NORTH HARRIS COUNTY WATER SUPPLY CORPORATION

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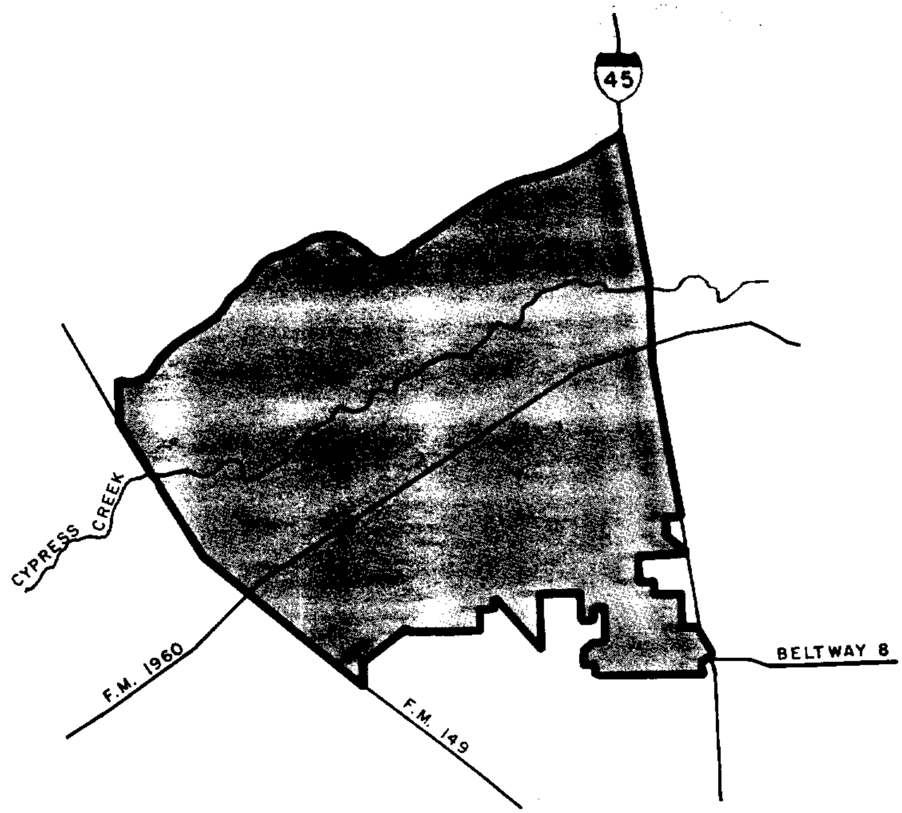

SURFACE WATER CONVERSION PLAN

PATE ENGINEERS/JONES & CARTER
A Joint Venture

JUNE 1987

PATE / JONES & CARTER
A JOINT VENTURE

OCT 23 1987

October 5, 1987

Board of Directors
North Harris County
Water Supply Corporation
c/o Vinson & Elkins
2801 First City Tower
1001 Fannin
Houston, Texas 77002-6760

Dear Directors:

We are pleased to submit the enclosed Surface Water Conversion Plan for the North Harris County Water Supply Corporation (NHCWSC).

This report includes an analysis of existing groundwater usage and outlines future surface water requirements for the NHCWSC service area. Potential surface water resources are listed and analyzed. The report includes recommendations on the source of surface water as well as proposed surface water facilities. These facilities include a surface water treatment plant, conveyance lines, and distribution system. The cost of these surface water facilities and an economic analysis of the project are also provided.

It is our opinion that the project is both economically feasible and extremely necessary in order to ensure the long-term water supply for the NHCWSC area.

Sincerely,

JONES & CARTER, INC.

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NORTH HARRIS COUNTY WATER SUPPLY CORPORATION

SURFACE WATER CONVERSION PLAN

Prepared for

The North Harris County Water Supply Corporation

JUNE 1987

ACKNOWLEDGEMENTS

We would like to express our thanks to the City of Houston, Harris County, Harris-Galveston Coastal Subsidence District, United States Geological Survey, Harris County Central Appraisal District, and the San Jacinto River Authority for providing helpful service and information. We especially appreciate the input from the Texas Water Development Board and its staff. We are also grateful for the cooperation from the consultants representing various utility districts within the study area and the time and efforts of the various utility district board members.

AUTHORIZATION

In February 1986, the North Harris County Water Supply Corporation (NHCWSC) was formed to address the problems of groundwater usage in the FM 1960/Cypress Creek area. The joint venture of Pate Engineers/Jones & Carter, Inc. were authorized to represent the NHCWSC in surface water discussions with the City of Houston and other public entities. In March 1986, the NHCWSC applied to the Texas Water Development Board for a grant to study possible surface water regionalization. The grant was approved by the Texas Water Development Board on September 15, 1986. Upon approval of this grant, Pate Engineers/Jones & Carter, Inc. were authorized to conduct a feasibility study and to develop an implementation plan for a regionalized surface water program to serve the NHCWSC service area.

NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION STUDY

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EXECUTIVE SUMMARY

North Harris County Water Supply Corporation

The North Harris County Water Supply Corporation (NHCWSC), a non-profit corporation, was formed in February 1986 to address groundwater problems in the FM 1960/Cypress Creek area. The NHCWSC service area covers approximately 38,000 acres of land and includes a current population of 116,000 people generating a water demand in excess of 19 million gallons per day (MGD). This study was authorized by the NHCWSC to address the water supply problems and to develop a facility and implementation plan to bring surface water into the area.

Background

Heavy demand on the groundwater supply throughout the NHCWSC service area is resulting in a rapidly declining water table. Groundwater sources currently supply all of the water utilized in the entire service area. The water table decline provides strong evidence that groundwater is being withdrawn from the Chicot and Evangeline aquifers much faster than the aquifers are being recharged.

Many local wells are starting to experience problems with rapidly declining production capacity. Chemical contaminants, such as irons, sulfates, and chlorides, are appearing with increasing frequency in many wells. As the water table has declined, numerous water suppliers are also encountering the problem of natural gas intrusion into their water wells. The gas problems range from occasional and spotty gas problems to conditions severe enough to require water/gas separators. Some wells have been rendered inoperable due to explosive danger or vapor lock.

All of these water quality problems are generally created by excessive pumping from the aquifers.

Population projections prepared by the Rice Center indicate that the population for the NHCWSC area will reach approximately 250,000 people by the year 2010. This population growth will increase the water demand in the area to approximately 30 MGD by the year 2010. The increased water demand must be met by groundwater unless a new water supply source is developed. The additional groundwater withdrawals will cause the existing problems to rapidly increase in severity.

In addition, the Harris-Galveston Coastal Subsidence District has mandated conversion to surface water in the two-county area according to a published timetable. According to this mandate, most of the service area must convert its water supplies to 80 percent surface water by the year 2005.

Surface Water Resources

Water for this project should be supplied from an existing nearby reservoir which will allow the NHCWSC to independently control the construction of its proposed surface water conversion project. The proposed Lake Creek, Lake Millican, and Lake Bedias Reservoirs, as well as the proposed diversions from east Texas river systems, are in the conceptual planning stages and will not be available to the NHCWSC in the required time. Additionally, a review of available cost information shows that the delivered water costs for all of these projects exceeds the costs of water from Lake Houston and Lake Conroe.

Lake Houston and Lake Conroe are the two most feasible sources of surface water to serve this area. Both are existing sources and are close enough to the service area that conveyance lines to the area could be constructed by the NHCWSC. Lake Houston was selected for use by the NHCWSC because the needs of the entire service area can be met and because the total capital and operating cost of conveyance from Lake Houston is substantially less than from Lake Conroe. Increasing the attractiveness of this source, the City of Houston has expressed an interest in sharing in the cost of a conveyance line from Lake Houston. If this occurs, the NHCWSC will benefit from the resulting economy of scale. Moreover, future water supply projects under consideration by others, including those listed before, will supplement the yield of Lake Houston.

Facility and Implementation Plan

The major facilities to be constructed are a water purification plant on the west shore of Lake Houston, conveyance lines to the service area, and a local distribution system. The initial project, which is scheduled for completion by late 1990 to mid-1991, will include all of the conveyance and distribution lines and 10 million gallons per day of plant capacity. This will serve about half of the current demand. Additional water plant capacity will be added in the future as the demand for water increases due to growth, as new groundwater problems occur, and as the Harris-Galveston Coastal Subsidence District mandate for surface water conversion approaches.

To finance and operate this project, the NHCWSC plans to dissolve in favor of a regional district which has the authority to implement a program of this nature, including the power to sell general obligation bonds and levy taxes for debt service. The NHCWSC's total capital cost for this program, assuming City of Houston participation in the conveyance lines, will be approximately $77 million. Including interest during the construction period, $84 million in bonds will be required.

The area has a current assessed value estimated at $5.2 billion. Based on the construction sequence and costs outlined above, and assuming assessed value growth due to population growth only--no inflation in values--taxpayers in the area will see a rate of $.05 per $100 assessed valuation for 1988 and 1989, with the tax rate increasing to $.089 per $100 assessed valuation in 1990, where it will stay until 1999. The rate will increase to $.095 for the period 1999 through 2003, and then will decrease through the remainder of the project life. An 8.9-cent tax rate equates to an annual tax of $89 on a $100,000 house.

Operating costs for this surface water supply will be significantly higher than the current costs experienced by most districts in the area for producing groundwater. The cost to purchase the raw water from the Lake Houston source, treat the water, and pump it through the NHCWSC's lines will be approximately $.75 per 1,000 gallons of water produced. This is approximately $.50 per thousand gallons more than the typical cost to produce groundwater in this area of $.25 per thousand gallons.

Conclusion

Increasing water table declines coupled with growing gas intrusion into the water supply provide evidence that the NHCWSC service area faces acute water shortages over the next few years. Additional water supplies must be developed to address these problems. The proposed program which utilizes Lake Houston water for the NHCWSC service area is consistent with the master plans to provide water to the eight-county area including Harris and adjoining counties. The proposed program is a feasible and economical solution to current water supply problems and meets the water needs of the area.

INTRODUCTION

The quality and quantity of the groundwater supply in the North Harris County Water Supply Corporation (NHCWSC) service area is being threatened by the heavy groundwater withdrawal rates experienced over the past few years. General water table decline caused by the heavy groundwater withdrawals has created water quality problems, such as gas intrusion and chemical contamination. The water supply problems experienced in the NHCWSC service area and surrounding areas can be solved only with the development of an additional source of water.

This report analyzes various surface water sources along with the necessary conveyance and distribution lines required to service the NHCWSC service area. Pursuant to the scope of work, the following items have been addressed in this report. Information has been provided on existing facilities and users. The northeast water purification plant service area has been defined with considerations from the City of Houston Water Master Plan. Major conveyance and distribution facilities have been examined based upon service area definition and growth projections. A financial plan for bringing surface water to the NHCWSC service area has been established. The financial and facility plans have been incorporated to create an implementation plan which details costs, benefits, and various funding sources.

I. NORTH HARRIS COUNTY WATER SUPPLY CORPORATION SERVICE AREA

Service Area Description

The North Harris County Water Supply Corporation (NHCWSC) consists of approximately 38,000 acres of land located in north Harris County. The service area is bounded by Interstate 45 (I-45) on the east, Spring-Cypress Road on the north, Farm-to-Market Road 149 (FM 149) on the west, and approximately by North Belt on the south. (See Figure 1, Vicinity Map.)

The NHCWSC service area is well developed with a current population in excess of 116,000 people. The vast majority of all the developed areas receive water service from a utility district. (See Figure 2, NHCWSC Boundary Map.)

There are currently 63 utility districts within the service area. These utility districts include Public Utility Districts (PUD), Municipal Utility Districts (MUD), Water Control and Improvement Districts (WCID), as well as a Fresh Water Supply District (FWSD) which converted to a MUD. Of the 63 districts in the service area, five (5) are new districts with little or no development, four (4) are inactive, and 54 are active districts. (See Table 1, Utility Districts within NHCWSC Service Area.)

Utility districts account for over 60 percent of the acreage within the service area. (See Table 2, NHCWSC Acreage.) The utility districts also account for approximately 93 percent of all water used and 95 percent of the assessed value for the NHCWSC service area. Consequently, the 63 utility districts give a good indication of the existing conditions in the service area. The water related data available from the many utility

TABLE NO. 1

DISTRICTS WITHIN
NHCWSC SERVICE AREA

ACTIVE UTILITY DISTRICTS

1. BAMMEL UD
2. BILMA PUD
3. CHARTERWOOD MUD
4. C N P
5. CY CHAMP
6. CYPRESS FOREST PUD
7. CYPRESS-KLEIN UD
8. CYPRESSWOOD UD
9. FOUNTAINHEAD MUD
10. HCFWSD No. 52
11. HCMUD No. 16
12. HCMUD No. 24
13. HCMUD No. 44
14. HCMUD No. 48
15. HCMUD No. 58
16. HCMUD No. 104
17. HCMUD No. 150
18. HCMUD No. 159
19. HCMUD No. 180
20. HCMUD No. 189
21. HCMUD No. 191
22. HCMUD No. 200
23. HCMUD No. 202
24. HCMUD No. 203
25. HCMUD No. 205
26. HCMUD No. 211
27. HCMUD No. 215
28. HCMUD No. 217
29. HCMUD No. 233
30. HCMUD No. 254
31. HEATHERLOCH MUD
32. KLEIN PUD
33. KLEINWOOD MUD
34. LOUETTA NORTH
35. LOUETTA ROAD MUD
36. NORTH FOREST MUD
37. NWHCMUD No. 6
38. NWHCMUD No. 20
39. NWHCMUD No. 21
40. NWHCMUD No. 22
41. NWHCMUD No. 23
42. PONDEROSA FOREST UD
43. PRESTONWOOD FOREST MUD
44. RANKIN ROAD WEST
45. SPRING CREEK FOREST
46. TERRANOVA WEST
47. WCID No. 91 PUD
48. WCID No. 109 PUD
49. WCID No. 110 PUD
50. WCID No. 114 PUD
51. WCID No. 116 PUD
52. WCID No. 119 PUD
53. WCID No. 132 PUD
54. WESTADOR PUD

INACTIVE DISTRICTS

55. FOREST EDGE MUD
56. HCMUD No. 14
57. HCMUD No. 97
58. HCMUD No. 164

NEW DISTRICTS

59. HCMUD No. 86
60. HCMUD No. 275
61. HCMUD No. 304
62. NWHCMUD No. 36
63. SPRING WEST MUD

TABLE NO. 2

NHCWSC ACREAGE

	UTILITY DISTRICTS	ACREAGE *
1.	BAMMEL	324.02
2.	BILMA	505.09
3.	CHARTERWOOD	311.35
4.	C N P	560.10
5.	CY CHAMP	465.39
6.	CYPRESS FOREST	841.22
7.	CYPRESS KLEIN	440.41
8.	CYPRESSWOOD	427.85
9.	Forest Edge (Inact.)	101.66
10.	FOUNTAINHEAD	430.79
11.	FWSD 52	866.20
12.	HCMUD 14 (Inact.)	287.92
13.	HCMUD 16	277.91
14.	HCMUD 24	659.88
15.	HCMUD 44	299.56
16.	HCMUD 48	293.55
17.	HCMUD 58	99.82
18.	HCMUD 86 (new)	366.00
19.	HCMUD 97 (Inact.)	179.49
20.	HCMUD 104	345.00
21.	HCMUD 150	661.42
22.	HCMUD 159	243.07
23.	HCMUD 164 (Inact.)	?
24.	HCMUD 180	488.20
25.	HCMUD 189	466.27
26.	HCMUD 191	230.12
27.	HCMUD 200	679.86
28.	HCMUD 202	312.23
29.	HCMUD 203	665.53
30.	HCMUD 205	147.96
31.	HCMUD 211	277.75
32.	HCMUD 215	89.40
33.	HCMUD 217	192.35
34.	HCMUD 233	148.19
35.	HCMUD 254	234.15
36.	HCMUD 275 (new)	76.45
37.	HCMUD 304 (new)	321.00
38.	HEATHERLOCH	288.52
39.	KLEIN	285.43
40.	KLEINWOOD	546.21
41.	LOUETTA NORTH	262.75
42.	LOUETTA ROAD	208.49
43.	NORTH FOREST	162.34
44.	NWHCMUD 6	327.82
45.	NWHCMUD 20	279.76
46.	NWHCMUD 21	180.47
47.	NWHCMUD 22	313.06
48.	NWHCMUD 23	259.96
49.	NWHCMUD 36 (new)	129.00
50.	PONDEROSA FOREST	727.40
51.	PRESTONWOOD FOREST	382.05
52.	RANKIN ROAD WEST	314.00
53.	SPRING CREEK FOREST	356.51
54.	SPRING WEST (new)	377.33
55.	TERRANOVA WEST	289.56
56.	WCID 91	320.00
57.	WCID 109	716.74
58.	WCID 110	585.12
59.	WCID 114	674.99
60.	WCID 116	338.92
61.	WCID 119	454.71
62.	WCID 132	322.45
63.	WESTADOR	600.00
	AVERAGE	384.92
	TOTAL	22,970
**	OTHERS	14,810
	TOTAL FOR NHCWSC	37,780

* Values are from boundary maps or District Engineers

** Includes all remaining areas

? HCMUD 164 has not been created and has no official boundary districts was used extensively to evaluate existing area conditions and to provide a reliable basis for projections on future growth and demand.

Groundwater Hydrology

The size, shape, and position of geologic formations dictate how groundwater is transmitted and stored. Geologic formations along the Texas Gulf Coast typically dip towards the gulf at an angle greater than the slope of the land surface, with the dip increasing as the formations approach the coastline. The formations also tend to thicken as their depth increases. (See Figure 3, Hydrogeologic Cross Section.)

The geologic formations along the Texas Gulf Coast consist of oceanic and alluvial deposits, which are several million years old. These sediments either contained salt water at the time of deposition or were deposited in fresh water and filled with salt water at a time of a higher sea level. When the sea receded, fresh water from rain began to seep into the formations displacing the salt water. This process continued until equilibrium between fresh water and salt water was reached. The fresh water within these formations is the source of the groundwater used along the Texas Gulf Coast.

Two types of hydrologic units considered in groundwater studies are aquifers and aquicludes. "An aquifer is a geologic formation, group of formations, or part of a formation that contains and transmits water. An aquiclude is a relatively impermeable formation, group of formations, or part of a formation that may contain water but is relatively impermeable or incapable of transmitting significant quantities in comparison to adjacent aquifers."[1]

There are three major hydrologic units contributing to groundwater availability within the NHCWSC service area. They are the Chicot aquifer, the Evangeline aquifer, and the Burkeville aquiclude. The Chicot aquifer is the shallower of the two aquifers. The base of the Chicot aquifer lies at a depth of approximately 200 feet along the northern limit of the service area, gently sloping to an approximate depth of 600 feet along the southern boundary. The Evangeline aquifer lies directly beneath the Chicot with its base starting at a depth of approximately 1000 feet along the northern limit sloping to an approximate depth of 1500 feet along the southern boundary. Within the NHCWSC service area, the Chicot has a thickness ranging from 200 to 600 feet, while the Evangeline ranges in thickness from 800 to 1200 feet. Both the Chicot and the Evangeline aquifers consist of intertwining layers of sand and clay.

The distinguishable characteristics between the aquifers include differences in stratigraphic position, lithology, and permeability. The permeability of the Chicot is approximately 500 gallons per day (GPD) per square foot (ft^2), while the permeability of the Evangeline is approximately 250 GPD/ft^2. Horizontal movement of water through the aquifers is estimated at anywhere between 20 ft/yr to 400 ft/yr. Vertical movement of water is limited to areas where the aquifers are interconnected.

The Burkeville aquiclude is the confining layer which underlies the Evangeline aquifer. The Burkeville aquiclude is a massive clay formation which prohibits water from moving between the Evangeline aquifer and the underlying Jasper aquifer. The Jasper aquifer contains a poor quality water (high mineral content) and is extremely deep within the NHCWSC service area. Neither the Jasper aquifer nor the Burkeville aquiclude are used as a source of groundwater for this area.

Groundwater is currently the only source of water for the NHCWSC service area. The United States Geological Survey (USGS) and the Harris-Galveston Coastal Subsidence District (HGCSD) were two of the major sources used in obtaining groundwater information. The USGS monitors and records water well information and has records on over 150 wells within the NHCWSC service area. The HGCSD regulates groundwater withdrawal and keeps records of well pumpage on both a monthly and yearly basis. Operators and engineers for all active utility districts within the service area were contacted to provide additional information on groundwater usage. From this large amount of information, various trends were observed including groundwater pumpage, water table decline, gas intrusion, and water quality.

Water withdrawal and rate of recharge are the two major parameters which limit the capacity of an aquifer as a long-term water source. Water withdrawal is easily measured by metering the water pumped by wells in a given aquifer. The measurement of groundwater recharge is much more complicated to measure partially because only a small percentage of rain may actually recharge an aquifer. Evaporation, transpiration, and surface runoff account for most of the rain which falls on the Chicot and Evangeline recharge zones. Another difficulty in determining groundwater recharge is the long time required for water to travel underground. Based on the Evangeline aquifer recharge rates estimated by the USGS, it would take anywhere between 100 to 5,000 years to completely recharge the aquifer within the NHCWSC service area.

The groundwater occurs under one of two conditions, either artesian or water-table. Artesian conditions exist where an aquifer is confined by an impermeable or nearly impermeable layer. This confining layer allows head pressure to build up within the aquifer. Water levels from wells drilled in artesian areas will rise above the level of the aquifer itself and with sufficient pressure, an artesian well will actually flow above the land surface. Water-table conditions exist when water is under atmospheric pressure only. Under water-table conditions, water levels are free to rise or fall in relation to the volume of water stored within the aquifer.

Whenever groundwater withdrawal becomes greater than natural recharge, there will be a loss of static water pressure and consequently a corresponding water table decline. This effect can be seen during seasonal changes in pumpage. Typically, more water is used during summer months than winter months. The same relationship holds true for the rate of recharge. Although the rate of recharge remains fairly constant over large areas, localized areas may experience seasonal variations. There is typically more recharge in winter months than summer months due to less evaporation and transpiration of rainwater. Figure 4 illustrates the monthly variations in pumpage (note the high water pumpage during summer months), while Figure 5 shows the water level variations over a given year (note the water level declines in summer months). Because the rate of recharge for an entire aquifer remains fairly constant, water level variation must be directly related to groundwater withdrawal.

The historical decline in the Evangeline aquifer in the NHCWSC service area indicates that the aquifer is effectively being mined. Groundwater withdrawal is greatly exceeding the safe yield or normal recharge rate for the aquifer.

II. EXISTING CONDITIONS

Groundwater Withdrawal

Groundwater pumpage within the NHCWSC service area has drastically increased over the past several years. According to HGCSD records in 1980, wells within the NHCWSC service area pumped approximately 11 million gallons per day (MGD); in 1985 the pumpage had increased to nearly 19 MGD.

The USGS information shows that since 1960, 121 wells have been drilled within the area; prior to 1960, only 22 wells had been drilled in the same area. (See Figure 6, Well Completions.) Table 3, Well History, lists the drilling activity within the NHCWSC area as well as the activity within the USGS four-quadrant area. The four-quadrant area is simply the area of four USGS quadrangle maps and is used to show general trends around the NHCWSC area. Figure 7 shows the relationship of the NHCWSC area to the four-quadrant area.

Data obtained from the USGS and HGCSD was combined to locate and categorize over 150 wells within the NHCWSC service area. (See Figure 8, Well Location Map.) Tables 4 and 5 give some of the corresponding information known about each well. Appendix E lists more detailed information known about the wells within the NHCWSC service area.

Water Table Decline

Historical data from the USGS indicates an average water level decline of 7.3 feet/year within the Evangeline aquifer over the life of all wells within the NHCWSC service area. The Chicot aquifer has shown an average decline of 1.5 feet/year. The Evangeline aquifer was actually an artesian system at the turn of the century. Most of the early decline in the local water table is attributable to pumpage outside the NHCWSC service area.

TABLE NO. 3

WELL HISTORY

TYPICAL WELL (Since 1975)	Chicot	Evangeline
Average Depth (ft)	394 (90-740)	1084 (538-1514)
Average Flow (gpm)	273 (13-1212)	1186 (219-2260)
Average Drawdown (ft)	38 (2-125)	82 (35-263)
Average Screen Setting (ft)	260 - 290	716 - 975

TOTAL NUMBER OF WELLS DRILLED (Before 1960)	NHCWSC Service Area	4-Quadrant Area
	22	105
	-8 Destroyed	-54 Destroyed
	14	51

TOTAL NUMBER OF WELLS DRILLED (1960-1974)	NHCWSC Service Area	4-Quadrant Area
Chicot	51	177
Evangeline	21	66
Both	7	28
Total	79	271

TOTAL NUMBER OF WELLS DRILLED (Since 1975)	NHCWSC Service Area	4-Quadrant Area
Chicot	4	35
Evangeline	29	75
Both	9	24
Total	42	134

TABLE NO. 4

PUBLICLY OWNED WELLS

PUBLIC WELLS WITHIN NHCWSC SERVICE AREA

NO.	OWNER'S NAME	ITEM*	HGCSD WELL	USGS WELL	PURPOSE OF WELL	WELL DEPTH	YEAR DRILLED
1	BAMMEL U.D.	98	3862	LJ-60-60-9__	PUBLIC WATER SUPPLY	994	1971
2	BAMMEL U.D.	122	4099	LJ-60-60-9__	PUBLIC WATER SUPPLY	1070	1986
3	CHARTERWOOD M.U.D.	92	2424	LJ-60-60-806	PUBLIC WATER SUPPLY	580	1974
4	CHARTERWOOD M.U.D.	87	3529	LJ-60-60-809	PUBLIC WATER SUPPLY	680	1980
5	CNP U.D.	135	1658	LJ-60-61-825	PUBLIC WATER SUPPLY	1148	1972
6	CNP U.D.	137	2634	LJ-60-61-827	PUBLIC WATER SUPPLY	1143	1976
7	CNP U.D.	117	3564	LJ-60-61-836	PUBLIC WATER SUPPLY	1136	1981
8	CY-CHAMP P.U.D.	61	1630	LJ-65-04-313	PUBLIC WATER SUPPLY	890	1972
9	CYPRESS FOREST P.U.D.	91	3161	LJ-60-60-9__	PUBLIC WATER SUPPLY	?	1978
10	CYPRESS FOREST P.U.D.	79	4086	LJ-65-04-3__	PUBLIC WATER SUPPLY	1300	?
11	CYPRESS-KLEIN U.D.	129	1620	LJ-60-60-913	PUBLIC WATER SUPPLY	1100	1973
12	FOUNTAINHEAD M.U.D.	55	1854	LJ-65-05-1__	PUBLIC WATER SUPPLY	1041	1974
13	FOUNTAINHEAD M.U.D.	56	2938	LJ-65-05-114	PUBLIC WATER SUPPLY	296	1977
14	FOUNTAINHEAD M.U.D.	31	2939	LJ-65-05-1__	PUBLIC WATER SUPPLY	1200	1977
15	HARRIS CO. F.W.S.D. 52	62	1529	LJ-65-04-309	PUBLIC WATER SUPPLY	788	1969
16	HARRIS CO. F.W.S.D. 52	66	1528	LJ-65-04-312	PUBLIC WATER SUPPLY	785	1972
17	HARRIS CO. M.U.D. 16	65	3478	LJ-65-05-119	PUBLIC WATER SUPPLY	1274	1982
18	HARRIS CO. M.U.D. 24	140	1779	LJ-60-60-912	PUBLIC WATER SUPPLY	1103	1975
19	HARRIS CO. M.U.D. 44	114	2546	LJ-60-61-7__	PUBLIC WATER SUPPLY	1300	?
20	HARRIS CO. M.U.D. 44	113	2438	LJ-60-61-7__	PUBLIC WATER SUPPLY	?	?
21	HARRIS CO. M.U.D. 58	90	3110	LJ-60-61-7__	PUBLIC WATER SUPPLY	1200	1978
22	HARRIS CO. M.U.D. 86	105	3537	LJ-60-61-8__	PUBLIC WATER SUPPLY	?	?
23	HARRIS CO. M.U.D. 150	23	2729	LJ-65-05-113	PUBLIC WATER SUPPLY	1050	1977
24	HARRIS CO. M.U.D. 150	22	3256	LJ-65-05-1__	PUBLIC WATER SUPPLY	?	1979
25	HARRIS CO. M.U.D. 159	19	3330	LJ-65-04-614	PUBLIC WATER SUPPLY	795	1980
26	HARRIS CO. M.U.D. 159	20	3331	LJ-65-04-615	PUBLIC WATER SUPPLY	784	1980
27	HARRIS CO. M.U.D NO. 180	17	3349	LJ-65-05-406	PUBLIC WATER SUPPLY	950	1979
28	HARRIS CO. M.U.D. 180	27	3803	LJ-65-05-1__	PUBLIC WATER SUPPLY	1200	1982
29	HARRIS CO. M.U.D. 189	78	3482	LJ-65-05-217	PUBLIC WATER SUPPLY	1160	1980
30	HARRIS CO. M.U.D. 189	64	3695	LJ-65-05-2__	PUBLIC WATER SUPPLY	1300	1981
31	HARRIS CO. M.U.D. 189	84	3990	LJ-65-05-2__	PUBLIC WATER SUPPLY	300	?
32	HARRIS CO. M.U.D. 191	42	3751	LJ-65-04-317	PUBLIC WATER SUPPLY	815	1983
33	HARRIS CO. M.U.D. 200	54	3863	LJ-65-05-2__	PUBLIC WATER SUPPLY	1300	?
34	HARRIS CO. M.U.D. 200	38	3567	LJ-65-05-2__	PUBLIC WATER SUPPLY	1300	1981
35	HARRIS CO. M.U.D. 202	18	3867	LJ-65-04-618	PUBLIC WATER SUPPLY	940	1983
36	HARRIS CO. M.U.D. NO. 203	11	3660	LJ-65-05-517	PUBLIC WATER SUPPLY	1050	1981
37	HARRIS CO. M.U.D. NO. 203	2	3780	LJ-65-05-516	PUBLIC WATER SUPPLY	1424	1982
38	HARRIS CO. M.U.D. 205	71	3550	LJ-65-05-2__	PUBLIC WATER SUPPLY	1500	?
39	HARRIS CO. M.U.D. 215	47	3868	LJ-65-05-2__	PUBLIC WATER SUPPLY	1200	?
40	HARRIS CO. M.U.D. 217	28	3781	LJ-65-05-120	PUBLIC WATER SUPPLY	950	1982
41	HARRIS CO. M.U.D. 254	43	3889	LJ-65-04-2__	PUBLIC WATER SUPPLY	1300	?
42	HARRIS CO. M.U.D.304	45	4037	LJ-65-05-1__	PUBLIC WATER SUPPLY	1400	?
43	HARRIS CO. W.C.& I.D. 91	118	1538	LJ-60-61-817	PUBLIC WATER SUPPLY	752	1967
44	HARRIS CO. W.C.& I.D. 91	119	1537	LJ-60-61-824	PUBLIC WATER SUPPLY	1236	1971
45	HARRIS CO. W.C.& I.D. 109	48	1378	LJ-65-04-310	PUBLIC WATER SUPPLY	802	1970
46	HARRIS CO. W.C.& I.D. 109	39	1379	LJ-65-04-3__	PUBLIC WATER SUPPLY	1058	1970
47	HARRIS CO. W.C.& I.D. 109	40	3333	LJ-65-04-316	PUBLIC WATER SUPPLY	680	1979
48	HARRIS CO. W.C.& I.D. 110	144	2903	LJ-60-61-526	PUBLIC WATER SUPPLY	700	1978
49	HARRIS CO. W.C.& I.D. 114	136	1534	LJ-60-60-803	PUBLIC WATER SUPPLY	615	1970
50	HARRIS CO. W.C.& I.D. 114	121	3409	LJ-60-60-9__	PUBLIC WATER SUPPLY	1200	1980
51	HARRIS CO. W.C.& I.D. 116	75	2093	LJ-65-04-314	PUBLIC WATER SUPPLY	520	1974
52	HARRIS CO. W.C.& I.D. 116	76	2094	LJ-65-04-3__	PUBLIC WATER SUPPLY	1210	?
53	HARRIS CO. W.C.& I.D. 116	70	3316	LJ-65-04-3__	PUBLIC WATER SUPPLY	1200	1979
54	HARRIS CO. W.C.& I.D. 119	120	2183	LJ-60-60-804	PUBLIC WATER SUPPLY	962	1970
55	HARRIS CO. W.C.& I.D. 119	131	4091	LJ-60-60-8__	PUBLIC WATER SUPPLY	1000	?
56	HARRIS CO. W.C.& I.D. 132	139	3648	LJ-60-61-720	PUBLIC WATER SUPPLY	1165	1982
57	HEATHERLOCH M.U.D.	77	1867	LJ-65-04-315	PUBLIC WATER SUPPLY	775	1975
58	KLIEN P.U.D.		2943	LJ-60-61-717	PUBLIC WATER SUPPLY	1185	1977
59	KLEINWOOD U.D.	106	1727	LJ-60-60-911	PUBLIC WATER SUPPLY	1005	1973
60	LOUETTA NORTH P.U.D.	111	3956	LJ-60-60-810	PUBLIC WATER SUPPLY	1210	1984
61	LOUETTA RD. U.D.		1860	LJ-60-61-715	PUBLIC WATER SUPPLY	1063	1974
62	NORTH FOREST M.U.D.	94	2186	LJ-60-61-814	PUBLIC WATER SUPPLY	1170	1968
63	NORTHGATE FOREST DEV/HCMUD 233	101	3726	LJ-60-61-7__	PUBLIC WATER SUPPLY	1300	1982
64	NW HARRIS CO. M.U.D. NO. 6	16	2731	LJ-65-04-613	PUBLIC WATER SUPPLY	8768	1977
65	NW HARRIS CO. M.U.D. NO. 6	14	3605	LJ-65-04-617	PUBLIC WATER SUPPLY	950	1981
66	NW HARRIS CO. M.U.D. 20	86	3635	LJ-60-61-7__	PUBLIC WATER SUPPLY	1300	?
67	NW HARRIS CO. M.U.D. 21	60	3448	LJ-65-05-116	PUBLIC WATER SUPPLY	1020	1979
68	NW HARRIS CO. M.U.D. 23	41	3447	LJ-65-05-118	PUBLIC WATER SUPPLY	1290	1982
69	PONDEROSA FOREST U.D.	115	1663	LJ-60-61-713	PUBLIC WATER SUPPLY	1165	1971
70	PONDEROSA FOREST U.D.	123	2947	LJ-60-61-718	PUBLIC WATER SUPPLY	1211	1978
71	PONDEROSA FOREST U.D.	93	3631	LJ-60-61-835	PUBLIC WATER SUPPLY	680	1981
72	PRESTONWOOD FOREST U.D.	34	1544	LJ-65-04-210	PUBLIC WATER SUPPLY	1120	1970
73	PRESTONWOOD FOREST U.D.	51	3293	LJ-65-04-214	PUBLIC WATER SUPPLY	1164	1979
74	RANKIN ROAD WEST M.U.D.	44	3992	LJ-65-05-2__	PUBLIC WATER SUPPLY	1400	?
75	SPRING CREEK FOREST P.U.D.	138	1664	LJ-60-60-908	PUBLIC WATER SUPPLY	672	1972
76	TERRANOVA WEST M.U.D.	134	4058	LJ-60-60-9__	PUBLIC WATER SUPPLY	1100	?
77	WESTADOR M.U.D.	133	1904	LJ-60-61-819	PUBLIC WATER SUPPLY	1020	1969
78	WESTADOR M.U.D.	132	1905	LJ-60-61-826	PUBLIC WATER SUPPLY	1030	1972

