WATER RESOURCES OF WEST CAPE COD:
AN INVESTIGATION OF
WATER SUPPLY AND DEMAND PLANNING

by

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Submitted to the Department of Civil and Environmental Engineering
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ABSTRACT

The provision of an adequate water supply has become one of the major priorities for West Cape Cod. This report discusses water supply and demand issues for West Cape Cod. For the purpose of this study the West Cape Cod Towns of Bourne, Falmouth, Mashpee and Sandwich are considered. These towns are currently the most threatened by future reduced water supply. The analysis includes a detailed investigation of historical and projected water demand and supply, which results in an estimate of expected deficits in water supply. The communities that are projected to experience deficiencies will need to further investigate improvements to remedy these issues by 2020. The issues of available land use for well development, and the increased water usage based on future growth trends represent significant issues that should direct the future planning of water supply sources on West Cape Cod. This study demonstrates that the preservation and development of future water supply sources does not solely depend on the success of remediation alone, but rather on an understanding that the provision of an adequate water supply for West Cape Cod is a multi-dimensional problem. This study introduces the questions of how deficiencies should be remedied and who should be responsible for coordinating such efforts. It is the opinion of the author that the water supply and demand projections that have been developed to date contain several inconsistencies, and do not represent a realistic analysis of future conditions. At this time, no entity has performed a detailed analysis of the projected water needs for the West Cape Cod community.

Thesis Supervisor: David H. Marks

Title: Professor of Civil and Environmental Engineering

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Section 1: Introduction

1.1 Objective

The purpose of this report is to perform a detailed investigation of the existing water supply and demand forecasting and associated planning strategies. This report examines estimates of future water demand that West Cape Cod will experience by the year 2020, and how that will correspond to the projected water supply sources. Land use and contaminants emanating from numerous sources have limited the availability of suitable sites for future municipal wells, and continue to threaten existing supplies.

Groundwater remediation efforts at the Massachusetts Military Reservation (MMR), and land use restrictions within West Cape Cod have been initiated for the purpose of protecting pristine water supply sources. However, the issue of future water demand planning and existing water supply facility upgrades and/or expansions have not been addressed. This study will review existing analyses, consider other methods of projecting future needs, and discuss water supply management. Water supply management on West Cape Cod needs to be aggressive and consistent if the West Cape Cod Communities, and the MMR Installation Restoration Program (IRP) have the provision of quality drinking water as their highest priority.

1.2 Scope/Background

The provision of an adequate water supply has become one of the major issues on Cape Cod, Massachusetts. One of the largest obstacles is the number of individuals involved in the preservation of Cape Cod Water Supply. Despite the political hurdles, the determination of future water supply resources should not be ignored. The public should be ensured clean water for the future. This report will discuss the methods for providing a proper level of service to the affected communities of West Cape Cod.

For the purpose of this study the West Cape Cod Towns of Bourne, Falmouth, Mashpee, and Sandwich shall be considered. These towns are currently the most threatened by future reduced water supply. Contamination by residential septic systems, improper use and disposal of chemical products at commercial and residential sites, and the contamination of the ground water supply by contaminant plumes migrating from the Massachusetts Military Reservation (MMR) may cause water supply shortages. This study will investigate the projected supply sources and demands through the planning year 2020.

The scope of the investigation provided by this report will address the following four (4) tasks, which include:

- Establish and review a data base that includes historical population and water demand data required for the development of a detailed investigation of existing and future water demands. The data base includes data previously considered by such entities as the Cape Cod Commission (CCC) and the Department of Environmental Management (DEM).

- Recommend a methodology for projecting future water demand for West Cape Cod in 10-year increments spanning the years 2000 through 2020.

- Review existing and future demand and regulatory requirements placed on Bourne, Falmouth, Mashpee, and Sandwich to provide adequate water system service through the planning year 2020.

- Compile the above data and associated findings into a final report that provides a general direction of water supply management for West Cape Cod.

