Hydraulic Analysis and Recommended Improvements

for the
Cape Hatteras Water Association Distribution System

prepared for:

Dare County

211 Budleigh Street
Manteo, North Carolina 27954

March, 1997

prepared by:

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SOUTHERN PINES, NORTH CAROLINA

MARCH, 1997

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3/31/97

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EXECUTIVE SUMMARY

HYDRAULIC ANALYSIS
and
RECOMMENDED IMPROVEMENTS
for the
CAPE HATTERAS WATER ASSOCIATION
DISTRIBUTION SYSTEM

Hobbs, Upchurch & Associates, P.A. evaluated the Cape Hatteras Water Association (CHWA) system with respect to future water needs and distribution improvements needed to deliver the projected 2020 system capacity. (A table summarizing our recommended system improvements is provided on page *iv* of this Executive Summary.) The system evaluation was performed in conjunction with a proposal to upgrade the CHWA water treatment plant to 3.0 mgd. Therefore, we knew from the beginning that the distribution system must necessarily handle a minimum of 3.0 mgd.

The **current system** is supplied by an 8" trunk main that runs along Hwy 12 from the ferry landing in Hatteras to the northern limits of Avon. Many of the laterals off of the trunk main are small diameter (less than 6") pipe and of low quality material. Several of these lateral sections are subject to line breaks. Many of the laterals are without fire hydrants. The cost estimates in this report provide costs for upgrading substandard lateral mains.

The system is charged by the high service pumps at the water treatment plant (WTP) which fill the 400,000 and 100,000 gallon tanks in Buxton. At night a main line valve located at the dormant Frisco booster pump station (BPS) is opened manually to allow the Hatteras tank to fill. The 400k tank is located so close to the WTP that the high service pumps do not allow any discharge from the tank, causing water to stagnate in the tank. In addition to the Frisco BPS, a BPS at the CHWA office is also dormant (not used in daily operation).

A 10 hp BPS located at the east end of Buxton fills the 100 kgal tank in Avon. Suction from this pump causes low pressures in the vicinity of the Coast Guard Station and along Lighthouse and Flowers Ridge Roads.

To evaluate the **future water demands** for the CHWA system, we utilized population projections from the Booz, Allan and Hamilton, Inc. Dare County Carrying Capacity Study. The 1985 report projected the population of Avon, Buxton, Frisco and Hatteras through 2000. We extended their projections through 2020, increasing the percent growth by an additional one percent each five years. These projections are summarized below.

Year	1995	2000	2005	2010	2020
Population	22,070	23,593	25,245	27,265	32,690

The CHWA staff provided billing records for July 1996 from which we established the average water demand for the peak water usage month. We used this information to accurately distribute the water demand in a hydraulic model of the distribution system. We then interpolated the 2020 projected water demand using the July 1996 demand and the population projections shown above. From billing records, the current average daily water demand is 724,000 gpd. Peak demand is estimated as 3.5 times average or 2.5 mgd. The projected 2020 average daily demand is 1.1 mgd with peak demand of 3.8 mgd.

To understand the **hydraulic performance** of the system under present and future water demands, we constructed a computer model of the system using CYBERNET, a hydraulic modeling and simulation package. We then analyzed the performance of the CHWA system under present average day and peak day demands. The model results indicated that the system struggles to maintain water levels in Avon and Hatteras during peak usage periods. Fire flow analyses indicated very low available fire flow in the vicinity of Flowers Ridge Road, the Coast Guard Station and along Hwy 12 between Avon and Buxton.

The hydraulic model indicated that the current distribution system would be unable to deliver the projected 2020 peak water demands of 3.85 mgd. We experimented with two system improvement scenarios that would enable the system to handle the projected demand. After comparing the pros and cons of the two alternatives, we combined the best aspects of the two for our recommended system improvements.

Alternative One involves renovating the now-dormant booster pump station (BPS) at the CHWA office. In this scenario, high service pumps at the WTP pump treated water to the 400k tank at the office. The office BPS charges the distribution system, filling the Buxton and Hatteras 100 kgal elevated tanks. The trunk main along Hwy 12 is improved by installing 12" water main paralleling the existing 8" water main between the Hatteras tank and the southern limits of Avon (installed in 2 phases). Alternative One makes use of the now-stagnant 400k tank, provides three means of supplying water to the distribution system and delivers good system-wide fire protection. The three-phased project costs $8,391,240. The costs and project phasing are detailed in Appendix 1. Alternative One is explained in detail in Section 4.3.1 of this report.

Alternative Two takes advantage of the high service pumps at the WTP in conjunction with the proposed plant upgrade. The first phase of 12" pipe installation runs from the WTP west to the Frisco BPS and east to the Avon BPS. In this scenario, we investigated renovating the now-dormant Frisco BPS to fill the Hatteras tank. This allows for smaller pumps at the WTP. However, as system demand increases, the Frisco BPS needs upgrading from 10 hp to 20 hp, and 12" water main then must be extended the remaining distance to the Hatteras tank as in Alternative One. Upgrading the 8" trunk main to Avon was also necessary as in Alternative One. The 400k tank is not useful in its present location in this scenario, so it is dismantled and re-erected to replace the existing 100k Buxton tank (to maintain adequate elevated storage). Alternative Two provides good system-wide fire protection but only one means of supplying water into the system. The booster pumps are spread out in the system and would all require backup power generators in case of power outage. The three-phased project costs $8,888,360.

The costs and project phasing are detailed in Appendix 2. Alternative Two is explained in detail in Section 4.3.2 of this report.

Our **Recommended System Improvement** draws from the best aspects of the above two alternatives. We recommend using the high service pumps in the upgraded WTP to charge the system. The high service pumps will fill the Hatteras and Buxton 100 kgal tanks without the need to renovate and utilize the Frisco BPS. In a first construction phase, 12" water main will be installed from the WTP to the Hatteras tank and to the Avon BPS. A new above ground Avon BPS will be constructed to replace the existing outdated below ground BPS. Water main will be installed to complete the 6" loop along Flowers Ridge Road. The 400 kgal tank at the CHWA office will be dismantled and re-erected to replace the Avon 100 kgal tank. This will eliminate the unused 400 kgal tank and provide additional storage in Avon for emergencies and fire protection. Altitude valves and telemetry will be installed on the three remaining system tanks. Total cost for phase one is estimated at $3,263,130.

An option which could be performed as part of phase one is to upgrade all lateral water mains which are less than 6" diameter. This would provide improved flow to residential areas and allow for fire hydrants along all side streets. There are approximately 82,000 feet of water main which could be upgraded. The estimated cost for upgrading the lateral water mains is $2,846,350.

When system demand increases to projected 2002 levels, phase two of the project will become necessary: 25,000 feet of 12" water main extended from the Avon BPS to Avon. Estimated cost for phase two is $965,640.

Phase three of construction will be necessary in conjunction with projected 2007 water demands: replace the Hatteras tank with a 300,000 gallon tank and install 3,200 feet of additional 12" pipe between the Hatteras tank and Eagle Pass Road to improve fire protection and emergency water supply. The estimated cost for phase three is $819,520.

The **Recommended System Improvements** are explained in detail in Section 6.0 of this report. The three-phased project totals $7,894,640. The costs and project phasing are summarized below and detailed in Appendix 3.

PROJECT SUMMARY AND ASSOCIATED COSTS

PHASE 1:
Total Cost: **$3,263,130**
(to be constructed in conjunction with WTP expansion)

- Install 12" water main, Hatteras tank and Avon BPS
- Complete Flowers Ridge Road loop
- Construct new Avon BPS
- Dismantle 400k tank, use to replace Avon tank
- Install altitude valves at the Avon, Buxton and Hatteras tanks
- Upgrade telemetry network

PHASE 1 OPTION:
Total Cost: **$2,846,350**
(timing to be determined)

- Upgrade all laterals mains to 6"

PHASE 2:
Total Cost: **$965,640**
(to be constructed in 2002)

- Extend 12" water main from Avon BPS to Avon

PHASE 3:
Total Cost: **$819,520**
(to be constructed in 2007)

- Replace Hatteras 100 kgal tank with 300 kgal tank
- Extend 12" water main from the Hatteras tank to Eagle Pass Road

PROJECT TOTAL: $7,894,640

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and
RECOMMENDED IMPROVEMENTS
for the
CAPE HATTERAS WATER ASSOCIATION
DISTRIBUTION SYSTEM

1.0 INTRODUCTION

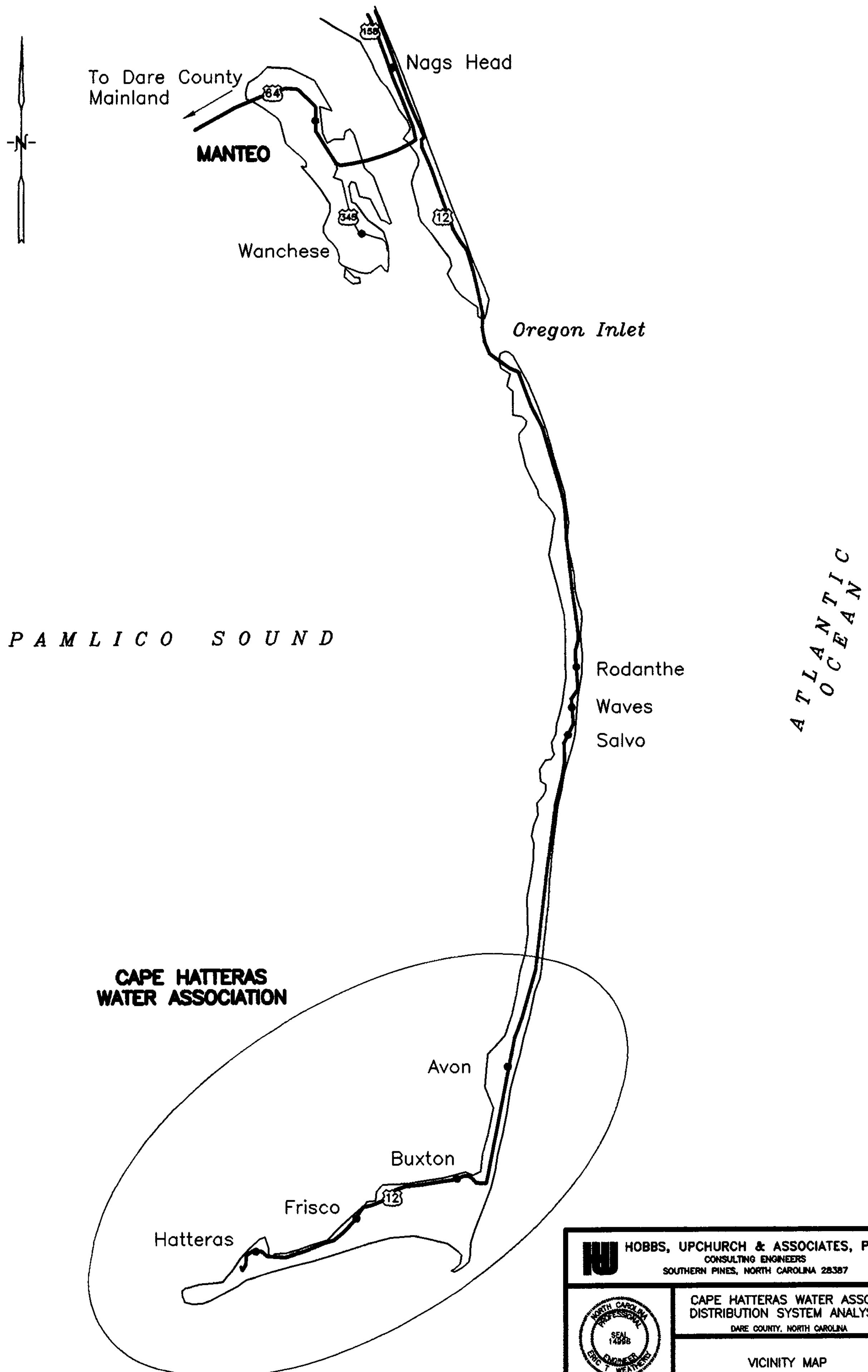
The Cape Hatteras Water Association (CHWA) serves the communities of Avon, Buxton, Frisco and Hatteras on the southern Outer Banks of Dare County (Figure 1). The system was started from limited Farmers Home Administration funding in the mid to late 1960's and initially served from Buxton to Hatteras. In the late 1970's work was begun to extend service to Avon. As of July 1996, the CHWA system maintained approximately 3049 accounts.

Dare County and the CHWA have expressed mutual interest in transferring maintenance and operation of the CHWA system to the County. This transfer is in conjunction with plans to increase the CHWA production capacity to 3.0 mgd. Prior to this transfer, Dare County requested that the distribution system be investigated and analyzed as to its ability to deliver 3.0 mgd and any improvements that may be necessary to deliver 3.0 mgd. Dare County retained Hobbs, Upchurch & Associates, P.A. to perform this analysis, the results of which are reported herein.

1.1 Distribution System Analysis - Project Approach

This report presents the methodology and findings of the CHWA distribution system analysis performed by Hobbs, Upchurch & Associates, P.A. (HUA). The project approach was as follows:

1. Formulate population and water demand projections through 2020 using data provided by CHWA and Dare County.
2. Construct a computer hydraulic model of the system, accurately reflecting the system layout, construction materials, age, etc.
3. Using the computer model Cybernet, analyze the system's hydraulic performance under present operating conditions.
4. Analyze system performance under projected 2020 demands.
5. Evaluate improvements in the distribution system needed to deliver the projected 2020 daily peak demand.
6. Formulate a phased construction approach to implement recommended improvements and provide construction cost estimates.



HOBBS, UPCHURCH & ASSOCIATES, P.A. CONSULTING ENGINEERS SOUTHERN PINES, NORTH CAROLINA 28387		MAR., 1997
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NORTH CAROLINA PROFESSIONAL SEAL 14998 ENGINEER ERIC T. WEATHERLY	CAPE HATTERAS WATER ASSOC. DISTRIBUTION SYSTEM ANALYSIS DARE COUNTY, NORTH CAROLINA	DMS
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2.0 EXISTING FACILITIES

Water for the system is obtained from the Buxton Woods well field southwest of the water treatment plant (WTP). The well field, located off Water Association Road, contains 37 wells screened in the surficial aquifer. The WTP is rated at 2.0 mgd and treats water through aeration, flocculation, sedimentation, filtration and ion exchange softening. The limiting factor in system production capacity is the well field which is capable of producing approximately 1.6 mgd.

The distribution system is supplied through an 8" trunk main along Hwy 12 from Hatteras (near the ferry landing) to the north end of Avon with the exception of approximately 1.8 miles of 6" main through Buxton. Except for minor system loops in Hatteras and Buxton, the remainder of the distribution system consists of 2", 3", 4" and 6" dead-end lateral mains off of the trunk main. The first phase of the distribution system (Buxton to Hatteras, 1960's) was constructed largely with asbestos concrete (AC) pipe. The remainder of the system, including most of the laterals, consists primarily of PVC pipe. Several short laterals are constructed of 3/4" flexible polybutylene pipe.

Elevated water storage is provided in four (4) tanks located throughout the system as shown in Figure 2. The Buxton and Hatteras 100 kgal tanks and the 400 kgal tank at the CHWA office are filled by the high-service pumps at the WTP. The WTP pumps consist of one 50 hp 780 gpm pump and two 25 hp 350 gpm pumps. A below ground 10 hp 250 gpm booster pump station located at the eastern end of Buxton pumps to the Avon 100 kgal tank. A check valve on the south end of Avon prevents flow from Avon back toward Buxton. A check valve at the dormant Frisco booster pump station prevents flow from Hatteras back toward Buxton.

There are two booster pump stations in the system which were installed in 1987 but never placed in service. The booster pump station (BPS) located at the CHWA office contains two 40 hp 600 gpm vertical turbine pumps. The Frisco BPS contains two 40 hp 400 gpm vertical turbine pumps.

2.1 <u>Current Operating Conditions</u>

The CHWA distribution system is charged with water using the high service pumps at the WTP. The high service pumps operate via telemetry off of the water level in the 100 kgal Buxton Tank; alternately, they may be operated manually. The high service pumps supply sufficient head to fill the 400 kgal tank and the Hatteras and Buxton tanks. The 10 hp booster pump station at the east end of Buxton operates via telemetry to fill the Avon tank.

The system layout coupled with the demand distribution are such that the Buxton tank cycles fairly frequently, causing the high service pumps to operate frequently. Furthermore, because of its hydraulic position in the system, the 400 kgal tank empties very little during the Buxton tank cycle. As a result, the high service pumps keep the 400 kgal tank filled virtually around the clock. Thus, the

400 kgal tank requires an altitude valve to prevent over filling. The high water level in the 400 kgal tank is kept set relatively low to minimize the volume of water stagnating in the tank.

The Hatteras tank, lacking an altitude valve, can overflow under the influence of the high service pumps. To avoid overfilling the Hatteras tank, a valve in the 8" trunk main at the dormant Frisco booster pump station is manually closed each morning. During the day the Hatteras end of the system operates solely off of the Hatteras tank. The valve is then manually opened at the end of the work day, allowing the tank to fill overnight. The tank is generally near full the following morning without having overflowed.

Keeping the Hatteras end of the distribution system valved off during the day directs flow from the high service pumps to Buxton and Avon. This becomes necessary during summer months to maintain a sufficient water level in the Avon tank.

The now dormant Frisco booster pump station was installed in 1987-88. It was installed to provide dedicated, automated control of the Hatteras tank water level. However, the pumps were oversized and poorly located resulting in dangerously high pressure downstream of the BPS and extreme suction upstream. The pumps were subsequently never used in daily service. The pump station now houses a chlorine booster unit which is used only as necessary.

Likewise, the booster pump station located at the base of the 400 kgal tank has never been utilized in daily service. The pressure produced by this BPS would cause catastrophic line breaks unless several nearby fire hydrants were left open as emergency pressure relief valves. These pumps are occasionally used in this fashion for line flushing.

2.2 Condition of Distribution System Lateral Mains

Throughout the history of the CHWA system, developers and other private entities have installed most of the line extensions off of the trunk main. Much of this work was completed using substandard materials and with limited or no inspection. This practice has manifested itself in frequent pipe breaks and ruptures.

T.J. Ketterman of the Dare County Water Distribution Department (Rodanthe) has ridden the CHWA system and interviewed the CHWA staff to formulate an opinion of which areas need piping improvements or upgrades. One approach is to upgrade all laterals which are currently less than 6" to 6" pipe with fire hydrants. New residential services would be installed at each affected dwelling. Currently there are areas where several dwellings are served off of one meter. Without considerable additional research or street-by-street house counts, we must estimate the number of new services required. For the purposes of providing a cost estimate, we assumed 25 services per 1000 feet of new 6" pipe. Only laterals whose entire length are less than 6" pipe were included. The cost estimate is presented in Section 5.1 of this report.

Another approach is to upgrade only those individual laterals listed as critical by Mr. Ketterman. The remaining substandard lines can be attended to as need arises, using the O&M budget. A final approach may be to consider improvements to laterals as an operation and maintenance expense from the beginning, performing upgrades on an as needed basis.

