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Managing Water Supply Operations in the Caribbean

Lessons from the U.S. Virgin Islands

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This paper describes the characteristics and problems of water resources and water supply systems in the United States Virgin Islands and indicates the ways in which those are shared by other small islands of the Caribbean and West Atlantic. The history of development of the water supply, including groundwater, desalination and barging, is described as well as supply and demand factors and management of the system. Institutional issues are discussed and the applicability of Virgin Island experience to other islands is analyzed.

Cet article décrit les caractéristiques et les problèmes des ressources aquifères et des réseaux de distribution d'eau dans les Iles Vierges américaines. Il montre la façon dont les autres petites îles des Caraïbes et de l'Atlantique occidental partagent ces ressources et réseaux de distribution. L'article fait l'historique de l'approvisionnement en eau, y compris les eaux souterraines et décrit la dessalinisation et le transport par barges. Il étudie également l'offre et la demande et les problèmes de gestion. Il examine les questions institutionnelles et analyse la manière dont l'expérience des Iles Vierges peut être appliquée aux autres îles.

Este artículo describe las características y los problemas del suministro y recursos de agua en las Islas Virgenes (USA) e indica como los mismos problemas se encuentran en otras pequeñas islas del Caribe y el Atlántico Oriental. El artículo cubre el desarrollo histórico del suministro de agua, incluyendo agua subterranea, desalinización y transporte marítimo de agua, y analiza los aspectos de la oferta y la demanda de agua y la administración de los sistemas de suministro. Se discute también los aspectos institucionales y la posible aplicación de la experiencia ganada en otras áreas geográficas.

1. INTRODUCTION

The U.S. Virgin Islands and other small islands of the Caribbean and West Atlantic share both common characteristics and common problems with respect to water resources and, in particular, operations of water supply systems. Located about 1100 miles east-southeast of Miami, Florida, and 500 miles north-northeast of Caracas, Venezuela, the U.S. Virgin Islands consist of more than 40 islands and cays. The inhabited islands are St. Thomas, St. Croix, and St. John whose respective land areas are approximately 32, 84, and 19 square miles. Their respective 1980 census populations are 44 170, 49 280 and 2480. St. Thomas and St. John are composed almost entirely of steep rocky mountains of volcanic origin, some rising 1000 to 1500 feet. In St. Croix, several mountains rise over 1000 feet in altitude but about half of this island's land area is composed of largely alluvial flatlands. The islands display diverse ecosystems ranging from beaches and dry thorn scrub of the lowlands to the deciduous

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forests of the higher elevations (Forman, 1974).

Monthly mean temperatures, ranging from 73°F to 83°F, are moderated by easterly trade winds. The average annual rainfall overall is 44 inches per year, distributed between 50 to 60 inches at the higher elevations and 20 to 30 inches at lower elevations. Rainfall is highly variable on a monthly basis however and from year to year, and potential evaporation rates exceed annual rainfall. Only small percentages of rainfall enter the groundwater regime or become runoff; the rest returns to the atmosphere by evapotranspiration. A few streams with drainage areas up to about 10 square miles flow intermittently on each island. Groundwater is a limited resource and is often mineralized as the high evapotranspiration rates concentrate chlorides and other minerals in the groundwater. There have also been incidences of salt water intrusion and septic tank contamination (Francois, 1980).

Many islands of the Caribbean and West Atlantic share in common some of the basic operating conditions and problems found in the water supply system of the U.S. Virgin Islands. For example, barging is presently being practised in the Grenadines and the Bahamas due to growing demand for potable water, limited water resources, and deteriorating distribution systems. Rationing has been necessary in the British Virgin Islands and Antigua. Other islands such as the Cayman Islands, St. Kitts, Nevis, and St. Lucia will need additional resources, capital improvements, and improved operations and maintenance to meet the growing demands resulting from agriculture, industry, and tourism (Hadwen, 1980).

Some of the problems encountered in Caribbean islands are listed below. The occurrence of these problems in the Virgin Islands will be illustrated in the following discussion:

Limited sources of fresh water and rapidly growing demand;
Power water accountability and revenue collection;
Deterioration of distribution facilities;
Insufficient and poorly sited storage capacity;
Need to upgrade the skills and capabilities of operators;
Difficulty in recruiting and retaining engineering personnel;
Fragmentation of water supply functions among many authorities and lack of coordinated planning and management;
Fiscal policy which does not reflect the true cost of water in pricing.

These problems and others are presently being dealt with in the Virgin Islands. While much progress is still needed, the experience and lessons learned in the Virgin Islands may be instructive to professionals facing similar problems on other islands of the Caribbean and West Atlantic. To understand some of these problems, it is helpful to review the historic development of Virgin Islands water supply operations.