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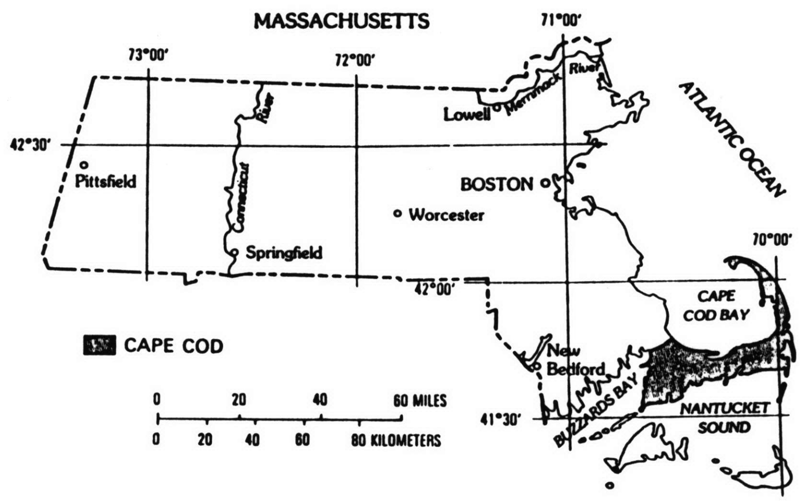

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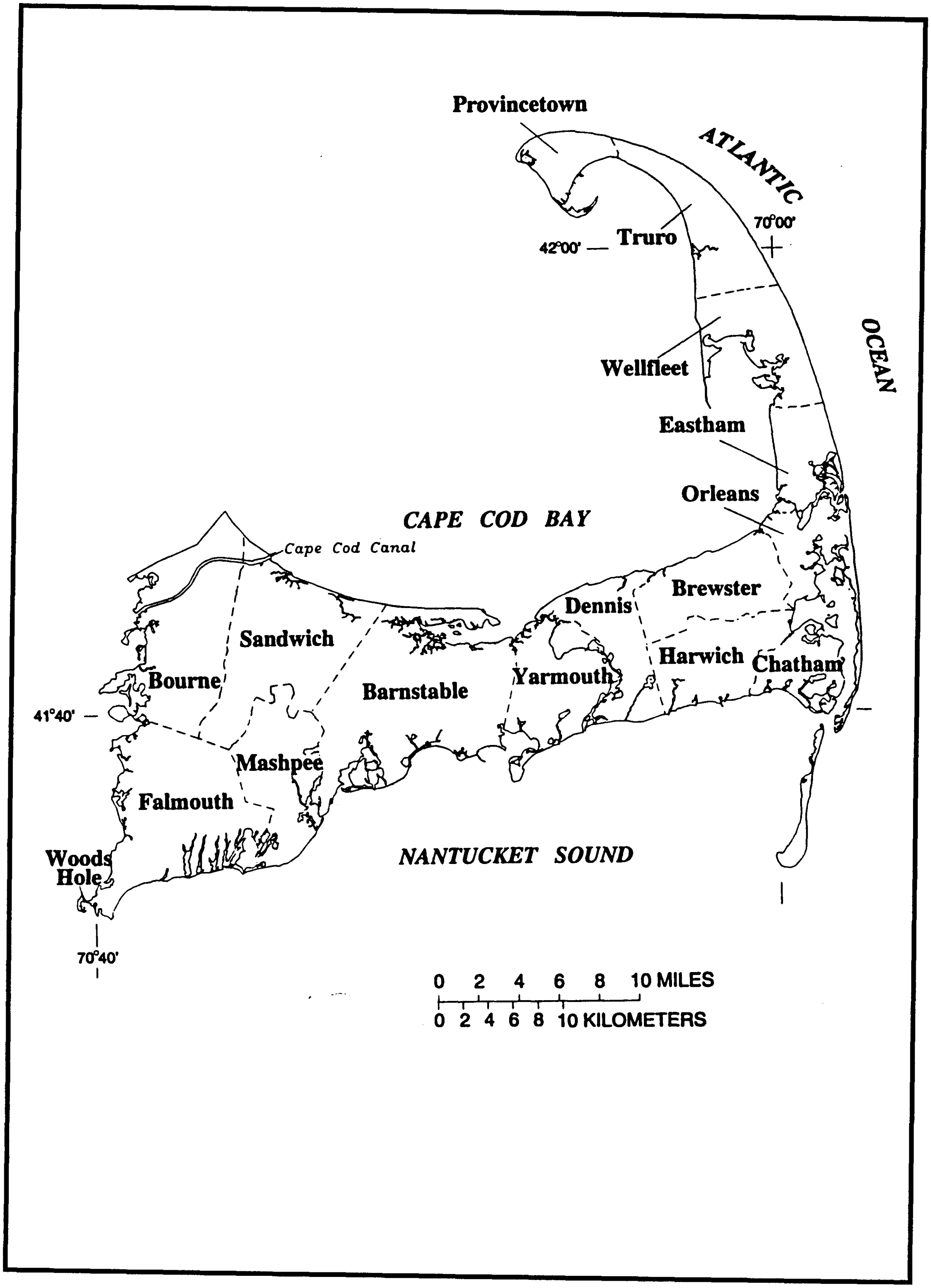
WATER RESOURCES OF WEST CAPE COD
Figure 2-1: Location of Cape Cod, Massachusetts



