IMPROVING THE WATER DISTRIBUTION SYSTEM AT KOLONIA, POHNPEI STATE THROUGH USE OF A DIGITAL WATER DISTRIBUTION MODEL

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Technical Report 66
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WATER AND ENERGY RESEARCH INSTITUTE
OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM

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Abstract

In spite of adequate input water to the modern water distribution system of Kolonia, Pohnpei, substandard quality water is available to consumers for only a few hours per day. The implementation and continuation of water hours in a place where rain pours, often all day long, and where streams gush with the resulting runoff, frustrates not only the government but the people as well. Previous studies indicate certain technical flaws in the system, such as system leakage, nonefficient operation of the system and inappropriate consumer behavior and attitudes toward water use.

A hydraulic model of the Kolonia, Pohnpei, water system was developed. This model characterizes the geometry of the system as well as the existing operation of the system. From this model the best system operation, as well as the pressure and flow in each pipe of the system, can be determined. Also, this model can be used as a tool for leak detection and prediction of flow and pressure toward additional pipes.

Development of a water distribution model is only the first phase of solving the many problems with the Pohnpei distribution system. Future studies for improving the water system are required, such as: 1) a training program for all levels at the Department of Public Works 2) a metering program, and counting the legal and illegal connections in Kolonia which determine the actual consumer usage and required water for the Pohnpei system 3) repair and maintenance of the leakage in the system 4) providing additional sources of water and 5) a public education program about the water system.

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INTRODUCTION

The state of Pohnpei (Ponape), Capital of the Federated States of Micronesia, is one of the Eastern Caroline Islands of Micronesia in the northwestern Pacific. Pohnpei is approximately 500 miles north of the equator, 1,950 miles southeast of Japan, 2,200 miles east of the Philippines, and 2,575 miles southeast of Hawaii, as shown in Figure 1.

The island is roughly ten miles in diameter, with a total land area of 110 square miles. Pohnpei is divided into six municipalities; Kolonia, is the seat of the state and national governments. Figure 2 shows the location of Kolonia.

Pohnpei is well known for its high yearly rainfall. The interior of the island is estimated to receive 400 inches of rain a year while coastal zones receive an average of 190 inches a year (Vander Brug, 1984).

It would seem that there isn't a water resource problem in Pohnpei. In one sense the foregoing sentence is true. The high annual rainfall, and a predominately steep, basaltic geological substrate, produce abundant raw water year-round. But the availability of protable water is quite another matter. This causes the Pohnpei state government to restrict water service to a few hours during the morning and evening. The problems which have been suggested before are as follows: 1) technical difficulties with the water distribution system such as leakage, inadequate maintenance, untrained personnel to operate the system and improper operation of or lack of understanding of the distribution system, and 2) consumer attitudes and behavior, specifically, inappropriate water use habits which result in excessive water consumption.

A digital water distribution system model which is used to predict flows and pressures at different points in an actual water supply system was developed to improve the operation of the Kolonia water system. A fully developed system model, with accurate input data can be used to identify areas of leakage and to define new operating strategies for more efficient system operation. The purpose of this study was to collect information about Kolonia's water system as accurately as possible and to construct a digital model of the water system, which would help the Pohnpei Department of Public Works in improving the operation of the water system.