2. HISTORY OF DEVELOPMENT

The booming population growth of the 1960s and early 1970s (see Table I), precipitated by the switch from an agrarian-based economy to one based on industry and tourism, created unprecedented demands on the public water supply system. The problem was exacerbated by water losses due to the deteriorating condition of the public distribution system, large portions of which were installed in the 1930s and were badly corroded due to their saline environment. Desalination was introduced during this period by the Virgin Islands Water and Power Authority (VIWAPA) to supplement the existing groundwater and cistern sources. Aided by marginal increases in groundwater production the overall result, as shown in Fig. 1, was a dramatic increase over a short period of time in the amount of water being supplied. The increased water production represented a more than doubling of capacity and introduced new challenges to the operating authorities.

Capacity continued to expand through the 1970s primarily through desalination, but the ageing of the desalination plants in the late 1970s coupled with difficulty in obtaining replacement parts and lack of adequate maintenance programs resulted in long periods of down-time. Combined with periods of drought, overpumping of well fields, periodic failure of the distribution system, and the lack of adequate storage capacity, failures of the desalination units resulted in frequent shortages and rationing of water. During 1979-1980, the Government of the Virgin Islands was forced to resort to barging water from neighbor-

TABLE I
Virgin Islands population growth 1960–1981

Year	St. Thomas	St. Croix	St. John	Totals
1960	16 201	14 973	925	32 099
1970	37 285	35 945	1921	75 151
1971	38 365	37 960	1985	78 310
1972	39 360	39 870	2050	81 280
1973	40 180	40 950	2100	83 230
1974	40 665	41 920	2145	84 730
1975	40 950	42 690	2190	85 830
1976	41 280	43 600	2230	87 120
1977	41 900	44 845	2295	89 040
1978	42 615	46 210	2355	91 180
1979	43 380	47 750	2420	93 550
1980	44 170	49 280	2480	95 930
1981	44 886	50 898	2523	98 307

Source: Virgin Islands Office of Policy, Planning and Research (1979)

TABLE II
Virgin Islands Water and Power Authority water production capacity[a]

Unit	Year installed	Name plate capacity (gallons)	Present capacity (gallons)
St. Thomas			
Envirogenics[b]	1974	2 250 000	0
BLH[c]	1968	2 500 000	0
IDE 1[d]	1981	1 250 000	1 300 000
IDE 2	1981	1 250 000	1 300 000
IDE 6	1983	550 000	Due on line Sept 1983
St. Croix			
Envirogenics[b]	1974	2 250 000	1 100 000
IDE 3	1982	1 250 000	1 300 000
IDE 4	1983	550 000	Due on line June, 1983
IDE 5	1983	550 000	Due on line Aug., 1983.

[a] As of February 11, 1983.
[b] Envirogenics units nos. 1 and 2 require major retrofitting.
[c] BLH unit is planned to be surplused.
[d] IDE = Israeli Desalination Engineering.

ing Puerto Rico. In the 1981–82 period, as shown in Table II, VIWAPA installed 2.50 million gallons (MGD) of new desalination capacity on St. Thomas and 1.25 MGD on St. Croix. This new capacity was sufficient to end the need for rationing.

Accountability did not keep pace with the growth in water production. System leakage, faulty metering, and illegal connections together resulted in an accountability of only about 50% of the water produced. Revenue collection was also poor and, as a result, system expenditures far outweighed revenues. In 1982 for example,

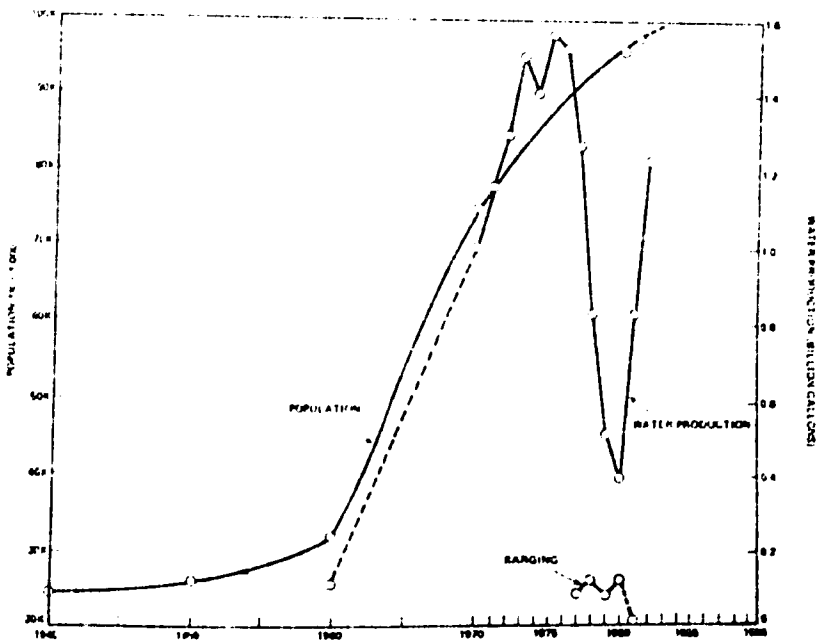

Fig. 1. Water production and population trends in the U.S. Virgin Islands.

the public water system operated at a deficit of US $10.3 million. The annual deficits have been made up by funding from the Virgin Islands Legislature and the United States federal government, in effect as 'subsidies' to the operation.