WATER RESOURCES OF WEST CAPE COD

Figure 2-2: Location of Bourne, Falmouth, Mashpee, and Sandwich between these communities. This will be accounted for in this study when water demand is projected for the planning year 2020.

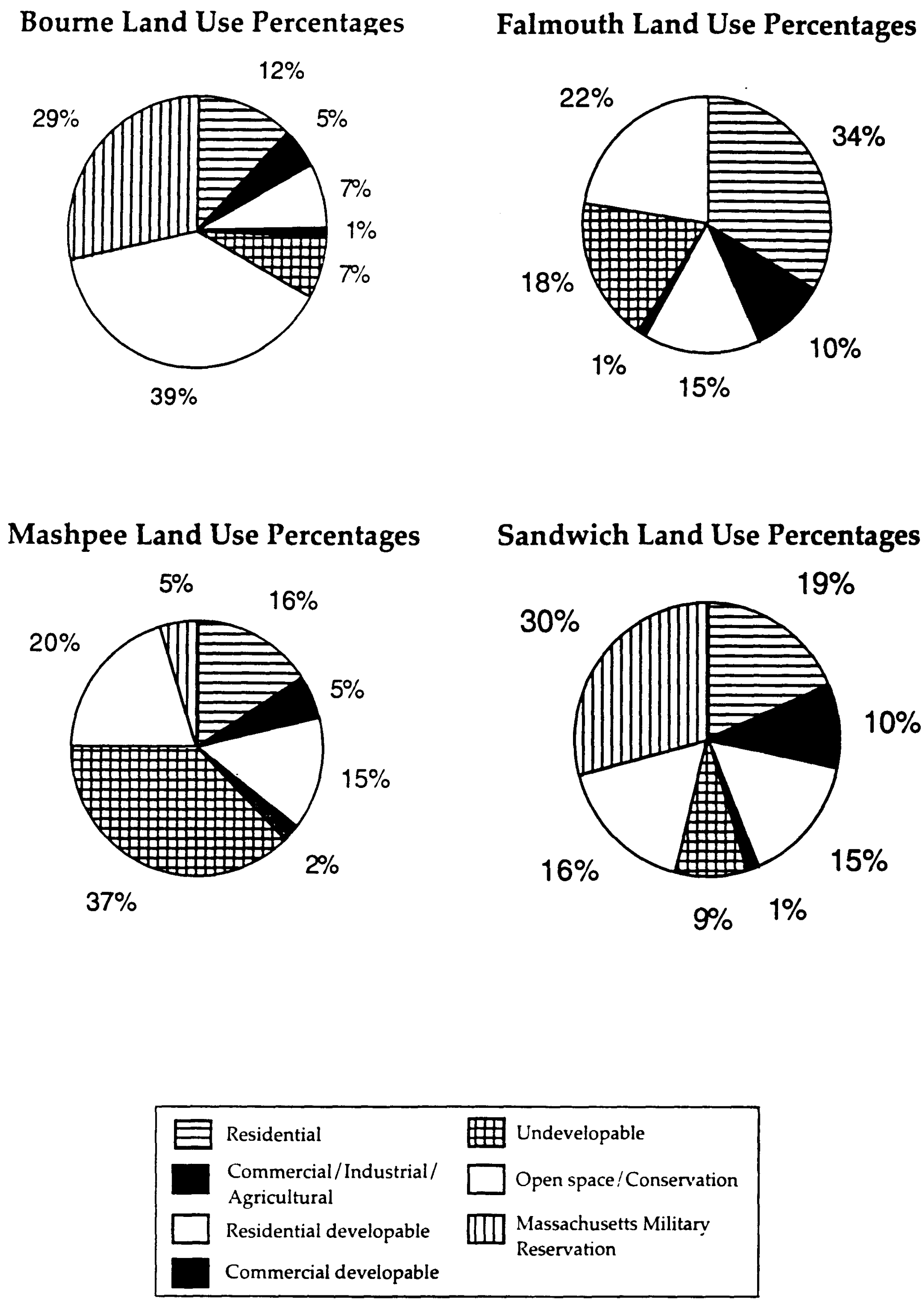
Land use plays an integral role in water supply planning. The amount of available free space is utilized in locating future water supply wells. While, the existing developed land use areas should be analyzed in investigating existing and future water demands, as well as possible points of contamination. Land usage in the Towns of Bourne, Falmouth, Mashpee, and Sagamore is illustrated in Figure 2-3.