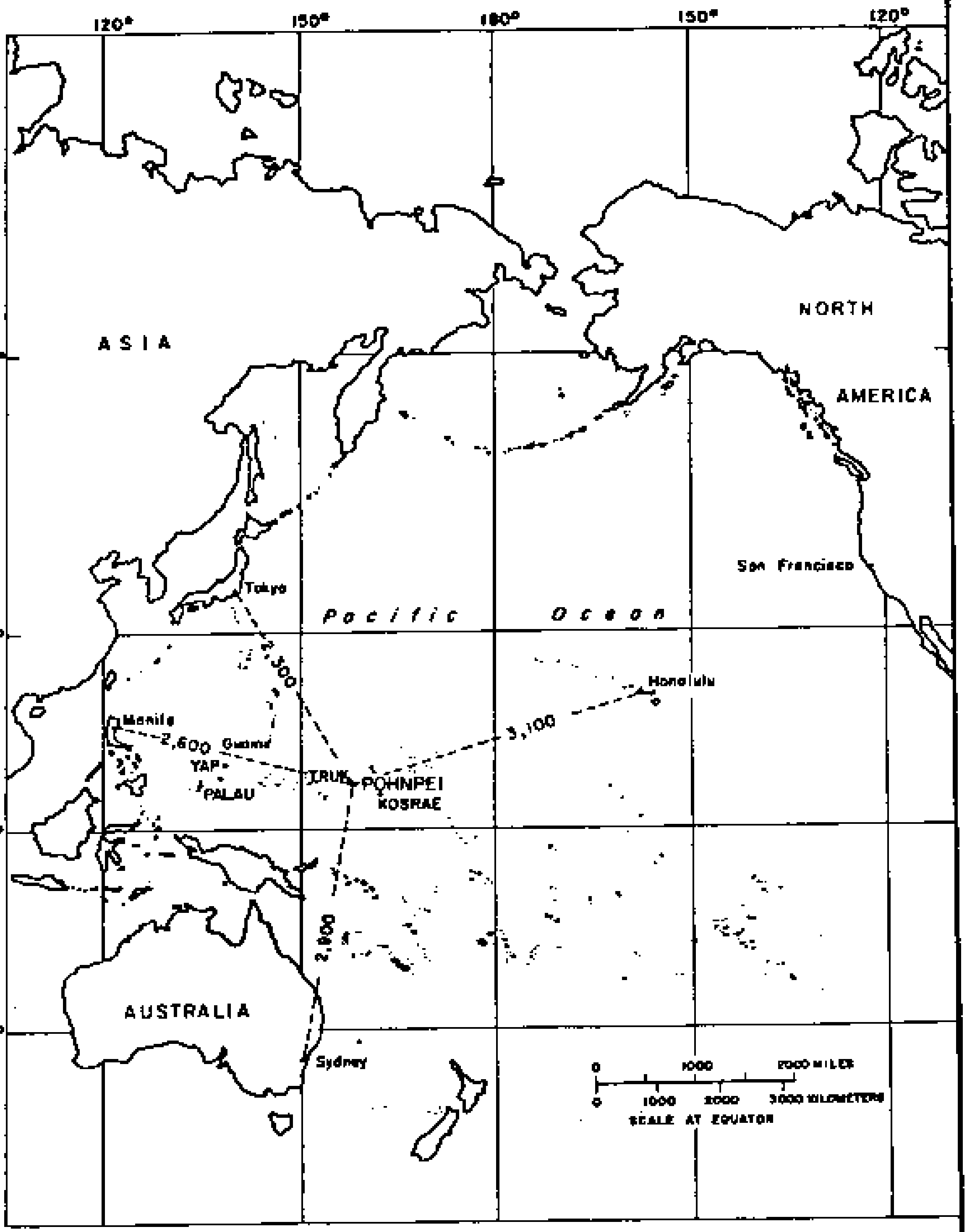

FIGURE I. LOCATION OF POHNPEI

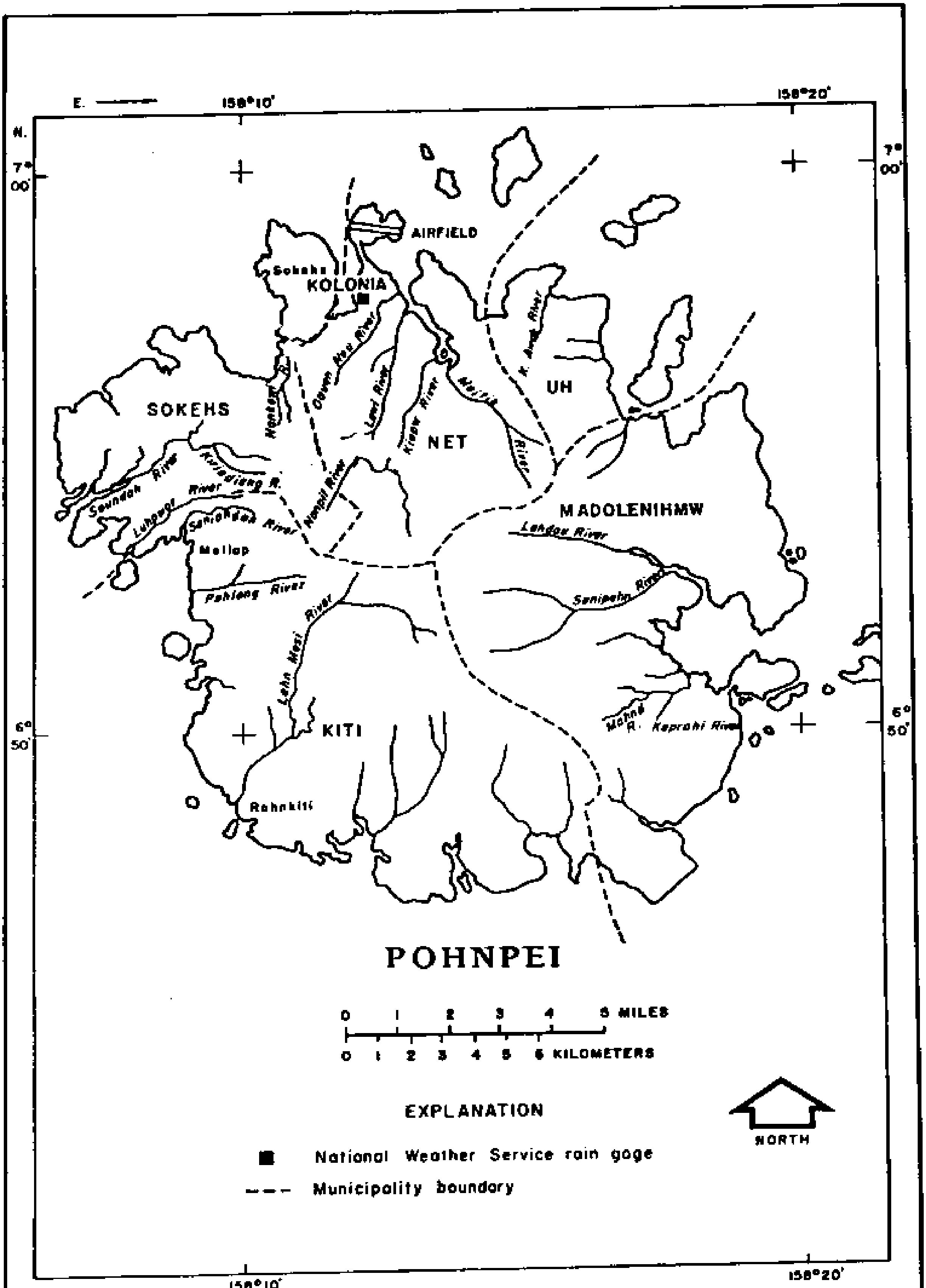

FIGURE 2. ISLAND OF POHNPEI

OBJECTIVES

The scope of this project was to develop a computerized model which would characterize a water distribution system serving Kolonia, Pohnpei.

The primary objectives were to:

1. Gather the hydraulic data required to develop the system model. This information includes:
   a. Piping system layout, including size, location, and roughness of the pipes in the system.
   b. Characteristics of pumping stations and storage reservoirs.
   c. Timing and quantities of demands on the system.
   d. Nature and availability of the water supply.

2. Develop the digital model using field-measured conditions and reviewing as built drawing maps of the system.

PREVIOUS STUDIES

A number of studies have been done in the past on Pohnpei's water distribution system. Some of these studies, which gave a better understanding of the existing system were reviewed; the others were listed in the reference.

Juan C. Tenorio and Thomas J. Davis, Inc. (1980) did a joint venture water resource development plan study. Their conclusion was that the system is operated in a less than desirable manner and is poorly maintained. Large amounts of water are lost through leakage and outright waste by consumers. Also, the population growth rate appears to be exceeding that of the projection made in 1968.

Barrett, Harris & Associates Inc. (1983) did a leak detection study of Pohnpei's water system. This study measured flow in various water line sections, and included sound readings on water lines using electronic instruments. It was found that there is a significant leakage and water loss problem in the Kolonia water system, which results in a higher outflow than inflow to the system. The implementation of "water hours" is necessary to control distribution losses. The authors recommended that water conservation needs to be encouraged on an individual household basis, and that distribution system leakage and water losses, through household plumbing, need to be identified and quantified on a system-wide basis.

OMI Inc. (1986) reviewed the operation, maintenance management, and capabilities of the Pohnpei Public Works Department related to the water system. They recommended that 1) by reducing leakage and development of new sources, the water hours can be expanded, 2) the system needs considerable maintenance, 3) the quality, quantity, and pressures of water distributed to customers need to be monitored, 4) the adequacy of the existing facilities to meet future demands needs to be determined, and 5) a training program for system operation, maintenance and supervision is required.

The use of a digital distribution model for Pohnpei's water system is the first of its kind, but this digital model has been widely adopted by engineering consultants and researchers (Jefferson 1977, Walsh 1983).

DESCRIPTION & CHARACTERISTICS OF THE EXISTING WATER SYSTEM

The present water system on Pohnpei developed over two distinct administrative periods:

The period of Japanese administration (1914-1940). The first modern water distribution system was built during this period. The system included: diversions on several streams and rivers, a small treatment plant, several concrete storage tanks, and a transmission network of mainly galvanized iron pipes.

The period of administration by the United States under the United Nations Trusteeship of the Pacific Islands after World War II. Beginning in 1968, under several contracts administered by the United States Navy's Officer in Charge of Construction (OICC), an expanded and modernized water distribution system, consisting of intake, transmission, treatment plant, storage, and distribution facilities, was developed. Several of the facilities constructed by the Japanese were retained and integrated into the system. These tasks were completed by OICC by 1976. Since then, the Pohnpei District Department of Public Works (DPW), under the district administration of the Trust Territory Government, became involved in constructing new water lines, for providing service to areas not covered by the Japanese and U.S. Navy-constructed systems.

EXISTING WATER SYSTEM FACILITIES

The existing water system facilities are shown in Figure 3 and include:

1. A diversion dam and primary settling tank located on the Nanpil River at an elevation of 340 feet above sea level.

2. Transmission lines with 2990 feet of 16-inch ductile iron and 12,180 feet of 12-inch asbestos cement pipe sections. The transmission lines consist of 15 air-relief valves.

3. The Nanpohnmal Water Treatment Plant (WTP) which includes a 300,000 gallon settling tank, five sand bed filters, two 750 gpm (40 hp) pumps, a chlorination system, and a 30,000 gallon clearwell. Recently, two flow meters, one on the inflow, and the other on the outflow, pipe at the WTP have been installed. They do not operate properly (according to recent flow measurements). The elevation at the WTP is 265 feet above sea level.

4. Four steel storage tanks, three with capacities of one million gallons each and one with a half-million gallons of storage capacity. Presently one of them (Ipat tank) is used. The Sokes, Nanpohnmal, and Hospital storage tanks are not used because of inadequate water in the system.

5. A distribution system of galvanized iron and asbestos cement pipes with sizes ranging from three inches to twelve inches in diameter. Pohnpei's water system covers the area from Nanpohnmal to Sokehs Island to Kolonia and to Nett (Figure 3). It covers approximately 2 square miles.

