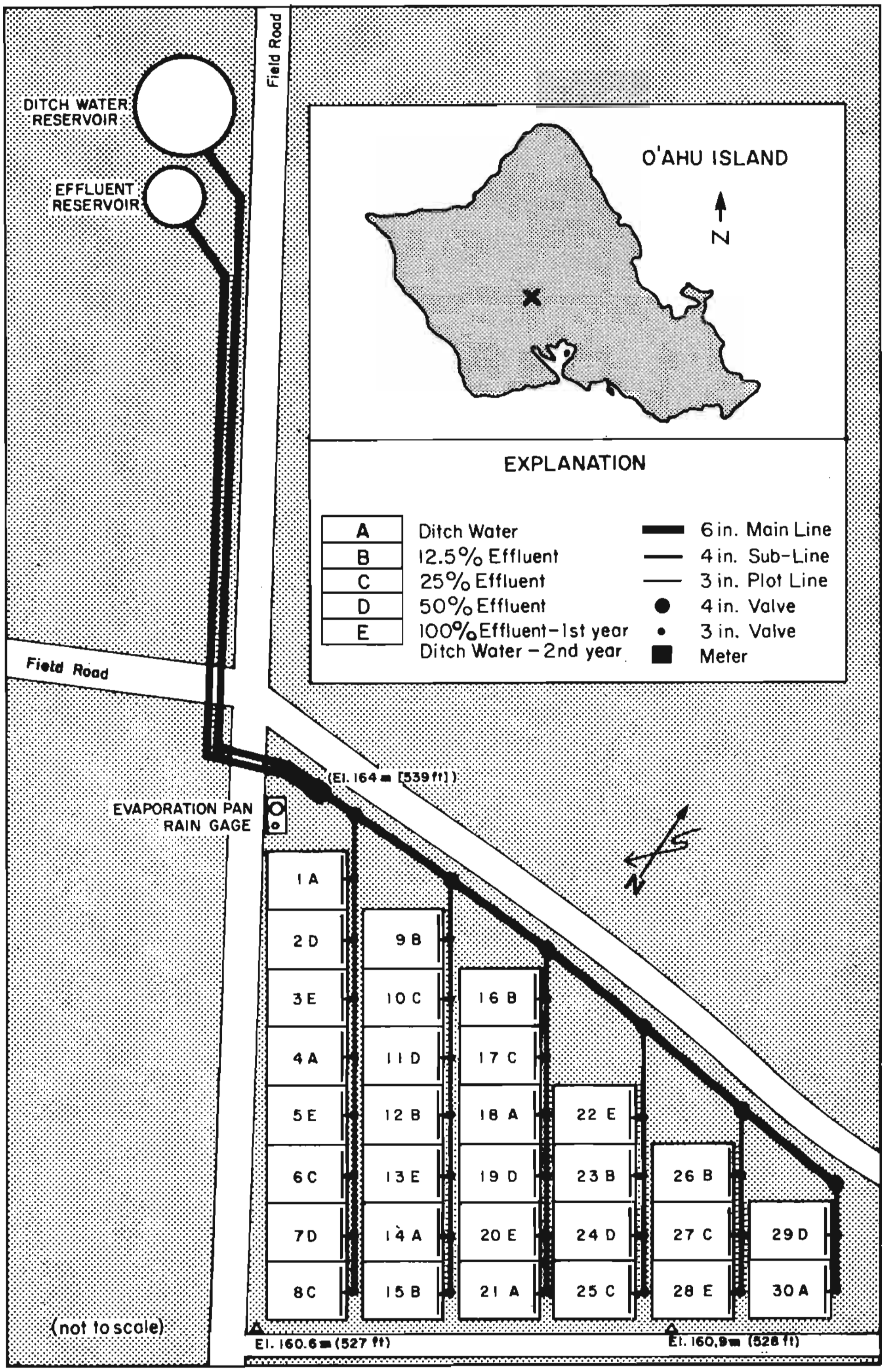

Figure 2. Schematic layout of reservoirs and test plots

to enable the formulation of five mixtures of effluent to ditch water: 0 (100% ditch water), and 12.5, 25, 50, and 100% (effluent—1st yr only), which were respectively applied to the A, B, C, D, and E treatments. For each treatment there were six replicates for 30 plots in a randomized, complete block design. The treatments, dilutions, and their respective time frames are presented in Table 1.

TABLE 1. SECONDARY SEWAGE EFFLUENT TO DITCH-WATER DILUTIONS FOR OSC FIELD NO. 246 TEST PLOTS, O'AHU, HAWAI'I

TREAT-MENT	DILUTION % Sewage Effluent	DILUTION % Ditch Water	RATIO Effluent: Ditch Water
A	0.0	100.0	0:1
B	12.5	87.5	1:7
C	25.0	75.0	1:3
D	50.0	50.0	1:1
E, 1st yr	100.0	0.0	1:0
2d yr	0.0	100.0	0:1

Each plot (Fig. 2) was 10 sugarcane rows wide or about 16.8 m (55 ft) wide by 22.9 m (75 ft) long, or a total area of 383 m^2 (0.0947 acre) per plot. The measured area of the actual test plots ranged from 361.8 to 418.9 m^2 (0.0894-0.1035 acre). Access roads separating the sugarcane test plots were about 3 m (10 ft) wide.

The quantity, time of application, and type (N, P, K) of chemical fertilizers to be applied to the test plots for each of the treatments are presented in Table 2. The total quantity of fertilizers N, P, and K in the commercial fertilizers, and the estimated amount to be derived from the applied treated sewage effluent are presented in Table 3. The schedule was based on an average application rate of 7.12 kg (15.7 lb) of N, 3.92 kg (8.65 lb) P, and 3.61 kg (7.95 lb) K per 0.1-m (4-in.) round of irrigation. Herbicides were hand sprayed on the test plots, roads, and irrigation ditches.

Irrigation with 0.1 m (4 in.)/round was scheduled at 14-day intervals from April to October and at 14- to 21-day intervals from November to March. Irrigation was scheduled to terminate 80 days prior to harvest. Tensiometers were installed in the furrows of treatment A plots, 4, 18, and

TABLE 2. COMMERCIAL FERTILIZER APPLICATION SCHEDULE FOR TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

TREATMENT	RATE OF APPLICATION (lb/acre) N*						P†	K‡				
	Age at Application (mo)											
	0	2	4	6	8	Total	0	0	2	4	6	Total
A	80	80	100	70	50	380	105	100	124	133	100	457
B	80	80	100	70	0	330	105	100	124	133	75	432
C	80	80	80	0	0	290	105	100	124	133	54	411
D	80	70	60	0	0	210	105	100	108	108	50	366
E	80	50	0	0	0	130	105	100	83	75	50	308

*As urea, $CO(NH_2)_2$.
†As treble superphosphate, primarily monocalcium phosphate, $Ca(H_2PO_4)_2 \cdot H_2O$.
‡As potassium chloride of muriate of potash (KCl).

TABLE 3. SCHEDULED NUTRIENT APPLICATIONS AT END OF 2-YR CROP CYCLE* FOR TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

TREAT-MENT	RATE OF APPLICATION (lb/acre) N			P			K		
	Sew. Effl.	Comm. Fert.	Total	Sew. Effl.	Comm. Fert.	Total	Sew. Effl.	Comm. Fert.	Total
A	0	380	380	0	105	105	0	457	457
B	65	330	395	36	105	141	33	432	465
C	130	290	420	71	105	176	66	411	477
D	259	210	469	143	105	248	132	366	498
E	314	130	444	173	105	278	159	308	467

NOTE: 4 in./round @ 15.7 lb N, 8.65 lb P, and 7.95 lb K/acre/round (17.3, 9.5, and 8.8 mg/ℓ, respectively) of effluent.
NOTE: Lb/acre × 0.000 112 = kg/m^2.
*Assuming 20 irrigation rounds in the 1st yr and 13 in the 2d yr.

30, at depths of 0.3, 0.5, and 0.6 m (12, 18, 24 in.) to monitor the soil moisture. Rainfall, soil moisture, and other factors may determine the actual irrigation application rate. Soil samples were collected after planting and after harvesting in each test plot with a soil auger by extracting a 0.05-m (2-in.) diameter soil core to a 0.3-m (12-in.) depth from halfway up the furrow bank. Samples were analyzed by the Hawaiian Sugar Planters' Association (HSPA) for K, Ca, Na, Mg (standard method by 1 *N* ammonium acetate extraction); available N (standard method by 0.5 *N* potassium sulfate extraction); P and Si (0.5 *N* sodium bicarbonate method); and for electrical conductivity and pH.

Water Quality Parameters

The scheduled analysis of water quality parameters for the project are outlined in Table 4. Basically, the parameters that were used determined an input-output relationship for the test plots and for base-line groundwater monitoring. Direct observation of groundwater quality changes was precluded by the presence of other large nearby percolate sources and the 152-m (500-ft) depth to the groundwater table.

TABLE 4. SCHEDULED ANALYSES OF WATER QUALITY PARAMETERS FOR TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

Monitoring Location	Frequency	Water Quality Parameter Grouping*
Sewage treatment plant effluent	Weekly	1, 2
	Monthly	3, 4
	6 mo	5, 6
Percolate at bottom of root zone	After each irrigation	1, 3
Groundwater (baseline quality)	Once each crop	2, 5, 6
Groundwater (potable)	3 mo	2, 5, 6
Groundwater (brackish)	6 mo	2, 5, 6

NOTE: For analytical methods, see App. Table D.6.
*1 = Nitrogen series; 2 = Viruses; 3 = Cl, TDS, Na, Ca, Mg, K, Si, pH; 4 = Suspended solids, grease; 5 = Toxic chemicals (heavy metals, pesticides); 6 = Complete analysis (pH, TDS, total hardness, SS, BOD_5, TOC, total N series, total P, Mg, Na, Ca, K, Cl, SO_4, SiO_2, B, electrical conductivity, grease, fecal coliform, total coliform, alkalinity).

Water quality monitoring was accomplished for the applied treated sewage effluent/ditch-water dilutions. The soil-water percolate was collected within the tillage pan (0.23-0.3 m [9-12 in.] below the ground surface) by horizontally mounted 0.05-m (2-in.) diameter, porous plastic "Porvic" samplers, 1.5 m (5 ft) long with 2-µm diameter pores. The Porvic samplers were placed in furrows 2 and 9 of one plot of each treatment (App. Table D.9). As concluded in Phase I (Lau et al. 1975), the N series was the critical input-output constituent that required monitoring, with virus monitoring considered critical for treated sewage effluent handling and application on the soil. Thus, the parameters were selected for the most frequent monitoring according to the previous findings.

Viral Analysis and Studies

The Phase I study indicated the feasibility of applying treated sewage effluent to the growth of sugarcane. However, since viruses were not completely removed from the treated effluent, the necessity of monitoring the treated effluent to be used for irrigation was indicated. This aspect of the project was initiated on 2 July 1975, prior to the actual official start of Phase II-A, but was temporarily interrupted for a 3.5-mo period (August-December 1976) when the Mililani STP underwent major expansion and redesign.

The objectives pursued under the viral phase studies were

1. To determine the frequency, concentration, and types of human enteric viruses in the raw, the activated sludge, and the final chlorinated effluent at the Mililani STP before and after redesign and reconstruction of the activated sludge and the chlorination facilities
2. To determine the frequency, concentration, and stability of viruses in the effluent during storage in the reservoir before irrigation
3. To determine the persistence of viruses in the wet and dried sediment of the effluent reservoir
4. To determine the recoverability of viruses from soil after irrigation with sewage effluent and also the stability of marker viruses in the OSC Field No. 246 test plots during growth, drying, and after burning the sugarcane.

Samples of raw sewage, unchlorinated effluents, and chlorinated effluents were periodically assayed for the presence of human enteroviruses. The methodologies and cell cultures that were employed for the concentration, isolation, growth, and identification of the human enteroviruses were those established in the WRRC Virus Laboratory (Lau et al. 1972, 1974, 1975). A summary of the five different methods that were utilized to concentrate viruses is presented in Appendix B.

Sugarcane Growth and Sugar Yield

Hot water Benlate-treated 3-eye seed pieces of sugarcane variety H59-3775 (used also in Phase I) were hand planted on the 15th and 19th of October 1976 in the 30 test plots. Gaps of 0.6 m (2 ft) or more were replanted on 6 December 1976. The growth of the sugarcane in the test plots was monitored by the "crop log method" (Clements 1980), which includes complete chemical analysis and moisture determination every 35 days (amplified phosphorus index samples at 9.6, 10.8, and 12.0 mo). Sheath moisture determinations from initiation of ripening through harvest were conducted approximately on a weekly basis.

The chemical ripener, Polaris, was sprayed by helicopter at a rate of 2.02×10^{-4} kg/m^2 (4 lb/acre), active ingredient, to all plots 8 wk before harvest. The center 4 lines, 6.7 m (22 ft) × 12.19 m (40 ft)—a total area of 81.8 m^2 (880 ft^2)—were hand harvested from each plot; tons cane/acre (TCA), juice quality (POL), and fiber content determined; and tons sugar/acre (ETSA) estimated.

Project Responsibilities

The basic project responsibilities in Phase II-A were defined for the four cooperating agencies involved (App. C): City and County of Honolulu (Department of Public Works, Board of Water Supply), Hawaiian Sugar Planters' Association (Crop Science Department), Oahu Sugar Company, Ltd., and the University of Hawaii (Water Resources Research Center). However, as in all interdisciplinary cooperative projects, there was some overlapping of responsibilities and redefining and reassigning of responsibilities during the course of the study.

PROJECT RESULTS

As mentioned previously for the research activities, the results produced for this report are categorized into four areas: (1) Irrigation, Fertilization, and Sugarcane Cultural Practices; (2) Water Quality Analysis; (3) Viral Analysis; and (4) Assessment of Sugarcane Growth.

Irrigation, Fertilization, and Sugarcane Cultural Practices

To ensure uninterrupted irrigation, the effluent reservoir was filled the day before the scheduled irrigation. About 17 hr was required to fill the reservoir with effluent pumped from the Mililani STP at a rate of approximately 6.3×10^{-5} m^3/s (100 gpm). The ditch-water reservoir was filled with Waiāhole Ditch water from the OSC reservoir No. 245B either the day before or the morning of the scheduled irrigation. Approximately 3 days were required to complete each irrigation.

During the first seven irrigation rounds (through 12 January 1977), only ditch water was applied since the installation of the effluent delivery and storage systems was not finished. A propeller-type flow meter was used to measure the volume of flow; however, when effluent-ditch water dilutions were initiated in round eight, the propeller-type flow meter was not sensitive enough to obtain the required effluent dilutions at the plots, as determined by the K balance. Consequently, the tenth and subsequent irrigation rounds used the pitot-type flow meters with adequate results.

On the initial day of irrigation, the air in the lines was bled to insure full pipe-flow conditions, which in turn assured a constant delivery rate during actual irrigation. Manometers were connected to the pitot-type flow meters (Annubar) and zero-flow conditions were standardized. The normal procedure was to irrigate the ditch-water treatment plots (A first, followed by the 12.5, 25, 50, and 100% effluent dilution plots. This procedure reduced the chances of nutrient carryover in the water lines.

The total quantity of ditch water and effluent applied to a particular plot was controlled by a combination of the Annubar readings and elapsed time. When irrigation was completed in one plot, the valves were opened for the succeeding plot before closing off the one being irrigated to ensure a clean, constant flow as well as to reduce the possible chance of back flow. When irrigation was completed, the pipelines were flushed with ditch water and then drained. Irrigation applications to the individual plots are shown in Appendix Table D.1.

The tensiometer measurements of water stress conditions at depths of 0.30, 0.46, and 0.76 m (12, 18, 30 in.) in the root zone are presented in Appendix Table D.2. The tensiometer water column was broken (air bubbles in tensiometer) just prior to irrigation most of the time during 1977. Since the water column on the tensiometer breaks at tensions slightly greater than 0.7 bar, the soil water stress often exceeded the 0.5 bar which has been shown to reduce cane growth rates (Robinson 1963; Clements 1980).

From December 1977 through May 1978, the tensiometric water stress generally was less than 1 bar at the 0.46- and 0.76-m depth, however, the water column broke occasionally at the 0.30-m depth. The June, July, and August 1978 irrigations were spaced so that the water column broke before the irrigation rounds. Based on tensiometric indications of soil-water stress, the rates of irrigation and the irrigation intervals used in the first year of the experiment were not adequate to fully supply the water demands of the cane.

The fertilizer amounts actually applied were identical with those scheduled. The dates of application and the types of fertilizer are given in Appendix Table D.3. At planting, fertilizer was applied with the seedpiece. Subsequent fertilizer applications were on the soil surface.

The type, concentration, and placement of herbicide used on the test plots are shown in Table 5.

TABLE 5. HERBICIDE APPLICATION TO TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

DATE	HERBICIDE APPLICATION			
	Type Name	Concentration (lb/100 gal)*	Spray Method	Location
11/01/76	Metribuzin	6	Hand	Entire Field
12/21/76	Ametryn	20	Hand	Entire Field
03/16/77	Ametryn	15	Hand	Entire Field
05/19/77	Metribuzin	6	Hand	Roads, Ditches
05/26/77	Glyphosate	5	Hand	Roads, Ditches

*Lb/100 gal × 1.198 = kg/m^3.

Rainfall and Evaporation

The median long-term rainfall at the Mililani site (Table 6) can be estimated from the record for the nearby station at Oahu Sugar Company's Field No. 245 (Hawaii State Index No. 815, 1923-1959). The winter months from October 1976 through April 1977 had 403.9 mm (15.9 in.) and the winter of 1977 to 1978, 368.3 mm (14.5 in.) of rainfall. Both winters were dry when compared to the long-term median of 561.3 mm (22.1 in.) for station 815. The summer months of May through September 1977 had 322.6 mm (12.7 in.) and the summer months of 1978 had 294.6 mm (11.6 in.) of rainfall. These were, respectively, 2.35 and 2.16 times the median value of 137.2 mm (5.40 in.); thus, the summers of 1977 and 1978 were relatively wet. In each case, the high summer amounts occurred as late spring rains in May and

TABLE 6. MONTHLY RAINFALL AND ELEVATED CLASS A PAN EVAPORATION QUANTITIES FOR TEST PLOTS, OSC FIELD NO. 246

MONTH	RAINFALL Quantity (in.)	RAINFALL Fraction of Long-Term Rainfall*	RAINFALL Days of Rainfall >0.25 in. (No.)	EVAPORATION PAN Quantity (in.)	EVAPORATION PAN Fraction of Long-Term Pan†
1976					
Oct. 17-31	0.14	0.156	0	3.19	----
November	1.01	0.361	0	7.01	1.57
December	0.37	0.071	0	6.18	1.55
Subtotal	1.52	0.171		16.38	
1977					
January	0.93	0.251	0	5.91	1.33
February	0.92	0.256	0	6.66	1.50
March	4.83	1.558	5	9.44	1.59
April	4.55	2.395	8	7.91	1.26
May	6.09	5.536	8	9.54	1.33
June	4.96	6.200	3	7.30	0.95
July	0.55	0.458	0	8.94	1.09
August	0.68	0.618	0	8.59	1.07
September	0.42	0.350	0	8.35	1.16
October	0.79	0.439	1	7.60	1.26
November	0.79	0.282	0	5.84	1.31
December	5.36	1.031	5	5.73	1.43
Subtotal	30.87	0.848		91.81	1.26
1978					
January	1.04	0.281	1	5.93	1.33
February	0.18	0.050	0	6.38	1.44
March	2.15	0.694	2	7.95	1.34
April	4.14	2.179	6	7.00	1.11
May	4.82	4.382	6	7.00	0.98
June	2.87	3.588	3	7.48	0.97
July	0.92	0.767	0	8.73	1.06
August	2.23	2.027	4	7.09	0.89
September	0.80	0.667	1	8.60	1.19
Oct. 1-17	0.08	0.089	0	4.84	----
Subtotal	19.23	1.034		71.00	
TOTAL	51.62			179.19	

*Located in OSC Field No. 245; Hawaii State Index No. 815, 1923-1959.
†Located at Pineapple Research Institute Station; Hawaii State Index No. 820.2, 1955-1966.

June.

The evaporation measurements (Table 6) were obtained from an elevated Class A evaporation pan (positioned 1.5 m [5 ft] above the ground surface) that was located on the northwest corner of the test plots (Fig. 2). Evaporation rates from elevated pans in general are 15% greater than those from ground-level pans (Ekern 1977, App. Table C.1; DOWALD 1973).

Solar radiation values (Table 7) at the Mililani STP, when compared to longer term measurements from the nearby (approx. 3 200 m [2 miles] away) Pineapple Research Institute (PRI) site (Hawaii State Index No. 820.2, 1955-1962), were below normal, with winter 1976 to 1977 values of 96.7%; summer 1977, 95.2%; winter 1977 to 1978, 94.8%; and summer 1978, only 90.4% of the long-term amounts. These lower sunlight values should have reduced the actual amounts of water needed for evapotranspiration, and might also have been sufficient to reduce the potential cane and sugar tonnage.

For comparitive purposes, evaporation, determined from the calculated net radiation, is the potential amount of evaporation (assuming 1 500 cal/cm^2/in. as the energy required to vaporize water at 20°C) that may result from radiation only. The elevated pan evaporation at Mililani was 1.5 times the calculated net radiation, whereas the elevated pan at the Kunia Substation for 1971 to 1972 was 1.1 times the net radiation. This is further evidence of the abnormally high rate of evaporation from the elevated pan in the test plots at Mililani.

Soil Sampling Results

Chemical analyses of soil samples from each plot after the initial irrigation round and after harvesting are presented, along with the method of soil analysis, in Appendix Table D.4. A summary of the mean values for each irrigation treatment is shown on a before (1976) and after (1978) basis in Table 8.

The increase in pH is not significant. The decrease in readily available phosphorus (P) probably represents increased P adsorption on the Oxisols that may be available for subsequent crops (Fox and Searle 1978). The initial level of mineralizable N was low and indicates that the probability of response to added N in the fertilizer and effluent was great (Stanford, Ayres, and Doi 1965). The increase in mineralizable N by the end of the cycle indicates storage of part of the added N as readily decomposable

TABLE 7. SOLAR RADIATION VALUES, MILILANI, O'AHU, HAWAI'I

MONTH	SOLAR RADIATION* Mean	Max.	Min.	FRACTION OF LONG-TERM MEAN†	EVAPORATION CALCULATED FROM RADIATION‡	
	-------(cal/cm^2/day)-------				(in./day)	(in.)
1976						
Oct. 17-31	423.0	560.2	237.3	1.06	0.154	2.15
November	302.7	448.7	150.0	0.84	0.082	2.46
December	334.6	427.6	218.1	0.97	0.101	3.13
Subtotal	-----	-----	-----	----	-----	7.74
1977						
January	329.5	416.9	241.8	0.91	0.096	2.98
February	428.2	510.5	238.2	1.03	0.157	4.40
March	440.6	579.9	304.5	0.95	0.164	5.08
April	514.1	702.1	215.4	1.03	0.208	6.24
May	496.7	692.3	203.3	0.97	0.198	6.14
June	517.6	696.3	290.6	0.89	0.211	6.33
July	550.5	673.9	340.3	0.96	0.230	7.13
August	530.0	655.1	326.9	1.00	0.218	6.76
September	463.9	630.9	267.8	0.95	0.178	5.34
October	413.1	555.3	209.1	1.03	0.148	4.59
November	336.3	458.5	188.1	0.93	0.102	3.06
December	309.8	406.2	147.8	0.90	0.086	2.67
Subtotal	-----	-----	-----	----	-----	60.72
1978						
January	343.3	446.9	125.4	0.94	0.106	3.29
February	418.9	540.0	129.4	1.01	0.151	4.23
March	435.1	589.3	221.3	0.93	0.161	4.99
April	446.7	623.8	185.4	0.89	0.168	5.04
May	451.0	654.7	106.1	0.88	0.171	5.30
June	499.2	682.9	195.7	0.86	0.200	6.00
July	527.1	665.9	371.2	0.92	0.216	6.70
August	509.6	662.7	111.5	0.96	0.206	6.39
September	505.2	593.8	369.9	1.03	0.203	6.09
Oct. 1-17	389.4	582.6	35.8	0.97	0.134	2.28
Subtotal	-----	-----	-----	----	-----	50.31
TOTAL	-----	-----	-----	----	-----	118.77

NOTE: 1 in. × 25.4 = mm.
*Measured at the Mililani STP.
†Located at Pineapple Research Institute Station; Hawaii State Index No. 820.2, 1955-1962.
‡Net Radiation = (0.9 solar radiation - 150 cal/cm^2/day). 1 in. of evaporation = 1 500 cal/cm^2.

TABLE 8. MEAN SOIL ANALYTICAL VALUES* AT TIME OF FIRST IRRIGATION AND AFTER HARVESTING THE SUGARCANE, OSC FIELD NO. 246 TEST PLOTS, MILILANI, O'AHU, HAWAI'I

TREAT-MENT	pH		PHOSPHORUS (P) (lb/acre-ft)		POTASSIUM (K) (lb/acre-ft)		NITROGEN (N) Available (lb/acre-ft)		NITROGEN (N) Mineralizable (lb/acre-ft)	
	1976	1978	1976	1978	1976	1978	1976	1978	1976	1978
A	5.9	6.1	175	112	630	578	82	49	53	75
B	5.7	5.8	160	160	460	498	79	48	41	84
C	5.7	5.8	205	132	405	513	67	44	49	77
D	5.8	6.0	200	179	420	350	66	43	48	80
E	5.8	6.0	190	162	535	519	51	35	52	75

NOTE: Analysis performed by the Hawaiian Sugar Planters' Association.
*Depth 0 to 0.30 m (0-12 in.).

organic matter. The levels of available potassium (K) were high; however, the addition of large amounts of N from the effluent might induce an N/K imbalance and affect sugar yield, particularly in the D treatment.

As reported in Phase I, the major changes in P and pH were expected to take place in the top 0.08 to 0.10 m (3-4 in.); thus, it is possible that the mean values reported in Table 8 for the 0 to 0.30 m (0-12 in.) depth somewhat mask potential constituent changes near the surface of the soil.

The ripener, Polaris, was sprayed by the helicopter on 10 August 1978. Electrical transmission lines forced the application at greater altitudes over several of the plots. Two plots of each treatment were directly beneath the lines. However, wind drift at the time of application reduced the Polaris application on three plots for the A, B, and D treatments; two plots for the E treatment; but only one plot for the C treatment (Fig. 3). Thus, the reduced application of Polaris to only a single plot for the C treatment may have biased the results toward higher sugar yields.

The test area was burned on 16 October 1978 when the crop was 24.1 mo old. Hand harvest of the center 4 lines 6.7 m (22 ft) by 12.19 m (40 ft) of each plot began the same day and was completed on 17 October 1978.

Water Quality Analysis Results

Average monthly values for chemical parameters of the raw sewage and chlorinated secondarily treated effluent for the Mililani STP for the Octo-

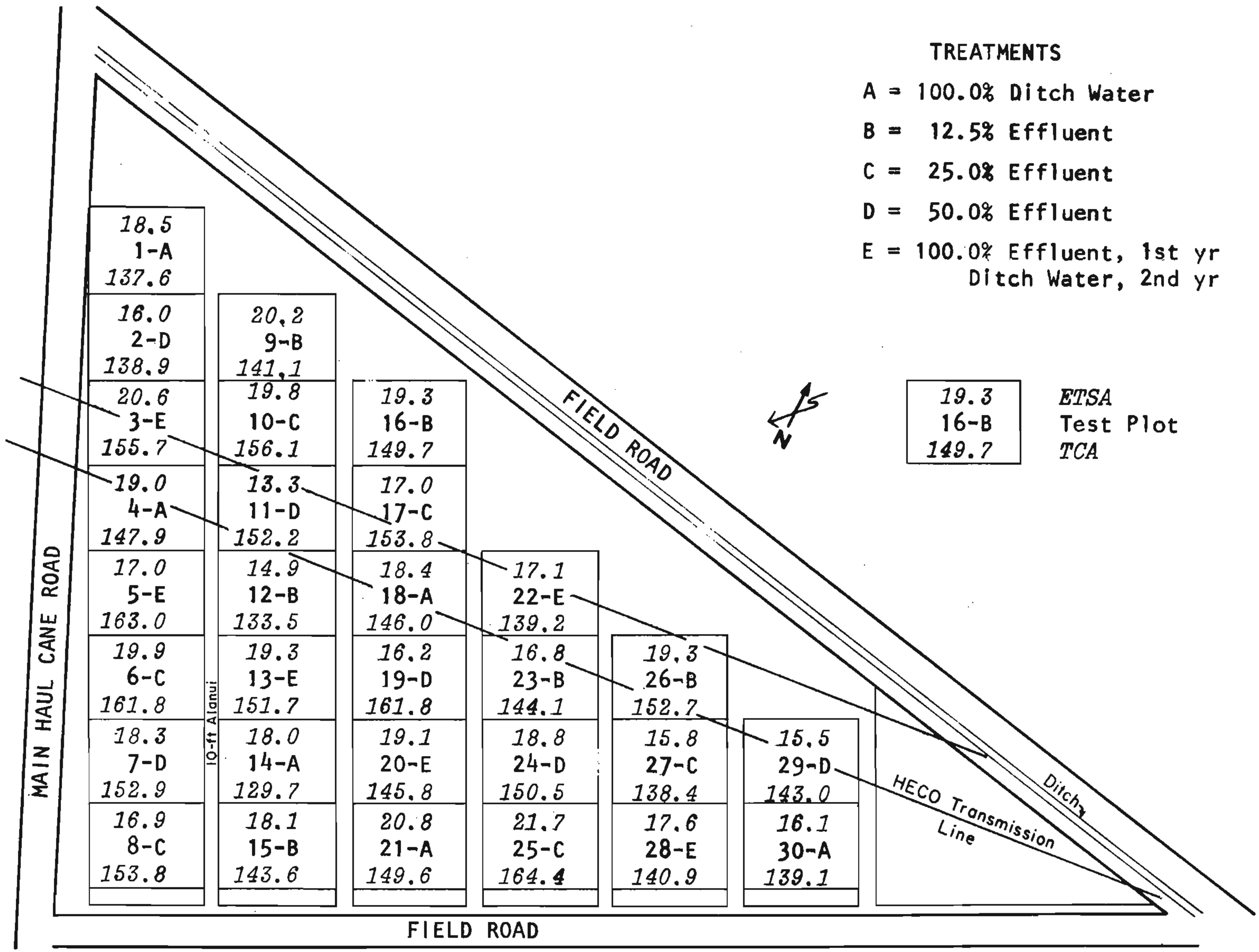

Figure 3. Individual test plot harvest results, OSC Field No. 246

ber 1976 through August 1978 period, as determined by the Division of Wastewater Management, City and County of Honolulu for NPDES discharge permit reporting purposes, are presented in Table 9. The grab and 24-hr composite samples were collected once a week; however, N and P analyses were made on only one composite sample a month.

It is interesting to note that the raw sewage strength, as measured by the biochemical oxygen demand (BOD_5), increased from a median of 204 mg/ℓ, as reported in Phase I (Lau et al. 1975), to a median of 280 mg/ℓ and a mean of 314 mg/ℓ (Table 9). However, the suspended solids (SS) median values for the raw sewage were nearly the same with 196 mg/ℓ in Phase I and 198 mg/ℓ in Phase II-A. Total N concentrations fluctuated during Phase I, but the mean of 17.3 mg/ℓ was much lower than the 25.2 mg/ℓ median and 24.1 mg/ℓ mean of Phase II-A (Table 9). Phosphorus concentrations remained in the same general range (8.9 median, 8.7 mean) as for Phase I.

As a supplement to the values presented in Table 9, as well as an expansion of the number of constituents being analyzed, samples of raw sewage, primary sewage effluent, and secondary effluent from the Mililani STP were collected and analyzed by the Water Resources Research Center (App. Table D.5). Medians of the results in Table 9 and in Appendix Table D.5 for BOD_5, suspended solids, total N, and P are within a fairly close range, except for the median BOD_5 values for the raw sewage, which are 280 mg/ℓ in Table 9, and 200 mg/ℓ in Appendix Table D.5. Results for heavy metals (App. Table D.7) indicate that the average heavy metal concentration in the Mililani STP effluent is below the levels in the Department of Health (1977, chap. 49) *Public Health Regulations*.