AVERAGE: 1083

*Item No. corresponds to Figure No. 7

TABLE NO. 5

PRIVATELY OWNED WELLS

PRIVATE WELLS WITHIN NHCWSC SERVICE AREA

NO	OWNER'S NAME	ITEM *	HGCSD WELL	USGS WELL	PURPOSE OF WELL	WELL DEPTH	YEAR DRILLED
1	BAMMEL FOREST UTILITY COMPANY	109	3120	LJ-60-61-701			
2	BAMMEL FOREST UTILITY COMPANY	108	1916	LJ-60-61-710	PUBLIC WATER SUPPLY	428	1957
3	BAMMEL FOREST UTILITY COMPANY	110	4098	LJ-60-61-7__	PUBLIC WATER SUPPLY	660	1969
4	BROWN CONSTRUCTION, INC.	58	3835	LJ-65-04-2__	PUBLIC WATER SUPPLY	950	?
5	CHAMPIONS GOLF CLUB, INC.	50	1593	LJ-65-04-301	INDUSTRIAL	400	1983
6	CHAMPIONS GOLF CLUB, INC.	59	1594	LJ-65-04-303	IRRIGATION	653	1957
7	CHEVRON U.S.A., INC.	146	3289	LJ-60-61-4__	IRRIGATION	263	1963
8	CIRCLE K CORPORATION	33	2058	LJ-65-04-2__	PRIVATE USE	250	1978
9	COE UTILITIES, INC.	149	3504	LJ-60-61-4__	PRIVATE USE	270	1972
10	COE UTILITIES, INC.	150	3666	LJ-60-61-4__	PRIVATE USE	303	1978
11	COE UTILITIES, INC.	151	4002	LJ-60-61-4__	PRIVATE USE	300	1978
12	CORNELIUS, INC.	112	2988	LJ-60-61-8__	PRIVATE USE	300	1981
13	CSA LIMITED	15	4004	LJ-65-04-6__	PRIVATE USE	?	1973
14	CY-FOREST SERVICE ASSOCIATION	53	2907	LJ-65-04-2__	PRIVATE USE	600	?
15	EXXON COMPANY, U.S.A.	25	2828	LJ-65-04-202	PUBLIC WATER SUPPLY	?	?
16	EXXON COMPANY, U.S.A.	97	3007	LJ-60-61-7__	PRIVATE USE	270	1964
17	FMC CORPORATION	5	1884	LJ-65-05-512	PRIVATE USE	?	?
18	FMC CORPORATION	6	1885	LJ-65-05-511	INDUSTRIAL	282	1970
19	FRIENDSWOOD DEVELOPMENT CO.	1	4118	LJ-65-05-5__	INDUSTRIAL	366	1968
20	GARY CUTSINGER COMPANY	88	4039	LJ-60-60-9__	PUBLIC WATER SUPPLY	300	1980
21	GOODYEAR TIRE & RUBBER CO.	154	1422	LJ-60-61-515	PRIVATE USE	515	?
22	GULF OIL COMPANY - U.S.	37	3420	LJ-65-04-2__	PRIVATE USE	542	1969
23	H & J WATER COMPANY, INC.	13	3334	LJ-65-04-6__	PRIVATE USE	300	1979
24	H & J WATER COMPANY, INC.	12	3335	LJ-65-05-4__	PUBLIC WATER SUPPLY	300	1979
25	H & J WATER COMPANY, INC.	9	3336	LJ-65-05-4__	PUBLIC WATER SUPPLY	300	1977
26	HARRIS COUNTY C/O COUNTY JUDGE	152	3018	LJ-60-61-4__	PUBLIC WATER SUPPLY	300	1977
27	HARRIS COUNTY C/O COUNTY JUDGE	148	3147	LJ-60-61-4__	PUBLIC WATER SUPPLY	?	?
28	HARRIS COUNTY C/O COUNTY JUDGE	130	3326	LJ-60-61-7__	PUBLIC WATER SUPPLY	347	?
29	HARRIS COUNTY C/O COUNTY JUDGE	107	3947	LJ-60-60-9__	PUBLIC WATER SUPPLY	175	1979
30	HARRIS COUNTY C/O COUNTY JUDGE	153	4120	LJ-60-61-5__	PUBLIC WATER SUPPLY	400	?
31	HEIGHTS SAVINGS ASSOCIATION	57	2215	LJ-65-04-3__	PUBLIC WATER SUPPLY	400	1986
32	H.L. & P. COMPANY	4	1169	LJ-65-04-601	PRIVATE USE	256	1967
33	H.L. & P. COMPANY	10	1170	LJ-65-04-602	INDUSTRIAL	734	1956
34	H.L. & P. COMPANY	3	1171	LJ-65-04-608	INDUSTRIAL	725	1957
35	H.L. & P. COMPANY	52	1200	LJ-65-04-3__	INDUSTRIAL	951	1959
36	H.L. & P. COMPANY	29	3828	LJ-65-05-2__	INDUSTRIAL	368	1972
37	HNG PETROCHEMICALS, INC.	82	1915	LJ-65-05-109	INDUSTRIAL	297	1982
38	HOUSTON HOME CRAFT, INC.	95	3092	LJ-60-61-8__	INDUSTRIAL	614	1966
39	HOUSTON HOME CRAFT, INC.	96	3093	LJ-60-61-8__	PUBLIC WATER SUPPLY	?	1969
40	HOUSTON SHELL & CONCRETE	8	2856	LJ-65-04-6__	PUBLIC WATER SUPPLY	?	1969
41	HOUSTON SHELL & CONCRETE	9	2857	LJ-65-04-6__	INDUSTRIAL	469	1969
42	KLEIN I.S.D.	147	2698	LJ-60-61-4__	INDUSTRIAL	469	1969
43	KLEIN I.S.D.	125	2699	LJ-60-60-902	PUBLIC WATER SUPPLY	?	1978
44	KLEIN I.S.D.	124	2700	LJ-60-60-910	PUBLIC WATER SUPPLY	455	1962
45	KLEIN I.S.D.	145	3517	LJ-60-60-603	PUBLIC WATER SUPPLY	476	1976
46	MARSHALL, DOUGLAS B., JR.	83	2358	LJ-65-04-2__	PUBLIC WATER SUPPLY	502	1980
47	MARSHALL, DOUGLAS B., JR.	67	2617	LJ-65-04-2__	PRIVATE USE	400	1954
48	MARSHALL, HUGH ROY TRUST	142	2333	LJ-60-60-8__	PRIVATE USE	594	1977
49	MARSHALL, HUGH ROY	143	2418	LJ-60-60-8__	PRIVATE USE	550	1975
50	MCDERMOTT, JOE A., INC.	126	1922	LJ-60-61-8__	PRIVATE USE	120	1969
51	MOBIL OIL CORPORATION	26	3049	LJ-65-04-2__	PRIVATE USE	220	1963
52	NORTHGATE FOREST DEVELOPMENT	127	3910	LJ-60-61-721	PRIVATE USE	?	?
53	NORTHWEST PINES ASSOCIATES, LT	72	3620	LJ-65-05-1__	IRRIGATION	530	1983
54	NORTHWEST PINES ASSOCIATES, LT	68	3621	LJ-65-05-1__	PUBLIC WATER SUPPLY	500	1981
55	NORTHWEST PINES ASSOCIATES, LT	73	3622	LJ-65-05-1__	PUBLIC WATER SUPPLY	294	1978
56	NORTHWEST PINES ASSOCIATES, LT	69	3931	LJ-65-05-122	PUBLIC WATER SUPPLY	600	1964
57	NORTHWOOD FARMS JOINT VENTURE	141	2636	LJ-60-61-7__	PUBLIC WATER SUPPLY	1240	1983
58	PAUL'S GREEN THUMB NURSERY	63	3036	LJ-65-04-3__	PRIVATE USE	400	1977
59	RAIF, F.A.	74	3385	LJ-65-04-2__	PRIVATE/IRRIGATION	278	?
60	RAVENEAUX COUNTRY CLUB	80	3380	LJ-65-04-3__	PRIVATE USE	?	?
61	RAVENEAUX COUNTRY CLUB	81	3861	LJ-65-04-3__	IRRIGATION	450	?
62	RUSCHE, A.N. DIST. CO.	35	2914	LJ-65-04-3__	IRRIGATION	700	?
63	SAFEWAY STORES, INC.	99	2791	LJ-60-61-711	PRIVATE USE	250	1976
64	SAFEWAY STORES, INC.	100	2792	LJ-60-61-712	PRIVATE USE	430	1971
65	SHELL OIL COMPANY	116	3151	LJ-60-61-820	PRIVATE USE	430	1971
66	SHELL OIL COMPANY	32	3842	LJ-65-04-2__	PRIVATE USE	347	1970
67	SIGMOR CORPORATION	36	3059	LJ-65-04-3__	PRIVATE USE	360	?
68	SIGMOR CORPORATION	89	3241	LJ-65-05-6__	PRIVATE USE	265	1970
69	SILVER DOLLAR CITY, INC.	155	3773	LJ-60-61-5__	PRIVATE USE	272	1977
70	SOUTHWESTERN BELL TELEPHONE CO	46	2881	LJ-65-05-108	PRIVATE USE	500	?
71	SOUTHWESTERN BELL TELEPHONE CO	156	2888	LJ-60-61-519	PRIVATE USE	310	1964
72	SPRING I.S.D.	128	2663	LJ-60-61-8__	INDUSTRIAL	333	1969
73	SPRING I.S.D.	102	2664	LJ-60-61-8__	PUBLIC WATER SUPPLY	312	1965
74	SPRING I.S.D.	103	2665	LJ-60-61-8__	PUBLIC WATER SUPPLY	344	1969
75	SPRING I.S.D.	104	3262	LJ-60-61-8__	PUBLIC WATER SUPPLY	344	1974
76	TEXACO, INC.	24	2806	LJ-65-04-206	PUBLIC WATER SUPPLY	344	?
77	TEXACO, INC.	49	3558	LJ-65-05-2__	PRIVATE USE	374	1966
78	TRANSCONT. GAS PIPELINE CORP.	30	2216	LJ-65-05-105	INDUSTRIAL	400	1980
					INDUSTRIAL	320	1965
AVERAGE:						376	

*Item No. corresponds to Figure No. 7

Rapid growth in this area over the last 30 years has accelerated the rate of decline. Figure 9 shows water table decline during the last 10 years.

It should be noted that only 10 percent of all wells within the NHCWSC service area rely on water strictly from the Chicot aquifer; conversely, 74 percent of the wells rely on water strictly from the Evangeline aquifer. Table 6, Well Summary, lists the breakdown of well sizes for the NHCWSC area as well as the four-quadrant area. Considering the smaller yield of wells in the Chicot aquifer, approximately 95 percent of all water used in the NHCWSC service area comes from the Evangeline aquifer. Historically, the Chicot aquifer has not been able to supply the increasing amounts of water required by the NHCWSC. Because of this limitation, it is likely that future large capacity wells will continue to be completed within the Evageline aquifer. Since most of the water in the NHCWSC area comes from the Evangeline aquifer, the rapid water level decline within the Evangeline will continue until groundwater withdrawal is reduced.

Groundwater Problems

Figure 10 illustrates water table decline within the NHCWSC service area. The water decline is representative of wells drilled in the Evangeline aquifer only. One phenomenon to notice in Figure 10 is the pump drawdown. If the pump drawdown should go below the level of the pump, the pump will essentially begin sucking air. In order to solve this problem, the pump must be lowered. Water wells in this area are typically constructed with a blank liner extending 50 to 100 feet above the first screen. This blank liner is the same diameter as the screen and serves as a reserve supply for the gravel pack. In most wells the original pump will not fit below the blank liner. In some cases, it is

TABLE NO. 6

SUMMARY OF WELLS

	NHCWSC Service Area	4-Quadrant Area
PERCENTAGE OF WELLS IN EACH AQUIFER (Since 1975)		
Chicot	10%	26%
Evangeline	69%	56%
Both	21%	18%
PERCENTAGE OF WELLS SERVING UTILITY DISTRICTS (All Years)		
Chicot	10%	14%
Evangeline	74%	75%
Both	16%	11%
WATER LEVEL DECLINE (Historical)		
Evangeline	-7.3 (ft/yr)	-6.7 (ft/yr)
Chicot	-1.5 (ft/yr)	-2.7 (ft/yr)
All Wells	-6.2 (ft/yr)	-5.9 (ft/yr)

possible to find a smaller diameter pump which will fit inside the blank liner; however, a smaller diameter pump would generally reduce the well capacity. Even if a smaller diameter pump can be used, the pump should never be placed below the first screen.

Solutions to the water table decline can be costly to the well owner, and there is no guarantee on how long the well will continue to operate and to provide water effectively. Water table declines will create additional maintenance costs as well as reduced well capacities. Other problems related to water table decline include gas intrusion, poor water quality, and subsidence.

Gas intrusion, the occurence of natural gas within the aquifer, is another problem facing the NHCWSC service area. This problem is compounded by the water table declines experienced within the NHCWSC service area. As the water table declines, natural gas within the aquifer will expand and migrate throughout the aquifer. Natural gas has been encountered in wells from at least 14 of the existing utility districts. Figure 11 highlights the location of districts which have experienced or are currently experiencing problems with gas intrusion.

Bammel Utility District and Northwest Harris County Municipal Utility District No. 20 are just two of the districts to experience major problems caused by natural gas intrusion. Bammel abandoned one of its water wells in 1984 when an explosive concentration of natural gas made plant operations unsafe. Northwest No. 20 has installed a water/gas separator in order to remove gas from the water. These two districts illustrate that gas intrusion can be a dangerous as well as an expensive problem within water plant operations. As the water table continues to decline, undoubtedly more and more utility districts will be subjected to natural gas problems.

Water quality is another factor to be considered within the NHCWSC service area. With declining water tables, there is an increased probability of chemical contamination. Iron, chloride, sodium, manganese, sulfate, fluoride, and arsenic are some of the contaminants which may be found in groundwater. As the water table declines, direction of the water movement will change. Water will migrate towards the cone of depression. (See Figure 9.) This change in water movement may bring contaminants from geologic formations which previously provided no water to the area.

Groundwater withdrawal is also the primary cause of land subsidence. Large withdrawals of water from aquifers result in a reduction of water pressure within the aquifer. As pressures are reduced within the aquifer, water will slowly migrate from clay formations to sand formations, allowing the clay layers to become compacted. As clay layers compact, overlaying formations will subside. Records of land subsidence in the NHCWSC service area indicate an increase in subsidence in recent years. Subsidence within the NHCWSC area is as follows:

Range in Years	Range of Subsidence (in feet)
1906 to 1943	0-0.5
1943 to 1973	0.75-1.5
1973 to 1978	0.25-0.5
1978 to 1987	0.5-1.5

Figure 12 illustrates the total land subsidence within the NHCWSC service area since 1906.

Problems associated with subsidence, such as area flooding and fault activation which cause structural settlement of houses and buildings, are not considered a major problem within the NHCWSC area at the present time. However, with continued subsidence, these problems will likely increase in the future.

The Harris-Galveston Coastal Subsidence District, in an effort to reduce area subsidence, has issued a mandate requiring surface water conversion for Harris and Galveston counties. Figure 13, HGCSD Regulatory Areas, shows the mandate areas and corresponding surface water requirements. The NHCWSC is located almost entirely in Areas 6 and 7.

Area	Surface Water Required
1	90% by 1990
2	80% by 1990
3	80% by 1995
4	80% by 2000
5	80% by 2000
6	80% by 2005
7	80% by 2010
8	Goundwater may not be supplied to other areas.

III. STUDY CONSIDERATIONS

Projections

Future water usage for the NHCWSC service area will be directly related to population. Population estimates and projections were obtained from the Houston-Galveston Area Council, Metropolitan Transit Authority, Rice Center, Houston Water Master Plan, and individual utility district consultants. Census tract data was used extensively to determine population projections. (Figure 14 shows census tracts relative to the NHCWSC area.) Population projections range from the limits of 1990 to the ultimate build out projections in the distant future. Despite the variance in future number of years projected, most of the population studies show similar growth rates.

For purposes of this study, the planning horizon was established as the year 2010. The population projections were used to evaluate present and future water requirements, but it was necessary to establish a target date to develop a reasonable program. The HGCSD mandate calls for substantial conversion of most of the NHCWSC service area to surface water by 2005, with the balance to be converted by 2010. This mandate, coupled with the near-term needs of the area, set the planning horizon for the year 2010. The Rice Center data and the Houston Water Master Plan were used in this study because they correlated best with the planning horizon set for the study as well as the HGCSD mandate for surface water conversion. The Houston Water Master Plan projected population and the corresponding water usage for the Houston metropolitan area. Figure 15 shows the projected population and water demand for the NHCWSC service area as found in the Houston Water Master Plan. Tables 7 and 8 show existing population and water demands.

Water demands estimated by the Houston Water Master Plan are as follows:

Year	Water Demand (MGD)
2000	22.4
2010	29.7
2020	34.2

These demands indicate a lower per capita water consumption than the current per capita water consumption experienced in the NHCWSC service area. This lower consumption rate is based on the assumption that water conservation brought on by water conservation programs and more expensive water in the future will force better use of water.

Remaining consistent with the Houston Water Master Plan projections and planning horizon discussed earlier, water demands were determined. Houston Water Master Plan projections indicate an average daily demand of 22.9 MGD in the year 2005 for the portion of the NHCWSC planning area which lies in HGCSD Area 6. An average daily demand of 3.8 MGD is projected in the year 2010 for the portion lying in Area 7. The total surface water required and the conveyance capacity needed to meet the HGCSD mandate and NHCWSC planning horizon targets is 26.7 MGD. The 26.7-MGD demand should be used to design the treatment facilities and conveyance system.

Assessed values for the NHCWSC were also projected. Information obtained from the Harris County Central Appraisal District on assessed values and tax rates for the various utility districts within the NHCWSC service area was used to make the projection. Tax rates and assessed values from 1977 through 1986 were obtained and compiled in Tables 9 and 10. Assessed values from 1977 through 1986 give a good indication of the rapid

TABLE NO. 7

CENSUS TRACT POPULATION

Census Tracts Within NHCWSC	1985 Population
555.02	16,531
556.02	11,703
558.02	14,307
538.01	13,294
538.02	18,118
537.01	6,542
537.02	16,920
536.01	13,514
536.02	4,697
	115,626

TABLE NO. 8

NHCWSC WATER USAGE

UTILITY DISTRICTS	AVERAGE DAILY USAGE (MGD)		
	1984 *	1985 *	1986 *
1. BAMMEL	0.3332	0.4101	0.3400
2. BILMA	0.1890	0.2411	0.2712
3. CHARTERWOOD	0.2603	0.2512	0.2096
4. C N P	0.8082	0.7693	0.7937
5. CY CHAMP	0.2411	0.2633	0.2679
6. CYPRESS FOREST	0.7490	0.7049	0.6373
7. CYPRESS-KLEIN	0.4003	0.4373	0.4753
8. CYPRESSWOOD/WCID 132	0.8685	0.9499	1.0115
9. FOREST EDGE (Inact.)			
10. FOUNTAINHEAD	0.4186	0.4408	0.4759
11. FWSD 52	0.7074	0.7852	0.7518
12. HCMUD 14 (Inact.)			
13. HCMUD 16	0.2153	0.2726	0.3685
14. HCMUD 24	0.5096	0.5408	0.6014
15. HCMUD 44	0.3921	0.4416	0.4085
16. HCMUD 48	N/A	0.0192	N/A
17. HCMUD 58	0.1216	0.1266	0.1318
18. HCMUD 86 (new)	0.0000	0.0000	0.0000
19. HCMUD 97 (Inact.)			
20. HCMUD 104	0.0679	0.0729	0.0819
21. HCMUD 150	0.6586	0.6551	0.6129
22. HCMUD 159	0.2523	0.2732	0.3151
23. HCMUD 164 (Inact.)			
24. HCMUD 180	0.1833	0.1789	0.2225
25. HCMUD 189	0.2381	0.2775	0.3016
26. HCMUD 191	0.0000	0.0619	0.0899
27. HCMUD 200	0.2658	0.4482	0.5323
28. HCMUD 202	0.0000	0.0767	0.0721
29. HCMUD 203	0.3737	0.5112	0.4189
30. HCMUD 205	0.0000	0.0121	0.0099
31. HCMUD 211/233	0.0918	0.0964	0.0756
32. HCMUD 215	0.0000	0.0008	0.0000
33. HCMUD 217	0.0605	0.0649	0.0556
34. HCMUD 254	0.0164	0.0211	0.0666
35. HCMUD 275 (Inact.)			
36. HCMUD 304 (new)	0.0000	0.0000	0.0022
37. HEATHERLOCH	0.4145	0.4674	0.5408
38. KLEIN	0.2030	0.2441	0.2288
39. KLEINWOOD	0.3271	0.3682	0.3690
40. LOUETTA NORTH	0.0055	0.1501	0.1460
41. LOUETTA ROAD	0.4164	0.2244	0.2167
42. NORTH FOREST	0.2668	0.3060	0.2710
43. NWHCMUD 6	0.2427	0.2142	0.2205
44. NWHCMUD 20	0.2189	0.2014	0.1159
45. NWHCMUD 21/22	0.2463	0.2414	0.1663
46. NWHCMUD 23	0.1951	0.1942	0.1800
47. NWHCMUD 36 (new)	0.0000	0.0000	0.0000
48. PONDEROSA FOREST	0.8460	0.9581	0.9290
49. PRESTONWOOD FOREST	0.4359	0.4663	0.4356
50. RANKIN ROAD WEST	0.0000	0.0074	0.0375
51. SPRING CREEK FOREST	0.3249	0.3414	0.2847
52. SPRING WEST (new)	0.0000	0.0022	0.0014
53. TERRANOVA WEST	N/A	0.2323	0.2597
54. WCID 91	0.4981	0.5556	0.5389
55. WCID 109	1.3151	1.4052	1.3860
56. WCID 110	0.5077	0.5912	0.5397
57. WCID 114	0.7471	0.7485	0.7679
58. WCID 116	0.6633	0.6386	0.6145
59. WCID 119	0.4553	0.5038	0.4359
60. WESTADOR	0.6792	0.7586	0.7551
TOTAL	17.43	19.23	19.04
AVERAGE	0.33	0.35	0.35

* Information was obtained from Harris - Galveston Coastal Subsidence District pumpage reports

TABLE NO. 9

UTILITY DISTRICT TAX RATES

UTILITY DISTRICTS	TAX RATES* $/$100					
	1977	1980	1983	1984	1985	1986
1. BAMMEL	0.90	0.55	0.65	0.40	0.40	0.40
2. BILMA			1.00	1.00	1.00	1.00
3. CHARTERWOOD	1.15	1.00	1.15	1.15	1.12	1.44
4. C N P	1.00	1.05	0.60	0.60	0.60	0.75
5. CY CHAMP				0.53	0.56	0.70
6. CYPRESS FOREST	0.95	0.65	0.55	0.50	0.48	0.58
7. CYPRESS KLEIN			0.35	0.35	0.35	0.35
8. CYPRESSWOOD				0.32	0.32	0.32
9. FOREST EDGE (inactive)						N/L
10. FOUNTAINHEAD	0.80	0.72	0.50	0.40	0.40	0.40
11. FWSD 52	0.50	0.15	0.23	0.20	0.17	0.19
12. HCMUD 14 (inactive)						N/L
13. HCMUD 16			1.25	0.99	0.99	0.99
14. HCMUD 24				0.90	0.85	0.82
15. HCMUD 44				0.25	0.25	0.30
16. HCMUD 48				0.65	0.68	0.77
17. HCMUD 58				1.25	1.25	1.35
18. HCMUD 86 (new)			0.10	0.25	0.25	0.50
19. HCMUD 97 (inactive)						N/L
20. HCMUD 104				1.18	1.18	1.25
21. HCMUD 150			1.15	1.00	1.00	0.97
22. HCMUD 159			0.70	0.58	0.51	0.51
23. HCMUD 164 (inactive)						N/L
24. HCMUD 180		1.25	1.35	1.25	1.25	1.40
25. HCMUD 189			1.30	1.30	1.30	1.40
26. HCMUD 191			1.25	1.30	1.30	1.99
27. HCMUD 200			1.05	1.05	1.05	1.07
28. HCMUD 202				1.45	1.45	1.50
29. HCMUD 203			0.60	0.60	0.80	0.95
30. HCMUD 205					1.43	N/L
31. HCMUD 211				0.90	1.05	1.05
32. HCMUD 215			0.00	0.00	0.00	1.15
33. HCMUD 217			1.40	1.35	1.35	1.50
34. HCMUD 233				0.00	1.50	1.75
35. HCMUD 254				1.07	1.07	1.07
36. HCMUD 275 (new)						N/L
37. HCMUD 304 (new)						N/L
38. HEATHERLOCH	1.00	0.77	0.45	0.35	0.35	0.50
39. KLEIN				0.69	0.58	0.56
40. KLEINWOOD			0.55	0.40	0.40	0.50
41. LOUETTA NORTH				1.25	1.25	1.40
42. LOUETTA ROAD				0.48	0.52	0.53
43. NORTH FOREST				0.46	0.43	0.43
44. NWHCMUD 6		0.85	0.85	0.67	0.67	0.78
45. NWHCMUD 20			1.30	1.35	1.35	1.39
46. NWHCMUD 21		0.55	0.75	0.95	0.78	0.86
47. NWHCMUD 22		0.90	1.20	1.20	1.30	1.40
48. NWHCMUD 23		0.95	1.18	1.25	1.40	1.50
49. NWHCMUD 36 (new)						N/L
50. PONDEROSA FOREST		0.50	0.49	0.48	0.48	0.55
51. PRESTONWOOD FOREST				0.70	0.65	0.65
52. RANKIN ROAD WEST					1.45	1.45
53. SPRING CREEK FOREST				0.55	0.55	0.62
54. SPRING WEST (new)						0.00
55. TERRANOVA WEST				0.95	0.95	0.95
56. WCID 91				0.20	0.20	0.21
57. WCID 109		0.40	0.35	0.25	0.25	0.25
58. WCID 110				0.40	0.50	0.50
59. WCID 114				0.70	0.47	0.42
60. WCID 116				0.44	0.46	0.43
61. WCID 119		0.77	0.77	0.70	0.65	0.75
62. WCID 132				0.45	0.38	0.42
63. WESTADOR	0.40	0.28	0.33	0.18	0.21	0.21
AVERAGE	0.84	0.67	0.78	0.71	0.77	0.79

*INFORMATION WAS OBTAINED FROM HARRIS COUNTY CENTRAL APPRAISAL DISTRICT AND TAX ASSESSOR - COLLECTORS

N/L - TAXES NOT YET LEVIED

TABLE NO. 10

ASSESSED VALUES

	UTILITY DISTRICTS	ASSESSED VALUES* ($)					
		1977	1980	1983	1984	1985	1986 **
1	BAMMEL	34,949,238	58,169,933	74,941,736	114,512,060	113,776,330	101,529,820
2	BILMA			32,658,900	50,845,420	60,589,250	68,263,490
3	CHARTERWOOD	7,338,986	25,010,410	38,692,470	45,402,090	48,674,450	48,043,630
4	C N P	30,076,000	77,647,500	149,300,800	199,530,782	197,792,870	188,321,370
5	CY CHAMP				90,769,240	97,981,210	90,403,220
6	CYPRESS FOREST	5,511,260	75,513,150	162,270,460	205,199,180	212,493,480	199,817,950
7	CYPRESS KLEIN			86,187,100	116,599,360	117,590,490	106,402,390
8	CYPRESSWOOD				99,919,400	104,645,710	96,354,410
9	FOREST EDGE (Inact.)						
10	FOUNTAINHEAD	27,323,000	78,333,700	103,010,740	156,716,100	159,713,510	143,507,510
11	FWSD 52		79,000,000	159,000,000	184,000,000	182,000,000	167,263,380
12	HCMUD 14 (Inact.)						
13	HCMUD 16			48,488,900	91,577,430	105,923,110	106,460,240
14	HCMUD 24				122,411,940	128,255,690	123,718,520
15	HCMUD 44				119,169,820	121,443,060	108,222,320
16	HCMUD 48				16,897,400	17,960,460	19,280,540
17	HCMUD 58				39,899,330	37,264,860	36,645,160
18	HCMUD 86 (new)			35,703,920	32,715,313	30,408,350	35,658,400
19	HCMUD 97 (Inact.)						
20	HCMUD 104				29,209,100	29,181,290	28,316,440
21	HCMUD 150			76,102,414	124,229,370	142,056,170	133,142,950
22	HCMUD 159			133,421,360	161,614,430	194,478,300	208,441,720
23	HCMUD 164 (Inact.)						
24	HCMUD 180		8,047,640	28,553,450	52,196,250	63,576,990	64,838,960
25	HCMUD 189			61,131,200	92,189,300	98,304,450	94,598,020
26	HCMUD 191			29,474,810	28,991,360	29,338,200	27,182,030
27	HCMUD 200			67,132,100	109,323,200	108,090,310	119,944,660
28	HCMUD 202				17,374,400	18,740,730	21,554,950
29	HCMUD 203			151,105,720	161,435,400	189,220,550	183,341,030
30	HCMUD 205				10,862,520	10,011,330	8,834,100
31	HCMUD 211				9,505,520	12,945,440	17,183,840
32	HCMUD 215				7,151,950	9,712,700	9,870,550
33	HCMUD 217			6,812,300	16,923,740	19,287,850	17,660,200
34	HCMUD 233				5,609,700	8,432,590	7,162,240
35	HCMUD 254				23,037,540	33,933,240	20,617,070
36	HCMUD 275 (new)						
37	HCMUD 304 (new)					7,039,880	8,751,570
38	HEATHERLOCH	9,592,370	43,986,995	87,144,262	96,158,560	115,008,680	107,251,540
39	KLEIN				62,416,580	67,316,520	62,328,270
40	KLEINWOOD			39,293,080	63,358,060	66,246,680	62,948,850
41	LOUETTA NORTH				31,010,050	36,075,030	39,993,250
42	LOUETTA ROAD				47,457,650	47,693,370	42,226,250
43	NORTH FOREST				41,897,440	35,542,940	39,953,100
44	NWHCMUD 6		19,426,970	47,298,894	63,177,310	64,264,320	56,727,650
45	NWHCMUD 20			52,204,825	67,103,550	73,270,220	73,826,650
46	NWHCMUD 21		11,497,485	38,832,785	79,448,360	89,277,480	91,783,090
47	NWHCMUD 22		5,688,120	21,922,310	38,624,830	44,488,710	48,687,340
48	NWHCMUD 23		4,784,184	26,813,640	43,922,820	48,721,770	51,089,080
49	NWHCMUD 36 (new)						
50	PONDEROSA FOREST		113,186,274	159,188,183	209,654,300	229,147,130	238,413,770
51	PRESTONWOOD FOREST				91,016,620	93,042,360	95,013,180
52	RANKIN ROAD WEST				6,626,160	6,631,460	9,561,510
53	SPRING CREEK FOREST				79,273,060	78,339,090	72,109,580
54	SPRING WEST (new)						11,989,320
55	TERRANOVA WEST				54,831,310	59,308,160	57,018,420
56	WCID 91				105,764,810	104,374,360	97,694,330
57	WCID 109		157,241,600	171,525,700	298,371,050	294,323,160	267,587,900
58	WCID 110				95,803,370	121,206,890	112,223,020
59	WCID 114				162,965,930	182,719,830	176,560,400
60	WCID 116				174,977,490	170,723,360	165,441,350
61	WCID 119		44,389,800	63,158,640	83,983,140	82,843,430	74,553,720
62	WCID 132				63,764,640	67,507,800	78,391,140
63	WESTADOR	71,453,152	103,747,576	134,420,259	185,874,920	176,500,720	189,673,390
	Total Assessed Value	186,244,006	905,671,337	2,285,790,958	4,783,331,145	5,065,941,320	4,943,382,780
	Average Assessed Value	26,606,287	56,604,459	78,320,378	86,969,657	90,463,238	86,726,014

* Assessed values were obtained from Harris County Central Appraisal District
** 1986 values may not include values under protest.

growth within the NHCWSC area. A graphic illustration of utility district assessed values for 1985 is shown on Figure 16. The total 1985 value for utility districts within the NHCWSC area was over $5 billion.

Assessed values from 1986 were used to project future values and to establish a tax base. Random samples of 1986 land values outside utility districts indicated an average value of approximately $15,000 per acre. Since only the largest tracts of land were evaluated in the random sampling, $15,000 per acre is a conservative estimate for any single tract of land. However, this value is acceptable for use in assessed value projections. Projections of assessed values were based on 1986 utility district values and estimated values for remaining acreage.

Assessed Values for NHCWSC Service Area	1986
Utility Districts	$4,943,382,780
Remaining Acreage - 15,540 Acres @ $15,000/Acre	233,100,000
Total Assessed Value	$5,176,482,780

The total assessed value for 1986 was projected on a per-capita basis to project future values. Using these values, a valuation of $42,000 per person was obtained for projection purposes. Applying this per-capita value to the Rice Center population projections, the following values were obtained:

Year	Population	Projected Value
1985	116,000	$ 4,870,000,000
1990	150,000	6,300,000,000
2000	183,000	7,686,000,000
2010	250,000	10,500,000,000
2015	270,000	11,340,000,000

These projections are illustrated graphically on Figure 17.

Conveyance Capacity

To define the required capacity of treatment plant and conveyance facilities, an analysis of seasonal pumping patterns was performed for districts in the NHCWSC service area. A review of this data, displayed on Figure 4 in terms of millions of gallons per day (MGD) demand by month for 1984, 1985, and 1986, shows substantial variations in monthly water demand.

Analysis of this data shows that for the three-year period within the NHCWSC planning area, monthly average daily demands have historically been as low as 74 percent of total average annual demand expressed on an average daily basis. Similarly, peak monthly demands have been as high as 167 percent of total average annual demand expressed on an average daily basis. These variations imply that the capacity of the desired surface water facilities is between these extremes.

A theoretical analysis of water usage within Harris County was also used in determining the daily amount of water that would be required to supply an 80 percent volume of surface water each year as mandated by the HGCSD. This analysis indicates that a conveyance line sized to supply 100 percent of the average daily flow will meet the 80 percent surface water requirement.

Average daily flow within the NHCWSC service area for the past three years was 18.56 MGD as indicated by the dashed line on Figure 4. Conveyance capacity sized using average daily flow could have provided 89 percent of the total water used over the three-year period. This is indicated by all water usage below the dashed line on Figure 4. The three years of pumping data correlates very well with the generally accepted standard that assumes 10 to 20 percent of annual water usage is needed to meet peak demands. Peaks for the three years of data account for 11 percent of the total water used.

The surface water facility is therefore recommended to have a capacity equal to the annual demand on an average daily basis. This capacity allows for daily demand variations and possible changes in water consumption patterns in the future. A surface water facility with this capacity will meet the HGCSD mandate and will also ensure that the NHCWSC surface water can adequately be supplied on a daily basis. Supplying average daily flow, as stated earlier, indicates that in low demand periods the surface water facility will not utilize its full capacity. Conversely, in high demand periods, this capacity will not only be fully utilized, but also supplemental groundwater will be required to meet demand.

Design Considerations and Assumptions

The design of a surface water supply system to serve the NHCWSC area must provide for minimal disruption in current systems operations, minimize the capital cost of surface water delivery system required, and maximize the use of the available groundwater while at the same time meeting the surface water planning goals and the HGCSD mandates. This can be accomplished through a system which delivers treated surface water to the existing ground storage facilities of each water supplier at some fixed rate. Peak water demands would always be supplemented with groundwater sources. This approach allows the daily operation of the various water distribution systems to remain essentially unchanged.

Supplying surface water at average daily flows, as stated earlier, will allow the NHCWSC to meet the 80 percent surface water requirement.

However, the specific rate required to accomplish the split between 80 percent surface water and 20 percent groundwater will vary from year to year. Total demand will grow in the future and the amplitude of seasonal fluctuations may change. Also, since there is an economic incentive to use the maximum amount of groundwater allowable under the plan, the delivery system should allow flexibility to adjust surface water consumption as actual demand changes. From the earlier analysis of area wide water use as well as the analysis of other similar systems in the Houston metropolitan area, the average daily demand was selected as the basis for design of the conveyance system. This design recommendation is consistent with similar projects in the Houston area where conjunctive use of groundwater and surface water is anticipated and has been reviewed with and approved by City of Houston Public Works Department personnel.

The North Harris County Water Supply Corporation is located entirely within the extraterritorial jurisdiction of the City of Houston and is, therefore, subject to the authority of the City in planning and constructing water supply facilities. The City of Houston requires that design of project components conform to all applicable standards and design criteria. In addition, satisfying the surface water considerations cited in the preceding paragraphs implies that design assumptions regarding pressures and pipe flow characteristics must be made. The following is a summary of the major design parameters and criteria which apply for both conveyance and distribution:

Initial Pressures - Water plants typically develop initial pressure of approximately 90 pounds per square inch (psi) for conveyance. Attainment of these pressures is reasonable and assumed for all alternatives examined.

Velocities - A maximum design velocity of six (6) feet per second (fps) and minimum design velocity of two (2) fps is permitted.

Right-of-Way - All waterlines should be adjacent or within public or semipublic rights-of-way. In those cases where rights-of-way cannot be obtained, an exclusive waterline easement 15 feet wide is required. In undeveloped areas, a 30-foot-wide easement is required to assure access.

Delivery Pressure - A minimum delivery pressure of 20 psi is permitted. This pressure will permit filling a typical ground storage tank.

C-Values - The following "C" values were assumed in preliminary design calculations:

Diameter (Inches)	Value
54	135
48	135
42	120
36	120
24	120

High pressures are required to deliver water directly to existing systems which maintain pressures of 55 to 70 psi. Therefore, a delivery plan which supplies surface water directly to existing water storage tanks was conceived. This allows surface water to be delivered at a minimum pressure of 20 psi. Using this delivery plan, surface water and groundwater will be supplied in sufficient quantities such that average and peak day demands can be satisfied. Peak hour demands will continue to be met with stored water.

Existing storage facilities within the NHCWSC service area account for nearly 38 million gallons, 32.6 million gallons of ground storage capacity and 5.2 million gallons of elevated storage capacity. (See Appendix H.)

From a utility district or other consumer perspective, implementing this delivery plan has little or no impact on operation of the water distribution system relative to current practice. Surface water simply replaces a substantial amount of groundwater in the storage facilities, resulting in reduced groundwater production. Mixing of groundwater and surface water will occur at each district's water plant. Other surface water users routinely mix groundwater and surface water in their systems with minimum adverse effects.

This supply plan will provide surface water at a base level demand up to approximately average daily flow and will meet peak demands with groundwater. The conveyance system will be designed with the capacity to carry average daily flow with the distribution system sized to meet localized peak demands. The HGCSD mandate requires reduction in annual groundwater consumption to 20 percent of the total annual requirements for the area. This proposed plan to deliver water up to average daily flow rates will meet this mandate.

IV. SURFACE WATER RESOURCES

Surface Water Sources

The study included a review and evaluation of existing surface water sources. Existing sources reviewed included Lake Houston, Lake Conroe, the Lake Livingston/Trinity River System and the Lake Toledo Bend/Sabine River System. Proposed projects reviewed include the Lake Creek, Lake Bedias, and Lake Millican projects. (See Figure 18, Surface Water Resources.)