2.3 Condition of Elevated Storage Tanks

Hobbs, Upchurch & Associates, P.A. did not perform detailed inspections of the four (4) CHWA elevated tanks. However, from ground-level visual inspection, interviews with CHWA staff and previous reports, the following observations can be reported.

The Buxton 100 kgal tank had its periodic maintenance last year (1995). The Avon and Hatteras 100 kgal tanks will receive their scheduled maintenance later this year. These projects are currently being prepared for bid. Following this maintenance episode, these tanks will be in the best condition as can be expected of tanks of their vintage, assuming quality workmanship and proper inspection.

	Year of Construction	Year Last Painted
Avon	1978	1997*
Buxton	1968	1995
400k	1987/88	1991
Hatteras	1968	1997*

* scheduled to be painted

The 400k tank is beginning to show signs of corrosion and paint system failure (chalking, hair-line cracks). This tank will need maintenance soon, within the next couple of years. Past maintenance of this tank has proven difficult due to weather conditions, winds and proximity to adjacent houses. It may be necessary to fully shroud the 400k for the future painting episodes to prevent over-spray onto adjacent properties. Shrouding will add considerable cost to tank maintenance.

3.0 POPULATION AND WATER DEMAND

Dare County provided historic population data and partial projections with which to estimate 2020 population and water demand. Much of this information was taken from Scenario 1 of the Dare County Carrying Capacity Study (Booz, Allan & Hamilton, Inc., 1985). CHWA staff provided water consumption data from billing records.

3.1 Population

Few sources were available to provide population data in greater detail than overall county population. However, the Carrying Capacity Study listed population individually for Avon, Buxton, Frisco and Hatteras and further broke population into permanent and seasonal peak categories. The combined peak season projections along with the 1985 baseline population are presented below.

Combined CHWA Peak Season Population

	1985		1990		1995		2000
Avon	5,100		5,389		5,773		6,185
Buxton	5,220		5,519		5,914		6,338
Frisco	4,105		4,337		4,643		4,972
Hatteras	5,145		5,405		5,740		6,098
Total	19,570		20,650		22,070		23,593
Percent Increase (to nearest 1.0%)		6%		7%		7%	

From Booz, Allan & Hamilton, Inc. (1985), Exhibit III-1, Scenario 1

Note the percent population increase per five years projected in the table above. Dare County officials have found the Scenario 1 Carrying Capacity population projections to be fairly accurate; therefore, we used these numbers to formulate estimates of the CHWA service area population through 2020. These figures are presented in the table below. Note that the percent growth has been increased stepwise to produce conservative estimates.

Projected Peak Season Population for CHWA Service Area

	2000		2005		2010		2015		2020
Population	23,593		25,245		27,265		29,719		32,690
Percent Increase		7%		8%		9%		10%	

3.2 *Water Demand*

CHWA's highest water production month of 1996 was July. Total distribution for the month based on meter readings was 21,715,900 gallons. Based on 30 day months, the average daily demand is 724,000 gpd (503 gpm). Extrapolating between the 1995 and 2020 populations in the two tables above gives a projected July 2020 demand of 32,165,508 gallons. Assuming 30 day months, the 2020 projected average daily demand is 1,072,200 gpd (745 gpm) for the peak month. This is equivalent to a demand increase of approximately 10 gpm per year through build-out.

All numbers used thus far in population and demand projections have been conservative, meaning that the estimates should be over-estimates for safe engineering analysis. To evaluate the hydraulic performance of the CHWA distribution system under 2020 demands, we performed hydraulic analyses assuming average daily distribution of 1.1 mgd (764 gpm) with peak demand periods 3.5 times the daily average, or 3.85 mgd (2674 gpm).

4.0 SYSTEM ANALYSIS - HYDRAULIC MODEL

Hobbs, Upchurch & Associates, P.A. (HUA) constructed the CHWA distribution system in Cybernet, an AutoCADD-based hydraulic computer model. Using as-built drawings, design plans and word-of-mouth descriptions from CHWA staff, we input the distribution system components to represent, as nearly as possible, the physical distribution system. A brief description of the system layout was described in Section 2.0 above.

As discussed previously in Section 3.2, CHWA staff provided July 1996 billing records from which we determined the overall system demand for the peak usage month. The CHWA billing department then mapped their 22 billing zones, allowing HUA to appropriately distribute the system demand in the computer model, mimicking the actual distribution and pipe flow conditions.

4.1 Model Calibration

To optimize hydraulic modeling accuracy, a computer model must be calibrated to the parameters and characteristics of the physical piping network. HUA, with help from the CHWA staff, performed field tests to calibrate the model. Eight (8) field tests were conducted throughout the distribution system. A field test is conducted as follows: the maximum available flow is measured at a selected fire hydrant while residual system pressure is measured at other fire hydrants located peripherally about the flowing hydrant. Static pressure is also measured at the flow hydrant and the peripheral hydrants.

Whenever possible, field testing should be conducted with no system pumps running, minimal system demand and good knowledge of tank water elevations. These conditions were met in the CHWA tests by filling all the elevated storage tanks and manually shutting down all system pumps prior to testing. Furthermore, the tests were conducted during February when system demands are at or near their lowest.

The model was then calibrated by inputting the measured hydrant flow rates and comparing the model residual pressures with those measured in the field. Discrepancies in the results were accounted for by making corrections in the model such as adjusting pipe diameters where appropriate, changing node elevations or varying friction loss coefficients (C-factors). Primarily, C-factors along piping segments and across check valves were adjusted until model results and field results produced a reasonable match.

Avon Area: Calibrating the model revealed considerable head losses throughout much of the distribution system. Head loss naturally occurs as water travels through pipe due to friction between the water and the pipe. However, the head loss observed from field tests was much higher in the Avon area than would be expected for pipe of the age and material used in the CHWA system. The CHWA staff reports negligible scale build-up in pipe sections that have been investigated.

AC and PVC pipe of most any age would not be expected to accumulate scale. Therefore, the observed head losses could not be attributed to pipe friction alone.

An unknown but suspect system component where head loss may occur is the (alleged) check valve at the southern end of Avon. Using a metal detector, the CHWA staff identified what they believe is a check valve beneath the parking lot of the BP gas station in southern Avon, just north of Askins Creek Drive. Differential flows and pressures on either side of this feature suggest that it is indeed a check valve.

Given the above information, we calibrated the Avon portion of the model assuming minor degradation of C-factors in piping from Buxton through Avon (C=130). In new pipe, C=140-150. The remainder of the head loss was attributed to the check valve.

Buxton Area: Calibrating the model to field results in the Buxton area was achieved by lowering C-factors to C=130 along Hwy 12. Constriction through legs of 6" pipe along Hwy 12 between the high school and the Avon BPS also accounted for some head loss. Along Buxton Back Road C-factors were lowered to C=120. Additionally, field results suggested that approximately midway along Buxton Back Road there is either a partially closed valve or a constriction through smaller diameter pipe. Plan sheets and as-built drawings show 6" pipe along the length of Buxton Back Road. To account for the observed head loss, a section of approximately 3,000 feet of pipe was modeled as 4-inch.

Frisco and Hatteras Areas: The distribution system experiences some considerable head loss between the 400 kgal tank and the Hatteras tank. In calibrating the model, much of this head loss was attributed to piping, valving and fittings in the vicinity of Water Association Road where the WTP ties into the distribution system. Another portion of the head loss toward Hatteras was accounted for in the bypass of the dormant Frisco booster pump station. Field results suggest high head loss here, possible due to a constriction through smaller diameter pipe, fittings or valving. The remainder of the head loss was attributed to pipe C-factor of C=110 from Water Association Road to the Hatteras tank.

4.2 *Hydraulic Analysis of Existing System*

After calibrating the model as described above, we ran the model to analyze the hydraulic performance of the present system under July 1996 demand conditions. Average and peak conditions were analyzed with all system pumps running to simulate the most demanding hydraulic conditions. The system was analyzed using the daytime valving scenario (Hatteras valved off from the rest of the system at the Frisco BPS) and the nighttime valving scenario (Hatteras open to incoming flow).

We also analyzed available fire flows during the pumping cycle and when the system is supplied only from elevated storage. The results of these analyses are presented below.

Average Day: Under daytime average day demand (0.72 mgd, 503 gpm) with the 50 hp high service pump and Avon BPS running:

- System pressure ranges between 50 and 100 psi. Pressures between 60 and 100 psi result from pump discharge and are distributed throughout Buxton. The model also exhibits high discharge pressure from the Avon BPS. Hatteras and Avon sustain system pressure of 50-55 psi.
- The 6" loop along Hwy 12 and Buxton Back Road and the 8" main from the CHWA office experiences very high friction head loss. Moderate head loss occurs along Hwy 12 between Buxton and Avon. A large head loss apparently occurs at the Avon check valve (see calibration discussion above).
- The Buxton 100k tank is filling at 240 gpm. The altitude valve of the 400k tank is closed. The Hatteras tank is emptying at 170 gpm since it is valved off at the dormant Frisco BPS. The Avon tank is emptying at 10 gpm.

Under nighttime average day demand (Hatteras end of system open to incoming flow):

- System pressure ranges between 50 and 80 psi except for 145 psi from the Avon BPS discharge.
- Friction head loss patterns are the same as described above.
- The Buxton and Hatteras 100k tanks are filling at 130 and 85 gpm, respectively. The altitude valve of the 400k tank is closed. The Avon tank continues to empty at 10 gpm.

From these results it appears that for the Avon tank to fill overnight, all of the WTP high service pumps must be activated. This is not necessarily the case but the calibration discussion (Section 4.1) described several unknowns in the distribution system that may account for this discrepancy.

Peak Day: Under peak day demand (3.5 times average day, 2.53 mgd, 1760 gpm) the system pumps deliver more water but are unable to keep up with the tank empty rates. The altitude valve on the 400k remains closed. There are similar head losses as described above. Pressure of 100 psi and above may occur toward the dormant Frisco BPS where the Hatteras end of the system is valved off. Peak flow conditions would not be expected at night when the Hatteras valve is open.

Fire Flow Analysis: To model fire flow availability, we give the model a minimum needed flow (500 gpm, which is moderate) at each junction node and the minimum allowable residual pressure (20 psi, State regulations). To simulate an average or moderate condition in which fire flows may be needed, the model was run with the 50 hp high service pump running and the Avon BPS running. The valve to Hatteras was assumed open.

Under these parameters, the area near the Coast Guard Station and along Flowers Ridge Road in Buxton were unable to deliver 500 gpm and 20 psi. Available flows as low as 240 gpm were observed on Flowers Ridge Road. The section of Hwy 12 between Buxton and Avon has limited fire protection; however, there are neither fire hydrants nor structures along this stretch. The Askins Creek subdivision (Park Drive) on the south end of Avon also has less than 500 gpm at 20 psi available fire flow. Results from the model and field testing indicate available flow near 400 gpm.

The available fire flow in Askins Creek is limited due to the distance from the Buxton tank and the Avon check valve, just north of Park Drive, preventing flow from the Avon elevated tank. The CHWA is planning to replace the Avon check valve south of Askins Creek which will allow flow from the Avon tank to alleviate fire flow deficiencies in Askins Creek.

Under system conditions where only the elevated tanks supply pressure (no pumps running), considerably more areas are deficient in available fire flow. Areas furthermost from an elevated tank are most vulnerable to fire flow deficiency. This is also the case under peak day conditions even with system pumps running.

4.3 *Hydraulic Analysis for System Improvement*

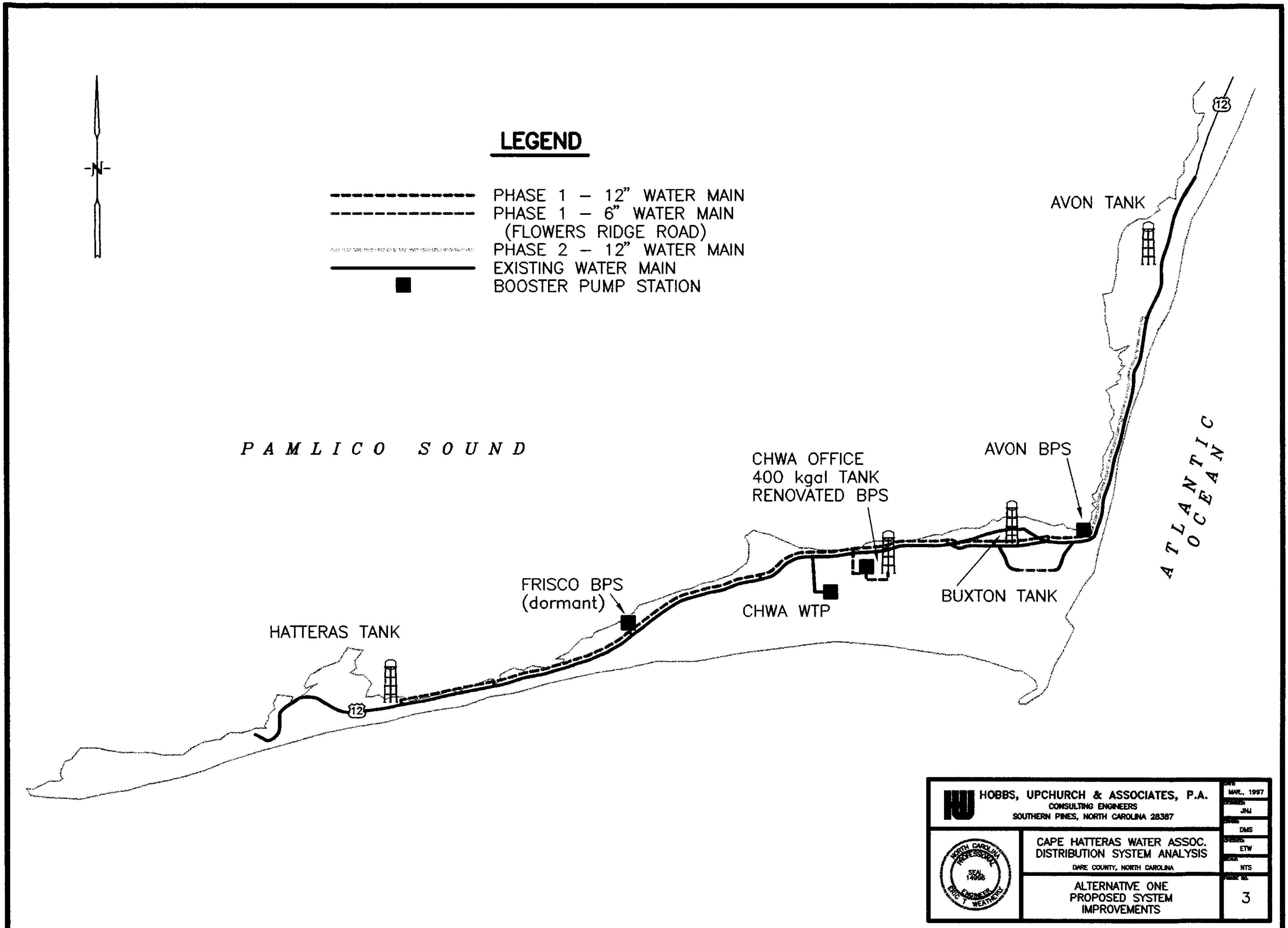
The preceding discussion in Sections 2.0 and 4.2 indicate deficiencies in the CHWA distribution system. These deficiencies result in the following list of problems:

- No circulation in 400k tank, altitude valve closed virtually full time.
- High service pumps at WTP are the only means of supplying water to distribution system.
- Extreme head losses occur along extended sections of pipe.
- Sustained high pressures of 100 psi or greater along extended sections due to pump discharge.
- Low tank fill rates barely able to keep up with system demand.
- Manual valving required to prevent tank overflow at Hatteras and induce greater flow to Avon.

4.3.1 *System Improvement Alternative One*

The primary goal in modeling system improvements was to use as much of the existing system as possible while improving the flow to the system extremities (Hatteras and Avon) and reducing the extreme system pressures.

In order to accomplish this goal, we developed the following system concept and built upon it to maximize the hydraulic performance. A schematic of this concept is provided in Figure 3. Cost estimates are provided in Appendix 1.



N
LEGEND
PHASE 1 – 12" WATER MAIN
PHASE 1 – 6" WATER MAIN (FLOWERS RIDGE ROAD)
PHASE 2 – 12" WATER MAIN
EXISTING WATER MAIN
BOOSTER PUMP STATION
PAMLICO SOUND
ATLANTIC OCEAN
12
AVON TANK
AVON BPS
BUXTON TANK
CHWA OFFICE
400 kgal TANK
RENOVATED BPS
CHWA WTP
FRISCO BPS (dormant)
HATTERAS TANK
12
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CAPE HATTERAS WATER ASSOC.
DISTRIBUTION SYSTEM ANALYSIS
DARE COUNTY, NORTH CAROLINA
ALTERNATIVE ONE
PROPOSED SYSTEM
IMPROVEMENTS
MAR., 1997
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NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 14998 ERIC T. WEATHERLY

1. Renovate the booster pump station at the CHWA office to pump from the 400k tank into the distribution system. The 400k tank will then become the control tank. Size pumps to provide the required flows at system pressures not to exceed 95 psi.
2. Upgrade the line size from the WTP to the 400k tank. The high service pumps at the WTP will then pump solely to the 400k tank. Valving at the intersection of Water Association Road and Hwy 12 will allow the system to be fed from the WTP high service pumps when the 400k tank is taken off line for maintenance.
3. Extend 12" water main from the new office BPS east and west along Hwy 12 to deliver the needed flow at acceptable pressures to the Hatteras and Buxton tanks and the Avon BPS (and eventually the Avon tank). The new 12" water main will parallel the existing 8" water main, tying in every 2,000 to 3,000 feet.
4. Install altitude valves on the Avon, Buxton and Hatteras tanks since the office BPS will be capable of overflowing each of them. Install telemetry components on the Hatteras and Buxton tanks to communicate with the office BPS.
5. Extend 6" water main to complete the Flowers Ridge Road loop. This will improve fire protection locally and improve flow to the Avon BPS.

<u>Model 1</u>: The hydraulic model was configured as described above with 12" pipe extending from the Frisco BPS to the Avon BPS, paralleling the existing trunk main and tying into it every 2,000 to 3,000 feet. The office BPS was modeled as a 25 hp (effective) pump and the Avon BPS was modeled as it is now (10 hp, approximately 80% efficiency). The model was run with July 1996 demands.

Under these operating conditions, the model indicates good hydraulic performance with respect to system head loss and pressure distribution. However, there is enough head loss in the 8" main, between the Frisco BPS (where the 12" pipe ends) and the Hatteras tank, to limit the fill rate of the Hatteras tank. Under average day demand the Hatteras tank fills at 120 gpm but empties at 270 gpm under peak day demand. The design target is a fill rate of at least 200 gpm under average day demand with the empty rate under peak day demand not exceeding twice the fill rate. Since the model "fails" under July 1996 demands, it follows that the system performance would decrease with increasing water demands.