The suitability of secondarily treated sewage effluent as an irrigation water supply depends on numerous factors, among which are soil type, internal drainage, type of crop, and chemical composition of the effluent. However, based on criteria for mainland U.S. temperate zones (FWPC 1968), total dissolved solids (TDS), electrical conductivity, chlorides, percentage of sodium, and boron (B) have been the parameters that have been traditionally used. As noted in Appendix Table D.5, TDS, electrical conductivity, and chlorides average considerably less than the respective limiting values of <700 mg/ℓ, <1 000 μmhos/cm, and <175 mg/ℓ for sensitive crops. The percentage of sodium (Na) is calculated in comparison with the total major cations (Ca, Mg, Na, and K) on an equivalent basis. However at concentrations in

TABLE 9. AVERAGE VALUES OF SEWAGE ANALYSIS, MILILANI STP, O'AHU, HAWAI'I

REPORT PERIOD (mo/yr)	FLOW* (mgd)	GRAB SAMPLES pH	Fecal Coliform (No./100 mℓ)	Settleable Solids (mℓ/ℓ)	Total Residual Chlorine (mg/ℓ)	24-hr COMPOSITE SAMPLES BOD$_5$ Raw (mg/ℓ)	BOD$_5$ Effl. (mg/ℓ)	BOD$_5$ Removal (%)	Suspended Solids Raw (mg/ℓ)	Suspended Solids Effl. (mg/ℓ)	Suspended Solids Removal (%)	Total N (mg/ℓ)	Total P (mg/ℓ)
10/76	1.34	6.6-7.0	1148	1.7	3.0	353	37	89	226	34	84	12.8	8.9
11/76	1.33	6.5-7.8	33	4.6	3.73	268	41	85	279	32	88	27.8	10.2
12/76	1.34	6.3-7.6	34	0.7	3.52	225	33	85	198	41	78	19.5	10.2
01/77	1.36	6.8-7.0	131	0.8	3.65	442	32	90	268	24	90	25.2	8.9
02/77	1.33	6.9-7.0	104	0.9	1.93	276	35	87	237	46	80	36.8	11.3
03/77	1.15	6.8-7.1	53	0.8	3.32	788	43	90	370	29	89	23.4	9.7
04/77	1.12	6.9-7.1	136	0.9	4.0	315	24	92	252	15	94	18.7	7.8
05/77	1.18	6.8-7.3	176	0.4	3.04	298	32	89	188	16	91	23.7	7.6
06/77	1.07	6.7-7.2	65	---	2.19	284	28	90	162	21	87	12.3	7.1
07/77	1.08	6.7-7.2	592	---	3.03	346	33	89	198	32	84	25.4	8.5
08/77	1.13	6.9-7.2	7	---	4.52	282	47	83	206	24	88	27.5	8.6
09/77	1.09	6.8-7.5	279	---	3.57	208	51	74	170	24	86	29.0	7.2
10/77	1.12	6.0-7.2	218	---	2.90	268	50	80	205	19	89	25.6	9.1
11/77	1.06	7.3-7.5	175	---	2.71	265	38	85	190	38	77	38.1	9.9
12/77	1.36	7.2-7.3	245	---	3.09	243	34	85	198	31	83	15.0	8.2
01/78	1.42	7.1-7.3	7	---	6.20	247	44	82	143	41	58	33.8	9.9
02/78	1.38	6.8-7.1	88	---	3.63	281	31	88	248	40	82	26.3	9.6
03/78	1.47	6.8-7.6	9	---	4.71	224	39	81	161	30	80	28.7	7.2
04/78	1.56	7.1-7.2	58	---	2.96	274	56	80	287	48	80	12.4	8.9
05/78	1.54	6.9-7.4	115	---	1.81	497	87	77	338	73	65	27.2	9.1
06/78	1.61	6.8-7.1	69	---	1.83	280	108	61	172	65	62	22.3	5.9
07/78	1.61	7.0-7.5	23	---	2.94	303	110	64	182	68	63	20.0	8.4
08/78	1.64	6.7-7.0	257	---	2.30	264	50	81	172	65	62	22.8	9.0
Mean†	1.32	-------	175	---	3.24	314	47	85‡	220	37	83‡	24.1	8.7
Median†	1.34	-------	88	---	3.04	280	39	86§	198	32	84§	25.2	8.9

SOURCE: Division of Wastewater Management, Dept. of Public Works, City and County of Honolulu, Hawai'i.
NOTE: Frequency of all analyses, except total N and total P, once in 7 days; total N and total P, once in 30 days. All samples are for effluent, except as noted for BOD$_5$ and suspended solids.
*Measured on a continuous basis.
†Calculated from total number of individual analyses, thus monthly averages may be slightly different.
‡Based on overall mean.
§Based on overall median.

the Mililani STP effluent (maximum 56 mg/ℓ), Na, in general, is not considered a problem. Moreover, the Oxisols have very low susceptibility to Na induced change in hydraulic conductivity (El Swaify et al. 1976). The median concentration of B during a 7-mo period at the beginning of the project was 0.39 mg/ℓ (Lau et al. 1972), which is less than the 0.50 mg/ℓ value set for sensitive crops.

The nutrient concentration for each irrigation round in the ditch water and the sewage was determined from samples taken at the test plots prior to actual application and analyzed by the Hawaiian Sugar Planters' Association (App. Table D.8). These results tend to be more uniform than the "grab samples" collected at the sewage effluent discharge point or the ditch water channel, since the sewage effluent and ditch water were stored in their respective reservoirs before application to the test plots. The values of the median nutrient concentrations in the sewage effluent samples from the reservoir corresponded well with the values of the samples (Table 9, App. Table D.5) which were collected by both the composite and grab methods at the discharge point of the Mililani STP.

The accuracy of the percent dilution of sewage effluent with ditch water, for the B, C, and D plots was determined by the concentration of the conservative element, K, in the mixtures in comparison to its concentration in the sewage effluent. The results of these analyses are also shown in Appendix Table D.8. The actual percent effluent in the individual irrigation round varied somewhat, but the overall medians for the B, C, and D plots are, respectively, 12.45, 26.30, and 49.85%, which compared favorably to the scheduled respective values of 12.5, 25, and 50%.

The nutrient load applications of N, P, and K to the test plots by means of commercial fertilizer, sewage effluent, ditch water, and rainfall are presented in Table 10. The actual N applications compared to the original estimates (Table 3) were 11 to 48% greater; the P application unchanged except for the E treatment which was 11% less; and the K treatment, 9 to 12% greater.

Rainfall from October 1976 to October 1977 was much lower than the long-term median annual rainfall of approximately 1 015 mm (40 in.). Originally, 33 irrigation rounds were planned at 101.6 mm (4 in.) each, or a total of 3 342.8 mm (132 in.). Actually, 39 rounds were used: 7 initial rounds for a total of 381.0 mm (15 in.) of ditch water to each plot, then 32 rounds of the five treatment dilutions for a total of 3 675.4 mm

TABLE 10. IRRIGATION AND NUTRIENT APPLICATIONS TO TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

Treatment	% Effl.	Item	Irrig. (in.)	N	P	K
				--(lb applied/acre)[a]--		
A	0.0	Rounds 1-7[b]	16.0	3	0	4
		Rounds 8-42[c]	145.3	34	4	37
		Comm. Fertilizer[d]	-----	380	105	457
		Rainfall[e]	51.6	5	0	0
		Total	212.9	422	109	498
		Original Est.[f]	-----	380	105	457
		Difference	-----	+42	+4	+41
B	12.5	Rounds 1-7[b]	16.1	3	0	4
		Rounds 8-42[c]	145.7	148	39	77
		Comm. Fertilizer[d]	-----	330	105	432
		Rainfall[e]	51.6	5	0	0
		Total	213.4	486	144	513
		Original Est.[f]	-----	395	141	465
		Difference	-----	+91	+3	+48
C	25.0	Rounds 1-7[b]	15.9	3	0	4
		Rounds 8-42[c]	142.5	247	70	112
		Comm. Fertilizer[d]	-----	290	105	411
		Rainfall[e]	51.6	5	0	0
		Total	210.0	545	175	527
		Original Est.[f]	-----	420	176	477
		Difference	-----	+125	-1	+50
D	50.0	Rounds 1-7[b]	16.0	3	0	4
		Rounds 8-42[c]	144.0	463	137	188
		Comm. Fertilizer[d]	-----	210	105	366
		Rainfall[e]	51.6	5	0	0
		Total	211.6	681	242	558
		Original Est.[f]	-----	469	248	498
		Difference	-----	+212	-6	+60
E	100-0	Rounds 1-7[b]	15.9	3	0	4
		Rounds 8-42[c]	146.2	518	143	196
		Comm. Fertilizer[d]	-----	130	105	308
		Rainfall[e]	51.6	5	0	0
		Total	213.7	656	248	508
		Original Est.[f]	-----	444	278	467
		Difference	-----	+212	-30	+41

[a]Rounded off to nearest whole number

[b]Ditch water only; N, P, K concentration values of 0.77, 0.05, and 1.05 mg/ℓ, respectively, for ditch water are median values of A plot, App. Table D.8.

[c]Data from App. Table D.8.

[d]Data from App. Table D.3

[e]Data from Table 6; N, P, K for rainfall assumed to be 0.4, 0.15, and 0.015 mg/ℓ, respectively.

[f]Data from Table 3.

(144.7 in.) or a grand total per plot of 4 056.4 mm (159.7 in.).

As shown in Table 3 the scheduled nutrient applications per round for N, P, and K were, respectively, 1.758×10^{-3}, 9.688×10^{-4}, and 8.904×10^{-4} kg/m^3 (15.7, 8.65, 7.95 lb/acre), which were based on respective secondary sewage effluent concentrations of 17.33, 9.55, and 8.77 mg/ℓ from Phase I. This compares to median concentrations at the test plots of 27.9, 8.18, and 10.6 mg/ℓ (App. Table D.8), respectively, for N, P, and K for the treated sewage effluent concentrations during Phase II-A. Thus, the applied N concentrations per round average 61% higher, P 14% lower, and K 21% higher than the original estimate. The 61% higher N concentration was obviously the major factor for the considerably higher N load to the test plots.

The results of the analyses of percolate samples which commenced at irrigation round 10 (2 irrigation rounds after the diluted sewage irrigation series began) are presented in Appendix Table D.9. At the time of irrigation round 10, three chemical fertilizer applications of N and K had been completed, except for the E plots which received only two N fertilizer applications. Each plot received one more K application. The A plots received two more N fertilizer applications and the B and C plots one more N fertilizer application each (App. Table D.3). The application of P in the form of chemical fertilizer occurred only at the time of planting.

Furrow-to-furrow variation within treatments was considerable as indicated by the quality of the percolate samples (App. Table D.9). As in Phase I, the P concentration in the percolate decreased to less than 0.1 mg/ℓ, except for a few samples in which the concentration approached 0.15 mg/ℓ; the K concentration decreased to typically less than 1.0 mg/ℓ. The fourth and final application of K in chemical fertilizer on 29 April 1977 (the only one in which percolate samples were taken) did not appear to have any apparent effect on the K concentration in the percolate.

To estimate the N load in the percolate, Appendix Table D.10 was constructed for all plots. The effect of chemical fertilizer applications is especially reflected in the N concentration of the percolate (App. Table D.10). The N load in the percolate (App. Table D.10) was based on evapotranspiration calculated as 0.8 of pan evaporation.

Water use by cane was positively correlated with either pan evaporation or net radiation estimated from sunlight (Ekern 1977). Daily water-use rates measured in drip irrigation studies of sugarcane (Ekern 1977) for the summer months had r^2 correlation values with calculated net radiation that were 0.66 for the plant crop, 0.4 for the first ratoon, and 0.73 for the second ratoon. These values were slightly greater than the correlation between cane use and pan evaporation for the plant crop and second ratoon, and were approximately the same for the first ratoon. In winter, the r^2 values between cane-water use and either pan evaporation or calculated net radiation were often 0.3 or less.

In general, both pan evaporation and calculated net radiation overestimated the rate of winter water use. The annual water use by cane for the years 1971 and 1972 was 0.64 of the evaporation from a pan elevated at 1.5 m (5 ft), and was 0.7 the equivalent energy from calculated net radiation. In Phase I, the water use by Bermudagrass sod was about 0.8 the evaporation from a pan at a 1.5-m elevation. Percolate-style lysimeters with furrow-irrigated cane in Phase I (Lau et al. 1975) had measured water use of about 0.8 the evaporation from the pan at the 1.5-m elevation. These ratios of about 0.8 the evaporation from an elevated pan were in sharp contrast to the ratios of about 1.0 reported from the percolate lysimeter studies on Maui (Campbell, Chang, and Cox 1960, pp. 637-49).

The summary water budget for the cane cycle based on the 0.8 evapotranspiration (ET) factor of pan is

Treatment	Irrigation (in.)	Rainfall (in.)	Calculated ET (in.)	Calculated Percolate (in.)
A	161.28	49.71	128.85	82.14
B	161.79	49.71	128.85	82.65
C	158.46	49.71	128.85	79.32
D	160.03	49.71	128.85	80.89
E	162.05	49.71	128.85	82.91

NOTE: In. × 0.025 4 = m.

The data show that there was an estimated percolate equivalent to >50% of the irrigation.

Appendix Table D.10 is based on the assumption of cane-water use equivalent to 0.8 of the elevated pan. This factor may give an underestimate of the percolate amounts, since some evidence indicates that a factor as low as 0.7 is warranted. The 0.7 pan factor, for example, would increase the percolate amount by 0.41 m (16 in.) or about 20%, whereas the use of the calculated net radiation would increase percolate by 0.3 m (12 in.) or about 10%.

As reported in Phase I, N in its oxidized forms (nitrite and and nitrate) is essentially found only in nature in the soluble form, except for saltpeter deposits. Anion sorption can play a major role in sulfate and nitrate balances of tropical soils; however, the relatively low content of amorphous material in the Lahaina soil, on which the test plot are located, minimizes the importance of the sorption in the nitrate balance. Thus, the assumption is made that oxidized N in the percolate has escaped the root zone and could potentially reach the underlying groundwater table.

Although a precise N balance sheet cannot be made, the importance of the fate of N demands that some attempt be made. An estimation of the N budget shown in Table 11 was based on several assumptions, which include the N content of the harvest cane, the cane root mass, and the percolate losses from the early irrigation rounds before the percolate was sampled. The applications of N from fertilizer and effluent applications are taken from Table 10 and the soil reserve from Table 8. The N content of harvest cane has been estimated based on 1 lb N/ton of cane (Stanford 1963). Root mass was assumed to be one-fourth that of the top. The initial percolates (rounds

TABLE 11. APPROXIMATE NITROGEN BALANCE SHEET FOR THE CROP CYCLE

Treatment % Effluent	A 0	B 12.5	C 25	D 50	E 100 then 0
	(lb/acre)				
Fertilizer	380	330	290	210	130
Effluent	42	156	255	471	526
Total Source	422	486	545	681	656
Sinks					
Cane Harvest	141.6	144.1	154.6	149.9	149.4
Roots	35.4	36.0	38.7	37.5	37.4
Percolate	241.0	69.3	92.6	146.0	254.3
Soil Reserve	-11.0	+12.0	+5.0	+9.0	+7.0
Total Sink	307.0	261.4	290.9	342.4	448.1
Balance	-115.0	-224.6	-254.1	-338.6	-207.9

NOTE: Lb/acre × 0.000 112 = kg/m^2.

1-7), before the application of secondary effluent, were assumed to have a nitrate content of 30 mg/ℓ, since the urea fertilizer tended to leach readily when the irrigation was immediately applied after fertilization. The unexplained deficit in the N balance was one-fourth to one-third the application in the A and E treatments where no N was applied as effluent or as fertilizer the second year. On the other plots, where effluent continued to be applied throughout the cycle, the N budget deficit was about one-half the application. These unexplained deficits (Sze and Rice 1976) in the N budget are rather typical of the results from fertilizer studies. These denitrification losses are quite high, but well within the range of Oxisols if an energy source (carbon compounds in the secondary effluent) is available (Balasubramanian and Kanehiro 1976; Bremner and Blackmer 1978).

The 11 August 1977 through 8 August 1978 period for irrigation rounds 20 through 42, except for the E treatment, was chosen to estimate the increased N loss in percolate from the various effluent treatments after the effects of the commercial fertilizer applications had disappeared (Table 12). The N concentration was weighted by the volume of percolate determined from Appendix Table D.10.

As expected, when the effects of commercial fertilizer are not considered, the N content of the percolate increased with the increased percent of effluent used in irrigation. Rounds 20 through 42 represented more than 70% of the total irrigation applied after the initial 7 rounds of ditch-

TABLE 12. EXTRAPOLATED NITROGEN IN THE PERCOLATE EXCLUDING THE EFFECTS OF COMMERCIAL FERTILIZER APPLICATION, TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

TREATMENT			PERCOLATE		EXTRAPOLATED N
	Rounds	% Effluent	Nitrogen* Concentration (mg/ℓ)	Nitrogen (lb/acre)	Rounds 8-42 (lb/acre)
A	20-42	0.0	1.30	16.8	23.6
B	20-42	12.5	1.65	21.1	29.8
C	20-42	15.0	2.60	33.5	46.1
D	20-42	50.0	5.93	77.0	106.6
E	10-26	100.0	26.55	207.7	248.1
	27-42	0.0	2.28	23.2	

NOTE: Lb/acre × 0.000 112 = kg/m^2.
*Weighted mean.

water irrigation on all plots. The total N loss in the percolate, except for the E treatment, was projected from the fractional irrigation in rounds 20 through 42, e.g., A treatment = 16.8/0.713 = 23.6 lb/acre. The relative losses, excluding the effects of commercial fertilizer applications, among the treatments were ditch water only, 1.0; 12.5% effluent, 1.26; 25% effluent, 1.95; 50% effluent, 4.52; and 100% effluent, 10.5. The difference in the percolate N (lb/acre) between Tables 11 and 12 is the amount attributed to commercial fertilizer. This amounts to 0.013, 0.004, 0.001, and 0.000 1 kg/m^2 (117.4, 39.5, 46.5, 39.4, 6.3 lb/acre) for the respective A, B, C, D, and E treatments. The effects of the heavy slug loads of commercial fertilizer on the percolate for the A treatment is thus readily apparent. As can be observed in Table 11, the unaccounted N losses—attributed to gaseous losses—are two to three times greater than the control A plots which receive slug loads of commercial fertilizer. The total N taken up by the cane plant was no greater than 0.002 kg/m^2/mo (15 lb/acre/mo). Irrigation with undiluted effluent supplied 0.006 to 0.008 kg/m^2/mo (50-70 lb/acre/mo) of N, which was greatly in excess of the potential uptake of the cane. Percolate accounted for 0.003 to 0.007 kg/m^2/mo (30-60 lb/acre/mo); thus, the remnant attributed to denitrification ranged from 0.002 to 0.005 kg/m^2/mo (15-45 lb/acre/mo). In Phase I, also, the cane plant took up no more than 0.002 kg/m^2/mo of N; however, the rates of N from irrigation with effluent were generally less than 0.004 kg/m^2/mo (40 lb/acre/mo), and the remnant assigned to denitrification was less than 0.002 kg/m^2/mo. Irrigation with undiluted effluent thus added N at rates far greater than the uptake capability of the cane and increased the N in percolate well above that from ditch-water irrigation once the effect of commercial fertilizer was dissipated.

Fischer, Green, and Burbank (1977) reported that only a few chlorinated compounds in the Mililani STP effluent were isolated and that these same compounds were also found in distilled water blanks. The halogenated organics in the sewage effluent were removed by percolation; however, parafins and steroids were not as effectively removed. The apparent failure of the soil to remove parafins needs further evaluation in relation to their potential impact on groundwater quality.

Viral Analysis Results

The feasibility of using the activated sludge-treated and disinfected sewage effluent for the irrigation of sugarcane was indicated by the results of Phase I. However, since viruses in the sewage used for irrigation were not completely removed, the need to monitor the sewage effluent in Phase II-

A was indicated. The Phase I and II-A studies should result in an additional assessment of the health risks involved and also in the incorporation of proper precautions to be taken. Thus, three significant changes in the treatment of the sewage used in Phase II-A, compared to the Phase I study, were planned and these changes were expected to have a direct effect on the concentration and stability of the viruses in the effluent.

First, in anticipation of the future increase in the volume of sewage, the chlorine contact chamber at the Mililani STP was doubled in size, the chlorine dose increased, and aeration was provided to enhance mixing and to prevent particulates from settling to the bottom of the chamber. The use of this enlarged and redesigned contact chamber became fully operational in December 1976.

Second, the more efficient, complete-mix aeration system was completed in March 1977 and the previous Rapid Bloc activated sludge facility was kept on line to be used as flow increased. Even if this new activated sludge process does not inactivate more viruses than the Rapid Bloc process, the improvement in the effluent quality should result in more efficient disinfection in the chlorine contact chamber.

Third, the treated effluent was initially pumped to an open reservoir where it was stored overnight or up to four days before it was used for irrigation. Under these conditions, growth and an increase in the population of algae and bacteria in the effluent are expected. In contrast human enteric viruses in the effluent cannot multiply and are expected to be inactivated. However, the fraction of the virus population which adsorb onto particulate matter in the effluent are expected to resist inactivation and to persist within the sediment at the bottom of the reservoir. Thus, to evaluate the virus removing capacity of the sewage treatment procedure and the health hazard potential of using the treated sewage effluent to irrigate sugarcane, the following objectives were pursued.

1. To determine the frequency, concentration, and types of human enteric viruses in the raw, the activated sludge-treated, and the final chlorinated effluent at the Mililani STP before and after redesign and reconstruction of the activated sludge and the chlorination facilities at the Mililani STP
2. To determine the frequency, concentration, and stability of viruses in the effluent stored in the reservoir
3. To determine the persistence of viruses in the wet and dried sediment of the effluent reservoir

4. To determine the recovery of viruses from soil after irrigation with sewage effluent and also the stability of marker viruses in OSC Field No. 246 during growth, drying, and after burning of the sugarcane.

The viral studies for the project were conducted by the Environmental Virus Laboratory which represents the first facility of its kind in Hawai'i and which is also one of the few laboratories with these capabilities in the nation.

MATERIALS AND METHODS

Cells and Media. An established line of African green monkey kidney cells (BGM) was grown in Eagle's basal medium using either Hank's or Earl's salt supplemented with 5 to 7% fetal calf serum at 36°C in a CO_2 incubator and used for virus isolation and identification. Viral growth was quantified by using either the 50% tissue culture infectious dose ($TCID_{50}$) method under liquid overlay or as plaque forming units (PFU) under agar overlay. The isolated enteroviruses were identified by the neutralization test using the Lim-Benyesh-Melnick pooled antisera as described and supplied by the National Institute of Health (NIH). The Sabin type 1 attenuated poliovirus was used as control and marker for the various tests when concentrations of natural viruses in the effluent could not be predicted or were too low.

Samples and Sampling Sites. Grab samples of the raw, the activated sludge, and the chlorinated sewage effluent were collected at the Mililani STP. Samples of the sewage effluent for irrigation were similarly collected from the reservoir near the OSC Field No. 246 test plots after an overnight to 3-day storage. Initially, samples were taken from the surface of the effluent reservoir but, subsequently, samples were taken from the irrigation pipe line used to irrigate the Field No. 246 test plots.

Sodium thiosulfate to a final concentration of 0.001% was added to the chlorinated effluent from the Mililani STP as well as reservoir effluent samples to immediately neutralize further action of the residual chlorine in the samples. Samples to be assayed for bacteria, N, and solids were immediately refrigerated and returned to the laboratory. Samples collected for viral analysis were generally conducted on the day of collection but occasionally after 15-hr storage at 4°C. Surface soil samples from Field No. 246 were collected after various periods following irrigation. After the reservoir was drained, sediment samples were collected from the bottom of the reservoir the next day and up to 6 days later.

Concentration of Viruses From Sewage Effluent. The methods to concentrate viruses and the volume of sample assayed were based on the results of Phase I. Chlorinated effluent samples of 0.004 m^3 (1 gal) were concentrated by the protamine sulfate method, while 0.01- to 0.02-m^3 (3- to 5-gal) samples were concentrated by the $AlCl_3$ gel precipitation method. For larger samples, either the $AlCl_3$ gel precipitation (0.015-0.019 m^3 [4-5 gal]) or the portable virus concentrator (Aquella) (0.02-0.10 m^3 [6-26 gal]) or both were used. The effluent samples from the reservoir had varied turbidity due to growth of algae and other microorganisms during storage.

Recovery of Viruses From Soil and Reservoir Sediment. Viruses adsorbed to solids must first be eluted from the solids before they can be assayed. Soil samples from OSC Field No. 246 or sediments from the effluent reservoir were mixed with at least 10 times their volume of 3% beef extract for 2 hr at room temperature (final pH 8), or overnight at 4°C (final pH 8), before raising the pH to 9 and mixing for 1 hr at room temperature. The liquid portion of the mixture was then separated from the solids by centrifugation and precipitated subsequently by lowering the pH of the mixture to 3.5. The precipitate, including the virus, was then recovered by centrifugation and redissolved into a small volume of 0.15 m disodium phosphate and assayed for virus.

Bacteria, Solids, Nitrogen, and Moisture Analysis. The chlorinated sewage effluents before and after storage in the reservoir were assayed for fecal indicator bacteria (total coliform, fecal coliform, fecal streptococci) as well as suspended and total solids, and ammonia and organic N by methods outlined in *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA, and WPCF 1976). Soil moisture was obtained by the methof outlined in the *Annual Book of ASTM Standards* (ASTM 1977, pp. 276-77).

RESULTS AND DISCUSSION

Recovery of Viruses From Sewage Effluent at the Mililani STP Before Redesign and Reconstruction. To determine the efficiency of the virus removal capability of the Mililani STP before redesign and reconstruction of the activated sludge and chlorinated facilities, samples of the raw, activated sludge effluent, and chlorinated effluent were assayed for virus during the July 1975 to July 1976 period. The results in Table 13 show that all the samples of raw sewage (5/5) and unchlorinated sludge effluent (5/5) were positive for virus at respective concentrations ranging from 300 to

TABLE 13. VIRUS ISOLATIONS AT MILILANI STP, O'AHU, HAWAI'I, 2 JULY 1975-13 JULY 1976

	Samples Positive/ No. Tested	Percent Positive	Range of Virus Concentrations (PFU/ℓ)*
Raw Sewage	5/5	100.0	300-27,000
Unchlorinated Effluent (Activated Sludge)	5/5	100.0	68-980
Chlorinated Effluent	26/33	78.8	8-190

*PFU = Plaque-forming units.

27,000 PFU/ℓ and 68 to 980 PFU/ℓ. In contrast, 26 of 33 (79%) samples of the chlorinated effluents were positive at concentrations ranging from 8 to 190 PFU/ℓ.

Analysis of the Sewage Effluent at Mililani STP After Redesign and Reconstruction. Analysis of the activated sludge as well as the chlorinated effluent was resumed in January 1977 after reconstruction of the chlorine contact chamber and the redesign of the activated sludge treatment facility. The results in Table 14 show that while 100% (7/7) of the unchlorinated effluent samples were still positive for virus, the concentration of viruses recovered (3-560 PFU/ℓ) was lower than that recovered from the activated sludge-treated effluent before reconstruction at the STP (Table 13). Furthermore, the results in Table 15 show that the frequency of detection (10/21 samples or 48%), as well as the concentration of virus (1-15 PFU/ℓ) recovered from the reconstructed chlorine contact chamber, was substantially lower than the frequency of detection (79%) and concentration (8-190 PFU/ℓ) of virus recovered from the original chlorine contact chamber.

Viruses isolated from the activated sludge effluent, as well as chlorinated effluent, were identified and determined to be human enteric viruses (poliovirus types 1, 3; coxsackievirus types B-1, -3, -4; echovirus type 16), similar to those recovered from the raw sewage. Besides the assay for virus, the chlorinated effluent was assayed for indicator organisms, total and fecal coliforms, and fecal streptococci, as well as solids and N content.

The results in Table 15 show that chlorination is generally effective in decreasing the fecal coliform bacterial concentrations in the effluent to the acceptable level of <100 colonies/100 mℓ. Generally, the samples in which the total coliform count exceeded the 100 colonies/100 mℓ contained greater concentrations of suspended solids which probably interfered

TABLE 14. VIRUSES RECOVERED FROM THE UNCHLORINATED EFFLUENT, MILILANI STP, O'AHU, HAWAI'I, JANUARY 1977-JUNE 1978

Sample No.	Date	Volume Assayed (gal)	Virus Recovered*
1	1/10/77	2.5	P-3
2	2/09/77	2.0	P-3, C-B1
3	3/02/77	0.5	P-1
4	9/21/77	0.5	C-B4
5	1/31/78	1.5	C-B5
6	4/03/78	0.5	C-B5
7	6/20/78	0.5	C-B4

NOTE: Range of virus concentration recovered = 3-560 PFU/ℓ.
*P = Poliovirus, C = Coxsackievirus.

with the chlorine disinfection efficiency. The accumulated results indicated that the redesign and reconstruction of the activated-sludge process and the chlorination process at the Mililani STP had increased the efficiency of the virus removal in the sewage treatment. It should be noted, however, that by doubling the volume of the treatment facilities at the time when the input volume of sewage had not yet doubled, the virus removal efficiency of the Mililani treatment process was probably at its maximum at that time. These results again emphasize the necessity for continued monitoring for virus of the chlorinated effluents in any planned recycle scheme.

Analysis of Sewage Effluent Stored in the Reservoir. For irrigation, the chlorinated effluent from the Mililani STP was pumped into an open reservoir and stored from 15 to 96 hr before it was used. Under these conditions, human enteric viruses cannot multiply and may be inactivated. However, the growth of algae (green coloration) and bacteria (offensive odor, increased turbidity) in the stored effluent was apparent. Thus, storage of the effluent can be expected to result in a drastic change in the microbial population of the effluent and, consequently, its potential as a source of pathogens. To evaluate the health hazard potential of using the stored effluent for irrigation, the effluent in the reservoir was analyzed for viruses and, whenever feasible, for indicator organisms, total and fecal coliforms, fecal streptococci, solids, and N content. The results (Table 16) confirmed the visual changes in the quality of the effluent on storage in the open reservoir. Thus, the solids (total and suspended), N (ammonia and

TABLE 15. VIROLOGICAL ANALYSIS OF CHLORINATED EFFLUENT FROM MILILANI STP, JANUARY 1977 TO JUNE 1978

Sample Date	Date	Volume Assayed (gal)	Virus Recovered*		Susp. Solids	Total Solids	Total Coliform	Fecal Coliform	Fecal Strep.	Ammonia N	Organic N
					----(mg/ℓ)----		---------(No./100 mℓ)---------			-----(mg/ℓ)------	
1	01/04/77	4.0	-	---	11.2	320	ND	ND	ND	14.8	6.2
2	01/10/77	5.0	+	C-B1	ND	ND	ND	ND	ND	ND	ND
3	01/20/77	4.0	-	---	13.2	340	4	<2	<2	15.7	4.1
4	01/31/77	5.0	-	---	11.5	572	ND	ND	ND	ND	ND
5	02/09/77	2.0	-	---	ND	ND	ND	ND	ND	ND	ND
6	02/16/77	8.0	+	P-1	ND	ND	3	4	0	ND	ND
7	02/23/77	5.0	-	---	3.0	335	ND	ND	ND	ND	ND
8	03/02/77	2.5	-	---	ND	ND	ND	ND	ND	ND	ND
9	03/30/77	4.75	+	P-1	9.5	345	38	0	7	ND	ND
10	04/06/77	20.0	+	C-B1	3.2	310	4	0	2	ND	ND
11	04/12/77	25.0	-	---	2.8	320	172	<2	12	ND	ND
12	04/27/77	7.0	+	P-3	ND	ND	ND	ND	ND	ND	ND
13	05/18/77	7.0	-	---	8.5	312	<10	<10	40	12.0	2.4
14	06/14/77	10.0	+	P-3	28.0	336	700	0	435	ND	ND
15	07/06/77	3.0	-	---	6.0	296	<10	<10	<10	ND	ND
16	09/21/77	2.5	+	P-3	8.0	320	20	20	10	13.9	4.7
17	12/07/77	1.0	+	C-B3	20.0	316	2×10^3	1.65×10^3	200	10.4	3.01
18	01/31/78	3.0	-	---	32.0	352	7.5×10^5	90	<10	13.5	4.1
19	03/03/78	2.0	-	---	27.0	328	990	12	130	5.04	3.85
20	04/03/78	3.0	+	NI	27.0	392	10	10	10	15.4	5.81
21	06/20/78	8.0	+	E-16	ND	ND	ND	ND	ND	ND	ND

NOTE: Range of virus concentration = 1-15 PFU/ℓ.
NOTE: NA = Not analyzed; NI = Not identified.
*C = Coxsackievirus, P = Poliovirus, E = Echovirus.