Lake Millican and Lake Bedias are projects under preliminary feasibility study by the U.S. Army Corps of Engineers and the U.S. Department of Interior, Bureau of Reclamation, respectively. Due to the preliminary status of these projects, and the absence of a party to implement them, definitive information about these proposed projects is limited. However, some data was developed for the Houston Water Master Plan, referenced elsewhere.

The proposed Lake Millican lies about 50 miles north and west of the NHCWSC on the Navasota River. Projected raw water cost is $1.00 per thousand gallons for the 275 MGD projected yield. The proposed Lake Bedias lies about 60 miles north of the NHCWSC on a tributary of the Trinity River. Projected raw water costs are $.70 per thousand for the 97 MGD projected yield.

These raw water costs are based on the assumption that the project cost is amortized against the entire yield. If the NHCWSC were to construct these reservoirs and attempt to pay for them by amortizing the cost against the 26.7 MGD required, raw water costs would go up proportionately. Thus, another participant in these projects is essential. At the present time, no party capable and willing to participate in either project's cost has been identified. Additionally, no conveyance system, along with increased cost to deliver water, has been identified for either project.

Due to the preliminary nature of these projects, the high cost of water and their overall uncertainty, these two reservoirs were not considered further.

Lake Creek is a proposed project on the San Jacinto River, about ten miles north of the NHCWSC service area. Due to this project's proximity, it was considered for further evaluation.

The Lake Livingston/Trinity River System and the Toledo Bend/Sabine River System would have an ample supply of water for this area. However, there is not an existing inter-basin transfer system in place to deliver water to the NHCWSC. A review of prior studies performed for the Houston Metropolitan Area showed that transporting water from either system to the NHCWSC was not economical for the quantity of water needed to meet NHCWSC needs. Projects to convey substantially greater quantites to Lake Houston have been proposed to meet the long-term needs of the Houston area, but are not scheduled in the near term. Such projects will substantially increase the yield of Lake Houston.

Due to the absence of existing transfer capacity and the relatively high cost of water from these two systems, they were not considered for further evaluation.

Lake Houston lies about 16 miles to the east of the NHCWSC, while Lake Conroe lies about 30 miles north. Due to their proximity to the area, these sources were considered, along with Lake Creek, for further evaluation. The location of these lakes are shown on Figure 19.

The advantages and disadvantages of each project are discussed below.

Lake Creek

Lake Creek is a proposed reservoir project on a tributary of the San Jacinto River about 10 miles north of the planning area. The United States Department of Interior, Bureau of Reclamation, has conducted extensive feasibility studies of this project.

As currently proposed, this reservoir would yield about 55 MGD, well in excess of the service area requirements. However, the project is not expected to commence construction prior to the late 1990s, if it proceeds at all. Completion of the project, and thus surface water availability, would be well past the NHCWSC time frame for conversion. Bureau of Reclamation studies project that the cost to amortize construction of the project against the impounded water--excluding delivery cost--will be $1.13 per thousand gallons.

This is an extremely high cost for raw water by today's measures. Additionally, this cost assumes amortization of the project cost against the full 55 MGD. If the excess yield over the NHCWSC is not sold or if another party does not participate in the project, this cost will increase proportionally.

Based on the timing of the project and the high cost of the raw water, Lake Creek was not considered further.

Lake Conroe

Lake Conroe lies about 30 miles north of the NHCWSC planning area, impounding water on the main channel of the San Jacinto River. The entire yield of this reservoir, 89.3 MGD, is jointly owned by the City of Houston and the San Jacinto River Authority (SJRA). Raw water costs for SJRA and City of Houston's San Jacinto River system water are about equal in the $.22 to $.23 per-thousand-gallon range.

The City of Houston currently utilizes its entire share of 59.3 MGD, taking delivery downstream of Lake Conroe at a pumping station on Lake Houston. The SJRA has about 9 MGD that is uncommitted. Discussions with SJRA personnel indicate that another 7 MGD could potentially be made available through renegotiation of existing contracts.

Currently, there is insufficient water available in Lake Conroe to meet the NHCWSC need for 26.7 MGD by the year 2010. As discussed, several projects have been proposed to bring out-of-basin water to Lake Houston. If one or more of these projects were implemented, it is possible that water which is now taken downstream could be made available at Lake Conroe. Although a plan for accomplishing this has not been defined at this time, Lake Conroe was not eliminated as the NHCWSC source of surface water solely on the basis of water availability.

The shortage of water plus the higher cost of the Lake Conroe conveyance system discussed later tipped the decision in favor of Lake Houston.

Lake Houston

Lake Houston impounds San Jacinto River water and lies approximately 16 miles to the east of the planning area. The entire yield of this reservoir is owned and used by the City of Houston as raw water supply for the City's East Water Purification Plant on Federal Road, just north of the Houston Ship Channel. The Coastal Industrial Water Authority is constructing a new conveyance line from the Trinity River System to the East Purification Plant. This project will be complete by 1989. There will be a sufficient quantity of water available in Lake Houston to meet the needs of the NHCWSC. Further, there are a number of projects which have been identified to bring additional water to Lake Houston from out-of-basin river systems. As previously mentioned, the Lake Houston raw water cost is in the $.22 to $.23 per-thousand-gallon range.

On the basis of its proximity to the NHCWSC planning area, and its capability to provide the total water needs of the NHCWSC, Lake Houston is the preferred surface water supply source. Conveyance costs of the Lake Conroe and Lake Houston systems are evaluated below.

Conveyance Facilities for Lake Conroe and Lake Houston Options

The Lake Conroe and Lake Houston surface water conveyance facilities, routes, and estimated costs were defined on a preliminary basis to allow for a valid comparison of the two reservoirs on the basis of delivery costs. These facilities were evaluated based on the size of line required to convey the NHCWSC water requirements of 26.7 MGD. No joint participation with other similar entities, utility districts, or the City of Houston was considered in the comparison.

Preliminary design calculations were made consistent with criteria discussed earlier. Pipeline routing was based on a review of aerial photographs, USGS topographic quadrangle sheets, property ownership maps, and other available information. Cost estimates were based on costs of similar projects in the Houston area. In preparing these estimates, allowances were made for wet soil conditions, tunneling under major rights-of-way, appurtenances, fittings, and corrosion protection. A cost estimate of treatment facilities was not made since this cost would be essentially the same for both options.

For the Lake Conroe option, a raw waterline was sized to flow by gravity from Lake Conroe approximately 16 miles to a treatment plant on Spring Creek. Treated water would be pumped about 10 miles to the northeast corner of the NHCWSC planning area, where it would enter the main distribution system.

The normal pool elevation of Lake Conroe is 201 feet Mean Sea Level (MSL), some 75 feet above the outfall point into Spring Creek. The described system takes advantage of this natural elevation difference. The only pumping required in this conveyance system is the relatively small amount required to lift water from the lake into the conveyance system plus the pumping required to move water through the treatment plant and to convey treated surface water to the planning area.

A 48-inch gravity line is required to bring raw water to the Spring Creek outfall, while a 42-inch pressure line is required to carry treated water to the planning area. The capital cost of this conveyance system, excluding the treatment plant cost, totals approximately $53 million. Table 11 is a detailed cost estimate of the capital costs of this system.

There is no significant pumping cost associated with the Lake Conroe to Spring Creek reach. Based on a cost of $.06 per kwh, the annual cost of pumping water at the treatment plant and boosting to the required pressure for distribution within the planning area is approximately $2 million per year.

It should be noted that it would be possible to take water from the San Jacinto River closer to the NHCWSC service area. However, water removed directly from the river would carry high levels of solids and would require the construction at a large stilling basin to allow silt and solids to

TABLE NO. 11

CAPITAL COST ESTIMATE
LAKE CONROE ALTERNATIVE

	ITEM	QUANTITY	UNIT	UNIT PRICE	DISTRICT COST
1.	48" PCCP	86,400	L.F.	$ 233.00	$20,131,000
2.	48" Tunnel	1,600	L.F.	700.00	1,120,000
3.	48" Valves	10	Ea.	25,000.00	250,000
4.	48" Wet Sand	4,300	L.F.	20.00	86,000
5.	48" Corrosion Protection	86,400	L.F.	7.50	648,000
6.	48" Appurtenances (20% of Items 1-5)				4,447,000
7.	Clearing & Access	84,400	L.F.	25.00	2,110,000
8.	Intake @ Lake Conroe	1	L.S.		1,250,000
9.	42" PCCP	56,000	L.F.	171.00	9,576,000
10.	42" Tunnel	1,900	L.F.	650.00	1,235,000
11.	42" Valves	7	Ea.	25,000.00	175,000
12.	42" Wet Sand	2,800	L.F.	20.00	56,000
13.	42" Corrosion Protection	56,000	L.F.	7.50	420,000
14.	42" Appurtenances (20% of Items 9-15)				2,292,000
15.	Contingency (10% of Items 1-14)				4,380,000
15.	Engineering (10% of Items 1-15)				4,818,000
	TOTAL CAPITAL COST				$52,994,000

settle out of the water. This need for a large tract of land and expensive excavation eliminated the San Jacinto River as a point of withdrawl for the water supplies.

For the Lake Houston option, it is assumed that surface water would be treated at or near a site owned by the City of Houston for its future Northeast Water Purification Plant. This site is on the shores of Lake Houston near the intersection of the proposed Beltway 8 and Lockwood Drive.

The Lake Houston pool elevation at 45 feet MSL is well below the average elevation of the planning area. Thus the conveyance system must be sized to overcome both hydrostatic and frictional head losses. Reflecting these considerations, this conveyance system requires a 42-inch line which would convey treated water westward, generally along the Beltway 8 and other thoroughfares about 16 miles to the NHCWSC planning area boundary near the intersection of Interstate Highway 45 and Rankin Road. At this point, water would be repressurized and enter a distribution system within the planning area.

The capital cost of this conveyance option is approximately $26 million. Table 12 is a detailed cost estimate of the capital cost of this conveyance system. Pumping costs total approximately $2.7 million annually on the same basis as the Lake Conroe option.

Comparison of Lake Conroe and Lake Houston Alternatives

Primarily due to the closer proximity of Lake Houston to the planning area, the capital cost of the Lake Houston alternative is considerably lower than the capital cost of the Lake Conroe alternative. The Lake Conroe alternative is a lower cost system to operate than the Lake Houston alternative, because of the relative elevations of the two lakes compared to the planning area.

TABLE NO. 12

CAPITAL COST ESTIMATE
LAKE HOUSTON ALTERNATIVE

	ITEM	QUANTITY	UNIT	UNIT PRICE	DISTRICT COST
1.	42" PCCP	80,800	L.F.	$ 171.00	$13,817,000
2.	42" Tunnel	1,900	L.F.	650.00	1,235,000
3.	42" Valves	12	Ea.	25,000.00	300,000
4.	42" Wet Sand	27,000	L.F.	20.00	540,000
5.	42" Corrosion Protection	80,800	L.F.	7.50	606,000
6.	42" Appurtenances (20% of Items 1-5)				3,300,000
7.	Right-of-Way	750,000	S.F.	2.00	1,500,000
8.	Contingency (10% of Items 1-7)				2,130,000
9.	Engineering (10% of Items 1-8)				2,343,000
	TOTAL CAPITAL COST				$25,771,000

To evaluate the two alternatives on an equal basis, the capital costs were added to the present value of the operating costs. To compute the present value of the operating costs, these annual costs were discounted at a 7 percent rate over 20 years.

Evaluated on this basis, the present value of the pumping costs of the Lake Conroe alternative is approximately $22 million. On the same basis, the present value of the pumping costs of the Lake Houston alternative is $29 million. Adding the present value of the operating costs to the capital costs results in total costs of $75 million for the Lake Conroe alternative compared to $55 million for the Lake Houston alternative.

Recognizing the City of Houston's authority to plan and approve water supply projects within the extra-territorial jurisdiction of the City, Public Works Department personnel were consulted in performing this anaylsis. These discussions showed that major east to west conveyance lines to serve North Harris County from Lake Houston are an integral part of the City's Master Water Supply Plan.

Based on this analysis, the Lake Houston source of surface water is recommended for the following reasons:

1. The total quantity of water needed by the NHCWSC is available to meet both short- and long-term requirements.

2. The combined capital and operating costs of the conveyance system from Lake Houston is approximately $20 million less than the cost to deliver Lake Conroe water.

3. The Lake Houston alternative is consistent with the water supply planning for the eight-county area.

V. LOCAL DISTRIBUTION SYSTEM

Distribution Alternatives

Surface water will be delivered to the surface water distribution system located at W. Rankin Road and IH-45 at a pressure of approximately 15 pounds per square inch (psi) where a pump station will increase the pressure to approximately 75 psi. Water will then be distributed to each of the individual distribution systems. Three alternatives were chosen as possible waterline layouts. (See Figure 20.) Each of the three alternatives provides for delivery of surface water to each of the individual distribution systems within the NHCWSC service area. Alternate routes were chosen on the basis of water plant locations and availability of right-of-way.

Figure 17 refers to several lines as common lines. These lines represent lines which are required in each of the three alternatives. Ella Boulevard, T.C. Jester Boulevard, and Spears Road are locations for common lines which provide major corridors for the distribution system. Other major corridors studied include FM 1960, Cypresswood, Louetta, Cutten, W. Richey, W. Rankin, Champion Forest, Stuebner-Airline, Walters, and Kuykendahl. Each of the corridors were analyzed for distribution capability and right-of-way availability. The best corridors were then incorporated into three alternate routes. The three alternatives were initially selected to provide easy access to districts, utilize existing corridors, minimize local disruption of activities, and provide for flexibility to allow phased construction.

Alternate 1 - consists of corridors along Ella and T.C. Jester from W. Rankin to Cypresswood; Champion Forest from W. Richey to Cypresswood;

W. Rankin from IH-45 to Stuebner-Airline; Stuebner-Airline from W. Rankin to W. Richey; W. Richey from Stuebner-Airline to Champion Forest; and Cypresswood from Champion Forest to Ella. Various extensions from these corridors will supply water to the remaining areas. (See Figure 21 for a layout of Alternate 1.)

Alternate 2 - consists of corridors along Ella and T.C. Jester from W. Rankin to Louetta; Champion Forest from W. Richey to Louetta; W. Rankin from IH-45 to Stuebner-Airline; Stuebner-Airline from W. Rankin to W. Richey; W. Richey from Stuebner-Airline to Champion Forest; and Louetta from Champion Forest to Ella. Various extensions from these corridors will supply water to the remaining areas. (See Figure 22 for a layout of Alternate 2.)

Alternate 3 - consists of corridors along Ella and T.C. Jester from W. Rankin to Louetta; Cutten from W. Richey to Louetta; W. Rankin from IH-45 to Stuebner-Airline; Stuebner-Airline from W. Rankin to W. Richey; W. Richey from Stuebner-Airline to Cutten; and Louetta from Cutten to Ella. Various extensions from these corridors will supply water to the remaining areas. (See Figure 23 for a layout of Alternate 3.)

Corridor Description

Kuykendahl Road. Within the NHCWSC study area, Kuykendahl extends from I-45 north to Spring-Cypress Road. The ROW is generally 100 feet although some 200-foot ROW exists. From I-45 north to FM 1960, paving is concrete, curb-and-gutter, four-lane road separated by esplanades. At FM 1960, the paving changes to asphalt with roadside ditches and converges to four-lane traffic. HL&P lines alternate on both sides of the road but are not continuous. Gas pipelines are located in the east and west ROWs as well as the esplanade. The pipelines generally range in size from two (2) to 18 inches with a 30-inch gas pipeline crossing Kuykendahl at Rankin Road. Southwestern Bell Telephone has cables located along both ROWs. Waterlines are typically in the east ROW. Most of the utilities cross the road occasionally and may be found in the esplanade at times. All intersections have several utilities crossing each other. Kuykendahl crosses Cypress Creek just before reaching Louetta Road. From I-45 to FM 1960, Kuykendahl is generally clear. North of FM 1960, Kuykendahl becomes fairly crowded with residential and commercial tracts fronting the road.

Stuebner-Airline. Within the NHCWSC study area, Stuebner-Airline extends from Greens Road north to Spring-Cypress Road. There is a 100-foot-wide ROW throughout. From W. Rankin Road to FM 1960 and Strack to Cypresswood, paving is concrete, curb-and-gutter, four lanes with esplanades. From FM 1960 to Strack and Cypresswood to Louetta Road, paving is two-lane asphalt with roadside ditches. Southwestern Bell Telephone has cables located on the west side of Stuebner-Airline. Television cables are located on the east side of the road to Middlestaedt where they cross to the west side. HL&P lines alternate on both sides of the road. Where concrete paving exists, the storm sewer alternates on both sides of the road and some box culverts are located within the esplanades. Waterlines are typically located on the east side of Stuebner-Airline. Entex, Houston Pipeline, and other gas pipelines ranging from two (2) to eight (8) inches parallel both sides of Stuebner-Airline at various locations. Stuebner-Airline is fronted by both residential and commercial lots.

FM 1960. Within the NHCWSC study area, FM 1960 extends from I-45 west to FM 149. The ROW is 100 feet wide throughout. From I-45 to Edwards Street, paving is concrete, curb-and-gutter, six-lane road with esplanades. From the west side of Edwards Street to FM 149, FM 1960 is four-lane asphalt with roadside ditches. HL&P lines are located in either or both ROWs and are usually continuous. Entex, Houston Natural Gas, Houston Pipeline Co., Warren, Mobil, United, and other gas pipelines ranging from four (4) to 24 inches are located along both sides of the road and several cross FM 1960. Southwestern Bell Telephone has cables, conduits, and ducts located in both ROWs and under the roads. Sanitary sewers are typically located in the south ROW while storm sewers are located in both ROWs and under the road. Waterlines are generally located in the north ROW and outside the south ROW. There is also a sprinkler system within the south ROW between Stuebner-Airline and Kuykendahl. Several utilities cross at all the intersections along FM 1960. FM 1960 is mostly fronted by commercial tracts and is extremely congested.

Walters Road. Within the NHCWSC study area, Walters Road extends from Spears Road north past FM 1960 into the Olde Oaks Subdivision. From Spears Road to Old Walters Road, Walters Road is four-lane concrete, curb-and-gutter, separated by esplanades. From Old Walters Road to FM 1960, there is two-lane asphalt paving with roadside ditches. The ROW ranges from 80 to 100 feet. The sanitary and storm sewers are located in the west ROW and the waterline is in the east ROW. Southwestern Bell Telephone has a cable located in the west ROW. Walters Road is undeveloped from Spears to Old Walters Road. It has residential frontage north of FM 1960 and commercial frontage south of FM 1960, but is generally clear. HL&P

lines are generally located on the east side of the road. At this date, no power lines have been installed from Spears Road to Old Walters Road.

Ella Boulevard. Within the NHCWSC study area, Ella Boulevard extends north from W. Rankin Road to Spring-Cypress Road. From W. Rankin Road to W. Richey Road, Ella Boulevard is a four-lane concrete, curb-and-gutter road with esplanades. From W. Richey to FM 1960, Ella Boulevard is four-lane asphalt pavement with roadside ditches. From FM 1960 to Bamorst, Ella Boulevard is two-lane concrete, curb-and-gutter. Ella Boulevard dead-ends at Bamorst and begins again approximately 800 feet north of Cypress Creek continuing to Louetta Road. The pavement north of Cypress Creek is two-lane concrete, curb-and-gutter. The ROW is generally 100 feet wide. Sanitary sewers are located along both sides of Ella Boulevard in various locations. Storm sewer lines are generally located in the east ROW (or the esplanade). Waterlines are typically on the west side and in the esplanades. HL&P lines alternate sides of the road and are not continuous. South of FM 1960, Southwestern Bell Telephone's cables are typically located within the west ROW. Ella Boulevard is fronted by both commercial and residential tracts but is generally clear. North of FM 1960, residential tracts typically front the road while south of FM 1960 is generally fronted by commercial tracts.

Louetta Road. Within the NHCWSC study area, Louetta Road extends west from Spring-Cypress Road to FM 149. From Spring-Cypress Road to Kleinwood, Louetta Road is four-lane asphalt with roadside ditches. From Kleinwood to Old Spring Road, Louetta Road is four-lane asphalt with curbed medians and roadside ditches. West from Old Spring Road to FM 149, Louetta becomes two-lane concrete with curbs and gutters. This section is currently being expanded to a four-lane boulevard. The ROW is 100 feet wide and from Stuebner-Airline to Spring-Cypress Road is generally clear. The storm sewer alternates along both sides of Louetta Road as well as the esplanade. Some sanitary sewers are located in the north ROW. Waterlines are generally in the south ROW. Southwestern Bell Telephone has cables located on both sides of the road and in the median at times. Gas pipelines range in size from four (4) to ten (10) inches and are located in both ROWs. The pipelines cross Louetta Road occasionally. Most intersections have several utilities crossing and are crowded.

Bammel N. Houston. Within the NHCWSC study area, Bammel N. Houston extends southwest from T.C. Jester Boulevard to Green Pines. From T.C. Jester to Walters Road, Bammel N. Houston is a four-lane boulevard with curbs and gutters. From Walters Road to Green Pines, Bammel N. Houston is a two-lane asphalt with roadside ditches. The ROW is currently 80 to 100 feet wide, but will be expanded to 100 feet in the future. The storm sewer is generally located on the west side of the road in a 30-foot easement. Sanitary sewer lines are located both in the east and west ROWs and cross the road at Sylvanfield Drive. Waterlines are also located in both ROWs and a force main crosses approximately 200 feet north of Stuebner-Airline. Television cables are located along the east ROW. HL&P lines alternate discontinuously along both sides of the ROW. Gas pipelines ranging from four (4) to 24 inches are located along both sides of the road with an occasional crossing.

W. Rankin/Spears Road. Within the NHCWSC study area, W. Rankin/Spears Road extends west from I-45 to Stuebner-Airline. From I-45 to Cambury Drive, W. Rankin/Spears is four-lane concrete, curbs and gutters with esplanades. At Cambury Drive it becomes two-lane asphalt with roadside ditches. The ROW is 100 feet wide. HL&P lines are located on the south side of the road. Storm sewers are typically located within the esplanades. The sanitary sewer and waterlines alternate sides of the road. Utilities cross the road at various points. W. Rankin/Spears Road is fronted by both commercial and residential property.

T.C. Jester. Within the NHCWSC study area, T.C. Jester extends north from Rankin Road to Spring-Cypress Road but is not continuous. T.C. Jester is four-lane concrete, curb-and-gutter with esplanades. Proposed pavement will also be four-lane concrete curb-and-gutter with esplanades. Existing sections of T.C. Jester are: from Rankin Road north to Laurel Oaks; from Cornerstone Park Drive north to FM 1960; from Pebble Trace north to Ivy View; from Cypresswood north to Slashwood; and from Louetta Road north to Center Court. ROW has been obtained from Laurel Oaks north to Cornerstone Park for construction of that segment of T.C. Jester. Storm and sanitary sewers are generally located on the west side of T.C. Jester. Waterlines are typically along the east side up to Winding Ridge Drive where they cross to the west side. The majority of T.C. Jester is fronted by residential tracts. Esplanades along T.C. Jester may be a good location for future water distribution lines.

Champion Forest Drive. Within the NHCWSC study area, Champion Forest Drive extends north from Bammel N. Houston to Spring-Cypress Road. Champion Forest Drive is four-lane concrete, curb-and-gutter, separated by esplanades. In some sections, only half of the boulevard exists at this time, but will be completed in the future. The storm sewer is usually located in the esplanade and occasionally in either the east or west ROW.

Sanitary sewer and waterlines are located on opposite sides of the road from one another. Their location depends on the arrangement used by the different subdivisions which Champion Forest Drive passes through. The ROW is 100 feet wide throughout. HL&P has (aerial) lines located on the east and west side of the road in alternating sections. Champion Forest Drive is fronted mostly by residential tracts although some commercial tracts exist also.

W. Richey Road. Within the NHCWSC study area, W. Richey Road extends west from Stuebner-Airline to Bourgeois Road. W. Richey Road is four-lane concrete, curb-and-gutter with esplanades. The storm sewer is generally located in the esplanade and the sanitary sewer is typically within the south ROW. The waterline is normally in the esplanade, but occasionally it is located within the north ROW. HL&P has lines alternating on both sides of the road. Southwestern Bell Telephone has a conduit in the north ROW. Houston Natural Gas has an abandoned four-inch line in the esplanade and Texaco has a six-inch line there. W. Richey Road crosses a 150-foot-wide HCFCD drainage easement and is fronted mostly by residential property.

Cypresswood Drive. Within the NHCWSC study area, Cypresswood Drive extends west from I-45 to FM 149 but is not continuous. Cypresswood Drive, when completed, will be four-lane concrete, curb-and-gutter, separated by esplanades. Existing ROW is typically 100 feet wide. Some ROW will be needed for the completion of Cypresswood Drive, such as the area from FM 149 to Schroeder Road. HL&P lines are generally located on the north side of the road. Waterlines are usually located within either the north or south ROW. The sanitary sewer is located within the north ROW or the esplanades and the storm sewer is generally located within the south ROW. The esplanades all along Cypresswood Drive are fairly clear and most of the frontage property is residential.

Bourgeois. Within the NHCWSC study area, Bourgeois extends southwest from W. Richey Road at Bourgeois Road to Cutten Road. Bourgeois is a two-lane asphalt road with roadside ditches along both sides. Waterlines are generally located on the north side. Sanitary sewers, when present, are on the south side in most cases. Southwestern Bell Telephone has conduits located within the north ROW. Bourgeois is generally clear and there are few obstructions near the road. HL&P has lines running continuously along the north side of Bourgeois.

Evaluation of Distribution Alternatives

Evaluations were made to compare the ability of each alternative to meet the various design requirements. Water pressure, pipe velocity, cost of the distribution system, and future capabilities were all evaluated in order to choose the alternative with the best overall qualities. This evaluation process determined the best alternative available for providing surface water distribution to the entire NHCWSC service area.

A computer analysis of the three alternatives was conducted to compare the hydraulic properties of each of the three alternatives. The computer analysis incorporates the Hazen-Williams equation to give a breakdown of pipe losses and pressure differences throughout the system. The distribution system alternatives are modeled using pipe and node data to reflect the characteristics of the system. Pipe data consists of pipe sizes, pipe lengths, connecting nodes, Hazen-Williams coefficient, and minor loss factors. Pumps and starting hydraulic gradients are added along with this pipe data. Pumps are modeled on the basis of a three-point curve to more closely represent actual conditions. Node data consists of water demands, elevations, and interconnecting pipes. A node represents a change in pipe size, a location of water demand, or several pipes converging at one point.

Values used as input data were chosen to reflect as closely as possible the actual conditions expected for the distribution system. A Hazen-Williams coefficient of 120 was chosen for use in the computer model. This value accounts for the use of either concrete-lined cylinder pipe or ductile iron pipe. Either pipe material is acceptable for waterline usage and comes in a wide range of sizes. Minor loss coefficients do not greatly affect the final results of the model; therefore, blanket values were used for most of the pipes being modeled. Minor loss factors used in the model were chosen to account for bends and values in each line. The pump was modeled using actual pump curves from a manufacturer's design manual. This does not endorse any manufacturer's pump, but rather serves to give realistic values to be used in the model. The pump configuration which was chosen is not intended to serve as the final design, but it is intended to provide a workable design which can be easily modeled.

The water demand values indicate the projected water usage at each node location in millions of gallons per day (MGD). A more detailed analysis of the water demands will be discussed later in this report. Elevations from USGS quadrant maps were used to obtain node elevations. Although these elevations were interpolated from contour lines on the

USGS quads and may not be exact, they provide a common elevation basis for the computer model.

The computer analysis for each of the three alternatives is included as Appendix A. Figures 21-23 illustrate corresponding layouts for the computer models. This analysis represents the delivery of a projected average daily flow (ADF) of 34.2 MGD for the year 2020. The results of the computer analysis indicates that all three of the alternatives are capable of delivering water to the service area at minimum pressures. A pressure of 12 psi is the absolute minimum pressure for delivery to a water plant. Higher minimum pressures are preferred in order to account for losses which may occur between transmission lines and actual water plant tie-ins. From this criteria for pressure, Alternate 3 is clearly the best alternative.

Water velocities within a distribution system should be high enough to allow for flushing of the lines. As stated earlier, a minimum velocity of 2.0 ft/sec is required to flush sediments from the line. With any lower velocities, sediments will settle in the lines, effectively reducing the line capacity. Each of the three alternatives has lines which will not reach acceptable flushing velocities. It should be noted that the computer model is conservatively based upon the assumption that ADF will be delivered to all areas at the same time. In all probability, ADF will not be delivered to all areas of the district at the same time, but rather water will be taken from the system as needed. Under these conditions all waterlines will reach an acceptable flushing velocity on a regular basis. Based on velocity, all three alternatives are considered equal.

The cost of each alternative was evaluated and compared. Cost estimates are based on the unit costs found in Tables 13 and 14. Unit costs are based on contractor's estimates, pipe manufacturer's costs, previously bid jobs, and engineering considerations. Besides standard pipe installation costs, additional costs were included for road crossings, ditch crossings, sidewalk repairs, boring and jacking, landscaping, pipeline crossings, plant tie-ins, and right-of-way acquisition. Other additional costs include dewatering, cathodic protection, pump station, contingencies, and engineering. Each alternative was evaluated in two phases, north of Cypress Creek and south of Cypress Creek. By using two phases, the cost breakdowns were simplified. Total costs for each alternative are as follows:

	Million
Alternate 1	$28.4
Alternate 2	$28.2
Alternate 3	$27.9

Tables 15-17 give summaries of all three estimates. Based on cost analysis alone, Alternate 3 is considered the best alternative.

A final comparison which can be made with respect to the three alternatives is the future capabilities of each of the alternatives. Alternates 1 and 2 have a large number of "dead end" lines extending from the main loop to areas which are not fully developed. These "dead end" lines are limited in the capacity to serve additional areas extending beyond the looped system. Alternate 3, on the other hand, extends the looped system and eliminates many of the "dead end" lines to undeveloped areas. Alternate 3 has the best capability for future expansion to undeveloped areas.

TABLE NO. 13

UNIT PRICES FOR NHCWSC FINAL ESTIMATE

		Road Crossings		Ditch Crossings	
Pipe Size	Unit Cost (A)	Minor (B)	Major (C)	Minor (D)	Major (E)
42"	$171.00	$30,500.00	$51,700.00	$14,000.00	$25,000.00
36"	140.00	27,000.00	48,000.00	13,000.00	23,500.00
30"	110.00	7,000.00	45,300.00	12,000.00	22,000.00
24"	50.00	5,600.00	40,000.00	11,000.00	20,100.00
16"	25.00	4,550.00	20,000.00	11,000.00	20,100.00
12"	20.00	4,500.00	15,000.00	10,000.00	18,000.00

A. Pipe cost includes labor, materials, bedding and backfill (C-700 PVC or A.C. pipe may be used for 16" and 12").

B. Bore and Jack cost at 15' depth and 70' length; does not include liner or pipe.

C. Bore and Jack cost at 15' depth and 100' length, including liner; does not include pipe.

D. Assumes 100' crossing with no shoring; does not include pipe.

E. Assumes 150' crossing with 40' of shoring. Lines are to be laid 5' below ditch/creek flowline; does not include pipe.

TABLE NO. 14

ADDITIONAL COSTS

Item	Units	Costs
1. Bore and Jack 12" Waterline for Driveways	L.F.	$ 50.00
2. Sidewalk Replacement, 4½" thick, 4' wide	L.F.	7.10
3. Landscaping		
A. with trees	S.F.	0.60
B. without trees	S.F.	0.50
4. Pipeline Crossing (A)	Ea.	5,000.00
5. Plant Tie-in (B)	Ea.	10,000.00
6. R.O.W. Acquisition	Ac.	40,000.00

(A) Cost for special materials, and approvals required to cross oil and gas pipelines.

(B) Cost for water plant connection, includes piping, switch control modifications, and automatic valve.

TABLE 15

PRELIMINARY COST ESTIMATE
for
NORTH HARRIS COUNTY WATER SUPPLY CORPORATION
DISTRIBUTION ALTERNATES

Alternate No. 1

	Phase I		Phase II		Total
*Line Cost	$13,109,100		$ 4,568,200		$17,677,300
Dewatering	194,000		114,100		308,100
Corrosion Protection	723,800		60,000		783,800
Subtotal	$14,026,900		$ 4,742,300		$18,769,200
In-Line Booster Pump Station	$ 900,000		$ 800,000		$ 1,700,000
Miscellaneous	1,492,700	(10%)	1,108,500	(20%)	2,601,200
Contingencies (10%)	1,642,000		665,000		2,307,000
Engineering (10%)	1,806,200		731,600		2,537,800
Total	$19,867,800		$ 8,047,400		$27,915,200
Site Acquisition (5 Ac)	500,000		-0-		500,000
GRAND TOTAL	$20,367,800		$ 8,047,400		$28,415,200

*Line costs, landscaping, ROW, special crossings, boring, and tunneling.

TABLE 16

PRELIMINARY COST ESTIMATE
for
NORTH HARRIS COUNTY WATER SUPPLY CORPORATION
DISTRIBUTION ALTERNATES

Alternate No. 2

	Phase I		Phase II		Total
*Line Cost	$13,109,100		$ 4,396,400		$17,505,500
Dewatering	194,000		114,100		308,100
Corrosion Protection	723,800		60,000		783,800
Subtotal	$14,026,900		$ 4,570,400		$18,597,300
In-Line Booster Pump Station	$ 900,000		$ 800,000		$ 1,700,000
Miscellaneous	1,492,700	(10%)	1,074,100	(20%)	2,566,800
Contingencies (10%)	1,642,000		644,400		2,286,400
Engineering (10%)	1,806,200		708,900		2,515,100
Total	$19,867,800		$ 7,797,800		$27,665,600
Site Acquisition (5 Ac)	500,000		-0-		500,000
GRAND TOTAL	$20,367,800		$ 7,797,800		$28,165,600

*Line costs, landscaping, ROW, special crossings, boring, and tunneling.

TABLE 17

PRELIMINARY COST ESTIMATE
for
NORTH HARRIS COUNTY WATER SUPPLY CORPORATION
DISTRIBUTION ALTERNATES

Alternate No. 3

	Phase I		Phase II		Total
*Line Cost	$12,775,900		$ 4,523,400		$17,299,300
Dewatering	194,000		114,100		308,100
Corrosion Protection	723,800		60,000		783,800
Subtotal	$13,693,700		$ 4,697,500		$18,391,200
In-Line Booster Pump Station	$ 900,000		$ 800,000		$ 1,700,000
Miscellaneous	1,459,400	(10%)	1,099,500	(20%)	2,558,900
Contingencies (10%)	1,605,300		659,700		2,265,000
Engineering (10%)	1,765,800		725,700		2,491,500
Total	$19,424,200		$ 7,982,400		$27,406,600
Site Acquisition (5 Ac)	500,000		-0-		500,000
GRAND TOTAL	$19,924,200		$ 7,982,400		$27,906,600

*Line costs, landscaping, ROW, special crossings, boring, and tunneling.

The design for water distribution reflects a system that will meet the needs of the 52 separate distribution systems that currently exist within the area. This design also allows for some flexibility which will tolerate changes in order to meet future requirements.

The basic factors involved in the design of the surface water distribution system were location, pipe size, and cost. Along with these basic design factors, several other design criteria were incorporated. The waterlines are large enough to deliver average daily flow (ADF) throughout the entire system. Waterlines are able to handle peak flows within localized areas. The distribution system is located such that it is able to serve all individual distribution systems within the NHCWSC service area. By delivering surface water directly to ground storage tanks, high pressure conditions are avoided, individual characteristics of each water system can be accounted for, and all direct waterline tie-ins will be avoided.

VI. SURFACE WATER FACILITY PLAN

Plan Considerations

The primary components of the surface water conversion system are the following:

Surface Water Supply Resources
Water Purification Plant
Conveyance Line
Distribution System

Previous sections have discussed the various surface water sources, culminating in a recommendation to draw surface water from Lake Houston.

Siting the plant near Lake Houston eliminates the need for on-site raw water storage as the natural storage of the lake fulfills this function. Thus, a system which includes a purification plant near Lake Houston defined herein as the Northeast Water Purification Plant, conveyance lines to the NHCWSC planning area, and a distribution system within the NHCWSC planning area has been defined.

Reflecting the authority of the City of Houston regarding facilities of this type within its extraterritorial jurisdiction, the conversion facility plan must be coordinated with the City's master planning efforts. To accomplish this, discussions were held with appropriate City of Houston Public Works Department personnel to review the objectives of the plan and to receive input as to how the NHCWSC could ensure compatibility with the City's plans.

A significant issue addressed was how the City and the NHCWSC could benefit from participating together in facility construction, thereby capturing the advantages of potential economies of scale. With Lake Houston defined as the raw water supply source, a study was undertaken to define the area to be served within the planning horizon by the Northeast Water Purification Plant.

Utilizing forecasts prepared for the Houston Water Master Plan, recent information developed for conveyance facilities associated with the City's East Water Purification Plant and the HGCSD Plan, an area generally bounded to the south by the East Water Purification Plant Service Area (approximately Loop 610 and Buffalo Bayou), the HGCSD Regulatory Area 4 and Area 7 boundaries to the west, HGCSD Regulatory Areas 5, 6, and 7 boundaries to the north, and Lake Houston to the east was identified as requiring over 200 MGD of surface water volumes within the planning horizon to comply with the HGCSD Plan. Transporting surface water from Lake Houston westward through this area is consistent with Houston Water Master Plan proposed planning efforts. Thus, the facility plan was developed to address not only the NHCWSC water requirements, but also the City's potential surface water requirements in this area.