3. WATER SUPPLY AND DEMAND IN THE VIRGIN ISLANDS

A review of the extensive literature on the availability of water resources in the Virgin Islands reveals a general theme that the islands are faced with a critical shortage of fresh water. Many of these studies and reports are listed in Coffin and Richardson (1981) which reviews the subject of overcoming water shortages.

The popularly accepted view of the Virgin Islands as a water-deficient area does not stand scrutiny, however. Coffin and Richardson (1981) cite the fact that the islands have an inexhaustible supply of sea water which can be turned into fresh water, at a price. Furthermore, the long-term mean annual rainfall of slightly more than forty inches would suggest that, given adequate storage, the Virgin Islands have abundant rainfall which can be harvested. However, storage problems need to be overcome as periods of drought occur throughout the year.

The various sources of water available to the Virgin Islands are:

(a) Rainwater from catchment-cistern systems;
(b) groundwater from wells;
(c) surface impoundment;
(d) barging from Puerto Rico;
(e) wastewater reclamation,
(f) desalination.

The relative importance of each of these sources varies with time and from island to island. Prior to 1963 when the first desalination plant became operational, the public water supply system was based on hillslope catchments and wells. Shortfalls in water demand were met by barging water from Puerto Rico. Subsequently there has been a shift in strategy by government agencies to increasing dependence on desalinated water to meet the public water demand.

In discussing water supplies in the Virgin Islands, it is necessary to identify at least four different suppliers. Government agencies provide water supplies for the general public. Some private businesses provide their own supplies. Private individuals also provide their own water from rooftop catchments and/or wells. Commercial water haulers sell supplemental supplies to residents and small businesses. The amount of water available for distribution in the public system on St. Thomas and St. Croix from 1970 to 1982 is shown in Table III (figures for St. John are not available). These figures do not include the amount of water produced by private industry, most of whom do not depend on the public distribution system.

The water demand on the three islands is highly variable and is really conditioned by the available supplies. The population growth, Table I, on all three islands since 1940 is shown in Fig. 1 and the amount of water available from all sources for the distribution system is also shown in that Figure. There is no doubt that the demand would be much higher if the public distribution system was much more extensive. For example, the public distribution system on St. Thomas covers an area of only three square miles out of a total of thirty-two square miles, or less than ten percent of the island. The total population served by the public distribution system is estimated at thirteen thousand or less than thirty percent of the total current population of approximately forty-five thousand. Water consumption data for 1982, Table IV show that of the nearly 840 million gallons of water produced, less than 40 million gallons

TABLE III
Water available for distribution in the Virgin Islands, 1960–1982 (gallons × 10^6)

Year	*St. Thomas*	*St. Croix*
1960	N.A.	N.A.
1970	0.712	0.312
1971	0.757	0.409
1972	0.843	0.453
1973	0.877	0.608
1974	0.813	0.612
1975	0.891	0.674
1976	0.785	0.750
1977	0.443	0.832
1978	0.407	0.412
1979	0.311	0.206
1980	0.192	0.212
1981	0.557	0.275
1982	0.800	0.438

Sources: V.I. Office of Policy, Planning and Research (1979); Black, Crow and Eidsness (1976).

TABLE IV
Disposition of potable water in St. Thomas -- 1982 (gallons × 10^6)

Months	*Potable distribution system*	*Standpipes*
January	73.17	3.24
February	59.80	2.97
March	67.99	5.38
April	71.10	5.28
May	72.48	2.48
June	62.40	2.70
July	63.26	2.60
August	63.69	2.56
September	63.69	2.03
October	66.51	2.21
November	65.43	2.27
December	73.28	2.71
	842.50	36.43

Unpublished data supplied by V.I. Department of Public Works.

were sold at standpipes while more than 800 million gallons were delivered to the public distribution system. These quantities show that seventy percent of the population which is not dependent on the public distribution system require less than five percent of the total water produced as supplemental water to their rooftop catchments and cistern systems plus any groundwater produced privately.

The major constraint in expanding the public distribution system or providing an adequate level of service is inadequate financing of the system from user charges or government appropriations. The pricing policy also needs to be restructured such that water users of the public distribution system face the true cost of water in order to reduce the demand on the system and make it self-supporting.