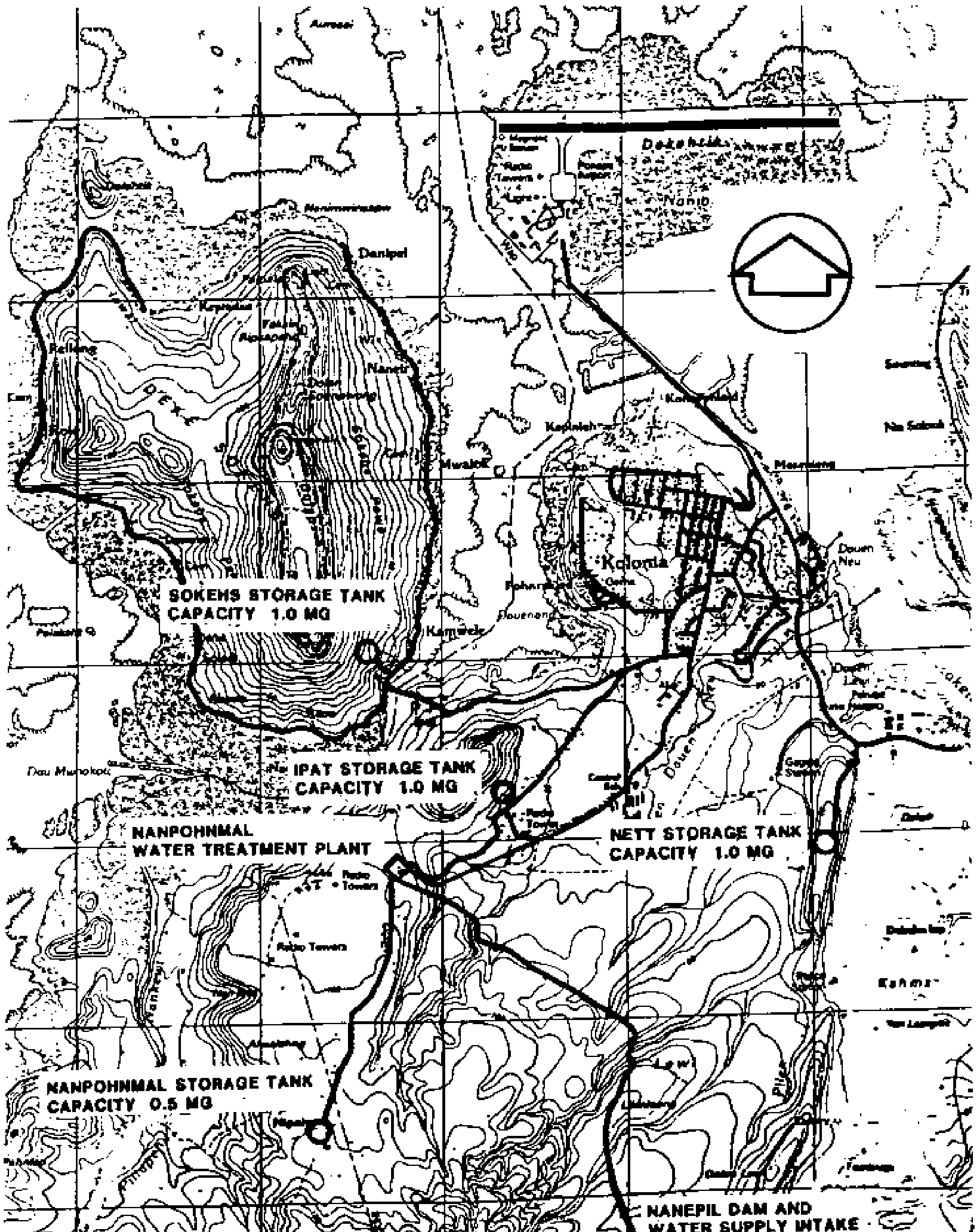

FIGURE 3. EXISTING WATER FACILITIES

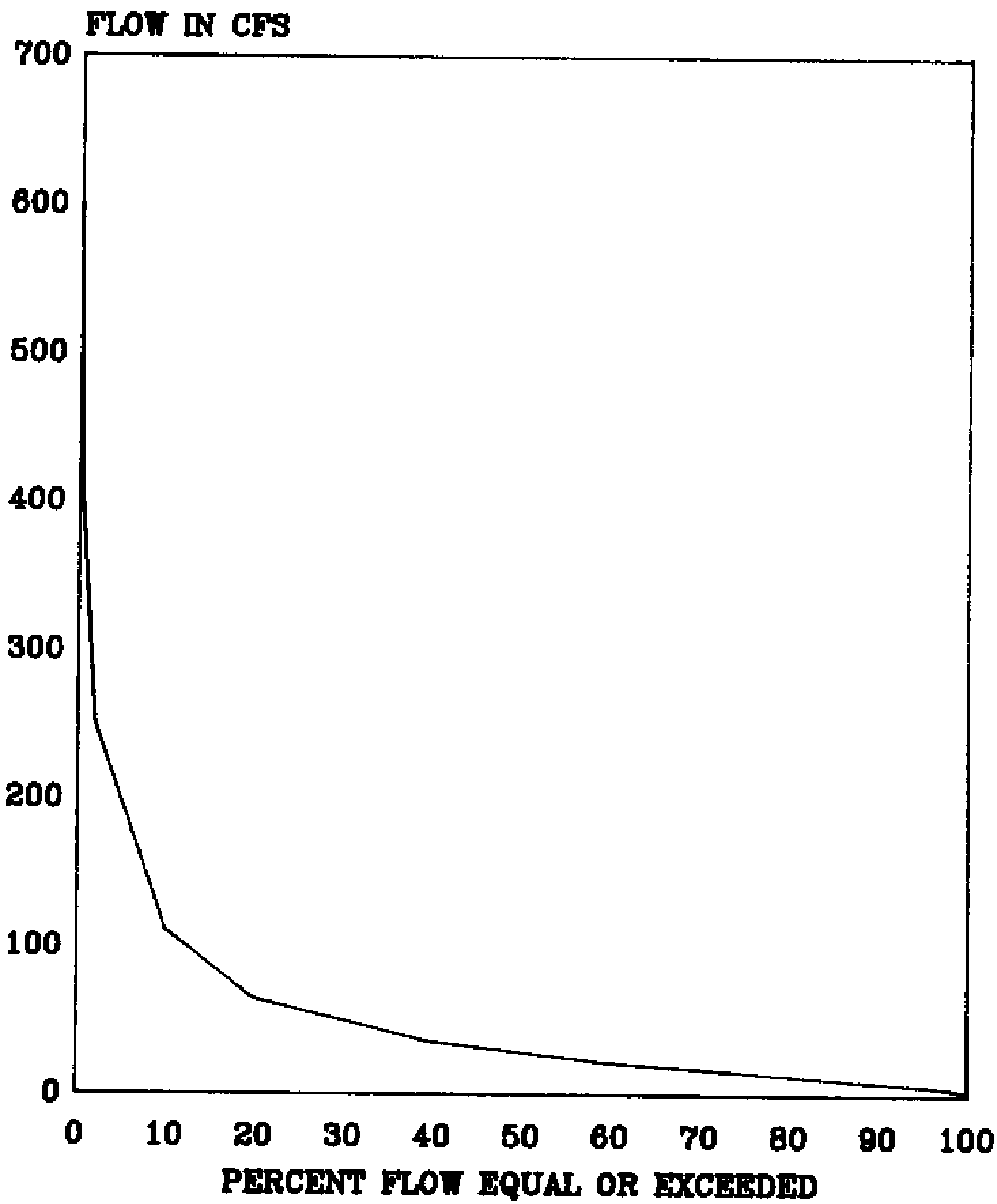

FIGURE 4. Flow Duration Curve for Nanpil River

WATER SUPPLY SOURCES

Surface sources

There are two surface supply sources, one major and one minor, serving the existing Pohnpei water system. The major source is the Nanpil River. The dam and intake had a normal capacity of 2.2 million gallons a day (mgd). However, due to poor maintenance of transmission lines, and also to draw- down of flow of the Nanpil River, the intake at site divert is 3.0 cubic feet per second (cfs), or 1.94 mgd of flow. This amount of flow is available 99 percent of time as shown in Figure 4. The summary of existing facility capacities is shown in Table 1. The raw water flows to the WTP by gravity. The estimated total average flow to the Nanpohnmal Treatment Plant is 1.70 mgd.

The minor source of surface water is an infiltration gallery on the Danen (Tdwanwu) River above PIC High School. This water is chlorinated only and enters a line leading to the Nett area and the Hospital. The capacity of the pump on this source is estimated to be 150 gpm. Recently, due to possible pollution of this source, the DPW is not using water from this source unless an emergency arises.

Ground water

Presently DPW is looking to find other water supply sources such as ground water. This interest mostly is based on the availability of ground water to the main pipeline (Hospital line), which is less expensive compared to improving the intake structure and transmission lines at the Nanpil River.

The system presently has two wells (K-1 and K-2) in which pumping rates are 105 gpm for K-1 and 110 gpm for K-2. The locations of these wells are shown in Figure 3. Pump and well characteristics are shown in Table 2. It is anticipated that at least 8 wells will be operational upon installation of pumping equipment in FY 1987. The current estimated combined average sustainable yield of the developed wells is 0.3 mgd.

OPERATION OF THE EXISTING SYSTEM

Daily 1.94 mg draw from the sediment box at the Nanpil River to Water Treatment Plant (WTP) by a 15,170 foot transmission line. The raw water discharges into a 300,000 gallon concrete primary settling tank at WTP. From the settling tank, the raw water is fed to five sand bed filters. From these filters water flows into a small 30,000 gallon clear water well through two separate lines, a 6 and a 12 inch. A chlorinator is connected only to the 12 inch line leading to the clear well. Mixing of chlorinated and unchlorinated water occurs at the clear well. From the clear well, two 12 inch pipes carry water to the Kolonia water distribution system. The two lines run parallel for a short distance before parting in separate directions, one leading to the Ipat storage tank and the other to Hospital line. Also, the two wells K-1 and K-2 feed into the Hospital line. During the water hours, water from WTP and wells feed the Hospital line. In off-hours well K-1 and K-2 feed this line in order to keep water in this line for 24 hrs.

Table 1.