Following is a discussion of each facility plan component:

Water Purification Plant

The City of Houston intends to construct a water purification plant at a site near Lake Houston and has purchased a site for that purpose. Discussions with City Public Works Department personnel have indicated a willingness on the City's part to allow the NHCWSC to participate in the construction of the plant by sharing in the plant's capital cost. Plant capital costs are estimated at $1.20 per gallon of plant capacity. A similar approach was recently adopted by the City with regard to its Southeast Water Treatment Plant.

The principles of this arrangement, as expressed in contracts related to participation in the Southeast Plant, include ownership of capacity in a regional water plant and sharing of actual operating expenses on a pro-rata basis related to treated water flow. Capacity is acquired by an entity by contributing a pro-rata share of the construction cost of the plant. Operating costs are allocated quarterly based on proportion of flow relative to total flow treated on behalf of participating entities.

Although the City of Houston is presently planning to construct the Northeast Plant in the required time frame, and participation in this plant is considered the lead case for this report, there is a possibility that the City may choose to postpone its project. City of Houston Public Works Department personnel have stated the City's willingness to permit the NHCWSC to construct its own plant at this location should a decision be made to postpone plant construction. To do so would require a formal agreement with the City. Under the terms of this agreement, the City would lease a portion of its site at fair market value. The NHCWSC would be responsible for the entire operating costs of this plant.

Conveyance Line

In a previous section, facilities required to deliver surface water to the NHCWSC planning area were generally defined. Based on this effort, a more detailed route study was performed, including site visits. Starting at the Northeast Plant site and moving west, this line would parallel Beltway 8 approximately nine miles to the proposed Vickery Drive interchange. At this point, the line alignment would turn north to the intersection of Vickery Drive and Greens Road. From this intersection, the line would turn west paralleling Greens Road to an intersection with Aldine-Westfield Road. The line will parallel Aldine-Westfield until its intersection with Rankin Road. From this intersection, the line alignment would parallel Rankin Road until its intersection with Interstate Highway 45, which is the eastern boundary of the NHCWSC planning area. Near this point, surface water would be repressurized at a pump station to be constructed for the distribution system. Figure 24 shows the detailed alignment of this line. The Figure also shows the location of the Northeast Water Purification Plant and the selected distribution alternate previously described.

Discussions with City Public Works Department personnel were held to define the line capacity required to meet the ultimate NHCWSC needs and projected Houston Water Master Plan demands. Based on these discussions, the conveyance line for the reach from the water purification plant to the Greens Road and Aldine-Westfield intersection was defined as a 54-inch line. The line from this point on to I-45 will be a 48-inch line. These two lines are oversized to provide future service capacity for the City of Houston, solely at the cost of Houston.

As a result of the oversizing, the NHCWSC will benefit from the "economy of scale." The cost to acquire the NHCWSC's ultimate capacity of 26.7 MGD in this larger line is lower for the NHCWSC than if a dedicated line of this capacity were constructed for the NHCWSC only.

This conveyance system will not serve the entire long-term needs of areas outside of the NHCWSC. However, it will serve the interim demands of the City. The City is the only other party capable and willing to participate financially in a water supply line at this time. In the future, an additional line will be required to move water west from the Northeast Water Purification Plant to meet the ultimate needs of the City of Houston. This future line may parallel the proposed line or lie along a completely different alignment.

Distribution System

The distribution system was designed to deliver surface water to utility districts and individual water suppliers within the NHCWSC service area. The system alignment was designed to meet the individual needs of each utility district and water supplier with minimal disruption to area residents. The proposed alignment reflects these points as well as the design criteria discussed previously.

Surface water from the conveyance line will connect to a large pump station near I-45 at Rankin and Kuykendahl Roads. The pump station will repressurize the water and pump it into the distribution system. From this pump station proposed distribution lines run west along Rankin Road and Richey Road, north along Ella Boulevard, T.C. Jester Boulevard, and Cutten Road, looped together by a line down Louetta Road. Another distribution line will run north along Champion Forest Drive to provide convenient access to water suppliers in that area. See Figure 25 for the Distribution System Layout and corresponding line sizes.

Facility Costs

A cost estimate was prepared for the water purification plant, conveyance system, and distribution system. Purification plant cost estimates are based on meeting NHCWSC requirements of 26.7 MGD only without regard to City of Houston requirements. Conveyance line costs are based on the larger conveyance system described rather than the dedicated line meeting NHCWSC requirements only. A cost estimate for the distribution system addresses only the NHCWSC requirements. The City of Houston will pay all costs for oversizing the NHCWSC system for the benefit of Houston.

Water purification plant costs are based on recent bids for the City of Houston's Southeast Water Purification Plant. In allocating these costs, the City differentiated between the cost of treatment capacity and distribution pumping capacity. Because distribution, per this plan, will be accomplished from local water pumping facilities as opposed to facilities at the plant, pumping capacity to be purchased equals treatment plant capacity. Plant capital costs are estimated at $1.20 per gallon of plant capacity.

Conveyance and distribution system cost estimates developed are based on current construction costs of similar facilities in the Houston area. Allowances have been made for right-of-way acquisition and special crossings under major thoroughfares and drainageways. Reflecting the developed state of the NHCWSC planning area, allowances have been made for landscaping and pavement repair. Costs for delivery lines to individual district water plants are also included.

A detailed cost estimate of the conveyance line showing NHCWSC and City of Houston share of the construction cost is included as Table 18. The cost of the distribution system is detailed on Table 17. Comparing the estimate of the NHCWSC share of the conveyance line to the cost of a dedicated line serving the NHCWSC only shows a benefit of almost $9 million resulting from the economics of scale afforded by City of Houston participation.

TABLE NO. 18

CAPITAL COST ESTIMATE
CONVEYANCE LINE FROM NORTHEAST WATER PLANT TO
NORTH HARRIS COUNTY WATER SUPPLY CORPORATION SERVICE AREA

	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST	DISTRICT COST	COH COST
1.	48" PCCP	23,700	L.F.	$ 233.00	$ 5,522,000	$ 3,429,000	$ 2,093,000
2.	48" Tunnel	850	L.F.	700.00	595,000	369,000	226,000
3.	48" Valves	4	Ea.	25,000.00	100,000	62,000	38,000
4.	48" Wet Sand	8,000	L.F.	20.00	160,000	99,000	61,000
5.	48" Corrosion Protection	23,700	L.F.	7.50	178,000	110,000	68,000
6.	48" Appurtenances (15% of Items 1-5)				983,000	610,000	373,000
7.	54" PCCP	57,100	L.F.	260.00	14,846,000	6,718,000	8,128,000
8.	54" Tunnel	1,050	L.F.	700.00	735,000	333,000	402,000
9.	54" Valves	8	Ea.	25,000.00	200,000	91,000	109,000
10.	54" Wet Sand	19,000	L.F.	20.00	380,000	172,000	208,000
11.	54" Corrosion Protection	57,100	L.F.	7.50	428,000	194,000	234,000
12.	54" Appurtenances (15% of Items 7-11)				2,488,000	1,126,000	1,362,000
13.	Right-of-Way	750,000	S.F.	2.00	1,500,000	743,000	757,000
14.	Contingency (10% of Items 1-13)				2,812,000	1,407,000	1,405,000
15.	Engineering (10% of Items 1-14)				3,093,000	1,547,000	1,546,000
	TOTAL CAPITAL COST				$34,020,000	$17,010,000	$17,010,000

Following is a summary of the proposed project cost by major plan element:

	City Share	NHCWSC Share	Total
Plant		$32,000,000	$32,000,000
Conveyance Line	$17,000,000	17,000,000	34,000,000
Distribution System		28,000,000	28,000,000
Total	$17,000,000	$77,000,000	$94,000,000

VII. IMPLEMENTATION PLAN

To implement surface water conversion, a plan was developed addressing the issues of delivering required surface water volumes, phasing the project appropriately, capital cost sharing, and financing. Plan components include definition of the initial project and provision for future projects, institutional considerations, financial requirements, and schedule.

Initial Project Definition

As previously shown, groundwater supplies in the area are dwindling and gas intrusion, while unpredictable, is increasing. Thus, constructing facilities to enable the delivery of surface water to every district at the earliest opportunity is recommended. This implies construction of the entire distribution system in the initial project.

To capture economies of scale, the conveyance line defined to serve both ultimate NHCWSC demands and interim Houston metropolitan area demands should be built in the first phase. If the City wishes, additional right-of-way for future additional lines should be purchased at this time also.

At this time, 10 MGD plant capacity should be built. This level is more than half of the existing demand in the area and will significantly alleviate the worst groundwater problems in the area. Water plant capacity can subsequently be added incrementally as demands warrant.

Institutional Considerations

Implementation of the surface water conversion plan described herein requires consideration of a wide range of institutional considerations. Activities related to these issues will require focus and coordination by a management entity. Functions to be managed include the relationship of the surface water conversion plan to water consumers in the planning area, negotiation of terms with the City of Houston, financing of capital and operating expenses, and system operation.

The facilities described herein are for the purpose of delivering treated surface water to existing district or industrial customer water plants on a wholesale basis. It is contemplated that entities in the planning area will continue existing relationships with the ultimate retail water consumer. The mechanics of this wholesale/retail relationship will require supervision and management.

The City of Houston is expected to participate in the construction and operation of certain facilities. As currently envisioned, the City will construct and operate the treatment plant while the entity implementing the surface water conversion plan will construct and operate the conveyance line. This relationship will require formal definition and management.

The estimated cost of the system excluding any additional participation in the conveyance line is $77 million, an amount well beyond the reach of any existing individual district. Construction funds must be secured and a method for allocation and repayment developed. System operating expenses for treatment plant operations and routine system maintenance will require management, stewardship, and accounting.

To address these issues, as well as others which will develop as the plant is implemented, a management entity with fairly broad powers is recommended. A review of suitable entities indicates that the formation of a regional district is most appropriate. In this report, this entity will be referred to as the "District." The District will negotiate and administer contracts with the City of Houston regarding water supply and system operations. The District will also negotiate and administer contracts with individual entities for delivery of surface water.

A regional district of this type is well suited to the role of wholesale water supplier to individual districts. This District can overlay other districts, such that any taxes levied would be added to and collected separately from current taxes. Upon authorization of resident voters, this District would have the authority to issue tax-exempt general obligation bonds for facility construction backed by ad valorem taxes.

For these reasons, formation of a regional district as a management entity is recommended.

Financial Requirements

The surface water conversion implementation plan addresses financial considerations. These include capital cost allocation, project financing, and operating costs for surface water purification and for system maintenance.

As previously discussed, participation in the proposed NHCWSC/City of Houston Northeast Water Purification Plant is considered the lead case. Alternatively, the District may construct its own plant. In either case, the capital cost is expected to be approximately the same. Participation in the Northeast Water Purification Plant would be advantageous to the NHCWSC by remaining with the consistent long-range planning goals of the Houston Master Water Plan.

The conveyance line has been sized to carry large portions of the water demands of the Northeast Treatment Plant's service area. The City of Houston is expected to bear the cost of this additional capacity on a pro-rata basis. To allocate the cost of the line, pro-rata computations based on capacity have been performed for the two major line segments. As shown in Table 18, the District's share of this line computed on this basis is estimated at $17 million.

The distribution system serves district requirements only. Thus no cost allocation is necessary.

Following is a summary of project costs after allocation as described.

Water Plant	$32,000,000
Conveyance Line	17,000,000
Distribution System	28,000,000
Total	$77,000,000

The benefits of surface water conversion will extend past those entities which convert in the initial phase. This is true because when groundwater pumping is reduced, the rate of decline of the water table in the area will slow. This implies the possibility of reduced in-migration of natural gas and other contaminants and the postponement of groundwater equipment adjustment for those NHCWSC area entities which remain on groundwater. Additionally, the existence of the facilities will provide an alternative available for districts remaining on groundwater if their water supply problems increase. For these reasons, it is fair to allocate costs to all water consumers in the planning area.

This allocation can be accomplished by utilizing the authority of the implementing regional district to sell bonds for facility construction. The annual debt from these bonds will be paid by all property owners in the form of property taxes.

To test the impact of this plan on area ad valorem taxes, a financial projection was made. This projection was based on the ad valorem tax value discussed later in this section of the report. For purposes of financial projections, the finance plan was based on issuing bonds in the traditional format. When bonds are ultimately sold, other available techniques will be explored. The traditional format was selected due to its conservatism.

Consistent with a conservative philosophy of financial planning, neither construction costs nor assessed value were inflated. Construction costs were stated in 1986 dollars, while assessed value projections reflect population growth only at 1986 values.

Following are the project construction expenditures on which this plan was based:

Phase I	1988-1989	$32,000,000
	1990-1991	25,000,000
Phase II	1998-2002	15,400,000
Phase III	2009	4,600,000
		$77,000,000

Consistent with these construction expenditures, five bond installments are projected. Bond issues are sized to include capitalized interest (12 months); cost of issuance is estimated at 3 percent; and investment income on capitalized interest is estimated at an interest rate of 5.5 percent. Following are the projected bond installments:

Series 1988	$34,710,000
Series 1990	27,360,000
Series 1998	8,575,000
Series 2002	8,575,000
Series 2008	5,120,000
	$84,340,000

Series 1988 and 1990 bonds secure funding for the District's portion of the water plant, conveyance line, and the entire in-district distribution defined previously as the initial project. Subsequent installments cover the cost of expansion of the purification plant. If population growth does not occur as forecasted, later series issues can be postponed or accelerated as required.

The projections displayed in Table 19 are based on current market conditions (7.5 percent average annual interest rate for an "A" rated bond issue, and the amortization of each issue over 25 years). Alternatively, bonded indebtedness could be serviced through higher water rates. For the initial project, this would require as much as $1.25 per thousand gallons of surface water. This amount is extremely high and does not reflect the benefit accrued to consumers remaining on groundwater. For these reasons, amortizing facility construction bonds with water rates was not considered further.

Based on these projections, tax rates range from $.05 per $100 assessed value in the project's initial years to $.095 per $100 of assessed value after issuance of the series 1989 bonds. Tax rates are projected to remain at this level through the end of the century.

TABLE NO. 19

HARRIS COUNTY REGIONAL DISTRICT NO. 2
TAX RATE STUDY

CASH FLOW ANALYSIS FOR SERIES 1988, SERIES 1990, SERIES 1998, SERIES 2002, SERIES 2009
PHASES I, II, IIIa, IIIb AND IV

TAX YEAR 12-31	BEGINNING I&S FUNDS	INVESTMENT INCOME(A)	INCOME FROM TAXATION				TOTAL FUNDS AVAILABLE	ANNUAL DEBT SERVICE	ENDING I&S FUNDS
			TAX YEAR	ASSESSED VALUE(B)	TAX RATE	TAX INCOME(D)			
1988	$ 0	$2,603,250	1987	$ 5,422,000,000(C)	$0.000	$ 0	$2,603,250	$1,735,500	$ 867,750
1989	867,750	0	1988	5,728,000,000	0.050	2,577,600	3,445,350	2,603,250	842,100
1990	842,100	2,052,000	1989	6,014,000,000	0.050	2,706,300	5,600,400	4,142,250	1,458,150
1991	1,458,150	0	1990	6,300,000,000	0.089	5,046,300	6,504,450	4,655,250	1,849,200
1992	1,849,200	0	1991	6,438,600,000	0.089	5,157,319	7,006,519	4,655,250	2,351,269
1993	2,351,269	0	1992	6,577,200,000	0.089	5,268,337	7,619,606	5,333,813	2,285,793
1994	2,285,793	0	1993	6,715,800,000	0.089	5,379,356	7,665,149	5,333,875	2,331,274
1995	2,331,274	0	1994	6,854,400,000	0.089	5,490,374	7,821,648	5,868,813	1,952,835
1996	1,952,835	0	1995	6,993,000,000	0.089	5,601,393	7,554,228	5,871,563	1,682,665
1997	1,682,665	0	1996	7,131,600,000	0.089	5,712,412	7,395,077	5,870,875	1,524,202
1998	1,524,202	643,125	1997	7,270,200,000	0.089	5,823,430	7,990,757	6,348,719	1,642,038
1999	1,642,038	0	1998	7,408,800,000	0.089	5,934,449	7,576,487	6,510,438	1,066,049
2000	1,066,049	0	1999	7,547,400,000	0.095	6,453,027	7,519,076	6,515,688	1,003,388
2001	1,003,388	0	2000	7,686,000,000	0.095	6,571,530	7,574,918	6,509,688	1,065,230
2002	1,065,230	643,125	2001	7,967,400,000	0.095	6,812,127	8,520,482	6,994,031	1,526,451
2003	1,526,451	0	2002	8,248,800,000	0.095	7,052,724	8,579,175	7,326,938	1,252,237
2004	1,252,237	0	2003	8,530,200,000	0.095	7,293,321	8,545,558	7,322,875	1,222,683
2005	1,222,683	0	2004	8,811,600,000	0.092	7,296,005	8,518,687	7,317,875	1,200,812
2006	1,200,812	0	2005	9,093,000,000	0.090	7,365,330	8,566,142	7,320,438	1,245,704
2007	1,245,704	0	2006	9,374,400,000	0.089	7,508,894	8,754,599	7,492,313	1,262,286
2008	1,262,286	384,000	2007	9,655,800,000	0.087	7,560,491	9,206,777	7,486,813	1,719,964
2009	1,719,964	0	2008	9,937,200,000	0.085	7,601,958	9,321,922	7,781,250	1,540,672
2010	1,540,672	0	2009	10,218,600,000	0.085	7,817,229	9,357,901	7,873,750	1,484,151
2011	1,484,151	0	2010	10,500,000,000	0.083	7,843,500	9,327,651	7,873,625	1,454,026
2012	1,454,026	0	2011	10,668,000,000	0.083	7,968,996	9,423,022	7,869,813	1,553,209
2013	1,553,209	0	2012	10,836,000,000	0.081	7,899,444	9,452,653	7,879,688	1,572,965
2014	1,572,965	0	2013	11,004,000,000	0.047	4,654,692	6,227,657	4,699,563	1,528,094
2015	1,528,094	0	2014	11,172,000,000	0.047	4,725,756	6,253,850	4,696,938	1,556,912
2016	1,556,912	0	2015	11,340,000,000	0.021	2,143,260	3,700,172	2,106,438	1,593,734
2017	1,593,734	0	2016	11,340,000,000	0.021	2,143,260	3,736,994	2,109,250	1,627,744
2018	1,627,744	0	2017	11,340,000,000	0.021	2,143,260	3,771,004	2,106,438	1,664,566
2019	1,664,566	0	2018	11,340,000,000	0.021	2,143,260	3,807,826	2,107,625	1,700,201
2020	1,700,201	0	2019	11,340,000,000	0.021	2,143,260	3,843,461	2,112,963	1,730,498
2021	1,730,498	0	2020	11,340,000,000	0.021	2,143,260	3,873,758	2,109,375	1,764,383
2022	1,764,383	0	2021	11,340,000,000	0.021	2,143,260	3,907,643	2,104,375	1,803,268
2023	1,803,268	0	2022	11,340,000,000	0.021	2,143,260	3,946,528	2,106,313	1,840,215
2024	1,840,215	0	2023	11,340,000,000	0.010	1,020,600	2,860,815	1,295,938	1,564,877
2025	1,564,877	0	2024	11,340,000,000	0.013	1,326,780	2,891,657	1,299,938	1,591,719
2026	1,591,719	0	2025	11,340,000,000	0.013	1,326,780	2,918,499	1,293,875	1,624,624
2027	1,624,624	0	2026	11,340,000,000	0.005	510,300	2,134,924	1,292,563	842,361
2028	842,361	0	2027	11,340,000,000	0.005	510,300	1,352,661	486,750	865,911
2029	865,911	0	2028	11,340,000,000	0.005	510,300	1,376,211	483,500	892,711
2030	892,711	0	2029	11,340,000,000	0.005	510,300	1,403,011	483,563	919,448
2031	919,448	0	2030	11,340,000,000	0.005	510,300	1,429,748	486,563	943,185
2032	943,185	0	2031	11,340,000,000	0.005	510,300	1,453,485	482,500	970,985
2033	970,985	0	2032	11,340,000,000	0.005	510,300	1,481,285	486,188	995,097
2034	995,097	0	2033	11,340,000,000	0.005	510,300	1,505,397	482,438	1,022,959

(A) INCLUDES ONE YEAR CAPITALIZED INTEREST ON EACH ISSUE
(B) PROJECTIONS BY THE DEVELOPERS
(C) 1987 ESTIMATED VALUE
(D) ASSUMES A 90 PERCENT COLLECTIONS RATE

Tax Rate Study prepared by Underwood, Neuhaus & Co., Inc.
and Greer Moreland Fosdick Shepherd Inc.

VIII. OPERATING PLAN

Operating Costs

Plant operating costs include expenditures to administer, maintain, and operate the plant, including chemical addition, chlorination, and initial pressurization. A survey of surface water plant operators in the metropolitan Houston area was conducted to develop an estimate of this cost. Based on the results of this survey, an operating cost of $.35 per thousand gallons of treated water is projected.

Conveyance and distribution system operating expenses will include maintenance of these facilities and energy costs to boost the system pressure at the Rankin Road pump station. Data regarding various distribution system operating and maintenance cost is not available. However, provisions should be made for major repairs, such as valve failures and line leaks, as well as minor repairs, such as damage to air release valves. To develop the amount required for these activities, the cost of a major repair every five years was estimated. Annual minor repair requirements were estimated by reviewing typical large utility district experience. A $.04 per-thousand-gallon charge is estimated to be required to defray these expenses. At $.06 per kwh, energy costs for repressurization are projected at $.10 per thousand gallons.

Administrative costs include maintenance management, contract negotiation and administration, record keeping, and reporting and billing. For a system of this magnitude, a staff cost of approximately $100,000 per year is appropriate. At an initial flow of 10 MGD, $.03 per thousand gallons will be required to develop these funds.

Combining these cost components, an operating cost of $.52 per thousand gallons is projected. Unlike capital costs, it is proposed that these costs be borne by the water consumer.

Surface Water Rates

To recover operating costs, $.52 per thousand gallons will be required. Additionally, raw water costs of $.23 per thousand gallons will be charged by the City of Houston for a total of $.75 per thousand gallons. The surface water rate of $.75 per thousand gallons will be required to be collected from surface water consumers. However, those districts which convert to surface water will save approximately $.12 to $.25 per thousand gallons in groundwater pumping costs for a net increase of about $.50 to $.63 per thousand gallons in water costs.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Heavy groundwater pumpage has resulted in significant water table decline which has created major water supply problems, such as decreased well capacity and poor water quality.

2. Unless surface water is brought into the service area to supplement the existing groundwater, the continued growth and increased water demand will exacerbate the existing problems of gas intrusion, loss of well capacity, and deteriorating water quality.

3. Based on the findings of this study and on the Water For Texas report published by the Texas Department of Water Resources, the groundwater supply will not be able to meet the needs of the area by 1990 to 1995.

4. The HGCSD has issued mandates on groundwater usage that require the majority of the NHCWSC service area to convert to 80 percent surface water by the year 2005 with most of the remainder of the area converting to 80 percent surface water by the year 2010.

5. This study defines a surface water facility plan that will provide an adequate supply of surface water to meet the NHCWSC needs.

6. There is not an existing governmental entity charged with the responsibility to bring surface water to the NHCWSC service area. Some type of regional district entity that is charged with the responsibility and authority to implement and finance the plan is required.

7. Once an entity is in place, the surface water facilities can be constructed through the sale of tax exempt municipal bonds. Based on this study, approximately $84 million in bonds will be required for the construction of the project. Debt service on the bonds will require

an initial tax of approximately $.05/$100 assessed value, with taxes to range between $.05 and $.10 over the life of the project.

8. Surface water supplies sufficient to meet the NHCWSC needs can be obtained most economically from the Lake Houston System.

9. The cost to purchase the raw water from the Lake Houston source, treat the water, and pump it through the NHCWSC's distribution lines will be approximately $.75 per thousand gallons of water produced. This is approximately $.50 per thousand gallons more than the typical cost to produce groundwater in this area of $.25 per thousand gallons.

10. Any program related to water supply should include recommendations for implementing a long-term plan for water conservation to help reduce the increasing water demand within the service area.

Recommendations

1. Approve the surface water facility plan as presented in this report.

2. Encourage the creation of Regional District as the entity to deal with the various water districts, water suppliers, and the City of Houston for implementation of the surface water plan.

3. Encourage implementation of the first phase of the plan, including the conveyance and distribution system and 10 MGD of plant capacity, by 1990-91.

4. Complete contract negotiations on behalf of the NHCWSC (or any subsequent regional entity) with the City of Houston for the purchase of raw water from the Lake Houston System, participation in the construction of the northeast water purification plant, and sharing in the cost of the conveyance facilities.

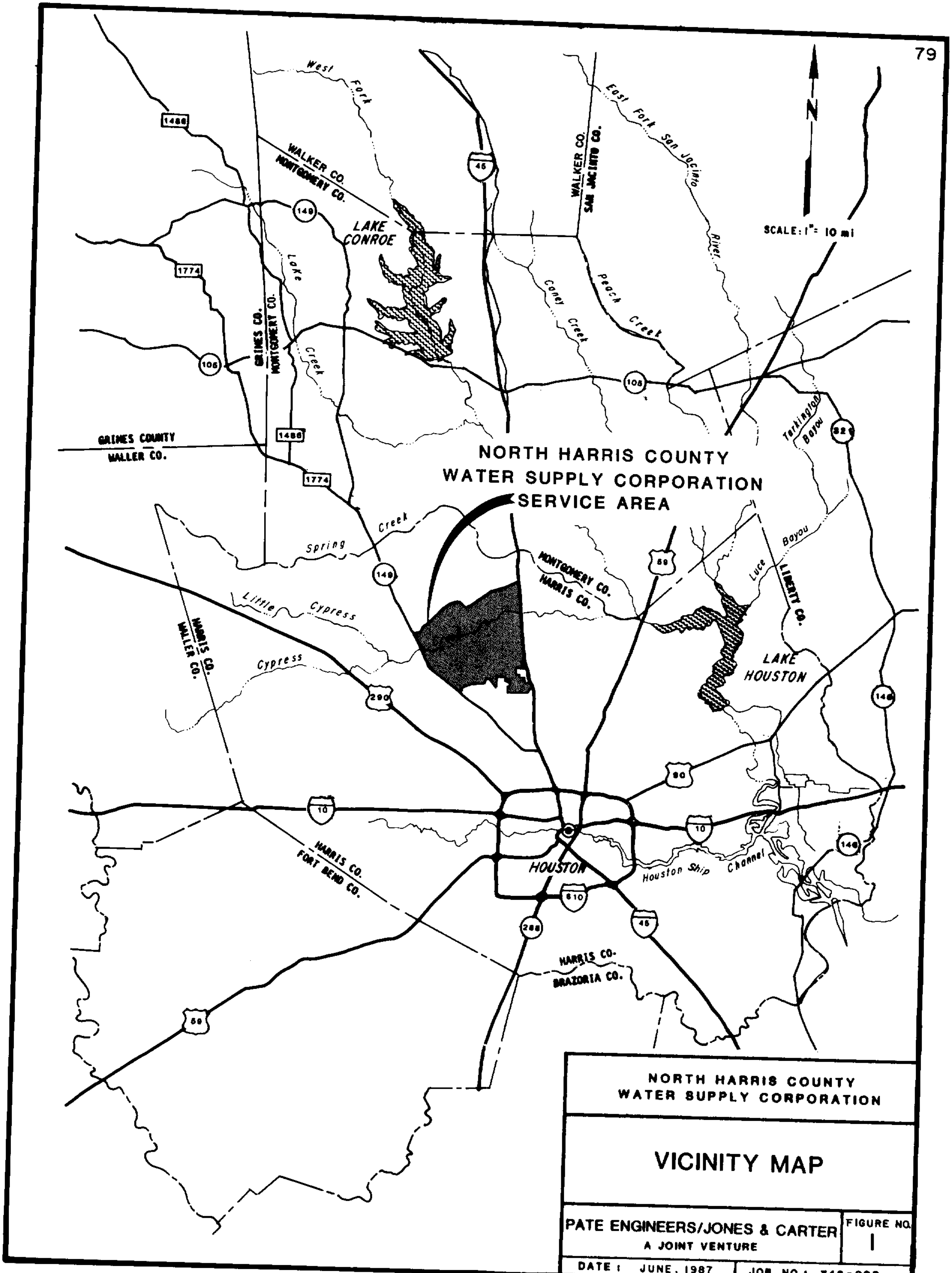
5. Continue discussions with districts and water suppliers to determine the contract parameters necessary for delivery of surface water to the NHCWSC service area.

6. The NHCWSC (or any subsequent regional entity) should work with the districts and water suppliers to develop a long-term water conservation program that will help slow the increasing water demand in the area.

NOTES

[1]Texas Water Development Board, Ground-Water Resources of Montgomery County, Texas, Report 136, Austin, Texas Water Development Board, 1971, p. 11.

EXHIBITS



NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

VICINITY MAP

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE NO. 1

DATE: JUNE, 1987

JOB NO.: 348-002

NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION
BOUNDARY MAP

PATE ENGINEERS/JONES & CARTER A JOINT VENTURE	FIGURE No. 2
DATE: MAY, 1987	JOB NO. 225-02-00

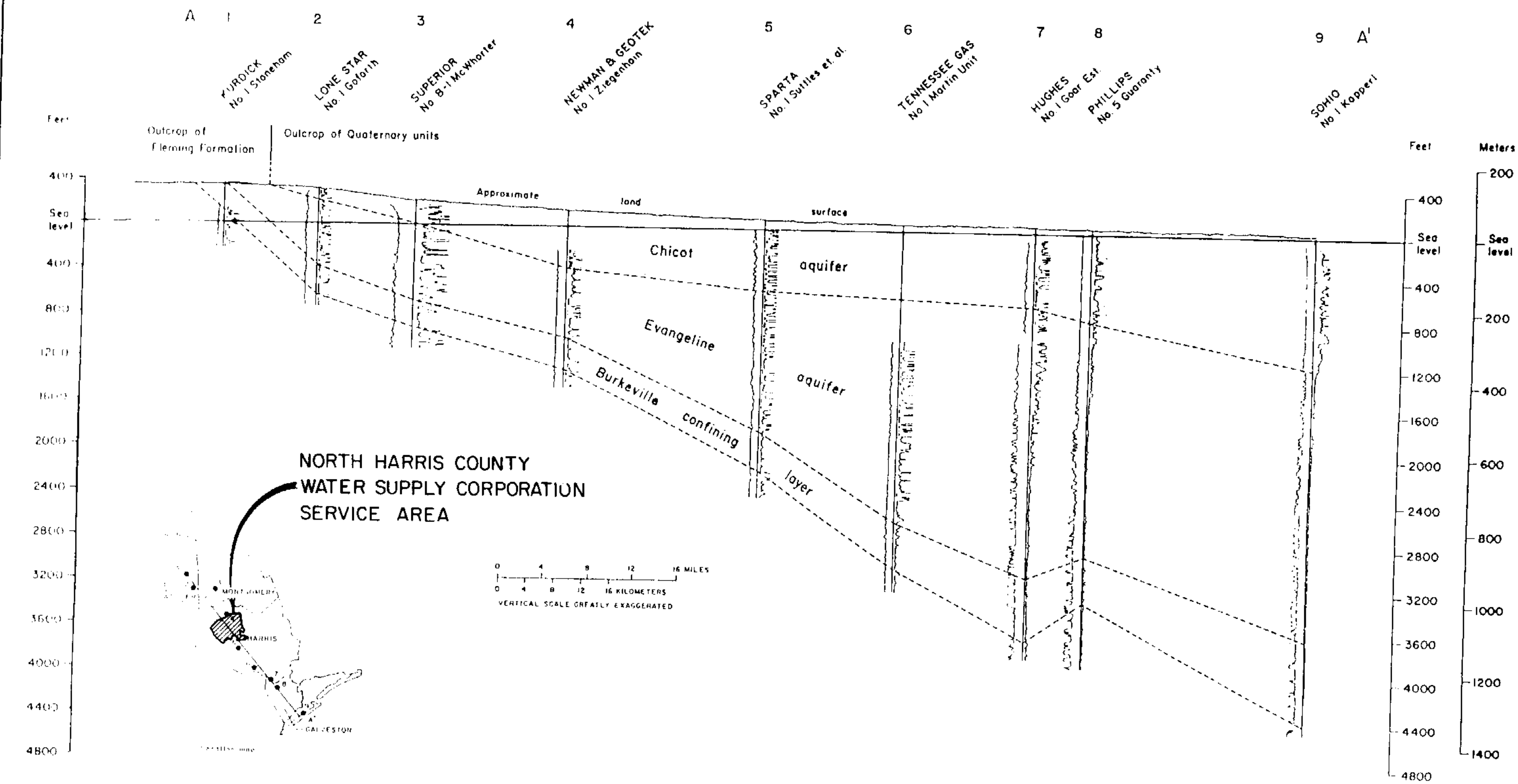


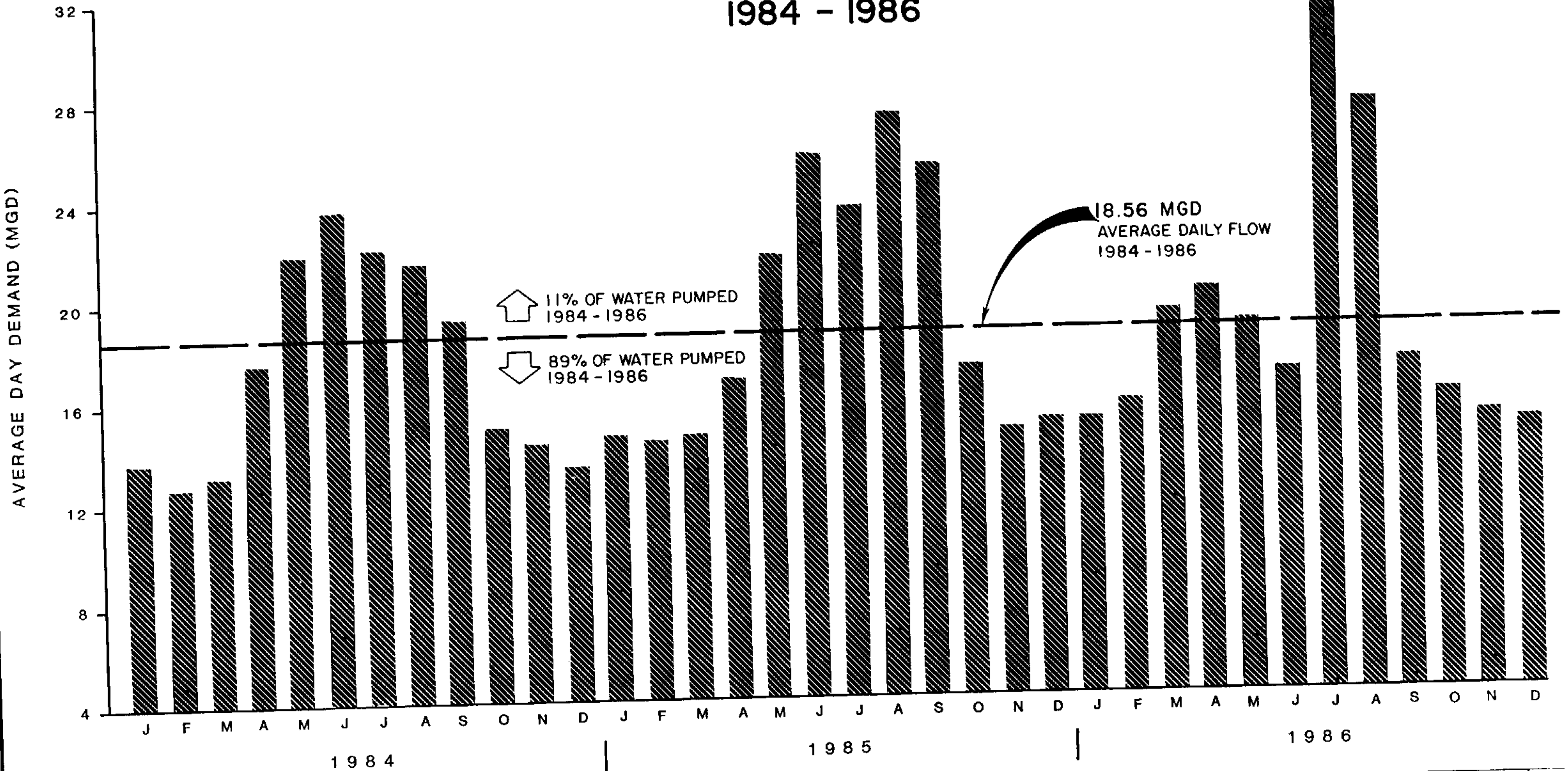
FIGURE NO. 3
HYDROGEOLOGIC CROSS SECTION

Figure 2
Hydrogeologic Section in Northern Region

Courtesy of Texas Department of Water Resources

Modified from Baker, 1978

NORTH HARRIS COUNTY WATER SUPPLY CORPORATION
MONTHLY PUMPING RATES
1984 - 1986



PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE
DATE : MAY , 1987 | JOB NO. 225-02-00
FIGURE 4