4. WATER RESOURCES DEVELOPMENT

In October 1980, the Virgin Islands Department of Conservation and Cultural Affairs commissioned the development of a Comprehensive Water Resources Management Plan (CWRMP) which would be the basic planning tool for short-term and long-term public water requirements. The preliminary CWRMP report, issued in April 1982, recommends that the short-term action (FY 1983–1986) has two primary objectives: (a) improving the financial viability of the existing system and (b) ensuring appropriate water quality CH2M Hill Southeast, 1981, p. 1-7). The first objective could be achieved through increased accountability of water in the distribution system and improved collection procedures. Accountability can only be increased in the Virgin Islands system through improved metering and an extensive program presently planned for the detection and correction of leaks and illegal connections. Improved collection requires more thorough accounting procedures and aggressive enforcement. The second short-term objective of improving water quality requires capital improvements which were identified in the report, such as converting the distribution system to a total gravity feed system.

The long-term plan is aimed at improving and expanding service which will require additional sources of potable water. Table V indicates the recommended sources of potable water for St. Croix and St. Thomas for the year 2000. (St. John's relatively modest water needs would be met by incremental groundwater development and/or modular reverse osmosis desalination units which could be added as needed.) The recommendation for the two main islands recognizes present plans for desalination capacity under the ownership of the Virgin Islands Water and Power Authority (VIWAPA) and the proposed Government owned resource recovery/desalination facilities. These two sources would supply most of the

TABLE V
Recommended Virgin Island potable water supply sources (year 2000)[a]

Source	*Firm capacity (MGD)*[b]	
	St. Croix	*St. Thomas*
Seawater Desalination (VIWAPA)	3.0	3.2
Seawater Desalination (VI Government)	0.5	0.5
Groundwater	1.0	0.3
Total	4.5	4.0

[a] Adapted from CH2M Hill Southeast, Inc. (1982).
[b] This is the reliable capacity. Each source should be capable of producing a greater quantity but should have sufficient standby capacity to produce at least this amount.

Virgin Islands' future water needs. This may not however be a realistic approach to water resource development for many Caribbean islands due to the high energy costs involved in desalination. The purchase price of VIWAPA's water, which is produced by low temperature, multi-effects desalination, is about US $10 to US$11/kgal (CH2M Hill Southeast, 1981, p. 2-3). It is estimated that desalinated water from the Government's proposed resource recovery/desalination facilities, which would employ the multi-stage flash distillation method of desalination, will cost $5 to $7/kgal. Lower costs, in the order of US$2 to US$4/kgal may be possible with reverse osmosis although this process is normally used in package installations and requires skilled operations and maintenance workers.

In addition, it was recommended in the preliminary CWRMP report that inexpensive groundwater (about US$1 to US$2/kgal) supply the balance of the Virgin Islands' water requirement and that consideration be given to augmenting groundwater supplies with artificial recharge using reclaimed wastewater. This approach may represent a more realistic alternative, financially, for many islands. It is recognized however that there are limitations and concerns related to groundwater development on small islands. On islands with developable fresh water aquifers, care must be taken to avoid inducing sea water intrusion caused by overpumping. Numerous well fields on various islands have been degraded in this manner such as St. Croix's Mahogany field on the island's west end which had a projected safe yield of 85 000 gpd. Partially as a result of the loss of the Mahogany well field, the Government of the Virgin Islands, in cooperation with the United States Geological Survey, instituted a monitoring program in 1977 to guard against overpumping of the productive Negro Bay and Golden Grove wellfields on St. Croix's southern shore. The program consisted of the installation and regular sampling and analysis of a series of observation wells on the southern perimeter of the wellfields near the shoreline. Ideally, monitoring of the quantities of groundwater withdrawn from the aquifers should also have been a part of the program. A second concern related to groundwater development for water supply purposes relates to the potential for groundwater contamination from sources such as domestic septic tanks and municipal and industrial solid waste disposal sites. Groundwater sources in the Virgin Islands have been protected to a large extent from the former source of contamination by the installation of sanitary sewer systems in population centers.

It is interesting to note that rainwater harvesting using hillside and roof catchments was not recommended in the preliminary CWRMP report as a means of expanding the islands' water supply although the use of these facilities formed the main source of water supply in the Virgin Islands for many years and they are still widely used throughout the Caribbean. The actual cost of water produced by rainwater harvesting is, surprisingly, reported to be quite high (in the order of US$25/kgal, according to the consultant's report) due to the high capital cost of the concrete cistern (CH2M Hill Southeast, 1982, p. 2–1). Cisterns are also prone to contamination by wind transport and animals.

4.1 System expansion and improvements

In addition to recommending sources for future water supply, the preliminary CWRMP report recommended capital expenditures aimed at expanding and improving service. Some of the general objectives to be achieved include:

(a) Increasing the service area to provide water to a larger population base;

(b) maintaining 10 days storage capacity;

(c) converting the distribution system to all gravity feed in order to maintain positive pressure throughout,

(d) providing substitute storage tanks to allow for emergencies or repair situations;

(e) increasing the system's capability to mix desalinated water with groundwater to improve taste and acceptability;

(f) providing a flexible distribution and storage system that can accommodate unpredicted population shifts;

(g) increasing the production of inexpensive groundwater; and

(h) decreasing operating costs by improved water accountability through improved metering.