SUMMARY OF FACILITY CAPACITIES

FACILITY	DESIGN CRITERIA	EXISTING CAPACITY (MGD)	YEAR EXCEEDED	REQUIRED CAPACITIES (MGD)*				
				1980	1985	1990	1995	2000
INTAKE	Maximum Day + Industrial Use	2.2	1976	2.7 2.7	3.5 3.2	4.7 3.8	6.3 4.6	8.4 5.6
TRANSMISSION LINE	Maximum Day + Industrial Use	2.0	1975	2.7 2.7	3.5 3.2	4.7 3.8	6.3 4.6	8.4 5.6
TREATMENT PLANT FILTERS	Maximum Day + Industrial Use	3.14	1983	--- ---	3.5 3.2	4.7 3.8	6.3 4.6	8.4 5.6
DISTRIBUTION RESERVOIRS	Fire Protection + 50% Day Demand	3.5	1988 1990	--- ---	--- ---	3.7 ---	4.5 4.1	5.5 4.8
DISTRIBUTION MAINS	Peak Demand	2.85	1972	4.8 4.8	6.4 5.8	8.6 6.8	11.4 8.2	15.6 10.0
	Fire Protection + 50% Average Day Demand	2.85	1983	--- ---	3.1 3.0	3.7 3.5	4.5 4.1	5.5 4.8

* Capacities shown are upper & lower bounds of the probable range for the indicated years (Juan C. Tenorio and Associates Inc. 1980)

Table 2.

LISTING & STATUS OF MAJOR PRODUCTION WELLS
KOLONIA WATER SYSTEM

WELL NO.	GROUND ELEV.	WELL DEPTH FT.	PUMP MODEL #	USEFULL POWER (h.p.)	PUMP DATA SETTING FT.	RATE GMP	DD FT.	DESIGN TDH FT.
K-1	155	297	Grundfos SP 16-8	7.5	200	80	143	270
K-2	145	260	SP 27-6	10	150	125	80	230

4 to 6 additional wells to be drilled under contract recently awarded.

There are four steel storage tanks in the system (mentioned earlier) which recently Ipat storage tank is in used. The Sokhes and Hospital storage tanks are not in use because there is not enough water in the system. Nanpohmal storage tank is used for back-washing of the sand filters at the WTP. There are two 40 Hp pumps at the WTP; one is used for pumping water to customers at Nanpohmal areas and the other is used as a stand-by.

Normal service to customers is from 5:30 to 9 a.m. and 5:30 to 9 p.m. each day. Opening and closing of the system invariably involves manipulating some gate valves and diverting water from one area to others.

DESCRIPTION OF COMPUTER MODEL USED

The computer program used in this project is one of a series of computerized pipe network programs developed by Dr. Donald J. Wood of the University of Kentucky at Lexington, Kentucky. The program that was used is operational on an IBM personal computer with title EPS84. This particular program has been superceded by a new program called KYPIPE. Complete program manuals and program documentation for all of the pipe network programs developed by Dr. Wood are available through the Civil Engineering Software Center at the University of Kentucky (Wood, 1985).

GENERAL DESCRIPTION OF PIPE NETWORK FLOW EQUATIONS

All pipe network models are required to solve a system of simultaneous nonlinear and linear equations with flow in each pipe as the unknown variable. The linear equations are developed by applying the continuity equation (inflow must equal outflow) to the pipe junctions in the system. The nonlinear equations are developed when the head losses due to pipe friction are analyzed around the closed loops in the system. The sum of losses around each closed loop must sum algebraically to zero. Since head losses in pipes are a nonlinear function of flow in the pipe the loop equations are nonlinear in nature. The system of linear and nonlinear equations cannot be solved by conventional methods of solving linear equations. The two most popular techniques for solution of these equations is the Hardy Cross and the linearization methods.

The Hardy Cross method requires that flows be assumed for each pipe that satisfies the continuity equation at each junction point. A set of corrector equations are developed for each loop in the system. These corrector values are the change in flow required to force the nonlinear loop head loss equations to go to zero. Adjacent loops contain common pipes and computed correctors for one loop would not normally be appropriate for the adjacent loop. To handle this problem, an iterative technique is developed and a series of correctors are computed and applied to previously used flow values in an iterative fashion until the corrector value is very small compared to the actual flow value computed. The computed correctors are applied in such a fashion to maintain continuity of flow at each junction so that the final corrected flows satisfy both the continuity equation and the loop head loss requirements.

The linearization scheme is slightly different than the Hardy Cross technique. In the linearization scheme the nonliner loop equations are linearized in the following fashion. The loop equations take the form:

$$k_1(Q_1)^n + k_2(Q_2)^n + k_3(Q_3)^n + \ldots k_m(Q_m)^n = 0$$

(One equation for each closed loop)

where:

$k = f * L * 0.02517 / D^5$ Darcy Weisbach equation

$k = L * 4.7495 / D^{4.869} / CH^{1.85}$ Hazen- Williams equation

k = head loss coefficient involving diameter, roughness and length of pipe

f = Darcy Weisbach Friction Factor

L = Length of pipe (feet)

D = Diameter of pipe (feet)

CH = Hazen Williams roughness coefficient

Q = Flow in each individual pipe

n = power term depending on the head loss equation used (1.85 for Hazen Williams, 2.0 for Darcy Weisbach method)

m = Pipe number

The junction continuity equations take the form:

$$Q_i = 0$$

(One equation for each of (N - 1) junctions)

where:

Q_i = flow i into or out of the junction. May be a pipe flow or external demand or supply.
N = Total number of junctions in the system

The next step in the process is to linearize the nonlinear loop equation. This is accomplished by rewriting the loop equations in the following form in order to get each unknown pipe flow value to be to the power of unity:

$$k_1(Qtrial_1)^{n-1} * Q_1 + k_2(Qtrial_2)^{n-1} * Q_2 + \ldots k_m(Qtrial_m)^{n-1} * Q_m = 0$$

(ONE equation for each closed loop)

The above linearized loop equations are combined with the linear junction equations to form a set of simultaneous linear equations that can be solved by conventional matrix means. An iterative technique is required though, because the values of Q trial are not known for each pipe. The Q trial values must be equal (or very close to equal) to the Q values resulting from the solution of the simultaneous equations before the correct solution to the flow system is obtained.

The iterative technique involves first assuming pipe flows in the systems. Some schemes call for using a flow value of 1 where other schemes compute flow values in each pipe based on a reasonable value of velocity, say 4 ft./sec. (1 m/sec.). Using these trial values, the simultaneous equations are solved resulting in a set of Q values for each pipe. These values are compared to the previously assumed trial Q values. If the change in Q is very small in each pipe then the correct solution has been obtained. If the change of Q is above some preset limit then another iteration is required. For the next iteration, new trial Qs are computed by averaging the previous trial Q for each pipe with the Q just computed and calling this the new trial Q. The iteration procedure is repeated until the required accuracy between trial and computed Q is obtained.

The program used in this study uses the linearization technique described above. The program has methods for inputing minor loss coefficients (losses due to pipe fittings) and methods for establishing tanks and pumps in the system. The procedure for adding these features follows is much the same as that used for linearization of the loop equations for pipe friction. The manual for the program covers these options in detail (Wood, 1980).

MODEL INPUT DATA

The computer model handles all the linearization procedures internally and all that is required is an adequate geometric description of the pipe system and an accurate list of demands and supplies to the system. The data requirements can be broken down into physical description data and flow data. Physical description data include the following:

1. Number of pipes

2. Number of junction points

3. Pipe data for each pipe including:
   a. Length
   b. Diameter
   c. Roughness
   d. Minor losses in the pipe
   e. Pump type in the line
   f. Junction numbers connected by the pipe

4. Pump characteristic data input such as head vs. flow data or effective power data

5. Elevation of each junction point

6. Storage tank data including:
   a. Diameter of tanks (program assumes round tanks)
   b. Height of tanks
   c. Maximum and minimum water elevations in the tanks
   d. Pipe numbers of pipes connecting the tanks to the system

Available supply and demand are input to the program through the following data types.

1. Flow demands on the system concentrated at each junction point
2. Supply flows available at each junction point
3. Elevation of water in wells and starting elevations of water in storage tanks

The model has the capability of doing one-time hydraulic simulations to find the flows for a single set of hydraulic conditions or to do time simulations to investigate the long-term effects of various operation schemes. Models using both modes of operation were developed in these study.

METHOD OF INVESTIGATION AND DATA COLLECTION

The principal investigation methods used in this project were: a) site inspections of the Pohnpei water distribution system, b) studies of as built drawings of the system, c) field measurements, and d) interviews with local officials handling the management, operation and maintenance of the system. After completion, the hydraulic model was calibrated by measuring the pressure at fire hydrants. Several trips were made to Pohnpei, during which all previous plans and reports were reviewed. Several flow measurement stations were established, at which flow was measured each trip.