2.3 Population

Population growth on Cape Cod has been very dynamic over the last several years as described in the introductory chapters of this report. Permanent population on Cape Cod increased 26-percent from 1980 to 1990. Barnstable County experienced a 35.3 % rate of housing unit growth during this same period. Cape Cod also experiences large seasonal increases in population. As stated before, beaches and a variety of recreational activities create a substantial tourism climate, and result in a significant seasonal population increase during the summer months. (DEM, 1994)

Historical population and growth for the period 1970 through 1990 was gathered West Cape Cod from the U.S. Census Bureau. According to this data the total year-round or permanent historical population for these four (4) communities ranged from 35,105 in 1970 to 67,397 in 1990. The increase in population from 1970 to 1980 equates to a 42-percent growth rate, and the population increase from 1980 to 1990 equates to a 35-percent growth rate. This data and associated data is summarized in Table 2-1 for the four (4) individual communities.(DEM, 1994)

Another measure of demographics on West Cape Cod is the measure of the number of housing units. The U.S. Census Bureau has also compiled total housing unit estimates for Barnstable County. For the period 1970-1990 the total historical housing units for these four communities ranged from 20,012 in 1970 to 41,405 in 1990. The percent



(CCC, 1996)

WATER RESOURCES OF WEST CAPE COD
Figure 2-3: Land Use Percentages

TABLE 2-1

WATER RESOURCES OF WEST CAPE COD

Historical Population
1970-1990

Town	1970 Population	1980 Population	Difference (1970-1980)	% Change (1970-1980)	1990 Population	Difference (1980-1990)	% Change (1980-1990)
Bourne	12,636	13,874	1,238	9.8%	16,064	2,190	15.8%
Falmouth	15,942	23,640	7,698	48.3%	27,960	4,320	18.3%
Mashpee	1,288	3,700	2,412	187.3%	7,884	4,184	113.1%
Sandwich	5,239	8,727	3,488	66.6%	15,489	6,762	77.5%
TOTAL	35,105	49,941	14,836	42.3%	67,397	17,456	35.0%

Note: Data is taken from U.S. Census Bureau Data for Barnstable County (1970-1990) increase from 1970 to 1980 equates to 48-percent, and the percent increase from 1980 to 1990 equates to 40-percent growth. This data and associated data for the individual towns for 1970-1990 is summarized in Table 2-2. The average household size based on permanent population in 1990 for these four communities is calculated to be 1.63 persons/household. This is a slight decrease from the 1970 and 1980 figures.(DEM, 1994)

Since the West Cape Cod public water system service area does not encompass West Cape Cod in its entirety, the historical population was adjusted to reflect the actual population of those serviced. The total serviced population in 1990 for West Cape Cod is estimated to be 47,841 customers. The town with the greatest percentage of serviced population is Falmouth at 85-percent. This data is presented in Table 2-3.(DEM, 1994)

Another consideration for historical population is the effect of seasonal population on defining the total number of serviced customers during the In-Season. It was assumed for the purpose of the DEM study performed in 1994 that 100-percent of the seasonal population is serviced. It is extremely difficult to determine an actual percentage of serviced seasonal customers, and therefore this provides a conservative estimate.