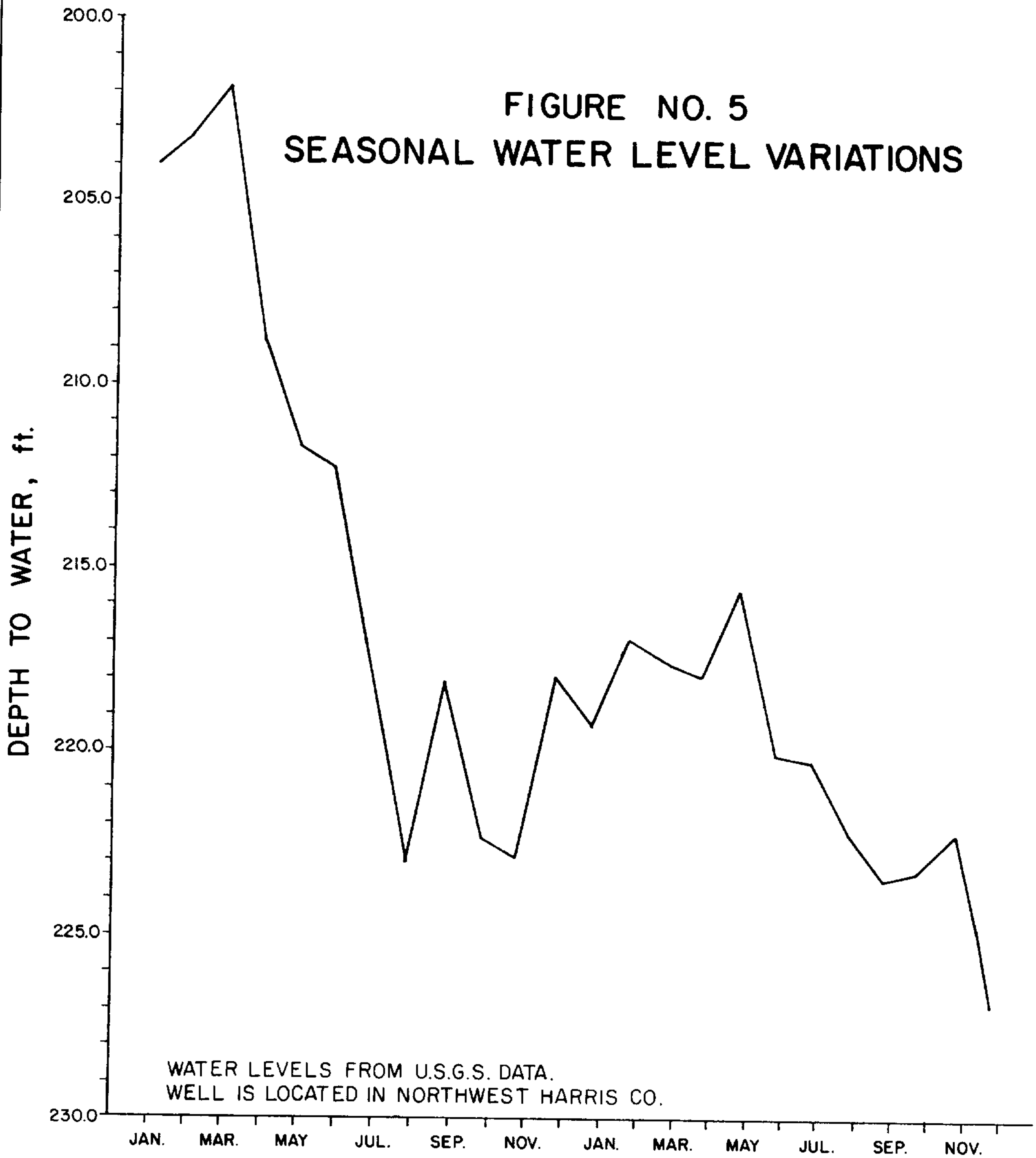
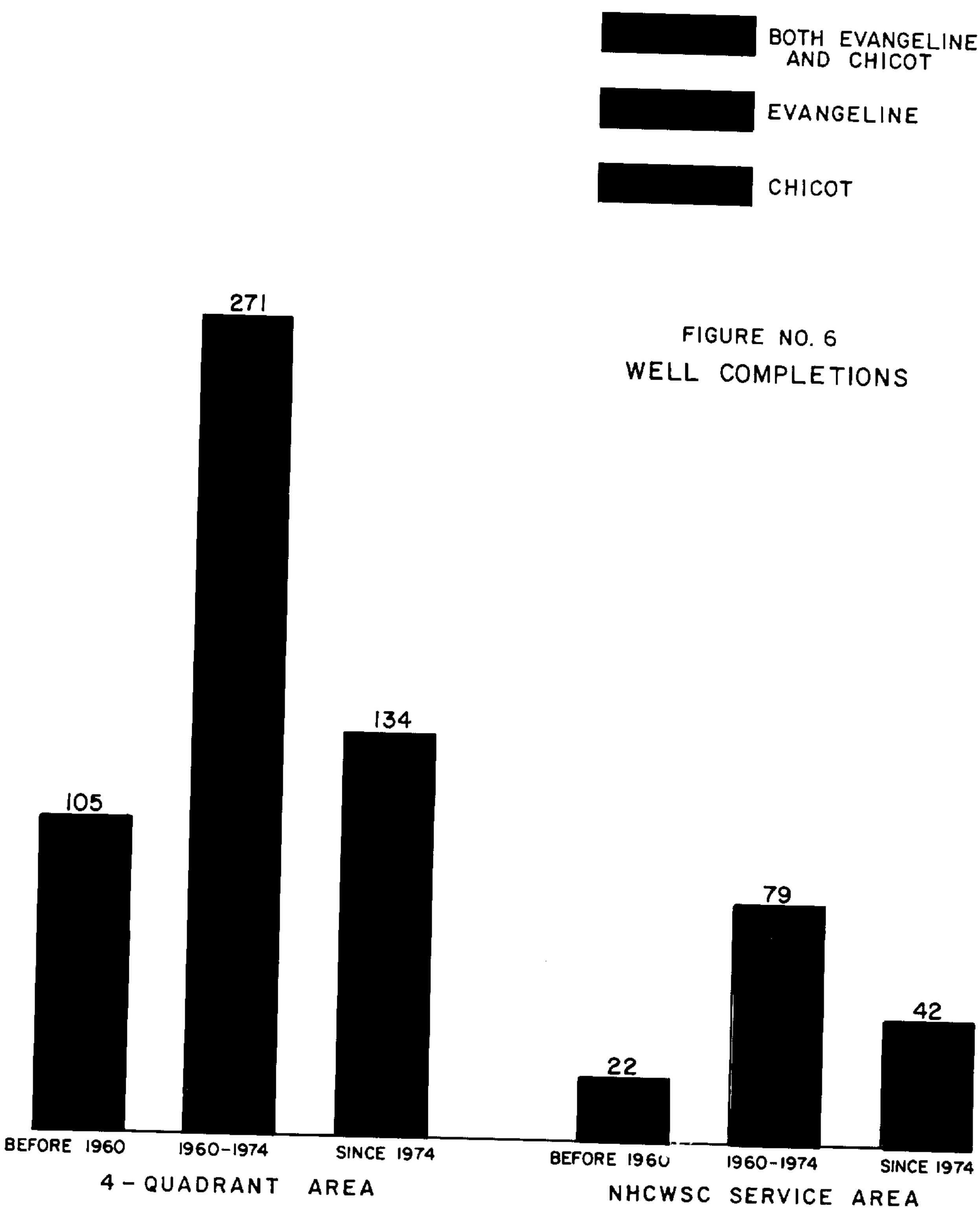


FIGURE NO. 5
SEASONAL WATER LEVEL VARIATIONS
DEPTH TO WATER, ft.
200.0
205.0
210.0
215.0
220.0
225.0
230.0
JAN.
MAR.
MAY
JUL.
SEP.
NOV.
JAN.
MAR.
MAY
JUL.
SEP.
NOV.
WATER LEVELS FROM U.S.G.S. DATA.
WELL IS LOCATED IN NORTHWEST HARRIS CO.

FIGURE NO. 5



TOTAL NUMBER OF WELLS COMPLETED

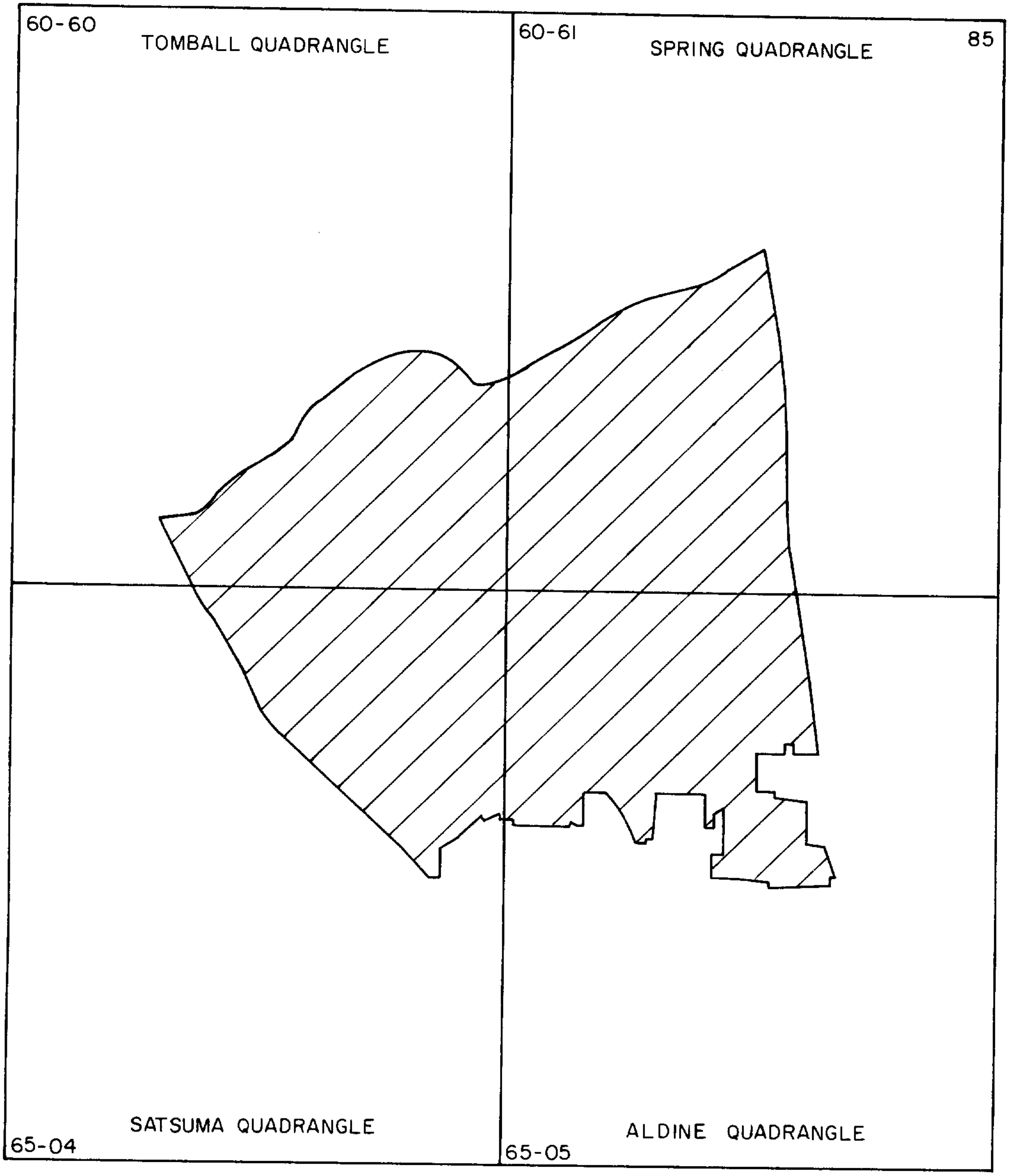
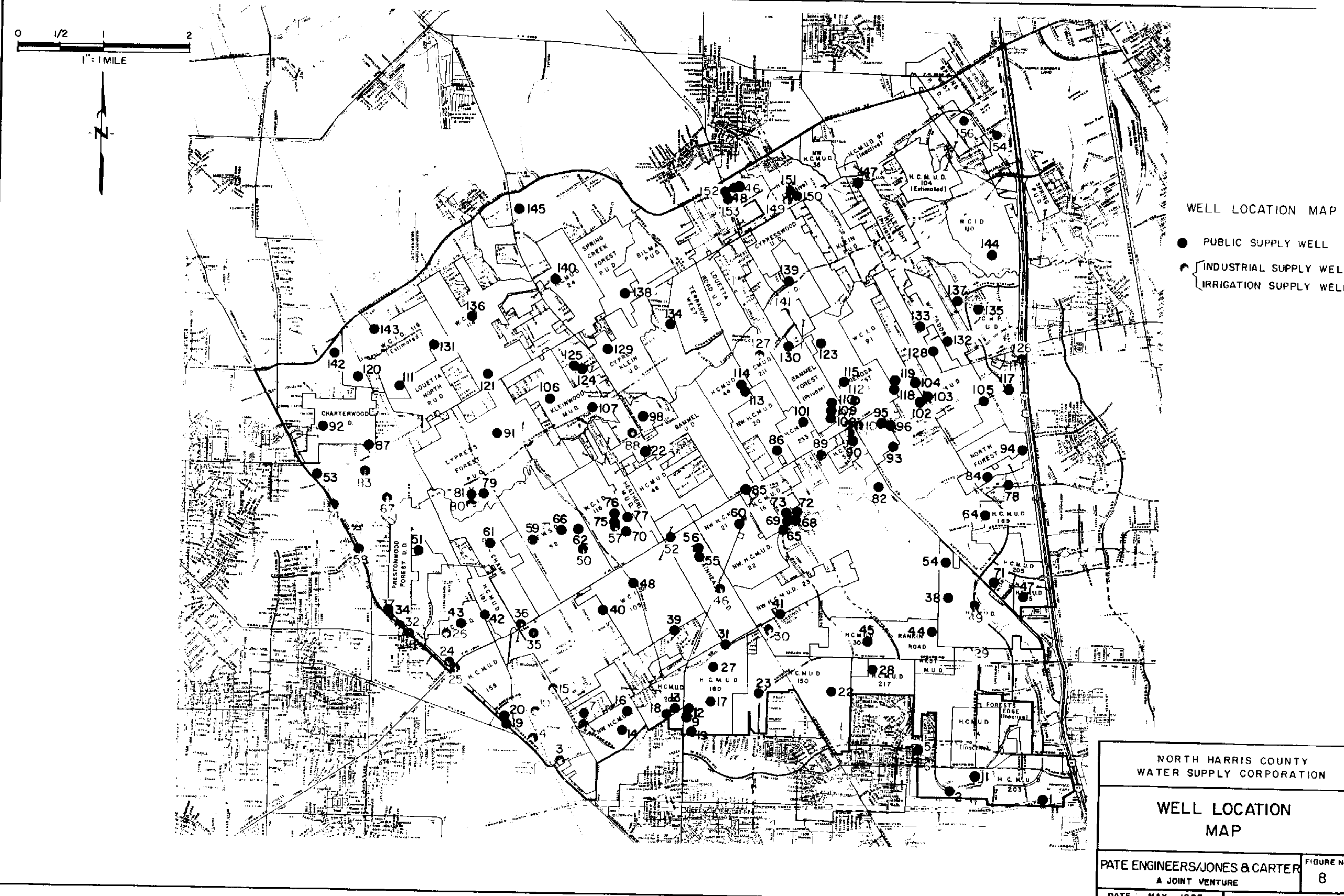


FIGURE No. 7
4 QUADRANT AREA

MAY, 1987



NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

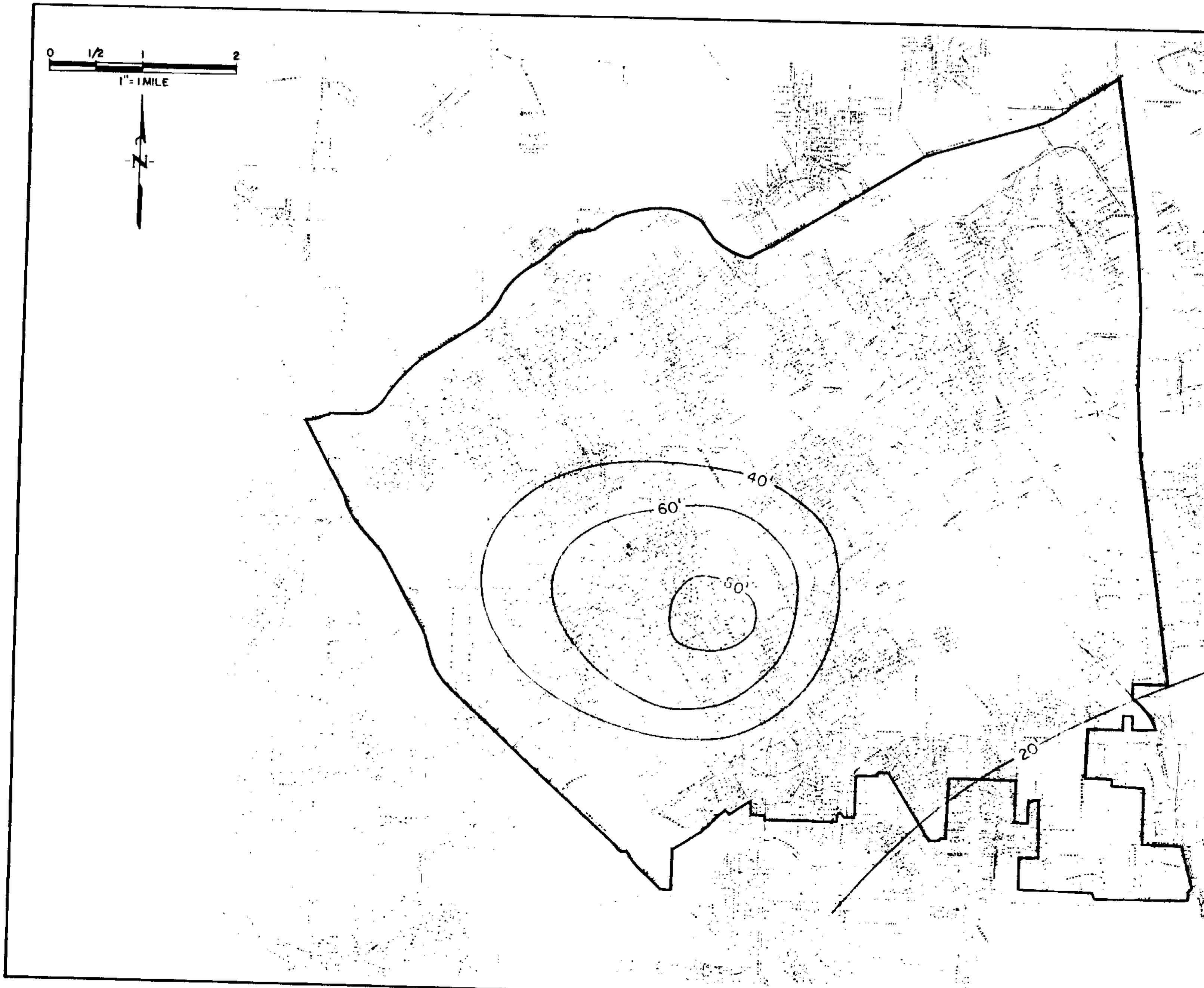
WELL LOCATION MAP

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE No. 8

DATE: MAY, 1987

JOB NO. 225-02-00



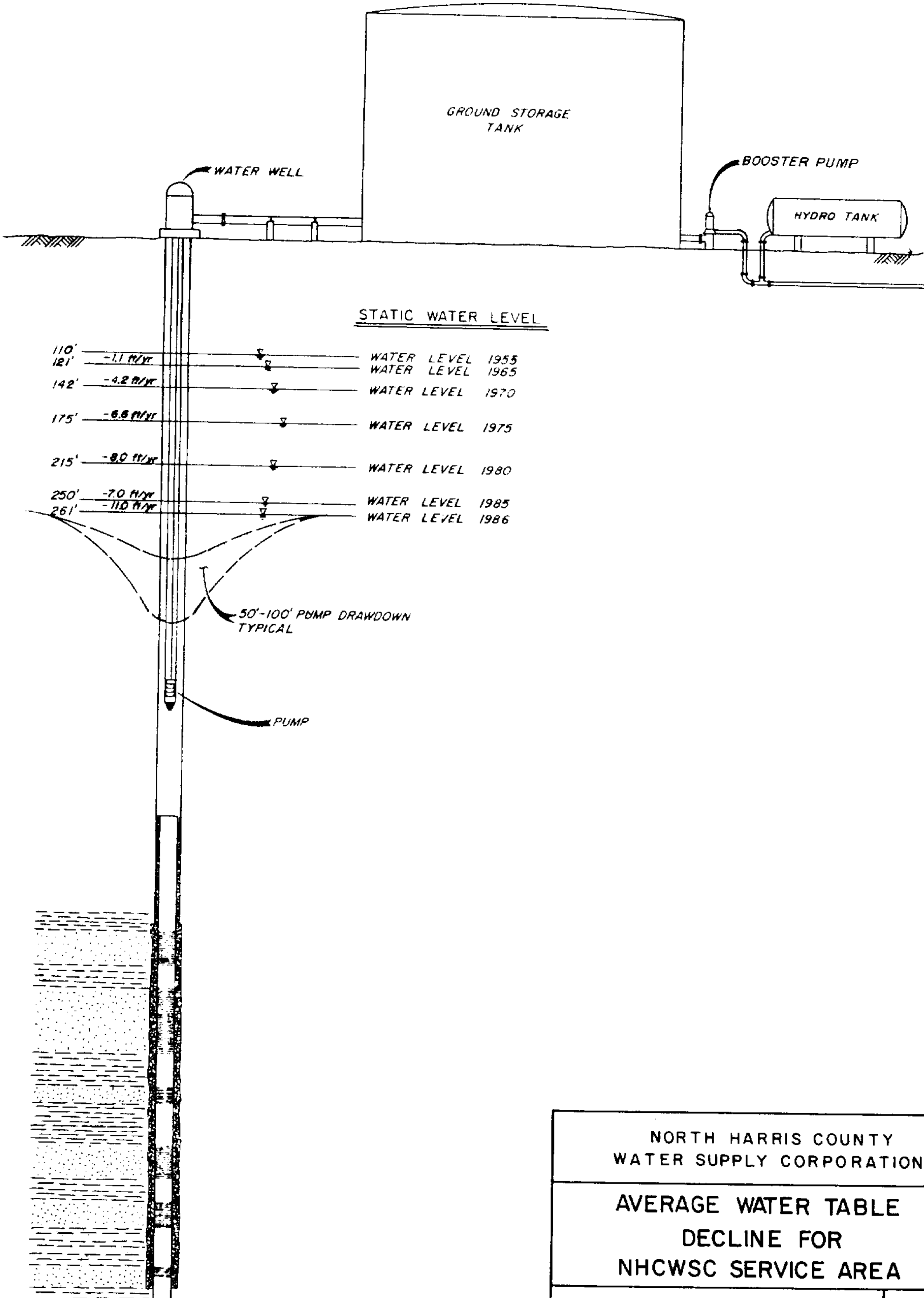
NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

AREA OF WATER
TABLE DECLINE
1977 - 1987

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE No 9

DATE: MAY, 1987 | JOB NO. 225-02-00



NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

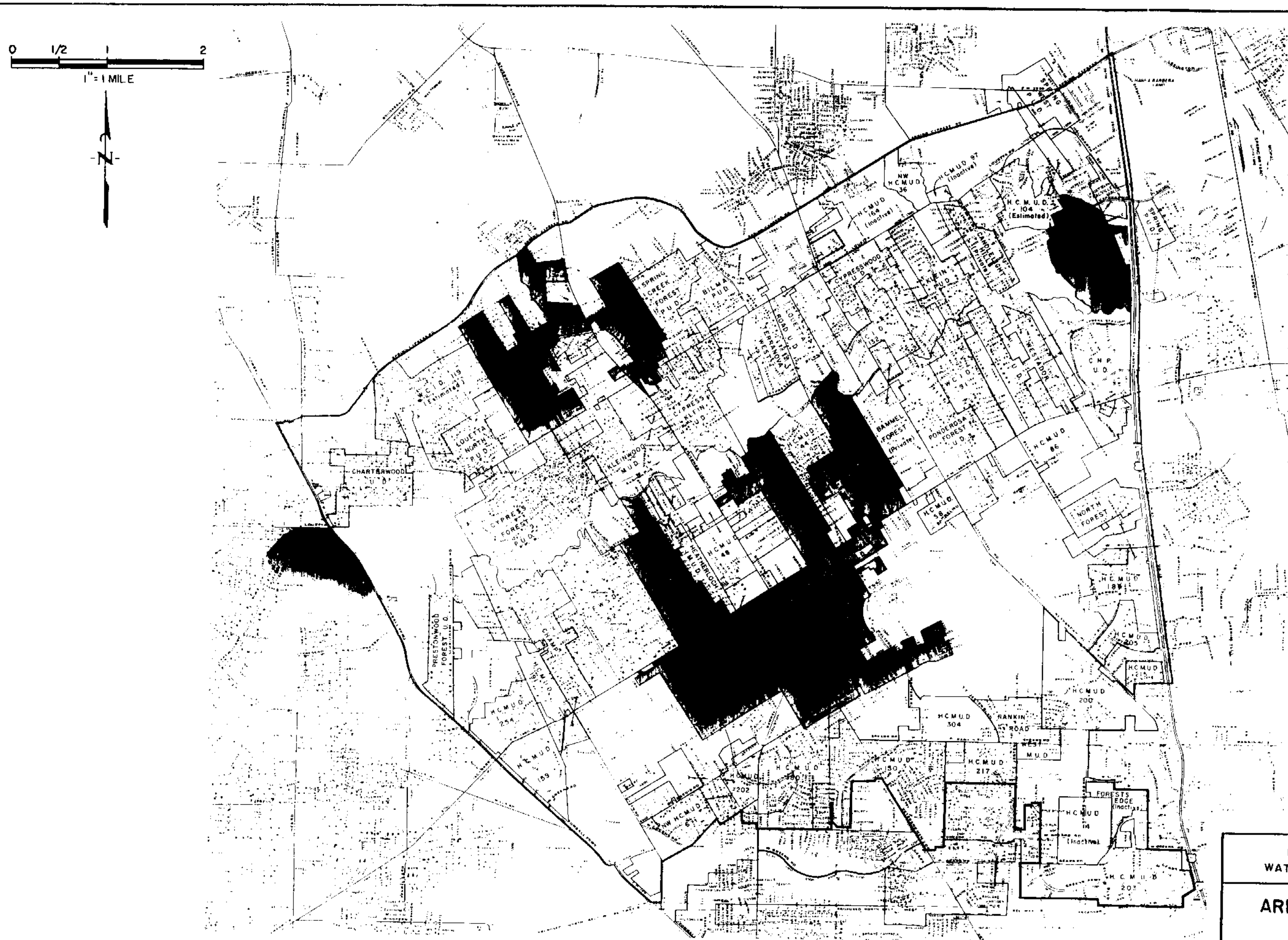
AVERAGE WATER TABLE DECLINE FOR NHCWSC SERVICE AREA

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE No. 10

DATE: MAY, 1987

JOB NO. 225-02-00



NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

AREAS EXPERIENCING GAS INTRUSION

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE No. 11

DATE: MAY ,-1987 | JOB NO. 225-02-00

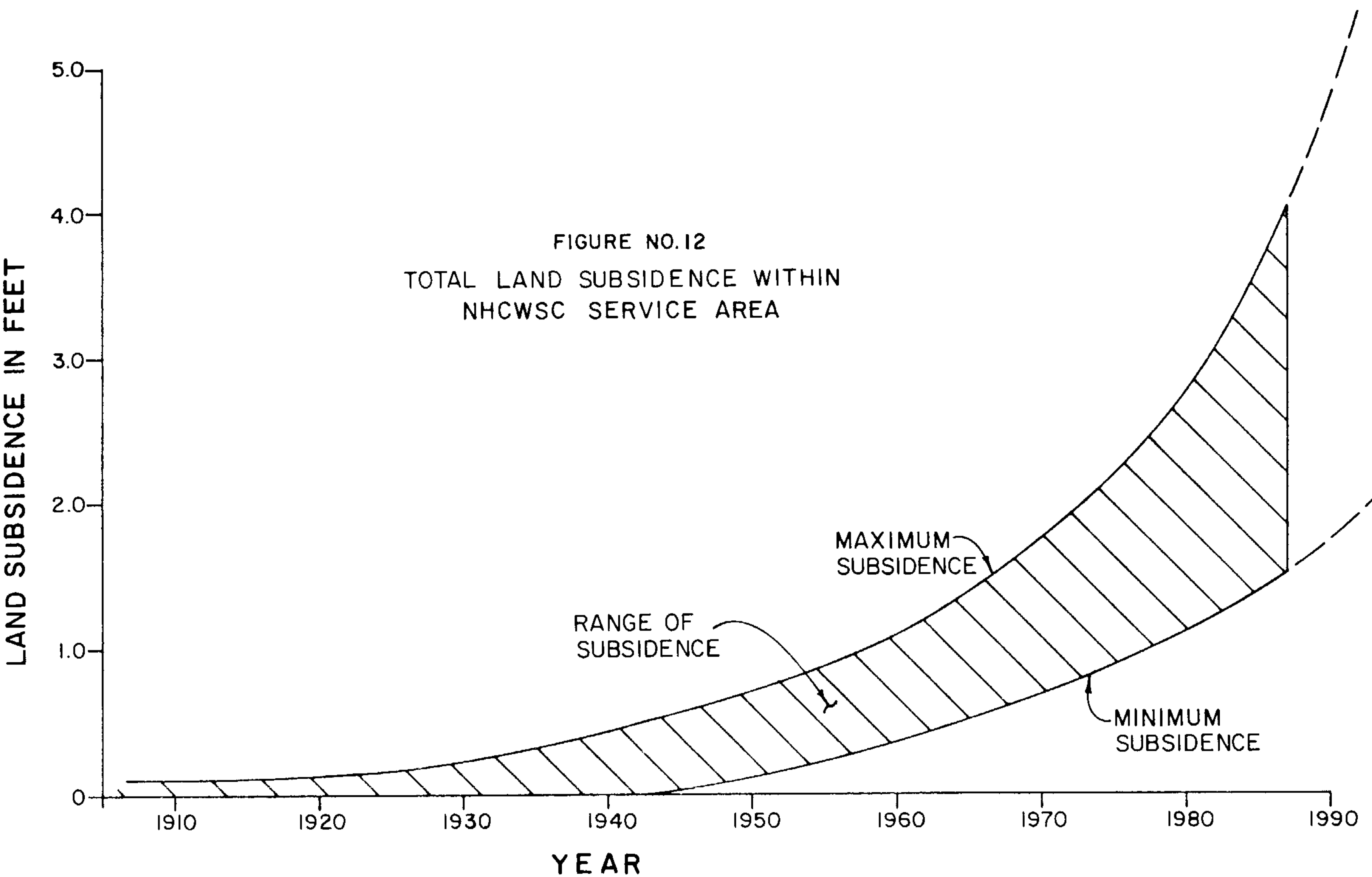
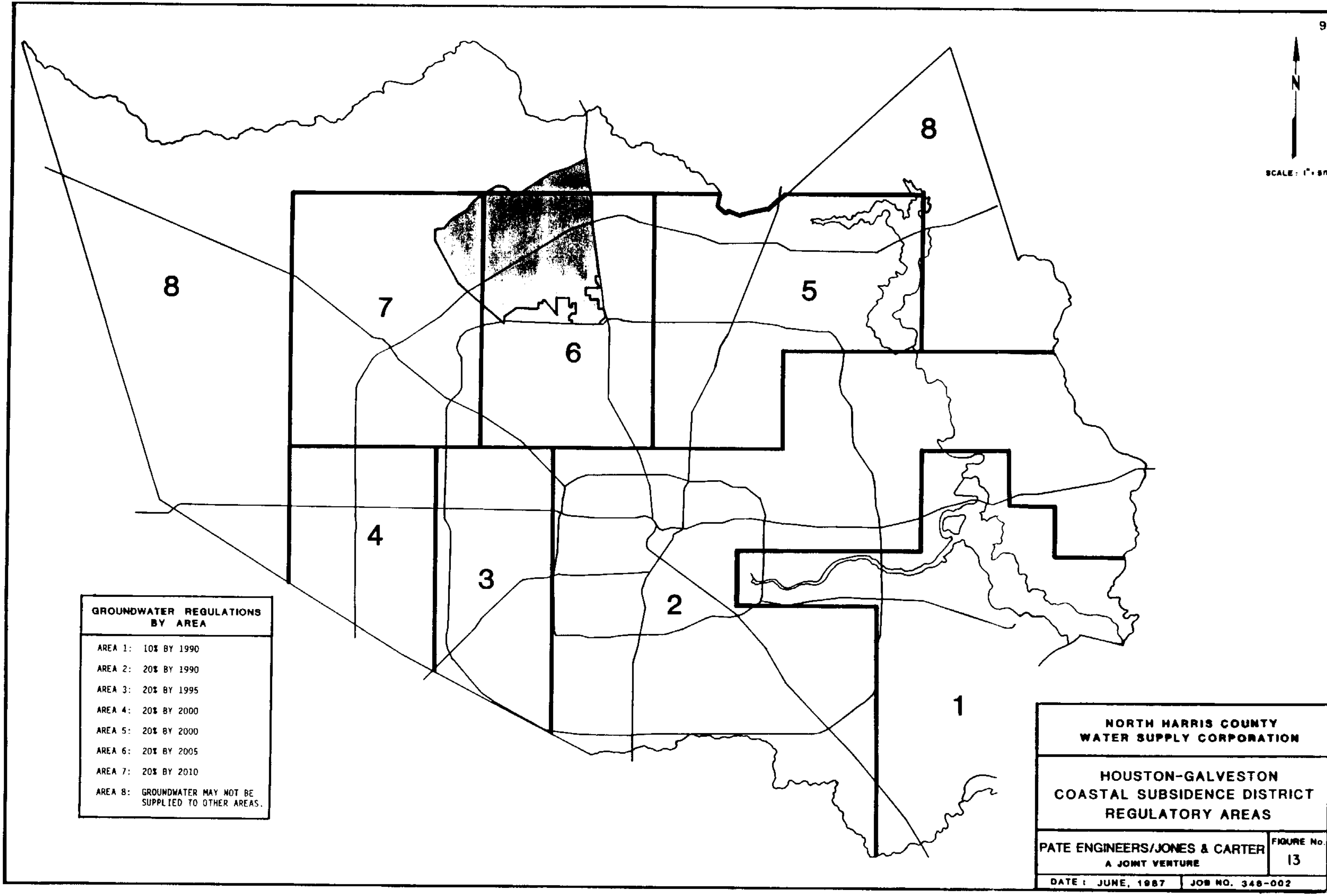
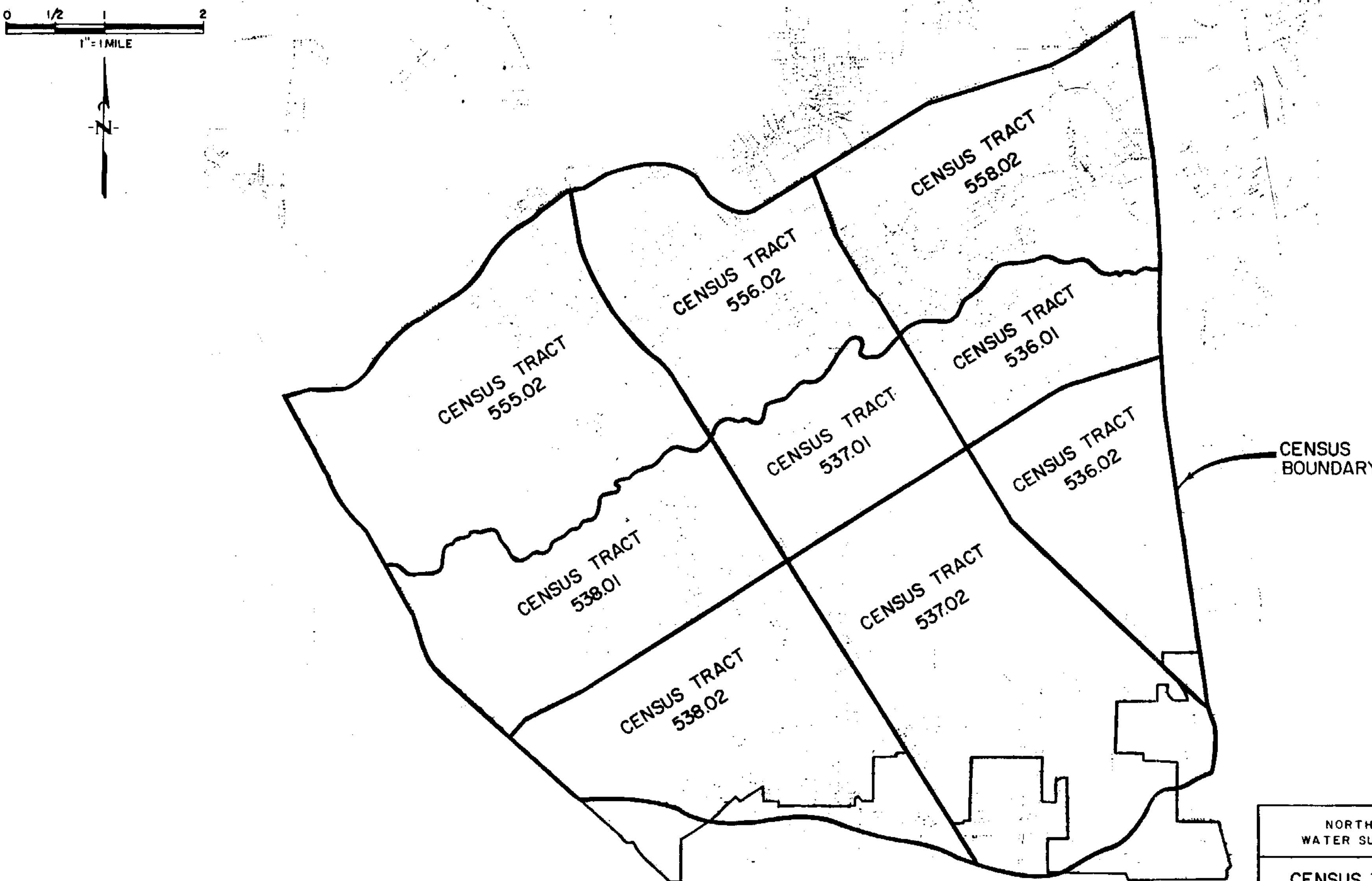