The data collected were as follows: Item 1, physical description data. As mentioned before Pohnpei's water system (consist of pipes which) were installed by OICC (early 1970's), the Japanese pipeline, and pipes installed by DPW. By reviewing the existing maps complete information about size, length, and location of pipes which make up 80% of the existing system were obtained. The pipes built by the Japanese, making up about 10% of the system were, ignored since there is no information available. The pipes which were built by DPW have not been recorded. Size and location of these lines were surveyed during field investigations. As a first attempt, the map of the distribution system was constructed. The layout of the system was coded in a form acceptable to the KYPIPE computer program as shown in Figure 5. There were three PRV's in the system which two of them are in operation. The pressure as mentioned on plate was recorded. Pressures downstream of these values were measured and the final pressure on PRV was adjusted, which is recorded in Appendix I.

It must be remembered that the model is a "skeletal" model in that it does not include every pipe in the Pohnpei system, but only the major lines. Thus, most of the smaller neighborhood lines have been omitted. Several parallel pipes may be represented by a single large pipe. Similarly, withdrawals of water by users located in large areas may be considered to occur together at a single node.

Item 2, water use (flow demand) at each node was calculated as an accurate account of the number of individual connections to the water system was impossible to obtain. It may never be possible to get an accurate account since there are many illegal connections plus legal connections that were made by the Department of Public Works that were not recorded. Also there are many leaks in the system, making it impossible to compute the exact demand of the system. The DPW has a total of 1641 meters in the system (as of November 1986) which are located in 6 areas, as shown in Figure 5. Total water input to the system is 1.9 mg per day from the Nanpohnmal reservoir and 0.3 mg per day from two wells. This flow was divided between nodes in Figure 5 by considering the number of meters in each area. The demands at each node were calculated for 24, 8, and 4 hours as shown in Table 3. Since the water service is four hours in the morning and evening except the hospital line, the input data for each nodes were chosen for 4 hours demand.

Item 3, the required data for an extended period simulation, was obtained from the existing operation of the Pohnpei water system. Appendix I and II contains a complete listing for the actual data of the entire system. A 5¼ inch IBM compatible disk containing the above described data is available from the Water and Energy Research Institute of the Western Pacific at the University of Guam.

Table 3

DEMAND-FLOW CALCULATIONS

AREA	NO. OF WATER METERS	NO. OF NODES	GPM 24 hrs/nodes	GPM 8 hrs	GPM 4 hrs
R02 R01	517	37	11.88	35.64	71.28
R03	253	16	13.44	40.32	80.64
R04 & R08	221	6	31.31	93.93	187.86
R05A	99	7	12.02	36.06	72.12
R06	26	1	22.10	66.30	132.60
R05C & D	158	12	11.19	33.58	67.16
R05B	96	7	11.66	34.97	70.00
R10A & B, R07 & R09	271	5	46.07	138.21	276.42

Total Water Meters = 1641
Total Water Input = 2 Million Gallons Per Day

SUMMARY AND CONCLUSION

In spite of an existing modern water distribution system in Kolonia, Capital of Pohnpei State, people are on water hours. This unconvenient water service is due to many problems which exist, with the Kolonia water system. These problems include low system maintenance, non-efficient system operation, and no trained personnel to operate the system. Also, the attitude of consumers toward water distribution system in which contributes to the causes high consumption rate.

In order to improve the operation of the Kolonia water system, a computer model of the entire system was developed. The computer model is very comprehensive, including the physical description of water distribution system, flow/demands as well as extended time simulation. This model, which is able to calculate the pressure and flow at each pipe in the system, can be useful in determining the different operation strategies to best to utilize the available water in storage tanks and in system. Also, the effect of any change in the system, such as demand increase or decrease, change in flow to the system and elevation of water in storage tanks, could be monitored.

Completion of Kolonia's computer model required a review of all drawing and maps of the water system as built. Also, some pipes were surveyed during field work. Therefore, the computer model of Kolonia's water system presents the most accurate information about the existing water system, available it includes size, length, elevation of each pipe, as well as other components such as storage tanks, PRVS and pumps (listed in Appendix I, and II). These data will be valuable to those wishing to make future studies of the water system.

The developed computer model of Kolonia's water system also can be used for detecting the leaks in the system. Because of many illegal connections plus legal connections that were not recorded by public works department, it was not possible to obtained an accurate flow demand at each node. Recently DPW is installing meters for each connection in the system. If this program is successful, then by using the Kolonia's computer model, the unaccounted water in each pipe can be known.

Another result of this project was training the officials at the Pohnpei Department of Public Works who are in charge of system operation and maintenance. Since the completion of this project required close cooperation with DPW, a training program was scheduled at each stage of data collection. The basic hydraulics of pipe networks were reviewed. Also, the effects of individual components of the water system on the operation of the entire system were explained.

RECOMMENDATION & FUTURE INVESTIGATION

The development of the computer model is only the first step in improving Pohnpei's water distribution system. Reviewing the design, construction, maintenance, operation and socio-political background of the Pohnpeian people indicated certain flows exist in the system, such as: a) complexity of the water system design not matching the level of DPW training b) climatic conditions not adequately considered in the design c) ignorance of cultural and social background of local people which are responsible for the high consumption rate. These problems have been accumulated during the past which now is creating the inconvenient water service. Expanding this water hours in Kolonia requires implementation of some practical steps which should be taken as soon as possible. These can be summarized as:

1. Training program for Department of Public Works personnel.
2. Repairing leaks in the main pipes and also in household service lines.
3. Installation of water service meters for all existing and future customers served by the water system.
4. Allocation of additional source of water for water system.
5. Public education regarding to the water conservation and water use.
6. Operation studies, using developed computer model.

Each recommendation described above is discussed in the following pages. It should be mentioned that implementation of the practical steps mentioned above requires the government as well as communities support. Probably the key to the sources of water service improvement is public education toward the water system which was ignored in the past.

<u>Training Program</u>

Personnel of DPW need intensive training in maintenance, operation and knowledge of the hydraulics of pipe networks. Improving the Kolonia water service requires a training program for groups involved in water and sewer functions and in the water treatment plant. This training program should review the following topics:

1. Fluid statics and fluid flow such as units of measurement, pressure, flow, energy loses and pipe sizing equations.

2. Basic hydraulics of groundwater, wells and pumps and the function of pipe network components such as valves, PRVS and storage tanks.

3. The water treatment system filtration, chlorination, testing and analyzing turbidity, fluorine and chloride levels, and other miscellaneous testing should be reviewed.

4. Water system maintenance, such as pumps, wells, chlorination system, valves, fittings and water meters.

This training should include administration and management training for the Public Works supervisors, including on the job training in procurement, scheduling, and employee supervision.

1. Individual customers should be encouraged to repair leaking household service line.

2. Gate valves on the main waterlines should be inspected for leaks.

Prevention of Leakage

A leakage study by Barrett, Harris and Associates Inc. (1983) indicated that Kolonia's water system has a large amount of water leakage. The sources of leakage are small but numerous. The cumulative flow through the entire water distribution combined with normal domestic water consumption, result in a rate of outflow from the distribution system that exceeds the rate of inflow.

They found four major sources of leakage and water loss in the system as:

1. leaks in service laterals leading from the water main to the customer's home

2. leaks in household plumbing

3. water loss through plumbing fixtures, and

4. leaks in all gate valves, primarily from wear and tear due to repeated opening and closing for maintaining water hours

Reducing the water leakage requires the following implementation:

1. Individual customers should be encouraged to repair leaking household service lines.

2. Gate valves on the main waterlines should be inspected for leakage.

3. All service laterals to be surveyed to determine if they are leaking.

<u>Metering Program</u>

There are 1641 registered meters in Kolonia's water system with many other legal and illegal non-meter connections. The present water rate is $1.50/month regardless of the amount of water used. A review the socio-political background of the Pohnpeian's (Khosrowpanah and Hunter-Anderson, 1987) indicated that Pohnpeian cultural traditions do not include a water conservation ethic. The lack of conservation is reinforced by the existing flat rate. Also, there is no adverse result if the bill is not paid.

Improving the water service in Kolonia requires immediate implementation of a metering program and scheduling a reasonable water rate for water used. Although Pohnpei's water resources are plentiful, delivery of water to consumers cannot be accomplished without cost to the state of Pohnpei. The new water rate should reflect the cost of operation, maintenance and delivery of water to consumers. After implementation of the metering program, DPW should establish an effective and accurate method of money collection and information about each accounts. Also, adopt a policy for discontinuance of service for non-payment account. A metering implementation program can be summarized as follows:

1. Meter all customers and users that have 24 hour water service. After completion of this stage, areas which have the most leakage according to their priority should be metered.