The estimated seasonal population for 1990 was then added to the number of permanent serviced customers to determine the total number of serviced customers during the In-season. The total permanent serviced population for 1990 was estimated to be 89,555. Therefore, the total number of In-season serviced population for 1990 was calculated to be 137,396. This data is also summarized in Table 2-3. (DEM, 1994)

2.4 Level of Service

Water supply on West Cape Cod is provided by public water supply systems, and by private residential supply wells. The Town of Bourne consists of four (4) public water supply entities. North of the Cape Cod Canal the water supply entities are the Buzzards

TABLE 2-2

WATER RESOURCES OF WEST CAPE COD

Historical Housing Units
1970-1990

Town	1970 Units	1980 Units	Difference (1970-1980)	% Change (1970-1980)	1990 Units	Difference (1980-1990)	% Change (1980-1990)
Bourne	6,034	7,169	1,135	18.8%	8,999	1,830	25.5%
Falmouth	9,619	14,414	4,795	49.8%	18,168	3,754	26.0%
Mashpee	1,991	3,582	1,591	79.9%	7,002	3,420	95.5%
Sandwich	2,368	4,358	1,990	84.0%	7,236	2,878	66.0%
TOTAL	20,012	29,523	9,511	47.5%	41,405	11,882	40.2%

Note: Data is taken from U.S. Census Bureau Data for Barnstable County (1970-1990)

TABLE 2-3

WATER RESOURCES OF WEST CAPE COD

Off-Season and In-Season Population
and Service Connections
1990

Town	Permanent Population	Permanent % Serviced	Permanent Service Pop.	Seasonal Population	Seasonal % Serviced	Seasonal Service Pop.	In-Season Service Pop.
Bourne	16,064	54%	8,674	8,150	100%	8,150	16,824
Falmouth	27,960	85%	23,766	41,940	100%	41,940	65,706
Mashpee	7,884	48%	3,784	20,104	100%	20,104	23,888
Sandwich	15,489	75%	11,617	19,361	100%	19,361	30,978
TOTAL	67,397		47,841			89,555	137,396

Note: Data is from the DEM Office of Water Resources, 1994

Bay and North Sagamore Water Districts. South of the canal the water suppliers include the Bourne Water District and the South Sagamore Water District.

The Town of Falmouth is supplied by the Town of Falmouth Water Department. The Town of Mashpee water system is operated by the Mashpee Water District. The Town of Mashpee also receives water from the Town of Sandwich Water District and the Town of Falmouth Water Department. The Town of Sandwich is supplied with water from the Town of Sandwich Water District. (CCC, 1996)

Level of service requirements are established prior to projecting water demand. The level of service required for West Cape Cod is based on historical per capita demand. Per capita water use averaged from 65 to 130 gallons per capita day (gpcd) during the Off-Season and from 25 to 95 gpcd during the In-Season during 1990. The results for each community are located in Table 2-4. The decrease in per capita water use during the In-Season may be related to the increase in seasonal population that is using the public water supply for limited purposes. The discrepancy could also be a result of the DEM estimating that 100-percent of the seasonal population is serviced by public supply sources.

TABLE 2-4

WATER RESOURCES OF WEST CAPE COD

Historical Level of Service
1990

Town	Off-Season			In-Season		
	Permanent Service Pop.	Water Demand (MGD)	Consumption (gpcd)	In-Season Service Pop.	Water Demand (MGD)	Consumption (gpcd)
Bourne	8,674	0.83	96	16,824	1.54	92
Falmouth	23,766	3.00	126	65,706	5.49	84
Mashpee	3,784	0.25	66	23,888	0.63	27
Sandwich	11,617	1.13	97	30,978	1.74	56
TOTAL	47,841			137,396		

Note: Data is from the DEM Office of Water Resources, 1994

Section 3: Existing System

3.1 Introduction

This section of the report summarizes the existing water facilities owned and operated by the various water districts of West Cape Cod. The existing water system facilities include raw water supply, water treatment at some locations, and water transmission and distribution systems. The majority of the water supply systems in West Cape Cod are raw water supply wells connected directly to the water transmission and distribution network.