FIGURE NO. 12
TOTAL LAND SUBSIDENCE WITHIN
NHCWSC SERVICE AREA

FIGURE NO. 12


N
SCALE: 1" = 5mi
8
8
7
6
5
4
3
2
1
GROUNDWATER REGULATIONS BY AREA
AREA 1: 10% BY 1990
AREA 2: 20% BY 1990
AREA 3: 20% BY 1995
AREA 4: 20% BY 2000
AREA 5: 20% BY 2000
AREA 6: 20% BY 2005
AREA 7: 20% BY 2010
AREA 8: GROUNDWATER MAY NOT BE SUPPLIED TO OTHER AREAS.
NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION
HOUSTON-GALVESTON
COASTAL SUBSIDENCE DISTRICT
REGULATORY AREAS
PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE
FIGURE No.
13
DATE: JUNE, 1987
JOB NO. 348-002



NORTH HARRIS COUNTY WATER SUPPLY CORPORATION	
CENSUS TRACTS WITHIN NHCWSC SERVICE AREA	
PATE ENGINEERS/JONES & CARTER A JOINT VENTURE	FIGURE No. 14
DATE: MAY, 1987	JOB NO. 225-02-00

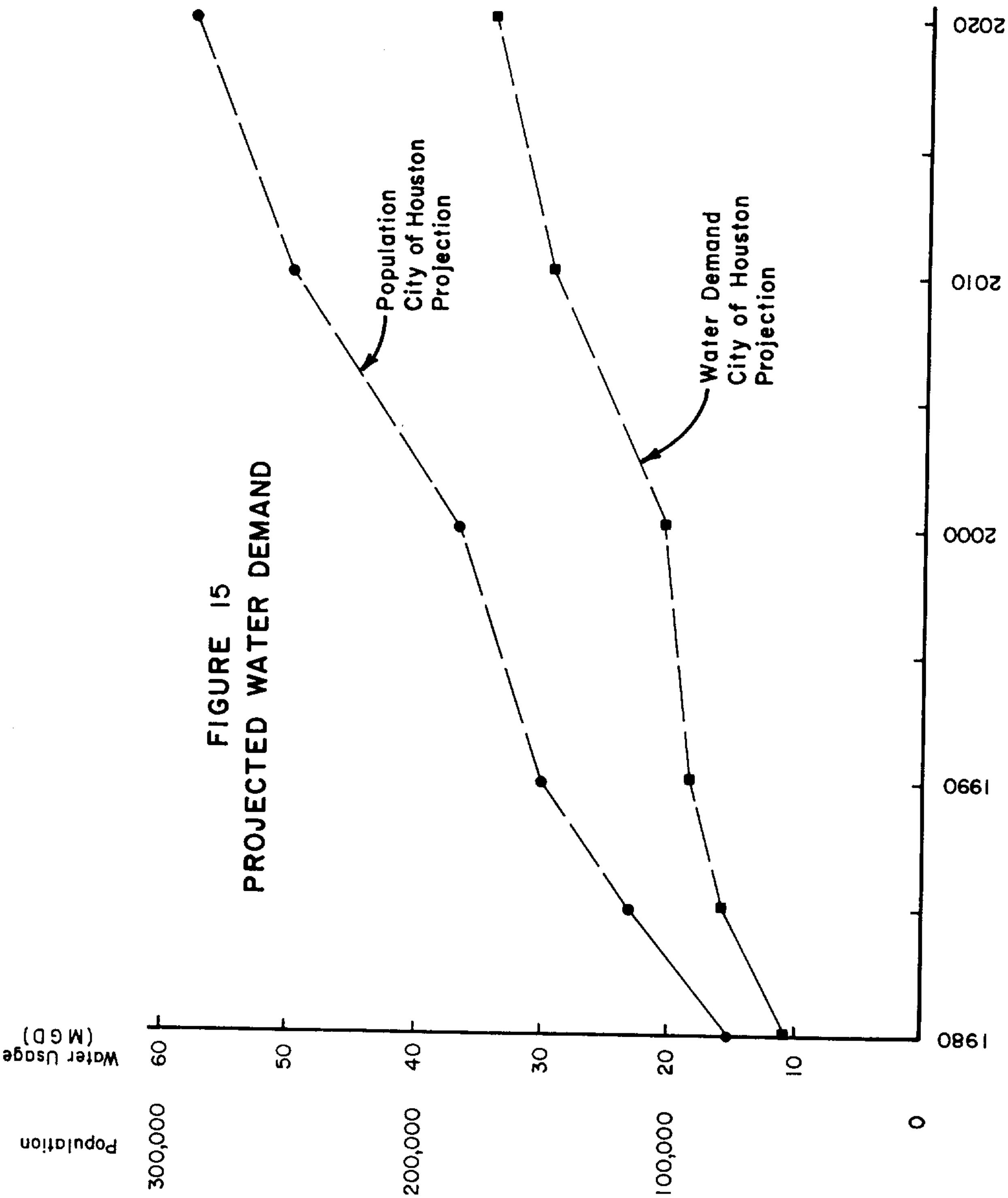


FIGURE 15
PROJECTED WATER DEMAND

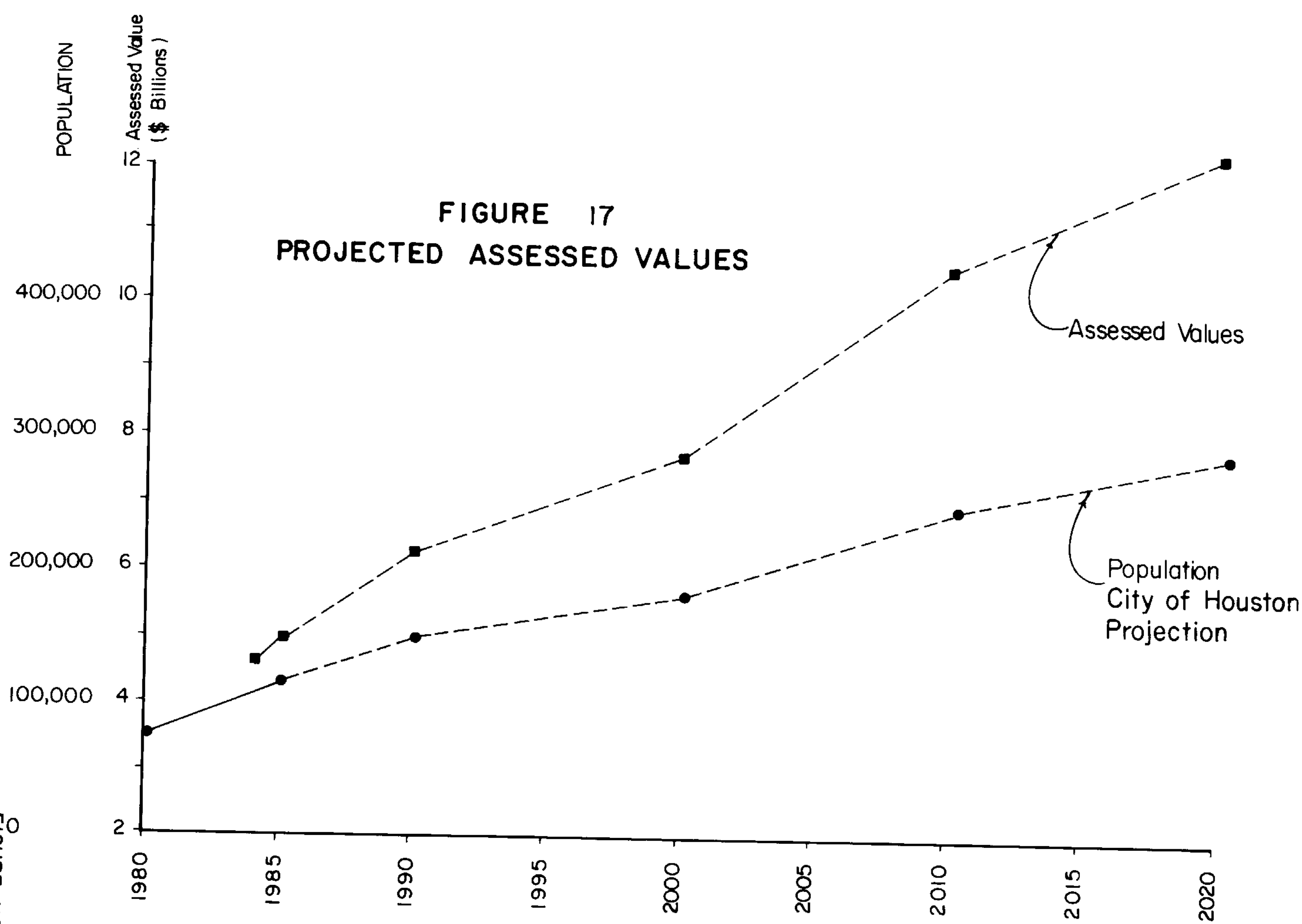
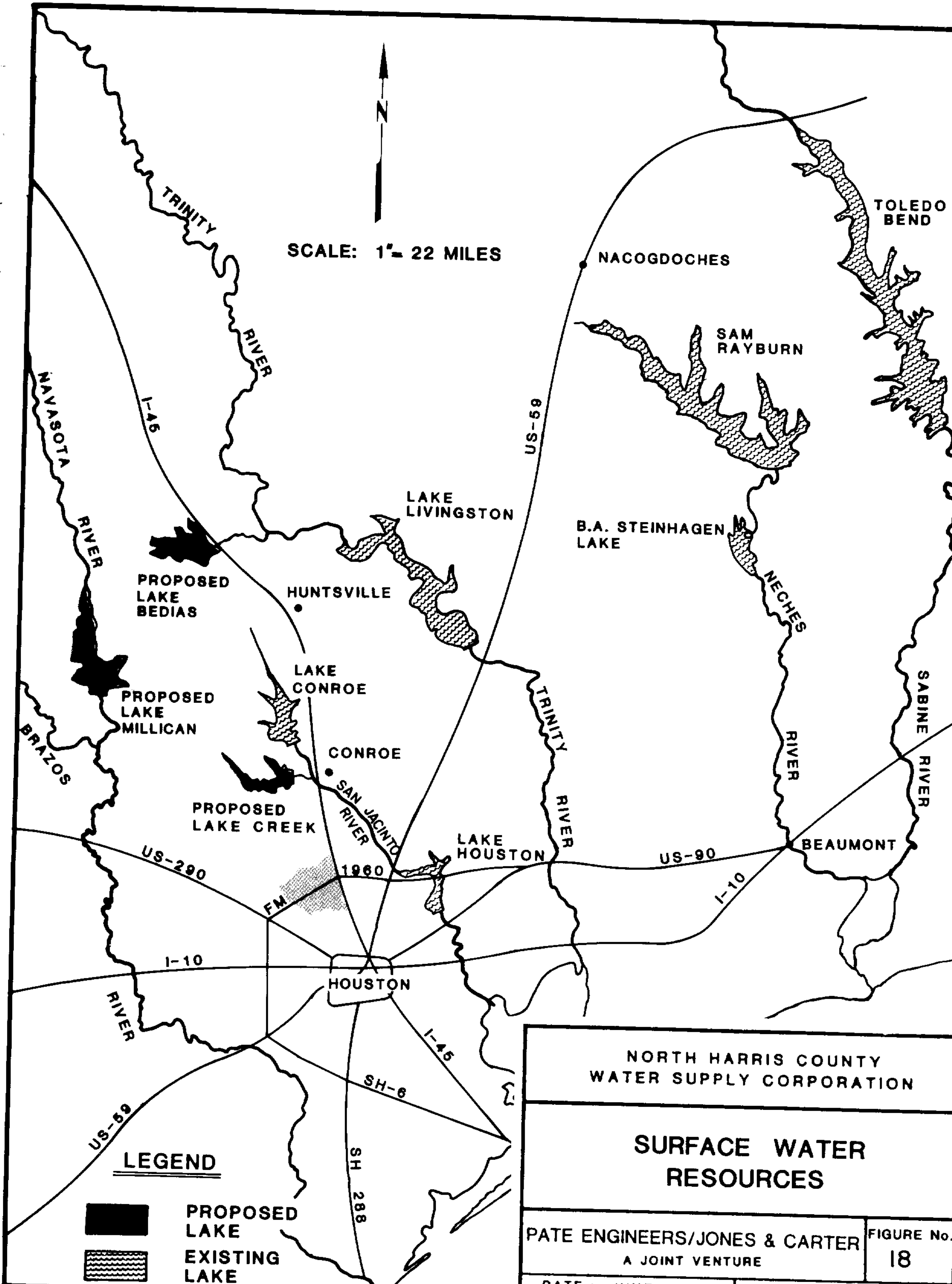

POPULATION
Assessed Value ($ Billions)
400,000
300,000
200,000
100,000
0
12
10
8
6
4
2
1980
1985
1990
1995
2000
2005
2010
2015
2020
FIGURE 17
PROJECTED ASSESSED VALUES
Assessed Values
Population
City of Houston
Projection

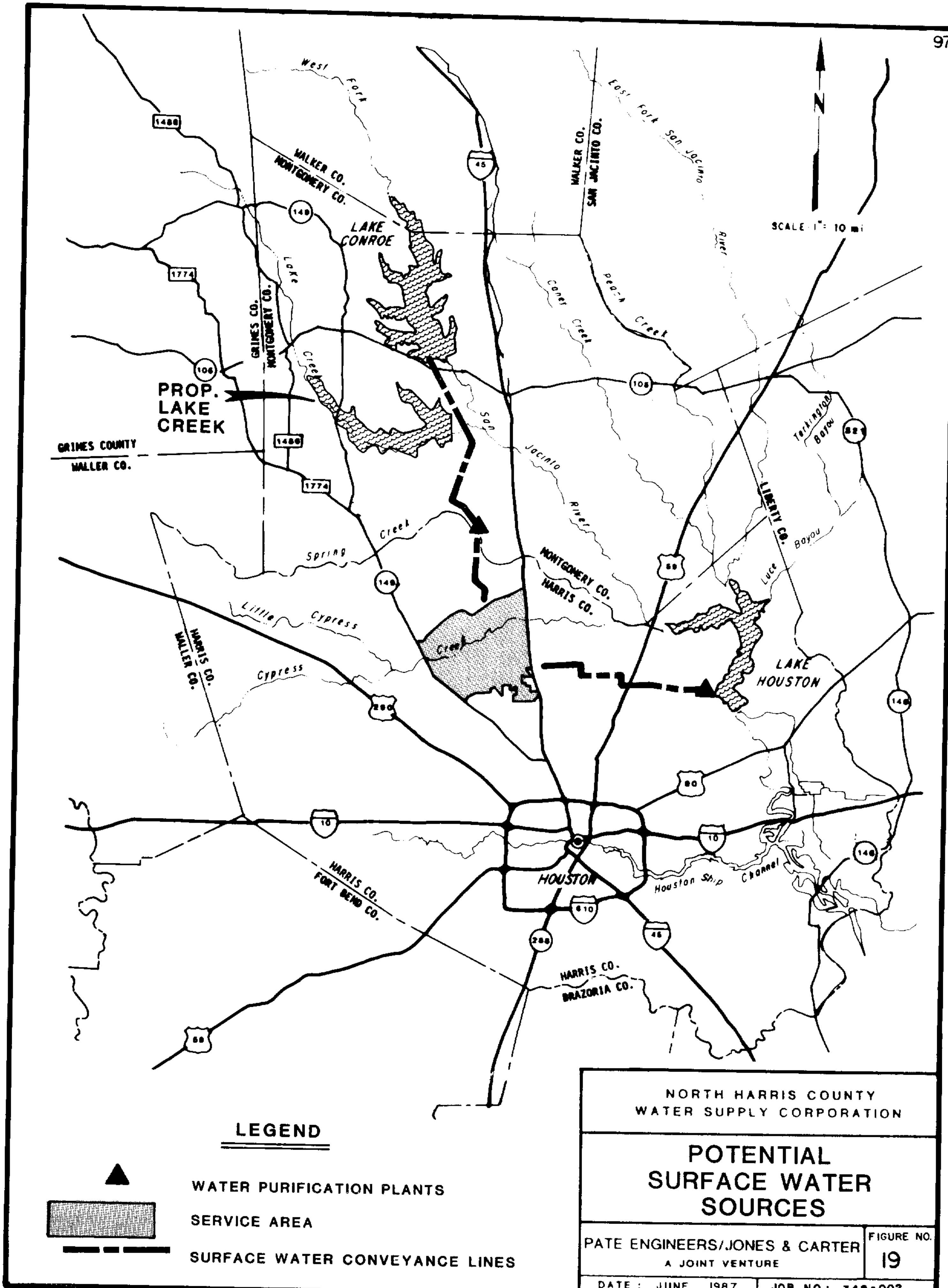
FIGURE NO. 17



NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

SURFACE WATER RESOURCES

PATE ENGINEERS/JONES & CARTER A JOINT VENTURE	FIGURE No. 18
DATE : JUNE, 1987	JOB NO. 348-002



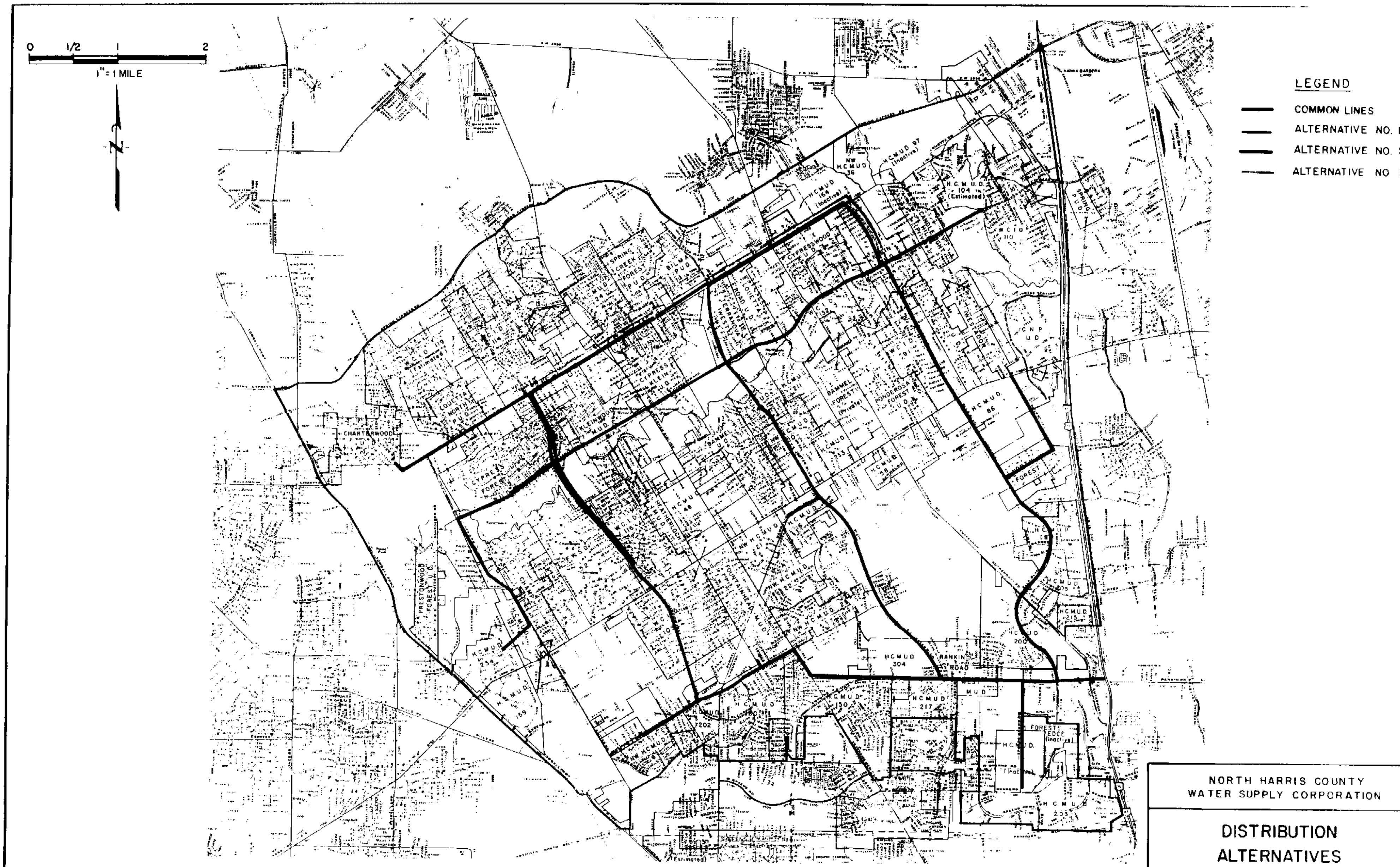
NORTH HARRIS COUNTY WATER SUPPLY CORPORATION

POTENTIAL SURFACE WATER SOURCES

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE NO. 19

DATE: JUNE, 1987 | JOB NO.: 348-002



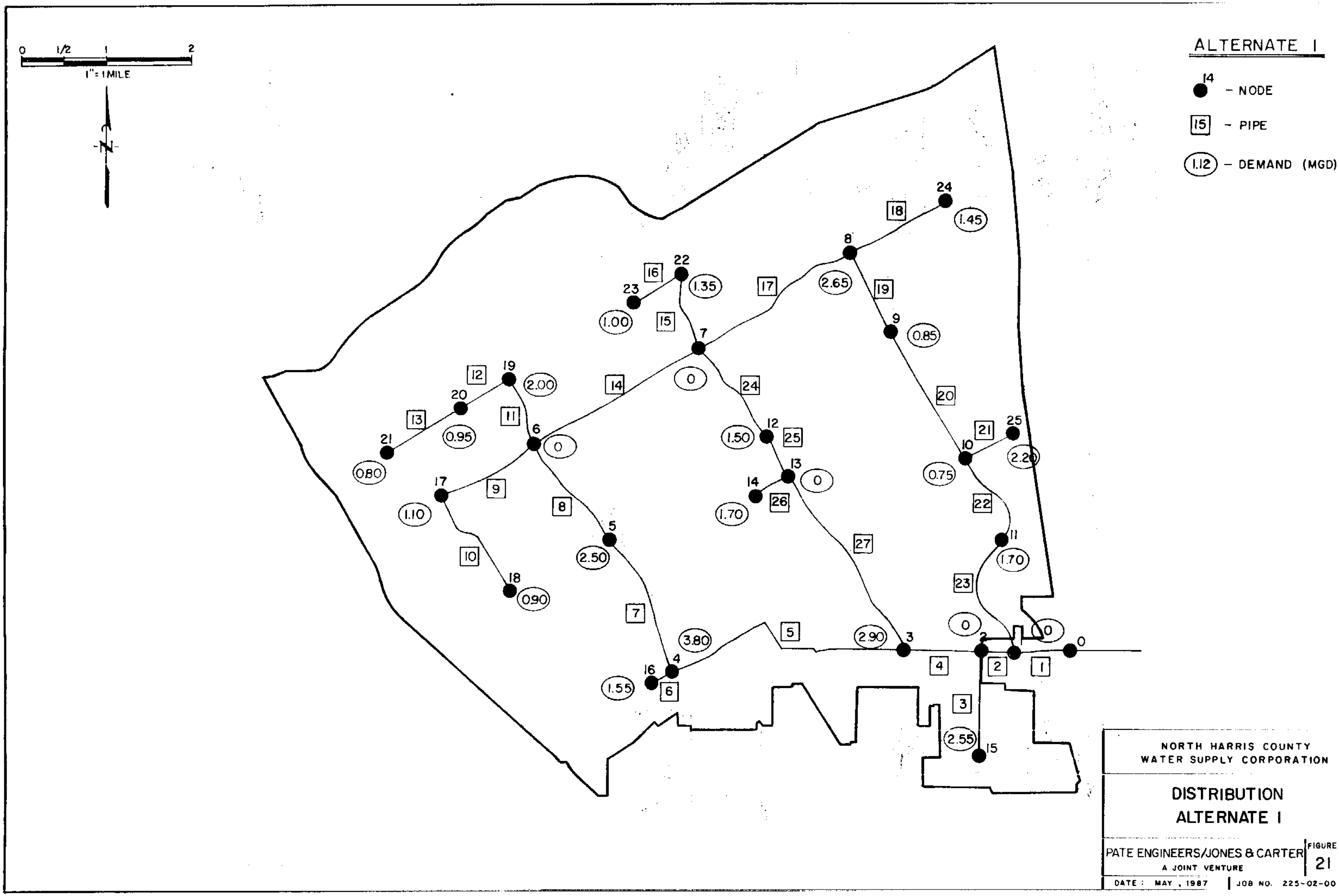
NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

DISTRIBUTION ALTERNATIVES

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE No. 20

DATE: MAY, 1987 | JOB NO. 225-02-00



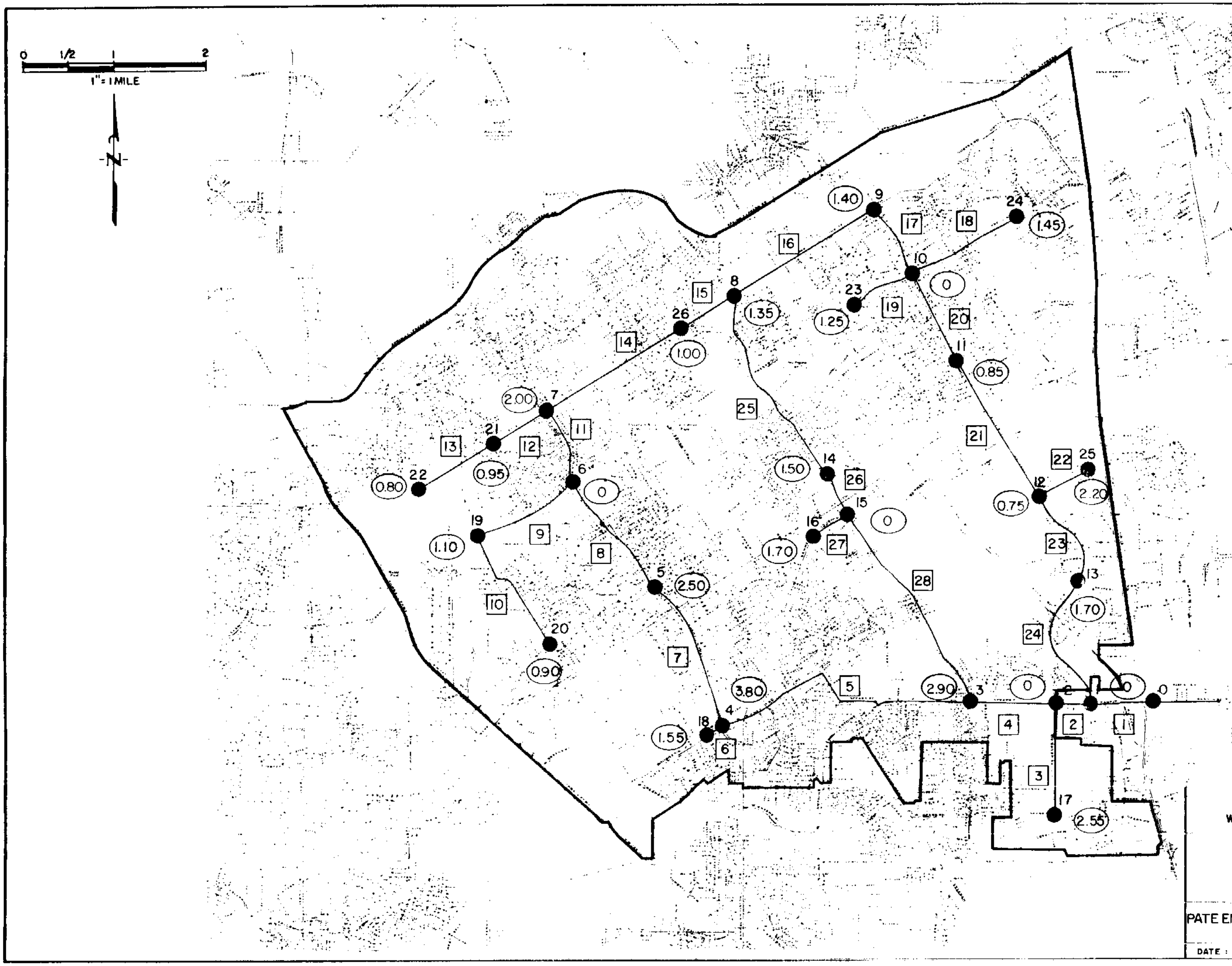
NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

DISTRIBUTION
ALTERNATE I

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE 21

DATE: MAY, 1987 | JOB NO. 225-02-00



ALTERNATE 2

- 14 ● - NODE
- [15] - PIPE
- (1.12) - DEMAND (MGD)

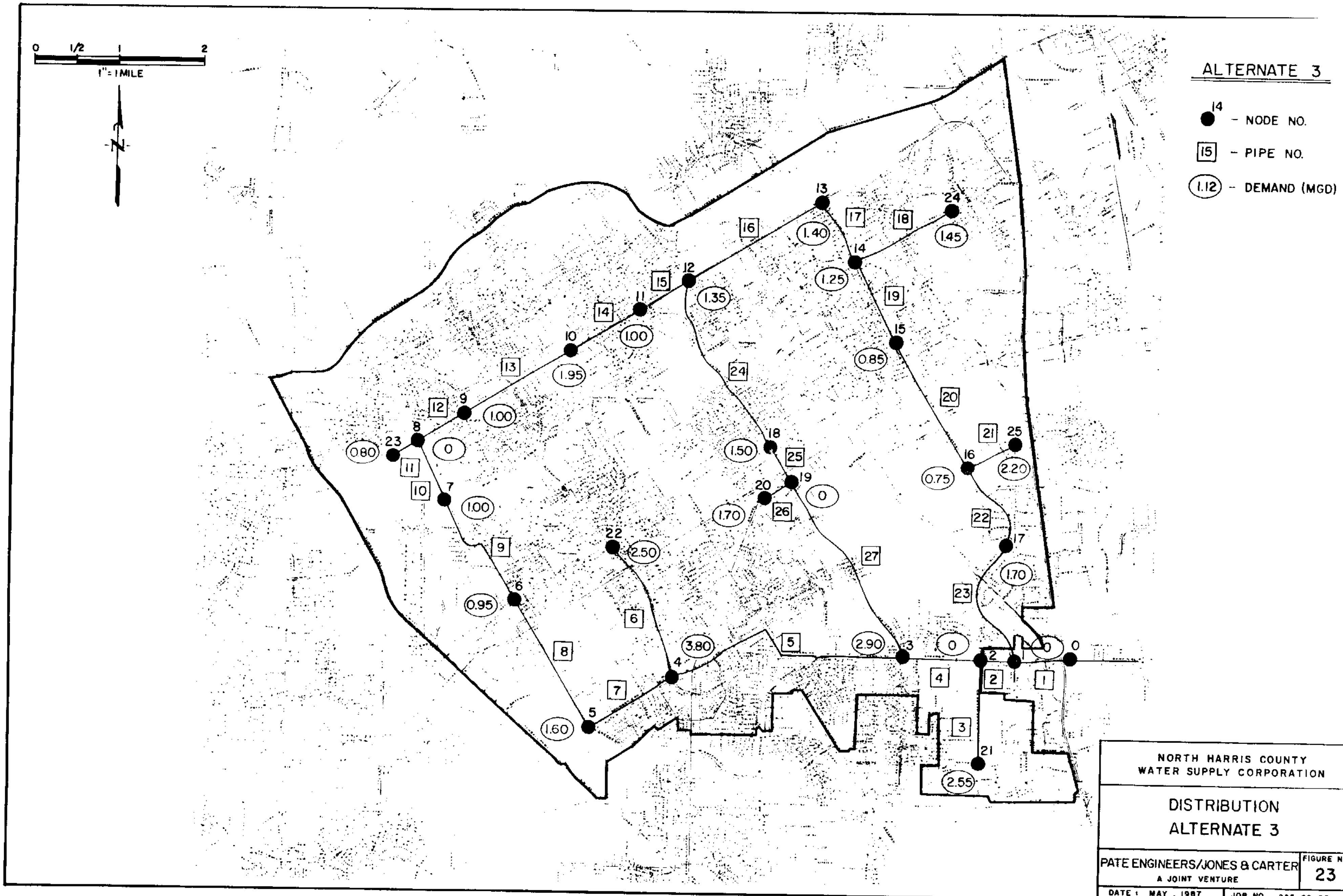
NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

DISTRIBUTION
ALTERNATE 2

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE No. 22

DATE: MAY, 1987 | JOB NO. 225-02-00



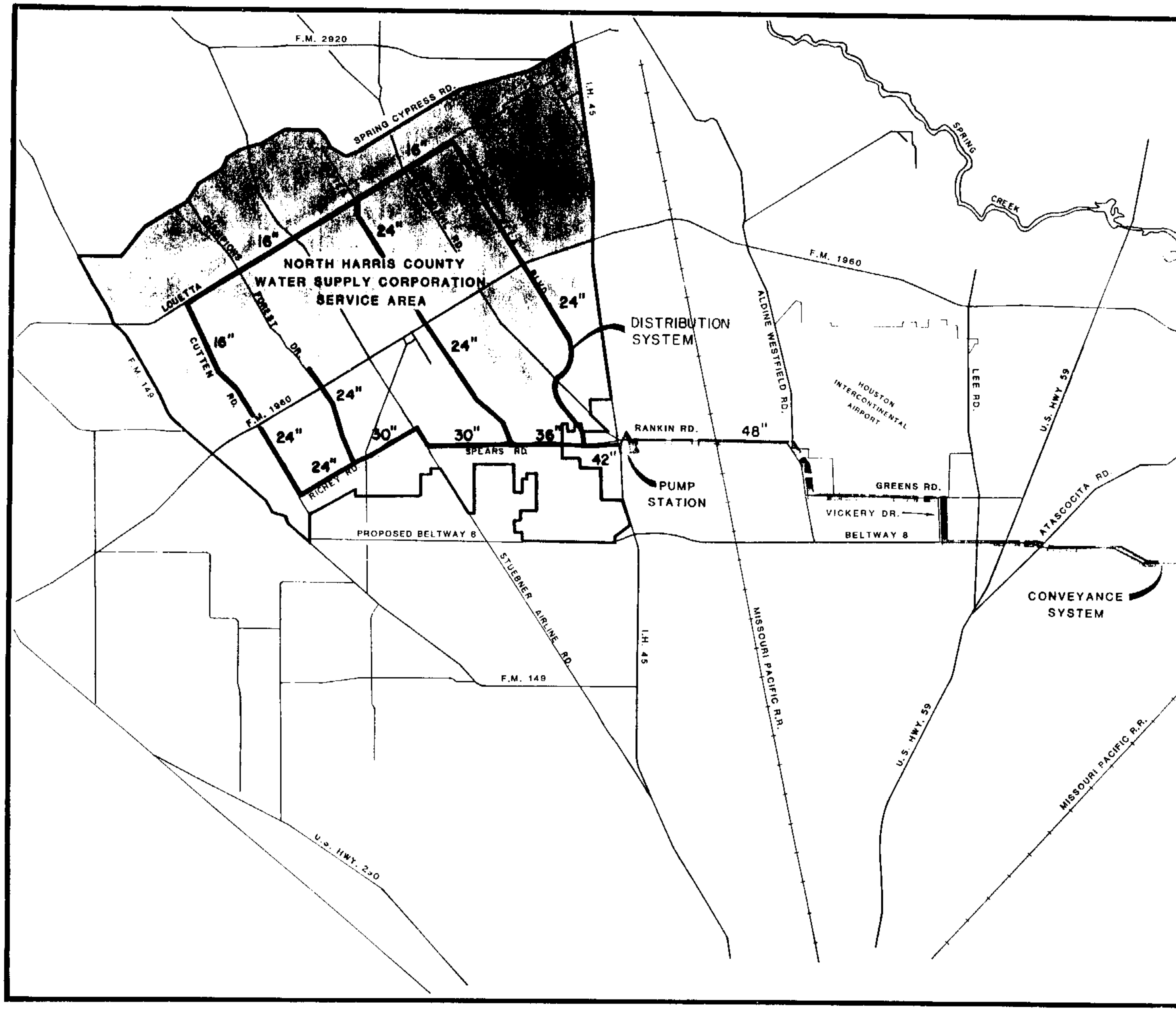
NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