One solution to increase the flow rate to the Hatteras tank could be to renovate and reactivate the Frisco BPS. The drawback to this option is two-fold: 1) the system would have the operating expense of running an additional BPS and 2) eventually the system demand will increase to require a 12" pipe all the way to Hatteras, making the renovated Frisco BPS obsolete.

Model 2: Another solution for increasing the flow to Hatteras is to extend the 12" water main further toward Hatteras. In the hydraulic model, we simulated the 12" pipe extending from the Avon BPS to a point approximately half way between the Frisco BPS and the Hatteras tank.

The hydraulic model performs well with this layout and July 1996 water demands, based on the criteria described in Model 1. The Avon and Hatteras tanks fill at greater than 200 gpm during average day demand and empty at approximately 150 gpm during peak day demand. However, under 2020 demands the same two tanks fill at only 145 gpm while emptying at 400 gpm during peak day demand.

These operating conditions may be acceptable using a phased improvement (construction) approach. That is, install the 12" water main as described above as Phase 1. When the system demand increases to the point of diminished hydraulic performance, additional water main extension may be installed. A drawback to this approach is that the office booster pump station would be sized according to the hydraulic conditions set up by the Phase 1 piping network. At such time that additional pipe would be installed, the hydraulics would change such that renovations of the office booster pumps would be necessary.

Model 3: The previous two models revealed situations where a second construction phase would involve changes to booster pump stations that were renovated (at high costs) in the first construction phase. In Model 3 we simulated the 12" water main extending completely to the Hatteras tank (and to the Avon BPS). Performing this improvement in the first construction phase allows the office BPS to be sized for present through projected build-out demands.

Under this model simulation, the Avon and Hatteras tanks fill at 220 and 600 gpm, respectively, under July 1996 average day demands. Under peak day demand the Avon tank empties at 140 gpm while the Hatteras tank continues to fill at a moderate 130 gpm.

Under 2020 demands the Hatteras tank fills at 510 gpm (average day) and empties at 205 gpm (peak day). The Avon tank fills at only 150 gpm and empties at 395 gpm. The Avon end of the system can be said to "fail" under 2020 demands. However, the system performs well until the overall system demand reaches approximately 560 gpm. Based on the demand projections presented in Section 3.2 of this report, system improvements for the Avon area may be necessary in approximately 5 years (2002).

Model 4: When the time arrives to perform system improvements to increase flow to Avon, 12" main will be needed from the Avon BPS to the southern end of Avon (near the present Avon check valve). The model simulation of this piping network indicates Avon and Hatteras tank fill rates under 2020 average day demands of 325 and 510 gpm, respectively. Under peak demands the two tanks empty at 165 and 205 gpm, respectively.

System pressures created under Models 3 and 4 range between 50 and 90 psi. The high range of pressure occurs during Office BPS and Avon BPS pump cycles. There are no areas of excessive friction head loss.

Fire Flow Analysis: To analyze the fire protection ability of the proposed system, we simulated node by node fire demands with the piping network configured as in Model 3 and system pressure provided only by the elevated storage tanks (no pumps running). Fire demands were superimposed over 2020 average day demands.

Fire flows of at least 600 gpm (20 psi minimum zone pressure) were available throughout the system with the following exceptions. The section of Hwy 12 between the Avon BPS and the Avon check valve can achieve flow of only 405 to 495 gpm. Acceptable flows are obtainable with the Avon BPS running and after the 12" water main is extended to Avon (Phase 2). The Askins Creek subdivision is currently within this low flow area. However, the CHWA has plans to move the Avon check valve south of Askins Creek so that all of Avon can pull from the Avon tank. This will give Askins Creek adequate fire protection under the described condition.

The possibility does exist for fire to occur during peak usage periods of the day. Modeling this condition (fire flows superimposed over 2020 peak day demand) indicates available flows as low as 265 gpm in the Hatteras area. Fire flow in extreme north Avon dip as low as 465 gpm. Fire flows in the Hatteras area can be increased to a minimum of 600 gpm throughout the area by extending 12" main along Hwy 12 from the Hatteras tank to the first intersection with Eagle Pass Road. Based on demand projections, this improvement may be needed in approximately five years (2002).

4.3.2 System Improvement Alternative Two

A second system improvement scenario was developed to take advantage of improvements to be made at the WTP. The proposed WTP upgrade will include a 3.0 million gallon clearwell and new or reconfigured high service pumps with an emergency power generator. The Alternative Two system improvement utilizes the WTP high service pumps to charge the distribution system, eliminating the renovation of the office BPS and the need for the 400k tank.

The 400k tank is a liability to the CHWA system. As described in Section 2.1 of this report, the 400k tank's location relative to the high service pumps prevents it from emptying, making it essentially wasted storage. Furthermore, its proximity to neighboring residences creates great difficulty and high costs to prevent overspray from affecting adjacent houses. This scenario would allow for the dismantling of the 400k tank. The 400 kgal tank could then be used to replace one of the other 100 kgal tanks.

An additional aspect of Alternative Two is the renovation and use of the Frisco BPS to fill the Hatteras tank. A schematic of the proposed improvements is provided in Figure 4. The system concept is summarized below. Cost estimates are provided in Appendix 2.

1. Utilize the new WTP high service pumps to charge the distribution system.

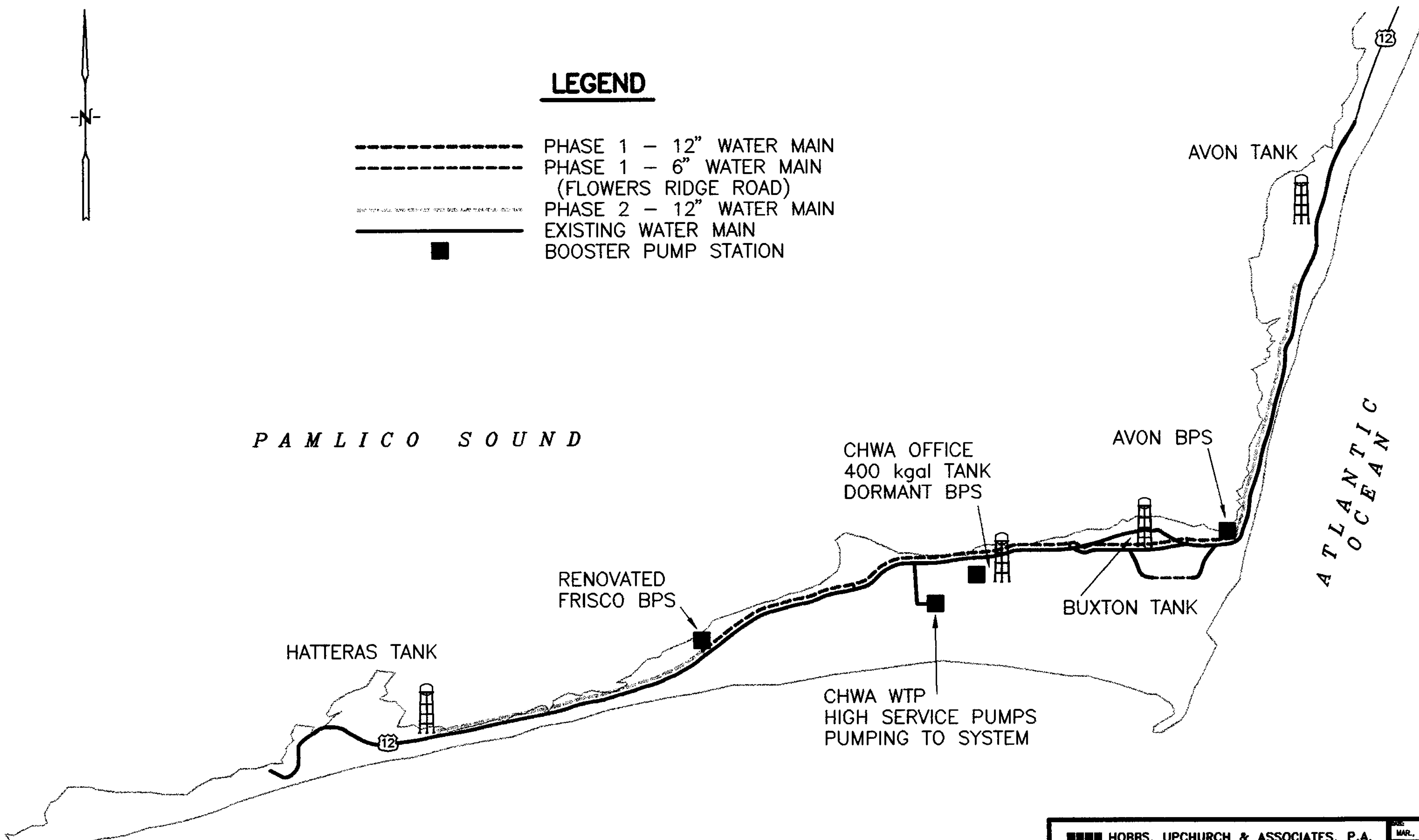
2. Extend 12" water main from Water Association Road west to the Frisco BPS and east to the Buxton 100 kgal tank and the Avon BPS.

3. Renovate the Frisco BPS, replacing the existing 40 hp pumps with 10 hp pumps. Provide emergency power generation at the Frisco and Avon BPS.

<u>Model 1</u>: We ran the model with a 50 hp high service pump charging the system from the WTP and 10 hp pumps running at the Frisco BPS and Avon BPS. Under July 1996 demand conditions, the system achieves good hydraulic performance with respect to system pressures and tank fill/empty rates. However, with increasing demands, the Avon BPS is eventually unable to keep the Avon tank filled. The break point occurs in approximately five years (2002), based on the Section 3.2 demand projections.

At projected 2020 demands, the Frisco BPS is barely able to keep the Hatteras tank filled, even with both a 25 hp and a 50 hp high service pump running at the WTP. There is too much head loss for the Frisco BPS to pump against. The two high service pumps do not improve flow to Avon.

<u>Model 2</u>: We were able to increase the flow to Avon and Hatteras by increasing the horse power of the Avon and Frisco BPSs to 20 hp. However, in doing so the discharge head and friction head losses were too high and the Buxton 100 kgal tank empties to quickly. To alleviate this problem the model was run with 10 hp pumps in the Avon and Frisco BPSs and 12" pipe extended to the Hatteras tank and to the southern limits of Avon. Running the model in this way indicated satisfactory hydraulics and tank fill/empty rates. Note that the 12" water main is necessary in



LEGEND

- PHASE 1 – 12" WATER MAIN
- PHASE 1 – 6" WATER MAIN (FLOWERS RIDGE ROAD)
- PHASE 2 – 12" WATER MAIN
- EXISTING WATER MAIN
- BOOSTER PUMP STATION

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both scenarios, regardless of whether the Frisco BPS is utilized. Using correctly sized pumps at the WTP, the system can be operated and construction phased as in Alternative One.

Fire Protection: To analyze the fire protection ability of the Alternative Two system, we simulated fire demands under two possible system operating conditions:

1. Nighttime with the tanks full and no pumps running, fire demand superimposed over 2020 average day demand. Under these conditions, only the area between the Avon BPS and the Avon check valve could not achieve a minimum fire flow of 500 gpm at 20 psi. Here the available flow ranged between 405 and 495 gpm.

2. Average daytime conditions with Frisco and Avon BPS and WTP high service pumps running, average day 2020 demand. Under these conditions, the section of Hwy 12 between the Avon BPS and the Avon check valve was able to maintain approximately 560 gpm at a minimum system pressure of 20 psi. The remainder of the system was capable of at least 600 gpm.

Although fire protection appears adequate as analyzed here, the possibility exists for fires to occur during peak day water demand. There are two areas that are unable to achieve 500 gpm fire flows during 2020 peak day demands (all system pumps running). The extreme north end of Avon has available fire flow of between 475 and 495 gpm under peak demand conditions. The Hatteras area west of the Hatteras tank can obtain fire flows ranging between 320 and 490 gpm.

The limited available fire flow in north Avon may not be an extreme concern since it is in a small localized area. Furthermore, the peak demands modeled here are slightly aggressive for conservative engineering purposes. In other words the frequency and intensity of peak demands coupled with the likelihood of fire may make 475 gpm an acceptable available fire flow.

The low Hatteras area fire flows are a greater concern but can be alleviated by extending 12" water main along Hwy 12 from the Hatteras Tank to the first intersection with Eagle Pass Road. Performing this improvement allows for fire flows in excess of 600 gpm throughout the Hatteras area, maintaining 20 psi system pressure. The need for this system improvement is projected to occur in approximately five years (2002).

5.0 *COMPARISON OF ALTERNATIVES*

5.1 *Alternative One*

Alternative One benefits the system by utilizing two existing system components that are currently not used: the 400K tank and the office BPS. The central booster pump station (CHWA office BPS) is capable of filling the Hatteras tank without the need for the Frisco BPS. The office BPS will also fill the Buxton tank and provide limited flow to the Avon tank. Configuring the system as described allows for circulation in the 400k tank which is not currently possible. The system would have 700,000 gallons of elevated storage, which could be advantageous during periods of power outage.

Alternative Two provides three ways to supply water to the distribution system: 1) the office BPS, 2) the WTP high service pumps, and 3) gravity flow from the 400K tank. Fire protection provided by Alternative One is somewhat better than the second alternative due to the greater amount of 12" pipe in the system. Consequently, overall system head loss is also less. Since two of the pumping sites are located at the WTP and the CHWA office, maintenance and response to emergency conditions (power outage) is somewhat easier than if the Frisco BPS were operative.

One potential drawback of Alternative One is its higher cost due mostly to the additional length of 12" water main. Also, since the office BPS will pump water both east and west along Hwy 12 when either the Buxton or Hatteras tank called for water, the discharge pressure near the CHWA will fluctuate between approximately 55 and 95 psi. Series pumping in Alternative Two somewhat controls such pressure fluctuation.

Another potential problem in Alternative One could occur with tank maintenance at the 400K tank. As previously described, it is difficult and costly to paint the 400K tank without considerable overspray complications.

5.2 *Alternative Two*

As detailed in Appendices 1 and 2, an advantage to Alternative Two is a lower initial (Phase 1) cost. Additionally, this alternative takes advantage of new or renovated high service pumps at the WTP, pumps that would necessarily be part of the WTP design. Charging the distribution system from the WTP works essentially the same as using the renovated office BPS, as in Alternative One.

Alternative Two allows for the dismantling of the problem 400k tank and the possibility of using the tank elsewhere in the system. The dormant office BPS also could be dismantled and the space used for storage.

The Alternative Two system improvement scenario does have some drawbacks. The Frisco BPS and Avon BPS can deliver water to Hatteras and Avon through 8" water main until demand increases to projected 2007 levels. There is also a great deal of head loss in the 8" pipe between the booster pump stations and their respective tanks. Pumping against this high head may accelerate pump deterioration. Furthermore, the 12" pipe proposed in Alternative One would still eventually be necessary in this alternative, necessitating upgrades to the newly renovated Avon and Frisco BPSs.

Alternative Two provides only one means of supplying water to the distribution system: high service pumps at the WTP. In the event of extended power outage, emergency generators will be necessary to power the high service pumps. If there were a failure of the emergency generators during an extended power outage, there is no elevated storage in Alternative Two to charge the distribution system.

Alternative Two utilizes an additional remote pump station (Frisco) further spreading system maintenance concerns, especially during power outage when emergency generators must be started. Relying so heavily on smaller, remote booster pumps while also dismantling the 400k tank limits system elevated storage to 300,000 gallons. This may precipitate the need to upgrade the remaining three tanks to larger volume tanks to reduce pump cycle times and provide greater storage for periods of extended power outage. As a consequence, the increased storage volume may create tank turnover problems during the off season, potentially leading to stagnation, chlorine residual and THM problems.

6.0 RECOMMENDED SYSTEM IMPROVEMENTS

Section 4.0 of this report developed and explained the hydraulics of two potential system improvement scenarios. Section 5.0 presented the advantages and disadvantages of the two alternatives. The following summarizes our recommendations for performing system improvements in a phased construction approach. The recommendation is a hybrid of the two alternatives developed and described in Sections 4.0 and 5.0. A schematic of the recommended system improvements is provided in Figure 5. Cost estimates for the recommended improvements are provided in Appendix 3. CYBERNET hydraulic analyses of the improved system under 2020 average day, peak day and fire flow conditions are provided in Appendix 4.

Alternative One developed a distribution system around a central pump station, located at the CHWA office, capable of filling the Hatteras and Buxton tanks. Only a small 10 hp BPS was needed to fill the Avon tank, much the way the system functions presently. As system demands increase, additional 12" water main is extended along Hwy 12 to carry the additional capacity.

To obtain the needed water main carrying capacity for projected build-out demands, 12" water main, ultimately extended from the Hatteras tank to the southern limits of Avon, was necessary in both Alternative One and Alternative Two, regardless of whether the Frisco BPS was put into service. Therefore, renovating the Frisco BPS is *not* part of the recommended system improvements.

Alternative Two utilized the high service pumps at the upgraded WTP, eliminating the need for renovating the office BPS. Since the 400k tank would be of no benefit to the system in this scenario, it could be dismantled and used elsewhere in the system to provide additional storage.

Dismantling the 400k tank creates a deficiency in elevated storage; the system would have only 300,000 gallons of elevated storage. We recommend upgrading the Avon tank by replacing it with the dismantled 400k tank. Avon is the fastest growing area in the system and the furthest from the water source (WTP); therefore, it is the area most likely to need additional elevated storage for emergencies and fire protection.

In a later construction phase we recommend upgrading the Hatteras tank to 300,000 gallons. This would provide a total of 800,000 gallons of elevated storage in the system, nearly 75% of a day's summertime storage.

The following summarizes our recommendations for system improvements. Construction should be performed in phases based on the timing indicated or as system demand dictates. Phase 1 should be implemented as soon as possible to ready the distribution system for the proposed WTP expansion.

Phase 1:
(to be constructed in conjunction with WTP expansion)

- Install 12" water main between the Hatteras tank and Avon BPS, tying into the WTP at Water Association Road
- Complete 6" loop on Flowers Ridge Road
- Construct new 10 to 20 hp above ground BPS to replace Avon BPS
- Dismantle 400k tank and replace existing 100k Avon tank with dismantled 400k tank
- Install altitude valves at the Avon, Buxton and Hatteras tanks
- (Optional) Upgrade all laterals currently less than 6" to 6" water main, with fire hydrants

Additional 12" water main will become necessary as system demand approaches approximately 600 gpm, as discussed in Section 4.3 (Model 3). Based on demand projections, this system improvement should be performed in approximately 5 years (2002).