TABLE 16. VIROLOGICAL ANALYSIS OF SEWAGE EFFLUENT FROM RESERVOIR, FEBRUARY 1977 TO AUGUST 1978

Sample No.	Date	Volume Assayed (gal)	Virus Recovered*		Susp. Solids ----(mg/ℓ)----	Total Solids	Total Coliform ----------(No./100 mℓ)----------	Fecal Coliform	Fecal Strep.	Ammonia N -----(mg/ℓ)-----	Organic N
1	02/16/77	4.0	-	---	ND	ND	2	0	0	ND	ND
2	03/09/77	6.0	-	---	6.5	340	ND	ND	ND	ND	ND
3	04/12/77	26.0	-	---	5.5	330	6.6×10	300	4	ND	ND
4	05/14/77	7.0	-	---	ND	ND	ND	ND	ND	ND	ND
5	05/26/77	7.0	+	P-1	ND	ND	ND	ND	ND	ND	ND
6	06/07/77	9.0	+	P-1	20.0	388	7000	10	110	18.8	3.9
7	07/13/77	8.0	-	---	91.0	324	ND	ND	ND	15.7	0.6
8	07/27/77	10.0	-	---	14.0	360	11×10^6	0	1470	26.0	3.85
9	08/09/77	7.5	-	---	1.5	300	0	0	0	18.8	1.61
10	08/25/77	5.0	-	---	19.5	848	ND	ND	ND	21.5	5.6
11	09/07/77	20.0	-	---	22.0	380	1100	210	10	20.4	5.46
12	10/07/77	23.0	-	---	17.0	384	1.96×10^5	1×10^4	170	18.3	4.0
13	10/20/77	6.0	+	P-3	20.0	340	5×10^3	2.2×10^3	--	16.0	4.94
14	11/02/77	4.5	-	---	21.3	360	1.2×10^4	9×10^3	80	24.8	7.62
15	11/22/77	6.0	-	---	17.3	364	<10	<10	<10	21.1	4.52
16	12/20/77	7.5	-	---	12.0	344	1×10^3	500	0	17.4	4.0
17	01/17/78	15.0	-	---	19.0	372	2.2×10^4	1.25×10^3	60	18.4	3.75
18	02/02/78	13.5	+	P-1	ND	ND	ND	ND	ND	ND	ND
19	02/15/78	13.5	+	NI	11.0	364	2.1×10^6	3×10^5	500	10.0	2.75
20	03/07/78	8.0	+	P-3	25.0	336	21	18	0	9.1	5.08
21	03/22/78	10.5	-	---	ND	ND	ND	ND	ND	ND	ND
22	05/01/78	5.0	+	P-3	9.5	320	2.9×10^3	500	<10	ND	ND
23	06/08/78	5.0	+	E-16	ND	ND	ND	ND	ND	ND	ND
24	06/20/78	15.0	+	P-3	ND	ND	ND	ND	ND	ND	ND
25	08/10/78	6.0	+	E-7	ND	ND	ND	ND	ND	ND	ND

*P = Poliovirus; E = Echovirus. NA = Not analyzed; NI = Not identified.

organic), as well as bacterial concentrations (total and fecal coliform, fecal streptococci) were generally higher in the reservoir effluent than in the chlorinated effluent at the Mililani STP (Table 15). Viruses were recovered from 10 of 25 reservoir effluent samples. However, because of the poorer quality of the reservoir effluent, larger volumes of samples and different virus concentration methods (Aquella virus concentrator and gel precipitation method) were used. The 40% recovery of viruses from the reservoir therefore represents a substantial reduction when compared to the 48% recovery of viruses in the chlorinated effluent from the Mililani STP. It was concluded that storage of the sewage effluent in the reservoir aided in the destruction of viruses but should not be depended upon to destroy all the viruses in the effluent.

Stability of Viruses in the Reservoir Effluent. The field data (Table 16) indicated that some viruses appeared to persist in the reservoir effluent during storage. To estimate the stability of enteric viruses in the reservoir effluent, an effluent sample was obtained from the reservoir, the residual chlorine neutralized with sodium thiosulfate, and the sample transported back to the laboratory. Marker poliovirus type 1 was added to 100 mℓ of this unmodified effluent as well as to another 100 mℓ of the same effluent which had been filtered through a 0.22-μm membrane to remove most of the particulates, including all bacteria, algae, and protozoans. These samples were then stored at room temperature (24°C) and aliquots taken daily to determine the surviving fraction of viruses in the sample. The results (Table 17.1) show that after 1, 2, and 3 days of incubation, 100, 70, and 36%, respectively, of the input viruses were recovered from the filtered effluent, while only 48, 33, and 0.8%, respectively, of the viruses were recovered from the unmodified effluent sample. These laboratory results suggest that human enteroviruses in the effluent can be expected to be inactivated on storage and that it is the particulate component of the effluent which enhances inactivation or possibly acts as an adsorptive surface for viruses.

Since the preceding experiment was conducted under strict laboratory conditions and the results could not be directly applied to field conditions, two additional experiments were conducted with one carried out under laboratory conditions (constant temperature of 24 ±1°C; absence of sunlight), and the other at the reservoir site under field conditions (temperature ranged from approximately 22 to 27°C; presence of sunlight).

TABLE 17. STABILITY OF POLIOVIRUS IN EFFLUENT RESERVOIR

1. Inactivation of Poliovirus Added to Dechlorinated Reservoir Effluent and Incubated Under Laboratory Conditions*

Effluent Treatment	% Virus Remaining After Day		
	1	2	3
No treatment	48	33	0.8
Filtered through 0.22-µm membrane to remove turbidity, bacteria, protozoa, and algae	100	70	36

2. Inactivation of Poliovirus in Dialysis Bag Immersed in Tap Water or Reservoir Effluent Under Laboratory and Field Conditions with No Residual Chlorine

Incubation Conditions	Virus Reaction Conditions	% Virus Remaining After Day	
		1	2
Laboratory Conditions*	Dialysis bag immersed in tap water	100	100
	Effluent in glass flask	46	40
Field Conditions†	Dialysis bag immersed in reservoir	40	48
	Effluent in open pan	3.8	0.3

3. Inactivation of Poliovirus in Dialysis Bag Immersed in Tap Water or Reservoir Effluent Under Laboratory and Field Conditions with 1.6 mg/ℓ Residual Chlorine

Incubation Conditions	Virus Reaction Conditions	% Virus Remaining After Day		
		1	2	3
Laboratory Conditions*	Dialysis bag immersed in tap water	100	NA	53
	Effluent in glass flask	0.2	<0.1	<0.1
Field Conditions†	Dialysis bag immersed in reservoir	1.6	NA	0.2
	Effluent in open pan	0.25	<0.1	<0.1

*Constant temperature (24 ±1°C); without sunlight. NA = Not analyzed.
†Variable temperature (22-27°C); with sunlight.

In the earlier experiments, effluent in the reservoir did not contain any detectable levels of residual chlorine and the inactivation of viruses thus reflected factors other than chlorine in the effluent. In the present experiment, poliovirus was added to dialysis bags and one set of bags immersed directly into the reservoir effluent, while the second set of bags was immersed in tap water and kept in the laboratory. Poliovirus was also directly added to the effluent and one set of bags incubated in a glass flask under laboratory conditions, while the second set of virus-seeded effluent was placed into an open plastic dishpan which was floated on the reservoir effluent. Samples were taken from all these reaction conditions after 1 and 2 days and assayed for viruses. Table 16.2 shows that when viruses were mixed with the effluent and stored under laboratory conditions, 46 and 40% of the input virus were respectively recovered after 1 and 2 days of incubation. These results closely approximated those obtained in the previously described laboratory experiment (Table 16.1). When viruses were mixed with effluent and placed in an open pan left floating in the reservoir, only 3.8 and 0.3% of the input viruses were recovered after 1 and 2 days, respectively, thus indicating that under field conditions the rate of virus inactivation was much faster than under laboratory conditions. Table 16.2 also shows that when viruses were placed in dialysis bags and immersed in tap water under laboratory conditions, no virus inactivation was observed after 2 days. In contrast, 60 and 52% of the viruses in the dialysis bags were inactivated when immersed in the reservoir effluent for 1 and 2 days, respectively. These results support the earlier conclusions that the particulate components of the effluent which cannot pass through the dialysis bags are primarily responsible for the inactivation or adsorption of viruses suspended in the effluent. These results further indicate that under field conditions 96% of the virus suspended in the effluent and stored in the reservoir can be expected to be inactivated or adsorbed to particulate matter after 24 hr.

A comparable experiment was conducted with effluent stored in the reservoir which contained 1.6 mg/ℓ of residual chlorine. The results (Table 16.3) show that in the presence of this high concentration of chlorine, only 0.2% of virus in the effluent, whether stored under laboratory or field conditions, remained viable after 1 day of storage. Furthermore, although 100% of the viruses in dialysis bags immersed in tap water remained viable after 1 day, only 1.6% of the virus in dialysis bags immersed in the effluent at the reservoir remained after the same time period, thereby suggesting that chlorine penetrated the dialysis bags and inactivated the viruses in the bags. Thus, in the presence of 1.6 mg/ℓ of residual chlorine in the effluent, approximately 99.8% of the viruses in the effluent can be expected to be inactivated over a 24-hr storage period.

Persistence of Viruses in the Sediment of the Reservoir Effluent. Despite the evidence that viruses were inactivated during storage of the effluent in the reservoir, viruses were recovered with fair regularity from the effluent in the reservoir (Table 16). Two obvious factors could account for the regular recovery of viruses from the reservoir. First, it was learned that although the reservoir was filled with effluent on the day before irrigation, it was often refilled with more fresh effluent with undoubtedly more infectious viruses on succeeding days. Second, several reports have indicated that when viruses adsorb readily onto particulate matter, they become more resistant to inactivating agents, including chlorine, and eventually settle to the bottom resulting in an increase in the concentration of viruses in the sediment. Infectious viruses may be eluted from these sediments from time to time and released into the overlying water. To determine whether viruses are adsorbed onto particulate matter and persist in the sediment of the reservoir, sediment samples were collected from the bottom of the reservoir at various time periods after the reservoir was drained of effluent and assayed for virus. The results (Table 18) show that recovery of viruses from the reservoir sediment was related to the time after the reservoir was drained and to the sediment remaining in a wet state. Although viruses were never recovered from sediment samples which had completely dried in the sun, they were recovered from two sediment samples which were collected only a day after the reservoir had been drained and before the sediment had dried. These results support earlier reports that viruses do tend to adsorb onto particulates, which settle as sediment, and that viruses in the sediment can persist when the sediment remains wet.

Corollary Studies Using Poliovirus Type 1 as a Marker. The results of the previous field studies (Percolation of Sewage-Borne Viruses; Survival of Sewage-Borne Viruses) have yielded some evidence as to the extent and the possible mechanism of virus-soil interactions. To obtain a clearer understanding of the interaction of viruses with soil, poliovirus type 1 was added to the Lahaina soils and the fate of the virus followed. It should be clearly understood that these experiments using added poliovirus as a marker are not directly analogous to natural field conditions. This is especially true with the extremely high concentrations of viruses used, concentrations which would seldom if ever be experienced under natural field conditions but which were used in these experiment to facilitate the detection of viruses. Nevertheless, similar mechanisms of virus-soil interaction are likely to operate whether under natural or artificially created field conditions.

TABLE 18. VIROLOGICAL ANALYSIS OF MILILANI RESERVOIR SEDIMENT, O'AHU, HAWAI'I

Date of Experiment	Days After Draining Reservoir	Condition of Sediment	Grams Assayed	Virus* Recovered	
10/14/77	4	Dried and caked	13	-	---
03/28/78	1	Wet and slimy	44	+	P-1
			73	+	P-1
04/11/78	4	Dried and rehydrated due to sunlight and rainy periods	40	-	---
			80	-	---
05/06/78	1	Only slurry obtained due to heavy overnight rain	24	-	---
			55	-	---
07/05/78	1	Wet, slimy	40	-	---
07/24/78	1	Wet, slurry	50	+	C-B4
	2	Wet, slurry	50	-	---
07/25/78	3	Wet, slimy	91	-	---

*P = Poliovirus, C = Coxsackievirus.

Information obtained from these experiments, therefore, can provide useful data of the mechanisms and virus-soil interactions in operation and, when extrapolated, provide some reasonable explanation of the fate of enteroviruses in the soil under normal irrigation practices.

Persistence of Viruses in OSC Field No. 246 Soil. Since viruses were recovered from the effluent used to irrigate sugarcane, it would be logical to assume that viruses were applied to the Field 246 soil. To determine whether viruses persist and can be recovered from a field irrigated with sewage, soil from various plots in Field 246 were sampled and assayed for virus. The results (Table 19) show that viruses were never recovered from any of the soil samples and suggest that viruses are possibly unstable in the soil environment. It is also possible that some viruses remain viable in the soil but because of the small sample of soil (5-50 g) assayed and the low efficiency of recovering viruses adsorbed to soil aggregates, the likelihood of recovering viruses from the soil would be very low. At any rate, the results indicated that infectious viruses were not accumulating in the soil.

In an experiment to estimate the theoretical stability of viruses in the soil in Field No. 246, an extremely high dosage of poliovirus type 1

TABLE 19. VIROLOGICAL ANALYSIS OF SOIL FROM OSC FIELD NO. 246 TEST PLOTS, O'AHU, HAWAI'I

Date of Experiment	Plot Size	Days After Last Irrigation	Grams Assayed	Virus Recovered
10/14/77	13E	0	30.0	Neg.
12/07/77	29D	7	5.0	Neg.
01/18/78	29D	21	25.0	Neg.
02/13/78	11D	2	50.0	Neg.
			50.0	Neg.
			50.0	Neg.
06/26/78	19D	2	50.0	Neg.
	11D	2	50.0	Neg.
07/05/78	18A	2	24.0	Neg.
	19D	2	21.0	Neg.
07/25/78	10C	3	23.0	Neg.
	12B	3	21.0	Neg.
08/14/78	2D	4	34.0	Neg.
	10C	4	29.5	Neg.
	11D	4	37.5	Neg.
08/29/78	10C	19	33.4	Neg.
	11D	19	25.0	Neg
	12B	19	29.3	Neg.

(1.62×10^{10} PFU in 50 mℓ of water), was evenly spread over a 0.99-m^2 (1.0-ft^2) area of soil near the base of the sugarcane in the 11D test plot. At the initiation of this experiment (22 June 1978), the 11D test plot was still being irrigated with 50% effluent every 2 to 3 weeks and the soil was kept moist. Furthermore, the cane was very tall—2.4 to 3 m (8-10 ft)—and the underbrush was so thick with growth that the soil was not directly exposed to sunlight. Soil samples from this seeded area were periodically taken and assayed for virus. Since stability of viruses have been reported to be directly related to the moisture content of their environment, soil samples were assayed for moisture content as well as for viruses. The results (Table 20) show that poliovirus was recovered from the soil up to 77 days after seeding under these conditions. It should be noted that the normal practice of irrigating the field every 2 to 3 weeks continued until 8 August 1978, or up to 49 days after the soil was seeded with virus. Thus, during this period, the soil was always moist and tacky with moisture contents of at least 24 to 29%, and viruses were readily recovered from the soil samples. After 10 August 1978, the soil became progressively drier

TABLE 20. RECOVERY OF POLIOVIRUS SEEDED ONTO SOIL IN OSC FIELD NO. 246 TEST PLOTS, O'AHU, HAWAI'I

Date	Days Since Virus Seeded	Days Since Last Irrig.	Soil Appearance	Soil Moisture	Assayed (g)	Virus Recovered
07/12/78	20	7	Moist Sticky	ND	7.4	+
07/24/78	32	7	Moist Sticky	24.8	5.0	+
08/15/78	54	5	Moist Sticky	29.0	10.0	+
09/07/78	77	28	Moist Crumbly	21.1	7.4	+
09/20/78	90	41	Moist Crumbly	20.2	11.2	-
10/06/78	106	56	Dry	ND	68.4	-
10/13/78	113	73	Dry	10.8	50.0	+

ND = Not detectable.

as natural rainfall was insufficient to replenish the moisture in the soil. The soil became less moist and crumbly (moisture content 20-21%) and then became air dry (moisture content 10.8%) as water was withdrawn from within the aggregates. The last virus-positive soil sample, which was taken 77 days after seeding and 28 days after the last irrigation, had a moisture content of 21.1%; while the succeeding sample negative for virus, taken 90 days after seeding and 41 days after the last irrigation, had a moisture level of 20.2%. As expected, the next soil sample—also negative for virus, taken 106 days after seeding and 56 days after the last irrigation, was visibly drier. These accumulated results show a correlation between soil moisture and viability of virus in the soil; furthermore, the critical soil moisture for recovery of virus from soil appears to be approximately 20%. However, a few days before the cane field was to be harvested and 113 days after seeding, the entire seeded soil area was collected, removed from the field, and 50 g of this very dry soil (soil moisture content 10.8%) were analyzed for viruses. Four of the five bottles of cells used to assay for virus were negative, whereas the last bottle was positive and determined to be poliovirus type 1—the same type seeded in the soil. These results indicate that poliovirus can survive in soil with only a 10.8% moisture content or that in collecting the entire soil sample area, a fraction of the soil may have had a higher moisture content which allowed the virus to survive.

Effect of Burning the Sugarcane. Since the entire sugarcane field is burned prior to harvesting, it was originally believed that this practice might disinfect the soil of any pathogen, including viruses, which may have persisted on the soil. To test this hypothesis, the Lahaina soil sample from Field No. 246 was carefully sifted and 17-g (0.6-oz) aliquots were placed into five 60-mm petri dishes. To these were added 2 mℓ of type 1 poliovirus (2×10^7 PFU). As a control, one seeded soil sample was kept in the laboratory while the other four seeded soil samples were placed in the 10C plot in Field No. 246 two days before burning (two samples on the ridge and two samples in the trough of the irrigation furrow). The field was burned on 16 October 1978 using a slow, controlled, back burning method, rather than the rapid burning method, because of the overhead electrical transmission lines. The soil samples were immediately recovered from the field after the cane was burned and returned to the laboratory for virus assay. Viruses were recovered from all soil samples, including the control sample, and the results were similar to those obtained for Phase I. Neither the dehydration nor the soil temperatures from the burning of cane can be relied upon to sterilize the soil.

The detection of human enteric viruses in treated sewage effluent to be used for irrigation demonstrates that all viral pathogens were not removed or destroyed in the sewage treatment process. Thus, one is confronted with assessing the health risk of using this effluent for irrigation. At least three obvious problems should be considered in the assessment process. First, there is no simple method, such as coliform monitoring, that can reliably indicate the presence or absence of viruses in the effluent. The methods used to detect the presence of viruses in the effluent are complicated, expensive, time consuming, and of relatively low efficiency. Second, there are approximately 100 different types of human enteric viruses, some of which are more pathogenic than others and some, such as hepatitis viruses, which cannot be easily assayed. It should also be noted that use of the live oral poliovirus vaccine to immunize the population ensures that these artificially administered and "safe" vaccine viruses will be also found in the sewage. Third, there have not been any definitive studies or standards established to determine that a certain level of virus in the water represents a certain risk factor.

One is thus left to make decisions based on prudence. The use of treated sewage effluent to irrigate fresh vegetables, such as lettuce which would be normally eaten uncooked, would not be considered a prudent practice. On the other hand, the irrigation of sugarcane by treated sewage effluent constitutes prudent practice based on the following evidence: (1) viruses are not transmitted by physical contact but must be ingested before they can infect a person; thus, viruses in soils that have undergone dessication are generally inactivated and when stirred up into clouds of dust during sugarcane harvest will not represent an ingestion hazard to humans; (2) few people are directly involved in the handling of the sewage effluent in the irrigation of sugarcane, and simple precautionary measures (sanitation and personal hygiene) for field workers should minimize the risk of contracting infection; (3) viruses have been determined to be inactivated in the soils and are adversely affected by environmental conditions, including direct sunlight, high temperature, and dessication; (4) sugarcane fields are generally located away from population centers and the crop is allowed to dry during the last 2 to 3 mo before it is harvested; (5) harvesting of the sugarcane initially involves burning the entire sugarcane field which aids, but cannot be relied upon, in decontaminating the field; (6) it is the cane juice which is extracted from the plant and processed by heat and pressure into sugar crystals, a process which virtually assures the absence of any viruses associated with irrigation water in the final crystallized sugar; and (7) the absence of viruses in the soil percolates sampled over a 2-yr period plus other virus studies conducted during Phase I, all suggest strongly that the possibility of viruses percolating through the soil and contaminating deep, underground water sources is extremely remote or nonexistent.

Cane and Sugar Yields

The crop log analyses (App. Table D.11) indicated adequate leaf N levels of 1.5 to 2.0% for all treatments, while the K-H_2O index varied from 0.4 to 0.5. No significant differences were observed among treatments. The K-H_2O values are lower than the generally recommended levels of greater than 0.5 (Clements 1980). Leaf water content of 85% was considered adequate, although tensiometer readings (App. Table D.7) indicate brief periods of moisture stress between irrigations.

TABLE 21. EFFECT OF SEWAGE EFFLUENT ON AVERAGE CANE YIELD, JUICE QUALITY, AND SUGAR YIELD IN OSC FIELD NO. 246 TEST PLOTS, MILILANI, O'AHU, HAWAI'I

	TREATMENT					
	Ditch Water (%)	Effluent (%)	Duration (yr)	YIELD (TCA)*	JUICE QUALITY (POL)†	SUGAR YIELD (ETSA)‡
A	100.0	----	2	141.6	15.8	18.5
B	87.5	12.5	2	144.1	15.2	18.1
C	75.0	25.0	2	154.6	14.6	18.5
D	50.0	50.0	2	149.9	13.8	16.4
E	0.0 100.0	100.0 0.0	1st 2d	149.4	15.1	18.5

STATISTICAL SIGNIFICANCE SUMMARY OF DIFFERENCES BETWEEN TREATMENTS

TCA

	A	B	C	D	E
A			●		
B			○		
C					
D					
E					

POL

	A	B	C	D	E
A				●	
B				●	
C					
D					●
E					

ETSA

	A	B	C	D	E
A				○	
B					
C				○	
D					○
E					

● Difference significant at 5% probability level.
○ Difference significant at 10% probability level.

*Tons cane per acre.
†Concentration of sucrose (% by weight) in juice.
‡Estimated tons sugar per acre.

Average treatment yields with their statistical significance are shown in Table 21 and the individual plot yields are shown in Figure 3 and Appendix Table D.12. The correlation coefficient between percent effluent and tons cane per acre (TCA) was +0.67. The apparent decrease in TCA, despite the extra N in the D treatment (50% effluent), was unexpected and suggests the results from the C treatment (25%) may be biased and greater than they should be because of uneven Polaris applications.

The correlation coefficient between percent effluent and juice quality (POL) was -0.99, and between percent effluent and estimated tons of sugar per acre (ETSA) was -0.86 for the A through D treatments. The only significant loss in POL and ETSA was for the D treatment where the extra N in the second year maintained very slightly greater leaf N values.

For very high N applications, the amount of available K must be increased if optimum yield is to occur (Clements 1980). Lack of K to balance the higher N applications in the D treatment may have reduced sugar yields although the K-H_2O index was little if any different for these plots.

Sugar yields, under furrow irrigation for effluent concentration up to 25% (≅7 ppm N), equaled the control treatment. Results from Phases I and II-A indicate that further gain in TCA from greater effluent concentration is offset by reduced POL so that ETSA is reduced. Excessive N in the second year or a combination of high N without compensatory increase in K can result in poor juice quality.

The results of Phases I and II-A also indicate that the use of 100% sewage effluent in the first year followed by ditch water the second year is an acceptable treatment in terms of sugar yield. This type of treatment is expected to be comparable to the yield from using commercial fertilizer and ditch water. It should thus decrease the quantity of ditch water and commercial fertilizer required and their associated costs.

CONCLUSIONS

Except for the Na content, the chemical composition of the Mililani domestic sewage effluent, secondarily treated and chlorinated, satisfactorily meets the requirements for irrigation water supplies outlined by the report of the National Technical Advisory Committee on *Water Quality Criteria* (FWPC 1968, pp. 143-75).

WATER BUDGET. Rainfall of 1.31 m (51.62 in.) and 39 rounds of irrigation for all treatments supplied an average total of 5.41 m (212.9 in.) of water for the 2-yr cane cycle. The irrigation was equivalent to an annual average of approximately 2.03 m (80 in.) and would thus require 6×10^{-8} m^3/m^2 (0.006 mgd/acre). Therefore, about 6.8×10^5 m^2 (167 acres) could be irrigated with each 0.04 m^3/s (1 mgd) from the Mililani STP. An estimated amount equivalent to 55% of the irrigation percolated beyond the crop root zone.

NUTRIENT BUDGET. The actual amounts of N and K from fertilizer and effluent exceeded the scheduled amounts since the effluent concentration of N and K was greater than anticipated. The N concentration of the effluent was 61% greater than expected. Since N is an increasingly expensive fertilizer, a critical factor in cane growth and sugar yield, as well as a potential threat to groundwater quality, potential annual variation in the effluent quality poses a significant management problem.

NITRATE LOSS IN PERCOLATE. Although the nitrate content in the percolate greatly exceeded the recommended level (10 mg/ℓ) for potable water immediately after each fertilizer application, the median level in the percolate after the initial effects of fertilization passed would not form a health hazard when only 25% or less effluent was used. However, the use of 50 or 100% effluent had NO_3-N concentrations greater than the critical level during the first year of cane growth.

NITROGEN BUDGET. The total N in the percolate ranged from a calculated low of 0.008 kg/m^2 (69.3 lb/acre) to a high of 0.028 kg/m^2 (254.3 lb/acre). There was an otherwise unexplained N deficit of 0.013 to 0.038 kg/m^2 (115-338.6 lb/acre) for the cycle that has been assigned to gaseous N loss.

VIRUS INACTIVATION. The changeover to a complete-mix activated sludge treatment unit and the reconstruction of the chlorine contact chamber in 1978 decreased the number of positive chlorinated samples with virus from 79 to 48% and decreased the concentration range from 8 to 190 PFU/ℓ to only 1 to 15 PFU/ℓ. Fecal coliform concentrations of some of the samples with virus were 0 to 10 colonies/100 mℓ, thus supporting the contention that low coliform concentrations cannot be used to indicate the absence of virus.

Forty percent of the samples from the field effluent reservoir after 15 to 72 hr of storage were positive, but experiments showed that at least 96% of the virus were removed after 1 day of reservoir storage. Virus in the sediments in the reservoir were inactivated by air drying. No virus was recovered from the plots under effluent irrigation. However, virus applied at 10^9 times the concentrations in the effluent survived beneath the cane canopy in the soil for 77 to as many as 113 days. The preharvest burning of the cane did not destroy these test applications of concentrated virus in the soil.

CROP LOG. Crop log analyses indicated adequate leaf N levels and leaf water contents with no significant differences among the treatments at the final log. Inequalities in the distribution of the ripener Polaris may have biased the sugar yields toward slightly higher values for the 25% effluent mixture, the C treatment.

CROP YIELD. In Phase I the application of sewage effluent for the first year of a 2-yr sugarcane crop increased the sugar yield by about 6% compared with control plots. However, when sewage effluent was applied for the entire 2-yr crop cycle, sugar yield was reduced by about 6% and the cane quality by about 16% even though the total cane yield increased by about 11%. In Phase II-A the correlation coefficient between percent effluent and cane yield (TCA) was +0.66; between percent effluent and juice quality (POL), -0.99; and between percent effluent and sugar (ETSA), -0.86.

There was a significant loss in juice quality and sugar yield for the 50% effluent mixture where the extra N in the second year maintained a slightly greater leaf N value and sugar yield was 0.488 kg/m^2 (2 tons/acre) less than the other treatments. However, sugar yields did not appear to decrease in comparison to the control (plantation practice) plots for sewage effluent concentrations up to 25% or the use of undiluted effluent the first year with only ditch water the second year.

MAJOR RECOMMENDATIONS

1. Chlorinated, secondarily treated, domestic sewage effluent with N concentrations up to approximately 25 mg/ℓ, can be successfully used in furrow irrigation for the entire 2-yr crop cycle of sugarcane if the effluent is diluted with fresh water so that the concentration of effluent is 25% or less.

2. The nutrients in the effluent are a resource which can replace a significant portion of the N-P-K normally supplied by fertilizer application during the first year.

3. The substitution of extended low rates of N application in the effluent for the initial high rates of N fertilizer application can reduce the excessive peak levels of nitrate in the percolate water.

4. Among the parameters of effluent quality whose level must be monitored are N, herbicides and pesticides, heavy metals, and human enteroviruses.

5. Field workers should practice precautionary sanitation and personal hygiene measures against potential pathogenic infection.

6. More effective methods of pathogenic virus inactivation should be sought.

7. Additional study is needed on grassland and sugarcane production with the use of sewage effluent which has become saline from sea- or brackish-water infiltration in the sewage collection system.

8. A study is desirable on cane irrigation with effluent from primary treatment where a high degree of grease, oil, and suspended solids remains.

9. Studies should be made to trace the large N remnant that has been assigned to gaseous N formation.

PRINCIPLES AND GUIDELINES FOR SEWAGE EFFLUENT IRRIGATION IN HAWAI'I

In Hawai'i the concept of waste water recycling for irrigation emerged in recent years as a result of one or a combination of several major factors: (1) as an alternative to ocean disposal, (2) to augment the natural surface and subsurface-water sources for irrigation supply and, thus, afford an alternative in meeting the near- and long-term water needs for all domestic, agricultural, and industrial requirements.

The situations mentioned above represent opportunities as well as possible problems. Incidental to the application of effluent on land is the recharge of the groundwater, which in Hawai'i must be protected from all possible contamination, including that through application of sewage effluent on agricultural lands. Sugarcane as a cash crop and grassland, as in golf course fairways and public park grounds, are presently potential high-volume users of the effluent.

As the concept of water and nutrient recycling is being developed and tested, several interrelated principles have evolved and may serve as guidelines to consider the use of waste water recycling in Hawai'i. As presented here, waste water is limited to domestic and municipal sewage, and excludes agricultural and industrial waste waters.

Effluent Quality Requirements for Irrigation

Chlorinated, secondarily treated, domestic and municipal sewage effluents containing insignificant amounts of toxic chemicals represent a usable water supply for irrigation because of many acceptable and even desirable water quality factors for the crops presently considered in Hawai'i. Nitrogen in the effluent applied to sugarcane during the second year of growth can be undesirable and should be avoided from the standpoint of sugar yield;

however, management techniques, including dilution of the effluent, can improve its acceptability. Generally speaking, a desirable sewage effluent for irrigation is characterized by its nutrient content with concentrations commensurate with the crop requirement, by the low concentration of total dissolved solids (TDS), boron (B), sodium (Na), suspended solids (SS), and grease, and by its acceptability for groundwater and public health protection.

From the standpoint of groundwater quality protection, the effluent should possess low concentrations of chloride and total dissolved solids. This requirement is especially important for sugarcane because chemical fertilizers that are added to supplement nutrients in the effluent to promote initial growth contribute additional leachable salts to the percolating water in the subsurface.

Toxic chemicals, such as heavy metals, and pesticide residues, at this time receive national attention in the context of the safety of drinking water. Domestic sewage without the admixture of industrial waste water should be reasonably free of toxic chemicals but monitoring is a necessary and desirable requirement to insure the quality of the effluent.

Nutrients present in sewage effluent are generally desirable for plant growth. These include the major nutrients, N, P, and K, and micronutrients. Secondarily treated effluent retains a considerable amount of the nutrients present in the raw sewage because secondary treatment processes are not designed to effectively remove nutrients. Sewage effluent, however, does not necessarily contain a proper balance of nutrients for all plants, thus supplementary chemical fertilizers may be required, as is the case for sugarcane. On the other hand, significant additions of N are not desirable after the first 10 to 12 mo of sugarcane growth. It is only through plant yield under field conditions that the ultimate crop response can be determined. Grasslands can generally utilize the sewage nutrients on a year-round basis without chemical fertilizers; however, addition of chemical fertilizers should promote more lush growth.

Nitrogen in its nitrate form, in concentrations exceeding 10 mg/ℓ as N, is undesirable in drinking water for infant health reasons (methemoglobinemia). Plants, like sugarcane, that cannot fully utilize and retain all of the applied N, allow N to escape the root zone and add potentially to the underlying groundwater—a fact that has been demonstrated by this project.

Thus, special management measures are desirable to reduce the quantity of excess N and to restrict its movement out of the root zone and the field.

Boron concentration in the Mililani effluent averaged less than the 0.5-mg/ℓ level which is considered deleterious to sensitive crops.

Sodium in soil water exchanges with Ca in the soil, thereby causing an expansion of the clay structure and physical swelling of the soil and a reduction of the soil permeability. A level of suspended solids can result in a clogging, soil surface deposit. Similarly, grease in irrigation water adversely affects the infiltration capacity of soils, therefore high concentrations of Na, suspended solids, and grease in irrigation water are undesirable. Secondarily treated sewage effluent produced by well-designed and well-operated treatment plants should be free of excesses in suspended solids and grease, but the sodium content of sewage is unaffected in conventional sewage treatment.

Infiltration of brackish or ocean water into sewer pipes in coastal areas, a phenomenon to which many Hawai'i sewerage systems are susceptable when they are constructed below the groundwater table, presents a potential problem in terms of Na, Cl^-, and total dissolved solids. Thus, monitoring these quality parameters is essential.

Consistency in the effluent quality through high performance in the sewage treatment plant operation and maintenance is also essential for successful fertility management. It is especially true for sugarcane which has a prolonged 2-yr growth period in Hawai'i.

Microbiological and public health aspects are extremely significant and therefore require separate attention.

Soils and Plants

Soils that have the desirable physical and chemical properties for selected crops, with other than sewage as irrigation water, should be the starting point in soil selection and management for sewage irrigation. These may include such factors as water holding and drainage properties, soil acidity, and nutrient availability.

Continued applications of sewage effluent may alter or even impair the desirable properties of good agricultural soils. The Na-Ca relation already mentioned is an example. The nutrient content in soils, such as available N, P, and K, will continuously change with crop growth, fertilizer application, leaching, and the soil physicochemical and microbiological environment. However, impairment of the project soil planted with sugarcane and subjected to effluent irrigation for up to 2 yr was not apparent. In this study the data were insufficient to demonstrate a definite trend of changes in the soil chemical properties. Continuous monitoring during successive crops is clearly desirable to determine any long-term effects on the soil.

The adsorptive capacity of a soil has been demonstrated to be the principal factor related to virus removal from the percolating water. The Lahaina (Tropeptic Haplustox) soils which are the project soils and the soils on which most irrigated sugarcane is grown, have an exceptionally high virus adsorption capacity, perhaps because of their high iron-oxide content. The initial sorption capacity and continuous maintenance of this property for a soil subjected to effluent irrigation is absolutely essential for groundwater protection.