The preliminary CWRMP report identified specific capital improvement projects totaling about US$110 million but recognized that the actual pattern of development experienced in the islands

over the next 18 years would not necessitate the implementation of every project. It was recommended that approximately US$65 to US$75 million be expended on capital improvements to the year 2000, not including VIWAPA's costs for additional desalination capacity or the Government's resource recovery/desalination facilities. Many of the recommended improvements would increase revenues by improving accountability and would reduce costs by reducing leakage in the distribution system.

4.2 Management and training of personnel

Thus far we have directed our discussion to issues concerning water resources development and facilities expansion and improvements. Problems also exist on many Caribbean islands regarding management and training of personnel which seriously affect water supply operations. Operating authorities in the Virgin Islands and other islands of the Caribbean are faced with two main problems in this regard: the need to upgrade the skills and capabilities of operators; and difficulty in recruiting and retaining engineering personnel.

The typical Caribbean water supply operator is a 'multi-functional' individual in that he performs both operational and maintenance duties associated with both water supply and sanitary facilities. In the authors' experience, many of these individuals are dedicated and hard-working employees and resourceful mechanics, able to work minor miracles to repair and maintain systems in an environment where spare parts, materials, tools and equipment are often inadequately supplied. The operator mechanic's knowledge of operating facilities is usually specific to the local facilities with which he has been associated and has been gleaned from years of work experience with those particular facilities.

Difficulty arises when, as in the case of the Virgin Islands, new facilities are introduced for system expansion and improvement. The operator whose knowledge is specific to the now defunct facilities is suddenly confronted with an entirely new set of demands on his performance. In some instances he may be confronting a culture shock if the need for appropriate technology has not been addressed in the planning and design of the new facilities. Understandably, the result can be declining morale and failure to provide the level of operator attention required by the design of the system. Ideally, the operator should be trained with regard to general concepts and principles that can be applied to a variety of situations. In many cases however this approach is impractical either due to financial limitations or the operator's own level of academic background. As a minimum then, the operator caught in this situation is in need of rapid familiarization with his new job requirements presented in a manner appropriate to his individual educational level.

One approach to training utilized in the Virgin Islands in the past was to take advantage of various short courses and seminars sponsored or at least funded by U.S. federal agencies such as the Environmental Protection Agency. A more modest but realistic and satisfactory approach, in the experience of the authors, is to provide specific on-the-job training tailored to be compatible with each individual operator's intellectual abilities. This 'custom-made' approach is possible on a small island where the total number of individuals to be trained is small.

A simple example of this 'custom-made' approach to training is illustrated in Figs. 2 and 3. The Figures compare two operators' log sheets which were designed for training at two newly constructed, nearly identical sewage pumping stations. (The example is meant to be generic in that this approach to training is equally applicable to water supply or other types of operations.) While both log sheets request only basic information, the Christiansted log, Fig. 3, is simpler in appearance and makes use of drawings and figures. This was to accommodate the abilities of the day-shift operator who was semi-literate.

In training pump station personnel in all aspects of the newly developed operations and maintenance program for these facilities, the engineer worked closely with the O&M staff on a daily basis for a period of six months (Thompson, 1977). Operations and maintenance workers were involved from the start in the development of the program. Personal, consistent communication between the trainer and trainees was effective in permanently establishing an O&M program for new and sophisticated facilities. The program which was established in 1977–78 is still contributing to the successful operation of the facilities today.

Less success has been experienced in efforts to recruit and retain qualified engineering person-

OPERATOR _____

DATE:	TIME:	TODAY'S FLOW METER	
DATE:	TIME:	LAST FLOW METER	
		GALLONS PUMPED	
		FLOW CHART	

PUMP CONTROLS	☐ AUTOMATIC		☐ MANUAL			
LEAD PUMP SETTINGS	1		2		3	
PUMP HOUR METERS	1		2		3	
WET WELL LEVEL (FEET)	HI		LOW			
WET WELL CYCLE TIME	HI		LOW			

MOTOR NOISE (OK, NG)	1		2		3	
MOTOR VIBRATION (OK, NG)	1		2		3	
MOTOR TEMPERATURE	1		2		3	
DRIVE NOISE (OK, NG)	1		2		3	
DRIVE VIBRATION (OK, NG)	1		2		3	
DRIVE TEMPERATURE	1		2		3	