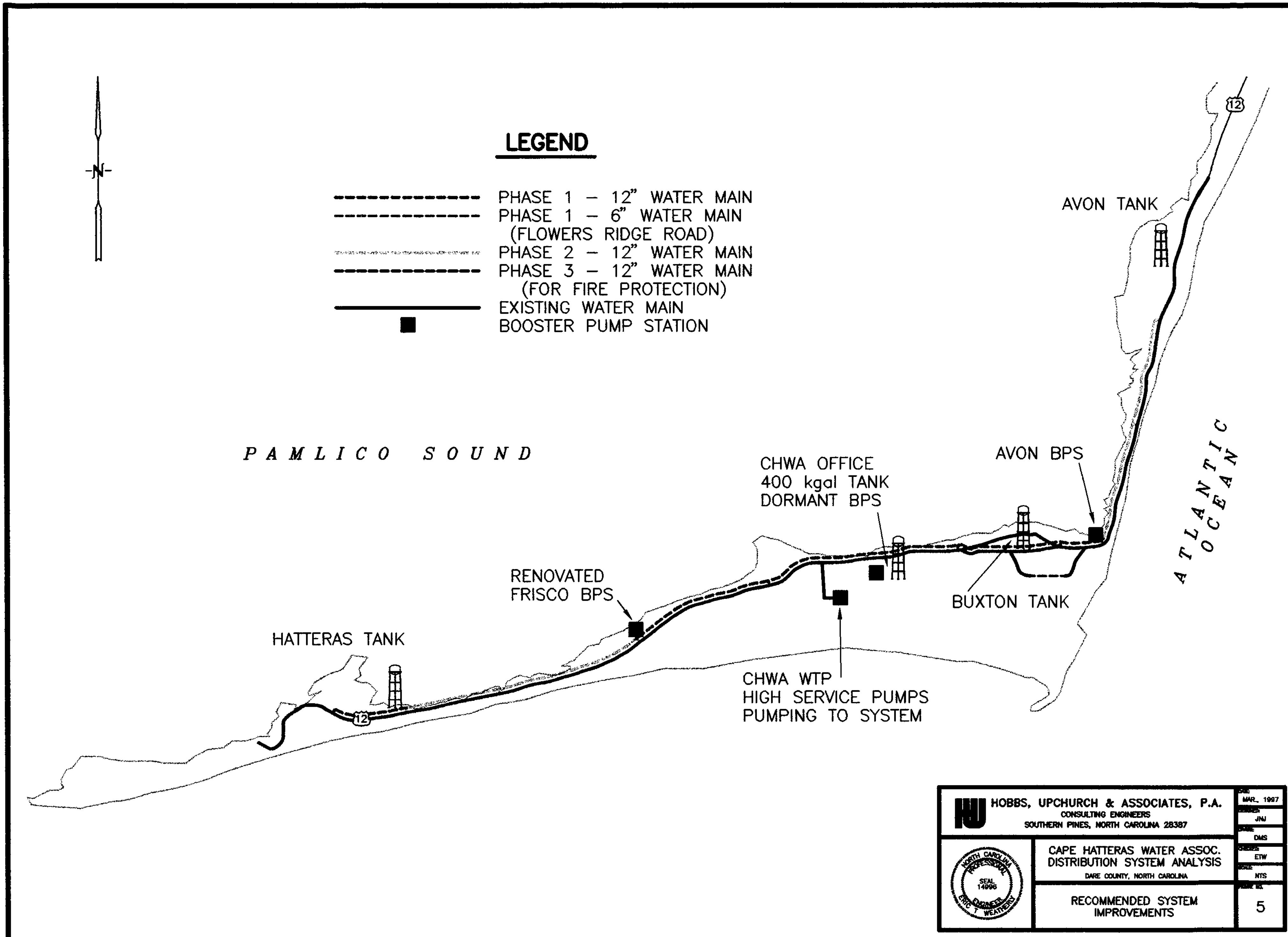
Phase 2:

- Extend 12" water main from Avon BPS to Avon

Phase 3 is a recommended improvement that should be performed to increase storage at the extremities of the system. The increased tank volume would reduce pump cycling frequency and provide greater reserve storage for fire protection and in case of service interruptions such as power outage or major line breaks. By 2007, water demands are projected to be such that fire flow will not be adequate in the Hatteras area. We recommend extending 12" water main from the Hatteras tank, along Hwy 12, to the first intersection with Eagle Pass Road. This construction phase should be performed in 2007.

Phase 3:

- Replace Hatteras 100 kgal tank with 300 kgal tank
- Extend 12" water main from the Hatteras tank along Hwy 12 to the first intersection with Eagle Pass Road (for fire protection in the Hatteras area)



LEGEND
PHASE 1 – 12" WATER MAIN
PHASE 1 – 6" WATER MAIN (FLOWERS RIDGE ROAD)
PHASE 2 – 12" WATER MAIN
PHASE 3 – 12" WATER MAIN (FOR FIRE PROTECTION)
EXISTING WATER MAIN
BOOSTER PUMP STATION
N
PAMLICO SOUND
ATLANTIC OCEAN
AVON TANK
AVON BPS
BUXTON TANK
CHWA OFFICE
400 kgal TANK
DORMANT BPS
CHWA WTP
HIGH SERVICE PUMPS
PUMPING TO SYSTEM
RENOVATED
FRISCO BPS
HATTERAS TANK
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APPENDIX 1

COST ESTIMATE FOR

ALTERNATIVE ONE

The project cost estimates provided here are based on current 1997 industry pricing. Several sources for pricing were utilized including contractors, equipment representative and files from similar, recently bid or constructed projects. A primary source for cost estimates was the recent water main work performed for Dare County in the Duck area. This information was valuable due to the similarity in projects and our understanding of the cost history of the project.

ALTERNATIVE 1 - COST ESTIMATE

PHASE 1
(To be constructed in conjunction with WTP expansion.)

	Quantity	Unit	Unit Price	Total
1. Renovate Office Booster Pump Station				
A. Replace Pumps	2	EA	$37,500	$75,000
B. Modify Wiring	1	LS	$20,000	$20,000
C. Piping and Valving	1	LS	$20,000	$20,000
D. Building Modifications	1	LS	$10,000	$10,000
E. Telemetry	1	Site	$7,000	$7,000
F. Power Generator	1	EA	$38,000	$38,000
				$170,000
2. Upgrade Piping from WTP to Office BPS and from BPS to Distribution System				
A. 16" Water Main	6,200	LF	$40	$248,000
B. 24" Steel Casing (Bore and Jack)	40	LF	$350	$14,000
C. Valves and Fittings	1	LS	$40,000	$40,000
				$302,000
3. 12" Water Main Between Hatteras Tank and Avon BPS				
A. 12" Water Main	54,000	LF	$25	$1,350,000
B. 20" Steel Casing (Bore and Jack)	50	LF	$250	$12,500
C. 12" x 8" Tees	18	EA	$500	$9,000
D. 12" Gate Valves	18	EA	$1,800	$32,400
E. 8" x 8" Tapping Sleeve and Valve	18	EA	$1,800	$32,400
F. Concrete Blocking and Repair	1	LS	$40,000	$40,000
G. Asphalt Cut and Patch	1	LS	$100,000	$100,000
H. Crushed Stone	1	LS	$20,000	$20,000
				$1,596,300
4. Install Altitude Valves at Avon, Buxton and Hatteras Tanks				
Altitude Valve	3	EA	$30,000	$90,000

	Quantity	Unit	Unit Price	Total
5. 6" Water Main to Complete Loop at Flowers Ridge Road				
A. 6" Water Main	1,600	LF	$10	$16,000
B. 6" Gate Valve	2	EA	$650	$1,300
C. Bends, Fittings, Tees	1	LS	$1,500	$1,500
D. Fire Hydrant Assembly	1	EA	$2,500	$2,500
				$21,300
6. New 10 hp Aboveground Booster Pump Station to Replace Existing Avon BPS				
A. 10 hp Package BPS	1	LS	$110,000	$110,000
B. Piping, Valve, Fittings	1	LS	$15,000	$15,000
C. Power Generator	1	EA	$18,500	$18,500
(Assumes land available from Dare Co. at no cost.)				$143,500
7. Upgrade Telemetry Network				
A. Elevated Storage Tanks	4	Site	$7,000	$28,000
B. Booster station	2	Site	$7,000	$14,000
C. Master Control at WTP	1	Site	$7,000	$7,000
				$49,000
Subtotal Phase 1				**$2,372,100**
Engineering, Surveying, Administration, Inspection (15%)				$355,815
Contingency (15%)				$355,815
Total Phase 1				**$3,083,730**

PHASE 1 OPTION

		Quantity	Unit	Unit Price	Total
1.	Upgrade Lateral Mains to 6" Avon Area				
A.	6" Water Main	20,000	LF	$10	$200,000
B.	14" Steel Casing (Bore and Jack)	200	LF	$200	$40,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$80,000	$80,000
D.	Fire Hydrant Assembly	20	EA	$2,000	$40,000
E.	Residential Service (meter not included)	500	EA	$350	$175,000
					$535,000
	Buxton/Frisco Area				
A.	6" Water Main	38,000	LF	$10	$380,000
B.	14" Steel Casing (Bore and Jack)	400	LF	$200	$80,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$152,000	$152,000
D.	Fire Hydrant Assembly	38	EA	$2,000	$76,000
E.	Residential Service (meter not included)	950	EA	$350	$332,500
					$1,020,500
	Hatteras Area				
A.	6" Water Main	24,000	LF	$10	$240,000
B.	14" Steel Casing (Bore and Jack)	200	LF	$200	$40,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$96,000	$96,000
D.	Fire Hydrant Assembly	24	EA	$2,000	$48,000
E.	Residential Service (meter not included)	600	EA	$350	$210,000
					$634,000
	Subtotal Phase 1 Option				**$2,189,500**
	Engineering, Surveying, Administration, Inspection (15%)				$328,425
	Contingency (15%)				$328,425
	Total Phase 1 Option				**$2,846,350**

PHASE 2
(To be constructed in 2002.)

		Quantity	Unit	Unit Price	Total
1.	12" Water Main from Avon BPS to Southern Avon				
A.	12" Water Main	25,000	LF	$25	$625,000
B.	20" Steel Casing (Bore and Jack)	50	LF	$200	$10,000
C.	12" x 8" Tees	8	EA	$500	$4,000
D.	12" Gate Valves	8	EA	$1,800	$14,400
E.	8" x 8" Tapping Sleeve and Valve	8	EA	$1,800	$14,400
F.	Concrete Repair and Blocking	1	LS	$19,000	$19,000
G.	Asphalt Cut and Patch	1	LS	$46,000	$46,000
H.	Crushed Stone	1	LS	$10,000	$10,000
	Subtotal Phase 2				**$742,800**
	Engineering, Surveying, Administration, Inspection (15%)				$111,420
	Contingency (15%)				$111,420
	Total Phase 2				**$965,640**

PHASE 3
(To be constructed in 2007.)

		Quantity	Unit	Unit Price	Total
1.	Replace Existing 100k Tanks with 300k Tanks				
A.	300,000 Gallon Elevated Tank	2	EA	$400,000	$800,000
B.	Altitude Valve	2	EA	$30,000	$60,000
C.	System Tie-in, Piping, Valving	2	Site	$10,000	$20,000
D.	Telemetry	2	Site	$5,000	$10,000
E.	Existing Tank Demolition	2	Site	$25,000	$50,000
F.	Tank Sites	2	Site	$50,000	$100,000
					$1,040,000
2.	Extend 12" Water Main for Hatteras Fire Protection				
A.	12" Water Main	3,200	LF	$25	$80,000
B.	20" Steel Casing (Bore and Jack)	50	LF	$250	$12,500
C.	12" x 8" Tees	2	EA	$500	$1,000
D.	12" Gate Valves	2	EA	$1,800	$3,600
E.	8" x 8" Tapping Sleeve and Valve	2	EA	$1,800	$3,600
F.	Concrete Blocking and Repair	1	LS	$2,500	$2,500

		Quantity	Unit	Unit Price	Total
G.	Asphalt Cut and Patch	1	LS	$6,000	$6,000
H.	Crushed Stone	1	LS	$1,200	$1,200
					$110,400
	Subtotal Phase 3				**$1,150,400**
	Engineering, Surveying, Administration, Inspection (15%)				$172,560
	Contingency (15%)				$172,560
	Total Phase 3				**$1,495,520**

APPENDIX 2

COST ESTIMATE FOR

ALTERNATIVE TWO

The project cost estimates provided here are based on current 1997 industry pricing. Several sources for pricing were utilized including contractors, equipment representative and files from similar, recently bid or constructed projects. A primary source for cost estimates was the recent water main work performed for Dare County in the Duck area. This information was valuable due to the similarity in projects and our understanding of the cost history of the project.

ALTERNATIVE 2 - COST ESTIMATE

PHASE 1

		Quantity	Unit	Unit Price	Total
1.	Renovate Frisco Booster Pump Station				
	A. Replace Pumps	2	EA	$20,000	$40,000
	B. Modify Wiring	1	LS	$20,000	$20,000
	C. Piping and Valving	1	LS	$20,000	$20,000
	D. Building Modifications	1	LS	$10,000	$10,000
	E. Power Generator	1	EA	$18,500	$18,500
	(including installation, electrical, building)				$108,500
2.	12" Water Main Between Frisco BPS and Avon BPS				
	A. 12" Water Main	36,000	LF	$25	$900,000
	B. 20" steel Casing (Bore and Jack)	50	LF	$250	$12,500
	C. 12" x 8" Tees	15	EA	$500	$7,500
	D. 12" Gate Valves	15	EA	$1,800	$27,000
	E. 8" x 8" Tapping Sleeve and Valve	15	EA	$1,800	$27,000
	F. Concrete Blocking and Repair	1	LS	$30,000	$30,000
	G. Asphalt Cut and Patch	1	LS	$75,000	$75,000
	H. Crushed Stone	1	LS	$15,000	$15,000
					$1,094,000
3.	Install Altitude Valves at Avon, Buxton and Hatteras Tanks				
	Altitude Valve	3	EA	$30,000	$90,000
4.	6" Water Main to Complete Loop at Flowers Ridge Road				
	A. 6" Water Main	1,600	LF	$10	$16,000
	B. 6" Gate Valve	2	EA	$650	$1,300
	C. Bends, Fittings, Tees	1	LS	$1,500	$1,500
	D. Fire Hydrant Assembly	1	EA	$2,500	$2,500
					$21,300

		Quantity	Unit	Unit Price	Total
5.	New 10 hp Aboveground Booster Pump station to Replace Existing Avon BPS				
	A. 10 hp Package BPS	1	LS	$110,000	$110,000
	B. Piping, Valve, Fittings	1	LS	$15,000	$15,000
	C. Power Generator	1	EA	$18,500	$18,500
	(includes installation, electrical, building)				$143,500
	(assumes land available from Dare Co. at no cost.)				
6.	Upgrade Telemetry Network				
	A. Elevated Storage Tanks	4	Site	$7,000	$28,000
	B. Booster station	2	Site	$7,000	$14,000
	C. Master Control at WTP	1	Site	$7,000	$7,000
					$49,000
7.	Dismantle 400k Tank and Remove from Site	1	LS	$50,000	$50,000
	Subtotal Phase 1				**$1,556,300**
	Engineering, Surveying, Administration, Inspection (15%)				$233,445
	Contingency (15%)				$233,445
	Total Phase 1				**$2,023,190**

PHASE 1 OPTION

		Quantity	Unit	Unit Price	Total
1.	Replace Buxton 100k Tank with Dismantled 400k Tank				
A.	Erect 400k Tank	1	LS	$510,000	$510,000
B.	Altitude Valve	1	EA	$30,000	$30,000
C.	System Tie-in, Piping, Valving	1	LS	$10,000	$10,000
D.	Telemetry	1	Site	$5,000	$5,000
E.	Tank Site	1	Site	$50,000	$50,000
F.	Existing Tank Demolition	1	LS	$35,000	$35,000
					$640,000
2.	Upgrade Lateral Mains to 6" Avon Area				
A.	6" Water Main	20,000	LF	$10	$200,000
B.	14" Steel Casing (Bore and Jack)	200	LF	$200	$40,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$80,000	$80,000
D.	Fire Hydrant Assembly	20	EA	$2,000	$40,000
E.	Residential Service (meter not included)	500	EA	$350	$175,000
					$535,000
	Buxton/Frisco Area				
A.	6" Water Main	38,000	LF	$10	$380,000
B.	14" Steel Casing (Bore and Jack)	400	LF	$200	$80,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$152,000	$152,000
D.	Fire Hydrant Assembly	38	EA	$2,000	$76,000
E.	Residential Service (meter not included)	950	EA	$350	$332,500
					$1,020,500
	Hatteras Area				
A.	6" Water Main	24,000	LF	$10	$240,000
B.	14" Steel Casing (Bore and Jack)	200	LF	$200	$40,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$96,000	$96,000
D.	Fire Hydrant Assembly	24	EA	$2,000	$48,000
E.	Residential Service (meter not included)	600	EA	$350	$210,000
					$634,000
	Subtotal Phase 1 Option				**$2,829,500**
	Engineering, Surveying, Administration, Inspection (15%)				$424,425
	Contingency (15%)				$424,425
	Total Phase 1 Option				**$3,678,350**

PHASE 2
(To be constructed in 2002.)

		Quantity	Unit	Unit Price	Total
1.	12" Water Main from Avon BPS to Southern Avon and from Frisco BPS to Hatteras Tank				
A.	12" Water Main	43,000	LF	$25	$1,075,000
B.	20" Steel Casing (Bore and Jack)	150	LF	$250	$37,500
C.	12" x 8" Tees	15	EA	$500	$7,500
D.	12" Gate Valves	15	EA	$1,800	$27,000
E.	8" x 8" Tapping Sleeve and Valve	15	EA	$1,800	$27,000
F.	Concrete Repair and Blocking	1	LS	$32,000	$32,000
G.	Asphalt Cut and Patch	1	LS	$76,000	$76,000
H.	Crushed Stone	1	LS	$19,000	$19,000
	Subtotal Phase 2				**$1,301,000**
	Engineering, Surveying, Administration, Inspection (15%)				$195,150
	Contingency (15%)				$195,150
	Total Phase 2				**$1,691,300**

PHASE 3
(To be constructed in 2007.)

		Quantity	Unit	Unit Price	Total
1.	Replace Existing 100k Tanks with 300k Tanks				
A.	300,000 Gallon Elevated Tank	2	EA	$400,000	$800,000
B.	Altitude Valve	2	EA	$30,000	$60,000
C.	System Tie-in, Piping, Valving	2	Site	$10,000	$20,000
D.	Telemetry	2	Site	$5,000	$10,000
E.	Existing Tank Demolition	2	Site	$25,000	$50,000
F.	Tank Sites	2	Site	$50,000	$100,000
					$1,040,000
2.	Extend 12" Water Main for Hatteras Fire Protection				
A.	12" Water Main	3,200	LF	$25	$80,000
B.	20" Steel Casing (Bore and Jack)	50	LF	$250	$12,500
C.	12" x 8" Tees	2	EA	$500	$1,000
D.	12" Gate Valves	2	EA	$1,800	$3,600
E.	8" x 8" Tapping Sleeve and Valve	2	EA	$1,800	$3,600
F.	Concrete Blocking and Repair	1	LS	$2,500	$2,500

		Quantity	Unit	Unit Price	Total
G.	Asphalt Cut and Patch	1	LS	$6,000	$6,000
H.	Crushed Stone	1	LS	$1,200	$1,200
					$110,400
	Subtotal Phase 3				**$1,150,400**
	Engineering, Surveying, Administration, Inspection (15%)				$172,560
	Contingency (15%)				$172,560
	Total Phase 3				**$1,495,520**

APPENDIX 3

COST ESTIMATE FOR

RECOMMENDED SYSTEM IMPROVEMENTS

The project cost estimates provided here are based on current 1997 industry pricing. Several sources for pricing were utilized including contractors, equipment representative and files from similar, recently bid or constructed projects. A primary source for cost estimates was the recent water main work performed for Dare County in the Duck area. This information was valuable due to the similarity in projects and our understanding of the cost history of the project.