2. Maintenance of all existing meters and newly installed meters.

3. Reading the meters monthly. A preliminary water rate schedule be adopted for customers with installed meters. This preliminary rate may not be reflect the actual cost, but before the installing meters for all customers, this rate can help DPW to determine the actual rate.

4. Establish an account for each meter. Bills should be sent to customers. Service to non-paying customers should be disconnected.

Implementation of a metering program will introduce the following improvements to Kolonia's water system: a) encourage the customers to report to DPW if there is a leak in their service line, b) lines with leakage can be identified c) customers will be encouraged to use less water, d) there would be a revenue for operation and maintenance cost of the system, e) the information about water outflow can be fed into the computer model, and efficient use of system can be determined.

Additional Source of Water

The 1980 census counted 22,081 people living on Pohnpei with 8,624 people living in Kolonia, Sokehs and Net. The rate of population growth is estimated at about 3.5% for the area of Kolonia, Net and Sokehs. Considering the future development in the area since Kolonia is the new administrative center for the Federated State of Micronesia, the population growth rate might be accelerated in the future.

The total average of water input to the Kolonia system is (1.7 mgd from treatment plant plus 0.3 mgd from wells). Considering leakage in the system and the tendency for Pohnpeian to use large amount of water, the present water input to Kolonia's water system is not sufficient.

Presently at the existing intake site on Nanpil River for the water supply system, an intake for hydropower generation is attached. It might be possible that the water intake for the water supply system will be affected by the intake for the hydropower plant, which draws a large amount of water. In order to secure the source of water supply and providing a 24 hours water to consumer it will be important task for Pohnpei state to consider additional source of water. There are several ways to achieve this additional source of water as:

1. Construction of additional wells.
2. Develop a secondary source on either the Tawannu or Lai River or both.
3. Increase the capacity of existing transmission lines on the Nanpil River.

A thorough investigation is required for Department of Public Works to select any items from the above.

Public Education

A review of the social-political background of the Pohnpeian people relevant to the water distribution system indicated the Pohnpeian cultural traditions do not include a water conservation ethic. The fresh water has always been viewed as an "unlimited free good". Pohnpeians living in Kolonia say they used to locate their homes near streams, as indicated by the archaeological record. They cite frequent bathing in streams, pools and water falls. Pohnpeians state that they do not feel clean unless the water flows abundantly on their bodies during bathing. They usually remove the shower head in modern facilities, to avoid the fine spray.

Field investigations indicated the Pohnpeians do not realize the consequences for the water system of leaving the tap open. Most do not know how the pipe system works and why there is not enough pressure in the pipes. Also, adequate water delivery in Kolonia is seen by the Pohnpeians as the government's responsibility, not that of individual householders. Now, when a household's or neighborhoods' water pipe breaks or starts to leak, it may go unreported for long periods, and no measures are taken by consumers to remedy the situation even temporarily.

Improving Kolonia's water system requires implementation of public education in terms of how the pipe system works, why DPW can-not deliver 24 hours water, how to be conservative in using water, community involvement, household metering, water-rate structure, and reporting leakage to DPW.

This information (implementation) could be disseminated throughout the adult communities. Community meetings, workshops, posters, direct mailings, radio and elementary and secondary schools could be involved.

ACKNOWLEDGEMENTS

I would like to thank Mr. Bermin Weilbacker, Director of Department of Community Services, Pohnpei State for his enthusiastic interest, guideness, and support in seeing the project to complete. I would also like to express my appreciation to Mr. Finale Henry and Mendiola from Public Works Division, Department of Community Services for their help on almost all phases of data gathering and field works. Finally, I wish to thank Albert Okada and Norma Blas for typing this report.

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APPENDIX 1

Raw Data for the
Kolonia Water Distribution System

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
RAW DATA FOR INPUT TO KENTUCKY MODEL

133 -2 101 1 2 0 4 3 0 1
84 102 124 133

2	0	2	5	12	111	.04	0	265
5	91	3	65	12	111	.6	0	
6	3	4	4160	12	111	.4	0	
7	4	5	1172	12	111	.8	0	
8	5	6	933	12	111	.6	0	
9	6	7	1500	8	111	1.6	0	
10	7	9	1650	8	111	1.2	0	
11	7	8	270	4	107	.5	0	
12	6	10	250	12	111	.2	0	
13	10	23	804	8	111	.5	0	
14	10	11	250	12	111	.4	0	
15	11	12	100	6	107	.4	0	
16	11	13	250	12	111	.4	0	
17	13	14	295	12	111	.5	0	
18	14	43	145	12	111	.2	0	
19	15	13	528	12	111	.4	0	
20	18	15	528	12	111	.8	0	
21	18	16	500	12	111	.5	0	
22	16	17	100	4	107	.5	0	
23	16	15	824	4	107	.6	0	
24	19	18	264	12	111	.8	0	
25	19	20	100	4	107	.5	0	
26	21	19	264	12	111	.2	0	
27	21	5	384	4	107	.5	0	
28	22	21	2904	12	111	1.8	0	
29	102	22	1447	12	111	.5	0	
30	23	24	454	8	111	.5	0	
31	24	25	332	8	111	.5	0	
32	25	26	400	8	111	.5	0	
33	26	27	971	8	111	1.2	0	
34	27	28	267	8	111	.5	0	
35	28	29	278	8	111	.5	0	
36	29	30	255	8	111	.5	0	
37	30	31	246	8	111	.5	0	
38	32	31	401	8	111	.5	0	
39	33	32	282	8	111	.5	0	
40	34	33	246	8	111	.5	0	
41	35	34	232	8	111	.5	0	
42	36	35	241	8	111	.5	0	
43	37	36	474	8	111	.5	0	
44	25	37	173	8	111	.5	0	
45	49	25	167	8	111	.5	0	
46	48	49	152	8	111	.5	0	
47	47	48	182	8	111	.5	0	
48	44	45	181	8	111	.5	0	
49	45	46	154	8	111	.5	0	
50	46	24	167	8	111	.5	0	
51	24	38	170	8	111	.5	0	

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
RAW DATA FOR INPUT TO KENTUCKY MODEL
(CONTINUED)

52	38	39	184	8	111	.5	0	
53	43	42	175	6	107	.5	0	
54	42	41	156	6	107	.5	0	
55	23	41	171	6	107	.5	0	
56	23	40	20	6	107	.5	0	
57	40	38	476	6	107	.5	0	
58	38	37	401	6	107	.5	0	
59	37	54	402	6	107	.5	0	
60	54	55	470	8	111	.5	0	
61	55	36	395	4	107	.5	0	
62	55	27	293	4	107	.5	0	
63	35	28	672	4	107	.5	0	
64	34	29	648	4	107	.5	0	
65	33	30	605	4	107	.5	0	
66	43	44	470	12	111	.5	0	
67	42	45	464	6	107	.5	0	
68	41	46	462	12	111	.5	0	
69	44	47	315	12	111	.5	0	
70	45	48	332	6	107	.5	0	
71	46	49	329	6	107	.5	0	
72	47	50	414	12	111	.5	0	
73	48	51	397	6	107	.5	0	
74	49	52	399	6	107	.5	0	
75	51	50	193	8	111	.5	0	
76	51	52	144	8	111	.5	0	
77	52	26	169	8	111	.5	0	
78	26	54	175	8	111	.5	0	
79	14	56	352	12	111	.5	0	
80	56	57	1446	12	111	1.4	0	
81	57	58	397	12	111	.5	0	
82	58	59	2190	12	111	1.0	0	
83	59	60	2820	8	111	.2	0	
84	59	0	2325	12	111	3.0	0	196
85	57	90	138	8	111	.2	0	
86	0	61	52	8	111	.2	0	45
87	62	61	205	6	107	.5	0	
88	62	63	180	6	107	.5	0	
89	64	62	290	6	107	.6	0	
90	65	64	440	6	107	.6	0	
91	66	64	1139	6	107	3.3	0	
92	61	82	99	8	111	.6	0	
93	65	82	474	8	111	1.2	0	
94	66	65	456	8	111	1.2	0	
95	67	66	614	8	111	.5	0	
96	68	67	323	8	111	.6	0	
97	68	69	1228	6	107	.6	0	
98	56	70	592	8	111	.2	0	
99	70	44	478	8	111	.5	0	
100	70	72	185	8	111	.5	0	
101	72	89	316	8	111	.6	0	
102	89	67	455	8	111	.5	0	

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
RAW DATA FOR INPUT TO KENTUCK MODEL
(CONTINUED)