SEWAGE PUMPS						
DISCHARGE PRESSURE	1		2		3	
BEARING HOUSING NOISE	1		2		3	
BEARING HOUSING VIBRATION	1		2		3	
BEARING HOUSING TEMPERATURE	1		2		3	
PACKING	1		2		3	
WEIGHTED LUBRICATORS	1		2		3	
LUBRICATOR PETCOCKS	1		2		3	
FOUNDATION VIBRATION	1		2		3	

SUMP PUMP CHECK – HAND OPERATE FLOAT (OK, NG)					

WET WELL CLEANING	TIME IN	TIME OUT			
SOLIDS REMOVED (BUCKETS)					

COMMENTS

Fig. 2. Daily log sheet (Figtree pumping station).

nel. Engineering positions at every level in Virgin Islands operating authorities frequently are unfilled for periods of months or even years. In some islands of the Caribbean, there is some reluctance to employ engineers from outside the Caribbean even at a time when many native engineers are migrating to North and South America and Europe. The migration of native professionals away from the Caribbean is largely due to the promise of greater compensation and improved standards of living. Caribbean operating authorities, including those in the Virgin Islands, can only stem the outward flow of local talent by raising their current salaries and offering

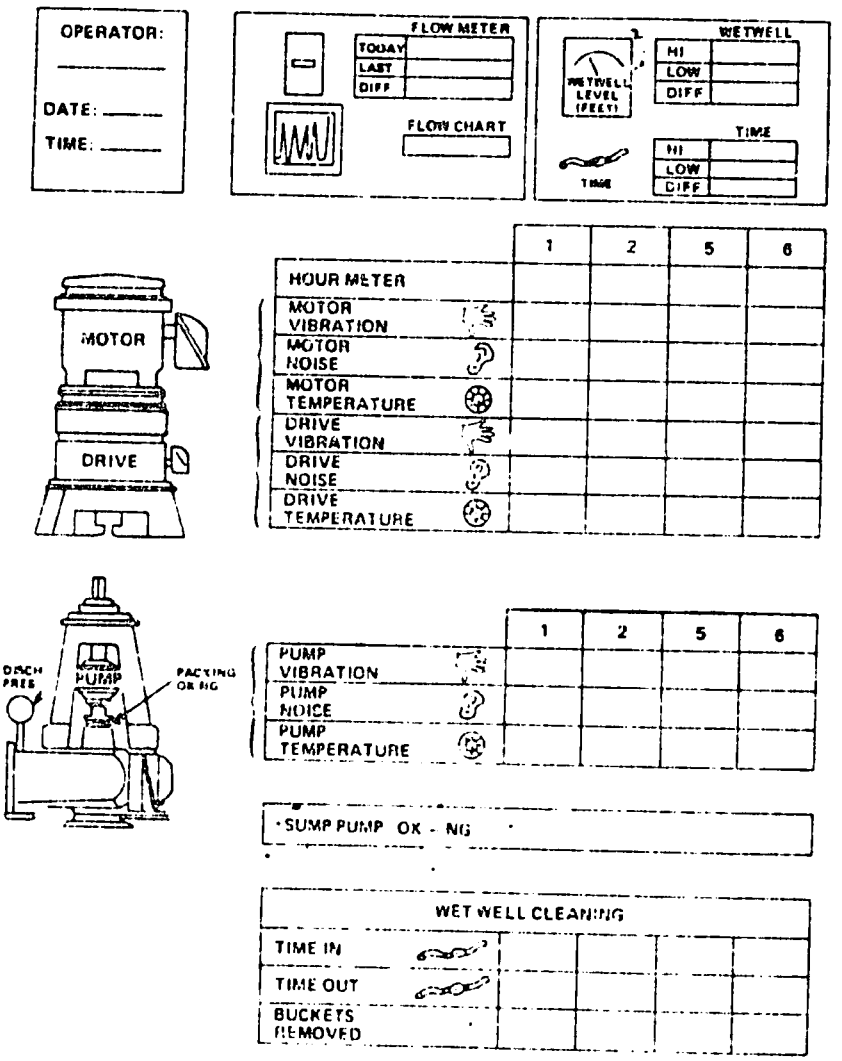

Fig. 3. Daily log sheet (Christiansted pumping station).

improved benefits. In most instances such a move would require legislative action and executive approval.

4.3 Institutional Issues

The institutional problem in water resources development and administration is to find an appropriate decision-making framework for maximizing the effective management of water resources at the minimum possible economic, political and social costs. The quality of water resources administration is determined and largely influenced by the choice of institutional arrangements adopted for governing the development and use of water resources. Institutions for water resources administration operate at the interface of the water resources system and the social system, constrained by other systems such as legal, political, economic or technological.