The soils at the project site have been shown to be incapable of removing significant amounts of the effluent-applied N without crop or plant cover. Thus, from the standpoint of reducing the transmission of excess N to the groundwater, fallow or bare soil represents an important condition to be considered especially during the rainy season when heavy rainfall results in rapid percolation.

Field preparation for sugarcane and golf-course fairways in Hawai'i commonly requires the use of heavy grading equipment. Relatively watertight or less permeable subsoil conditions that exist in nature or that can be created by land preparation of this type can result in perching of the percolating water and, thus, temporarily retaining or possibly diverting the downward path of the percolating water. Periodic field infiltration measurements are desirable.

The sugarcane variety, H59-3775, that was used in Phases I and II-A was capable of producing acceptable yields of cane, sugar, and juice quality when irrigated with undiluted effluent for the first year, followed by regular ditch water for the second year. These same results also occurred in Phase II-A when the crop was irrigated with 25% secondarily treated sewage effluent (<7 mg/ℓ total N) for the full cane crop cycle. These treatments of supplying nutrients when needed was consistent with plantation practice for obtaining good sugar yield. Application of sewage effluent for the first year of a 2-yr sugarcane crop appears to have no detrimental effect on the cane or sugar production and may be beneficial. Application of 100% sewage effluent for the entire crop cycle appears to benefit cane production, but lowers cane quality and commercial sugar production and is, therefore, undesirable.

Other sugarcane varieties known for their superior cane and juice quality and their tolerance for N should be experimented with to determine their adaptability for effluent irrigation.

With periodic cutting, Bermudagrass [*Cynodon dactylon* (L.) Pers.] is an excellent user of sewage nutrients, including N. It is possible that other plants with similar thickly matted, surface-root systems could equally well utilize sewage nutrients and thus reduce concern for groundwater quality.

Although all crops that are grown in Hawai'i for consumption may be tested for the effects of treated sewage effluent irrigation, psychological and health reasons may well exclude such crops as fresh pineapple and table vegetables that are consumed without cooking.

Irrigation Methods and Quantity and Fertilization for Sugarcane and Grasslands

The rationale for irrigation is to maintain a no moisture-stress condition (moisture above wilting point) for plants. The measurement of moisture by tensiometer is a recommended practice for determining when to irrigate.

However, in the case of irrigation with sewage effluent, an additional no-excess condition is highly desirable to eliminate or at least decrease the possibility of producing surface tailwater, and deep percolation or perched lateral flow in the subsurface.

Storage or bypass measures are necessary during rainy periods when irrigation is unnecessary. Under a no-moisture stress condition and by the furrow irrigation method, a supply of 0.04 m^3/s (1 mgd) is sufficient to irrigate 6.07×10^5 to 8.09×10^5 m^2 (150-200 acres) of sugarcane with the following schedule.

Treatment	Average Frequency	Avg. Qty./ Application (acre-in./ acre	Total Irrigation Water Requirement (acre-in./ acre/2 yr)	(gpd/ acre)	Acres Irrigated (per mgd)
25% diluted sewage effluent	Every 2 wk; irrigation omitted during rainy period	4.2	170	6300	160
Effluent, 12 mo; followed by ditch water		4.2	130	4800	210

NOTE: Acre-in./acre × 0.025 4 = m^3/m^2; gpd/acre × 1.08 × 10^{-11} = $m^3/s/m^2$; mgd × 0.043 81 = m^3/s.

Sprinkler irrigation of grasslands appears to be a satisfactory method for effluent application. Up to 14 385 m^3 (140 acre-in.) of effluent may be applied to each acre of grassland per year or 0.044 m^3/s (1 mgd) may be sufficient to irrigate about 4.05 × 10^5 m^2 (100 acres) of grassland under a no moisture-stress condition.

In effluent irrigation of sugarcane, addition of commercial fertilizers is desirable to give the sugarcane a rapid start. All necessary P may be added at the beginning of the crop cycle and N and K may be totally applied during the first 6 mo; however, nearly all the N could be supplied in with the sewage effluent. It is well known that N is the most critical element under most conditions in influencing cane tonnage and cane and juice quality. However, there is no significant adverse effect to the yield if there is an excess addition of P and K. In this study, a 20-5.8-7.6 (N-P-K) effluent (App. Table D.8) with commercial fertilizers added initially was apparently sufficient fertilization.

It is highly desirable to be able to control or to have available consistent nutrient quality in the effluent. It should also be remembered that heavy-rain periods not only eliminate the necessity of irrigation, but also leach and, thus, negate partially the effluent nutrients added. In addition, storage or bypass measures may be necessary during these heavy-rain periods.

Monitoring Methodology

Monitoring needs, especially at the initiation of a sewage effluent irrigation program, include water quality parameters on a relatively frequent basis, and soil and crop parameters on a relatively infrequent basis.

Water quality monitoring should consist of a schedule of location, frequency, and quality parameters to be assessed. The experience gained from this project helps to narrow down the following essential (E) and desirable (D) schedules.

Monitoring Point	Schedule*	Frequency	Water Quality Parameter Grouping†	Remarks
Sewage treatment plant effluent	E	Weekly Monthly 6 mo	1, 2, 3 4 5, 6	
Leachate at bottom of root zone	D	Monthly	1, 3	Porvic points at selected locations
Groundwater (baseline quality)	E	Start of each growing cycle	2, 3, 5, 6	Upgradient and downgradient from site as feasible
Groundwater (potable)	D	3 mo	2, 3, 5, 6	

*E = Essential; D = Desirable.
†1 = Nitrogen series
2 = Viruses
3 = Chloride, TDS
4 = Na, suspended solids, grease
5 = Toxic chemicals: heavy metals (As, Pb, Cu, Zn, Cd, Hg, Ni, Cr); pesticides (chlordane, dieldrin, DDT, DDD, lindane, pentachlorophenol)
6 = Complete analysis (TDS, total hardness, suspended solids, BOD_5, TOC, N series, total P, Ca, Mg, Na, K, Cl, SO_4, CO_3, HCO_3, SiO_2, B, electrical conductivity, grease, fecal coliform, total coliform).

The analytical methods for water quality parameters should follow either the *Standard Methods* (APHA, AWWA, and WPCF 1976) or EPA specifications. The Water Resources Research Center, University of Hawaii at Manoa, may be consulted for viral analyses.

Soil monitoring should be made before planting and after harvesting each sugarcane crop for (1) the adsorption/desorption capacity of viruses, and (2) selected physical and chemical properties, e.g., pH, N, P, K, Ca, Mg, SiO_2, both for the top few inches of soil and for standard depth of plantation practice.

Sugarcane monitoring should conform to standard industry tests as conducted by the Hawaiian Sugar Planters' Association, such as the periodic crop logs for specific parameters.

Geohydrologic Considerations

A geohydrologic survey is an essential part of the project planning program to ascertain any probable pathway of deep percolation, groundwater occurrence and circulation, ambient water quality, water level, and groundwater recharge and discharges.

For unconfined aquifers which are far more susceptible to contamination from deep percolation than confined aquifers, certain natural formations offer highly desirable protection and should be ascertained in the process of site selection. These include: (1) a minimum 1.5-m (5-ft) thickness of soil of high adsorptive capacity; (2) a minimum depth to water table to be determined on a case-by-case basis, with consideration given to the groundwater quality; and (3) water perching formations, such as clay layers, ash beds, or buried oils if present.

Disinfection of Sewage Effluent and Public Health Aspects

Human enteric viruses were present in all raw sewage samples tested in the project and, although in reduced concentrations, were also present in a significant portion of the secondarily treated effluent samples tested even after final chlorination. Thus, the treated sewage effluent used to irrigate sugarcane and grassland does contain infectious human viruses.

Complete inactivation using a more effective disinfection method than used presently and the improvement of the existing treatment plant operations should be held as the ultimate objectives. More effective disinfection methods should be developed.

There was evidence that the survival of sewage-borne viruses in the field is adversely affected by environmental conditions, including direct sunlight, high temperature, and dessication. Thus, the possible health hazard posed by the presence of viruses in the sewage effluent used to irrigate sugarcane cannot be completely ignored. Fortunately, these viruses are not transmitted by physical contact but must be ingested before they can infect a person. Thus, the following precautionary measures for field workers minimize the risk of contracting infection.

1. Post signs warning unauthorized persons about entering the sewage-irrigated area
2. Thoroughly wash hands which may have come into direct or indirect contact with the effluent
3. Wash daily outer clothing worn when working with effluent.

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APPENDICES

APPENDIX FIGURES

APPENDIX TABLES

APPENDIX A. ALTERNATIVE SEWAGE EFFLUENT DISPOSAL SCHEMES FOR MILILANI STP

The following alternative effluent disposal systems were evaluated for the Mililani STP by the Division of Wastewater Management, Department of Public Works, City and County of Honolulu (1977).

1. SURFACE DISPOSAL BY DEEP WELL INJECTION. This alternative will not be permitted by the Board of Water Supply since the groundwater in this area is the prime source of the area domestic water supply.
2. ADDITION OF TERTIARY TREATMENT FACILITIES AND CONTINUED DISCHARGE INTO KIPAPA-WAIKELE STREAM. The existing National Pollutant Discharge Elimination System (NPDES) permit for the Mililani STP effluent limits the total phosphorus concentration to 0.02 mg/ℓ (99.8% removal efficiency) and total nitrogen to 0.1 mg/ℓ (99^{+}% removal efficiency). The effluent limitations on total phosphorus and total nitrogen are technically not feasible at this time. Added to this are the high construction cost, the high operation and maintenance costs, and the drain of fossil fuel supplies.
3. DIVERSION OF UNTREATED WASTE WATER TO THE HONOULIULI STP. This alternative would consist of 15 240-m (50,000-ft) sewer lines from the Mililani STP to the Honouliuli STP at a cost of $7,700,000. Drawbacks of this alternative are
   a. Most of the funds expended for the present 0.16 m^3/s (3.6 mgd) Mililani STP would be lost.
   b. Capacity of the Honouliuli STP must be increased by 0.33 m^3/s (7.6 mgd) at public expense for the Mililani-Waipio flows.
   c. Increasing capacity at the Mililani STP, on the other hand, has been and will be accomplished at the developer's expense as part of his subdivision costs.
   c. The option of using Mililani effluent for cane irrigation in central O'ahu will be lost.
4. DIRECT DISCHARGE OF MILILANI EFFLUENT INTO THE BARBERS POINT SEWAGE OUTFALL. This alternative would also consist of a 15 240-m (50,000-ft) effluent outfall sewer from the Mililani STP to the Honouliuli STP. This is a viable alternative but is not as cost-effective as the reclamation-reuse alternatives. The present worth of this alternative is $7,532,000 vs. $6,802,000 to $3,663,000 for the four reclamation-reuse subalternatives.
   a. The other major disadvantage is the loss of the effluent for

cane irrigation and its nutrient value

b. This alternative would also have a negative effect on the BWS plan for exchange of water with the plantation.

5. RECLAMATION-REUSE OF MILILANI STP EFFLUENT FOR SUGARCANE IRRIGATION. This is the recommended alternative by all the agencies and institutions affected, including the Department of Health, Department of Public Works, Board of Water Supply, and Oahu Sugar Company. Reclamation-reuse is also a stated goal of the U.S. Environmental Protection Agency. Essentially it represents the "zero discharge" concept of PL 92-500. The four (4) subalternatives include:

   a. Discharging secondary effluent into Waiāhole Ditch without posttreatment (PW—$3,663,000)

   b. Discharging posttreated effluent into Waiāhole Ditch (PW—$4,640,000)

   c. Discharging secondary effluent into the proposed Five-Fingers Reservoir without posttreatment (PW—$5,831,000)

   d. Discharging secondary effluent into the proposed Five-Fingers Reservoir and providing posttreatment there (PW—$6,802,000).

Subalternatives "a" and "c" were acceptable proposals the the DPW prior to the commencement of the Phase II-A studies. The final choice of the subalternatives will be made by mutual agreement between the DPW and OSC.

In 1979, Oahu Sugar Company decided to switch to drip irrigation for all of their fields except for Field No. 215 and adjacent fields located north of Waipahu. Field No. 215 and the adjacent field will continue to be irrigated by the furrow method as a means of managing the plantation's mill wastes. As a result of the plantation's decision, subalternatives 5a and 5c were abandoned.

The present strategy is to construct an effluent disposal line from the Mililani STP to the Waipahu Sewage Pump Station (located adjacent to the municipal golf course) via OSC Field No. 215. The line from Field No. 215 and the pump station can be considered to be a bypass line and will be used whenever OSC is unable to use the effluent due to heavy rainfall, labor disputes, and withdrawal of leased lands. Under this arrangement, OSC is obligated to accept an average of 0.22 m^3/s (5 mgd) and up to 0.53 m^3/s (12 mgd) flow rate.

APPENDIX B. METHODS OF SAMPLE CONCENTRATION FOR VIRAL ASSAY

The five different methods which were adopted or modified for this project are:

1. Polyelectrolyte 60 (PE-60). The batch (Wallis et al. 1971) and sandwich (Wallis and Melnick 1970) techniques of using the synthetic, insoluble PE-60 (Monsanto Co.), which selectively adsorbs viruses from the water medium, were used. The PE-60 was subsequently recovered and the adsorbed viruses were eluted with a small volume of borate buffer (pH 9.0).
2. Polymer Two-Phase. A modification of the polymer two-phase separation method of Shuval et al. (1969) was used. Briefly, sodium dextran sulfate 500, polyethylene glycol 6000 and NaCl were dissolved in the water sample and allowed to separate overnight. The enteroviruses migrate preferentially to the dextran sulfate phase, which comprises only 1:150 of the total volume, resulting in the effective concentration of the viruses.
3. Aluminum Hydroxide [$Al(OH)_3$]. A modification of the Al(OH) methods as described by Wallis and Melnick (1967*b*) was used. Briefly, the performed $Al(OH)_3$ which is added to the water sample, selectively adsorbs viruses from the water medium. The $Al(OH)_3$ is subsequently recovered and the adsorbed viruses eluted with a small volume of borate buffer (ph 9.0).
4. Protamine Sulfate. A modification of the method of England (1972) was used. Briefly, protamine sulfate was added to the water sample to precipitate the viruses from the water medium. The precipitate was then recovered by filtering the entire sample through an AP-20 pad and the precipitate dissolved to recover the viruses by the addition of 1 *M* NaCl.
5. Cellulose Membrane. The method as described by Wallis et al. (1967*a*) was used. Briefly, $MgCl_2$ was added to the water sample, which had been adjusted to pH 5.0 to 5.5, and the entire sample filtered through a 0.45-μ cellulose membrane (Millipore Corp.). Under these conditions the cellulose membrane adsorbs viruses. The adsorbed viruses can then be eluted with a small volume of borate buffer (pH 9.0).

APPENDIX C. BASIC RESPONSIBILITIES OF PHASE II-A WRRC PROJECT AND PARTICIPATING AGENCY STAFFS (as stipulated prior to the initiation of the project)

A. HAWAIIAN SUGAR PLANTERS' ASSOCIATION, Crop Science Department and Kunia Substation (Project Leaders: Robert P. Bosshart and Karl T.S. How, from June 1977)

1. Assist cooperators in designing, installing, and maintaining the experiment; supervise irrigation of sewage effluent test in OSC Field No. 246
2. Collect and analyze soil samples
3. Hand plant "hand-cut" seed in the experimental areas (p. 73, C.3)
4. Grind and analyze crop log samples collected by Oahu Sugar Company personnel
5. Arrange for and assume cost of ripener application
6. Arrange for and assume cost of fertilizer application
7. Arrange for and assume cost of final harvest by Kunia Substation Task Force
8. Run statistical analyses on harvest data
9. Supply cooperators with one copy of all data collected
10. Publish data on cane yield, plant nutrient status, and water use (HSPA Crop Science Department staff member as senior author, WRRC staff member as junior author)

B. WATER RESOURCES RESEARCH CENTER, University of Hawaii (Project Leader: Paul C. Ekern)

1. Assist cooperators in designing, installing, and maintaining the experiment
2. Analyze sewage effluent samples from Mililani STP on a regular basis
3. Install, maintain, and collect data from ceramic-point or other type samplers
4. Conduct virus studies on effluent, as well as on soil samples taken prior to harvest
5. Provide the linings for storage of water and sewage effluent
6. Supply cooperators with one copy of all data collected
7. Publish data on nitrogen and water balance in plants and soil and on environmental effects (WRRC staff members as senior authors,

HSPA Agronomy Department staff member as junior author)

8. Draft final project report within 60 days following harvest

C. OAHU SUGAR COMPANY, LIMITED (Project Leader: Jerry K Wakatsuki)

1. Assist cooperators in designing, installing, and maintaining the experiment; provide land as required for test site and effluent storage
2. Prepare the field for planting, including land leveling and furrow formation
3. Supply hand-cut and hot-water Benlate-treated seedpieces of variety 59-3775; replant all gaps of 1.22 m (2 ft) or greater
4. Supply and assume cost of all commercial fertilizer materials and ripeners
5. Provide and install gated pipes and other specialized in-field irrigation hardware
6. Excavate land to form reservoir for water and effluent storage; install reservoir lining
7. Supply irrigation ditch water to edge of experimental site; assist in design and installation of irrigation system
8. Arrange for and assume cost of irrigators for application of ditch water and sewage effluent according to treatment designations
9. Supply and apply herbicides and assume material and application costs
10. Collect complete crop log samples as scheduled, dry, and send to HSPA (Att.: H. Hagihara) for analysis

D DEPARTMENT OF PUBLIC WORKS and BOARD OF WATER SUPPLY, City and County of Honolulu (Project Leaders: George C. Richardson and Larry Whang)

1. Provide technical assistance, materials, and/or funds; assist in effluent sample collection and analysis
2. Provide chlorinated secondary sewage effluent from Mililani STP to the experimental site in Oahu Sugar Company, Field No. 246, on a daily basis (5-day wk) at discharge rate of $\geqslant 0.008\ m^3/s$ ($\geqslant$125 gpm).

APPENDIX TABLE D.1. APPLICATION OF SEWAGE EFFLUENT/DITCH WATER DILUTIONS FOR IRRIGATION, TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

Test Plot[a]	(acre)		Irrigation Rounds (in./plot): 1 (1976) 10/15-29	2 (1976) 10/21[b]	3 (1976) 11/10	4 (1976) 11/23-24	5 (1976) 12/7-9	6 (1976) 12/22-23	7 (1977) 1/11-12	Trmt. Type	8 (1977) 2/1-2	9 (1977) 2/16-17	10 (1977) 3/7-9	11 (1977) 3/22-25	12 (1977) 4/12-14	13 (1977) 5/3-6	15 (1977) 5/24-26
1	0.0954		2.25[c]	2.25[c]	2.25[c]	2.37	2.28	2.47	3.01	A Ditch Water	3.17	3.17	4.40	4.00	3.8	3.8	3.8
4	0.0931					2.37	2.29	2.29	2.25		2.45	2.77	3.52	4.00	3.8	3.8	4.1
14	0.0968					2.28	2.32	2.24	2.32		2.24	2.67	3.39	4.00	3.8	3.8	3.8
18	0.0926					2.39	2.30	2.27	2.27		2.35	2.79	2.98	4.00	3.8	3.8	3.8
21	0.1029					2.15	2.29	2.25	2.25		2.29	2.51	3.01	4.00	3.8	3.8	3.8
30	0.1003					2.20	2.24	2.24	2.24		2.24	2.57	3.01	4.00	3.8	3.8	3.8
9	0.0923					2.39	2.27	2.23	2.71	B 12.5% Sewage Effluent	3.07	2.80	3.00	4.02	3.8	3.8	3.8
12	0.0918					2.41	2.29	2.25	2.37		3.17	2.81	3.09	3.86	3.8	3.8	3.8
15	0.1026					2.19	2.48	2.26	2.51		2.80	2.87	3.45	3.93	3.8	3.8	3.8
16	0.0900					2.58	2.29	2.25	2.25		3.07	2.87	3.23	3.83	3.8	3.8	3.8
23	0.0950					2.33	2.29	2.25	2.25		2.98	2.72	3.37	3.85	3.8	3.8	3.8
26	0.0932					2.37	2.29	2.25	2.25		3.24	2.77	5.45	3.93	3.8	3.8	3.8
6	0.0945	Ditch Water Only				2.32	2.30	2.30	2.30	C 25% Sewage Effluent	2.81	2.73	3.12	4.17	3.8	3.8	3.8
8	0.0995					2.15	2.29	2.29	2.26		2.63	2.59	3.81	--	3.8	3.8	3.8
10	0.0962					2.30	2.30	2.26	2.34		2.76	2.68	2.87	3.80	3.8	3.8	3.8
17	0.0925					2.43	2.31	2.31	2.27		2.95	2.79	3.30	--	3.8	3.8	3.8
25	0.1009					2.19	2.66	2.26	2.26		2.88	2.56	3.07	3.84	3.8	3.8	3.8
27	0.0958					2.31	2.31	2.27	2.27		3.04	2.69	3.08	--	3.8	3.8	3.8
2	0.0894					2.39	2.39	2.35	2.76	D 50% Sewage Effluent	3.17	2.89	3.30	3.14	3.8	3.8	3.8
7	0.0960					2.30	2.26	2.30	2.22		2.95	2.69	3.07	4.22	3.8	3.8	3.8
11	0.0920					2.40	2.28	2.24	2.28		3.08	2.80	3.20	4.08	3.8	3.8	3.8
19	0.0947					2.33	2.29	2.26	2.29		2.88	2.72	3.03	--	3.8	3.8	3.8
24	0.0944					2.34	2.30	2.26	2.26		3.04	2.73	3.12	--	3.8	3.8	3.8
29	0.0975					2.27	2.30	2.27	2.27		2.95	2.65	3.25	--	3.8	3.8	3.8
3	0.0909					2.43	2.31	2.31	2.27	E 100% Sewage Effluent	3.08	2.84	3.48	4.00	3.8	3.8	5.6
5	0.0935					2.44	2.28	2.26	2.32		2.99	2.76	3.94	4.00	3.8	3.8	3.8
13	0.0947					2.33	2.30	2.26	2.30		2.96	2.73	3.04	4.00	3.8	3.8	3.8
20	0.0966					2.29	2.25	2.25	2.25		2.90	2.67	3.05	4.00	3.8	3.8	3.8
22	0.09[illegible]					2.37	2.29	2.25	2.25		3.00	2.77	3.00	4.00	3.8	3.8	3.8
28	0.10[illegible]5					2.06	2.28	2.28	2.24		2.70	2.49	3.00	4.00	3.8	3.8	3.8

NOTE: Acre × 4 047 = m². in. × 0.025 40 = m.
[a]Refer to Fig. 2.
[b]Irrigation on 21 Oct. 1976 for Plots [illegible]15, and from 5-10 Nov. 1976 for Plots 16-30.
[c]Approximate application.
*Irrigation Rounds 14, 35, and 38 not performed during this period due to heavy rainfall which offset need for supplemental (irrigation) water.

APPENDIX TABLE D.1.—*Continued*

Test Plot[a]	(acre)	Trmt Type	16	17	18	19	20	21	22	23	24	25		26	27	28
			Irrigation Rounds (in./plot) 1977													
			6/7-9	6/21-23	7/13-15	7/25-27	8/10-12	8/23-25	9/7-9	9/14-16	10/3-5	10/19-21		11/2-4	11/21-23	12/20-21
1	0.0954	A	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	5.5
4	0.0931	Ditch Water	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.5
14	0.0968		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.5
18	0.0926		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.7	3.0
21	0.1029		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.8
30	0.1003		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	5.1	3.6
9	0.0923	B	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.7
12	0.0918	12.5% Sewage Effluent	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.8
15	0.1026		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.4
16	0.0900		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.1
23	0.0950		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.3
26	0.0932		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.4
6	0.0945	C	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.3
8	0.0995	25% Sewage Effluent	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.8
10	0.0962		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.2
17	0.0925		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.7
25	0.1009		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.9
27	0.0958		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.1
2	0.0894	D	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		5.2	4.5	5.2
7	0.0960	50% Sewage Effluent	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.5
11	0.0920		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.5
19	0.0947		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.1
24	0.0944		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.9
29	0.0975		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.0
3	0.0909	E	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5	Ditch Water	4.5	4.5	5.5
5	0.0935	100% Sewage Effluent	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	4.5
13	0.0947		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.6
20	0.0966		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.5	3.5
22	0.0933		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	4.7	4.6
28	0.1035		4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5		4.5	5.0	4.8

APPENDIX TABLE D.1.—*Continued*

Test Plot[a]	(acre)	Trmt. Type	Irrigation Rounds (in./plot) 29	30	31	32	33	34	36	37	39	40	41	42
			1978 1/16-19	2/1-3	2/14-16	3/6-8	3/21-23	4/5-7	5/1-3	5/16-18	6/6-8	6/27-29	7/18-20	8/8-11
1	0.0954	A	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
4	0.0931	Ditch Water	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
14	0.0968		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
18	0.0926		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
21	0.1029		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
30	0.1003		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
9	0.0923	B	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
12	0.0918	12.5% Sewage Effluent	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
15	0.1026		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
16	0.0900		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
23	0.0950		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
26	0.0932		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
6	0.0945	C	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
8	0.0995	25% Sewage Effluent	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
10	0.0962		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
17	0.0925		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
25	0.1009		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
27	0.0958		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
2	0.0894	D	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
7	0.0960	50% Sewage Effluent	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
11	0.0920		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
19	0.0947		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
24	0.0944		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
29	0.0975		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
3	0.0909	E	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
5	0.0935	Ditch Water	5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
13	0.0947		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
20	0.0966		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
22	0.0933		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5
28	0.1035		5.0	5.0	5.0	5.0	5.5	5.5	5.5	5.5	5.5	5.0	5.5	5.5

APPENDIX TABLE D.2. TENSIOMETER READINGS, TREATMENT A TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

Date	Plot 4A			Plot 18A			Plot 30A		
	Depth (in.)*								
	12	18	30	12	18	30	12	18	30
	(10^{-2} bar or 10^3 P)								
02/15/77	**	**	**	**	**	**	**	**	36
02/17/77	9	9	12	7	10	16	7	9	15
02/18/77	11	12	13	13	15	17	17	14	18
02/22/77	25	19	20	34	**	32	69	20	24
02/23/77	29	21	21	48	34	37	**	22	26
02/25/77	36	25	24	**	**	**	**	**	29
02/28/77	**	**	**	**	**	**	**	41	36
03/09/77	9	9	10	10	13	16	9	11	17
03/10/77	11	11	13	14	17	21	17	13	19
03/11/77	15	13	14	18	24	27	27	15	21
03/14/77	22	22	21	39	34	**	54	21	26
03/18/77	41	32	30	**	**	**	**	40	36
03/21/77	**	**	**	**	**	**	**	**	54
03/23/77	**	**	**	**	**	**	**	**	**
03/25/77	7	7	8	11	14	**	11	13	18
03/28/77	15	**	**	32	36	58	50	20	24
03/30/77	8	13	15	5	33	46	5	13	24
04/01/77	6	8	15	6	6	10	7	7	10
04/04/77	14	14	14	15	16	20	20	14	21
04/06/77	17	20	20	27	25	34	43	21	25
04/11/77	**	**	**	**	**	**	**	**	**
04/13/77	5	5	6	6	6	12	6	7	14
04/15/77	12	13	12	15	16	22	18	13	19
04/19/77	25	23	23	41	40	42	50	24	28
04/21/77	9	9	11	8	10	**	6	10	**
04/22/77	10	12	12	12	14	18	12	12	20
04/25/77	35	25	28	28	28	36	22	23	23
04/27/77	10	10	11	10	10	14	10	12	17
04/29/77	15	17	17	19	18	20	30	20	23
05/02/77	**	**	**	**	**	**	**	60	40
05/04/77	6	6	6	6	6	12	6	8	14
05/06/77	13	13	13	14	14	16	12	13	20
05/09/77	20	32	26	36	34	36	42	35	29
05/16/77	12	12	13	10	11	12	11	13	19
05/18/77	15	16	16	14	18	15	18	16	21
05/20/77	24	45	32	30	31	34	44	40	31
05/23/77	48	**	38	**	**	**	**	**	**
05/25/77	5	4	6	**	**	**	5	6	11
05/26/77	10	8	11	6	8	10	10	11	16
05/27/77	13	13	14	6	14	12	13	13	16

SOURCE: Hawaiian Sugar Planters' Association, Crop Science Dept.

*in. × 0.025 40 = m.

**Indicates air bubbles in tensiometer.

APPENDIX TABLE D.2.—*Continued*

Date	Plot 4A 12	18	30	Plot 18A 12	18	30	Plot 30A 12	18	30
	Depth (in.)* (10^{-2} bar or 10^{3} P)								
06/01/77	51	**	34	34	34	42	**	40	32
06/03/77	**	**	**	**	**	**	**	**	**
06/06/77	**	**	**	**	**	**	**	**	**
06/08/77	5	4	7	6	7	12	6	7	14
06/09/77	8	8	9	6	10	12	9	10	17
06/13/77	27	23	23	30	34	48	35	24	26
06/15/77	49	53	47	**	**	**	62	53	40
06/17/77	**	**	**	**	**	**	**	**	**
06/20/77	**	**	**	**	**	**	**	**	**
06/22/77	9	9	9	8	11	**	10	10	15
06/24/77	15	15	15	15	18	28	15	15	20
06/27/77	34	28	26	33	44	**	59	31	30
06/29/77	6	6	10	6	6	12	5	7	12
07/01/77	14	15	15	12	13	18	14	12	19
07/06/77	53	45	39	0	47	57	20	29	32
07/08/77	**	**	**	**	**	**	**	**	**
07/11/77	**	**	**	**	**	**	**	**	**
07/13/77	**	**	**	**	**	**	**	**	**
07/15/77	7	6	7	10	9	14	11	11	17
07/18/77	18	18	17	20	20	24	44	20	23
07/20/77	30	25	22	33	36	48	**	32	30
07/22/77	56	46	34	**	**	**	**	**	41
07/25/77	**	**	**	**	**	**	**	**	**
07/27/77	5	5	6	6	11	15	6	6	14
07/29/77	14	14	13	13	13	18	11	11	18
08/01/77	29	25	23	28	27	38	58	24	26
08/03/77	**	42	32	**	**	**	**	43	34
08/05/77	**	**	**	7	8	**	10	11	17
08/08/77	16	16	15	20	23	36	51	22	23
08/10/77	30	25	22	38	**	**	**	45	34
08/12/77	58	44	33	**	**	**	**	**	**
08/15/77	13	12	12	12	12	17	15	13	19
08/17/77	20	19	18	18	18	22	30	18	22
08/19/77	32	27	24	28	31	40	**	30	28
08/22/77	**	**	48	**	82	**	**	**	53
08/24/77	11	8	10	9	12	12	10	10	15
08/26/77	12	12	11	11	12	12	14	13	19
08/29/77	39	48	37	36	57	**	**	46	35
08/31/77	48	35	30	41	43	43	**	46	35
09/02/77	**	56	39	**	**	**	**	**	46
09/07/77	**	**	**	**	**	**	**	**	**

SOURCE: Hawaiian Sugar Planters' Association, Crop Science Dept.
*in. × 0.025 40 = m.
**Indicates air bubbles in tensiometer.

APPENDIX TABLE D.2.—*Continued*

Date	Plot 4A			Plot 18A			Plot 30A		
	Depth (in.)*								
	12	18	30	12	18	30	12	18	30
	(10^{-2} bar or 10^{3} P)								
09/09/77	8	6	6	6	7	11	7	8	15
09/12/77	30	18	17	20	22	27	33	20	23
09/14/77	4	2	4	2	4	11	3	6	10
09/16/77	11	11	10	10	9	12	11	11	17
09/19/77	22	20	18	19	18	22	**	22	25
09/21/77	52	58	50	38	**	47	**	**	42
09/23/77	**	47	38	49	**	56	**	**	42
09/26/77	**	**	**	**	**	**	**	**	**
09/28/77	**	**	**	**	**	**	**	**	**
09/30/77	**	**	**	**	**	**	**	**	**
10/03/77	**	**	**	**	**	**	6	7	15
10/05/77	12	10	11	9	11	15	11	11	18
10/07/77	18	17	17	17	20	26	27	19	22
10/10/77	34	28	26	34	45	**	**	33	30
10/12/77	49	38	32	48	**	**	**	47	35
10/14/77	**	**	42	**	**	**	**	**	43
10/17/77	**	**	**	**	**	**	**	**	**
10/19/77	**	**	**	**	**	**	**	**	**
10/21/77	12	12	12	12	14	17	12	12	18
10/24/77	18	19	18	18	21	26	27	19	23
10/26/77	23	24	22	23	27	31	42	22	26
10/28/77	40	35	28	36	49	48	**	38	32
10/31/77	**	**	45	**	**	**	**	**	43
11/02/77	**	**	**	**	**	**	**	**	**
11/04/77	9	7	8	7	8	9	7	8	16
11/07/77	16	16	16	15	15	20	18	16	22
11/09/77	22	22	21	21	28	26	40	22	26
11/11/77	33	30	27	31	46	40	**	32	30
11/14/77	55	59	41	**	**	**	**	**	40
11/16/77	**	**	50	**	**	**	**	**	48
11/18/77	**	**	59	**	**	**	**	**	53
11/21/77	**	**	**	**	**	**	**	**	66
11/23/77	6	5	6	6	7	10	7	9	16
11/28/77	18	19	18	18	19	22	26	19	24
11/30/77	24	25	24	24	27	30	49	25	27
12/02/77	32	31	28	31	34	36	**	30	30
12/05/77	11	19	18	7	8	11	8	10	18
12/07/77	13	22	20	5	7	15	9	12	21
12/09/77	15	25	24	10	12	17	13	17	23
12/12/77	19	30	26	13	17	22	25	23	27
12/14/77	28	38	30	18	25	30	55	32	32

SOURCE: Hawaiian Sugar Planters' Association, Crop Science Dept.
*in. × 0.025 40 = m.
**Indicates air bubbles in tensiometer.