3.2 Raw Water Supply

Cape Cod relies on a sole source aquifer for its groundwater supply. The Cape Cod Sole Source Aquifer is divided into six groundwater lenses. Lenses are regions of groundwater supply that are bordered by bodies of water and lined with bedrock on the bottom. West Cape Cod is supplied with fresh water from the Sagamore Lens of the Cape Cod Sole Source Aquifer. This lens is separated by the Cape Cod Canal to the west and by the Bass River to the east. This is described in more detail in Sections 5 and 6 of this report.

Groundwater within the Sagamore Lens moves from within the peninsula out towards the various salt water bodies. Based on the geology and topography of West Cape Cod the groundwater flows through the lakes and ponds of the region. The existing raw water supply facilities consist of groundwater supply wells, surface water reservoirs, and pumping equipment. A description of the various water supply facilities for the four communities is provided below. (CCC, 1996)

3.2.1 Bourne

The raw water supply facilities for the Town of Bourne are supplied with raw water from thirteen (13) public water supply wells. There are five (5) wells located in the Buzzards Bay Water District, one (1) well located in the North Sagamore Water District, one (1) well located in the South Sagamore Water District, and six (6) wells located in the Bourne Water District. The zones of influence for these wells are protected as wellhead protection areas. The water districts, public water supply wells, and wellhead protection areas are illustrated in Figure 3-1. This study only investigates the South Sagamore Water District, and the Bourne Water District. A summary of these water supply facilities is provided in Table 3-1.(CCC, 1996)

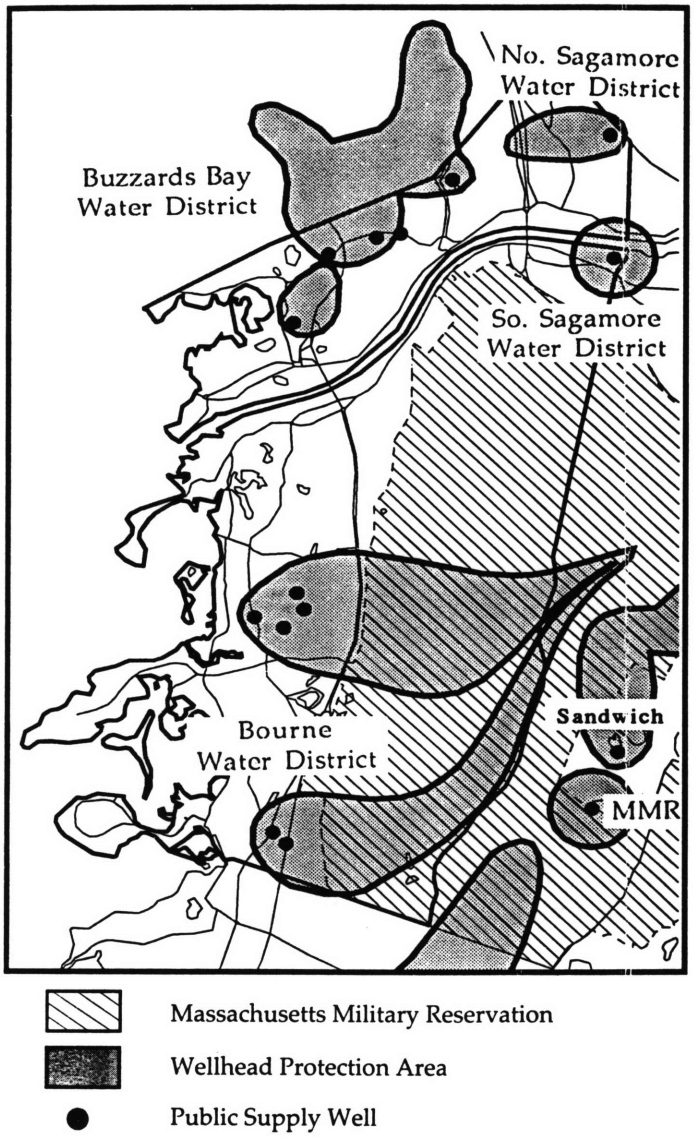
3.2.2 Falmouth

The raw water supply system for the Town of Falmouth is supplied with raw water from three (3) public groundwater supply wells, and several wells located at the surface water body of Long Pond. These facilities are owned and operated by the Falmouth Water Department. The zones of influence for these wells are protected as wellhead protection areas. The water district, public water supply wells, and wellhead protection areas are illustrated in Figure 3-2. The total rated pumping capacity of the well fields is 14.41 MGD. The Town of Falmouth's raw water supply sources are summarized in Table 3-2. (CCC, 1996)