DISTRIBUTION
ALTERNATE 3

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE No. 23

DATE: MAY, 1987 | JOB NO. 225-02-00



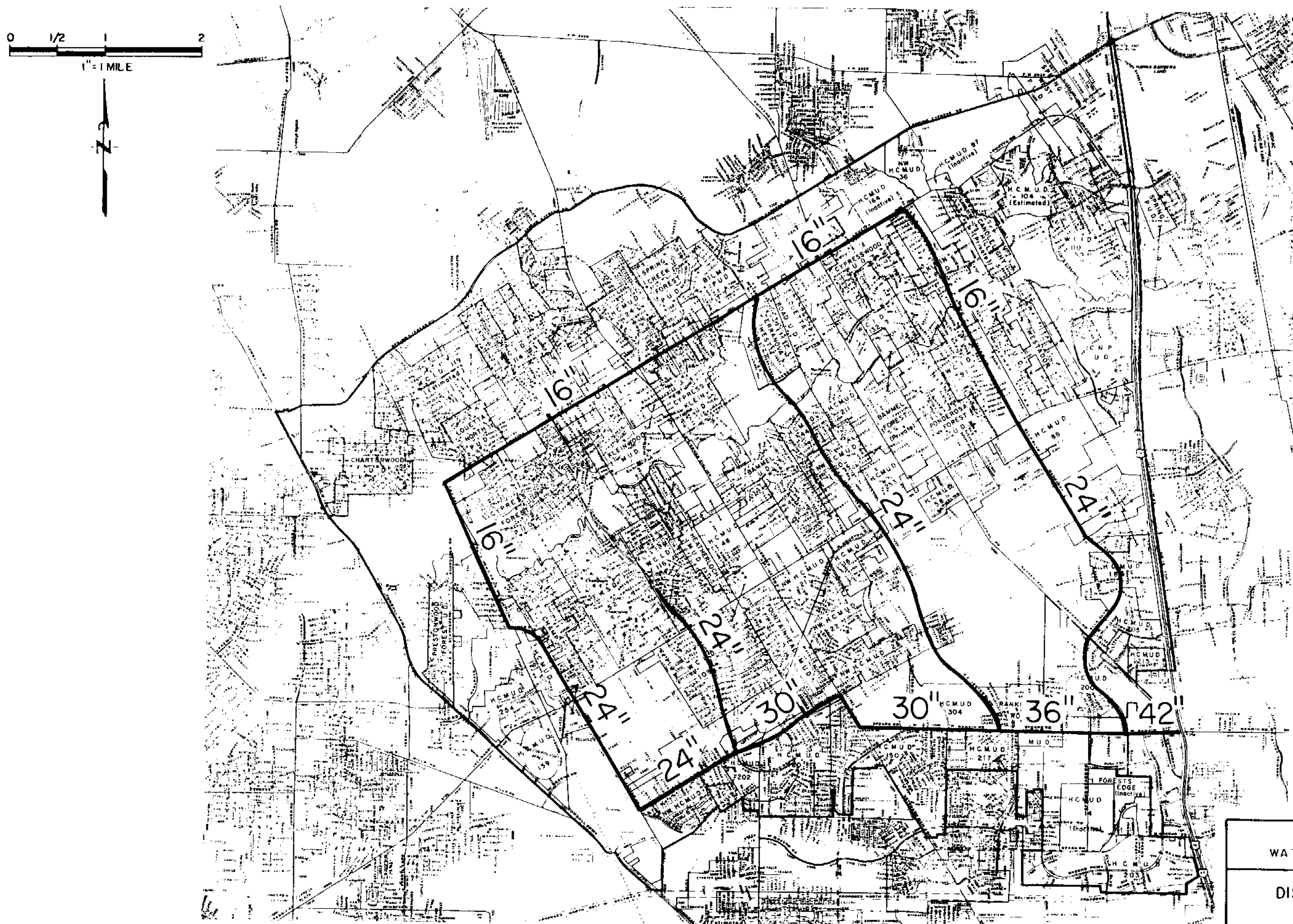
NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

PROPOSED
SURFACE WATER PROJECT

PATE ENGINEERS/JONES & CARTER
A JOINT VENTURE

FIGURE No 24

DATE : JUNE, 1987 | JOB NO. 348-002



NORTH HARRIS COUNTY
WATER SUPPLY CORPORATION

DISTRIBUTION SYSTEM
LAYOUT

PATE ENGINEERS/JONES & CARTER A JOINT VENTURE	FIGURE No. 25
DATE : MAY , 1987	JOB NO. 225-02-00

APPENDICES

JONES & CARTER Inc.
Consulting Engineers
6335 Gulfton, Suite 200
Houston, Texas 77081
(713) 777-5337

PRELIMINARY LINE SIZING FOR NHCWSC (ALTERNATE 1)
DESIGN FOR ULTIMATE DEMAND OF 34.2 MGD

Number of pipes: 27
Number of junction nodes: 25

Flow unit of measure: MGD
File name: ALT1

Summary of Input Data

Pipe Data:

Pipe	Node #1	Node #2	Dia (in)	Length (ft)	H-W Coeff	Minor Fact	Pump Type	FGN Grade
1	0	1	42.0	3100.0	120.0	3.0	1	135.00
2	1	2	36.0	2200.0	120.0	1.5	-	-
3	2	15	16.0	7000.0	120.0	1.5	-	-
4	2	3	36.0	5300.0	120.0	1.5	-	-
5	3	4	30.0	17200.0	120.0	1.5	-	-
6	4	16	16.0	1100.0	120.0	1.5	-	-
7	4	5	24.0	9700.0	120.0	1.5	-	-
8	5	6	24.0	8500.0	120.0	1.5	-	-
9	6	17	24.0	6800.0	120.0	1.5	-	-
10	17	18	16.0	8300.0	120.0	1.5	-	-
11	6	19	16.0	4700.0	120.0	1.5	-	-
12	19	20	16.0	3800.0	120.0	1.5	-	-
13	20	21	16.0	5300.0	120.0	1.5	-	-
14	6	7	16.0	12800.0	120.0	1.5	-	-
15	7	22	24.0	5000.0	120.0	1.5	-	-
16	22	23	16.0	3800.0	120.0	1.5	-	-
17	7	8	16.0	12400.0	120.0	1.5	-	-
18	8	24	16.0	7100.0	120.0	1.5	-	-
19	8	9	16.0	6000.0	120.0	1.5	-	-
20	9	10	24.0	9300.0	120.0	1.5	-	-
21	10	25	16.0	3600.0	120.0	1.5	-	-
22	10	11	24.0	5600.0	120.0	1.5	-	-
23	11	1	24.0	10400.0	120.0	1.5	-	-
24	7	12	24.0	7600.0	120.0	1.5	-	-
25	12	13	24.0	2800.0	120.0	1.5	-	-
26	13	14	16.0	2500.0	120.0	1.5	-	-
27	13	3	24.0	14200.0	120.0	1.5	-	-

Pump data:

Pump	Data type	Pump data (flows are in MGD)					
1	3-pt head/flow	160.0	21.6	135.0	34.6	110.0	43.2
2	3-pt head/flow	160.0	3.6	135.0	5.8	110.0	7.2

Junction Node Data:

Node #	Demand (MGD)	Elev (ft)	Connecting Pipes
1	0.00	97.0	1, 2, 23
2	0.00	100.0	2, 3, 4
3	2.90	105.0	4, 5, 27
4	3.80	118.0	5, 6, 7
5	2.50	125.0	7, 8
6	0.00	115.0	8, 9, 11, 14
7	0.00	110.0	14, 15, 17, 24
8	2.65	115.0	17, 18, 19
9	0.85	105.0	19, 20
10	0.75	110.0	20, 21, 22
11	1.70	105.0	22, 23
12	1.50	120.0	24, 25
13	0.00	117.0	25, 26, 27
14	1.70	120.0	26
15	2.55	95.0	3
16	1.55	118.0	6
17	1.10	115.0	9, 10
18	0.90	125.0	10
19	2.00	125.0	11, 12
20	0.95	130.0	12, 13
21	0.80	130.0	13
22	1.35	120.0	15, 16
23	1.00	122.0	16
24	1.45	100.0	18
25	2.20	105.0	21

Simulation Results

Number of trials: 4
Convergence : 0.0010

Pipe	Nodes (Q-->)		Dia (in)	Length (ft)	Flow (MGD)	Vel (fps)	Losses (ft) Head	Minor	Pump Head	Hd Loss /1000 ft
1	0	1	42.0	3100.0	34.20	5.50	7.21	1.41	135.89	2.78
2	1	2	36.0	2200.0	25.43	5.57	6.26	0.72	-	3.18
3	2	15	15.0	7000.0	2.55	2.83	14.61	0.19	-	2.11
4	2	3	36.0	5300.0	22.88	5.01	12.41	0.58	-	2.45
5	3	4	30.0	17200.0	12.12	3.82	30.17	0.34	-	1.77
6	4	16	16.0	1100.0	1.55	1.72	0.91	0.07	-	0.89
7	4	5	24.0	9700.0	6.77	3.34	17.16	0.26	-	1.80
8	5	6	24.0	8500.0	4.27	2.10	6.41	0.10	-	0.77
9	6	17	24.0	6800.0	2.00	0.98	1.26	0.02	-	0.19
10	17	18	16.0	8300.0	0.90	1.00	2.52	0.02	-	0.31
11	6	19	16.0	4700.0	3.75	4.16	20.04	0.40	-	4.35
12	19	20	16.0	3800.0	1.75	1.94	3.95	0.09	-	1.06
13	20	21	16.0	5300.0	0.80	0.89	1.29	0.02	-	0.25
14	7	6	16.0	12800.0	1.48	1.64	9.72	0.06	-	0.76
15	7	22	24.0	5000.0	2.35	1.16	1.25	0.03	-	0.26
16	22	23	16.0	3800.0	1.00	1.11	1.40	0.03	-	0.38
17	7	8	16.0	12400.0	0.83	0.92	3.25	0.02	-	0.26
18	8	24	16.0	7100.0	1.45	1.61	5.21	0.06	-	0.74
19	9	8	16.0	6000.0	3.27	3.62	19.83	0.31	-	3.36
20	10	9	24.0	9300.0	4.12	2.03	6.55	0.10	-	0.71
21	10	25	16.0	3600.0	2.20	2.44	5.72	0.14	-	1.63
22	11	10	24.0	5600.0	7.07	3.48	10.72	0.28	-	1.97
23	1	11	24.0	10400.0	8.77	4.32	29.68	0.43	-	2.90
24	12	7	24.0	7600.0	4.66	2.29	6.73	0.12	-	0.90
25	13	12	24.0	2800.0	6.16	3.03	4.15	0.21	-	1.56
26	13	14	16.0	2500.0	1.70	1.88	2.46	0.08	-	1.02
27	3	13	24.0	14200.0	7.86	3.87	33.09	0.35	-	2.35

Node #	Elev (ft)	Demand (MGD)	Press (psi)	Head (ft)	Hydr Grade (ft)
1	97.00	0.00	71.62	165.27	262.27
2	100.00	0.00	67.29	155.29	255.29
3	105.00	2.90	59.49	137.29	242.29
4	118.00	3.80	40.64	93.78	211.78
5	125.00	2.50	30.06	69.36	194.36
6	115.00	0.00	31.57	72.85	187.85
7	110.00	0.00	37.98	87.64	197.64
8	115.00	2.65	34.39	79.37	194.37
9	105.00	0.85	47.45	109.51	214.51
10	110.00	0.75	48.16	111.15	221.15
11	105.00	1.70	55.10	127.15	232.15
12	120.00	1.50	36.61	84.49	204.49
13	117.00	0.00	39.80	91.85	208.85
14	120.00	1.70	37.40	86.31	206.31
15	95.00	2.55	63.04	145.49	240.49
16	118.00	1.55	40.21	92.80	210.80
17	115.00	1.10	31.01	71.57	186.57
18	125.00	0.90	25.58	59.03	184.03
19	125.00	2.00	18.38	42.41	167.41
20	130.00	0.95	14.46	33.37	163.37
21	130.00	0.80	13.89	32.06	162.06
22	120.00	1.35	33.09	76.36	196.36
23	122.00	1.00	31.60	72.93	196.93
24	100.00	1.45	38.61	89.10	189.10
25	105.00	2.20	47.79	110.29	215.29

Summary of inflows (+) and outflows (-):

Pipe #	Flow (MGD)
1	34.19+

Net system demand: 34.2 MGD

Maximum-Minimum Summary:

Pipe #	Vel (fps)	Pipe #	HL/1000 ft	Node #	Press (psi)
2	5.57	11	4.26	1	71.62
1	5.50	19	3.31	2	67.29
4	5.01	23	2.85	15	63.04
23	4.32	2	2.85	3	59.49
11	4.16	4	2.34	11	55.10
16	1.11	10	0.30	5	30.06
10	1.00	17	0.26	18	25.58
9	0.98	15	0.25	19	18.38
17	0.92	13	0.24	20	14.46
13	0.89	9	0.18	21	13.89

NOTE: 'HL/1000 ft' does NOT include Minor Losses; and Pipes with zero flow are not included under Minimum 'Vel (fps)'.

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PRELIMINARY LINE SIZING FOR NHCWSC (ALTERNATE 2)
DESIGN FOR ULTIMATE DEMAND OF 34.2 MGD

Number of pipes: 28
Number of junction nodes: 26

Flow unit of measure: MGD
File name: ALT2

Summary of Input Data

Pipe Data:

Pipe	Node #1	Node #2	Dia (in)	Length (ft)	H-W Coeff	Minor Fact	Pump Type	FGN Grade
1	0	1	42.0	3100.0	120.0	3.0	1	135.00
2	1	2	36.0	2200.0	120.0	1.5	-	-
3	2	17	16.0	7000.0	120.0	1.5	-	-
4	2	3	36.0	5300.0	120.0	1.5	-	-
5	3	4	30.0	17200.0	120.0	1.5	-	-
6	4	18	16.0	1100.0	120.0	1.5	-	-
7	4	5	24.0	9700.0	120.0	1.5	-	-
8	5	6	24.0	8500.0	120.0	1.5	-	-
9	6	19	24.0	6800.0	120.0	1.5	-	-
10	19	20	16.0	8300.0	120.0	1.5	-	-
11	6	7	16.0	4700.0	120.0	1.5	-	-
12	7	21	16.0	3800.0	120.0	1.5	-	-
13	21	22	16.0	5300.0	120.0	1.5	-	-
14	7	26	16.0	9700.0	120.0	1.5	-	-
15	26	8	16.0	3800.0	120.0	1.5	-	-
16	8	9	16.0	10300.0	120.0	1.5	-	-
17	9	10	16.0	4600.0	120.0	1.5	-	-
18	10	23	16.0	3600.0	120.0	1.5	-	-
19	10	24	16.0	7100.0	120.0	1.5	-	-
20	10	11	16.0	6000.0	120.0	1.5	-	-
21	11	12	24.0	9300.0	120.0	1.5	-	-
22	12	25	16.0	3600.0	120.0	1.5	-	-
23	12	13	24.0	5600.0	120.0	1.5	-	-
24	13	1	24.0	10400.0	120.0	1.5	-	-
25	8	14	24.0	12600.0	120.0	1.5	-	-
26	14	15	24.0	2800.0	120.0	1.5	-	-
27	15	16	16.0	2500.0	120.0	1.5	-	-
28	15	3	24.0	14200.0	120.0	1.5	-	-

Pump data:

Pump	Data type	Pump data (flows are in MGD)					
1	3-pt head/flow	160.0	21.6	135.0	34.6	110.0	43.2
2	3-pt head/flow	160.0	3.6	135.0	5.8	110.0	7.2

Junction Node Data:

Node #	Demand (MGD)	Elev (ft)	Connecting Pipes
1	0.00	97.0	1, 2, 24
2	0.00	100.0	2, 3, 4
3	2.90	105.0	4, 5, 28
4	3.80	120.0	5, 6, 7
5	2.50	125.0	7, 8
6	0.00	125.0	8, 9, 11
7	2.00	130.0	11, 12, 14
8	1.35	120.0	15, 16, 25
9	1.40	120.0	16, 17
10	0.00	115.0	17, 18, 19, 20
11	0.85	105.0	20, 21
12	0.75	110.0	21, 22, 23
13	1.70	105.0	23, 24
14	1.50	120.0	25, 26
15	0.00	117.0	26, 27, 28
16	1.70	120.0	27
17	2.55	95.0	3
18	1.55	120.0	6
19	1.10	110.0	9, 10
20	0.90	125.0	10
21	0.95	132.0	12, 13
22	0.80	130.0	13
23	1.25	120.0	18
24	1.45	100.0	19
25	2.20	105.0	22
26	1.00	120.0	14, 15

Simulation Results

Number of trials: 4
Convergence : 0.0003

Pipe	Nodes (Q-->)		Dia (in)	Length (ft)	Flow (MGD)	Vel (fps)	Losses (ft) Head	Minor	Pump Head	Hd Loss /1000 ft
1	0	1	42.0	3100.0	34.20	5.50	7.21	1.41	135.89	2.78
2	1	2	36.0	2200.0	25.37	5.55	6.23	0.72	-	3.16
3	2	17	16.0	7000.0	2.55	2.83	14.61	0.19	-	2.11
4	2	3	36.0	5300.0	22.82	4.99	12.34	0.58	-	2.44
5	3	4	30.0	17200.0	12.14	3.83	30.25	0.34	-	1.78
6	4	18	16.0	1100.0	1.55	1.72	0.91	0.07	-	0.89
7	4	5	24.0	9700.0	6.79	3.34	17.24	0.26	-	1.80
8	5	6	24.0	8500.0	4.29	2.11	6.45	0.10	-	0.77
9	6	19	24.0	6800.0	2.00	0.98	1.26	0.02	-	0.19
10	19	20	16.0	8300.0	0.90	1.00	2.52	0.02	-	0.31
11	6	7	16.0	4700.0	2.29	2.54	8.04	0.15	-	1.74
12	7	21	16.0	3800.0	1.75	1.94	3.95	0.09	-	1.06
13	21	22	16.0	5300.0	0.80	0.89	1.29	0.02	-	0.25
14	26	7	16.0	9700.0	1.46	1.62	7.21	0.06	-	0.75
15	8	26	16.0	3800.0	2.46	2.73	7.42	0.17	-	2.00
16	8	9	16.0	10300.0	0.77	0.85	2.32	0.02	-	0.23
17	10	9	16.0	4600.0	0.63	0.70	0.73	0.01	-	0.16
18	10	23	16.0	3600.0	1.25	1.39	2.01	0.04	-	0.57
19	10	24	16.0	7100.0	1.45	1.61	5.21	0.06	-	0.74
20	11	10	16.0	6000.0	3.33	3.69	20.57	0.32	-	3.48
21	12	11	24.0	9300.0	4.18	2.06	6.74	0.10	-	0.74
22	12	25	16.0	3600.0	2.20	2.44	5.72	0.14	-	1.63
23	13	12	24.0	5600.0	7.13	3.51	10.91	0.29	-	2.00
24	1	13	24.0	10400.0	8.83	4.35	30.09	0.44	-	2.94
25	14	8	24.0	12600.0	4.58	2.25	10.79	0.12	-	0.87
26	15	14	24.0	2800.0	6.08	2.99	4.05	0.21	-	1.52
27	15	16	16.0	2500.0	1.70	1.88	2.46	0.08	-	1.02
28	3	15	24.0	14200.0	7.78	3.83	32.46	0.34	-	2.31

Node #	Elev (ft)	Demand (MGD)	Press (psi)	Head (ft)	Hydr Grade (ft)
1	97.00	0.00	71.62	165.27	262.27
2	100.00	0.00	67.31	155.32	255.32
3	105.00	2.90	59.54	137.40	242.40
4	120.00	3.80	39.78	91.80	211.80
5	125.00	2.50	30.03	69.30	194.30
6	125.00	0.00	27.19	62.74	187.74
7	130.00	2.00	21.47	49.56	179.56
8	120.00	1.35	32.25	74.43	194.43
9	120.00	1.40	31.24	72.09	192.09
10	115.00	0.00	33.72	77.82	192.82
11	105.00	0.85	47.11	108.71	213.71
12	110.00	0.75	47.90	110.55	220.55
13	105.00	1.70	54.92	126.74	231.74
14	120.00	1.50	36.98	85.34	205.34
15	117.00	0.00	40.13	92.60	209.60
16	120.00	1.70	37.72	87.05	207.05
17	95.00	2.55	63.06	145.52	240.52
18	120.00	1.55	39.36	90.82	210.82
19	110.00	1.10	33.13	76.47	186.47
20	125.00	0.90	25.53	58.92	183.92
21	132.00	0.95	18.86	43.52	175.52
22	130.00	0.80	19.16	44.21	174.21
23	120.00	1.25	30.67	70.77	190.77
24	100.00	1.45	37.94	87.55	187.55
25	105.00	2.20	47.53	109.69	214.69
26	120.00	1.00	28.96	66.83	186.83

Summary of inflows (+) and outflows (-):

Pipe #	Flow (MGD)
1	34.19+

Net system demand: 34.2 MGD

Maximum-Minimum Summary:

Pipe #	Vel (fps)	Pipe #	HL/1000 ft	Node #	Press (psi)
2	5.55	20	3.43	1	71.62
1	5.50	24	2.89	2	67.31
4	4.99	2	2.83	17	63.06
24	4.35	4	2.33	3	59.54
28	3.83	1	2.33	13	54.92
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10	1.00	10	0.30	6	27.19
9	0.98	13	0.24	20	25.53
13	0.89	16	0.23	7	21.47
16	0.85	9	0.18	22	19.16
17	0.70	17	0.16	21	18.86

NOTE: 'HL/1000 ft' does NOT include Minor Losses; and Pipes with zero flow are not included under Minimum 'Vel (fps)'.

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PRELIMINARY LINE SIZING FOR NHCWSC (ALTERNATE 3)
DESIGN FOR ULTIMATE DEMAND OF 34.2MGD

Number of pipes: 27
Number of junction nodes: 25

Flow unit of measure: MGD
File name: ALT3

Summary of Input Data

Pipe Data:

Pipe	Node #1	Node #2	Dia (in)	Length (ft)	H-W Coeff	Minor Fact	Pump Type	FGN Grade
1	0	1	42.0	3100.0	120.0	3.0	1	135.00
2	1	2	36.0	2200.0	120.0	1.5	-	-
3	2	21	16.0	7000.0	120.0	1.5	-	-
4	2	3	36.0	5300.0	120.0	1.5	-	-
5	3	4	30.0	17200.0	120.0	1.5	-	-
6	4	22	24.0	9700.0	120.0	1.5	-	-
7	4	5	24.0	6500.0	120.0	1.5	-	-
8	5	6	24.0	9800.0	120.0	1.5	-	-
9	6	7	24.0	8300.0	120.0	1.5	-	-
10	7	8	16.0	4400.0	120.0	1.5	-	-
11	8	23	16.0	1900.0	120.0	1.5	-	-
12	8	9	16.0	1600.0	120.0	1.5	-	-
13	9	10	16.0	8200.0	120.0	1.5	-	-
14	10	11	16.0	5200.0	120.0	1.5	-	-
15	11	12	16.0	3800.0	120.0	1.5	-	-
16	12	13	16.0	10400.0	120.0	1.5	-	-
17	13	14	16.0	4600.0	120.0	1.5	-	-
18	14	24	16.0	7100.0	120.0	1.5	-	-
19	14	15	16.0	6000.0	120.0	1.5	-	-
20	15	16	24.0	9300.0	120.0	1.5	-	-
21	16	25	16.0	3600.0	120.0	1.5	-	-
22	16	17	24.0	5600.0	120.0	1.5	-	-
23	17	1	24.0	10400.0	120.0	1.5	-	-
24	12	18	24.0	12600.0	120.0	1.5	-	-
25	18	19	24.0	2800.0	120.0	1.5	-	-
26	19	20	16.0	2500.0	120.0	1.5	-	-
27	19	3	24.0	14200.0	120.0	1.5	-	-

Pump data:

Pump	Data type	Pump data (flows are in MGD)					
1	3-pt head/flow	160.0	21.6	135.0	34.6	110.0	43.2
2	3-pt head/flow	160.0	3.6	135.0	5.8	110.0	7.2

Junction Node Data:

Node #	Demand (MGD)	Elev (ft)	Connecting Pipes
1	0.00	97.0	1, 2, 23
2	0.00	100.0	2, 3, 4
3	2.90	105.0	4, 5, 27
4	3.80	118.0	5, 6, 7
5	1.60	120.0	7, 8
6	0.95	125.0	8, 9
7	1.00	110.0	9, 10
8	0.00	135.0	10, 11, 12
9	1.00	132.0	12, 13
10	1.95	125.0	13, 14
11	1.00	120.0	14, 15
12	1.35	120.0	15, 16, 24
13	1.40	120.0	16, 17
14	1.25	115.0	17, 18, 19
15	0.85	105.0	19, 20
16	0.75	110.0	20, 21, 22
17	1.70	105.0	22, 23
18	1.50	120.0	24, 25
19	0.00	117.0	25, 26, 27
20	1.70	120.0	26
21	2.55	95.0	3
22	2.50	125.0	6
23	0.80	130.0	11
24	1.45	100.0	18
25	2.20	105.0	21

Simulation Results

Number of trials: 4
Convergence : 0.0025

Pipe	Nodes (Q-->)		Dia (in)	Length (ft)	Flow (MGD)	Vel (fps)	Losses (ft) Head	Minor	Pump Head	Hd Loss /1000 ft
1	0	1	42.0	3100.0	34.20	5.50	7.21	1.41	135.89	2.78
2	1	2	36.0	2200.0	25.36	5.55	6.23	0.72	-	3.16
3	2	21	16.0	7000.0	2.55	2.83	14.61	0.19	-	2.11
4	2	3	36.0	5300.0	22.81	4.99	12.33	0.58	-	2.44
5	3	4	30.0	17200.0	12.11	3.82	30.13	0.34	-	1.77
6	4	22	24.0	9700.0	2.50	1.23	2.71	0.04	-	0.28
7	4	5	24.0	6500.0	5.81	2.86	8.67	0.19	-	1.36
8	5	6	24.0	9800.0	4.21	2.08	7.20	0.10	-	0.75
9	6	7	24.0	8300.0	3.26	1.61	3.80	0.06	-	0.47
10	7	8	16.0	4400.0	2.26	2.51	7.37	0.15	-	1.71
11	8	23	16.0	1900.0	0.80	0.89	0.46	0.02	-	0.25
12	8	9	16.0	1600.0	1.46	1.62	1.20	0.06	-	0.79
13	9	10	16.0	8200.0	0.46	0.51	0.73	0.01	-	0.09
14	11	10	16.0	5200.0	1.49	1.65	3.99	0.06	-	0.78
15	12	11	16.0	3800.0	2.49	2.75	7.57	0.18	-	2.04
16	12	13	16.0	10400.0	0.76	0.84	2.30	0.02	-	0.22
17	14	13	16.0	4600.0	0.64	0.71	0.74	0.01	-	0.16
18	14	24	16.0	7100.0	1.45	1.61	5.21	0.06	-	0.74
19	15	14	16.0	6000.0	3.34	3.70	20.66	0.32	-	3.50
20	16	15	24.0	9300.0	4.19	2.06	6.76	0.10	-	0.74
21	16	25	16.0	3600.0	2.20	2.44	5.72	0.14	-	1.63
22	17	16	24.0	5600.0	7.14	3.52	10.93	0.29	-	2.00
23	1	17	24.0	10400.0	8.84	4.35	30.14	0.44	-	2.94
24	18	12	24.0	12600.0	4.59	2.26	10.87	0.12	-	0.87
25	19	18	24.0	2800.0	6.09	3.00	4.07	0.21	-	1.53
26	19	20	16.0	2500.0	1.70	1.88	2.46	0.08	-	1.02
27	3	19	24.0	14200.0	7.79	3.84	32.59	0.34	-	2.32

Node #	Elev (ft)	Demand (MGD)	Press (psi)	Head (ft)	Hydr Grade (ft)
1	97.00	0.00	71.62	165.27	262.27
2	100.00	0.00	67.31	155.32	255.32
3	105.00	2.90	59.54	137.41	242.41
4	118.00	3.80	40.71	93.94	211.94
5	120.00	1.60	36.00	83.08	203.08
6	125.00	0.95	30.67	70.77	195.77
7	110.00	1.00	35.50	81.91	191.91
8	135.00	0.00	21.40	49.40	184.40
9	132.00	1.00	22.16	51.14	183.14
10	125.00	1.95	24.87	57.40	182.40
11	120.00	1.00	28.80	66.46	186.46
12	120.00	1.35	32.15	74.20	194.20
13	120.00	1.40	31.15	71.88	191.88
14	115.00	1.25	33.64	77.64	192.64
15	105.00	0.85	47.07	108.61	213.61
16	110.00	0.75	47.87	110.48	220.48
17	105.00	1.70	54.90	126.69	231.69
18	120.00	1.50	36.91	85.19	205.19
19	117.00	0.00	40.07	92.47	209.47
20	120.00	1.70	37.67	86.93	206.93
21	95.00	2.55	63.06	145.52	240.52
22	125.00	2.50	36.48	84.19	209.19
23	130.00	0.80	23.36	53.91	183.91
24	100.00	1.45	37.86	87.37	187.37
25	105.00	2.20	47.50	109.62	214.62

Summary of inflows (+) and outflows (-):

Pipe #	Flow (MGD)
1	34.19+

Net system demand: 34.2 MGD

Maximum-Minimum Summary:

Pipe #	Vel (fps)	Pipe #	HL/1000 ft	Node #	Press (psi)
2	5.55	19	3.44	1	71.62
1	5.50	23	2.90	2	67.31
4	4.99	2	2.83	21	63.06
23	4.35	4	2.33	3	59.54
27	3.84	1	2.33	17	54.90
------	------	------	------	------	------
6	1.23	6	0.28	11	28.80
11	0.89	11	0.24	10	24.87
16	0.84	16	0.22	23	23.36
17	0.71	17	0.16	9	22.16
13	0.51	13	0.09	8	21.40

NOTE: 'HL/1000 ft' does NOT include Minor Losses; and Pipes with zero flow are not included under Minimum 'Vel (fps)'.

APPENDIX D

NORTH HARRIS COUNTY WATER SUPPLY CORPORATION — POPULATION AND WATER USAGE STUDY

UTILITY DISTRICTS	ACREAGE	POPULATION ** CURRENT * (district)	POPULATION ** ULTIMATE (district)	POPULATION ** CURRENT * (per acre)	POPULATION ** ULTIMATE (per acre)	WATER USAGE: CURRENT * (Mg/yr)	WATER USAGE: ULTIMATE (Mg/yr)	DAILY WATER USAGE: CURRENT * (gal/ac)	DAILY WATER USAGE: ULTIMATE (gal/ac)	DAILY WATER USAGE: CURRENT * (gal/person)	DAILY WATER USAGE: ULTIMATE (gal/person)	AVERAGE DAILY USAGE: CURRENT * (MGD)	AVERAGE DAILY USAGE: ULTIMATE (MGD)
BAMMEL	324.02	2,840	2,993	8.76	9.24	149.7	174.8	1266.06	1478.01	144.45	160.01	0.4102	0.4789
BILMA	505.09	1,540	10,071	3.05	19.94	88.0	588.2	477.51	3190.53	156.61	160.01	0.2412	1.6115
CHARTERWOOD	311.35	1,800	5,300	5.78	17.02	91.7	310.3	806.67	2730.05	139.53	160.38	0.2512	0.8500
C N P UD	560.10	3,940	9,550	7.03	17.05	280.8	631.8	1373.61	3090.40	195.27	181.25	0.7694	1.7309
CY CHAMP	465.39	1,950	13,342	4.19	28.67	96.1	779.2	565.87	4586.93	135.05	160.00	0.2634	2.1347
CYPRESS FOREST	841.22	4,400	8,230	5.23	9.78	257.3	480.6	837.93	1565.34	160.20	160.00	0.7049	1.3168
CYPRESS KLEIN	440.41	2,210	7,000	5.02	15.89	159.2	408.8	990.12	2543.08	197.31	160.00	0.4361	1.1200
CYPRESSWOOD	427.85	4,400	5,324	10.28	12.44	200.4	215.8	1283.48	1381.87	124.80	111.05	0.5491	0.5912
FOUNTAINHEAD MUD	430.79	2,800	6,796	6.50	15.78	160.9	235.0	1023.36	1494.55	157.45	94.74	0.4409	0.6438
FWSD 52	866.20	3,940	4,800	4.55	5.54	286.6	320.0	906.53	1012.14	199.30	182.65	0.7852	0.8767
HCMUD 16	227.91	1,430	6,900	6.27	30.28	99.5	327.4	1195.74	3935.70	190.57	130.00	0.2725	0.8970
HCMUD 24	659.88	2,740	9,375	4.15	14.21	197.4	547.5	819.49	2273.14	197.36	160.00	0.5408	1.5000
HCMUD 44	299.56	2,760	?	9.21	?	161.2	?	1474.32	0.00	160.02	?	0.4416	0.0000
HCMUD 48	293.55	120	5,800	0.41	19.76	7.0	455.0	64.86	4246.55	158.66	214.93	0.0190	1.2466
HCMUD 58	99.82	680	3,511	6.81	35.17	46.2	128.1	1268.48	3515.92	186.20	99.96	0.1266	0.3510
HCMUD 86 (NEW)	366.00	1	14,314	.00	39.11	0.0	679.0	0.00	5082.72	0.00	129.96	0.0000	1.8603
HCMUD 104	345.00	500	5,600	1.45	16.23	26.6	265.7	211.30	2110.14	145.80	130.00	0.0729	0.7280
HCMUD 150	661.42	3,980	5,500	6.02	8.32	239.1	321.2	990.51	1330.47	164.61	160.00	0.6551	0.8800
HCMUD 159	243.07	1,510	5,835	6.21	24.01	99.7	213.2	1123.63	2403.05	180.87	100.10	0.2731	0.5840
HCMUD 180	488.20	1,120	12,000	2.29	24.58	65.3	437.9	366.34	2457.45	159.69	99.98	0.1788	1.1997
HCMUD 189	466.27	1,950	23,000	4.18	49.33	101.3	1095.0	595.19	6434.04	142.32	130.43	0.2775	3.0000
HCMUD 191	230.12	400	?	1.74	?	22.6	456.3	269.35	5432.54	154.96	?	0.0620	1.2500
HCMUD 200	679.88	3,400	19,250	5.00	28.31	163.6	1095.0	659.08	4412.67	131.79	155.84	0.4481	3.0000
HCMUD 202	312.23	480	8,194	1.54	26.24	28.0	170.9	245.25	1499.60	159.53	57.14	0.0766	0.4682
HCMUD 203	665.53	3,200	26,000	4.81	39.07	186.6	1172.1	768.16	4825.08	159.76	123.51	0.5112	3.2112
HCMUD 205	147.96	90	4,642	0.61	31.37	4.4	282.9	81.06	5238.37	133.30	166.97	0.0120	0.7751
HCMUD 211	277.75	400	3,330	1.44	11.99	22.9	150.7	225.52	1486.50	156.60	123.99	0.0626	0.4129
HCMUD 215	89.40	5	4,194	0.06	46.91	0.3	229.6	8.64	7036.25	154.52	149.99	0.0008	0.6290
HCMUD 217	192.35	400	5,764	2.08	29.97	23.7	273.5	337.6	3895.58	162.25	130.00	0.0649	0.7493
HCMUD 233	148.19	210	1,395	1.42	9.41	12.3	261.0	227.6	4825.35	160.61	512.59	0.0337	0.7151
HCMUD 254	234.15	130	6,684	0.56	28.55	7.7	578.5	89.9	6768.87	161.92	237.12	0.0210	1.5849
HCMUD 304 (NEW)	321.00	1	20,363	.00	63.44	0.0	276.1	0.0	2356.51	0.00	37.15	0.0000	0.7564
HEATHERLOCH MUD	288.52	3,480	7,350	12.06	25.47	170.6	429.2	1620.3	4075.59	134.34	159.99	0.4675	1.1759
KLEIN PUD	285.43	1,650	3,000	5.78	10.51	89.1	146.0	855.6	1401.39	148.01	133.33	0.2442	0.4000
KLEINWOOD	546.21	2,700	10,500	4.94	19.22	134.7	574.9	675.6	2883.51	136.68	150.00	0.3690	1.5750
LOUETTA NORTH PUD	262.75	940	5,011	3.58	19.07	54.8	292.6	571.6	3050.98	159.79	159.98	0.1502	0.8016
LOUETTA ROAD UD	208.49	1,500	4,000	7.19	19.19	81.9	233.6	1076.3	3069.69	149.60	160.00	0.2244	0.6400
NORTH FOREST MUD	162.34	2,120	?	13.06	?	111.7	?	1885.0	0.00	144.35	?	0.3060	0.0000
NWHCMUD 6	327.82	1,300	6,617	3.97	20.18	78.2	241.6	653.6	2019.15	164.82	100.03	0.2143	0.6619
NWHCMUD 20	279.76	1,270	6,019	4.54	21.51	73.5	351.5	720.1	3442.38	158.64	160.00	0.2015	0.9630
NWHCMUD 21	180.47	1,050	6,268	5.82	34.73	54.7	297.4	829.6	4514.85	142.60	129.99	0.1497	0.8148
NWHCMUD 22	313.06	600	7,700	1.92	24.60	33.5	289.1	293.5	2530.04	153.16	102.86	0.0919	0.7921
NWHCMUD 23	259.96	1,420	5,145	5.46	19.79	70.9	193.2	747.2	2036.14	136.80	102.88	0.1943	0.5293
NWHCMUD 36 (NEW)	129.00	1	5,388	0.01	41.77	0.0	73.1	0.0	1552.51	0.00	37.17	0.0000	0.2003
PONDEROSA FOREST	727.40	6,000	13,000	8.25	17.87	349.7	759.2	1317.0	2859.50	159.67	160.00	0.9580	2.0800
PRESTONWOOD FOREST	382.05	2,380	4,312	6.23	11.29	170.2	196.0	1220.2	1405.54	195.87	124.53	0.4662	0.5370
RANKIN ROAD WEST	314.00	50	8,571	0.16	27.30	2.7	108.2	23.6	944.07	149.48	34.59	0.0075	0.2964
SPRING CREEK FOREST	356.51	2,100	3,100	5.89	8.70	124.6	169.7	957.7	1304.12	162.59	149.98	0.3414	0.4649
SPRING WEST	377.33	20	7,000	0.05	18.55	0.8	408.8	5.8	2968.22	108.49	160.00	0.0022	1.1200
TERRANOVA WEST	289.56	1,320	4,124	4.56	14.24	84.8	150.5	802.2	1423.98	175.98	99.98	0.2323	0.4123
WCID 91	320.00	3,200	3,300	10.00	10.31	202.8	225.0	1736.3	1926.37	173.63	186.80	0.5556	0.6164
WCID 109	716.74	8,180	10,000	11.41	13.95	513.0	839.5	1960.7	3208.97	171.80	230.00	1.4053	2.3000
WCID 110	585.12	3,440	5,800	5.88	9.91	215.8	339.0	1010.6	1587.31	171.90	160.13	0.5913	0.9288
WCID 114	674.99	3,910	5,400	5.79	8.00	273.2	295.7	1109.1	1200.22	191.46	150.03	0.7486	0.8101
WCID 116	338.92	3,440	5,100	10.15	15.05	233.1	300.0	1884.7	2425.11	185.69	161.16	0.6388	0.8219
WCID 119	454.71	2,630	?	5.78	?	183.9	?	1108.2	0.00	191.60	?	0.5039	0.0000
WCID 132	322.45	3,100	4,270	9.61	13.24	151.2	200.0	1285.1	1699.32	133.67	128.32	0.4144	0.5479
WESTADOR MUD	600.00	3,800	12,000	6.33	20.00	276.9	700.8	1264.5	3200.00	199.66	160.00	0.7587	1.9200
TOTALS	22,325	116,928	418,032	N/A	N/A	7,023	21,376	N/A	N/A	8,832	N/A	19.24	58.56
AVERAGES	384.92	2,016.00	7,207.45	4.92	20.21	121.08	368.55	796.00	2,782.21	152.27	135.89	0.33	1.01

* Current values based on 1985 information.
? No information was released by district engineer.
** Populations are based on equivalent connections from engineers and may not reflect actual district population.