RECOMMENDED SYSTEM IMPROVEMENTS

PHASE 1
(To be constructed in conjunction with WTP expansion.)

		Quantity	Unit	Unit Price	Total
1.	12" Water Main Between Hatteras Tank and Avon BPS				
A.	12" Water Main	54,000	LF	$25	$1,350,000
B.	20" Steel Casing (Bore and Jack)	50	LF	$250	$12,500
C.	12" x 8" Tees	18	EA	$500	$9,000
D.	12" Gate Valves	18	EA	$1,800	$32,400
E.	8" x 8" Tapping Sleeve and Valve	18	EA	$1,800	$32,400
F.	Concrete Blocking and Repair	1	LS	$40,000	$40,000
G.	Asphalt Cut and Patch	1	LS	$100,000	$100,000
H.	Crushed Stone	1	LS	$20,000	$20,000
					$1,596,300
2.	6" Water Main to Complete Loop at Flowers Ridge Road				
A.	6" Water Main	1,600	LF	$10	$16,000
B.	6" Gate Valve	2	EA	$650	$1,300
C.	Bends, Fittings, Tees	1	LS	$1,500	$1,500
D.	Fire Hydrant Assembly	1	EA	$2,500	$2,500
					$21,300
3.	New 10 to 20 hp Aboveground Booster Pump Station to Replace Existing Avon BPS				
A.	10 hp Package BPS	1	LS	$110,000	$110,000
B.	Piping, Valve, Fittings	1	LS	$15,000	$15,000
C.	Power Generator	1	EA	$18,500	$18,500
	(assumes land available from Dare Co. at no cost.)				$143,500
4.	Dismantle 400k Tank, Replace Existing 100k Avon Tank				
A.	Dismantle 400k Tank		Credit		$0
B.	Erect 400k Tank	1	LS	$510,000	$510,000
C.	System Tie-in, Piping, Valving	1	LS	$10,000	$10,000
D.	Telemetry	1	Site	$5,000	$5,000
E.	Tank Site	1	Site	$50,000	$50,000
F.	Existing Tank Demolition	1	LS	$35,000	$35,000
					$610,000

	Quantity	Unit	Unit Price	Total
5. Install Altitude Valves at Avon, Buxton and Hatteras Tanks				
Altitude Valve	3	EA	$30,000	$90,000
6. Upgrade Telemetry Network				
A. Elevated Storage Tank	4	Site	$7,000	$28,000
B. Booster Station	2	Site	$7,000	$14,000
C. Master Control at WTP	1	Site	$7,000	$7,000
				$49,000
Subtotal Phase 1				**$2,510,100**
Engineering, Surveying, Administration, Inspection (15%)				$376,515
Contingency (15%)				$376,515
Total Phase 1				**$3,263,130**

PHASE 1 OPTION

		Quantity	Unit	Unit Price	Total
Upgrade Lateral Mains to 6"					
Avon Area					
A.	6" Water Main	20,000	LF	$10	$200,000
B.	14" Steel Casing (Bore and Jack)	200	LF	$200	$40,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$80,000	$80,000
D.	Fire Hydrant Assembly	20	EA	$2,000	$40,000
E.	Residential Service (meter not included)	500	EA	$350	$175,000
					$535,000
Buxton/Frisco Area					
A.	6" Water Main	38,000	LF	$10	$380,000
B.	14" Steel Casing (Bore and Jack)	400	LF	$200	$80,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$152,000	$152,000
D.	Fire Hydrant Assembly	38	EA	$2,000	$76,000
E.	Residential Service (meter not included)	950	EA	$350	$332,500
					$1,020,500
Hatteras Area					
A.	6" Water Main	24,000	LF	$10	$240,000
B.	14" Steel Casing (Bore and Jack)	200	LF	$200	$40,000
C.	Tapping Sleeves, Valves, Fittings, Blowoffs	1	LS	$96,000	$96,000
D.	Fire Hydrant Assembly	24	EA	$2,000	$48,000
E.	Residential Service (meter not included)	600	EA	$350	$210,000
					$634,000
	Subtotal Phase 1 Option				**$2,189,500**
	Engineering, Surveying, Administration, Inspection (15%)				$328,425
	Contingency (15%)				$328,425
	Total Phase 1 Option				**$2,846,350**

PHASE 2
(To be constructed in 2002.)

		Quantity	Unit	Unit Price	Total
	12" Water Main from Avon BPS to Southern Avon				
A.	12" Water Main	25,000	LF	$25	$625,000
B.	20" Steel Casing (Bore and Jack)	50	LF	$200	$10,000
C.	12" x 8" Tees	8	EA	$500	$4,000
D.	12" Gate Valves	8	EA	$1,800	$14,400
E.	8" x 8" Tapping Sleeve and Valve	8	EA	$1,800	$14,400
F.	Concrete Repair and Blocking	1	LS	$19,000	$19,000
G.	Asphalt Cut and Patch	1	LS	$46,000	$46,000
H.	Crushed Stone	1	LS	$10,000	$10,000
	Subtotal Phase 2				**$742,800**
	Engineering, Surveying, Administration, Inspection (15%)				$111,420
	Contingency (15%)				$111,420
	Total Phase 2				**$965,640**

111,420
354,220

PHASE 3
(To be constructed in 2007.)

		Quantity	Unit	Unit Price	Total
1.	Replace Hatteras 100k Tank with 300k Tank				
A.	300,000 Gallon Elevated Tank	1	EA	$400,000	$400,000
B.	Altitude Valve	1	EA	$30,000	$30,000
C.	System Tie-in, Piping, Valving	1	Site	$10,000	$10,000
D.	Telemetry	1	Site	$5,000	$5,000
E.	Existing Tank Demolition	1	Site	$25,000	$25,000
F.	Tank Sites	1	Site	$50,000	$50,000
					$520,000
2.	Extend 12" Water Main for Hatteras Fire Protection				
A.	12" Water Main	3,200	LF	$25	$80,000
B.	20" Steel Casing (Bore and Jack)	50	LF	$250	$12,500
C.	12" x 8" Tees	2	EA	$500	$1,000
D.	12" Gate Valves	2	EA	$1,800	$3,600
E.	8" x 8" Tapping Sleeve and Valve	2	EA	$1,800	$3,600
F.	Concrete Blocking and Repair	1	LS	$2,500	$2,500

		Quantity	Unit	Unit Price	Total
G.	Asphalt Cut and Patch	1	LS	$6,000	$6,000
H.	Crushed Stone	1	LS	$1,200	$1,200
					$110,400
	Subtotal Phase 3				**$630,400**
	Engineering, Surveying, Administration, Inspection (15%)				$94,560
	Contingency (15%)				$94,560
	Total Phase 3				**$819,520**

APPENDIX 4

HYDRAULIC ANALYSIS RESULTS

IMPROVED SYSTEM

PER SECTION 6.0 RECOMMENDATION

1. AVERAGE DAY
2. PEAK DAY
3. FIRE FLOW

1. AVERAGE DAY

```
+------------------------------------------------+
|              MAXIMUM DIMENSIONS                |
|                                                |
|  Number of pipes ...................... 1000   |
|  Number of pumps ......................  250   |
|  Number junction nodes................. 1000   |
|  Flow meters ..........................  250   |
|  Boundary nodes .......................  100   |
|  Variable storage tanks ...............  250   |
|  Pressure switches ....................  250   |
|  Regulating Valves.....................  250   |
|  Items for limited output ............. 1000   |
|  limit for non-consecutive numbering ..10010   |
+------------------------------------------------+
```

Cybernet version 2.16 . SN: 1132160944-1000

Extended Description:

U N I T S   S P E C I F I E D

FLOWRATE .... = gallons/minute
HEAD (HGL) .... = feet
PRESSURE .... = psig

O U T P U T   O P T I O N   D A T A

OUTPUT SELECTION: ALL RESULTS ARE INCLUDED IN THE TABULATED OUTPUT

S Y S T E M   C O N F I G U R A T I O N

NUMBER OF PIPES ....(p) = 189
NUMBER OF JUNCTION NODES ....(j) = 148
NUMBER OF PRIMARY LOOPS ....(l) = 37
NUMBER OF BOUNDARY NODES ....(f) = 5
NUMBER OF SUPPLY ZONES ....(z) = 1

****
S I M U L A T I O N   R E S U L T S
****

The results are obtained after 7 trials with an accuracy = 0.00076

S I M U L A T I O N   D E S C R I P T I O N

CyberNet Version 2.16 . Copyright 1991,92 Haestad Methods Inc.
Run Description: 12" // Hat tank to AvonTL, both pumps
Drawing: CHWA3

P I P E L I N E   R E S U L T S

STATUS CODE: XX -CLOSED PIPE   BN -BOUNDARY NODE   PU -PUMP LINE
CV -CHECK VALVE   RV -REGULATING VALVE   TK -STORAGE TANK

PIPE NUMBER	NODE NOS. #1	#2	FLOWRATE (gpm)	HEAD LOSS (ft)	PUMP HEAD (ft)	MINOR LOSS (ft)	LINE VELO. (ft/s)	HL/ 1000 (ft/ft)
2	2	4	-21.28	0.01	0.00	0.00	0.14	0.02
4	4	6	-21.28	0.01	0.00	0.00	0.14	0.02
6	6	8	-30.60	0.01	0.00	0.00	0.20	0.03
8	8	14	-30.60	0.01	0.00	0.00	0.20	0.03
12	14	16	-30.60	0.01	0.00	0.00	0.20	0.03
14	16	18	-24.76	0.02	0.00	0.00	0.28	0.08
16	18	20	-24.76	0.03	0.00	0.00	0.28	0.08
18	20	22	-24.76	0.03	0.00	0.00	0.28	0.08
20	22	24	-40.66	0.06	0.00	0.00	0.46	0.20
22	24	26	-70.64	0.12	0.00	0.00	0.45	0.16
24	26	28	-70.64	0.07	0.00	0.00	0.45	0.16
26	28	30	-94.61	0.11	0.00	0.00	0.60	0.27
28	30	32	-94.61	0.31	0.00	0.00	0.60	0.27
30	32	34	-94.61	0.05	0.00	0.00	0.60	0.27
32	34	36	-94.61	0.09	0.00	0.00	0.60	0.27
34	36	38	-453.29	2.44	0.00	0.00	2.89	4.22
36	38	40	-453.29	1.04	0.00	0.00	2.89	4.22
38	40	42	-453.29	1.28	0.00	0.00	2.89	4.22
40	42	44	-463.55	1.29	0.00	0.00	2.96	4.40
42	44	46	-463.55	2.01	0.00	0.00	2.96	4.40
44	46	48	-470.21	1.80	0.00	0.00	3.00	4.52
46	48	50	-336.64	3.20	0.00	0.00	2.15	2.43
48	50	52	-336.64	2.04	0.00	0.00	2.15	2.43
50	52	54	-343.44	2.04	0.00	0.00	2.19	2.52
52	54	56	-343.44	2.21	0.00	0.00	2.19	2.52
54	56	58	-358.92	2.01	0.00	0.00	2.29	2.74
56	58	60	-507.57	5.85	0.00	0.00	3.24	5.20
58	60	62	-507.57	3.66	0.00	0.00	3.24	5.20
60	62	64	-523.16	6.23	0.00	0.00	3.34	5.50
62	64	66	-527.73	2.77	0.00	0.00	3.37	5.59
64	66	68	-532.85	3.68	0.00	0.00	3.40	5.69
66-CV	70	68	118.11	0.77	0.00	0.00	1.34	1.42
68	70	72	-123.23	0.18	0.00	0.00	0.79	0.38
70	72	74	-123.23	1.59	0.00	0.00	0.79	0.38
72	74	76	-123.23	0.59	0.00	0.00	0.79	0.38
74	76	78	-132.57	5.92	0.00	0.00	0.85	0.43
76-XX	78	80						
78-PU	80	78	548.19	0.61	57.74	0.00	6.22	24.36
80	80	82	-58.43	0.28	0.00	0.00	0.66	0.39
82	82	84	-69.48	0.16	0.00	0.00	0.79	0.53
84	84	86	-69.55	0.55	0.00	0.00	0.79	0.53
86	86	88	-140.00	0.56	0.00	0.00	0.89	0.48
88	88	90	-73.15	0.87	0.00	0.00	0.83	0.58
90	90	92	-95.24	0.79	0.00	0.00	1.08	0.95
92	92	94	-101.60	1.55	0.00	0.00	1.15	1.07
94	94	96	-103.73	1.31	0.00	0.00	1.18	1.12
96	96	98	-108.47	2.87	0.00	0.00	1.23	1.21
98	98	102	-203.79	0.74	0.00	0.00	1.30	1.11
100-BN	0	101	-325.07	0.05	0.00	0.00	0.92	0.28

101-XXCV	101	103						
102	36	100	358.68	0.37	0.00	0.00	1.47	1.07
103	101	103	-325.07	0.00	0.00	0.00	0.92	0.28
104	102	104	-210.19	1.75	0.00	0.00	1.34	1.18
105	100	103	325.07	0.07	0.00	0.00	0.92	0.37
106	104	106	-212.88	5.45	0.00	0.00	1.36	1.21
108-XX	106	108						
110-XXPU	110	108						
112-CV	110	112	0.00	0.00	0.00	0.00	0.00	0.00
114	112	108	0.00	0.00	0.00	0.00	0.00	0.00
116-XX	112	114						
120	116	118	602.82	0.14	0.00	0.00	3.85	7.15
122	114	120	46.20	0.00	0.00	0.00	0.29	0.06
124	116	114	-840.82	0.66	0.00	0.00	5.37	13.25
126	118	120	-933.50	0.80	0.00	0.00	5.96	16.08
128	106	122	-220.30	6.06	0.00	0.00	1.41	1.80
130	122	124	-230.25	1.21	0.00	0.00	1.47	1.96
132	124	116	-236.56	0.76	0.00	0.00	1.51	2.06
134	118	126	181.34	0.38	0.00	0.00	1.16	1.26
136	126	128	161.67	0.42	0.00	0.00	1.03	0.85
138	128	130	151.92	2.87	0.00	0.00	0.97	0.76
140	130	132	174.98	0.58	0.00	0.00	1.12	0.84
142	132	134	164.10	1.62	0.00	0.00	1.05	0.75
144	134	136	162.12	1.19	0.00	0.00	1.03	0.73
146	136	138	157.58	1.30	0.00	0.00	1.01	0.69
148	138	140	147.51	0.62	0.00	0.00	0.94	0.61
150	140	142	136.85	1.22	0.00	0.00	0.87	0.53
152-XXPU	142	144						
154	142	144	672.33	0.02	0.00	0.00	1.91	1.06
156	144	146	178.12	0.51	0.00	0.00	1.14	0.87
158	146	148	164.31	0.33	0.00	0.00	1.05	0.75
160	148	150	162.33	1.29	0.00	0.00	1.04	0.73
162	150	152	115.19	0.11	0.00	0.00	0.74	0.39
164	150	154	38.45	0.05	0.00	0.00	0.25	0.05
166	154	152	33.51	0.05	0.00	0.00	0.21	0.04
168	152	156	148.71	0.56	0.00	0.00	0.95	0.62
170	156	158	140.02	0.42	0.00	0.00	0.89	0.56
172	158	160	133.71	0.31	0.00	0.00	0.85	0.51
174	160	162	133.71	0.53	0.00	0.00	0.85	0.51
176	162	163	127.59	1.69	0.00	0.00	0.81	0.47
177	163	164	142.54	3.62	0.00	0.00	0.91	0.57
178	164	166	133.28	0.23	0.00	0.00	0.85	0.51
180	166	168	117.16	0.77	0.00	0.00	0.75	0.40
182	168	170	182.18	1.37	0.00	0.00	1.16	0.90
184	170	172	154.11	0.21	0.00	0.00	0.98	0.66
186	172	174	154.11	0.52	0.00	0.00	0.98	0.66
188	174	176	86.86	0.15	0.00	0.00	0.55	0.23
190	176	178	78.25	0.16	0.00	0.00	0.50	0.19
192	178	180	52.75	0.20	0.00	0.00	0.34	0.09
194	180	182	32.47	0.08	0.00	0.00	0.21	0.04
196	182	184	41.35	0.05	0.00	0.00	0.26	0.06
198	184	190	30.65	0.00	0.00	0.00	0.13	0.01
200-BN	0	110	0.00	0.00	0.00	0.00	0.00	0.00
202	186	188	6.45	0.00	0.00	0.00	0.03	0.00
204	190	186	12.42	0.00	0.00	0.00	0.05	0.00
206	188	192	3.22	0.00	0.00	0.00	0.02	0.00
220	16	220	-15.16	0.01	0.00	0.00	0.17	0.04
222	220	222	-2.83	0.00	0.00	0.00	0.03	0.00
224	222	224	-6.53	0.00	0.00	0.00	0.07	0.01
226	224	226	-10.24	0.02	0.00	0.00	0.12	0.02