The management of water supply operations in the Virgin Islands presents problems which are shared throughout the Caribbean. Even though the basic problem confronting management is the fundamental one of matching available supplies

to demand, the peculiarities of the available supply and demand preclude duplication of management efforts or institutions used elsewhere. For example, on the largely metropolitan island of St. Thomas, more than half of the population is not served by the public distribution mains. The majority of these people rely on water collected from rooftops and stored in cisterns. During periods of low rainfall and for those whose water demand exceeds the available rainfall harvest, trucking of water from government standpipes and commercial haulers are the only alternative sources of supply. Clearly then, matching supply and demand in these circumstances requires innovative institutional approaches.

Cistern storage is required by law in all private residential buildings. However, the unit cost of water associated with the usual domestic concrete storage cisterns is very high. Groundwater use in the Virgin Islands may be more significant in the overall supply than is acknowledged, simply because there are no reliable estimates of reserves or private groundwater production. Even though the law requires water meters on all wells producing above five hundred gallons per day, the requirement is poorly enforced and production records are not available.

Desalination is now the dominant method for producing additional water supplies. The experience in the Virgin Islands is that desalination is a high cost, high technology and high level management affair. The initial capital costs of procuring desalination equipment could be beyond the means of most other Caribbean nations, without foreign assistance. The U.S. Virgin Islands is in a unique situation to accept grants from the U.S. Federal Government to offset initial high capital costs. Continued successful operations require fairly high level technological skills which cannot be acquired in local institutions of higher learning, hence the significance of instituting training programs as discussed earlier. The emphasis on desalination stems from the simple fact that the islands are surrounded by limitless amounts of sea-water which can be turned into fresh water.

A critical institutional problem confronting the Virgin Islands concerns the competence and performance of the myriad of government agencies charged with responsibilities for water supply operations as shown in Fig. 4. Recurring water shortage problems have been blamed on incompetent government agencies. Others have pointed to the dispersal of water responsibilities among several government agencies without adequate coordination as the reason behind the perennial water shortage:

"The fragmentation of the planning, operation, construction, policy and management functions among numerous government agencies, departments, commissions and authorities results in a wasteful, cumbersome, inefficient, overlapping

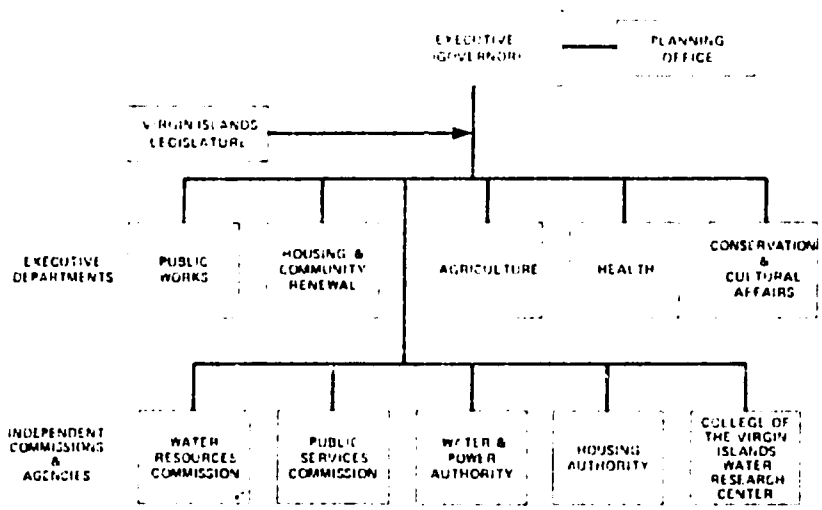

Fig. 4. Organizational impact on water supply operations in the U.S. Virgin Islands.

and bureaucratic system whereby there are duplications of efforts and/or numerous voids in meeting the water needs of the community.' (Adams and Associates, 1978).

Currently, VIWAPA, The Department of Public Works, the Virgin Islands Planning Office and the Department of Conservation and Cultural Affairs all engage in water supply planning for the Virgin Islands. Proposals have been made for the consolidation of most, if not all, water supply operations into one single department.

While the performance and coordination of the existing departments in providing adequate water supplies has been problematic, the consolidation of all water supply functions into one super agency may not lead to improved performance unless the real reasons for past poor performances are addressed simultaneously. The responsible agencies do not have the financial independence to operate and take business-like decisions. For example, the pricing of water is determined by the V.I. Legislature rather than by the Water and Power Authority (VIWAPA) which produces the water. Legislative approval is needed on all decisions affecting the performance of VIWAPA including the timing of the installation of additional production capacity, through the legislative appropriation process. Another government agency whose operations are affected by the Legislature is the Department of Public Works (DPW) which is responsible for the distribution of water. Replacement of the forty-year old public distribution system, which accounts for tremendous system losses, has been recommended for many years. The Legislature, however, has yet to act and release appropriations to replace the dilapidated system.

As long as decisions involving the timely acquisition of capital equipment are subject to the Legislature, water production efforts will continue to be constrained. The fixing of water prices by the Legislature at levels which cannot support amortization, operations, and maintenance costs ensure that water supply operations in the Virgin Islands will not be sound business.