103	50	79	366	8	111	.5	0	
104	79	80	275	8	111	.5	0	
105	79	88	118	8	111	.8	0	
106	0	68	375	8	111	.5	0	76
107	72	73	528	4	107	1.6	0	
108	73	74	528	4	107	.6	0	
109	74	75	528	4	107	1.1	0	
110	75	76	528	4	107	.6	0	
111	76	77	972	4	107	2.2	0	
112	77	78	972	4	107	1.8	0	
113	75	78	528	4	107	1.2	0	
114	15	81	528	4	107	1.2	0	
115	70	71	490	4	107	.6	0	
116	82	83	106	4	107	.6	0	
117	83	84	452	4	107	1.8	0	
118	83	85	126	4	107	.6	0	
119	85	86	194	4	107	.6	0	
120	85	87	209	4	107	.6	0	
122	92	91	10	12	111	.2	0	
123	0	92	5	12	111	.4	0	200
124	93	92	2705	12	111	4.0	0	
125	2	93	70	12	111	1.2	0	
126	2	94	50	8	111	.5	1	
127	94	95	300	4	107	1.4	0	
128	95	96	2650	2	107	1.4	0	
129	95	97	1650	4	107	2.0	0	
130	94	0	5372	8	111	4.2	0	375
131	4	98	4200	12	111	3.6	0	
132	98	99	800	8	111	.6	0	
133	99	0	10	8	111	.5	0	190
134	99	100	6822	8	111	12.6	0	
135	98	101	13514	8	111	2.4	0	
136	93	102	1382	12	111	1.1	0	
137	97	103	400	2	107	.4	0	
1		1		40				

2	264	0
5	86	70
6	85.8	70
7	106	70
9	93	70
10	88.4	71.28
13	86.3	67.16
15	116	67.16
16	95.5	67.16
21	95	67.16
22	150	-215
23	54	71.28
24	48	71.28
25	47.5	71.28
26	54.5	71.28
27	26	71.28

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
RAW DATA FOR INPUT TO KENTUCKY MODEL
(CONTINUED)

28	29.5	71.28
29	31.4	71.28
30	29.6	71.28
31	24.5	71.28
32	34	71.28
33	44	71.28
34	55.5	71.28
35	51.5	71.28
36	41	71.28
37	41.5	71.28
38	39.5	71.28
39	34	71.28
40	47.5	71.28
41	58.5	71.28
42	66.5	71.28
43	73.5	71.28
44	68.2	71.28
45	61	71.28
46	53.5	71.28
47	65.8	71.28
48	59.5	71.28
49	53	71.28
50	65.5	71.28
51	64	71.28
52	61.5	71.28
54	47	71.28
55	32.5	71.28
56	91.5	187.86
57	30	187.86
58	28.5	187.86
59	30	187.86
60	5.5	187.86
61	27.5	80.64
62	10.5	80.64
63	1.5	80.64
64	2.5	80.64
65	7.5	80.64
66	5	80.64
67	6	80.64
68	8	80.64
69	12	80.64
70	83.5	71.28
76	66.5	72.12
78	48	72.12
79	64	71.28
80	60.5	71.28
82	27	80.64
83	28	80.64
84	11.6	80.64
85	28.3	80.64
86	27.5	80.64

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
RAW DATA FOR INPUT TO KENTUCKY MODEL
(CONTINUED)

87	41.5		80.64	
-1				
88	106			
90	86			
0	0			
6	1	1	0	
123	200	182	65	0
4				
3	-122	-124	-126	
18	-1	0		
22	-215			
21	7.48			
19	7.48			
20	7.48			
18	7.48			
16	7.48			
17	7.48			
15	22			
14	7.48			
81	7.48			
13	22			
12	7.48			
56	22			
57	22			
58	22			
59	22			
60	22			
0	0	888		

APPENDIX II

Summary of Input Data for the
Kolonia Water Distribution System

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
INTERPRET DATA FOR KENTUCKY MODEL

NUMBER OF PIPES = 133
NUMBER OF JUNCTION NODES = 101
FLOW UNITS = GALLONS / MINUTE
PRESSURE UNITS = PSI

CLOSED LINES - 84 102 124 133

**** SUMMARY OF INPUT DATA ***

PIPE NO.	NODE #1	NODE #2	LENGTH (FT.)	DIAM. (IN.)	HW-C VALUE	SUM-M FACT.	PUMP TYPE	FGN GRADE
2	0	2	5.0	12.0	111.0	0.0	0.0	265.0
5	91	3	65.0	12.0	111.0	0.6	0.0	
6	3	4	4160.0	12.0	111.0	0.4	0.0	
7	4	5	1172.0	12.0	111.0	0.8	0.0	
8	5	6	933.0	12.0	111.0	0.6	0.0	
9	6	7	1500.0	8.0	111.0	1.6	0.0	
10	7	9	1650.0	8.0	111.0	1.2	0.0	
11	7	8	270.0	4.0	107.0	0.5	0.0	
12	6	10	250.0	12.0	111.0	0.2	0.0	
13	10	23	804.0	8.0	111.0	0.5	0.0	
14	11	10	250.0	12.0	111.0	0.4	0.0	
15	11	12	100.0	6.0	107.0	0.4	0.0	
16	13	11	250.0	12.0	111.0	0.4	0.0	
17	13	14	295.0	12.0	111.0	0.5	0.0	
18	14	43	145.0	12.0	111.0	0.2	0.0	
19	15	13	528.0	12.0	111.0	0.4	0.0	
20	18	15	528.0	12.0	111.0	0.8	0.0	
21	18	16	500.0	12.0	111.0	0.5	0.0	
22	16	17	100.0	4.0	107.0	0.5	0.0	
23	16	15	824.0	4.0	107.0	0.6	0.0	
24	19	18	264.0	12.0	111.0	0.8	0.0	
25	19	20	100.0	4.0	107.0	0.5	0.0	
26	21	19	264.0	12.0	111.0	0.2	0.0	
27	21	5	384.0	4.0	107.0	0.5	0.0	
28	22	21	2904.0	12.0	111.0	1.8	0.0	
29	102	22	1447.0	12.0	111.0	0.5	0.0	
30	23	24	454.0	8.0	111.0	0.5	0.0	
31	24	25	332.0	8.0	111.0	0.5	0.0	
32	25	26	400.0	8.0	111.0	0.5	0.0	
33	26	27	971.0	8.0	111.0	1.2	0.0	
34	27	28	267.0	8.0	111.0	0.5	0.0	
35	28	29	278.0	8.0	111.0	0.5	0.0	
36	29	30	255.0	8.0	111.0	0.5	0.0	
37	30	31	246.0	8.0	111.0	0.5	0.0	
38	32	31	401.0	8.0	111.0	0.5	0.0	
39	33	32	282.0	8.0	111.0	0.5	0.0	
40	34	33	246.0	8.0	111.0	0.5	0.0	
41	35	34	232.0	8.0	111.0	0.5	0.0	
42	36	35	241.0	8.0	111.0	0.5	0.0	
43	37	36	474.0	8.0	111.0	0.5	0.0	

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
INTERPRET DATA FOR KENTUCKY MODEL
(CONTINUED)