3.2.3 Mashpee

The raw water supply system for the Town of Mashpee is supplied with raw water from the Mashpee Water District. This Mashpee Water District owns and operates four (4) public water supply wells. The Town of Mashpee also receives water from the Falmouth Water Department, and the Sandwich Water District. The zones of influence for the Mashpee Water District wells are protected as wellhead protection areas. The water district, public water supply wells, and wellhead protection areas are illustrated in Figure 3-3. The total rated pumping capacity of the well fields is 3.07 MGD. The Town of Mashpee's raw water supply wells are summarized in Table 3-3. (CCC, 1996)

Bourne Public Supply Wells



(CCC, 1996)

WATER RESOURCES OF WEST CAPE COD
Figure 3-1: Bourne Water Districts

TABLE 3-1

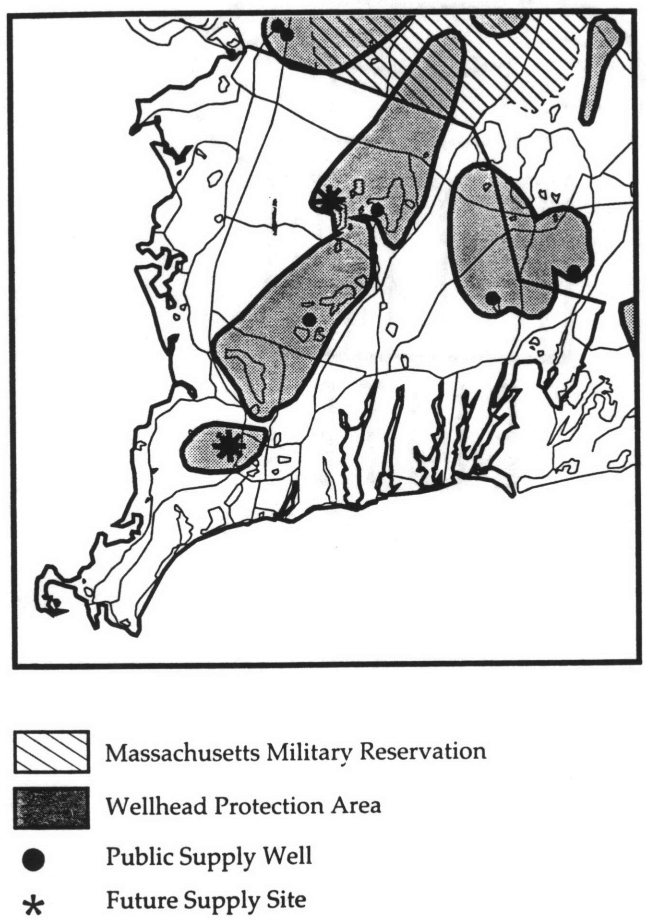
WATER RESOURCES OF WEST CAPE COD

Town of Bourne - Summary of Raw Water Supply Facilities
Bourne Water District and South Sagamore Water District
1995

Facility	Location of Facility	Pumping Rate (gpm)	Pumping Rate (MGD)
BWD - PS #1	County Road	960	1.38
BWD - PS #2 (1)	Route 28 A	600	0.86
BWD - PS #3	Town Forest	620	0.89
BWD - PS #4	n/a	620	0.89
BWD - PS #5	n/a	700	1.01
BWD - PS #6 (1)	n/a	720	1.04
SS - Tubular Wells	Sandwich Road	300	0.43
			0.00
TOTAL		4,520	6.51

Note: Data was supplied by the CCC and Town Water Departments
(1) These wells are taken off-line during the Off-Season

Falmouth Public Supply Wells



(CCC, 1996)