APPENDIX TABLE D.2.—*Continued*

Date	Plot 4A			Plot 18A			Plot 30A		
	Depth (in.)*								
	12	18	30	12	18	30	12	18	30
	(10^{-2} bar or 10^3 P)								
12/16/77	41	46	36	25	37	42	**	43	36
12/19/77	12	20	28	24	44	44	**	47	34
12/21/77	4	4	4	3	3	0	2	6	12
12/23/77	10	10	10	8	9	11	10	10	14
12/28/77	19	20	19	19	20	22	32	20	24
12/30/77	24	24	23	22	25	27	52	24	26
01/04/78	20	20	27	20	36	33	**	32	32
01/06/78	30	37	31	30	40	44	**	41	34
01/09/78	49	49	39	47	59	55	**	58	40
01/11/78	**	**	44	**	**	**	**	**	45
01/13/78	**	**	52	**	**	**	**	**	52
01/16/78	**	**	**	**	**	**	**	**	57
01/18/78	7	6	7	**	**	**	5	17	16
01/20/78	12	12	12	6	6	10	12	12	20
01/23/78	20	20	19	12	12	12	19	18	24
01/25/78	23	23	22	17	16	19	41	22	26
01/27/78	31	29	27	22	20	23	66	27	29
01/30/78	48	40	34	36	30	30	**	40	34
02/01/78	58	50	38	48	38	38	0	0	0
02/03/78	7	6	7	6	7	8	9	10	16
02/06/78	14	14	14	14	14	12	18	15	21
02/08/78	18	18	18	20	18	20	34	20	24
02/10/78	25	23	22	28	22	26	64	24	28
02/13/78	40	32	28	44	33	34	**	35	33
02/15/78	5	4	5	**	45	42	5	6	12
02/17/78	10	10	10	3	4	1	11	11	18
02/22/78	21	21	20	16	16	16	40	20	26
02/24/78	27	25	23	20	19	22	57	24	28
02/27/78	48	37	31	30	35	32	**	38	34
03/03/78	15	37	33	15	34	38	**	39	38
03/06/78	29	43	39	30	46	46	**	58	43
03/08/78	8	7	7	3	3	0	7	7	16
03/10/78	13	13	12	8	9	13	13	12	19
03/13/78	20	19	19	16	16	20	29	28	24
03/15/78	29	24	22	24	22	22	62	31	27
03/17/78	13	26	24	10	24	26	65	29	29
03/20/78	24	31	28	19	29	31	**	37	34
03/22/78	39	38	33	29	39	39	**	52	38
03/27/78	10	12	13	8	10	14	10	12	20
03/29/78	14	15	15	11	14	15	16	16	22
03/31/78	19	19	19	16	19	16	30	20	25

SOURCE: Hawaiian Sugar Planters' Association, Crop Science Dept.
*in. × 0.025 40 = m.
**Indicates air bubbles in tensiometer.

APPENDIX TABLE D.2.—*Continued*

Date	Plot 4A 12	Plot 4A 18	Plot 4A 30	Plot 18A 12	Plot 18A 18	Plot 18A 30	Plot 30A 12	Plot 30A 18	Plot 30A 30
	Depth (in.)* (10^{-2} bar or 10^3 P)								
04/03/78	34	26	24	29	31	32	**	31	30
04/05/78	52	35	30	45	50	43	**	44	35
04/07/78	7	6	7	5	5	8	5	5	14
04/10/78	11	12	12	9	11	15	10	12	19
04/12/78	10	11	14	9	11	15	11	12	20
04/14/78	12	14	17	9	12	16	16	16	22
04/17/78	5	5	12	3	7	16	5	10	20
04/19/78	12	11	13	10	12	12	12	15	21
04/21/78	5	3	6	2	3	4	5	5	12
04/24/78	13	10	12	9	10	12	12	12	9
04/26/78	18	15	16	14	15	15	21	17	22
04/28/78	24	18	19	19	20	16	31	20	25
05/01/78	**	26	25	33	34	33	**	30	30
05/03/78	8	5	7	5	6	8	5	7	12
05/05/78	8	7	11	7	9	12	6	8	16
05/08/78	15	13	15	12	15	12	14	14	22
05/10/78	23	18	18	18	20	22	25	19	24
05/12/78	32	22	22	25	27	28	39	22	26
05/15/78	49	28	27	40	38	36	**	29	31
05/17/78	63	35	32	55	56	46	**	37	35
05/19/78	5	5	5	6	7	10	4	7	12
05/22/78	7	4	9	3	5	10	6	7	14
05/24/78	6	2	6	3	4	5	5	6	14
05/26/78	11	7	11	6	8	8	9	10	17
05/31/78	18	15	18	16	18	19	23	18	24
06/02/78	23	20	21	20	23	25	36	22	26
06/05/78	17	25	26	31	32	32	64	28	31
06/07/78	7	2	7	2	3	7	6	7	14
06/09/78	12	8	11	7	10	12	10	10	18
06/14/78	27	19	20	21	22	23	32	20	25
06/16/78	37	24	24	29	30	29	48	22	28
06/19/78	58	33	32	50	50	44	**	33	33
06/21/78	**	43	38	**	**	52	**	40	37
06/23/78	**	50	44	**	**	57	**	48	42
06/26/78	**	**	54	**	**	**	**	**	51
06/28/78	7	0	6	0	32	56	7	7	14
06/30/78	8	4	8	5	7	12	8	9	18
07/03/78	17	11	16	14	15	18	17	15	21
07/05/78	22	15	19	20	20	20	26	19	23
07/07/78	32	21	23	30	28	28	43	23	27
07/10/78	**	31	31	**	**	43	**	32	33

SOURCE: Hawaiian Sugar Planters' Association, Crop Science Dept.
*in. × 0.025 40 = m.
**Indicates air bubbles in tensiometer.

APPENDIX TABLE D.2.—*Continued*

Date	Plot 4A			Plot 18A			Plot 30A		
	Depth (in.)*								
	12	18	30	12	18	30	12	18	30
	(10^{-2} bar or 10^3 P)								
07/12/78	**	43	38	**	**	**	**	45	39
07/14/78	**	**	**	**	**	**	**	**	**
07/17/78	**	**	**	**	**	**	**	**	**
07/19/78	7	5	7	3	4	10	9	9	17
07/21/78	12	7	11	9	11	12	14	14	20
07/24/78	20	14	17	18	20	22	29	21	26
07/26/78	25	17	21	26	26	26	43	25	30
07/28/78	35	22	24	40	36	36	**	32	35
07/31/78	55	32	32	**	**	52	**	54	45
08/02/78	**	37	36	**	**	**	**	**	51
08/04/78	**	50	45	**	**	**	**	**	**
08/07/78	**	**	**	**	**	**	**	**	**
08/09/78	3	1	5	**	**	**	6	6	13
08/11/78	10	5	10	6	8	10	11	12	18
08/14/78	18	12	17	16	18	17	22	18	24
08/16/78	26	17	20	27	27	24	36	22	28
08/18/78	35	22	24	40	36	27	56	23	31
08/21/78	56	33	33	**	**	36	**	38	39
08/23/78	**	37	36	**	**	33	**	43	42
08/25/78	**	44	41	**	**	23	**	54	47
08/28/78	**	**	**	**	**	25	**	**	57
08/30/78	**	**	**	**	**	20	**	**	**

SOURCE: Hawaiian Sugar Planters' Association, Crop Science Dept.
*in. × 0.025 40 = m.
**Indicates air bubbles in tensiometer.

APPENDIX TABLE D.3. COMMERCIAL CHEMICAL FERTILIZER APPLICATION ON OSC FIELD NO. 246 TEST PLOTS, O'AHU, HAWAI'I

Trmt.	Fertilizer Constituent	Application					
		10/14/76	01/07/77	02/15/77	04/29/77	06/13/77	Total[1]
		(lb/acre)[2]					
A	N^3	80	80	100	70	50	380
	P^4	105	--	--	--	--	105
	K^5	100	124	133	100	--	457
B	N^3	80	80	100	70	--	330
	P^4	105	--	--	--	--	105
	K^5	100	124	133	75	--	432
C	N^3	80	80	80	50	--	290
	P^4	105	--	--	--	--	105
	K^5	100	124	133	54	--	411
D	N^3	80	70	60	--	--	210
	P^4	105	--	--	--	--	105
	K^5	100	108	108	50	--	366
E	N^3	80	50	--	--	--	130
	P^4	105	--	--	--	--	105
	K^5	100	83	75	50	--	308

SOURCE: Hawaiian Sugar Planters' Association, Crop Science Department.
NOTE: All fertilizer applied by hand.
[1]Commercial fertilizer complete for present sugarcane crop.
[2]lb/acre × 0.000 112 = kg/m^2.
[3]As urea, $CO(NH_2)_2$.
[4]As treble superphosphate, primarily monocalcium phosphate $Ca(H_2PO_4)_2 \cdot H_2O$.
[5]As muriate of potash, KCl.

APPENDIX TABLE D.4. LAHAINA SOIL ANALYSIS OF SURFACE FOOT AFTER HARVESTING (1978) AND AFTER PLANTING (1976),* OSC FIELD NO. 246 TEST PLOTS, O'AHU, HAWAI'I

Trmt.	Test Plot (No.)	pH	P	K	Ca	Mg	Si	Na	N Available	N Mineralizable
			(lb/acre-ft)†							
A	1	6.3	100	750	----	---	---	---	39	76
		(6.3)	(175)	(730)	(5300)	(765)	(240)	(120)	(72)	(59)
	4	6.0	160	595	----	---	---	---	47	72
		(6.0)	(145)	(530)	(4300)	(800)	(200)	(125)	(70)	(47)
	14	5.6	78	470	----	---	---	---	51	73
		(5.6)	(130)	(545)	(3000)	(675)	(145)	(115)	(91)	(44)
	18	6.0	85	295	----	---	---	---	59	76
		(5.6)	(270)	(575)	(3300)	(750)	(165)	(130)	(86)	(57)
	21	5.9	110	505	----	---	---	---	39	76
		(5.6)	(165)	(645)	(2950)	(625)	(150)	(170)	(83)	(54)
	30	6.5	140	850	----	---	---	---	59	77
		(6.4)	(155)	(740)	(5050)	(765)	(270)	(145)	(91)	(56)
	Avg.	*6.1*	*112*	*578*	----	---	---	---	*49*	*75*
		(5.9)	*(175)*	*(630)*	*(4000)*	*(730)*	*(195)*	*(135)*	*(82)*	*(53)*
B	9	5.7	140	545	----	---	---	---	51	77
		(5.7)	(91)	(515)	(3650)	(700)	(205)	(255)	(74)	(39)
	12	5.6	94	590	----	---	---	---	39	82
		(5.6)	(120)	(570)	(3150)	(775)	(155)	(165)	(58)	(35)
	15	5.7	165	505	----	---	---	---	39	94
		(5.5)	(155)	(605)	(2800)	(640)	(130)	(170)	(81)	(44)
	16	5.8	255	400	----	---	---	---	51	84
		(5.8)	(175)	(505)	(4000)	(765)	(180)	(180)	(77)	(41)
	23	6.1	140	405	----	---	---	---	51	84
		(6.0)	(150)	(380)	(3950)	(750)	(195)	(175)	(102)	(45)
	26	5.6	165	540	----	---	---	---	59	82
		(5.6)	(175)	(440)	(3300)	(625)	(170)	(155)	(81)	(43)
	Avg.	*5.8*	*160*	*498*	----	---	---	---	*48*	*84*
		(5.7)	*(160)*	*(505)*	*(3500)*	*(710)*	*(175)*	*(185)*	*(79)*	*(41)*

SOURCE: Analysis by Hawaiian Sugar Planters' Association, Crop Science Department, Honolulu, Hawai'i.

NOTE: Soil Analysis Methods: P, Si (HSPA sodium bicarbonate method); K, Ca, Na, Mg (standard method by 1 *N*; available N (standard method by 0.5 *N*; mineralizable N(standard HSPA method by incubation and potassium sulphate extraction.

*Sampling dates: After harvesting 17 October 1978; after planting, 21 October 1976 (in parentheses).

†Lb/acre-ft × 0.000 368 = kg/m^3.

APPENDIX TABLE D.4.—*Continued*

Trmt.	Test Plot (No.)		P	K	Ca	Mg	Si	Na	N Avail-able	N Mineral-izable
			(lb/acre-ft)†							
C	6	5.7	130	630	----	---	---	---	39	86
		(5.6)	(195)	(445)	(3100)	(690)	(140)	(155)	(58)	(48)
	8	5.7	155	620	----	---	---	---	47	84
		(5.6)	(195)	(580)	(3100	(690)	(155)	(180)	(81)	(51)
	10	5.7	97	570	----	---	---	---	51	77
		(5.6)	(225)	(340)	(3550)	(765)	(145)	(180)	(78)	(47)
	17	5.9	180	505	----	---	---	---	39	72
		(6.0)	(180)	(345)	(4250)	(790)	(180)	(215)	(61)	(43)
	25	5.8	120	475	----	---	---	---	39	64
		(5.7)	(230)	(455)	(3250)	(765)	(160)	(190)	(53)	(44)
	27	5.8	105	275	----	---	---	---	47	76
		(5.7)	(150)	(325)	(3350)	(725)	(155)	(160)	(53)	(50)
	Avg.	*5.8*	*131*	*513*	----	---	---	---	*44*	*77*
		(5.7)	*(195)*	*(415)*	*(3450)*	*(740)*	*(155)*	*(200)*	*(65)*	*(47)*
D	2	5.9	290	395	----	---	---	---	50	85
		(6.0)	(240)	(495)	(4300)	(740)	(180)	(175)	(46)	(65)
	7	5.8	175	365	----	---	---	---	43	78
		(5.6)	(180)	(495)	(3400)	(690)	(150)	(190)	(69)	(46)
	11	6.0	130	275	----	---	---	---	38	81
		(5.8)	(240)	(400)	(3900)	(850)	(160)	(280)	(72)	(57)
	19	5.9	105	250	----	---	---	---	38	83
		(5.8)	(170)	(320)	(3450)	(725)	(155)	(220)	(91)	(45)
	24	5.7	195	350	----	---	---	---	43	78
		(5.7)	(215)	(305)	(3650)	(665)	(155)	(215)	(67)	(41)
	29	6.4	180	465	----	---	---	---	46	72
		(6.3)	(195)	(465)	(5150)	(740)	(245)	(180)	(63)	(44)
	Avg.	*6.0*	*179*	*350*	----	---	---	---	*43*	*80*
		(5.8)	*(200)*	*(420)*	*(3850)*	*(710)*	*(170)*	*(190)*	*(66)*	*(48)*
D	3	6.1	200	455	----	---	---	---	46	88
		(5.9)	(200)	(705)	(4000)	(765)	(170)	(155)	(47)	(55)
	5	5.9	170	505	----	---	---	---	31	78
		(5.7)	(215)	(545)	(3950)	(825)	(160)	(155)	(56)	(59)
	13	5.8	120	445	----	---	---	---	31	78
		(5.3)	(245)	(445)	(2700)	(690)	(130)	(145)	(83)	(45)
	20	5.7	130	625	----	---	---	---	31	70
		(5.7)	(145)	(425)	(3300)	(725)	(150)	(130)	(61)	(46)
	22	6.5	170	620	----	---	---	---	31	63
		(6.0)	(220)	(415)	(4750)	(725)	(205)	(125)	(47)	(50)
	28	6.0	180	465	----	---	---	---	38	72
		(5.9)	(195)	(525)	(3900)	(765)	(180)	(155)	(75)	(61)
	Avg.	*6.0*	*162*	*519*	----	---	---	---	*35*	*75*
		(5.8)	*(205)*	*(510)*	*(3770)*	*(750)*	*(165)*	*(145)*	*(62)*	*(53)*

APPENDIX TABLE D.5. MILILANI STP SEWAGE ANALYSES

	DATE	pH	TDS	COND. 25°C (µmhos /cm)	TOTAL HARD-NESS	SS	BOD_5	TOC	NITROGEN Kjel-dahl	NITROGEN NO_2+ NO_3	NITROGEN Total	PO_4 -P	Ca	Mg	Na	K	Cl	SO_4	SiO_2	B	GREASE	COLIFORM Fecal	COLIFORM Total
			(mg/ℓ)		----------	----------	----------	----------	----------	----------	----------	----------	(mg/ℓ)	----------	----------	----------	----------	----------	----------	----------	----------	(No./100 mℓ)	
Raw Sewage	07/07/77	7.8	327	390	50.5	259	334	120	30.8	0.02	30.8	7.5	12.0	5.0	45.0	7.5	50.0	32	72.0	0.51	60.5	------	------
	07/14/77	7.5	327	700	57.7	203	196	97	30.6	0.02	30.6	11.9	12.4	6.5	48.0	8.8	52.0	39	76.0	----	----	------	------
	01/10/78	7.1	---	510	106.3	583	499	182	35.3	----	----	----	30.8	7.2	39.9	0.2	42.0	70	78.9	0.63	----	3.8×10^6	4.9×10^6
	07/11/78	7.2	265	620	----	378	120	112	55.4	----	----	----	----	---	----	---	42.5	--	78.9	0.89	173.9	16	8.0×10^4
	08/02/78	7.0	489	650	----	185	163	141	47.2	0.20	47.4	8.2	----	---	----	---	42.5	--	77.4	----	9.9	------	8.4×10^5
	08/07/78	7.5	767	600	----	133	203	163	51.0	0.20	51.2	----	----	---	----	---	42.0	30	84.7	----	33.7	3.0×10^6	3.7×10^6
Primary Sewage	07/11/78	7.1	309	600	----	57	120	78	51.0	----	----	----	----	---	----	---	41.5	--	----	0.21	13.0	26	3.2×10^4
	08/02/78	6.7	335	600	----	71	147	89	39.4	0.13	39.5	4.2	----	---	----	---	41.5	--	74.7	----	4.0	------	3.3×10^5
	08/07/78	7.2	376	590	----	70	160	85	53.4	0.29	53.7	----	----	---	----	---	41.0	27	81.6	----	35.3	------	3.0×10^4
Secondary Sewage	06/09/77	7.2	---	530	----	---	---	---	----	----	----	----	----	---	----	---	----	--	70.0	----	----	------	------
	07/07/77	7.1	323	430	60.3	61	42	40	25.5	0.60	26.1	8.2	16.4	4.7	56.0	11.9	43.0	34	74.0	0.42	12.8	2	2
	07/14/77	7.0	338	460	57.1	28	19	38	21.4	2.90	24.3	12.2	12.0	6.6	48.0	10.1	43.0	35	74.0	----	5.4	4	4
	08/10/77	7.1	---	600	----	---	---	---	31.5	0.38	31.9	6.9	21.7	6.6	40.2	13.2	44.0	--	75.3	----	----	------	------
	09/07/77	7.9	---	595	----	---	---	---	36.9	0.10	37.0	7.9	27.6	7.2	47.4	9.6	50.5	--	73.2	----	----	------	------
	09/16/77	7.9	---	600	----	---	---	---	30.5	0.36	30.9	6.6	26.3	4.0	46.8	14.4	47.0	--	68.0	----	----	------	------
	10/05/77	7.5	---	550	----	---	---	---	25.2	0.84	26.0	5.3	27.9	6.2	40.2	8.2	49.5	--	63.8	----	----	------	------
	10/21/77	7.3	---	485	----	---	---	---	24.64	1.82	26.5	---	24.5	8.2	45.0	10.8	48.0	--	69.2	----	----	------	------
	11/02/77	6.8	---	450	----	---	---	---	22.2	1.88	24.1	---	22.7	5.8	40.2	9.6	44.0	--	----	----	----	------	------
	11/21/77	7.5	---	470	----	---	---	---	20.2	0.53	20.7	---	25.4	6.6	38.4	8.6	46.0	--	77.2	----	----	------	------
	12/21/78	6.8	---	500	----	---	---	---	21.21	3.81	25.1	---	24.5	6.7	43.2	9.6	45.5	--	73.7	----	----	------	------
	01/10/78	7.2	---	420	87.8	54	31	40	23.9	4.00	27.9	---	24.5	6.5	38.7	0.2	49.0	25	73.7	0.29	----	<1	90
	01/18/78	7.5	---	500	----	---	---	---	22.4	3.11	25.5	---	24.5	6.2	37.2	8.4	51.5	--	73.8	----	----	------	------
	02/01/78	7.2	---	500	----	---	---	---	23.25	1.13	24.4	---	29.0	6.7	40.8	10.2	52.5	--	76.4	----	----	------	------
	02/14/78	6.4	---	470	----	---	---	---	12.32	6.26	18.6	---	27.2	6.3	38.7	8.4	67.5	--	79.0	----	----	------	------
	03/08/78	6.8	---	520	----	---	---	---	15.40	3.66	19.1	---	22.7	6.1	40.8	10.8	60.0	--	76.3	----	----	------	------
	03/21/78	7.1	---	445	----	---	---	---	27.2	2.68	29.9	---	23.6	6.3	40.5	9.0	49.0	--	76.3	----	----	------	------
	04/05/78	7.1	---	410	----	---	---	---	22.4	0.22	22.6	---	26.3	6.1	39.0	6.6	45.0	--	73.6	----	----	------	------
	05/03/78	7.4	---	400	----	---	---	---	24.1	0.58	24.7	---	19.0	5.8	36.9	9.6	41.0	--	70.7	----	----	------	------
	06/07/78	7.0	---	470	----	---	---	---	28.7	0.01	28.7	---	26.3	6.2	42.0	9.6	46.5	--	73.3	----	----	------	------
	07/11/78	7.1	---	460	----	---	---	---	21.8	0.00	21.8	---	26.7	6.2	40.8	8.4	49.5	--	78.5	----	----	------	------
	07/11/78	6.9	388	500	----	44	48	40	27.03	----	----	---	----	---	----	---	51.5	--	----	0.44	12.8	0	0
	08/02/78	6.9	307	480	----	17	74	38	24.36	2.55	26.9	6.0	----	---	----	---	51.6	--	75.6	----	2.1	------	89
	08/07/78	7.0	345	490	----	43	88	42	21.56	0.33	21.9	---	----	---	----	---	51.0	28	82.9	----	40.7	------	20
Unchlorinated Secondary Sewage																							
	01/10/78	7.2	---	410	86.9	--	42	---	23.7	----	----	---	24.5	6.3	38.4	0.2	38.0	--	73.7	----	----	------	------

APPENDIX TABLE D.6. MILILANI STP SEWAGE ANALYSIS METHODS FOR TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

TEST	
pH	Corning Model 10 pH meter
Total Dissolved Solids	Reported as difference of total solids and suspended solids
Conductivity	YSI Model 33 S-C-T meter
Total Hardness	Reported as hardness contributed from Ca^{++} and Mg^{++} concentrations expressed as equivalents of $CaCO_3$ (*Standard Methods*, 14th ed., sec. 309 A)
Total Suspended Solids	Residue remaining on GF/C filter after drying at 103°C (*Standard Methods*, 14th ed., sec 208 D)
Total Solids	Residue remaining in crucible after evaporation on water bath followed by drying at 103°C (*Standard Methods*, 14th ed., sec. 208 A)
BOD_5	As per *Standard Methods*, 14th ed., sec. 507
Total Organic Carbon	Dohrmann DC-52 Total Organic Carbon Analyzer
NH_4 and Kjeldahl N	As per *Standard Methods*, 14th ed., sec. 418 418 A with acidimetric titration (sec. 418 D)
NO_3 + NO_2	Technicon AutoAnalyzer II System with Industrial Methodology 32-69W "Nitrate + Nitrate in Water"
Total Phosphorus	As per *Standard Method*, 14th ed.-Persulfate Digestion (sec. 425 C III), followed by Ascorbic Acid colorimetry (sec. 425 F) with Technicon AutoAnalyzer II System
Ca, Mg, Na, K	Perkin-Elmer Atomic Absorption Spectrophometer, Model 305 A-Absorption measured under Standard Conditions as presented in *Analytical Methods for Atomic Absorption Spectrophotometry*, Perkin-Elmer (1971)
Sulfate	Turbidimetric determination as per *Standard Methods*, 14th ed., sec. 427 C
Boron	Carmine colorimetry as per *Standard Methods*, 14th ed., sec 405 B
Oil and Grease	Partition-Gravimetric Method-*Standard Methods*, ed., sec. 502 A
Total Chlorine Residual	Hellige color comparator using Hellige DPD chlorine tablets Nos. 1 and 3
Settleable Solids	As per *Standard Methods*, 14th ed., sec. 208 F
Coliforms	As per *Standard Methods*, 14th ed., sec. 408 B-Mercuric Nitrate titration
Silica	Range, <100 mg/ℓ; Wavelength, 0.7 μm; Molybdate Blue Method, Hitachi, Perkin-Elmer. UV-VIS Spectrophotometer, Coleman 117, Serial No. 43726-24

SOURCE: Water Resources Research Center, University of Hawaii at Manoa.

APPENDIX TABLE D.7. HEAVY METAL CONCENTRATION, MILILANI STP, O'AHU, HAWAI'I

DATE	HEAVY METAL CONCENTRATION (mg/ℓ)																	
	Al		Cd		Cr		Cu		Fe		Pb		Hg		Ni		Zn	
	DETECTION LIMITS																	
	0.1		0.002		0.02		0.01		0.02		0.05		0.0002		0.02		0.005	
	Raw	Effl.	Raw	Effl.	Raw	Effl.	Raw	Effl.	Raw	Effl.	Raw	Effl.	Raw	Effl.	Raw	Effl.	Raw	Effl.
07/14/77	0.50	0.13	0.025	0.016	<0.020	<0.020	0.200	0.040	1.900	0.125	<0.05	<0.05	0.0003	0.0002	0.10	<0.02	3.380	<0.005
11/14/77[1]	0.75	0.25	0.010	0.006	0.342	<0.020	0.750	0.038	0.675	0.225	<0.05	<0.05	0.0007	0.0046	<0.02	<0.02	0.145	0.105
05/05/77	0.38	0.25	<0.002	<0.002	0.035	0.025	0.106	0.070	0.525	0.225	<0.05	<0.05	<0.0002	<0.0002	<0.02	<0.02	0.113	0.053
05/12/77	0.44	0.25	<0.002	<0.002	0.050	0.020	0.094	0.070	0.717	0.200	<0.05	<0.05	<0.0002	<0.0002	<0.02	<0.02	0.113	0.102
08/24/77	0.50	0.25	<0.002	<0.002	0.068	0.050	0.075	0.044	0.459	0.183	<0.05	<0.05	<0.0002	<0.0002	<0.02	<0.02	0.083	0.038
09/30/77	0.25	<0.10	<0.002	<0.002	0.038	0.025	0.100	0.050	0.650	0.155	<0.05	<0.05	<0.0002	0.0010	<0.02	<0.02	0.100	<0.005
12/19/77	3.19	0.12	<0.002	<0.002	0.020	<0.020	0.144	0.025	3.309	0.099	0.05	<0.05	0.0008	<0.0002	0.05	<0.02	0.260	0.260
01/10/78[2]	3.19	0.13	<0.002	<0.002	0.020	<0.020	0.144	0.025	3.308	0.099	0.05	<0.05	0.0008	<0.0002	0.05	<0.02	0.260	0.260
07/11/78	0.38	--	0.013	0.015	0.020	<0.020	0.070	0.040	0.493	0.267	<0.05	<0.05	--	--	0.02	0.03	0.185	0.173

[1]24-hr composite sample.
[2]Effluent sample collected before chlorination.

APPENDIX TABLE D.8. AVERAGE NUTRIENT LOADING APPLIED THROUGH IRRIGATION WITH VARIOUS QUANTITIES OF DITCH WATER AND SEWAGE EFFLUENT, OSC FIELD NO. 246, O'AHU, HAWAI'I