228	226	228	-26.27	0.07	0.00	0.00	0.30	0.10
230	24	228	29.98	0.04	0.00	0.00	0.34	0.13
232	226	220	12.33	0.02	0.00	0.00	0.14	0.03
234	100	230	33.61	0.04	0.00	0.00	0.21	0.04
236	230	232	6.94	0.02	0.00	0.00	0.08	0.01
238	232	230	-6.69	0.02	0.00	0.00	0.08	0.01
240	48	234	-133.57	0.60	0.00	0.00	1.52	2.07
242	234	236	-133.57	4.63	0.00	0.00	1.52	2.07
244	236	238	-138.71	5.41	0.00	0.00	1.57	2.22
246	58	238	148.66	0.86	0.00	0.00	1.69	2.52
248	52	236	6.80	0.00	0.00	0.00	0.08	0.01
250	56	240	8.28	0.00	0.00	0.00	0.03	0.00
252	240	242	8.28	0.01	0.00	0.00	0.09	0.01
300-BN	0	303	-281.02	0.04	0.00	0.00	0.80	0.21
301	84	300	-9.14	0.02	0.00	0.00	0.10	0.01
302	300	302	-0.37	0.00	0.00	0.00	0.00	0.00
303	303	305	-281.02	0.00	0.00	0.00	0.80	0.21
304	302	304	-5.60	0.08	0.00	0.00	0.14	0.04
305-XXCV	303	305						
306	300	304	-19.84	0.08	0.00	0.00	0.23	0.06
307	305	301	-281.02	0.04	0.00	0.00	0.80	0.21
308	304	306	-35.34	0.06	0.00	0.00	0.40	0.18
310	306	308	-47.87	0.76	0.00	0.00	0.54	0.31
312	308	310	-49.82	0.41	0.00	0.00	0.57	0.33
314	88	301	-61.92	0.56	0.00	0.00	0.70	0.50
316	301	312	-54.26	0.69	0.00	0.00	0.62	0.39
318	312	314	-64.25	0.17	0.00	0.00	0.73	0.53
320	314	316	-71.47	0.50	0.00	0.00	0.81	0.65
322	98	316	135.64	5.47	0.00	0.00	1.54	2.13
324	316	318	61.17	1.00	0.00	0.00	0.69	0.49
326	318	310	50.66	0.70	0.00	0.00	0.57	0.34
400-BN	0	401	-414.24	0.09	0.00	0.00	1.18	0.43
401	401	403	-414.24	0.00	0.00	0.00	1.18	0.43
402	174	400	58.64	0.31	0.00	0.00	0.67	0.53
403-XXCV	401	403						
404	400	402	28.97	0.22	0.00	0.00	0.33	0.14
405	168	403	414.24	0.08	0.00	0.00	1.18	0.43
406	402	404	20.00	0.11	0.00	0.00	0.23	0.07
408	404	406	12.23	0.01	0.00	0.00	0.08	0.01
410	406	408	12.23	0.00	0.00	0.00	0.08	0.01
412	184	408	7.48	0.02	0.00	0.00	0.08	0.01
414	182	400	-21.06	0.27	0.00	0.00	0.24	0.08
500-XX	36	500						
502	48	500	0.00	0.00	0.00	0.00	0.00	0.00
504-XX	500	502						
506	58	502	0.00	0.00	0.00	0.00	0.00	0.00
508-XX	502	504						
510	68	504	-424.96	0.00	0.00	0.00	1.21	0.45
511	76	505	9.34	0.00	0.00	0.00	0.03	0.00
512-CV	505	504	424.96	3.12	0.00	0.00	1.21	0.45
513	505	506	-415.63	5.61	0.00	0.00	1.18	0.43
514	78	506	415.63	0.31	0.00	0.00	1.18	0.43
516	86	508	53.87	0.00	0.00	0.00	0.15	0.01
517	80	508	-489.76	0.99	0.00	0.00	1.39	0.59
518	508	510	-435.90	0.55	0.00	0.00	1.24	0.47
520	88	510	435.90	0.00	0.00	0.00	1.24	0.47
521	88	511	-448.04	0.56	0.00	0.00	1.27	0.50
522	301	511	-288.68	0.00	0.00	0.00	0.82	0.22
523	98	511	736.72	6.84	0.00	0.00	2.09	1.26
524	98	512	-787.48	0.01	0.00	0.00	2.23	1.42

68-1	check valve	10.23	169.06	5.00	164.06	71.09
70-1	check valve	5.11	169.83	5.00	164.83	71.43
72-1		0.00	170.00	5.00	165.00	71.50
74-1		0.00	171.59	5.00	166.59	72.19
76-1		0.00	172.19	5.00	167.19	72.45
78-1	avon pump	0.00	178.11	5.00	173.11	75.01
80-1	avon pump	0.00	120.98	5.00	115.98	50.26
82-1		11.06	121.26	5.00	116.26	50.38
84-1		9.21	121.42	5.00	116.42	50.45
86-1		16.58	121.97	5.00	116.97	50.69
88-1		7.22	122.53	6.00	116.53	50.50
90-1		22.09	123.40	9.00	114.40	49.57
92-1		6.36	124.19	10.00	114.19	49.48
94-1		2.13	125.74	10.00	115.74	50.16
96-1		4.74	127.05	10.00	117.05	50.72
98-1		10.44	129.92	9.00	120.92	52.40
100-1	avon tank	0.00	125.13	5.00	120.13	52.06
101-1		0.00	125.05	5.00	120.05	52.02
102-1		6.41	130.66	10.00	120.66	52.29
103-1		0.00	125.06	5.00	120.06	52.02
104-1		2.68	132.41	11.00	121.41	52.61
106-1		7.43	137.86	7.00	130.86	56.70
108-1		0.00	125.00	7.00	118.00	51.13
110-1	400k tank	0.00	125.00	7.00	118.00	51.13
112-1		0.00	125.00	7.00	118.00	51.13
114-1		0.00	146.55	10.00	136.55	59.17
116-1		1.44	145.89	10.00	135.89	58.89
118-1		0.00	145.75	10.00	135.75	58.82
120-1		0.00	146.55	10.00	136.55	59.17
122-1		9.94	143.91	10.00	133.91	58.03
124-1		6.32	145.13	10.00	135.13	58.55
126-1		19.67	145.36	10.00	135.36	58.66
128-1		9.75	144.94	5.00	139.94	60.64
130-1		8.95	142.07	4.00	138.07	59.83
132-1		10.88	141.49	4.00	137.49	59.58
134-1		1.98	139.87	4.00	135.87	58.88
136-1		4.55	138.68	4.00	134.68	58.36
138-1		10.06	137.38	4.00	133.38	57.80
140-1		10.66	136.76	5.00	131.76	57.10
142-1	hatteras pum	0.00	135.54	5.00	130.54	56.57
144-1	hatteras pum	0.00	135.52	5.00	130.52	56.56
146-1		13.81	135.02	8.00	127.02	55.04
148-1		1.98	134.69	20.00	114.69	49.70
150-1		8.69	133.40	5.00	128.40	55.64
152-1		0.00	133.29	4.00	129.29	56.03
154-1		4.93	133.35	4.00	129.35	56.05
156-1		8.69	132.73	4.00	128.73	55.78
158-1		6.32	132.31	4.00	128.31	55.60
160-1		0.00	132.00	4.00	128.00	55.47
162-1		6.12	131.47	5.00	126.47	54.80
163-1		0.00	129.78	5.00	124.78	54.07
164-1		9.26	126.16	5.00	121.16	52.50
166-1		16.13	125.94	5.00	120.94	52.41
168-1	hatteras tan	0.00	125.17	5.00	120.17	52.07
170-1		28.06	123.80	5.00	118.80	51.48
172-1		0.00	123.60	5.00	118.60	51.39
174-1		8.61	123.07	3.00	120.07	52.03
176-1		8.61	122.93	3.00	119.93	51.97
178-1		25.50	122.77	3.00	119.77	51.90
180-1		20.28	122.57	3.00	119.57	51.81

182-1	12.18	122.49	3.00	119.49	51.78
184-1	3.22	122.44	3.00	119.44	51.76
186-1	5.97	122.44	3.00	119.44	51.76
188-1	3.22	122.43	3.00	119.43	51.76
190-1	18.23	122.44	3.00	119.44	51.76
192-1	3.22	122.43	3.00	119.43	51.75
220-1	0.00	124.62	4.00	120.62	52.27
222-1	3.70	124.62	4.00	120.62	52.27
224-1	3.70	124.62	4.00	120.62	52.27
226-1	3.70	124.63	4.00	120.63	52.27
228-1	3.70	124.70	4.00	120.70	52.30
230-1	19.98	125.09	5.00	120.09	52.04
232-1	13.64	125.07	4.00	121.07	52.46
234-1	0.00	135.97	5.00	130.97	56.75
236-1	11.94	140.60	5.00	135.60	58.76
238-1	9.94	146.01	5.00	141.01	61.10
240-1	0.00	144.86	5.00	139.86	60.60
242-1	8.28	144.85	4.00	140.85	61.03
300-1	11.07	121.44	9.00	112.44	48.73
301-1 buxton tank	0.00	123.08	6.00	117.08	50.74
302-1	5.24	121.44	9.00	112.44	48.73
303-1	0.00	123.04	6.00	117.04	50.72
304-1	9.90	121.52	10.00	111.52	48.33
305-1	0.00	123.04	6.00	117.04	50.72
306-1	12.52	121.59	10.00	111.59	48.35
308-1	1.95	122.34	10.00	112.34	48.68
310-1	0.84	122.75	10.00	112.75	48.86
312-1	9.99	123.78	13.00	110.78	48.00
314-1	7.22	123.95	10.00	113.95	49.38
316-1	3.00	124.45	10.00	114.45	49.60
318-1	10.52	123.45	10.00	113.45	49.16
400-1	8.61	122.76	3.00	119.76	51.90
401-1	0.00	125.09	5.00	120.09	52.04
402-1	8.97	122.54	3.00	119.54	51.80
403-1	0.00	125.09	5.00	120.09	52.04
404-1	7.77	122.43	3.00	119.43	51.75
406-1	0.00	122.42	3.00	119.42	51.75
408-1	19.71	122.42	3.00	119.42	51.75
500-1	0.00	135.37	5.00	130.37	56.49
502-1	0.00	146.87	5.00	141.87	61.48
504-1	0.00	169.06	5.00	164.06	71.09
505-1	0.00	172.19	5.00	167.19	72.45
506-1	0.00	177.80	5.00	172.80	74.88
508-1	0.00	121.97	5.00	116.97	50.69
510-1	0.00	122.52	6.00	116.52	50.49
511-1	0.00	123.09	5.00	118.09	51.17
512-1	0.00	129.94	9.00	120.94	52.41
514-1	0.00	139.17	7.00	132.17	57.27
516-1	0.00	135.55	5.00	130.55	56.57
518-1	0.00	125.18	5.00	120.18	52.08
520-1	0.00	123.07	3.00	120.07	52.03
528-1	0.00	145.71	5.00	140.71	60.97
531-1	0.00	142.07	4.00	138.07	59.83
535-1	0.00	129.78	5.00	124.78	54.07
600-1	0.00	149.21	5.00	144.21	62.49
601-1	0.00	151.03	5.00	146.03	63.28
602-1	0.00	17.36	5.00	12.36	5.36

S U M M A R Y   O F   I N F L O W S   A N D   O U T F L O W S

(+) INFLOWS INTO THE SYSTEM FROM BOUNDARY NODES
(-) OUTFLOWS FROM THE SYSTEM INTO BOUNDARY NODES

PIPE NUMBER	FLOWRATE (gpm)
100	-325.07
200	0.00
300	-281.02
400	-414.24
606	1774.32

NET SYSTEM INFLOW = 1774.32
NET SYSTEM OUTFLOW = -1020.33
NET SYSTEM DEMAND = 753.99

**** CYBERNET SIMULATION COMPLETED ****

DATE: 3/18/1997
TIME: 17:28:01

2. PEAK DAY

```
+-----------------------------------------------------+
|                  MAXIMUM DIMENSIONS                 |
|                                                     |
|  Number of pipes ..................... 1000         |
|  Number of pumps .....................  250         |
|  Number junction nodes................ 1000         |
|  Flow meters .........................  250         |
|  Boundary nodes ......................  100         |
|  Variable storage tanks ..............  250         |
|  Pressure switches ...................  250         |
|  Regulating Valves....................  250         |
|  Items for limited output ............ 1000         |
|  limit for non-consecutive numbering ..10010        |
+-----------------------------------------------------+
```

Cybernet version 2.16 . SN: 1132160944-1000

Extended Description:

U N I T S   S P E C I F I E D

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FLOWRATE ............ = gallons/minute
HEAD (HGL) .......... = feet
PRESSURE ............ = psig
```

O U T P U T   O P T I O N   D A T A

OUTPUT SELECTION: ALL RESULTS ARE INCLUDED IN THE TABULATED OUTPUT

S Y S T E M   C O N F I G U R A T I O N