44	25	37	173.0	8.0	111.0	0.5	0.0	
45	49	25	167.0	8.0	111.0	0.5	0.0	
46	48	49	152.0	8.0	111.0	0.5	0.0	
47	47	48	182.0	8.0	111.0	0.5	0.0	
48	44	45	181.0	8.0	111.0	0.5	0.0	
49	45	46	154.0	8.0	111.0	0.5	0.0	
50	46	24	167.0	8.0	111.0	0.5	0.0	
51	24	38	170.0	8.0	111.0	0.5	0.0	
52	38	39	184.0	8.0	111.0	0.5	0.0	
53	43	42	175.0	6.0	107.0	0.5	0.0	
54	42	41	156.0	6.0	107.0	0.5	0.0	
55	23	41	171.0	6.0	107.0	0.5	0.0	
56	23	40	20.0	6.0	107.0	0.5	0.0	
57	40	38	476.0	6.0	107.0	0.5	0.0	
58	38	37	401.0	6.0	107.0	0.5	0.0	
59	37	54	402.0	6.0	107.0	0.5	0.0	
60	54	55	470.0	8.0	111.0	0.5	0.0	
61	55	36	395.0	4.0	107.0	0.5	0.0	
62	55	27	293.0	4.0	107.0	0.5	0.0	
63	35	28	672.0	4.0	107.0	0.5	0.0	
64	34	29	648.0	4.0	107.0	0.5	0.0	
65	33	30	605.0	4.0	107.0	0.5	0.0	
66	43	44	470.0	12.0	111.0	0.5	0.0	
67	42	45	464.0	6.0	107.0	0.5	0.0	
68	41	46	462.0	12.0	111.0	0.5	0.0	
69	44	47	315.0	12.0	111.0	0.5	0.0	
70	45	48	332.0	6.0	107.0	0.5	0.0	
71	46	49	329.0	6.0	107.0	0.5	0.0	
72	47	50	414.0	12.0	111.0	0.5	0.0	
73	48	51	397.0	6.0	107.0	0.5	0.0	
74	49	52	399.0	6.0	107.0	0.5	0.0	
75	50	51	193.0	8.0	111.0	0.5	0.0	
76	51	52	144.0	8.0	111.0	0.5	0.0	
77	52	26	169.0	8.0	111.0	0.5	0.0	
78	26	54	175.0	8.0	111.0	0.5	0.0	
79	14	56	352.0	12.0	111.0	0.5	0.0	
80	56	57	1446.0	12.0	111.0	1.4	0.0	
81	58	57	397.0	12.0	111.0	0.5	0.0	
82	59	58	2190.0	12.0	111.0	1.0	0.0	
83	59	60	2820.0	8.0	111.0	0.2	0.0	
84	59	0	2325.0	12.0	111.0	3.0	0.0	196.0
85	57	90	138.0	8.0	111.0	0.2	0.0	
86	0	61	52.0	8.0	111.0	0.2	0.0	45.0
87	61	62	205.0	6.0	107.0	0.5	0.0	
88	62	63	180.0	6.0	107.0	0.5	0.0	
89	62	64	290.0	6.0	107.0	0.6	0.0	
90	65	64	440.0	6.0	107.0	0.6	0.0	
91	66	64	1139.0	6.0	107.0	3.3	0.0	
92	61	82	99.0	8.0	111.0	0.6	0.0	
93	82	65	474.0	8.0	111.0	1.2	0.0	
94	65	66	456.0	8.0	111.0	1.2	0.0	
95	67	66	614.0	8.0	111.0	0.5	0.0	

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
INTERPRET DATA FOR KENTUCKY MODEL
(CONTINUED)

96	67	68	323.0	8.0	111.0	0.6	0.0	
97	68	69	1228.0	6.0	107.0	0.6	0.0	
98	56	70	592.0	8.0	111.0	0.2	0.0	
99	70	44	478.0	8.0	111.0	0.5	0.0	
100	70	72	185.0	8.0	111.0	0.5	0.0	
101	72	89	316.0	8.0	111.0	0.6	0.0	
102	89	67	455.0	8.0	111.0	0.5	0.0	
103	50	79	366.0	8.0	111.0	0.5	0.0	
104	79	80	275.0	8.0	111.0	0.5	0.0	
105	79	88	118.0	8.0	111.0	0.8	0.0	
106	0	68	375.0	8.0	111.0	0.5	0.0	76.0
107	72	73	528.0	4.0	107.0	1.6	0.0	
108	73	74	528.0	4.0	107.0	0.6	0.0	
109	74	75	528.0	4.0	107.0	1.1	0.0	
110	75	76	528.0	4.0	107.0	0.6	0.0	
111	76	77	972.0	4.0	107.0	2.2	0.0	
112	77	78	972.0	4.0	107.0	1.8	0.0	
113	75	78	528.0	4.0	107.0	1.2	0.0	
114	15	81	528.0	4.0	107.0	1.2	0.0	
115	70	71	490.0	4.0	107.0	0.6	0.0	
116	82	83	106.0	4.0	107.0	0.6	0.0	
117	83	84	452.0	4.0	107.0	1.8	0.0	
118	83	85	126.0	4.0	107.0	0.6	0.0	
119	85	86	194.0	4.0	107.0	0.6	0.0	
120	85	87	209.0	4.0	107.0	0.6	0.0	
122	92	91	10.0	12.0	111.0	0.2	0.0	
123	92	0	5.0	12.0	111.0	0.4	0.0	200.0
124	93	92	2705.0	12.0	111.0	4.0	0.0	
125	2	93	70.0	12.0	111.0	1.2	0.0	
126	2	94	50.0	8.0	111.0	0.5	1.0	
127	94	95	300.0	4.0	107.0	1.4	0.0	
128	95	96	2650.0	2.0	107.0	1.4	0.0	
129	95	97	1650.0	4.0	107.0	2.0	0.0	
130	94	0	5372.0	8.0	111.0	4.2	0.0	375.0
131	4	98	4200.0	12.0	111.0	3.6	0.0	
132	98	99	800.0	8.0	111.0	0.6	0.0	
133	99	0	10.0	8.0	111.0	0.5	0.0	190.0
134	99	100	6822.0	8.0	111.0	12.6	0.0	
135	98	101	13514.0	8.0	111.0	2.4	0.0	
136	93	102	1382.0	12.0	111.0	1.1	0.0	
137	97	103	400.0	2.0	107.0	0.4	0.0	

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
INTERPRET DATA FOR KENTUCKY MODEL
(CONTINUED)

*** DATA FOR PUMPS FOR THIS SYSTEM ***

PUMP TYPE # 1 IS DESCRIBED BY USEFUL POWER = 40

JUNCT. NO.	DEMAND	ELEVATION
2	0.0	264.0
5	70.0	86.0
6	70.0	85.8
7	70.0	106.0
9	70.0	93.0
10	71.3	88.4
13	67.2	86.3
15	67.2	116.0
16	67.2	95.5
21	67.2	95.0
22	-215.0	150.0
23	71.3	54.0
24	71.3	48.0
25	71.3	47.5
26	71.3	54.5
27	71.3	26.0
28	71.3	29.5
29	71.3	31.4
30	71.3	29.6
31	71.3	24.5
32	71.3	34.0
33	71.3	44.0
34	71.3	55.5
35	71.3	51.5
36	71.3	41.0
37	71.3	41.5
38	71.3	39.5
39	71.3	34.0
40	71.3	47.5
41	71.3	58.5
42	71.3	66.5
43	71.3	73.5
44	71.3	68.2
45	71.3	61.0
46	71.3	53.5
47	71.3	65.8
48	71.3	59.5
49	71.3	53.0
50	71.3	65.5
51	71.3	64.0
52	71.3	61.5
54	71.3	47.0
55	71.3	32.5
56	187.9	91.5
57	187.9	30.0

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
INTERPRET DATA FOR KENTUCKY MODEL
(CONTINUED)

58	187.9	28.5
59	187.9	30.0
60	187.9	5.5
61	80.6	27.5
62	80.6	10.5
63	80.6	1.5
64	80.6	2.5
65	80.6	7.5
66	80.6	5.0
67	80.6	6.0
68	80.6	8.0
69	80.6	12.0
70	71.3	83.5
76	72.1	66.5
78	72.1	48.0
79	71.3	64.0
80	71.3	60.5
82	80.6	27.0
83	80.6	28.0
84	80.6	11.6
85	80.6	28.3
86	80.6	27.5
87	80.6	41.5

THERE IS A PRV IN LINE 106 UPSTREAM NODE = 88 SET GRADE = 76
THERE IS A PRV IN LINE 86 UPSTREAM NODE = 90 SET GRADE = 45

KOLONIA WATER DISTRIBUTION SYSTEM MODEL
INTERPRET DATA FOR KENTUCKY MODEL
(CONTINUED)

AN EPS SIMULATION IS SPECIFIED
SIMULATION PERIOD = 6 - TIME INCREMENT = 1

--- TANK DATA ---

PIPE NO.	MAX. EL.	MIN. EL.	DIAMETER	INIT. EL.	EXT. Q(IN)
123	200.0	182.0	65.0	200.0	0.0

EPS SIMULATION - TIME = 0 HOURS
EPS SIMULATION - TIME = 1 HOURS
EPS SIMULATION - TIME = 2 HOURS
EPS SIMULATION - TIME = 3 HOURS

THE FOLLOWING CHANGES ARE MADE
THE STATUS (OPEN-CLOSED) OF PIPE 122 IS CHANGED
THE STATUS (OPEN-CLOSED) OF PIPE 124 IS CHANGED
THE STATUS (OPEN-CLOSED) OF PIPE 126 IS CHANGED

JUNCT. NO. DEMAND
GLOBAL DEMAND FACTOR = 0

JUNCT. NO.	DEMAND
22	-215
21	7.48
19	7.48
20	7.48
18	7.48
16	7.48
17	7.48
15	22
14	7.48
81	7.48
13	22
12	7.48
56	22
57	22
58	22
59	22
60	22

EPS SIMULATION - TIME = 4 HOURS
EPS SIMULATION - TIME = 5 HOURS
EPS SIMULATION - TIME = 6 HOURS

******* END OF THIS SIMULATION *******