START OF IRRIG.	IRRIG. ROUND NO.	PLOTS: A (100% Ditch Water) Irrig. In.	Dil* %	N	P_2O_5	K_2O	B ($12\frac{1}{2}$% Effl., $87\frac{1}{2}$% Ditch Water) Irrig. In.	Dil.* %	N	P_2O_5	K_2O	C (25% Effl., 75% Ditch Water) Irrig. In.	Dil.* %	N	P_2O_5	K_2O	D (50% Effl., 50% Ditch Water) Irrig. In.	Dil.* %	N	P_2O_5	K_2O	E (100% Effluent) Irrig. In.	Dil.* %	N	P_2O_5	K_2O	DITCH WATER N	P	K	SEWAGE EFFLUENT N	P	K
				lb applied/acre					lb applied/acre					lb applied/acre					lb applied/acre					lb applied/acre			---mg/ℓ---			----mg/ℓ----		
1977																																
02/02	8	2.45	0	0.40	0.90	0.27	3.05	11.2	2.74	1.40	1.00	2.84	36.2	7.22	3.98	2.33	3.01	57.0	11.77	6.58	3.70	2.93	100	19.80	11.19	6.09	0.72	0.07	0.40	29.75	7.34	7.60
02/16	9	2.74	0	0.15	0.04	0.07	2.93	25.9	5.24	3.42	2.09	2.67	34.9	6.37	4.18	2.53	2.74	46.1	8.61	5.66	3.42	2.70	100	18.23	12.05	7.24	0.24	0.03	0.09	29.75	8.58	9.80
03/08	10	3.38	0	0.96	0.18	0.83	3.59	19.9	5.64	3.02	2.83	3.20	23.1	5.68	3.09	2.80	3.22	49.6	11.23	6.50	5.15	3.25	100	21.89	13.03	9.66	1.25	0.10	0.90	29.75	7.73	10.90
03/23	11	4.00	0	1.94	0.17	1.09	3.90	12.8	5.01	2.17	2.19	1.96	20.8	3.51	1.73	1.46	2.07	36.9	5.78	3.17	2.30	4.00	100	26.94	16.29	10.15	2.14	0.08	1.00	29.75	7.85	9.30
04/14	12	3.80	0	0.29	0.10	1.04	3.80	13.6	3.73	2.43	2.45	3.16	26.3	5.79	3.85	3.14	3.80	51.7	13.39	8.98	6.40	3.80	100	25.63	17.30	11.42	0.34	0.05	1.00	29.75	8.76	11.00
05/03	13	3.80	0	0.37	0.10	0.71	3.79	7.3	2.21	1.20	1.38	3.79	22.5	6.05	3.49	2.78	3.80	48.6	12.63	7.43	5.20	3.80	100	25.63	15.20	9.96	0.43	0.05	0.68	29.75	7.70	9.60
05/24	15	3.86	0	0.70	0.10	1.79	3.80	12.4	3.87	2.19	2.94	3.80	25.7	7.25	4.42	4.18	3.80	51.6	13.86	8.48	6.63	4.04	100	27.95	18.04	11.92	0.80	0.05	1.70	30.50	8.59	10.80
06/08	16	4.40	0	0.84	0.11	1.68	4.40	10.4	3.74	2.92	2.97	4.40	24.9	7.51	6.56	4.63	4.40	50.9	14.51	13.31	7.73	4.40	100	27.72	26.06	13.58	0.84	0.05	1.40	27.79	11.40	11.30
06/22	17	4.40	0	0.82	0.07	1.08	4.40	10.8	3.09	2.09	2.41	4.40	26.3	6.38	5.01	4.34	4.40	49.7	11.31	9.40	7.23	4.40	100	21.92	18.83	13.44	0.82	0.03	0.90	22.00	8.25	11.20
07/15	18	4.40	0	0.30	0.16	2.52	4.40	13.6	4.40	2.54	3.88	4.40	26.9	8.40	4.86	5.20	4.40	51.1	15.67	9.09	7.61	4.40	100	30.37	17.62	12.48	0.30	0.07	2.10	30.48	7.72	10.40
07/26	19	4.40	0	0.46	0.09	1.68	4.40	12.7	4.60	2.81	3.25	4.40	26.3	9.04	5.73	4.93	4.40	49.6	16.69	10.76	7.82	4.40	100	33.14	21.57	14.04	0.46	0.04	1.40	33.27	9.45	11.70
08/11	20	4.50	0	1.31	0.09	1.47	4.50	15.1	6.89	3.24	3.30	4.50	27.0	11.34	5.75	4.76	4.50	51.0	20.24	10.77	7.68	4.50	100	38.39	21.01	13.62	1.29	0.04	1.20	37.68	9.00	11.10
08/25	21	4.50	0	0.75	0.07	0.98	4.50	10.9	4.22	2.01	2.33	4.50	24.7	8.62	4.47	4.05	4.50	47.4	15.84	8.52	6.86	4.50	100	32.56	17.88	13.38	0.74	0.03	0.80	31.96	7.66	10.90
09/07	22	4.50	0	0.54	0.09	1.47	4.50	15.2	4.67	2.74	3.07	4.50	30.3	8.78	5.37	4.67	4.50	53.4	15.12	9.42	7.12	4.50	100	27.76	17.51	12.03	0.53	0.04	1.20	27.25	7.50	9.80
09/14	23	4.50	0	0.61	0.05	1.23	4.50	13.8	4.80	2.90	2.95	4.50	28.5	9.27	5.94	4.79	4.50	54.0	17.03	11.21	7.98	4.50	100	31.02	20.73	13.75	0.60	0.02	1.00	30.45	8.88	11.20
10/03	24	4.50	0	0.57	0.16	1.47	4.50	11.5	4.29	2.31	2.83	4.50	25.1	8.66	4.82	4.42	4.50	53.2	17.74	10.06	7.74	4.50	100	32.86	18.77	13.26	0.56	0.07	1.20	32.25	8.04	10.80
10/19	25	4.50	0	0.88	0.07	1.10	4.50	8.5	3.17	1.77	2.22	4.50	14.8	7.74	5.16	4.43	4.50	51.4	15.10	10.62	7.98	4.50	100	28.53	20.59	14.48	0.86	0.03	0.90	28.00	8.82	11.80
11/02	26	4.50	0	0.34	0.19	1.84	4.50	11.9	3.37	2.24	3.20	4.50	26.9	7.22	4.85	4.92	4.61	47.4	12.76	8.61	7.44	4.50	100	25.88	17.51	13.26	0.33	0.08	1.50	25.40	7.50	10.80
11/21	27	4.50	0	0.52	0.10	1.39	4.50	14.0	4.15	3.10	2.84	4.50	29.1	8.08	6.35	4.44	4.50	59.4	15.93	12.84	7.65	4.62	0	0.52	0.10	1.39	0.50	0.04	1.10	26.00	9.24	9.75
12/19	28	4.14	0	3.13	0.24	1.13	3.95	14.0	5.56	2.70	2.60	3.99	27.0	8.02	5.05	4.04	4.36	51.0	13.61	10.19	7.27	4.41	0	3.34	0.25	1.20	3.34	0.11	1.00	23.75	8.70	11.00
1978																																
01/02	29	5.00	0	1.13	0.13	1.77	4.95	12.2	4.65	3.07	3.39	5.00	26.3	8.80	6.53	5.33	5.00	48.5	15.28	11.93	8.33	5.00	0	1.13	0.13	1.77	1.00	0.05	1.30	26.75	9.42	11.20
01/16	30	5.00	0	0.93	0.21	1.64	4.96	12.5	4.07	3.03	3.12	5.00	14.8	4.67	3.57	3.42	5.00	43.2	11.83	10.01	6.83	5.00	0	0.93	0.21	1.64	0.82	0.08	1.20	23.10	8.82	10.00
02/14	31	5.00	0	0.63	0.10	1.36	4.96	11.8	3.48	2.93	2.85	5.00	29.8	7.91	7.32	5.19	5.00	51.1	13.10	12.46	7.92	5.00	0	0.63	0.10	1.36	0.56	0.04	1.00	22.10	9.36	10.40
03/06	32	5.00	0	0.36	0.18	1.36	4.96	12.0	3.28	2.57	2.85	5.00	20.7	5.43	4.33	3.96	5.00	50.0	12.61	10.22	7.64	5.00	0	0.36	0.18	1.36	0.32	0.07	1.00	21.93	7.80	10.20
03/21	33	5.50	0	0.52	0.29	1.80	5.50	11.5	4.40	2.93	3.46	5.50	20.9	7.57	5.09	4.81	5.50	48.0	16.70	11.32	8.71	5.50	0	0.52	0.29	1.80	0.42	0.10	1.20	27.50	8.16	10.80
04/05	34	5.50	0	2.14	0.17	1.95	5.50	16.5	7.31	3.54	3.91	5.50	28.4	11.27	6.13	5.41	5.50	54.4	19.60	11.56	8.56	5.50	0	2.14	0.17	1.95	1.72	0.06	1.30	27.50	7.40	9.40
05/01	36	5.50	0	1.38	0.11	1.47	5.50	23.1	8.06	5.37	3.91	5.50	28.8	9.71	6.66	4.51	5.50	60.2	18.76	13.78	7.81	5.50	0	1.38	0.11	1.47	1.11	0.04	0.98	24.80	8.00	8.00
05/16	37	5.50	0	1.34	0.09	1.95	5.50	10.8	5.06	2.76	3.46	5.50	19.4	8.02	4.89	4.66	5.50	40.9	15.42	10.21	7.66	5.50	0	1.34	0.09	1.95	1.08	0.03	1.30	28.70	8.70	10.60
06/06	39	5.50	0	0.21	0.06	1.80	5.50	12.3	3.59	2.50	3.46	5.50	25.6	7.27	5.16	5.26	5.50	48.9	13.70	9.81	8.41	5.50	0	0.21	0.06	1.80	0.17	0.02	1.20	22.30	7.00	10.20
06/27	40	5.00	0	6.20	3.42	1.64	4.96	12.5	9.39	5.63	3.05	5.00	13.8	9.77	5.89	3.22	5.00	46.3	18.18	11.69	6.94	5.00	0	6.20	3.42	1.64	5.84	1.32	1.20	28.33	8.20	9.60
07/18	41	5.50	0	1.73	0.14	2.35	5.50	13.5	6.13	2.93	3.31	5.50	19.6	8.15	4.21	4.21	5.50	47.5	17.26	9.97	8.26	5.50	0	1.73	0.14	1.35	1.39	0.05	0.90	27.65	7.30	10.60
08/08	42	5.50	0	1.10	0.06	1.35	5.50	10.8	3.59	2.09	2.86	5.50	26.9	7.31	5.11	5.11	5.50	45.2	11.52	8.55	7.66	5.50	0	1.10	0.06	1.35	0.88	0.02	0.90	19.40	6.60	10.20
TOTAL		145.27	0	33.55	8.04	44.28	145.71	425.0	148.40	88.55	92.36	142.51	812.3	246.81	159.55	133.93	144.01	1595.2	462.78	313.11	225.64	146.15		517.75	326.49	235.79	---	---	---	----	---	----
MEDIAN		4.50	0	----	---	----	4.50	12.5	-----	----	----	4.50	26.3	-----	-----	-----	4.50	49.85	-----	-----	-----	4.50		-----	-----	-----	0.77	0.05	1.05	27.90	8.18	10.60

SOURCE: Chemical analysis by Hawaiian Sugar Planters' Association, Crop Science Dept.
NOTE: In. × 0.025 40 = m.
*Actual percentage effluent in applied water determined by potassium analysis.

APPENDIX TABLE D.9. QUALITY CONSTITUENTS FROM LEACHATE SAMPLERS OF OSC FIELD NO. 246 TEST PLOTS, O'AHU, HAWAI'I

Date	Test Plot No.	Fur-row No.	Sam-ple No.	pH	Cond. (μmhos/cm)	Ca	Mg	K	Na	SiO_2	Cl	Org. + NH_4	NO_2 + NO_3	Total P
						(mg/ℓ)						(mg/ℓ N)		(mg/ℓ)
03/07/77	14A	2	1	4.9	700	176.4	48.72	2.45	27.6	14.0	181	0.09	113.7	0.05
03/07/77	14A	2	2	4.9	1100	159.6	46.94	2.54	25.8	13.8	171	0.09	110.2	0.01
03/07/77	14A	2	3	4.9	1150	147.0	45.15	2.64	25.8	13.7	151	0.09	106.8	0.01
03/07/77	14A	9	1	5.5	140	12.11	3.34	1.51	14.4	12.0	20	0.65	8.1	0.06
03/07/77	14A	9	2	5.4	109	10.38	2.84	1.60	14.4	11.2	20	0.56	6.7	0.02
03/07/77	14A	9	3	5.5	70	10.38	3.21	1.51	13.8	12.0	20	0.37	5.7	0.02
03/07/77	12B	2	1	5.4	147	31.13	8.40	2.24	20.4	15.1	50	0.09	27.7	0.02
03/07/77	12B	2	2	5.2	302	29.40	8.03	2.12	19.8	15.6	40	0.09	28.3	0.02
03/07/77	12B	2	3	5.3	125	27.67	7.78	2.14	18.0	15.6	50	0.19	22.5	0.02
03/07/77	12B	9	1	5.4	200	15.56	4.20	2.00	19.2	17.6	91	0.37	9.2	0.11
03/07/77	12B	9	2	5.4	135	15.56	3.83	1.72	20.4	17.4	30	0.37	8.3	0.07
03/07/77	12B	9	3	5.5	180	15.56	3.50	1.60	21.6	15.5	30	0.37	8.0	0.11
03/08/77	10C	2	1	5.6	241	22.48	6.67	0.61	23.4	14.0	50	0.28	18.5	0.06
03/08/77	10C	2	2	5.6	140	24.21	7.04	0.54	24.6	13.6	50	0.09	18.5	0.03
03/08/77	10C	2	3	5.6	249	25.94	7.64	0.66	24.0	13.6	40	0.09	19.9	0.03
03/08/77	10C	9	1	5.5	85	15.56	4.20	1.27	18.6	15.3	30	0.37	10.6	0.05
03/08/77	10C	9	2	5.6	92	15.56	4.08	1.27	21.0	15.6	30	0.37	10.4	0.04
03/09/77	11D	2	1	5.6	484	43.24	10.75	1.55	34.8	12.0	70	0.09	34.3	0.04
03/09/77	11D	2	2	5.6	250	41.51	10.62	1.27	33.6	11.5	70	0.09	31.4	0.03
03/09/77	11D	9	1	5.6	219	32.86	9.76	1.62	34.8	16.9	50	0.19	30.3	0.10
03/09/77	11D	9	2	5.6	201	29.40	9.02	1.29	31.8	17.1	60	0.09	29.7	0.06
03/09/77	13E	2	1	5.2	270	36.32	9.88	1.79	43.8	14.0	131	0.56	17.0	0.02
03/09/77	13E	2	2	5.2	250	32.86	9.02	1.84	43.2	16.0	111	0.65	14.4	0.03
03/09/77	13E	2	3	5.4	440	32.86	9.14	1.76	42.6	15.8	111	0.56	12.7	0.03
03/09/77	13E	9	1	5.4	250	24.21	7.16	2.64	37.8	19.8	60	0.65	18.4	0.05
03/09/77	13E	9	2	5.4	200	22.48	6.55	2.68	37.8	19.9	60	0.56	17.0	0.04
03/09/77	20E	2	1	5.4	530	43.24	9.88	0.52	37.2	10.0	101	0.19	36.0	0.05
03/09/77	20E	2	2	5.4	500	44.96	10.38	0.42	37.2	9.0	50	0.09	34.6	0.10
03/09/77	20E	9	1	5.5	505	42.00	10.80	3.01	36.0	11.6	80	0.09	25.6	0.01
03/09/77	20E	9	2	5.4	500	37.80	10.50	2.82	33.6	11.1	80	0.09	26.2	0.01
03/09/77	22E	2	1	6.2	520	53.61	9.39	1.41	34.2	9.2	101	0.56	20.2	0.04
03/09/77	22E	2	2	6.2	495	48.42	9.02	1.51	31.8	9.2	91	0.65	19.0	0.06
03/23/77	14A	2	1	5.4	805	88.2	21.6	0.89	16.8	9.5	90	0.0	116.10	0.01
03/23/77	14A	2	2	5.2	750	79.8	18.9	1.08	16.8	10.7	84	0.0	109.20	0.01
03/23/77	14A	2	3	5.0	700	75.6	17.1	0.99	15.0	10.0	81	0.0	106.32	0.01
03/23/77	14A	9	1	3.8	148	8.4	1.8	0.80	9.6	10.1	17	1.40	3.45	0.03
03/23/77	14A	9	2	3.0	351	4.2	1.5	0.78	10.8	10.9	16	0.37	2.30	0.02
03/23/77	12B	2	1	3.7	190	8.4	2.4	0.89	13.8	11.1	24	1.40	6.82	0.03
03/23/77	12B	2	2	5.4	143	8.4	2.1	0.78	13.2	12.0	24	0.37	6.82	0.03
03/23/77	12B	2	3	5.5	140	8.4	1.8	0.78	12.0	12.4	25	0.47	7.06	0.03
03/23/77	12B	9	1	5.6	172	10.5	2.7	0.89	15.0	13.2	25	1.12	16.47	0.08
03/23/77	12B	9	2	5.6	169	10.5	2.7	0.82	15.0	12.1	24	0.28	14.71	0.07
03/23/77	12B	9	3	5.7	160	8.4	2.4	0.75	18.6	11.6	24	0.37	12.94	0.08
03/23/77	10C	2	1	6.0	142	8.4	2.4	0.33	14.4	13.0	23	0.0	5.88	0.05
03/23/77	10C	2	2	6.1	128	46.2	2.7	0.35	15.6	12.9	23	0.37	5.88	0.05
03/23/77	10C	9	1	5.8	148	8.4	2.4	0.68	17.4	14.0	22	1.40	7.65	0.05
03/23/77	10C	9	2	5.9	145	8.4	2.1	0.61	16.2	12.8	22	0.28	7.65	0.04
03/23/77	11D	2	1	2.9	599	12.6	3.3	0.56	21.0	10.0	36	0.84	14.71	0.04
03/23/77	11D	2	2	3.2	328	12.6	3.0	0.45	19.2	9.5	34	0.37	12.35	0.04
03/23/77	11D	9	1	2.4	1590	21.0	6.3	0.99	25.8	16.0	39	2.61	32.35	0.06
03/23/77	11D	9	2	2.5	1260	21.0	6.3	0.99	25.2	16.2	38	0.37	28.82	0.06
03/22/77	13E	2	1	5.5	350	21.0	5.7	0.87	35.4	12.2	74	0.93	10.98	0.04
03/22/77	13E	2	2	5.6	340	16.8	5.4	0.89	34.2	14.5	72	0.84	10.37	0.04
03/22/77	13E	9	1	5.5	318	16.8	5.4	1.98	39.0	16.6	57	0.93	18.29	0.04
03/22/77	13E	9	2	5.7	342	16.8	4.8	1.93	39.0	16.6	57	0.75	15.24	0.04
03/22/77	20E	2	1	5.5	321	21.0	5.7	0.28	27.6	8.9	79	0.84	11.59	0.02
03/22/77	20E	2	2	5.5	310	21.0	5.4	0.28	28.8	8.5	79	0.84	11.60	0.02
03/22/77	20E	9	1	5.8	302	50.4	13.5	1.84	31.2	12.0	68	1.21	20.73	0.05
03/22/77	20E	9	2	5.5	369	50.4	13.2	1.84	31.2	12.0	70	0.19	20.73	0.03
03/22/77	22E	2	1	6.3	260	25.2	3.9	0.59	25.8	8.0	62	1.21	5.49	0.04
03/22/77	22E	2	2	6.4	302	25.2	4.2	0.61	25.8	8.2	62	1.03	5.49	0.04
04/13/77	14A	2	1	7.2	216	29.6	7.81	0.33	12.6	7.3	40	0.0	17.85	0.02
04/13/77	14A	2	2	7.2	199	25.0	6.96	0.38	10.8	8.1	38	0.0	18.42	0.01
04/13/77	14A	9	1	7.5	80	7.9	2.64	0.64	12.0	8.1	13	0.93	1.42	0.04
04/13/77	14A	9	2	7.5	78	6.6	1.60	0.64	12.6	8.1	13	0.28	0.85	0.03
04/13/77	12B	2	1	7.5	90	5.3	1.79	0.47	13.2	9.2	17	1.40	0.85	0.05
04/13/77	12B	2	2	7.5	118	5.3	1.69	0.38	12.0	9.5	17	0.37	0.85	0.04
04/13/77	12B	9	1	7.7	107	7.9	2.82	0.52	17.4	10.0	19	1.96	3.40	0.11
04/13/77	12B	9	2	7.5	86	7.9	2.64	0.49	18.0	9.3	19	----	3.40	0.11

APPENDIX TABLE D.9.—*Continued*

Date	Test Plot No.	Furrow No.	Sample No.	pH	Cond. (μmhos/cm)	Ca	Mg	K	Na	SiO_2	Cl	Org. + NH_4	NO_2 + NO_3	Total P (mg/ℓ)
						(mg/ℓ)						(mg/ℓ N)		
04/14/77	10C	2	1	6.4	142	7.9	2.45	0.33	16.2	10.1	20	2.05	2.83	0.08
04/14/77	10C	2	2	6.4	138	7.9	2.35	0.28	17.4	11.2	22	0.37	2.27	0.08
04/14/77	10C	9	1	6.3	140	7.9	2.16	0.52	17.4	16.0	23	1.40	1.70	0.10
04/14/77	10C	9	2	6.6	135	6.6	2.26	0.47	17.4	18.0	23	0.37	1.98	0.08
04/14/77	11D	2	1	3.1	600	9.2	2.45	0.45	21.6	7.9	30	----	2.83	0.06
04/14/77	11D	2	2	3.6	280	11.9	3.20	0.33	21.0	8.1	30	0.65	2.83	0.05
04/14/77	11D	9	1	4.0	290	15.8	4.89	0.73	25.8	14.0	36	1.59	8.50	0.09
04/14/77	11D	9	2	4.4	265	14.5	4.61	0.68	25.8	14.1	36	0.37	7.93	0.08
04/13/77	13E	2	1	7.5	240	13.2	3.67	0.61	37.2	12.1	56	2.33	6.23	0.07
04/13/77	13E	2	2	7.3	230	13.2	3.67	0.61	37.2	13.3	55	0.93	5.10	0.07
04/13/77	13E	9	1	7.3	238	11.9	3.76	1.15	40.8	14.6	53	2.33	7.08	0.08
04/13/77	13E	9	2	7.3	242	10.5	3.29	1.15	40.2	15.4	53	0.40	5.95	0.08
04/13/77	20E	2	1	7.3	237	15.8	3.76	0.24	36.0	8.8	64	1.03	7.08	0.06
04/13/77	20E	2	2	7.3	226	15.8	3.76	0.24	34.8	8.2	65	0.65	6.52	0.05
04/13/77	20E	9	1	7.2	278	19.8	5.08	1.01	39.6	8.6	57	1.40	18.70	0.05
05/03/77	14A	2	1	5.4	382	35.3	9.1	0.40	20.4	7.1	112	51.7	2.41	0.02
05/03/77	14A	2	2	5.3	385	37.1	9.8	0.40	18.6	7.8	112	48.4	2.36	0.02
05/03/77	14A	9	1	5.5	160	10.9	3.8	0.78	14.4	8.7	39	1.3	1.06	0.02
05/03/77	14A	9	2	5.5	165	11.8	3.9	0.80	15.6	9.3	40	0.9	0.72	0.02
05/03/77	12B	2	1	5.6	212	12.7	3.8	0.73	19.2	10.0	10	11.2	1.84	0.03
05/03/77	12B	2	2	5.5	200	10.9	3.7	0.61	24.6	9.6	10	10.5	1.41	0.02
05/03/77	12B	9	1	5.7	155	9.1	4.5	0.49	24.0	10.6	6	2.7	1.64	0.09
05/03/77	12B	9	2	5.7	155	8.2	3.4	0.47	23.4	11.0	7	2.1	1.26	0.09
05/03/77	12B	9	3	5.7	149	6.3	1.6	0.47	21.0	11.0	7	1.6	1.29	0.08
05/03/77	10C	2	1	6.0	199	12.7	4.8	0.38	19.2	10.1	38	4.1	3.68	0.07
05/03/77	10C	2	2	5.9	199	13.6	4.5	0.38	21.0	9.8	40	3.1	3.59	0.05
05/03/77	10C	9	1	5.7	185	10.9	3.5	0.52	21.6	10.2	40	4.7	2.11	0.06
05/03/77	11D	2	1	5.9	223	11.8	3.6	0.35	23.4	6.5	46	1.7	2.39	0.06
05/03/77	11D	2	2	6.0	222	11.8	3.5	0.33	25.8	7.5	45	0.7	2.21	0.04
05/03/77	11D	9	1	5.9	228	12.7	3.5	0.73	21.6	14.5	37	2.2	3.31	0.08
05/03/77	11D	9	2	5.8	222	11.8	3.6	0.66	22.2	15.3	37	0.7	3.22	0.10
05/03/77	13E	2	1	3.3	493	15.4	4.2	0.78	54.6	13.1	69	10.9	11.43	0.12
05/03/77	13E	9	1	5.8	280	9.1	3.6	0.89	43.8	15.4	50	2.5	3.43	0.18
05/03/77	20E	2	1	5.7	384	19.0	5.4	0.38	44.4	9.5	80	27.1	11.52	0.11
05/03/77	20E	2	2	5.6	298	20.8	5.4	0.35	45.0	7.9	85	26.7	12.00	0.09
05/03/77	20E	9	1	5.7	356	17.2	4.9	0.66	41.4	8.9	51	2.0	17.16	0.08
05/03/77	22E	2	1	6.4	465	30.8	6.0	0.80	50.4	6.1	101	62.7	3.86	0.14
05/03/77	22E	2	2	6.4	410	29.9	5.3	0.82	50.4	6.1	101	57.0	3.91	0.14
05/24/77	14A	2	1	5.5	355	33.52	9.14	0.26	9.6	7.7	35	3.45	29.06	0.02
05/24/77	14A	9	1	5.8	105	6.34	1.81	0.52	9.0	8.2	16	1.21	1.73	0.04
05/25/77	12B	2	1	6.0	152	7.25	2.20	0.45	13.8	8.0	18	1.59	5.78	0.04
05/25/77	12B	2	2	5.8	141	6.34	2.07	0.33	13.2	8.1	18	0.56	5.10	0.04
05/25/77	12B	9	1	5.9	118	5.44	1.55	0.31	13.2	9.0	16	1.49	3.15	0.10
05/25/77	12B	9	2	5.9	119	4.53	1.36	0.31	13.8	9.0	16	0.56	3.00	0.09
05/25/77	10C	2	1	6.0	268	17.21	4.72	0.38	25.2	9.7	23	1.87	19.72	0.05
05/25/77	10C	2	2	6.0	256	15.40	4.34	0.31	22.2	10.5	23	0.56	17.35	0.04
05/25/77	10C	9	1	5.9	227	11.78	3.11	0.38	19.2	9.4	23	1.68	14.48	0.04
05/27/77	11D	2	1	6.1	260	12.68	3.11	0.35	26.4	7.2	30	1.59	12.08	0.05
05/27/77	11D	2	2	6.1	261	11.78	2.72	0.31	26.4	7.2	30	0.65	2.68	0.04
05/27/77	11D	9	1	5.9	202	9.06	2.78	0.64	19.8	14.9	29	1.40	11.97	0.08
05/24/77	13E	2	1	5.7	392	19.02	5.31	0.54	40.8	11.4	44	1.87	27.54	0.03
05/24/77	13E	9	1	5.8	300	9.06	2.78	0.64	40.8	13.5	46	2.05	13.56	0.06
05/24/77	20E	2	1	5.7	700	36.24	8.52	0.33	55.2	7.9	43	1.12	54.3	0.03
05/24/77	20E	2	2	5.7	660	35.33	8.77	0.33	55.2	7.8	43	0.09	50.2	0.02
05/24/77	20E	9	1	5.8	437	17.21	4.53	0.56	43.2	7.9	34	1.96	33.5	0.03
05/24/77	22E	2	1	6.3	710	48.92	9.14	0.45	48.6	7.4	57	1.49	50.0	0.04
06/07/77	14A	2	1	5.8	130	10.87	2.98	0.19	10.8	8.7	19	1.49	6.21	0.02
06/07/77	14A	2	2	5.8	118	9.06	2.46	0.19	10.2	9.0	18	0.75	5.31	0.02
06/07/77	14A	9	1	5.8	94	4.53	1.42	0.45	12.0	8.7	14	1.21	0.56	0.04
06/08/77	12B	2	1	5.9	105	4.53	1.49	0.28	16.2	7.7	17	1.21	0.81	0.05
06/08/77	12B	9	1	6.0	106	4.53	1.16	0.26	16.8	8.0	16	1.12	2.43	0.08
06/08/77	10C	2	1	6.2	150	8.15	2.26	0.24	18.0	9.5	23	1.40	4.69	0.06
06/08/77	10C	9	1	6.1	131	5.44	1.42	0.24	19.2	8.7	23	1.40	3.59	0.06
06/09/77	11D	2	1	6.1	223	9.06	2.33	0.24	28.8	6.4	30	1.40	7.67	0.05
06/09/77	11D	9	1	6.0	242	10.87	3.30	0.56	26.4	14.4	32	1.96	8.97	0.08
06/07/77	13E	2	1	5.7	388	18.12	5.24	0.42	43.2	11.9	52	1.77	22.64	0.05
06/07/77	13E	9	1	6.1	360	9.96	2.91	0.59	49.8	14.0	53	2.43	17.25	0.09
06/07/77	13E	9	2	6.0	338	9.06	2.72	0.59	49.2	14.0	53	1.68	16.04	0.08
06/07/77	20E	2	1	5.9	371	18.12	4.36	0.26	40.2	6.6	52	1.87	20.34	0.08
06/07/77	20E	9	1	6.1	371	14.49	3.69	0.45	48.6	12.0	47	2.05	20.74	0.06
06/07/77	22E	--	1	6.4	465	33.52	5.69	0.38	42.6	6.9	54	1.96	28.94	0.08

APPENDIX TABLE D.9.—*Continued*

Date	Test Plot No.	Fur-row No.	Sam-ple No.	pH	Cond. (µmhos/cm)	Ca	Mg	K	Na	SiO_2	Cl	Org. + NH_4	NO_2 + NO_3	Total P
						(mg/ℓ)						(mg/ℓ N)		(mg/ℓ)
06/21/77	14A	2	1	5.7	152	14.49	5.08	0.14	9.6	9.0	15	3.08	8.99	0.01
06/21/77	14A	2	2	5.6	149	14.49	4.99	0.12	11.4	9.2	15	3.17	9.53	0.01
06/21/77	14A	9	1	5.8	105	8.15	2.73	0.33	10.8	8.0	17	0.84	1.32	0.02
06/21/77	14A	9	2	5.8	91	7.25	2.45	0.31	10.2	8.0	16	0.28	1.10	0.01
06/21/77	12B	2	1	5.8	98	4.53	1.79	0.21	13.8	9.0	17	0.93	0.22	0.02
06/21/77	12B	2	2	5.8	95	5.44	1.79	0.21	13.2	8.8	16	0.47	0.22	0.02
06/21/77	12B	9	1	6.0	107	4.53	1.41	0.19	16.2	8.9	18	0.84	1.10	0.06
06/21/77	12B	9	2	6.0	93	4.53	1.51	0.16	15.6	7.7	18	0.28	0.66	0.06
06/22/77	10C	2	1	6.1	147	7.25	3.11	0.19	19.2	10.0	24	1.12	3.78	0.05
06/22/77	10C	9	1	6.0	121	5.44	2.07	0.21	17.4	8.5	23	1.59	2.92	0.05
06/22/77	11D	2	1	6.1	233	9.06	3.11	0.24	26.4	8.2	33	1.12	7.57	0.05
06/22/77	11D	9	1	6.0	122	11.78	4.99	0.59	28.2	14.1	32	1.15	10.43	0.07
06/23/77	13E	2	1	5.8	421	20.84	8.09	0.40	43.8	14.6	54	1.21	25.64	0.05
06/23/77	13E	9	1	5.8	421	13.59	5.18	0.49	53.4	14.9	54	1.21	13.63	0.04
06/23/77	20E	2	1	6.0	380	19.02	5.74	0.24	41.4	11.5	52	1.21	14.65	0.03
06/23/77	20E	9	1	5.9	409	16.31	5.27	0.42	49.2	12.9	52	1.12	28.46	0.04
06/23/77	22E	--	1	6.4	460	30.80	6.78	0.28	43.2	6.8	53	----	-----	----
07/13/77	14A	2	1	5.8	213	19.93	4.66	0.12	10.2	9.0	15	0.37	17.28	0.02
07/13/77	14A	9	1	5.9	98	5.44	1.36	0.26	9.0	7.8	15	0.75	1.66	0.03
07/14/77	12B	2	1	5.8	101	4.53	0.97	0.31	12.0	9.5	16	0.47	0.30	0.06
07/14/77	12B	2	2	5.8	100	4.53	0.97	0.24	12.0	10.0	16	0.47	0.48	0.05
07/14/77	12B	9	1	5.9	102	4.53	0.91	0.24	12.6	8.9	16	0.65	1.21	0.11
07/14/77	12B	9	2	5.9	104	4.53	0.91	0.16	12.6	9.3	16	0.37	0.92	0.09
07/15/77	10C	2	1	6.2	161	7.25	2.07	0.24	15.0	9.6	23	1.12	1.90	0.06
07/15/77	10C	9	1	6.2	132	4.53	1.23	0.24	13.8	9.0	19	1.40	1.19	0.06
07/15/77	11D	2	1	6.2	202	6.34	1.55	0.19	22.2	9.5	36	0.93	2.93	0.05
07/15/77	11D	9	1	6.1	202	7.25	2.26	0.40	21.0	14.0	36	1.59	2.45	0.09
07/13/77	13E	2	1	6.0	340	19.93	4.98	0.33	38.4	12.0	44	1.12	17.84	0.02
07/13/77	13E	9	1	6.1	330	9.06	2.59	0.31	43.2	13.0	44	1.40	12.82	0.04
07/13/77	20E	2	1	5.9	288	11.78	2.59	0.14	34.2	9.0	41	0.93	7.76	0.03
07/13/77	20E	9	1	6.0	375	13.59	3.30	0.21	46.2	9.3	49	1.59	16.35	0.02
07/13/77	22E	--	1	6.4	345	19.93	3.36	0.14	36.0	8.9	41	1.49	9.70	0.05
07/26/77	14A	2	1	5.9	120	-----	----	----	----	9.6	10	1.12	5.53	0.02
07/26/77	14A	2	2	5.9	112	-----	----	----	----	10.8	11	0.19	4.78	0.02
07/26/77	14A	9	1	5.9	90	-----	----	----	----	9.0	10	0.56	1.49	0.03
07/26/77	14A	9	2	5.9	85	-----	----	----	----	7.7	11	0.28	1.58	0.03
07/27/77	12B	2	1	6.1	98	-----	----	----	----	8.4	13	0.93	0.68	0.03
07/27/77	12B	2	2	6.1	95	-----	----	----	----	9.3	13	0.37	0.63	0.03
07/27/77	12B	9	1	6.2	90	-----	----	----	----	9.0	13	0.84	1.78	0.07
07/27/77	10C	2	1	6.2	135	-----	----	----	----	10.0	18	0.93	2.74	0.05
07/27/77	10C	9	1	6.2	110	-----	----	----	----	9.7	17	1.03	1.48	0.05
07/27/77	11D	2	1	5.9	230	-----	----	----	----	7.5	25	1.12	8.68	0.05
07/27/77	11D	2	2	5.9	225	-----	----	----	----	8.3	26	0.75	8.03	0.04
07/27/77	11D	9	1	5.9	231	-----	----	----	----	15.4	27	1.21	8.62	0.09
07/27/77	11D	9	2	5.9	230	-----	----	----	----	15.6	28	0.75	8.12	0.09
07/26/77	13E	2	1	5.9	390	-----	----	----	----	9.9	44	1.12	20.17	0.04
07/26/77	13E	9	1	5.9	390	-----	----	----	----	14.4	45	1.31	20.77	0.07
07/26/77	20E	2	1	6.0	315	-----	----	----	----	11.6	44	1.59	11.06	0.06
07/26/77	20E	9	1	5.9	371	-----	----	----	----	12.5	45	1.03	19.43	0.05
07/26/77	22E	--	1	6.6	361	-----	----	----	----	7.4	46	1.31	15.39	0.05
08/12/77	14A	2	1	5.9	85	11.78	1.68	0.14	9.0	13.8	9	0.47	1.50	0.03
08/12/77	14A	2	2	5.9	85	11.32	1.68	0.09	5.4	13.9	9	0.19	1.39	0.02
08/12/77	14A	9	1	5.8	85	9.96	1.36	0.28	10.2	7.1	9	0.47	0.96	0.01
08/12/77	14A	9	2	5.8	83	9.96	1.49	0.24	9.6	7.1	9	0.09	0.86	0.02
08/11/77	12B	2	1	5.8	110	12.68	1.49	0.19	10.8	8.7	13	1.03	0.48	0.02
08/11/77	12B	9	1	5.9	106	9.96	1.16	0.24	12.0	8.8	14	0.65	0.86	0.08
08/11/77	10C	2	1	6.2	149	11.78	1.88	0.26	16.2	9.5	17	0.93	2.27	0.04
08/11/77	10C	9	1	6.2	135	11.78	2.01	0.33	17.4	9.2	18	0.84	1.19	0.06
08/12/77	11D	2	1	6.2	195	11.32	1.68	0.21	24.6	7.0	23	0.93	3.71	0.05
08/12/77	11D	9	1	6.2	195	11.59	2.01	0.33	24.0	12.5	24	1.03	3.21	0.09
08/10/77	13E	2	1	6.1	388	31.71	5.24	0.40	35.4	13.6	42	0.28	21.44	0.03
08/10/77	13E	2	2	6.1	380	32.61	5.24	0.28	36.6	14.3	41	0.37	19.82	0.02
08/10/77	13E	9	1	6.1	329	19.02	2.85	0.33	37.8	12.3	40	0.65	13.39	0.04
08/10/77	13E	9	2	6.0	308	19.93	2.98	0.52	37.2	12.8	42	0.65	10.72	0.07
08/10/77	20E	2	1	6.2	348	23.55	3.36	0.14	39.0	9.5	40	0.84	16.29	0.04
08/10/77	20E	9	1	6.1	369	25.36	3.36	0.19	40.2	8.5	38	0.75	16.86	0.03
08/10/77	22E	--	1	6.4	330	35.33	3.49	0.16	36.6	6.9	35	0.75	9.16	0.07