5. APPLICABILITY OF VIRGIN ISLANDS EXPERIENCE

The experience gained in the Virgin Islands in managing water supply operations is applicable to other Caribbean islands in several ways. In most instances the Caribbean islands will continue to draw on a variety of sources for potable water supply. It will usually be preferable however to develop groundwater sources to the maximum extent possible. In developing groundwater resources, it is imperative that safeguards against overpumping be implemented and that laws and regulations protecting groundwater quality from contamination from wastewaters or improper disposal of solid wastes be enacted and enforced.

Regarding rainwater harvesting using hillside and roof catchments, it has been noted earlier that the cost of water produced by this method is reported to be quite high (CH2M Hill Southeast, 1982, p. 2-1). Additional research is warranted in this area however particularly with regard to the feasibility of large communal cisterns serving several residences which might take advantage of economies of scale. Research into alternative cistern construction methods and materials, such as the ferrocement tanks persently being tried in the Grenadines by the Caribbean Appropriate Technology Centre (1982) is also appropriate. The authors also suggest that the use of cisterns in the Caribbean could be improved through government sponsored 'weather-watches' designed to advise cistern users in advance of impending drought conditions so that conservation of cistern water can begin prior to the arrival of droughts.

Although it is impractical to recommend specific capital improvement projects for other islands based on the Virgin Islands experience, some of the general objectives of the CWRMP discussed earlier are applicable, specifically: the maintenance of adequate storage capacity and substitute storage tanks; maintenance of positive pressure throughout the water distribution system via a gravity feed system; provision of a flexible system that can accommodate population shifts; and improved metering.

Regarding training of operations and maintenance workers, the example given herein of on-the-job training tailored to be compatible with individual operator's abilities has wide application throughout the Caribbean, particularly where the number to be trained is small. This presupposes of course that a trainer, such as an operating engineer, is available. With engineers in short supply throughout the islands and with native professionals migrating in numbers, many

of the Caribbean Islands might improve their operations by considering contract arrangements or other mutually acceptable means of recruiting engineers from outside of the Caribbean.

In instances where Caribbean water supply systems experience poor water accountability, as in the Virgin Islands, there is likely to be a need for extensive leak detection and repair due to the age of the system and corrosive environment. Where revenue collection is a problem, more thorough accounting procedures and aggressive enforcement may be in order.

The fragmentation of water supply functions among various agencies should be corrected, where it occurs, through the consolidation of responsibilities within a single agency or through improved coordination. More importantly however, the operating authority(ies) must have the independence to operate in a responsible business-like manner, effecting appropriate capital expenditures and balancing costs with pricing rates that reflect the true cost of water.

REFERENCES

Adams and Associates, 1978. *Water Supply Study of St. Thomas and St. John, U.S. Virgin Islands*, Rep. prepared for the U.S. Army of Corps of Engineers, Jacksonville District, Jacksonville, Fl.

Black, Crow and Eidsness, Inc., 1976. *A Water Management Plan for St. Croix, U.S. Virgin Islands*, Gainesville, Fl. p. xxii, 2-1–2-10.

Caribbean Appropriate Technology Centre, 1982. *Activity Profile*, Caribbean Conference of Churches, Bridgetown, Barbados, June 1982, p. 3.

CH2M Hill Southeast, Inc., 1982. *Water Management Plan for the Public Water System*, Prelim. Rep. prepared for the Government of the Virgin Islands, Gainesville, Fl. April 1982.

Coffin and Richardson, Inc., 1981. *Water Conservation Under Conditions of Extreme Scarcity: The United States Virgin Islands*, Tech. Completion Rep. for OWRI, Contract No. 14–34–001–9431.

Forman, R. T. T., 1974. *An Introduction to the Ecosystems and Plants on St. Croix, U.S. Virgin Islands*. Fairleigh Dickinson University West Indies Laboratory, St. Croix, Virgin Islands, Spec. Publ. No. 7.

Francois, P., 1980. Water resources development in the U.S. Virgin Islands, In: *Proc. United Nations Commonwealth Science Council*, CSC (80) SLR6, CAR-79-R01, October 1980, p. 266–279.

Hadwen, P. (Editor), 1980. Seminar on Small Island Water Problems. In: *Proc. United Nations Commonwealth Science Council, CSC (80)* SLR6, CAR-79-R01, October, 1980.

Thompson, T. P., 1977. *Operation and Maintenance Program—Christiansted and Figtree Pump Stations, St. Croix, USVI*. Virgin Islands Department of Conservation and Cultural Affairs, St. Croix, Virgin Islands, December 1977.

Virgin Islands Office of Policy, Planning and Research, 1979. *Annual Economic Review—1st Quarter, 1979*. Virgin Island Department of Commerce, St. Thomas, Virgin Islands.

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