```
NUMBER OF PIPES ...................(p) =  189
NUMBER OF JUNCTION NODES ..........(j) =  148
NUMBER OF PRIMARY LOOPS ...........(l) =   37
NUMBER OF BOUNDARY NODES ..........(f) =    5
NUMBER OF SUPPLY ZONES ............(z) =    1
```

****

S I M U L A T I O N   R E S U L T S

****

The results are obtained after 7 trials with an accuracy = 0.00098

S I M U L A T I O N   D E S C R I P T I O N

CyberNet Version 2.16 . Copyright 1991,92 Haestad Methods Inc.
Run Description: 12" // Hat tank to AvonTL, both pumps
Drawing: CHWA3

P I P E L I N E   R E S U L T S

STATUS CODE: XX -CLOSED PIPE   BN -BOUNDARY NODE   PU -PUMP LINE
CV -CHECK VALVE   RV -REGULATING VALVE   TK -STORAGE TANK

PIPE NUMBER	NODE NOS. #1	#2	FLOWRATE (gpm)	HEAD LOSS (ft)	PUMP HEAD (ft)	MINOR LOSS (ft)	LINE VELO. (ft/s)	HL/ 1000 (ft/ft)
2	2	4	-74.50	0.06	0.00	0.00	0.48	0.17
4	4	6	-74.50	0.06	0.00	0.00	0.48	0.17
6	6	8	-107.10	0.14	0.00	0.00	0.68	0.34
8	8	14	-107.10	0.13	0.00	0.00	0.68	0.34
12	14	16	-107.10	0.07	0.00	0.00	0.68	0.34
14	16	18	-86.65	0.18	0.00	0.00	0.98	0.80
16	18	20	-86.65	0.33	0.00	0.00	0.98	0.80
18	20	22	-86.65	0.30	0.00	0.00	0.98	0.80
20	22	24	-142.30	0.60	0.00	0.00	1.61	2.00
22	24	26	-247.22	1.25	0.00	0.00	1.58	1.59
24	26	28	-247.22	0.72	0.00	0.00	1.58	1.59
26	28	30	-331.12	1.11	0.00	0.00	2.11	2.74
28	30	32	-331.12	3.14	0.00	0.00	2.11	2.74
30	32	34	-331.12	0.53	0.00	0.00	2.11	2.74
32	34	36	-331.12	0.96	0.00	0.00	2.11	2.74
34	36	38	-281.62	1.01	0.00	0.00	1.80	1.75
36	38	40	-281.62	0.43	0.00	0.00	1.80	1.75
38	40	42	-281.62	0.53	0.00	0.00	1.80	1.75
40	42	44	-317.53	0.64	0.00	0.00	2.03	2.18
42	44	46	-317.53	1.00	0.00	0.00	2.03	2.18
44	46	48	-340.84	0.99	0.00	0.00	2.18	2.49
46	48	50	-244.38	1.77	0.00	0.00	1.56	1.34
48	50	52	-244.38	1.13	0.00	0.00	1.56	1.34
50	52	54	-271.04	1.32	0.00	0.00	1.73	1.63
52	54	56	-271.04	1.43	0.00	0.00	1.73	1.63
54	56	58	-325.22	1.67	0.00	0.00	2.08	2.28
56	58	60	-471.62	5.11	0.00	0.00	3.01	4.54
58	60	62	-471.62	3.20	0.00	0.00	3.01	4.54
60	62	64	-526.17	6.30	0.00	0.00	3.36	5.56
62	64	66	-542.18	2.91	0.00	0.00	3.46	5.88
64	66	68	-560.08	4.03	0.00	0.00	3.57	6.24
66-CV	70	68	122.40	0.82	0.00	0.00	1.39	1.52
68	70	72	-140.30	0.22	0.00	0.00	0.90	0.48
70	72	74	-140.30	2.02	0.00	0.00	0.90	0.48
72	74	76	-140.30	0.75	0.00	0.00	0.90	0.48
74	76	78	-148.43	7.30	0.00	0.00	0.95	0.53
76-XX	78	80						
78-PU	80	78	613.79	0.75	51.56	0.00	6.96	30.03
80	80	82	25.59	0.06	0.00	0.00	0.29	0.08
82	82	84	-13.10	0.01	0.00	0.00	0.15	0.02
84	84	86	-127.32	1.68	0.00	0.00	1.44	1.63
86	86	88	-200.50	1.08	0.00	0.00	1.28	0.93
88	88	90	9.96	0.02	0.00	0.00	0.11	0.01
90	90	92	-67.37	0.42	0.00	0.00	0.76	0.50
92	92	94	-89.63	1.23	0.00	0.00	1.02	0.85
94	94	96	-97.09	1.16	0.00	0.00	1.10	0.99
96	96	98	-113.68	3.13	0.00	0.00	1.29	1.32
98	98	102	-149.18	0.41	0.00	0.00	0.95	0.62
100-BN	0	101	167.15	0.02	0.00	0.00	0.47	0.08

101-CV	101	103	83.57	0.00	0.00	0.00	0.24	0.02
102	36	100	-49.50	0.01	0.00	0.00	0.20	0.03
103	101	103	83.57	0.00	0.00	0.00	0.24	0.02
104	102	104	-171.60	1.20	0.00	0.00	1.10	0.81
105	100	103	-167.15	0.02	0.00	0.00	0.47	0.11
106	104	106	-181.00	4.04	0.00	0.00	1.16	0.89
108-XX	106	108						
110-XXPU	110	108						
112-CV	110	112	0.00	0.00	0.00	0.00	0.00	0.00
114	112	108	0.00	0.00	0.00	0.00	0.00	0.00
116-XX	112	114						
120	116	118	605.99	0.14	0.00	0.00	3.87	7.22
122	114	120	45.24	0.00	0.00	0.00	0.29	0.06
124	116	114	-874.93	0.71	0.00	0.00	5.58	14.26
126	118	120	-965.68	0.86	0.00	0.00	6.16	17.12
128	106	122	-206.99	5.40	0.00	0.00	1.32	1.61
130	122	124	-241.79	1.33	0.00	0.00	1.54	2.14
132	124	116	-263.90	0.93	0.00	0.00	1.68	2.52
134	118	126	254.69	0.72	0.00	0.00	1.63	2.36
136	126	128	185.86	0.55	0.00	0.00	1.19	1.10
138	128	130	151.74	2.86	0.00	0.00	0.97	0.76
140	130	132	212.91	0.84	0.00	0.00	1.36	1.21
142	132	134	174.85	1.82	0.00	0.00	1.12	0.84
144	134	136	167.92	1.27	0.00	0.00	1.07	0.78
146	136	138	152.01	1.22	0.00	0.00	0.97	0.65
148	138	140	116.79	0.40	0.00	0.00	0.75	0.40
150	140	142	79.46	0.45	0.00	0.00	0.51	0.19
152-XXPU	142	144						
154	142	144	591.07	0.02	0.00	0.00	1.68	0.83
156	144	146	218.46	0.74	0.00	0.00	1.39	1.27
158	146	148	170.11	0.35	0.00	0.00	1.09	0.80
160	148	150	163.18	1.30	0.00	0.00	1.04	0.74
162	150	152	94.74	0.07	0.00	0.00	0.60	0.27
164	150	154	38.04	0.05	0.00	0.00	0.24	0.05
166	154	152	20.77	0.02	0.00	0.00	0.13	0.02
168	152	156	115.51	0.35	0.00	0.00	0.74	0.39
170	156	158	85.11	0.17	0.00	0.00	0.54	0.22
172	158	160	63.01	0.08	0.00	0.00	0.40	0.13
174	160	162	63.01	0.13	0.00	0.00	0.40	0.13
176	162	163	41.59	0.21	0.00	0.00	0.27	0.06
177	163	164	103.09	1.98	0.00	0.00	0.66	0.32
178	164	166	70.70	0.07	0.00	0.00	0.45	0.16
180	166	168	14.26	0.02	0.00	0.00	0.09	0.01
182	168	170	637.61	13.94	0.00	0.00	4.07	9.21
184	170	172	539.38	2.10	0.00	0.00	3.44	6.75
186	172	174	539.38	5.30	0.00	0.00	3.44	6.75
188	174	176	304.01	1.52	0.00	0.00	1.94	2.34
190	176	178	273.88	1.61	0.00	0.00	1.75	1.93
192	178	180	184.63	2.04	0.00	0.00	1.18	0.93
194	180	182	113.65	0.82	0.00	0.00	0.73	0.38
196	182	184	144.72	0.51	0.00	0.00	0.92	0.59
198	184	190	107.26	0.02	0.00	0.00	0.44	0.09
200-BN	0	110	0.00	0.00	0.00	0.00	0.00	0.00
202	186	188	22.58	0.00	0.00	0.00	0.09	0.00
204	190	186	43.47	0.01	0.00	0.00	0.18	0.02
206	188	192	11.29	0.00	0.00	0.00	0.07	0.00
220	16	220	-53.05	0.09	0.00	0.00	0.60	0.37
222	220	222	-9.88	0.01	0.00	0.00	0.11	0.02
224	222	224	-22.85	0.03	0.00	0.00	0.26	0.08
226	224	226	-35.82	0.16	0.00	0.00	0.41	0.18

228	226	228	-91.95	0.70	0.00	0.00	1.04	1.04
230	24	228	104.92	0.42	0.00	0.00	1.19	1.32
232	226	220	43.17	0.19	0.00	0.00	0.49	0.26
234	100	230	117.65	0.38	0.00	0.00	0.75	0.40
236	230	232	24.29	0.21	0.00	0.00	0.28	0.09
238	232	230	-23.43	0.21	0.00	0.00	0.27	0.08
240	48	234	-96.46	0.33	0.00	0.00	1.09	1.13
242	234	236	-96.46	2.53	0.00	0.00	1.09	1.13
244	236	238	-111.59	3.62	0.00	0.00	1.27	1.48
246	58	238	146.39	0.83	0.00	0.00	1.66	2.45
248	52	236	26.66	0.03	0.00	0.00	0.30	0.10
250	56	240	28.98	0.00	0.00	0.00	0.12	0.01
252	240	242	28.98	0.07	0.00	0.00	0.33	0.12
300-BN	0	303	318.97	0.05	0.00	0.00	0.90	0.27
301	84	300	81.98	1.19	0.00	0.00	0.93	0.84
302	300	302	22.98	0.03	0.00	0.00	0.26	0.08
303	303	305	159.50	0.00	0.00	0.00	0.45	0.07
304	302	304	4.65	0.06	0.00	0.00	0.12	0.03
305-CV	303	305	159.47	0.00	0.00	0.00	0.45	0.07
306	300	304	20.26	0.08	0.00	0.00	0.23	0.06
307	305	301	318.97	0.05	0.00	0.00	0.90	0.27
308	304	306	-9.74	0.01	0.00	0.00	0.11	0.02
310	306	308	-53.58	0.93	0.00	0.00	0.61	0.38
312	308	310	-60.40	0.59	0.00	0.00	0.69	0.48
314	88	301	-104.64	1.47	0.00	0.00	1.19	1.32
316	301	312	43.38	0.46	0.00	0.00	0.49	0.26
318	312	314	8.42	0.00	0.00	0.00	0.10	0.01
320	314	316	-16.83	0.03	0.00	0.00	0.19	0.04
322	98	316	127.48	4.88	0.00	0.00	1.45	1.90
324	316	318	100.14	2.50	0.00	0.00	1.14	1.21
326	318	310	63.34	1.06	0.00	0.00	0.72	0.52
400-BN	0	401	312.25	0.05	0.00	0.00	0.89	0.26
401	401	403	156.12	0.00	0.00	0.00	0.44	0.07
402	174	400	205.24	3.19	0.00	0.00	2.33	5.38
403-CV	401	403	156.12	0.00	0.00	0.00	0.44	0.07
404	400	402	101.40	2.25	0.00	0.00	1.15	1.46
405	168	403	-312.25	0.05	0.00	0.00	0.89	0.26
406	402	404	70.00	1.15	0.00	0.00	0.79	0.73
408	404	406	42.81	0.06	0.00	0.00	0.27	0.06
410	406	408	42.81	0.03	0.00	0.00	0.27	0.07
412	184	408	26.18	0.19	0.00	0.00	0.30	0.12
414	182	400	-73.70	2.80	0.00	0.00	0.84	0.81
500-XX	36	500						
502	48	500	0.00	0.00	0.00	0.00	0.00	0.00
504-XX	500	502						
506	58	502	0.00	0.00	0.00	0.00	0.00	0.00
508-XX	502	504						
510	68	504	-473.48	0.01	0.00	0.00	1.34	0.55
511	76	505	8.13	0.00	0.00	0.00	0.02	0.00
512-CV	505	504	473.48	3.82	0.00	0.00	1.34	0.55
513	505	506	-465.36	6.92	0.00	0.00	1.32	0.54
514	78	506	465.36	0.38	0.00	0.00	1.32	0.54
516	86	508	15.17	0.00	0.00	0.00	0.04	0.00
517	80	508	-639.38	1.63	0.00	0.00	1.81	0.97
518	508	510	-624.21	1.07	0.00	0.00	1.77	0.92
520	88	510	624.21	0.01	0.00	0.00	1.77	0.92
521	88	511	-755.28	1.47	0.00	0.00	2.14	1.31
522	301	511	170.94	0.00	0.00	0.00	0.48	0.08
523	98	511	584.34	4.45	0.00	0.00	1.66	0.82
524	98	512	-712.85	0.01	0.00	0.00	2.02	1.18

526	512	514	-712.85	7.68	0.00	0.00	2.02	1.18
527	118	528	1316.98	0.04	0.00	0.00	3.74	3.68
528	514	528	-712.85	5.44	0.00	0.00	2.02	1.18
529	130	531	-92.52	0.01	0.00	0.00	0.26	0.03
530	528	531	604.13	4.08	0.00	0.00	1.71	0.87
531	531	516	511.61	5.99	0.00	0.00	1.45	0.64
532	142	516	-511.61	0.01	0.00	0.00	1.45	0.64
533	163	535	-61.50	0.00	0.00	0.00	0.17	0.01
534	144	535	372.61	3.40	0.00	0.00	1.06	0.36
535	535	518	311.10	2.07	0.00	0.00	0.88	0.25
536	168	518	-311.10	0.00	0.00	0.00	0.88	0.25
538-XX	168	520						
540	174	520	0.00	0.00	0.00	0.00	0.00	0.00
600	120	600	-920.43	2.84	0.00	0.00	2.61	1.90
601	114	600	-920.17	2.84	0.00	0.00	2.61	1.89
602	600	601	-1840.60	1.95	0.00	0.00	5.22	6.84
603-XXCV	602	601						
604-PU	602	601	1226.70	0.16	129.00	0.00	3.48	3.23
605-PU	602	601	613.90	0.04	128.89	0.00	1.74	0.90
606-BN	0	602	1840.60	0.68	0.00	0.00	5.22	6.84

J U N C T I O N   N O D E   R E S U L T S

JUNCTION NUMBER	JUNCTION TITLE	EXTERNAL DEMAND (gpm)	HYDRAULIC GRADE (ft)	JUNCTION ELEVATION (ft)	PRESSURE HEAD (ft)	JUNCTION PRESSURE (psi)
2-1		74.50	115.39	5.00	110.39	47.83
4-1		0.00	115.44	5.00	110.44	47.86
6-1		32.60	115.50	5.00	110.50	47.88
8-1		0.00	115.64	5.00	110.64	47.94
14-1		0.00	115.78	5.00	110.78	48.00
16-1		32.60	115.84	5.00	110.84	48.03
18-1		0.00	116.02	5.00	111.02	48.11
20-1		0.00	116.35	5.00	111.35	48.25
22-1		55.65	116.65	5.00	111.65	48.38
24-1		0.00	117.25	5.00	112.25	48.64
26-1		0.00	118.49	5.00	113.49	49.18
28-1		83.89	119.21	5.00	114.21	49.49
30-1		0.00	120.32	5.00	115.32	49.97
32-1		0.00	123.46	5.00	118.46	51.33
34-1		0.00	123.99	5.00	118.99	51.56
36-1		0.00	124.95	5.00	119.95	51.98
38-1		0.00	125.97	5.00	120.97	52.42
40-1		0.00	126.40	5.00	121.40	52.61
42-1		35.91	126.93	5.00	121.93	52.84
44-1		0.00	127.57	5.00	122.57	53.11
46-1		23.31	128.57	5.00	123.57	53.55
48-1		0.00	129.56	5.00	124.56	53.97
50-1		0.00	131.32	5.00	126.32	54.74
52-1		0.00	132.45	5.00	127.45	55.23
54-1		0.00	133.77	5.00	128.77	55.80
56-1		25.20	135.19	5.00	130.19	56.42
58-1		0.00	136.87	5.00	131.87	57.14
60-1		0.00	141.98	5.00	136.98	59.36
62-1		54.55	145.17	5.00	140.17	60.74
64-1		16.01	151.47	5.00	146.47	63.47
66-1		17.90	154.38	5.00	149.38	64.73

68-1	check valve	35.81	158.41	5.00	153.41	66.48
70-1	check valve	17.90	159.24	5.00	154.24	66.84
72-1		0.00	159.46	5.00	154.46	66.93
74-1		0.00	161.48	5.00	156.48	67.81
76-1		0.00	162.24	5.00	157.24	68.14
78-1	avon pump	0.00	169.53	5.00	164.53	71.30
80-1	avon pump	0.00	118.72	5.00	113.72	49.28
82-1		38.69	118.66	5.00	113.66	49.25
84-1		32.24	118.67	5.00	113.67	49.26
86-1		58.01	120.35	5.00	115.35	49.98
88-1		25.25	121.43	6.00	115.43	50.02
90-1		77.33	121.41	9.00	112.41	48.71
92-1		22.26	121.82	10.00	111.82	48.46
94-1		7.45	123.06	10.00	113.06	48.99
96-1		16.59	124.21	10.00	114.21	49.49
98-1		36.54	127.35	9.00	118.35	51.28
100-1	avon tank	0.00	124.96	5.00	119.96	51.98
101-1		0.00	124.98	5.00	119.98	51.99
102-1		22.42	127.76	10.00	117.76	51.03
103-1		0.00	124.98	5.00	119.98	51.99
104-1		9.40	128.96	11.00	117.96	51.12
106-1		25.99	132.99	7.00	125.99	54.60
108-1		0.00	125.00	7.00	118.00	51.13
110-1	400k tank	0.00	125.00	7.00	118.00	51.13
112-1		0.00	125.00	7.00	118.00	51.13
114-1		0.00	141.37	10.00	131.37	56.93
116-1		5.04	140.65	10.00	130.65	56.62
118-1		0.00	140.51	10.00	130.51	56.55
120-1		0.00	141.36	10.00	131.36	56.92
122-1		34.81	138.39	10.00	128.39	55.64
124-1		22.10	139.72	10.00	129.72	56.21
126-1		68.83	139.79	10.00	129.79	56.24
128-1		34.13	139.24	5.00	134.24	58.17