APPENDIX TABLE D.9.—*Continued*

Date	Test Plot No.	Fur-row No.	Sam-ple No.	pH	Cond. (µmhos/cm)	Ca	Mg	K	Na	SiO_2	Cl	Org. + NH_4	NO_2 + NO_3	Total P
						(mg/ℓ)						(mg/ℓ N)		(mg/ℓ)
08/23/77	14A	2	1	5.9	100	10.87	1.55	0.21	7.2	9.0	10	0.65	0.97	0.02
08/23/77	14A	9	1	5.9	72	7.25	1.16	0.26	9.0	7.7	10	0.56	0.93	0.02
08/24/77	12B	2	1	5.9	81	7.25	0.91	0.21	16.2	9.3	14	0.56	0.63	0.04
08/24/77	12B	9	1	6.0	90	7.25	2.01	0.20	16.2	8.7	15	0.47	1.86	0.09
08/24/77	10C	2	1	6.1	130	13.59	2.20	0.28	17.4	10.8	19	0.75	4.43	0.06
08/24/77	10C	9	1	6.1	112	9.96	1.49	0.20	21.0	11.9	19	0.75	2.20	0.10
08/25/77	11D	2	1	6.1	210	23.55	2.01	0.22	28.5	8.1	26	0.93	7.79	0.06
08/25/77	11D	9	1	6.1	215	15.40	2.52	0.37	28.8	13.3	27	0.84	8.70	0.09
08/25/77	13E	2	1	5.8	400	26.47	5.44	0.47	39.0	18.0	48	0.37	22.02	0.05
08/25/77	13E	9	1	5.8	378	40.76	4.72	0.40	40.8	19.8	51	1.21	17.10	0.08
08/25/77	20E	2	1	5.8	341	22.65	3.17	0.24	40.8	12.6	45	0.75	15.46	0.06
08/25/77	20E	9	1	5.9	370	24.46	3.43	0.42	42.0	13.0	45	1.40	18.07	0.07
08/25/77	22E	--	1	6.3	407	42.58	3.69	0.35	39.0	9.6	44	0.93	17.80	0.09
09/08/77	14A	2	1	5.6	86	14.95	1.8	0.21	7.8	9.8	12	0.56	0.75	0.02
09/08/77	14A	9	1	5.6	87	---	---	----	----	7.6	13	0.47	1.18	0.02
09/08/77	12B	2	1	5.8	88	8.2	1.2	0.19	12.0	8.6	11	1.22	1.63	0.04
09/08/77	12B	9	1	5.8	100	10.9	1.2	0.26	15.0	8.5	10	1.22	4.15	0.08
09/09/77	10C	2	1	6.0	155	14.5	2.2	0.33	24.6	10.5	19	0.66	5.4	0.05
09/09/77	10C	9	1	6.0	135	10.9	1.5	0.21	18.6	11.4	18	0.66	3.5	0.07
09/09/77	11D	2	1	6.0	240	20.8	2.5	0.28	30.6	11.9	26	0.84	10.6	0.07
09/09/77	11D	9	1	6.0	236	19.5	2.8	0.38	28.8	15.2	26	0.93	10.1	0.08
09/07/77	13E	2	1	5.6	450	53.4	7.3	0.61	44.4	18.0	49	0.47	27.07	0.04
09/07/77	13E	9	1	5.7	480	47.1	6.3	0.45	50.4	18.6	52	0.75	28.29	0.07
09/07/77	20E	2	1	5.8	487	27.6	3.1	0.19	46.2	11.5	50	0.93	14.38	0.07
09/07/77	20E	9	1	5.9	430	33.5	4.1	0.33	45.6	12.1	48	0.37	22.33	0.06
09/07/77	22E	--	1	6.3	458	58.4	4.98	0.26	43.8	9.2	47	0.75	21.17	0.09
09/14/77	14A	2	1	6.0	82	10.87	----	0.31	9.6	8.5	9	0.50	0.87	0.01
09/14/77	14A	9	1	6.1	80	8.15	1.42	0.21	10.2	7.5	10	0.17	0.87	0.01
09/14/77	12B	2	1	6.0	100	8.15	1.29	0.21	14.4	8.7	14	0.67	1.46	0.02
09/14/77	12B	9	1	6.2	110	9.96	1.36	0.19	16.2	9.0	15	0.39	2.11	0.04
09/15/77	10C	2	1	6.3	171	14.5	2.33	0.32	21.3	10.1	19	0.39	7.11	0.02
09/15/77	10C	9	1	6.4	190	9.06	1.62	0.21	20.4	10.1	17	0.45	3.93	0.03
09/15/77	11D	2	1	6.3	260	21.7	4.01	0.33	35.4	10.5	26	0.56	12.68	0.04
09/15/77	11D	9	1	6.4	251	17.2	2.85	0.37	30.0	14.2	28	0.67	10.87	0.06
09/16/77	13E	2	1	5.9	505	45.3	7.37	0.55	50.4	16.4	48	0.00	30.31	0.02
09/16/77	13E	9	1	6.1	550	55.3	9.02	0.45	52.8	16.1	48	0.00	33.87	0.03
09/16/77	20E	2	1	6.1	381	22.7	4.34	0.24	48.6	10.7	50	0.67	15.74	0.04
09/16/77	20E	9	1	6.1	456	29.9	2.65	0.35	51.0	10.8	48	0.22	26.17	0.03
09/16/77	22E	--	1	6.8	515	50.7	4.98	0.26	47.4	8.2	48	0.11	26.85	0.01
10/03/77	14A	2	1	6.1	96	10.71	2.14	0.26	8.4	10.5	12	0.95	0.61	0.02
10/03/77	14A	9	1	6.1	80	7.50	1.84	0.31	7.2	10.6	13	0.62	0.85	0.01
10/03/77	12B	2	1	6.1	98	7.50	1.84	0.71	18.0	8.9	15	0.84	1.58	0.04
10/03/77	12B	9	1	6.3	102	8.57	1.53	0.33	13.2	8.0	17	0.56	2.06	0.07
10/04/77	10C	2	1	6.6	160	16.07	3.44	0.28	16.2	10.1	21	0.90	5.45	0.12
10/04/77	10C	9	1	6.7	130	7.50	3.98	0.21	14.4	11.7	20	0.90	2.01	0.13
10/04/77	11D	2	1	6.5	250	21.42	4.28	0.19	27.0	3.6	23	0.95	12.22	0.10
10/04/77	11D	9	1	6.5	239	20.35	2.33	0.24	25.8	13.7	29	0.84	10.41	0.10
10/05/77	13E	2	1	5.8	440	38.56	6.02	0.18	43.2	10.9	48	0.00	28.95	0.06
10/05/77	13E	9	1	6.0	440	19.93	5.89	0.38	45.6	21.3	49	0.00	30.24	0.06
10/05/77	20E	2	1	6.1	430	28.92	4.21	0.28	46.8	14.7	48	0.00	28.09	0.05
10/05/77	20E	9	1	6.0	380	42.84	2.63	0.19	43.8	12.4	48	0.34	18.03	0.07
10/05/77	22E	--	1	6.5	460	7.76	4.66	0.26	43.2	11.0	49	0.50	27.30	0.07
10/19/77	12B	2	1	6.9	100	4.5	1.0	0.28	13.8	9.0	9	0.67	5.05	----
10/19/77	12B	9	1	6.6	89	3.6	1.1	0.28	11.4	9.7	10	1.06	1.36	----
10/19/77	14A	2	1	6.5	79	3.6	1.2	0.38	7.2	8.0	10	0.50	0.93	----
10/19/77	14A	9	1	6.4	72	5.4	1.4	0.36	6.6	9.7	9	0.95	1.31	----
10/20/77	10C	2	1	6.4	143	7.2	2.2	0.38	18.6	12.4	21	1.06	3.90	----
10/20/77	10C	9	1	6.8	125	5.4	1.3	0.16	16.2	13.2	19	0.67	2.78	----
10/21/77	11D	2	1	6.3	240	10.9	2.6	0.28	31.8	12.4	28	1.06	12.31	----
10/21/77	11D	9	1	6.4	210	9.1	2.3	0.24	28.8	15.5	27	1.18	9.53	----
10/21/77	13E	2	1	6.2	455	27.2	6.9	0.78	50.4	25.2	53	0.39	29.58	----
10/21/77	13E	9	1	6.1	455	25.4	6.5	0.31	51.6	18.3	55	0.34	29.75	----
10/21/77	20E	2	1	6.1	380	14.5	3.0	0.16	48.6	12.3	56	0.73	27.62	----
10/21/77	20E	9	1	6.1	440	22.6	5.0	0.28	54.0	12.4	51	0.45	18.51	----
10/21/77	22E	--	1	6.4	460	34.4	5.2	0.33	50.4	11.5	53	0.50	24.82	----

APPENDIX TABLE D.9.—*Continued*

Date	Test Plot No.	Furrow No.	Sample No.	pH	Cond. (μmhos/cm)	Ca	Mg	K	Na	SiO_2	Cl	Org. + NH_4	NO_2 + NO_3	Total P
						(mg/ℓ)						(mg/ℓ N)		(mg/ℓ)
11/02/77	13E	2	1	6.8	265	28.1	6.2	0.47	40.8	20.8	31	0.00	48.66	----
11/02/77	13E	9	1	6.9	280	27.2	6.3	0.26	42.6	19.2	26	0.22	43.38	----
11/02/77	14A	2	1	6.9	80	55.3	1.9	0.33	7.8	9.4	12	0.73	2.34	----
11/02/77	14A	9	1	6.8	70	38.1	1.6	0.35	7.2	8.0	26	1.34	1.47	----
11/02/77	20E	2	1	6.7	268	8.6	4.5	0.21	41.4	11.4	29	0.62	29.90	----
11/02/77	20E	9	1	6.8	320	6.3	3.1	0.19	43.8	12.2	32	0.67	47.60	----
11/02/77	22E	--	1	6.8	340	36.2	4.9	0.26	45.0	10.6	33	0.28	45.61	----
11/03/77	10C	2	1	6.5	130	6.3	2.3	0.54	16.2	13.0	15	0.90	5.50	----
11/03/77	10C	9	1	6.7	110	5.4	1.4	0.19	17.4	11.5	19	0.67	1.40	----
11/03/77	11D	2	1	6.5	215	10.0	2.9	0.26	28.2	11.9	29	0.90	11.65	----
11/03/77	11D	9	1	6.6	200	7.3	2.6	0.28	26.4	15.5	27	1.57	6.90	----
11/03/77	12B	2	1	6.6	90	3.6	0.7	0.35	10.8	8.5	16	0.67	0.53	----
11/03/77	12B	9	1	6.5	190	4.5	0.8	0.21	13.2	9.5	18	0.79	2.69	----
11/21/77	20E	2	1	6.7	190	10.0	1.8	0.21	29.4	10.0	18	0.34	5.03	----
11/21/77	20E	9	1	6.4	234	17.2	2.5	0.38	34.2	9.8	20	0.39	14.10	----
11/21/77	22E	--	1	6.7	253	46.2	10.8	0.34	31.2	9.5	23	0.73	12.60	----
11/22/77	12B	2	1	6.4	70	6.3	1.0	0.32	11.1	9.0	14	0.73	1.01	----
11/22/77	12B	9	1	6.5	80	5.4	0.8	0.24	11.4	8.8	15	0.62	2.60	----
11/22/77	13E	2	1	6.2	190	17.2	3.0	0.49	26.4	18.0	19	0.39	8.05	----
11/22/77	13E	9	1	6.2	153	10.9	1.9	0.48	27.6	16.5	15	0.78	2.88	----
11/22/77	14A	2	1	6.3	72	10.0	1.4	0.33	7.8	7.4	13	0.67	0.86	----
11/22/77	14A	9	1	6.3	60	7.3	1.2	0.40	9.0	6.8	11	0.17	0.72	----
11/23/77	10C	2	1	6.8	135	10.9	1.9	0.47	18.0	8.0	20	1.06	5.04	----
11/23/77	10C	9	1	7.2	102	8.2	1.5	0.21	19.2	7.2	20	0.67	1.96	----
11/23/77	11D	2	1	6.6	220	17.2	2.6	0.33	27.6	8.6	28	0.50	15.26	----
11/23/77	11D	9	1	6.7	208	15.4	2.7	0.26	27.0	11.2	28	0.34	12.71	----
12/22/77	10C	2	1	6.4	140	15.4	1.8	0.35	11.4	8.5	29	0.84	1.96	----
12/22/77	10C	9	1	6.5	135	12.2	1.2	0.14	15.0	10.4	37	1.18	1.54	----
12/22/77	11D	2	1	6.6	190	19.9	2.6	0.26	25.2	8.0	46	0.73	7.14	----
12/22/77	11D	9	1	6.4	175	15.4	1.8	0.26	22.2	14.5	45	0.84	2.72	----
12/22/77	12B	2	1	6.7	120	10.0	0.9	0.20	7.2	8.0	22	0.45	0.90	----
12/22/77	12B	9	1	6.5	110	8.2	0.6	0.28	6.6	6.5	20	1.29	1.40	----
12/21/77	13E	2	1	6.2	285	19.9	2.7	0.66	20.4	15.3	35	0.34	6.02	----
12/21/77	13E	9	1	6.3	270	13.6	1.9	0.26	18.6	12.2	30	0.67	3.50	----
12/21/77	14A	2	1	6.1	85	15.0	1.6	0.41	1.8	7.0	21	0.84	0.98	----
12/21/77	14A	9	1	6.0	85	12.7	1.2	0.56	4.5	5.5	21	0.78	0.95	----
12/21/77	20E	2	1	6.3	290	9.5	0.8	0.34	25.2	6.7	22	0.84	1.82	----
12/21/77	20E	9	1	6.2	270	16.3	2.1	0.52	24.6	8.7	33	0.50	8.42	----
12/21/77	22E	--	1	6.5	330	25.8	2.3	0.40	24.0	6.0	39	0.67	2.41	----
01/17/78	13E	2	1	7.3	210	22.6	3.1	0.61	23.4	16.5	32	0.39	7.16	----
01/17/78	13E	9	1	7.1	150	11.8	1.7	0.29	20.1	14.0	18	0.84	2.25	----
01/17/78	14A	2	1	6.9	90	13.6	1.5	0.17	8.4	9.5	18	0.22	1.00	----
01/17/78	14A	9	1	6.9	70	9.1	1.2	0.39	7.2	7.6	14	0.67	0.92	----
01/17/78	20E	2	1	6.7	140	9.6	1.5	1.53	17.4	13.3	17	0.39	4.90	----
01/17/78	20E	9	1	6.7	198	14.5	1.9	0.17	24.0	9.0	26	0.22	7.80	----
01/17/78	22E	--	1	6.6	---	23.6	2.4	0.57	24.0	9.0	35	0.62	2.11	----
01/18/78	10C	2	1	6.7	150	15.4	2.3	0.40	17.4	10.5	26	0.39	4.88	----
01/18/78	10C	9	1	6.6	135	10.0	1.4	0.26	18.9	8.4	29	0.73	1.49	----
01/18/78	11D	2	1	6.8	260	22.7	2.9	0.24	30.0	12.4	37	0.67	10.69	----
01/18/78	11D	9	1	6.5	220	16.3	2.4	0.35	24.6	16.2	37	1.34	4.06	----
02/01/78	13E	2	1	7.5	110	15.4	2.5	0.71	19.8	16.5	23	0.45	3.86	----
02/01/78	13E	9	1	7.3	120	8.2	1.4	0.28	16.8	13.5	13	1.12	1.53	----
02/01/78	14A	2	1	6.9	80	9.1	1.5	0.24	7.2	9.5	15	0.50	0.87	----
02/01/78	14A	9	1	7.0	70	7.3	1.1	0.33	8.7	7.4	12	0.75	0.56	----
02/01/78	20E	2	1	6.8	140	7.3	1.1	0.71	18.6	11.4	14	0.54	0.90	----
02/01/78	20E	9	1	6.8	160	12.7	1.7	0.26	21.0	9.0	16	0.22	1.21	----
02/02/78	12B	2	1	6.7	70	6.3	0.9	0.24	12.6	8.6	17	1.01	0.87	----
02/02/78	12B	9	1	6.8	90	6.3	1.0	0.68	13.5	8.5	17	1.12	1.13	----
02/03/78	10C	2	1	7.6	147	11.8	1.9	0.35	17.4	9.0	21	0.95	4.04	----
02/03/78	10C	9	1	7.6	115	7.3	1.1	0.25	18.0	9.0	20	0.90	1.44	----
02/03/78	11D	2	1	6.5	235	19.0	2.9	0.19	28.8	7.4	32	0.50	9.62	----
02/03/78	11D	9	1	6.6	213	11.8	2.0	0.28	29.4	12.4	33	0.78	5.38	----
02/14/78	14A	2	1	6.7	80	7.7	1.2	0.21	6.0	10.3	12	0.39	0.90	----
02/14/78	14A	9	1	6.8	70	6.8	1.0	0.20	6.6	7.1	11	0.50	0.44	----
02/14/78	20E	2	1	6.9	140	8.2	1.4	0.64	16.2	13.7	13	0.34	0.67	----
02/14/78	20E	9	1	6.8	150	9.5	1.4	0.17	17.7	9.8	14	0.39	1.05	----

APPENDIX TABLE D.9.—*Continued*

Date	Test Plot No.	Furrow No.	Sample No.	pH	Cond. (µmhos/cm)	Ca	Mg	K	Na	SiO_2	Cl	Org. + NH_4	NO_2 + NO_3	Total P (mg/ℓ)
						(mg/ℓ)						(mg/ℓ N)		
02/15/78	10C	2	1	6.5	150	11.8	1.9	0.27	16.2	10.5	20	0.34	3.85	----
02/15/78	10C	9	1	6.7	115	8.2	1.3	0.39	15.0	10.0	22	0.56	1.28	----
02/15/78	11D	2	1	6.4	245	19.0	2.5	0.21	26.1	10.8	32	0.56	8.18	----
02/15/78	11D	9	1	6.5	220	16.3	2.3	0.38	25.2	14.7	32	1.23	5.33	----
02/15/78	12B	2	1	6.7	95	7.3	0.9	0.24	11.1	8.2	16	0.67	0.90	----
02/15/78	12B	9	1	6.7	95	6.8	0.8	0.29	10.5	6.8	16	0.73	0.95	----
03/08/78	10C	2	1	6.7	160	10.9	1.7	0.38	17.1	12.1	26	0.78	1.67	----
03/08/78	10C	9	1	6.8	120	8.2	1.3	0.26	16.2	9.7	21	0.45	1.05	----
03/08/78	11D	2	1	6.5	247	18.1	2.5	0.20	27.0	13.1	40	0.73	5.75	----
03/08/78	11D	9	1	6.4	220	19.5	1.8	0.28	26.4	18.4	38	0.95	2.41	----
03/21/78	10C	2	1	6.9	128	11.3	2.0	0.21	16.8	10.26	25	0.22	0.94	----
03/21/78	10C	9	1	6.9	110	7.4	1.0	0.14	15.9	10.79	23	0.45	2.20	----
03/21/78	11D	2	1	6.6	205	17.2	2.5	0.19	26.1	8.16	37	0.84	1.82	----
03/21/78	11D	9	1	6.7	180	12.7	1.9	0.22	24.9	12.10	35	0.90	5.54	----
03/22/78	12B	2	1	6.9	75	6.8	1.0	0.24	13.5	8.4	18	0.90	0.22	----
03/22/78	12B	9	1	6.8	80	7.7	1.0	0.54	13.5	7.4	19	0.95	0.28	----
03/22/78	13E	2	1	7.3	100	10.9	1.7	0.56	15.0	15.8	15	0.62	1.21	----
03/22/78	13E	9	1	7.4	110	7.3	1.1	0.14	13.8	12.1	14	0.28	0.65	----
03/22/78	14A	2	1	6.8	90	9.1	1.3	0.25	13.2	8.4	15	0.50	0.15	----
03/22/78	14A	9	1	7.0	80	7.3	1.1	0.31	10.2	6.8	15	0.67	0.60	----
03/22/78	20E	2	1	7.0	150	6.8	1.1	0.49	17.4	11.3	14	0.67	0.67	----
03/22/78	20E	9	1	6.9	170	8.2	1.1	0.17	16.2	8.7	15	0.50	0.47	----
03/22/78	22E	--	1	6.8	220	25.4	2.3	0.19	23.4	9.5	33	0.50	0.51	----
04/05/78	20E	2	1	6.6	110	6.3	0.7	0.47	17.7	9.7	13	0.45	0.36	----
04/05/78	20E	9	1	6.7	115	8.2	1.0	0.21	16.8	9.2	15	0.67	0.32	----
04/05/78	22E	--	1	6.6	140	15.4	1.5	0.45	16.8	8.9	15	0.56	0.50	----
04/06/78	12B	2	1	7.0	95	6.3	0.7	0.37	16.2	9.5	17	0.50	0.57	----
04/06/78	12B	9	1	7.0	90	5.4	0.8	0.31	13.8	10.0	19	0.39	0.41	----
04/06/78	13E	2	1	6.6	100	6.3	1.2	0.55	15.6	17.9	14	0.78	0.57	----
04/06/78	13E	9	1	6.6	85	7.3	1.1	0.27	13.8	13.9	14	0.56	0.61	----
04/06/78	14A	2	1	6.6	75	8.6	1.0	0.33	11.7	8.4	14	0.84	0.51	----
04/06/78	14A	9	1	6.7	75	7.3	0.8	0.31	11.1	6.8	14	0.84	0.61	----
04/07/78	10C	2	1	6.8	130	8.2	1.3	0.29	18.6	10.0	21	0.90	0.47	----
04/07/78	10C	9	1	6.9	120	6.8	0.9	0.21	16.8	8.9	19	0.90	1.04	----
04/07/78	11D	2	1	6.6	210	16.3	2.1	0.52	27.6	8.4	32	1.12	5.60	----
04/07/78	11D	9	1	6.7	190	11.8	1.7	0.25	24.6	8.4	31	1.18	1.42	----
05/03/78	10C	2	1	6.9	120	5.0	1.4	0.52	17.4	11.3	18	1.06	0.55	----
05/03/78	10C	9	1	6.8	100	1.8	0.8	0.22	14.4	9.2	16	1.06	1.41	----
05/03/78	11D	2	1	6.7	200	11.8	2.0	0.49	25.5	11.8	36	1.45	3.39	----
05/03/78	11D	9	1	6.8	150	5.4	1.2	0.52	15.9	15.2	25	1.68	0.32	----
05/03/78	12B	2	1	7.1	90	1.4	0.6	0.37	13.8	9.6	16	0.95	0.34	----
05/03/78	12B	9	1	6.9	110	2.7	0.6	0.45	14.7	8.1	22	1.06	0.41	----
06/06/78	14A	2	1	5.7	70	11.8	1.1	0.38	12.0	10.9	14	0.73	0.00	----
06/06/78	14A	9	1	5.8	85	10.0	0.9	0.31	10.8	6.9	16	1.01	0.00	----
06/07/78	12B	2	1	6.1	75	7.2	0.8	0.57	18.0	9.4	10	1.82	0.06	----
06/07/78	12B	9	1	6.3	90	6.3	0.7	0.64	18.6	7.9	21	0.86	0.02	----
06/07/78	10C	2	1	6.4	125	9.1	1.1	0.24	16.2	11.5	19	1.36	0.10	----
06/07/78	10C	9	1	6.7	90	8.2	1.0	0.19	15.6	8.6	19	1.15	0.82	----
06/07/78	11D	2	1	6.4	200	10.9	1.9	0.35	22.2	14.4	29	1.79	----	----
06/07/78	11D	9	1	6.6	150	9.1	1.6	0.28	18.0	17.3	23	1.71	0.16	----
06/06/78	13E	2	1	5.7	90	10.0	1.4	0.47	14.4	15.4	13	0.95	0.00	----
06/06/78	13E	9	1	5.8	80	8.2	1.2	0.35	12.6	12.8	15	1.06	0.00	----
06/06/78	20E	2	1	6.0	90	9.1	0.9	0.52	12.0	10.5	12	0.84	0.00	----
06/06/78	20E	9	1	6.1	85	10.9	1.0	0.42	10.8	8.4	12	0.62	0.00	----
06/06/78	22E	--	1	6.8	100	13.6	1.4	0.45	13.8	8.1	14	0.56	0.00	----
06/27/78	14A	2	1	6.0	75	5.4	0.7	0.26	10.5	11.0	16	0.77	0.00	----
06/27/78	14A	9	1	5.9	80	6.3	0.7	0.39	9.0	8.1	14	0.83	0.00	----
06/28/78	10C	2	1	6.5	180	8.2	1.2	0.38	16.5	11.5	38	0.84	0.01	----
06/28/78	10C	9	1	6.5	105	6.3	1.0	0.19	18.0	9.7	22	0.73	0.01	----
06/28/78	11D	2	1	6.1	190	13.6	1.7	0.41	25.5	16.7	30	1.68	0.04	----
06/28/78	11D	9	1	6.3	155	10.4	1.4	0.28	21.6	17.3	34	1.46	0.01	----
06/27/78	20E	2	1	6.1	90	5.0	0.5	0.35	13.5	10.2	12	0.78	0.00	----
06/27/78	20E	9	1	6.2	80	6.8	0.6	0.26	12.3	----	19	1.23	0.00	----
06/27/78	22E	--	1	6.5	110	18.1	1.7	0.66	12.6	11.8	18	0.62	0.00	----

APPENDIX TABLE D.10. HYDROLOGIC AND NITROGEN ASPECTS IN TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

	DATE	IRRIG. ROUND (No.)	CONDUCTIVITY[1] (μmhos/cm)	IRRIGATION[2]	RAINFALL[3]	CALC. EVAPOTRANSPIRATION[4]	CALC. LEACHATE	N Conc.[5] (mg/ℓ)	N Load (lb/acre)	COMM. FERT. (lb/acre)
				-------------	(in.)	-------------				
					TREATMENT A					
Ditch Water	10/15/76	1	---	2.25	----[a]	----[a]	2.25	-----	----	80 ← 10/14/76
	10/21/76	2	---	2.25	0.03	0.95	1.33	-----	----	
	11/10/76	3	---	2.25	0.53	3.68	-0.90	-----	----	
	11/23/76	4	---	2.29	0.28	2.63	-0.06	-----	----	
	12/07/76	5	---	2.29	0.53	2.15	0.67	-----	----	
	12/22/76	6	---	2.29	0.06	2.20	0.15	-----	----	
	01/11/77	7	---	2.39	0.31	3.35	-0.65	-----	----	80 ← 01/07/77
	02/02/77	8	---	2.45	0.84	3.37	-0.08	-----	----	
	02/16/77	9	---	2.74	0.13	2.44	0.43	-----	----	100 ← 02/15/77
	03/08/77	10	420	3.38	2.29	4.75	0.92	57.82	12.0	
	03/23/77	11	700	4.00	1.18	3.78	1.40	106.32	33.7	
	04/14/77	12	140	3.80	2.97	4.27	2.50	10.10	5.7	
	05/03/77	13	274	3.80	3.60	4.39	3.01	26.56	18.1	70 ← 04/29/77
	--------	14	---	----	----	----	----	-----	----	
	05/24/77	15	230	3.86	5.82	4.99	4.69	17.73	18.8	
	06/08/77	16	118	4.40	1.33	3.44	2.29	6.06	3.1	
	06/22/77	17	127	4.40	0.40	2.62	2.18	7.12	3.5	50 ← 06/13/77
	07/15/77	18	156	4.40	3.96	5.05	3.31	10.03	7.5	
	07/26/77	19	101	4.40	0.04	2.69	1.75	3.61	1.4	
	08/11/77	20	85	4.50	0.17	3.76	0.91	1.51	0.3	
	08/25/77	21	86	4.50	0.29	2.90	1.89	1.58	0.7	
	09/07/77	22	86	4.50	0.43	2.93	2.00	1.48	0.7	
	09/14/77	23	81	4.50	0.02	1.58	2.94	1.21	0.8	
	10/03/77	24	88	4.50	0.26	4.22	0.54	1.52	0.2	
	10/19/77	25	76	4.50	0.36	3.19	1.67	1.85	0.7	
	11/02/77	26	75	4.50	0.58	2.59	2.49	2.94	1.7	
	11/21/77	27	66	4.50	0.55	3.19	1.86	1.21	0.5	
	12/19/77	28	85	4.14	3.91	3.99	4.06	1.78	1.6	
	01/02/78	29	83[b]	5.00	1.67	1.93	4.74	1.60[b]	1.7	
	01/16/78	30	80	5.00	0.37	2.05	3.32	1.41	1.1	
	02/01/78	30A	75	----	----	----	----	1.34	----	
	02/14/78	31	75	5.00	0.56	5.11	0.45	1.12	0.1	
	03/06/78	32	81[b]	5.00	0.99	3.49	2.50	1.03[b]	0.6	
	03/21/78	33	85	5.50	1.03	2.85	3.68	0.96	0.8	
	04/05/78	34	75	5.50	0.38	3.60	2.28	1.40	0.7	
	--------	35	---	----	----	----	----	-----	---	
	05/01/78	36	80[b]	5.50	4.03	4.66	4.87	1.18[b]	1.3	

NOTE: in. × 0.025 4 = cm; lb/acre × 0.000 112 = kg/m^2.

APPENDIX TABLE D.10.—*Continued*

	DATE	IRRIG. ROUND (No.)	CONDUCTIVITY[1] (μmhos/cm)	IRRIGATION[2] (in.)	RAINFALL[3] (in.)	CALC. EVAPOTRANSPIRATION[4] (in.)	CALC. LEACHATE (in.)	N Conc.[5] (mg/ℓ)	N Load (lb/acre)	COMM. FERT. (lb/acre)
Ditch Water	05/16/78	37	83[b]	5.50	1.30	3.16	3.64	1.05[b]	0.8	
	--------	38	---	----	----	----	----	----	---	
	06/06/78	39	87	5.50	3.77	3.22	6.05	0.87	1.2	
	06/27/78	40	78	5.00	1.59	4.39	2.20	0.80	0.4	
	07/18/78	41	78[c]	5.50	1.61	4.77	2.34	0.80[c]	0.4	
	08/08/78	42	70[c]	5.50	1.54	4.52	2.52	0.80[c]	0.5	
	TOTAL			161.28	49.71	128.85	82.14		120.5	
					TREATMENT B					
Ditch Water	10/15/76	1	---	2.25	----[a]	----[a]	2.25	----	---	80 ← 10/14/76
	10/21/76	2	---	2.25	0.03	0.95	1.33	----	---	
	11/10/76	3	---	2.25	0.53	3.68	-0.90	----	---	
	11/23/76	4	---	2.38	0.28	2.63	0.03	----	---	
	12/07/76	5	---	2.31	0.53	2.15	0.69	----	---	
	12/22/76	6	---	2.25	0.06	2.20	0.11	----	---	
	01/11/77	7	---	2.39	0.31	3.35	-0.65	----	---	80 ← 01/07/77
Ditch Water	02/02/77	8	---	3.05	0.84	3.37	0.52	----	---	
	02/16/77	9	---	2.93	0.13	2.44	0.62	----	---	100 ← 02/15/77
	03/08/77	10	164	3.59	2.29	4.75	1.13	16.13	4.1	
	03/23/77	11	165	3.90	1.18	3.78	1.30	10.77	3.2	
	04/14/77	12	99	3.80	2.97	4.27	2.50	2.25	1.3	
	05/03/77	13	155	3.79	3.60	4.39	3.00	4.34	2.9	70 ← 04/29/77
	--------	14	---	----	----	----	----	----	---	
	05/24/77	15	130	3.80	5.82	4.99	4.63	5.15	5.4	
	06/08/77	16	106	4.40	1.33	3.44	2.29	2.79	1.4	
	06/22/77	17	96	4.40	0.40	2.62	2.18	1.05	0.5	
	07/15/77	18	102	4.40	3.96	5.05	3.31	1.12	0.8	
	07/26/77	19	95	4.40	0.04	2.69	1.75	1.61	0.6	
	08/11/77	20	108	4.50	0.17	3.76	0.91	1.51	0.3	
	08/25/77	21	86	4.50	0.29	2.90	1.89	1.76	0.8	
	09/07/77	22	94	4.50	0.43	2.93	2.00	4.11	1.9	
	09/14/77	23	105	4.50	0.02	1.58	2.94	2.32	1.5	
	10/03/77	24	100	4.50	0.26	4.22	0.54	2.52	0.3	
	10/19/77	25	95	4.50	0.36	3.19	1.67	4.07	1.5	
	11/02/77	26	140	4.50	0.58	2.59	2.49	2.34	1.3	
	11/21/77	27	75	4.50	0.55	3.19	1.86	2.48	1.0	
	12/19/77	28	115	3.95	3.91	3.99	3.87	2.02	1.8	

NOTE: in. × 0.025 4 = cm; lb/acre × 0.000 112 = kg/m².