APPENDIX E

GAS INTRUSION OF WELLS IN
NORTH HARRIS COUNTY WATER SUPPLY CORPORATION

UTILITY DISTRICTS	WELLS WITHIN NHCWSC AREA	WELL PERMIT NO.	GAS INTRUSION
1. BAMMEL	+Well #1	1527	Yes
	Well #2	4099	Yes
2. BILMA	Well #1	3229	No
3. CHARTERWOOD	Well #1	2424	No
	Well #2	3529	No
4. C N P	Well #1	1658	No
	Well #2	2634	No
	Well #3	3564	No
5. CY CHAMP*	Well #1	1630	
6. CYPRESS FOREST	Well #1	3161	No
	Well #2	4086	No
7. CYPRESS KLEIN*	Well #1	1620	
8. CYPRESSWOOD	Well #1	1673	No
	Well #2	1870	No
9. FOUNTAINHEAD	Well #1	1854	
	Well #3	2939	
10. FWSD 52	Well #1	1529	No
	Well #2	1528	No
11. HCMUD 16*	Well #1	3478	
12. HCMUD 24	Well #1	1779	Yes
	Well #2	3750	Yes
13. HCMUD 44*	Well #1	2546	No
	Well #2	2438	
14. HCMUD 48	None		
15. HCMUD 58	Well #1	3110	No
16. HCMUD 86 (new)	None		
17. HCMUD 104	Well #1	2970	No

UTILITY DISTRICTS	WELLS WITHIN NHCWSC AREA	WELL PERMIT NO.	GAS INTRUSION
18. HCMUD 150	Well #1	2729	No
	Well #2	3256	No
19. HCMUD 159	Well #1	3330	No
	Well #2	3331	No
20. HCMUD 180*	Well #1	3349	No
	Well #2	3803	
21. HCMUD 189	Well #1	3482	No
	Well #2	3695	
	Well #3	3990	
22. HCMUD 191*	Well #1	3751	
23. HCMUD 200*	Well #1	3863	No
	Well #2	3567	No
24. HCMUD 202	Well #1	3867	No
25. HCMUD 203*	Well #1	3660	
	Well #2	3780	
26. HCMUD 205*	Well #1	3550	
27. HCMUD 211	Well #1	3726	Yes
28. HCMUD 215	Well #1	3868	No
29. HCMUD 217	Well #1	3781	No
30. HCMUD 233	(shares well with HCMUD 211)		
31. HCMUD 254	Well #1	3889	No
32. HCMUD 304 (new)	Well #1	4037	No
33. HEATHERLOCH*	Well #1	1867	
34. KLEIN	Well #1	2943	No
35. KLEINWOOD*	Well #1	1727	
36. LOUETTA NORTH	Well #1	3956	No
37. LOUETTA ROAD	Well #1	1860	No
	(jointly owned by Terranova)		
38. NORTH FOREST*	Well #1	2186	
39. NWHCMUD 6	Well #1	2731	No
	Well #2	3605	No
40. NWHCMUD 20*	Well #1	3635	Yes

UTILITY DISTRICTS	WELLS WITHIN NHCWSC AREA	WELL PERMIT NO.	GAS INTRUSION
41. NWHCMUD 21	(same as NWHCMUD 22)		
42. NWHCMUD 22	Well #1	3448	Yes
	(jointly owned by NWHCMUD 21)		
43. NWHCMUD 23	Well #1	3447	Yes
44. NWHCMUD 36 (new)	None		
45. PONDEROSA FOREST	Well #1	1663	
	Well #2	2947	No
	Well #3	3631	No
46. PRESTONWOOD FOREST	Well #1	1544	No
	Well #2	3239	No
47. RANKIN ROAD WEST	Well #1	3992	No
48. SPRING CREEK FOREST	Well #1	1664	No
49. SPRING WEST (new)	Well #1	3556	No
50. TERRANOVA WEST	Well #1	4058	No
51. WCID 91	Well #1	1538	No
	Well #2	1537	No
52. WCID 109*	Well #1	1378	
	Well #2	1379	
	Well #3	3333	No
53. WCID 110	Well #1	1617	Yes
54. WCID 114	Well #1	1534	No
	Well #2	3409	Yes
55. WCID 116	Well #1	2093	No
	Well #2	2094	Yes
	Well #3	3316	No
56. WCID 119*	Well #1	2183	No
	Well #2	4019	
57. WCID 132	Well #1	3648	
58. WESTADOR	Well #1	1904	No
	Well #2		No

* Information not received on all wells for this district

\+ Well inoperative or abandoned due to gas intrusion

SHT 1 OF 3

1986 STANDARD WATER RATES FOR UTILITY DISTRICTS WITHIN NHCWSC SERVICE AREA

UTILITY DISTRICT	WATER RATES ($/ 1000 gal) Water Used	Rate
1 BAMMEL	1st 8000 gal	6.00 flat
	8000-20000	0.75
	20000-35000	1.00
	over 35000	2.00
2 BILMA PUD	1st 5000 gal	5.00 flat
	over 5000	0.50
3 CHARTERWOOD	1st 5000 gal	10.00 flat
	over 5000	1.00
4 C N P UD	1st 5000 gal	5.00 flat
	over 5000	0.50
5 CY CHAMP	*	
6 CYPRESS FOREST	*	
7 CYPRESS KLEIN	1st 8000 gal	7.00 flat
	over 8000	0.50
8 CYPRESSWOOD	1st 8000 gal	5.50 flat
	over 8000	0.50
9 FOUNTAINHEAD	*	
10 FWSD 52	*	
11 HCMUD 16	1st 2000 gal	8.00 flat
	2000-10000	1.00
	over 10000	0.75
12 HCMUD 24	1st 3000 gal	6.50 flat
	over 3000	0.75
13 HCMUD 44	1ST 10000 gal	12.00 flat
	10000-20000	0.75
	20000-30000	1.00
	over 30000	1.25
14 HCMUD 48	1st 10000 gal	8.00 flat
	over 10000	0.56
15 HCMUD 58	*	
16 HCMUD 86	No Connections	
17 HCMUD 104	1st 6000 gal	10.00 flat
	over 6000	1.00
18 HCMUD 150	1st 10000 gal	8.00 flat
	over 10000	0.80
19 HCMUD 159	1st 10000 gal	17.50 flat
	over 10000	1.75
20 HCMUD 180	1st 3000 gal	8.00 flat
	3000-10000	0.75
	over 10000	1.00

* Information not obtained

1986 STANDARD WATER RATES FOR UTILITY DISTRICTS WITHIN NHCWSC SERVICE AREA

UTILITY DISTRICT	WATER RATES ($/ 1000 gal) Water Used	Rates
21 HCMUD 189	1st 5000 gal	5.00 flat
	over 5000	0.50
22 HCMUD 191	*	
23 HCMUD 200	1st 10000 gal	4.00 flat
	over 10000	0.40
24 HCMUD 202	1st 8000 gal	10.00 flat
	over 8000	0.75
25 HCMUD 203	1st 5000 gal	5.00 flat
	over 5000	0.60
26 HCMUD 205	1st 10000 gal	8.00 flat
	over 10000	0.50
27 HCMUD 211	1st 10000 gal	13.50 flat
	10000-30000	0.70
	30000-47000	0.90
	over 47000	1.35
28 HCMUD 215	1st 5000 gal	15.00 flat
	5000-100000	1.00
	over 100000	12.50
29 HCMUD 217	1st 10000 gal	13.00 flat
	over 10000	0.50
30 HCMUD 233	1st 10000 gal	13.50 flat
	10000-30000	0.70
	30000-47000	0.90
	over 47000	1.35
31 HCMUD 254	1st 5000 gal	15.00 flat
	5000-125000	1.00
	over 125000	1.25
32 HCMUD 304	No Connections	
33 HEATHERLOCH	1st 10000 gal	3.00 flat
	10000-30000	0.75
	over 30000	1.25
34 KLEIN PUD	1st 5000 gal	8.00 flat
	over 5000	0.75
35 KLEINWOOD	1st 5000	6.00 flat
	over 5000	0.50
36 LOUETTA NORTH	*	
37 LOUETTA ROAD	1st 5000 gal	5.00 flat
	5000-10000	0.65
	10000-20000	0.75
	20000-35000	1.00
	35000-50000	1.50
	over 50000	2.00

* Information not obtained

1986 STANDARD WATER RATES FOR UTILITY DISTRICTS WITHIN NHCWSC SERVICE AREA

UTILITY DISTRICT	WATER RATES ($/ 1000 gal) Water Used	Rates
38 NORTH FOREST	*	
39 NWHCMUD 6	1st 5000 gal	7.50 flat
	over 5000	0.75
40 NWHCMUD 20	*	
41 NWHCMUD 21	(same as NWHCMUD 22)	
42 NWHCMUD 22	1st 3000 gal	6.00 flat
	over 3000	0.50
43 NWHCMUD 23	1st 3000 gal	6.00 flat
	over 3000	1.00
44 NWHCMUD 36 (new)	No Connections	
45 PONDEROSA FOREST	1st 15000 gal	5.00 flat
	over 15000	0.45
46 PRESTONWOOD FOREST	1st 10000 gal	6.00 flat
	11000-25000	1.00
	over 25000	1.25
47 RANKIN ROAD WEST	1st 8000 gal	10.00 flat
	8000-15000	0.85
	over 15000	1.25
48 SPRING CREEK FOREST	1st 5000 gal	6.00 flat
	over 5000	0.55
49 SPRING WEST (new)	No Connections	
50 TERRANOVA WEST	1st 20000	12.00 flat
	over 20000	0.50
51 WCID 91 **	1st 23000 gal	8.00 flat
	23000-40000	0.35
	over 40000	0.50
52 WCID 109	1st 10000 gal	3.75 min.
	10000-30000	0.38
	over 30000	1.86
53 WCID 110	*	
54 WCID 114	*	
55 WCID 116	1st 10000	7.50 flat
	over 10000	0.35
56 WCID 119	1st 10000 gal	8.00 flat
	over 10000	0.50
57 WCID 132	1st 10000 gal	5.50 flat
	over 10000	0.50
58 WESTADOR	1st 5000	4.00 flat
	5000-10000	0.60
	over 10000	0.50

* Information not obtained
** Bi-monthly rates

APPENDIX G
WELL CAPACITY

INFORMATION ON UTILITY DISTRICT WELLS WITHIN NHCWSC SERVICE AREA

UTILITY DISTRICTS		WELL PERMIT NO.	YEAR COMP.	WELL DEPTH, ft.	WELL CAP., gpm
1 BAMMEL	well #1	3862	1971	994	1,200
	well #2	4099	1986	1,070	1,000
2 BILMA	well #1	3229	1981	1,115	1,000
3 CHARTERWOOD	well #1	2424	1974	580	600
	well #2	3529	1980	1,180	950
4 C N P	well #1	1658	1971	1,148	1,000
	well #2	2634	1976	1,234	1,200
	well #3	3564	1981	1,200	1,800
5 CY CHAMP	well #1	1630	1972	890	1,050
6 CYPRESS FOREST *	well #1	3161	1978	----	1,150
	well #2	4086	----	1,300	2,800
7 CYPRESS KLEIN	well #1	1620	1975	1,100	950
8 CYPRESSWOOD	well #1	1673	1971	1,100	1,000
	well #2	1870	1973	1,150	1,800
9 FOUNTAINHEAD *	well #1	1854	1974	1,041	650
	well #2	2938	1977	300	1,000
	well #3	2939	1977	1,200	----
10 FWSD 52	well #1	1529	1969	788	725
	well #2	1528	1972	785	850
11 HCMUD 16	well #1	3478	1980	1,200	1,600
12 HCMUD 24	well #1	1779	1975	1,100	1,200
	well #2	3750	1982	1,100	1,000
13 HCMUD 44 *	well #1	2546	1976	1,300	1,000
	well #2	2438	----	----	----
14 HCMUD 48	None				
15 HCMUD 58	well #1	3110	1978	1,200	900
16 HCMUD 86 (new)	well #1	3537	not drilled yet		
17 HCMUD 104 *	well #1	2970	----	1,100	1,000
18 HCMUD 150 *	well #1	2729	1977	1,050	1,000
	well #2	3256	1979	----	1,000
19 HCMUD 159	well #1	3330	1980	1,000	1,120
	well #2	3331	1980	1,000	1,177

* Some information not recieved

INFORMATION ON UTILITY DISTRICT WELLS WITHIN NHCWSC SERVICE AREA

UTILITY DISTRICTS	WELLS WITHIN DISTRICT	WELL PERMIT NO.	YEAR COMP.	WELL DEPTH, ft.	WELL CAP., gpm
20 HCMUD 180 *	well #1	3349	1979	1,200	1,000
	well #2	3803			
21 HCMUD 189 *	well #1	3482	1980	1,300	1,500
	well #2	3695	----	1,300	2,000
	well #3	3990	1981	300	----
22 HCMUD 191 *	well #1	3751	1982	1,100	----
23 HCMUD 200 *	well #1	3863	1981	1,300	1,700
	well #2	3567	----	1,300	1,550
24 HCMUD 202	well #1	3867	1983	1,300	1,500
25 HCMUD 203 *	well #1	3660	1981	1,450	2,000
	well #2	3780	1982	1,424	----
26 HCMUD 205 *	well #1	3550	----	1,500	1,600
27 HCMUD 211	well #1	3726	1982	1,300	1,200
28 HCMUD 215 *	well #1	3868	----	1,200	1,350
29 HCMUD 217	well #1	3781	1982	950	1,000
30 HCMUD 233	(shares well with HCMUD 211)				
31 HCMUD 254 *	well #1	3889	----	1,300	1,500
32 HCMUD 304 *	well #1	4037	----	1,400	1,130
33 HEATHERLOCH	well #1	1867	1975	775	1,000
34 KLEIN	well #1	2943	1978	1,150	1,300
35 KLEINWOOD *	well #1	1727	----	400	1,000
36 LOUETTA NORTH *	well #1	3956	----	1,350	1,500
37 LOUETTA ROAD	well #1 (jointly owned by Terranova)	1860	1974	1,063	1,000
38 NORTH FOREST *	well #1	2186	----	----	----
39 NWHCMUD 6	well #1	2731	1977	1,400	1,200
	well #2	3605	1981	740	1,000
40 NWHCMUD 20 *	well #1	3635	----	1,300	1,200
41 NWHCMUD 21	(shares well with NWHCMUD 22)				

* Some information not recieved

INFORMATION ON UTILITY DISTRICT WELLS WITHIN
NHCWSC SERVICE AREA

UTILITY DISTRICTS	WELLS WITHIN DISTRICT	WELL PERMIT NO.	YEAR COMP.	WELL DEPTH, ft.	WELL CAP., gpm
42 NWHCMUD 22	well #1	3448	1979	1,100	1,200
43 NWHCMUD 23	well #1	3447	1979	1,100	1,000
44 NWHCMUD 36 (new)	None				
45 PONDEROSA FOREST	well #1	1663	1971	1,165	1,050
	well #2	2947	1978	1,320	1,100
	well #3	3631	1981	1,300	1,550
46 PRESTONWOOD FOREST	well #1	1544	1970	1,120	1,000
	well #2	3239	1978	1,120	1,000
47 RANKIN ROAD WEST *	well #1	3992	----	1,400	1,360
48 SPRING CREEK FOREST	well #1	1664	1972	675	829
49 SPRING WEST	well #1	3556	1981	1,200	1,600
50 TERRANOVA WEST *	well #1	4058	----	1,100	1,000
51 WCID 91	well #1	1538	1968	752	650
	well #2	1537	1972	1,239	1,000
52 WCID 109	well #1	1378	1970	802	1,200
	well #2	1379	1970	1,058	1,050
	well #3	3333	1979	1,200	1,500
53 WCID 110 *	well #1	1617	1969	1,091	1,100
	well #2	2903	1977	----	1,250
54 WCID 114	well #1	1534	1970	615	1,075
	well #2	3409	1980	1,200	900
55 WCID 116 *	well #1	2093	1974	520	1,007
	well #2	2094	----	1,210	----
	well #3	3316	1979	1,200	943
56 WCID 119 *	well #1	2183	1970	1,000	1,000
	well #2	4091	----	1,000	----
57 WCID 132	well #1	3648	1982	1,150	1,000
58 WESTADOR	well #1	1904	1969	1,020	1,000
	well #2	1905	1972	1,065	1,000

* Some information not recieved

APPENDIX H

NHCWSC
STORAGE CAPACITIES

UTILITY DISTRICTS	WELLS WITHIN DISTRICT	HGCSD PERMIT NO.	GROUND STORAGE, (gal)	ELEVATED STORAGE, (gal)
1 BAMMEL	well #1	1527	840,000	0
	well #2	4099	353,000	0
2 BILMA	well #1	3229	220,000	0
3 CHARTERWOOD	well #1	2424	840,000	0
	well #2	3529	420,000	0
4 C N P	well #1	1658	500,000	750,000
	well #2	2634	0	0
	well #3	3564	500,000	0
5 CY CHAMP	well #1	1630	650,000	0
6 CYPRESS FOREST	well #1	3161	0	750,000
	well #2	4086	1,400,000	0
7 CYPRESS KLEIN *	well #1	1620		
8 CYPRESSWOOD (WCID 132)	well #1	1673	0	500,000
	well #2	1870	420,000	0
	well #3	3648	420,000	0
9 FOUNTAINHEAD *	well #1	1854		
	well #2	2938	420,000	
	well #3	2939		
10 FWSD 52 *	well #1	1529	750,000	200,000
	well #2	1528	0	0
11 HCMUD 16	well #1	3478	1,000,000	0
12 HCMUD 24	well #1	1779	500,000	0
	well #2	3750	220,000	0
13 HCMUD 44 *	well #1	2546	840,000	0
	well #2	2438		
14 HCMUD 48	None			
15 HCMUD 58	well #1	3110	10,000	0
16 HCMUD 86 (new)	None			
18 HCMUD 150	well #1	2729	210,000	0
	well #2	3256	210,000	0
19 HCMUD 159	well #1	3330	500,000	0
	well #2	3331	500,000	0

* Some information not recieved

NHCWSC
STORAGE CAPACITIES

UTILITY DISTRICTS	WELLS WITHIN DISTRICT	HGCSD PERMIT NO.	GROUND STORAGE, (gal)	ELEVATED STORAGE, (gal)
20 HCMUD 180 *	well #1	3349	420,000	0
	well #2	3803		
21 HCMUD 189 *	well #1	3482	555,000	0
	well #2	3695	429,177	0
	well #3	3990		
22 HCMUD 191 *	well #1	3751	400,000	
23 HCMUD 200 *	well #1	3863	375,000	0
	well #2	3567	458,000	500,000
24 HCMUD 202	well #1	3867	420,000	0
25 HCMUD 203	well #1	3660	1,500,000	1,500,000
	well #2	3780	future plant	
26 HCMUD 205	well #1	3550	not in use yet	
27 HCMUD 211 *	well #1	3726	220,000	0
28 HCMUD 215	well #1	3868	568,000	0
29 HCMUD 217	well #1	3781	250,000	0
30 HCMUD 233	(shares well with HCMUD 211)			
31 HCMUD 254	well #1	3889	500,000	0
32 HCMUD 304	well #1	4037	524,641	0
33 HEATHERLOCH *	well #1	1867	126,000	0
34 KLEIN	well #1	2943	400,000	0
35 KLEINWOOD *	well #1	1727	240,000	0
36 LOUETTA NORTH	well #1	3956	420,000	0
37 LOUETTA ROAD	well #1	1860	660,000	0
	(Jointly owned well, TERRANOVA and LOUETTA ROAD)			
38 NORTH FOREST *	well #1	2186	400,000	
39 NWHCMUD 6	well #1	2731	500,000	0
	well #2	3605	0	0
41 NWHCMUD 21	(shares well with NWHCMUD 22)			
42 NWHCMUD 22	well #1	3448	440,000	0
	(jointly owned by NWHCMUD 21)			

* Some information not recieved

NHCWSC
STORAGE CAPACITIES

UTILITY DISTRICTS	WELLS WITHIN DISTRICT	HGCSD PERMIT NO.	GROUND STORAGE, (gal)	ELEVATED STORAGE, (gal)
43 NWHCMUD 23	well #1	3447	220,000	0
44 NWHCMUD 36 (new)	None			
45 PONDEROSA FOREST *	well #1	1663	325,000	0
	well #2	2947	1,200,000	0
	well #3	3631	500,000	0
46 PRESTONWOOD FOREST	well #1	1544	420,000	0
	well #2	3239	420,000	0
47 RANKIN ROAD WEST	well #1	3992	340,000	0
48 SPRING CREEK FOREST	well #1	1664	300,000	0
49 SPRING WEST	well #1	3556	500,000	0
50 TERRANOVA WEST	well #1 (See LOUETTA ROAD)	4058	525,000	0
51 WCID 91 *	well #1	1538	400,000	150,000
	well #2	1537	(same as above)	
52 WCID 109 *	well #1	1378	500,000	0
	well #2	1379	507,000	0
	well #3	3333	500,000	0
53 WCID 110 *	well #1	1617	960,000	400,000
	well #2	2903		
54 WCID 114	well #1	1534	600,000	0
	well #2	3409	720,000	0
55 WCID 116 *	well #1	2093	800,000	225,000
	well #2	2094	Abandoned May 1985	
	well #3	3316		
56 WCID 119 *	well #1	2183	420,000	0
	well #2	4019		
57 WCID 132	See Cypresswood - jointly owned facilities			
58 WESTADOR *	well #1	1904	250,000	300,000
	well #2	1905	750,000	same as above
	well #3	4115		
TOTALS			32,685,818	5,275,000

* Some information not recieved

APPENDIX I

UTILITY DISTRICT INTERCONNECTS WITHIN
NHCWSC SERVICE AREA

SHT 1 OF 3

UTILITY DISTRICTS	INTERCONNECTIONS *	SIZE (in.)
1 BAMMEL	HCMUD 16	12
	HCMUD 44	8
	NWHCMUD 21	8
2 BILMA	Spring Creek Forest	8
3 CHARTERWOOD	WCID 119	12
4 C N P	Westador	8
5 CY CHAMP	Cypress Forest	12
	HCMUD 191	12
6 CYPRESS FOREST	Cy Champ	12
	Louetta North	12
	WCID 114	12
7 CYPRESS KLEIN	Kleinwood	8
8 CYPRESSWOOD	Klein	8
	Louetta Road	12
9 FOUNTAINHEAD	WCID 109	8
10 FWSD 52	None	12
11 HCMUD 16	Bammel	12
	HCMUD 44	12
	NWHCMUD 21	12
12 HCMUD 24	Spring Creek Forest	12
13 HCMUD 44	Bammel	8
	HCMUD 16	12
	HCMUD 211	8
	NWHCMUD 20	8
14 HCMUD 48	WCID 109	8
15 HCMUD 58	Ponderosa Forest	8
16 HCMUD 86 (new)	None	
17 HCMUD 104	WCID 110	6
18 HCMUD 150	HCUD 15	8
	HCMUD 180	8
19 HCMUD 159	HCMUD 254	12
20 HCMUD 180	HCMUD 150	8
	HCMUD 202	16
21 HCMUD 189	HCMUD 205	16
	North Forest	16

* Information was obtained from Operators and District Engineers

UTILITY DISTRICT INTERCONNECTS WITHIN NHCWSC SERVICE AREA

UTILITY DISTRICTS	INTERCONNECTIONS *	SIZE (in.)
22 HCMUD 191	Cy Champ	12
	HCMUD 254	12
23 HCMUD 200	HCMUD 205	16
	HCMUD 215	8
	Laurel Oaks	12
	Northborough	12
	Rankin Road	8
24 HCMUD 202	HCMUD 180	16
25 HCMUD 203	Northborough	12
26 HCMUD 205	HCMUD 189	16
	HCMUD 200	16
27 HCMUD 211	HCMUD 44	8
	NWHCMUD 20	12
28 HCMUD 215	HCMUD 200	8
29 HCMUD 217	HCMUD 5	12
30 HCMUD 233	See HCMUD 211	
31 HCMUD 254	HCMUD 159	12
	HCMUD 191	12
32 HCMUD 304	Rankin Road West	12
33 HEATHERLOCH	WCID 116	12
34 KLEIN	Cypresswood/WCID 132	8
35 KLEINWOOD	Cypress Klein	12
	WCID 114	12
36 LOUETTA NORTH	Cypress Forest	12
37 LOUETTA ROAD	Cypresswood/WCID 132	12
	Terranova West	12,8,6
38 NORTH FOREST	HCMUD 189	16
39 NWHCMUD 6	None	
40 NWHCMUD 20	HCMUD 44	8
	HCMUD 211	12

* Information was obtained from Operators and District Engineers

UTILITY DISTRICT INTERCONNECTS WITHIN NHCWSC SERVICE AREA

SHT 3 OF 3

UTILITY DISTRICTS	INTERCONNECTIONS *	SIZE (in.)
41 NWHCMUD 21	Bammel	8
	HCMUD 16	12
	Fountainhead	12
	NWHCMUD 22	12
42 NWHCMUD 22	NWHCMUD 21	12
	NWHCMUD 23	12
43 NWHCMUD 23		
	NWHCMUD 22	12
44 NWHCMUD 36	NWHCMUD 28	
45 PONDEROSA FOREST	HCMUD 58	8
	WCID 91 (2)	8
46 PRESTONWOOD FOREST	None	
47 RANKIN ROAD WEST	HCMUD 200	8
	HCMUD 304	12
48 SPRING CREEK FOREST	Bilma	8
	HCMUD 24	12
49 SPRING WEST	None	
50 TERRANOVA WEST	Louetta Road	12,8,6
51 WCID 91	Ponderosa Forest (2)	8
52 WCID 109	Fountainhead	8
	HCMUD 48	8
53 WCID 110	HCMUD 104	6
54 WCID 114	Cypress Forest	12
	Kleinwood	12
55 WCID 116	Heatherloch	12
56 WCID 119	Charterwood	12
57 WCID 132	See Cypresswood	
58 WESTADOR	C N P	8

* Information was obtained from Operators and District Engineers

APPENDIX J

SUBDIVISIONS IN NHCWSC SERVICE AREA

UTILITY DISTRICT	SUBDIVISION(S)
1 Bammel	Olde Oaks
2 Bilma	Spring Creek Oaks
	Spring Creek Forest
3 Charterwood	Charterwood
4 CNP	Cypress Station
5 Cy-Champ	Champions
	Champions Place
	Champions Park
6 Cypress Forest	Champions Forest
7 Cypress Klein	Wimbeldon Estates
8 Cypresswood	Cypressdale
9 Fountainhead	Fountainhead
	Northcliff
10 FWSD 52	Champions
11 HCMUD 16	Cornerstone Village North
12 HCMUD 24	Woodbriar Place
	Oakwood Glen
13 HCMUD 44	Northgate Forest
	Olde Oaks
14 HCMUD 48	Huntwick Forest
15 HCMUD 58	Bammel Village
16 HCMUD 86	
17 HCMUD 104	Devonshire Woods
18 HCMUD 150	Northcliff Manor
	Camden Park
19 HCMUD 159	Willow Brook Mall
20 HCMUD 180	The Traces
	Klein Brook
	Copper Creek
21 HCMUD 189	Willow Green
22 HCMUD 191	Champions Centre
	Willow Centre
23 HCMUD 200	Cranbrook
24 HCMUD 202	Champions Point Village
25 HCMUD 203	Greens Crossing
26 HCMUD 205	Northbriar Place
27 HCMUD 211	Northgate Forest
28 HCMUD 215	Dominion Park
29 HCMUD 217	Heritage Village
30 HCMUD 233	
31 HCMUD 254	Centerfield
32 HCMUD 304	
33 Heatherloch	Woods of Wimbeldon
34 Klein	Cypresswood
35 Kleinwood	Kleinwood
36 Louetta North	Colony Creek Village
37 Louetta Road	Terranova
38 North Forest	North Forest
39 NWHCMUD 6	Cutten Green
40 NWHCMUD 20	Oak Creek Village
41 NWHCMUD 21	
42 NWHCMUD 22	Wimbeldon
	Torrey Pines
43 NWHCMUD 23	Sable Ridge
	Sable Chase
44 NWHCMUD 36	
45 Ponderosa Forest	Ponderosa Forest
	Ponderosa Trails
46 Prestonwood Forest	Prestonwood Forest
47 Rankin Road West	
48 Spring Creek Forest	Spring Creek Forest
49 Spring West	
50 Terranova West	Terranova West
51 WCID 91	Chantilly Woods
52 WCID 109	Greenwood Forest
53 WCID 110	Enchanted Oaks
	Devonshire Woods
54 WCID 114	Memorial Chase
	Memorial Northwest
55 WCID 116	Huntwick Forest
56 WCID 119	Memorial Chase
	Glenloch
57 WCID 132	Cypress Villas
58 Westador	Pine Oak Forest
	Westador

APPENDIX K
North Harris County Water Supply Corporation - Consultants

Attorney: **Vinson & Elkins**

The attorney works on behalf of the NHCWSC towards the legal creation of a regional entity which will provide surface water to the service area. The attorney also provides general legal consultation to the NHCWSC.

Vinson & Elkins
3300 First City Tower
1001 Fannin
Houston, Texas 77002-6760
(713) 651-2222

Bob Randolph or **Allison Dickson**

Vinson & Elkins was established over seventy years ago and now consists of approximately 432 lawyers. The principal office of Vinson & Elkins is in Houston, and with offices in Austin, Dallas, Washington D.C. and London. Approximately 55% of the lawyers have predominately business practice, while 45% are engaged in one of several litigation areas.

Vinson & Elkins specializes in the areas of municipal finance, water rights, land use, and environment law. A significant amount of its practice involves counseling entrepreneurial or start-up entities or organizational, financing, tax structuring and project development matters. The firm is actively involved in the representation of political subdivisions and municipal corporations in Texas, including the City of Houston, Harris County and approximately 240 conservation and reclamation districts in the State. In addition, Vinson & Elkins represents state agencies such as the 1) Texas Water Development Board; 2) Texas Housing Agency; 3) Texas Veteran's Land Board; and 4) Texas Turnpike Authority. Vinson & Elkins also serves as general counsel to the Texas Water Alliance, which is a state-wide nonprofit corporation involved in the development of water policy in Texas.

Engineer: **Joint Venture of Pate Engineers, Inc. and Jones & Carter, Inc.**

The engineers work on behalf of the NHCWSC providing technical knowledge on the feasibility of various surface water options for the service area. The engineer also provides general engineering consultation on behalf of the NHCWSC.

Pate Engineers, Inc.
13403 Northwest Freeway, Suite 160
Houston, Texas 77090-6071
(713) 462-3178

Alex Sutton, P.E.

Pate Engineers, Inc. offers a variety of civil engineering services including conceptual planning, preliminary engineering, design, preparation of construction plans, specifications, assistance in bidding and construction services including administration and field observation. Founded in 1970, the firm has grown to approximately 40 employees including 17 engineers of whom 13 are registered professional engineers in Texas. Pate Engineers has excellent working relationships with state and local agencies and is familiar with design criteria and approval policies of these agencies.

Pate Engineers has been and is currently involved in a number of significant civil engineering projects in the Houston metropolitan area. Including the West District Diversion; East Water Distribution System Expansion; Upper Brays Regional Wastewater Treatment Plant; The Greens, White Oak, Brays and Sims Bayou Regional Flood Plans; Water Resources Development Plans for the San Jacinto River Authority; Water System Pressure Study for the City of Conroe; City of Conroe Regional Master Plan.

Jones & Carter, Inc.
6335 Gulfton, Suite 200
Houston, Texas 77081
(713) 777-5337

J. R. (Bob) Jones, P.E.

Jones & Carter, Inc. was established in 1976 to provide general engineering services to Harris County and the surrounding area. The company provides engineering services to both municipal and private clients. Jones & Carter, Inc. has approximately 60 employees including 17 Engineers of whom nine are registered professional engineers in Texas. Jones & Carter, Inc. represent some forty municipal utility districts as well as serving as the city engineer for the City of Stafford.

The company is also employed by Harris County, Montgomery County and the City of Houston on several engineering projects. Work background includes broad experience with water and sewer utilities, paving, drainage, bridges, construction inspection, construction management, water plants and waste water treatment plants. Currently Jones & Carter is providing construction management services to the Harris County Toll Road Beltway 8 project.

Financial Advisor: **Co-Financial Advisor Services are provided by Underwood, Neuhaus & Company, Inc. and Greer Moreland Fosdick Shepherd Inc.**

The Financial Advisor works on behalf of the NHCWSC providing a resume of the various financial alternatives available to NHCWSC, or any subsequent regional entity, to accomplish the financing of the project. Included among these financing alternatives is loan participation in the project by the Texas Water Development Board ("TWDB"), and the Financial Advisors have recommended to the NHCWSC that such TWDB participation be actively explored. It is the further responsibility of the Financial Advisors to provide periodic updates of all financing plans and to implement the final plan after it has been adopted by NHCWSC.

Underwood, Neuhaus & Co. Incorporated
909 Fannin Street, 7th Floor
Houston, Texas 77010-1060

Lawrence R. Catuzzi

Underwood, Neuhaus & Co., Incorporated is the oldest Texas based investment banking firm. For over 80 years, Underwood, Neuhaus has provided clients and investors the highest quality of service available. On July 31, 1987, Underwood, Neuhaus & Co., Inc. completed a merger with The Franklin Savings Association of Kansas, a $9 Billion Savings Association with a net worth of over $300 Million. Underwood, Neuhaus & Co, Inc. will operate as a wholly owned subsidiary of Franklin. The firm presently maintains Texas offices in Austin, Houston, Dallas and San Antonio; together with offices in Jacksonville, Florida and New York City.

Throughout the firm's history, the municipal and tax-exempt activities have been the heart of Underwood, Neuhaus' business. For the past 10 years, the Municipal Bond Department has ranked as the leading underwriter of tax-exempt bonds sold in Texas. The firm's services also include divisions of Corporate Finance, Syndicate, Financial Services and Research.

Greer Moreland Fosdick Shepherd
Division of Lovett Mitchell Webb & Garrison
700 Rusk Street, 4th Floor
P. O. Box 4348
Houston, Texas 77210
(713) 226-5820

J. Marvin Moreland, Jr.

Greer Moreland Fosdick Shepherd Inc. and it predecessor have operated continuously in the field of municipal finance since 1923. The firm provides financial advisory services to Texas municipalities and engages in underwriting and distributing Texas municipal bonds. The firm serves as financial advisor to approximately 150 municipalities including cities, counties, school and junior college districts, special authorities, utility districts and non-profit corporations.

Greer Moreland Fosdick Shepherd operates as the Public Finance Division of Lovett Mitchell Webb & Garrison ("LMW&G"). In September, 1987, LMW&G was merged into Boettcher & Company, Inc., a Denver, Colorado based member firm of Kemper Financial Companies, Inc. Kemper Financial Companies, Inc. is a non-operating diversified financial services holding company which was incorporated in Delaware in May, 1986 by Kemper Corporation, a publicly traded Delaware corporation, to over see the operations of Kemper's asset management and security brokerage firm subsidiaries and one life insurance company subsidiary.

Greer Moreland Fosdick Shepherd has extensive experience in financing surface water conversion projects through its over 15-year representation of the Galveston County Water Authority ("GCWA"). GCWA has been engaged in the conversion from well water to surface water by Galveston County industries and municipalities, and Greer Moreland Fosdick Shepherd has assisted GCWA in the issuance of approximately $52,000,000 of tax-exempt securities to finance this effort.

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