130-1		31.34	136.38	4.00	132.38	57.36
132-1		38.06	135.54	4.00	131.54	57.00
134-1		6.93	133.72	4.00	129.72	56.21
136-1		15.91	132.45	4.00	128.45	55.66
138-1		35.23	131.23	4.00	127.23	55.14
140-1		37.33	130.84	5.00	125.84	54.53
142-1	hatteras pum	0.00	130.39	5.00	125.39	54.34
144-1	hatteras pum	0.00	130.37	5.00	125.37	54.33
146-1		48.35	129.64	8.00	121.64	52.71
148-1		6.93	129.28	20.00	109.28	47.36
150-1		30.40	127.98	5.00	122.98	53.29
152-1		0.00	127.91	4.00	123.91	53.69
154-1		17.27	127.93	4.00	123.93	53.70
156-1		30.40	127.56	4.00	123.56	53.54
158-1		22.10	127.39	4.00	123.39	53.47
160-1		0.00	127.31	4.00	123.31	53.44
162-1		21.42	127.18	5.00	122.18	52.95
163-1		0.00	126.97	5.00	121.97	52.85
164-1		32.39	124.99	5.00	119.99	51.99
166-1		56.44	124.92	5.00	119.92	51.96
168-1	hatteras tan	0.00	124.90	5.00	119.90	51.96
170-1		98.23	110.96	5.00	105.96	45.92
172-1		0.00	108.86	5.00	103.86	45.01
174-1		30.14	103.56	3.00	100.56	43.58
176-1		30.14	102.04	3.00	99.04	42.92
178-1		89.25	100.44	3.00	97.44	42.22
180-1		70.98	98.40	3.00	95.40	41.34

182-1		42.63	97.58	3.00	94.58	40.98
184-1		11.29	97.07	3.00	94.07	40.77
186-1		20.90	97.05	3.00	94.05	40.75
188-1		11.29	97.04	3.00	94.04	40.75
190-1		63.79	97.06	3.00	94.06	40.76
192-1		11.29	97.04	3.00	94.04	40.75
220-1		0.00	115.93	4.00	111.93	48.50
222-1		12.97	115.94	4.00	111.94	48.51
224-1		12.97	115.97	4.00	111.97	48.52
226-1		12.97	116.13	4.00	112.13	48.59
228-1		12.97	116.83	4.00	112.83	48.89
230-1		69.93	124.58	5.00	119.58	51.82
232-1		47.72	124.37	4.00	120.37	52.16
234-1		0.00	129.88	5.00	124.88	54.12
236-1		41.79	132.42	5.00	127.42	55.21
238-1		34.81	136.04	5.00	131.04	56.78
240-1		0.00	135.19	5.00	130.19	56.42
242-1		28.98	135.12	4.00	131.12	56.82
300-1		38.74	117.48	9.00	108.48	47.01
301-1	buxton tank	0.00	122.90	6.00	116.90	50.65
302-1		18.32	117.45	9.00	108.45	47.00
303-1		0.00	122.95	6.00	116.95	50.68
304-1		34.65	117.39	10.00	107.39	46.54
305-1		0.00	122.95	6.00	116.95	50.68
306-1		43.84	117.40	10.00	107.40	46.54
308-1		6.82	118.33	10.00	108.33	46.94
310-1		2.94	118.92	10.00	108.92	47.20
312-1		34.97	122.44	13.00	109.44	47.42
314-1		25.25	122.43	10.00	112.43	48.72
316-1		10.50	122.47	10.00	112.47	48.74
318-1		36.80	119.97	10.00	109.97	47.65
400-1		30.14	100.37	3.00	97.37	42.20
401-1		0.00	124.95	5.00	119.95	51.98
402-1		31.40	98.12	3.00	95.12	41.22
403-1		0.00	124.95	5.00	119.95	51.98
404-1		27.19	96.97	3.00	93.97	40.72
406-1		0.00	96.91	3.00	93.91	40.70
408-1		68.99	96.88	3.00	93.88	40.68
500-1		0.00	129.56	5.00	124.56	53.97
502-1		0.00	136.87	5.00	131.87	57.14
504-1		0.00	158.42	5.00	153.42	66.48
505-1		0.00	162.24	5.00	157.24	68.14
506-1		0.00	169.15	5.00	164.15	71.13
508-1		0.00	120.35	5.00	115.35	49.98
510-1		0.00	121.42	6.00	115.42	50.01
511-1		0.00	122.89	5.00	117.89	51.09
512-1		0.00	127.36	9.00	118.36	51.29
514-1		0.00	135.03	7.00	128.03	55.48
516-1		0.00	130.40	5.00	125.40	54.34
518-1		0.00	124.90	5.00	119.90	51.96
520-1		0.00	103.56	3.00	100.56	43.58
528-1		0.00	140.47	5.00	135.47	58.70
531-1		0.00	136.39	4.00	132.39	57.37
535-1		0.00	126.97	5.00	121.97	52.85
600-1		0.00	144.21	5.00	139.21	60.32
601-1		0.00	146.16	5.00	141.16	61.17
602-1		0.00	17.32	5.00	12.32	5.34

S U M M A R Y   O F   I N F L O W S   A N D   O U T F L O W S

(+) INFLOWS INTO THE SYSTEM FROM BOUNDARY NODES
(-) OUTFLOWS FROM THE SYSTEM INTO BOUNDARY NODES

PIPE NUMBER	FLOWRATE (gpm)
100	167.15
200	0.00
300	318.97
400	312.25
606	1840.60

NET SYSTEM INFLOW = 2638.97
NET SYSTEM OUTFLOW = 0.00
NET SYSTEM DEMAND = 2638.97

**** CYBERNET SIMULATION COMPLETED ****

DATE: 3/18/1997
TIME: 17:30:33

3. FIRE FLOW

Cybernet Version: 2.16 SN: 1132160944 12-03-1997
Description: Fire Anal: tanks only, avg day 2020 (STD17)
Drawing: H:\DR9604\CHWA3

Fire Flow Summary.

JCT No.	User 1 Demand (gpm)	User 1 Pressure (psi)	Zone No.	Needed Fire Flow (gpm)	Available Fire Flow (gpm)	@Residual Pressure (psi)	Min. Zone Pressure (psi)	@JCT No.
2	21.3	51.5	1	521.3	639.4	20.0	21.4	4
4	0.0	51.5	1	500.0	656.9	20.0	20.0	2
6	9.3	51.5	1	509.3	676.4	20.0	20.0	2
8	0.0	51.5	1	500.0	703.1	20.0	20.0	2
14	0.0	51.5	1	500.0	731.5	20.0	20.0	2
16	9.3	51.5	1	509.3	746.6	20.0	20.0	2
18	0.0	51.5	1	500.0	754.4	20.0	20.0	2
20	0.0	51.6	1	500.0	781.2	20.0	20.7	2
22	15.9	51.6	1	515.9	828.3	20.0	20.9	18
24	0.0	51.6	1	500.0	909.4	20.0	20.4	20
26	0.0	51.7	1	500.0	1048.5	20.0	19.9	2
28	24.0	51.7	1	524.0	1161.9	20.1	20.0	2
30	0.0	51.7	1	500.0	1302.6	20.2	20.0	2
32	0.0	51.9	1	500.0	2000.0	20.2	20.0	2
34	0.0	51.9	1	500.0	2000.0	26.5	26.1	2
36	0.0	51.9	1	500.0	2000.0	33.5	33.1	2
38	0.0	51.9	1	500.0	2000.0	46.2	44.4	148
40	0.0	51.9	1	500.0	2000.0	32.7	32.8	40
42	10.3	51.8	1	510.3	2000.0	27.6	27.7	42
44	0.0	51.8	1	500.0	1879.4	21.7	21.8	44
46	6.7	51.8	1	506.7	1679.6	20.0	20.3	46
48	0.0	51.7	1	500.0	1555.1	20.0	20.3	48
50	0.0	51.7	1	500.0	1356.4	20.0	20.5	50
52	0.0	51.7	1	500.0	1312.6	20.0	21.7	52
54	0.0	51.7	1	500.0	1228.3	20.0	20.5	54
56	7.2	51.6	1	507.2	1186.9	20.0	21.3	56
58	0.0	51.6	1	500.0	1175.0	20.0	21.6	58
60	0.0	51.6	1	500.0	1095.0	20.0	21.1	60
62	15.6	51.6	1	515.6	1056.6	20.0	20.7	62
64	4.6	51.6	1	504.6	1010.5	20.0	21.2	64
66	5.1	51.6	1	505.1	994.5	20.0	20.6	66
68	10.2	51.6	1	510.2	976.6	20.0	20.8	68
70	5.1	51.1	1	505.1	404.4*	20.0	22.0	66
72	0.0	51.1	1	500.0	409.5*	20.0	20.7	72
74	0.0	51.1	1	500.0	466.0*	20.0	20.0	70
76	0.0	51.1	1	500.0	493.4*	20.0	20.0	70
78	0.0	51.1	1	500.0	2000.0	20.0	20.0	70
80	0.0	51.1	1	500.0	2000.0	36.8	36.8	70
82	11.1	51.0	1	511.1	1870.4	39.8	39.8	70
84	9.2	51.0	1	509.2	1897.0	20.0	27.7	84
86	16.6	51.1	1	516.6	2000.0	20.0	27.1	82
						44.2	42.7	148

* Needed Fire Flow not attained.

Fire Flow Summary.

JCT No.	User 1 Demand (gpm)	User 1 Pressure (psi)	Zone No.	Needed Fire Flow (gpm)	Available Fire Flow (gpm)	@Residual Pressure (psi)	Min. Zone Pressure (psi)	@JCT Number
88	7.2	50.7	1	507.2	2000.0	46.1	42.8	148
90	22.1	49.3	1	522.1	1079.0	20.0	23.4	92
92	6.4	48.8	1	506.4	951.2	20.0	27.8	94
94	2.1	48.8	1	502.1	899.3	20.0	28.9	96
96	4.7	48.8	1	504.7	945.9	20.0	26.3	94
98	10.4	49.3	1	510.4	2000.0	36.8	33.0	148
100	0.0	52.0	2	500.0	2000.0	50.2	47.5	312
101	0.0	52.0	2	500.0	120.6*	20.0	20.0	230
102	6.4	48.8	1	506.4	2000.0	20.7	22.0	104
103	0.0	52.0	2	500.0	2000.0	51.2	47.5	312
104	2.7	48.4	1	502.7	1455.1	20.0	29.9	106
106	7.4	50.1	1	507.4	1207.3	20.0	35.2	104
114	0.0	48.8	2	500.0	1935.3	20.0	20.1	120
116	1.4	48.8	1	501.4	1864.4	22.1	20.0	148
118	0.0	48.8	1	500.0	1863.0	22.2	20.0	148
120	0.0	48.8	2	500.0	1935.8	20.0	20.1	114
122	9.9	48.8	1	509.9	1454.6	20.0	28.5	124
124	6.3	48.8	1	506.3	1682.2	20.0	21.4	122
126	19.7	48.8	1	519.7	1672.3	20.0	22.9	128
128	9.8	50.9	1	509.8	1574.7	20.0	24.2	126
130	9.0	51.4	1	509.0	1665.2	24.7	20.0	148
132	10.9	51.4	1	510.9	1505.6	20.0	22.1	134
134	2.0	51.4	1	502.0	1219.6	20.0	23.5	136
136	4.5	51.4	1	504.5	1165.5	20.0	25.7	138
138	10.1	51.4	1	510.1	1181.4	20.0	24.1	140
140	10.7	50.9	1	510.7	1219.0	20.0	22.5	138
142	0.0	50.9	1	500.0	1424.2	25.3	20.0	148
144	0.0	50.9	1	500.0	1423.5	25.3	20.0	148
146	13.8	49.6	1	513.8	1277.8	24.7	20.0	148
148	2.0	44.4	1	502.0	1196.1	20.0	28.3	146
150	8.7	51.0	1	508.7	1186.7	20.0	20.6	154
152	0.0	51.4	1	500.0	1185.1	20.0	20.5	150
154	4.9	51.4	1	504.9	1114.6	20.0	23.3	150
156	8.7	51.4	1	508.7	1136.5	20.0	21.6	158
158	6.3	51.5	1	506.3	1108.4	20.0	21.3	160
160	0.0	51.5	1	500.0	1092.0	20.0	22.0	162
162	6.1	51.1	1	506.1	1064.5	20.0	23.8	160
163	0.0	51.3	1	500.0	1072.8	20.0	28.2	162
164	9.3	51.7	1	509.3	1574.7	20.0	25.8	166
166	16.1	51.8	1	516.1	1709.6	20.0	20.6	164

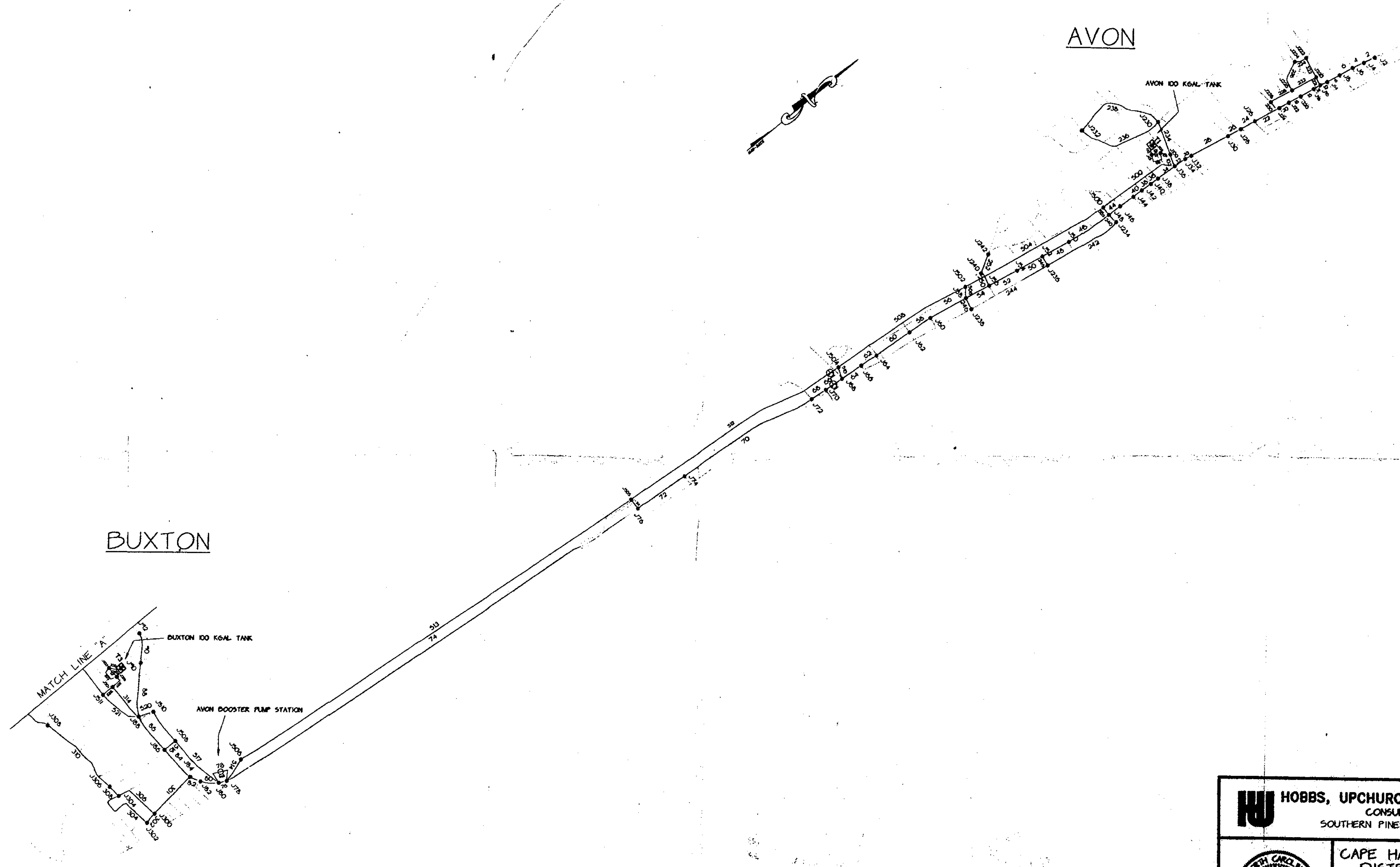
* Needed Fire Flow not attained.

Fire Flow Summary.

JCT No.	User 1 Demand (gpm)	User 1 Pressure (psi)	Zone No.	Needed Fire Flow (gpm)	Available Fire Flow (gpm)	@Residual Pressure (psi)	Min. Zone Pressure (psi)	@JCT Number
168	0.0	52.0	1	500.0	2000.0	50.4	44.0	148
170	28.1	51.4	1	528.1	1362.8	20.0	19.9	172
172	0.0	51.3	1	500.0	1222.5	20.0	20.4	192
174	8.6	51.9	1	508.6	999.1	20.3	20.0	192
176	8.6	51.9	1	508.6	916.1	20.0	20.1	178
178	25.5	51.8	1	525.5	851.4	20.0	20.6	180
180	20.3	51.7	1	520.3	768.4	20.0	21.5	182
182	12.2	51.7	1	512.2	736.0	20.0	20.1	192
184	3.2	51.6	1	503.2	702.9	20.0	20.0	192
186	6.0	51.6	1	506.0	691.4	20.0	20.0	192
188	3.2	51.6	1	503.2	676.8	20.0	20.0	192
190	18.2	51.6	1	518.2	699.4	20.0	20.0	192
192	3.2	51.6	1	503.2	648.1	20.0	22.1	188
220	0.0	52.0	2	500.0	752.0	20.0	20.7	222
222	3.7	52.0	2	503.7	702.1	20.0	21.3	224
224	3.7	52.0	2	503.7	697.3	20.0	21.7	222
226	3.7	52.0	2	503.7	760.0	20.0	20.6	224
228	3.7	52.0	2	503.7	826.0	20.0	21.1	226
230	20.0	52.0	2	520.0	1931.3	20.0	20.4	232
232	13.6	52.4	2	513.6	940.9	20.0	43.2	230
234	0.0	51.7	2	500.0	1259.2	20.0	29.1	236
236	11.9	51.7	2	511.9	1220.4	20.0	24.7	238
238	9.9	51.6	2	509.9	1049.6	20.0	28.4	240
240	0.0	51.6	2	500.0	1150.0	20.0	20.4	242
242	8.3	52.1	2	508.3	816.0	20.0	34.1	240
300	11.1	49.2	2	511.1	860.8	20.0	20.0	302
301	0.0	50.7	2	500.0	2000.0	49.1	45.9	312
302	5.2	49.2	2	505.2	763.1	20.0	25.8	300
303	0.0	50.7	2	500.0	2000.0	49.9	46.7	312
304	9.9	48.8	2	509.9	748.0	20.0	21.0	306
305	0.0	50.7	2	500.0	2000.0	49.9	46.7	312
306	12.5	48.8	2	512.5	720.1	20.0	23.3	304
308	2.0	48.8	2	502.0	649.6	20.0	25.5	310
310	0.8	48.8	2	500.8	656.5	20.0	24.8	308
312	10.0	47.5	2	510.0	1108.9	20.0	24.7	314
314	7.2	48.8	2	507.2	1125.5	20.0	23.0	312
316	3.0	48.8	2	503.0	1194.9	20.0	24.6	318
318	10.5	48.8	2	510.5	736.4	20.0	26.1	310
400	8.6	51.8	2	508.6	798.7	20.0	20.7	402
401	0.0	52.0	2	500.0	2000.0	51.1	47.5	312

* Needed Fire Flow not attained.

JCT No.	User 1 Demand (gpm)	User 1 Pressure (psi)	Zone No.	Needed Fire Flow (gpm)	Available Fire Flow (gpm)	@Residual Pressure (psi)	Min. Zone Pressure (psi)	@JCT Number
402	9.0	51.7	2	509.0	611.9	20.0	24.4	404
403	0.0	52.0	2	500.0	2000.0	51.1	47.5	312
404	7.8	51.6	2	507.8	590.0	20.0	21.0	406
406	0.0	51.6	2	500.0	592.6	20.0	20.6	408
408	19.7	51.6	2	519.7	594.5	20.0	20.4	406
500	0.0	51.7	3	500.0	1554.5	20.0	21.8	502
502	0.0	51.6	3	500.0	1174.7	20.0	24.2	504
504	0.0	51.6	3	500.0	976.5	20.0	31.5	505
505	0.0	51.1	3	500.0	493.4*	20.0	49.0	512
506	0.0	51.1	3	500.0	2000.0	34.4	36.8	505
508	0.0	51.1	3	500.0	2000.0	44.2	44.2	505
510	0.0	50.7	3	500.0	2000.0	46.1	46.5	505
511	0.0	51.1	3	500.0	2000.0	49.4	47.7	512
512	0.0	49.3	3	500.0	2000.0	36.8	37.7	514
514	0.0	50.1	3	500.0	2000.0	25.5	27.5	528
516	0.0	50.9	3	500.0	1588.0	20.0	28.9	531
518	0.0	52.0	3	500.0	2000.0	50.4	49.1	512
520	0.0	51.9	3	500.0	1004.3	20.0	49.2	512
528	0.0	50.9	3	500.0	2000.0	21.0	21.7	531
531	0.0	51.4	3	500.0	1845.9	20.0	20.3	516
535	0.0	51.3	3	500.0	1072.6	20.0	43.7	516
600	0.0	50.9	4	500.0	0.0*	0.0	0.0	0
601	0.0	50.9	4	500.0	0.0*	0.0	0.0	0



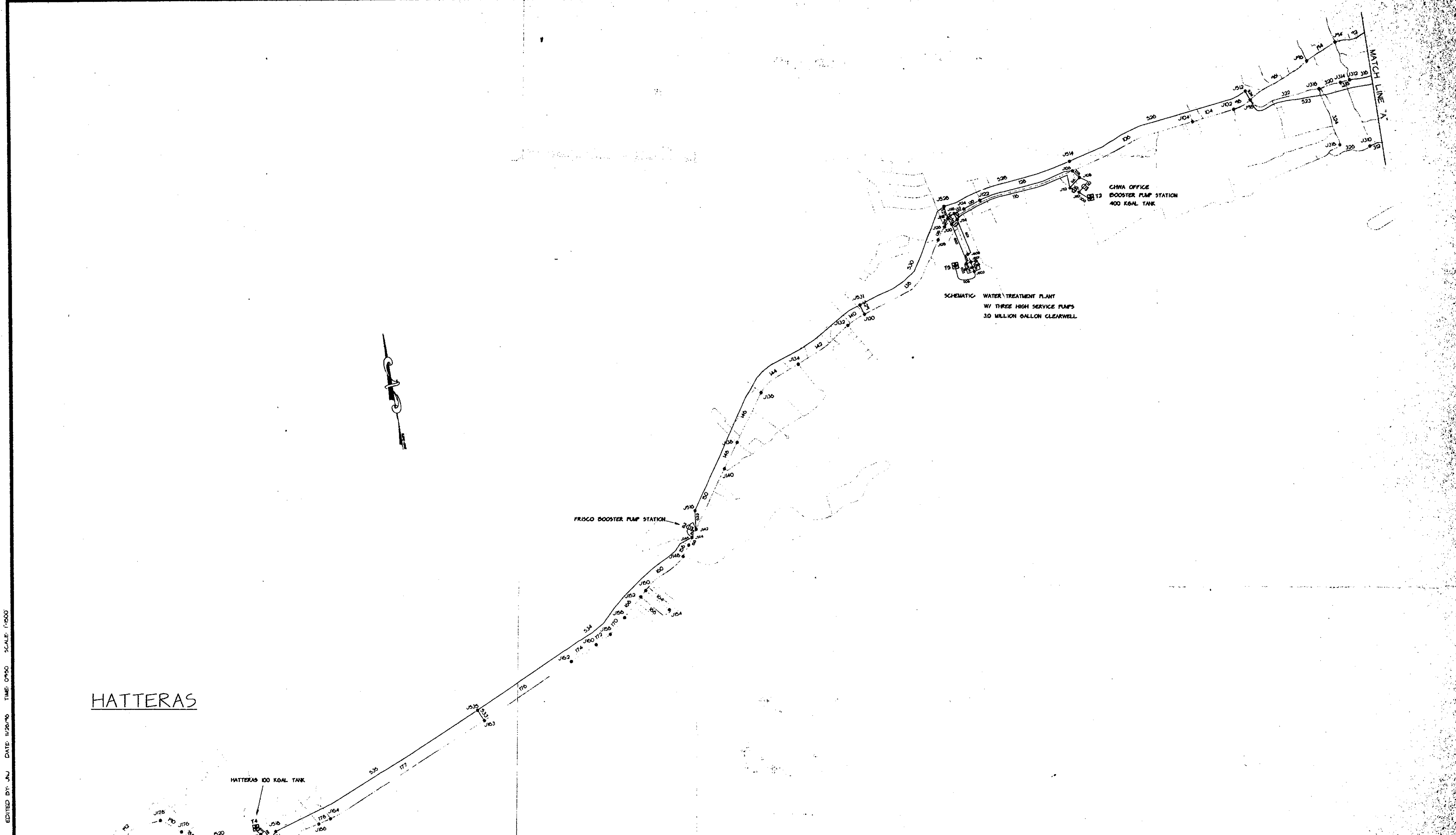
HOBBS, UPCHURCH & ASSOCIATES, P.A.
CONSULTING ENGINEERS
SOUTHERN PINES, NORTH CAROLINA 28387

CAPE HATTERAS WATER ASSO.
DISTR. SYSTEM ANALYSIS
DARE COUNTY, NORTH CAROLINA

HYDRAULIC NODE MAP

DATE: MARCH 1997
DESIGNED: JNJ
DRAWN: JNJ
CHECKED: ETW
SCALE: 1" = 500'
SHEET NO. 2 of 2

HOBBS UPCHURCH + ASSOC. HYDR4004SHEET.DWG EDITED BY: JNJ DATE: 11/26/96 TIME: 0950 SCALE: 1"=500'



HOBBS, UPCHURCH & ASSOCIATES, P.A.
CONSULTING ENGINEERS
SOUTHERN PINES, NORTH CAROLINA 28387

CAPE HATTERAS WATER ASSO.
DISTR. SYSTEM ANALYSIS
DARE COUNTY, NORTH CAROLINA

HYDRAULIC NODE MAP

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL — ERIC T. WEATHERLY

DATE	MARCH, 1997
DESIGNED	JNJ
DRAWN	JNJ
CHECKED	ETW
SCALE	1" = 1500'
SHEET NO.	1
OF	2

HOBBS UPCHURCH + ASSOC. HYDR9504\SHEET.DWG EDITED BY: JNJ DATE: 11/26/90 TIME: 0950 SCALE: 1:1500