APPENDIX TABLE D.10.—*Continued*

	DATE	IRRIG. ROUND (No.)	CONDUCTIVITY[1] (µmhos/cm)	IRRIGATION[2]	RAINFALL[3]	CALC. EVAPOTRANSPIRATION[4]	CALC. LEACHATE	N Conc.[5] (mg/ℓ)	N Load (lb/acre)	COMM. FERT. (lb/acre)
				(in.)	(in.)	(in.)	(in.)			
12½% Effluent	01/02/78	29	110[b]	4.96	1.67	1.93	4.70	1.92[d]	2.0	
	01/16/78	30	105[b]	4.96	0.37	2.05	3.28	1.82[d]	1.4	
	02/01/78	30A	80	----	----	----	----	2.07	---	
	02/14/78	31	95	4.96	0.56	5.11	0.41	1.62	0.2	
	03/06/78	32	85[b]	4.96	0.99	3.49	2.46	1.37[b]	0.8	
	03/21/78	33	78	5.50	1.03	2.85	3.68	1.18	1.0	
	04/05/78	34	93	5.50	0.38	3.60	2.28	0.94	0.5	
	--------	35	---	----	----	----	----	----	---	
	05/01/78	36	100	5.50	4.03	4.66	4.87	1.38	1.5	
	05/16/78	37	95[b]	5.50	1.30	3.16	3.64	1.38[b]	1.1	
	--------	38	---	----	----	----	----	----	---	
	06/06/78	39	88	5.50	3.77	3.22	6.05	1.38	1.1	
	06/27/78	40	88[c]	4.96	1.59	4.39	2.16	1.38[c]	0.7	
	07/18/78	41	88[c]	5.50	1.61	4.77	2.34	1.38[c]	0.7	
	08/08/78	42	88[c]	5.50	1.54	4.52	2.52	1.38[c]	0.8	
	TOTAL			161.79	49.71	128.85	82.65		42.3	
					TREATMENT C					
Ditch Water	10/15/76	1	---	2.25	----[a]	----[a]	2.25	----	---	80 ← 10/14/76
	10/21/76	2	---	2.25	0.03	0.95	1.33	----	---	
	11/10/76	3	---	2.25	0.53	3.68	-0.90	----	---	
	11/23/76	4	---	2.28	0.28	2.63	-0.07	----	---	
	12/07/76	5	---	2.36	0.53	2.15	0.74	----	---	
	12/22/76	6	---	2.28	0.06	2.20	0.14	----	---	
	01/11/77	7	---	2.28	0.31	3.35	-0.76	----	---	80 ← 01/07/77
25% Effluent	02/02/77	8	---	2.84	0.84	3.37	0.31	----	---	
	02/16/77	9	---	2.67	0.13	2.44	0.36	----	---	80 ← 02/15/77
	03/08/77	10	140	3.20	2.29	4.75	0.74	18.78	3.1	
	03/23/77	11	144	1.96	1.18	3.78	-0.64	7.09	-1.0	
	04/14/77	12	139	3.16	2.97	4.27	1.86	2.87	1.2	
	05/03/77	13	199	3.79	3.60	4.39	3.00	6.81	4.6	50 ← 04/29/77
	--------	14	---	----	----	----	----	----	---	
	05/24/77	15	256	3.80	5.82	4.99	4.63	17.91	18.8	
	06/08/77	16	141	4.40	1.33	3.44	2.29	5.54	2.9	
	06/22/77	17	134	4.40	0.40	2.62	2.18	4.71	2.3	
	07/15/77	18	147	4.40	3.96	5.05	3.31	2.81	2.1	
	07/26/77	19	123	4.40	0.04	2.69	1.75	3.09	1.2	

NOTE: in. × 0.025 4 = cm; lb/acre × 0.000 112 = kg/m^2.

APPENDIX TABLE D.10.—*Continued*

	DATE	IRRIG. ROUND (No.)	CONDUCTIVITY[1] (µmhos/cm)	IRRIGATION[2] (in.)	RAINFALL[3] (in.)	CALC. EVAPOTRANSPIRATION[4] (in.)	CALC. LEACHATE (in.)	N Conc.[5] (mg/ℓ)	N Load (lb/acre)	COMM. FERT. (lb/acre)
	08/11/77	20	142	4.50	0.17	3.76	0.91	2.62	0.5	
	08/25/77	21	121	4.50	0.29	2.90	1.89	4.07	1.7	
	09/07/77	22	94	4.50	0.43	2.93	2.00	5.11	2.3	
	09/14/77	23	181	4.50	0.02	1.58	2.94	5.94	4.0	
	10/03/77	24	145	4.50	0.26	4.22	0.54	4.63	0.6	
	10/19/77	25	134	4.50	0.36	3.19	1.67	4.21	1.6	
	11/02/77	26	120	4.50	0.58	2.59	2.49	4.24	2.4	
	11/21/77	27	119	4.50	0.55	3.19	1.86	4.37	1.8	
	12/19/77	28	138	3.99	3.91	3.99	3.91	2.76	2.4	
	01/02/78	29	140[b]	5.00	1.67	1.93	4.74	3.26[b]	3.5	
	01/16/78	30	143	5.00	0.37	2.05	3.32	3.75	2.8	
25% Effluent	02/01/78	30A	131	----	----	----	----	3.67	---	
	02/14/78	31	133	5.00	0.56	5.11	0.45	3.02	0.3	
	03/06/78	32	140	5.00	0.99	3.49	2.50	1.98	1.1	
	03/21/78	33	119	5.50	1.03	2.85	3.68	1.91	1.6	
	04/05/78	34	125	5.50	0.38	3.60	2.28	1.66	0.9	
	--------	35	---	----	----	----	----	----	---	
	05/01/78	36	110	5.50	4.03	4.66	4.87	2.04	2.3	
	05/16/78	37	109[b]	5.50	1.30	3.16	3.64	1.91[b]	1.6	
	--------	38	---	----	----	----	----	----	---	
	06/06/78	39	108	5.50	3.77	3.22	6.05	1.72	2.4	
	06/27/78	40	143	5.00	1.59	4.39	2.20	0.80	0.4	
	07/18/78	41	143[c]	5.50	1.61	4.77	2.34	0.80[c]	0.4	
	08/08/78	42	143[c]	5.50	1.54	4.52	2.52	0.80[c]	0.5	
	TOTAL			158.46	49.71	128.85	79.32		68.7	
					TREATMENT D					
	10/15/76	1	---	2.25	----[a]	----[a]	2.25	----	---	80 10/14/76
	10/21/76	2	---	2.25	0.03	0.95	1.33	----	---	
	11/10/76	3	---	2.25	0.53	3.68	-0.90	----	---	
Ditch Water	11/23/76	4	---	2.34	0.28	2.63	-0.01	----	---	
	12/07/76	5	---	2.30	0.53	2.15	0.68	----	---	
	12/22/76	6	---	2.28	0.06	2.20	0.14	----	---	
	01/11/77	7	---	2.35	0.31	3.35	-0.69	----	---	70 01/07/77
	02/02/77	8	---	3.01	0.84	3.37	0.48	----	---	
	02/16/77	9	---	2.74	0.13	2.44	0.43	----	---	60 02/15/77

NOTE: in. × 0.025 4 = cm; lb/acre × 0.000 112 = kg/m^2.

APPENDIX TABLE D.10.—*Continued*

50% Effluent

DATE	IRRIG. ROUND (No.)	CONDUCTIVITY[1] (µmhos/cm)	IRRIGATION[2] (in.)	RAINFALL[3] (in.)	CALC. EVAPOTRANSPIRATION[4] (in.)	CALC. LEACHATE (in.)	N Conc.[5] (mg/ℓ)	N Load (lb/acre)	COMM. FERT. (lb/acre)
03/08/77	10	235	3.22	2.29	4.75	0.76	30.99	5.3	
03/23/77	11	930	2.07	1.18	3.78	-0.53	22.37	-2.7	
04/14/77	12	285	3.80	2.97	4.27	2.50	8.30	4.7	
05/03/77	13	223	3.80	3.60	4.39	3.01	4.09	2.8	
--------	14	---	----	----	----	----	----	---	
05/24/77	15	260	3.80	5.82	4.99	4.63	13.37	14.0	
06/08/77	16	233	4.40	1.33	3.44	2.29	10.00	5.2	
06/22/77	17	178	4.40	0.40	2.62	2.18	10.64	5.3	
07/15/77	18	202	4.40	3.96	5.05	3.31	3.95	3.0	
07/26/77	19	230	4.40	0.04	2.69	1.75	9.35	3.7	
08/11/77	20	195	4.50	0.17	3.76	0.91	4.44	0.9	
08/25/77	21	213	4.50	0.29	2.90	1.89	9.13	3.9	
09/07/77	22	238	4.50	0.43	2.93	2.00	11.24	5.1	
09/14/77	23	256	4.50	0.02	1.58	2.94	12.39	8.3	
10/03/77	24	245	4.50	0.26	4.22	0.54	12.21	1.5	
10/19/77	25	225	4.50	0.36	3.19	1.67	12.04	4.6	
11/02/77	26	208	4.61	0.58	2.59	2.60	10.51	6.2	
11/21/77	27	214	4.50	0.55	3.19	1.86	14.41	6.1	
12/19/77	28	183	4.36	3.91	3.99	4.28	5.72	5.5	
01/02/78	29	212[b]	5.00	1.67	1.93	4.74	7.05[b]	7.6	
01/16/78	30	240	5.00	0.37	2.05	3.32	8.38	6.3	
02/01/78	30A	224	----	----	----	----	8.14	---	
02/14/78	31	232	5.00	0.56	5.11	0.45	7.65	0.8	
03/06/78	32	234	5.00	0.99	3.49	2.50	4.92	2.8	
03/21/78	33	193	5.50	1.03	2.85	3.68	4.55	3.8	
04/05/78	34	200	5.50	0.38	3.60	2.28	4.66	2.4	
--------	35	---	----	----	----	----	----	---	
05/01/78	36	175	5.50	4.03	4.66	4.87	3.42	3.8	
05/16/78	37	175[b]	5.50	1.30	3.16	3.64	2.77[b]	2.3	
--------	38	---	----	----	----	----	----	---	
06/06/78	39	175	5.50	3.77	3.22	6.05	1.87	2.6	
06/27/78	40	173	5.00	1.59	4.39	2.20	1.60	0.8	
07/18/78	41	173[c]	5.50	1.61	4.77	2.34	1.60[c]	0.8	
08/08/78	42	173[c]	5.50	1.54	4.52	2.52	1.60[c]	0.9	
TOTAL			160.03	49.71	128.85	80.89		118.3	

NOTE: in. × 0.025 4 = cm; lb/acre × 0.000 112 = kg/m^2.

APPENDIX TABLE D.10.—*Continued*

	DATE	IRRIG. ROUND (No.)	CONDUCTIVITY (µmhos/cm)	IRRIGATION (in.)	RAINFALL (in.)	CALC. EVAPOTRANSPIRATION (in.)	CALC. LEACHATE (in.)	N Conc.[s] (mg/ℓ)	N Load (lb/acre)	COMM. FERT. (lb/acre)
					TREATMENT E					
Ditch Water	10/15/76	1	---	2.25	----[a]	----[a]	2.25	-----	---	80 10/14/76
	10/21/76	2	---	2.25	0.03	0.95	1.33	-----	---	
	11/10/76	3	---	2.25	0.53	3.68	-0.90	-----	---	
	11/23/76	4	---	2.32	0.28	2.63	-0.03	-----	---	
	12/07/76	5	---	2.29	0.53	2.15	0.67	-----	---	
	12/22/76	6	---	2.27	0.06	2.20	0.13	-----	---	
	01/11/77	7	---	2.27	0.31	3.35	-0.77	-----	---	50 01/07/77
100% Effluent	02/02/77	8	---	2.93	0.84	3.37	0.40	-----	---	
	02/16/77	9	---	2.70	0.13	2.44	0.39	-----	---	
	03/08/77	10	495	3.25	2.29	4.75	0.79	19.05	3.4	
	03/23/77	11	320	4.00	1.18	3.78	1.40	12.44	3.9	
	04/14/77	12	238	3.80	2.97	4.27	2.50	8.11	4.6	
	05/03/77	13	384	3.80	3.60	4.39	3.01	38.62	26.3	
	--------	14	---	----	----	----	----	-----	---	
	05/24/77	15	549	4.04	5.82	4.99	4.87	42.88	47.3	
	06/08/77	16	371	4.40	1.33	3.44	2.29	22.50	11.7	
	06/22/77	17	178	4.40	0.40	2.62	2.18	21.36	10.5	
	07/15/77	18	340	4.40	3.96	5.05	3.31	14.22	10.7	
	07/26/77	19	371	4.40	0.04	2.69	1.75	20.46	8.1	
	08/11/77	20	348	4.50	0.17	3.76	0.91	17.13	3.5	
	08/25/77	21	378	4.50	0.29	2.90	1.89	18.73	9.4	
	09/07/77	22	458	4.50	0.43	2.93	2.00	22.73	10.3	
	09/14/77	23	505	4.50	0.02	1.58	2.94	26.96	18.0	
	10/03/77	24	440	4.50	0.26	4.22	0.54	28.09	3.4	
	10/19/77	25	455	4.50	0.36	3.19	1.67	28.35	10.7	
	11/02/77	26	280	4.50	0.58	2.59	2.49	45.89	25.9	
Ditch Water	11/21/77	27	190	4.62	0.55	3.19	1.98	8.44	3.8	
	12/19/77	28	285	4.41	3.91	3.99	4.33	4.17	4.1	
	01/02/78	29	230[b]	5.00	1.67	1.93	4.74	4.73[b]	5.1	
	01/16/78	30	174	5.00	0.37	2.05	3.32	5.29	4.0	
	02/01/78	30A	130	----	----	----	----	2.05	---	
	02/14/78	31	145	5.00	0.56	5.11	0.45	1.23	0.1	
	03/06/78	32	138[b]	5.00	0.99	3.49	2.50	1.10[b]	0.6	
	03/21/78	33	150	5.50	1.03	2.85	3.68	1.01	0.8	
	04/05/78	34	110	5.50	0.38	3.60	2.28	1.06	0.5	
	--------	35	---	----	----	----	----	-----	---	
	05/01/78	36	102[b]	5.50	4.03	4.66	4.87	0.95[b]	1.0	

NOTE: in. × 0.025 4 = cm; lb/acre × 0.000 112 = kg/m^2.

APPENDIX TABLE D.10.—*Continued*

	DATE	IRRIG. ROUND (No.)	CONDUCTIVITY[1] (µmhos/cm)	IRRIGATION[2] (in.)	RAINFALL[3] (in.)	CALC. EVAPOTRANSPIRATION[4] (in.)	CALC. LEACHATE (in.)	N Conc.[5] (mg/ℓ)	N Load (lb/acre)	COMM. FERT. (lb/acre)
↑ Ditch Water ↓	05/16/78	37	97[b]	5.50	1.30	3.16	3.64	0.91[b]	0.8	
	--------	38	---	----	----	----	----	----	---	
	06/06/78	39	90	5.50	3.77	3.22	6.05	0.84	1.2	
	06/27/78	40	90	5.00	1.59	4.39	2.20	0.78	0.4	
	07/18/78	41	90[c]	5.50	1.61	4.77	2.34	0.78[c]	0.4	
	08/08/78	42	90[c]	5.50	1.54	4.52	2.52	0.78[c]	0.4	
	TOTAL			162.05	49.71	128.85	82.91		230.9	

NOTE: in. × 0.025 4 = cm; lb/acre × 0.000 112 = kg/m².

[1]Median values.

[2]Data from Appendix Table D.1.

[3]Data from Table 6. Rainfall occurring between irrigation rounds added to the following round.

[4]Evaporation pan data × 0.8 estimated to be equal to evapotranspiration from test plots. Evaporation pan data from the U.S. Weather Bureau Class "A" Evaporation Pan mounted approximately 5 ft above the ground located at the test plots (Fig. 2).

[5]Median total N values (org. + NH_4 + NO_2 + NO_3) from Appendix Table D.6.

[a]Values from 10/15/76 to 10/21/76 included in 10/21/76 column, Irrigation Round 2.

[b]Prorated between preceding and following values.

[c]Assumed the same as preceding value.

[d]Prorated between 12/19/77 and 02/14/78.

APPENDIX TABLE D.11. AVERAGE ANALYSIS OF CROP LOG SAMPLES IN TEST PLOTS, OSC FIELD NO. 246, O'AHU, HAWAI'I

1977	CROP AGE (mo)	TREATMENT[a]	BLADE N (as % Dry Matter)	SHEATH: AVG. SHEATH WT. (g/Stalk)	SHEATH: H_2O (as % Wet Wt.)	SHEATH: Total Sugar (as % Dry Wt.)	SHEATH: Index P-IX (as % Sugar-Free Dry Wt.)	SHEATH: Index K-IX (as % Sugar-Free Dry Wt.)	SHEATH: Index Ca-IX (as % Sugar-Free Dry Wt.)	SHEATH: Index Mg-IX (as % Sugar-Free Dry Wt.)	SHEATH: $K-H_2O$ (K as % Sheath Moisture)
01/19	3.1	A	2.71	59.7	86.9	13.9	0.113	3.35	0.41	0.333	0.43
		B	2.71	62.0	86.6	14.3	0.099	2.93	0.43	0.339	0.39
		C	2.67	60.9	87.4	14.3	0.113	3.36	0.43	0.341	0 41
		D	2.72	64.5	87.1	14.6	0.096	3.25	0.40	0.332	0.41
		E	2.72	64.5	87.1	14.6	0.096	3.25	0.40	0.332	0.41
03/04	3.5	A	2.47	91.7	86.4	16.1	0.152	3.44	0.37	0.262	0.45
		B	2.31	90.9	86.6	15.7	0.150	3.42	0.39	0.263	0.44
		C	2.45	81.3	85.9	15.4	0.132	3.50	0.40	0.265	0.47
		D	2.17	83.5	86.0	13.7	0.125	3.33	0.40	2.66	0.46
		E	2.17	83.5	86.0	13.7	0.125	3.33	0.40	2.66	0.46
03/31	5.5	A	2.34	101.8	88.3	10.9	0.137	3.23	0.31	0.236	0.37
		B	2.32	105.3	88.3	12.0	0.136	3.24	0.29	0.246	0.37
		C	2.28	110.5	88.2	11.2	0.131	3.30	0.27	0.218	0.39
		D	2.34	104.3	88.2	10.6	0.141	3.37	0.31	0.242	0.40
		E	2.35	109.0	88.7	10.6	0.139	3.35	0.29	0.222	0.37
05/05	6.6	A	2.18	105.3	86.8	12.6	0.107	2.66	0.40	0.262	0.35
		B	2.08	115.3	86.5	13.6	0.108	2.52	0.38	0.238	0.33
		C	2.23	106.2	87.1	11.4	0.108	3.18	0.38	0.231	0.41
		D	2.20	111.9	87.0	12.8	0.124	3.07	0.42	0.258	0.39
		E	2.32	113.1	86.9	11.4	0.109	3.15	0.39	0.232	0.41
06/09	7.8	A	2.29	97.9	86.7	9.6	0.094	2.79	0.29	0.205	0.38
		B	2.21	93.9	86.2	9.9	0.089	2.67	0.32	0.210	0.38
		C	2.37	93.7	86.2	10.5	0.093	2.74	0.30	0.198	0.39
		D	2.42	92.9	86.2	10.4	0.100	2.98	0.34	0.206	0.42
		E	2.37	93.2	86.6	9.4	0.101	2.96	0.34	0.211	0.4
07/14	8.9	A	1.33	84.6	85.3	11.9	0.103	2.78	0.25	0.164	0.42
		B	1.76	79.8	84.4	13.2	0.117	2.97	0.29	0.187	0.47
		C	1.45	88.3	84.7	12.4	0.140	3.19	0.30	0.191	0.50
		D	1.59	91.4	84.1	13.6	0.118	2.93	0.28	0.174	0.47
		E	1.70	92.4	85.3	11.9	0.134	3.21	0.29	0.170	0.48
08/19	10.1	A	1.53	88.1	85.4	11.8	0.103	2.89	0.26	0.168	0.43
		B	1.37	85.9	84.6	11.4	0.090	2.52	0.28	0.176	0.40
		C	1.52	90.6	85.4	11.3	0.088	2.65	0.25	0.158	0.40
		D	1.55	92.9	85.9	12.2	0.107	2.81	0.28	0.170	0.40
		E	1.67	91.5	85.3	11.9	0.096	2.74	0.28	0.160	0.41
09/22	11.2	A	1.84	86.3	85.3	9.8	0.093	2.90	0.26	0.158	0.45
		B	1.86	80.4	85.6	9.8	0.103	3.18	0.29	0.170	0.48
		C	1.75	84.0	85.0	12.1	0.108	2.96	0.30	0.175	0.45
		D	2.00	86.2	83.5	11.5	0.105	3.01	0.32	0.178	0.52
		E	1.97	88.8	85.3	11.9	0.098	3.05	0.28	0.162	0.46
10/27	12.4	A	1.79	76.8	84.8	9.8	0.092	3.21	0.31	0.172	0.51
		B	1.74	74.5	85.3	9.8	0.114	3.15	0.35	0.194	0.48
		C	1.84	80.6	85.5	9.8	0.130	3.22	0.36	0.191	0.48
		D	1.92	84.0	85.7	10.3	0.120	3.22	0.39	0.217	0.48
		E	1.89	78.1	85.4	9.1	0.101	3.27	0.38	0.197	0.50

1978	CROP AGE (mo)	TREATMENT[a]	BLADE N (as % Dry Matter)	SHEATH: AVG. SHEATH WT. (g/Stalk)	SHEATH: H_2O (as % Wet Wt.)	SHEATH: Total Sugar (as % Dry Wt.)	SHEATH: Index P-IX (as % Sugar Free Dry Wt.)	SHEATH: Index K-IX (as % Sugar Free Dry Wt.)	SHEATH: Index Ca-IX (as % Sugar Free Dry Wt.)	SHEATH: Index Mg-IX (as % Sugar Free Dry Wt.)	SHEATH: $K-H_2O$ (K as % Sheath Moisture)
01/12	14.9	A	1.83	73.6	85.3	11.8	0.115	3.43	0.33	0.139	0.53
		B	1.96	70.1	85.3	11.4	0.099	3.19	0.35	0.153	0.48
		C	2.01	70.1	85.8	11.0	0.096	3.51	0.33	0.142	0.51
		D	1.85	66.1	86.4	10.5	0.095	3.18	0.37	0.158	0.44
		E	2.09	77.0	85.9	11.3	0.105	3.29	0.36	0.150	0.47
02/16	16.0	A	1.80	68.0	84.2	12.8	0.087	3.31	0.32	0.145	0.53
		B	1.86	70.0	84.0	13.4	0.076	2.92	0.31	0.142	0.47
		C	1.98	66.7	85.2	10.9	0.072	3.40	0.32	0.146	0.52
		D	1.94	68.0	85.1	12.3	0.084	3.18	0.34	0.157	0.48
		E	1.98	66.5	85.8	9.3	0.066	3.25	0.36	0.158	0.48
03/23	17.2	A	1.77	59.6	83.6	13.0	0.087	2.55	0.28	0.167	0.43
		B	1.83	67.3	82.0	13.0	0.079	2.43	0.26	0.151	0.45
		C	1.85	69.0	83.1	15.8	0.087	2.86	0.26	0.161	0.48
		D	2.09	68.3	82.7	13.9	0.089	2.89	0.27	0.159	0.51
		E	1.97	68.9	84.1	13.2	0.084	2.64	0.29	0.173	0.43
04/22	18.2	A	1.66	74.3	82.3	11.8	0.083	2.67	0.28	0.121	0.50
		B	1.61	76.1	82.7	11.9	0.094	2.81	0.30	0.123	0.51
		C	1.69	72.1	83.3	12.0	0.083	2.51	0.27	0.120	0.44
		D	1.70	76.1	83.4	12.9	0.081	2.38	0.27	0.116	0.40
		E	1.75	76.6	83.8	11.6	0.065	[illegible]93	0.28	0.129	0.32
06/01	19.5	A	1.57	71.1	83.3	12.1	0.085	2.01	0.24	0.153	0.35
		B	1.47	68.0	84.5	11.1	0.081	1.92	0.27	0.174	0.30
		C	1.54	74.8	85.0	11.9	0.089	2.21	0.25	0.160	0.34
		D	1.65	81.5	85.4	11.7	0.102	2.30	0.26	0.158	0.34
		E	1.62	84.3	84.7	11.5	0.089	2.19	0.[illegible]4	0.137	0.35

SOURCE: Hawaiian Sugar Planters' Association Crop Science Dept.

[a]Plots included in Treatment: A = 4, 18, 30; B = 12, 16, 23; C = 6, 17, 27; D = 2, 19, 24; E = 3, 13, 20.

APPENDIX TABLE D.12. CROP HARVEST DATA, OAHU SUGAR CO. FIELD NO. 246, 17 OCTOBER 1978

TREATMENT	Plot	REFRACTOMETER SOLIDS[1]	POL[2]	PURITY[3]	FIBER[4]	CANE YIELD	CANE RATIO[6]	YIELD % CANE[7]	SUGAR YIELD
		-----	----- (%)	-----	-----	(TCA)[5]		(%)	(ETSA)[8]
A	1	18.4	16.1	87.7	12.5	137.6	7.4	13.5	18.5
	4	18.1	15.6	86.0	12.5	147.9	7.8	12.8	19.0
	14	19.6	16.8	85.9	12.4	129.7	7.2	13.9	18.0
	18	17.8	15.2	85.5	11.4	146.0	7.9	12.6	18.4
	21	18.9	16.7	88.0	12.7	149.6	7.2	13.9	20.8
	30	17.0	14.3	84.0	12.4	139.1	8.6	11.6	16.1
Total		109.9	94.7	516.9	73.8	849.9		78.4	110.9
Mean		18.3	15.8	86.2	12.3	141.6	7.7	13.1	18.5
B	9	19.2	16.9	88.1	11.7	141.1	7.0	14.3	20.2
	12	16.6	13.8	82.7	11.2	133.5	9.0	11.2	14.9
	15	18.1	15.4	85.0	11.9	143.6	7.9	12.6	18.1
	16	17.9	15.5	86.5	12.0	149.7	7.7	12.9	19.3
	23	16.7	14.2	85.0	12.1	144.1	8.6	11.7	16.8
	26	17.5	15.2	86.6	12.2	152.7	7.9	12.6	19.3
Total		106.0	90.9	514.0	71.1	864.7		75.3	108.6
Mean		17.7	15.1	85.7	11.9	144.1	8.0	12.5	18.1
C	6	17.4	15.0	85.8	12.1	161.0	8.1	12.4	19.9
	8	16.7	13.7	81.9	11.6	153.8	9.1	11.0	16.9
	10	18.2	15.5	85.0	12.2	156.1	7.9	12.7	19.8
	17	16.8	13.7	81.5	10.8	153.8	9.1	11.0	17.0
	25	17.9	15.7	87.4	11.5	164.4	7.6	13.2	21.7
	27	17.2	14.2	82.6	12.1	138.4	8.8	11.4	15.8
Total		104.2	87.6	504.3	70.4	927.6		71.7	111.0
Mean		17.4	14.6	84.0	11.7	154.6	8.4	11.9	18.5
D	2	17.2	14.3	83.1	12.3	138.9	8.7	11.5	16.0
	7	17.2	14.5	84.1	10.9	152.9	8.4	12.0	18.3
	11	16.2	12.0	73.9	11.9	152.2	11.4	8.8	13.3
	19	16.6	13.0	78.1	11.8	161.8	10.0	10.0	16.2
	24	17.8	15.1	85.0	11.8	150.5	8.0	12.5	18.8
	29	17.6	13.9	79.3	12.2	143.0	9.3	10.8	15.5
Total		102.7	82.9	483.5	70.9	899.4		65.5	98.0
Mean		17.1	13.8	80.6	11.8	149.9	9.3	10.9	16.3
E	3	17.8	15.7	88.0	11.9	155.7	7.6	13.2	20.6
	5	16.2	13.1	81.3	11.7	163.0	9.6	10.5	17.0
	13	18.0	15.4	85.8	12.5	151.7	7.9	12.7	19.3
	20	19.0	16.1	84.6	12.4	145.8	7.6	13.1	19.1
	22	17.4	14.9	85.8	12.5	139.2	8.1	12.3	17.1
	28	18.4	15.4	83.7	12.1	140.9	8.0	12.5	17.6
Total		106.8	90.7	509.2	73.2	896.3		74.3	110.7
Mean		17.8	15.1	84.9	12.2	149.4	8.1	12.4	18.5

SOURCE: Oahu Sugar Company, Limited.

[1]Percent by weight in juice.

[2]Sucrose percent by weight in juice.

[3](POL/refractometer solids) × 100.

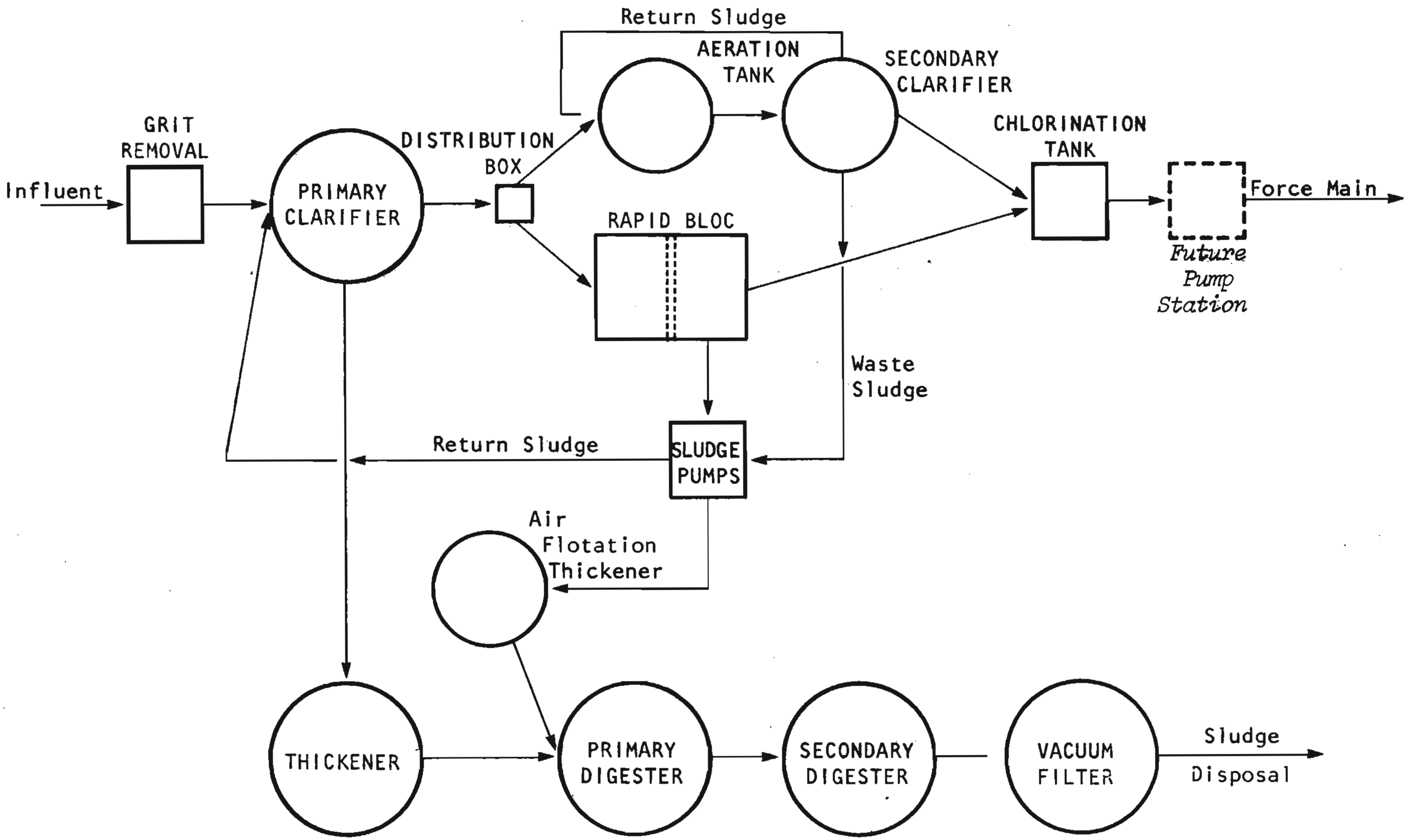
[4]Percent by weight dry fiber in wet cane.

[5]Tons of wet cane/acre.

[6][97.5/(POL × extraction/100 × recovery/100)] × 1/factor. Extraction = 94.5/100; Recovery = S(J-M)/J(S-M); S = sugar purity = POL/(100-sugar moisture) = 98.7; J = juice purity = POL/refractory solids; M = molasses purity = 35.5; factor = 96° conversion = 1[1 + .0175(POL-96)].

[7]100/cane ratio.

[8]Estimated tons sugar per acre = TCA/cane ratio.



Appendix Figure E.1. Schematic flow diagram of Mililani STP

APPENDIX F. PUBLICATIONS AND PRESENTATIONS

1971

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1972

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1973

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1974

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1975

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1977

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1978

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