WATER RESOURCES OF WEST CAPE COD
Figure 3-2: Falmouth Water District

TABLE 3-2

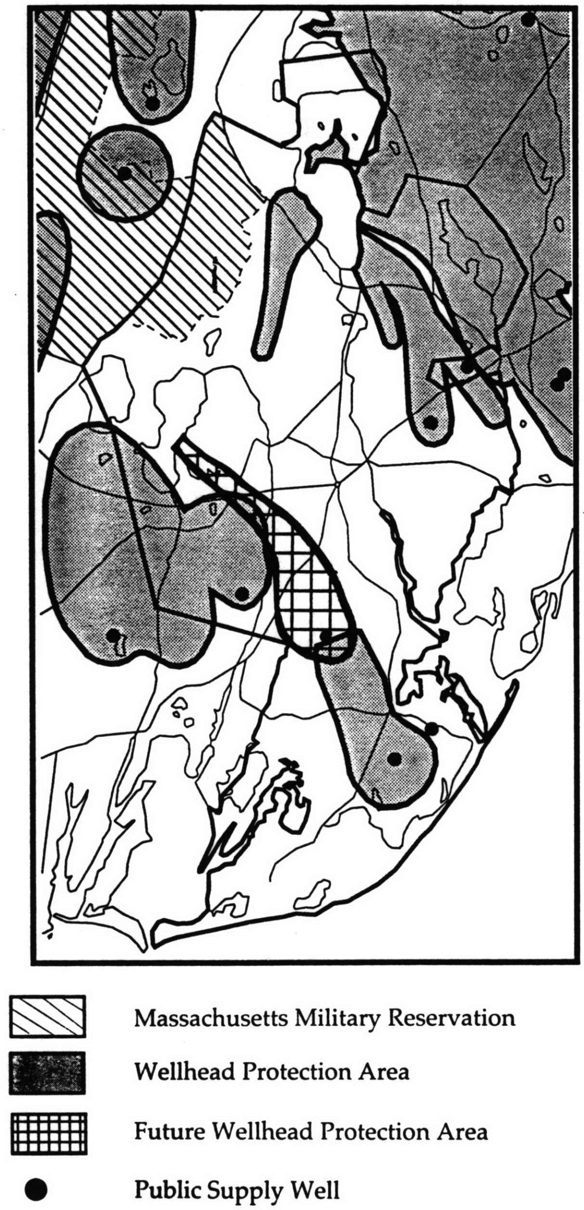
WATER RESOURCES OF WEST CAPE COD

Town of Falmouth - Summary of Raw Water Supply Facilities
1995

Facility	Location of Facility	Pumping Rate (gpm)	Pumping Rate (MGD)
Long Pond	Long Pond	8,340	12.01
Fresh Pond Well	Fresh Pond	695	1.00
Coonamessett Well	Coonamesset	695	1.00
Mares Pond Well	Mares Pond	280	0.40
TOTAL		10,010	14.41

Note: Data was supplied by the CCC and Town Water Departments

Mashpee Public Supply Wells



(CCC, 1996)

WATER RESOURCES OF WEST CAPE COD
Figure 3-3: Mashpee Water District

TABLE 3-3

WATER RESOURCES OF WEST CAPE COD

Town of Mashpee - Summary of Raw Water Supply Facilities
1995

Facility	Location of Facility	Pumping Rate (gpm)	Pumping Rate (MGD)
Well #1	Wading Place Road	235	0.34
Well #2	Rock Landing Road	700	1.01
Well #3	Rock Landing Road	700	1.01
Well #4 (T-4)	n/a	500	0.72
TOTAL		2,135	3.07

Note: Data was supplied by the CCC and Town Water Departments

3.2.4 Sandwich

The raw water supply system for the Town of Sandwich is supplied with raw water from eight (8) public water supply wells. The zones of influence for these wells are protected as wellhead protection areas. The water district, public water supply wells, and wellhead protection areas are illustrated in Figure 3-4. The total rated pumping capacity of the well fields is 7.70 MGD. The Town of Sandwich's raw water supply wells are summarized in Table 3-4. (CCC, 1996)

3.2.5 Otis ANG

The raw water supply facilities located at the Otis Air National Guard (ANG) or the MMR consist of one (1) raw water supply well. The zone of influence for this well is protected as a wellhead protection area. These public water supply wells, and wellhead protection areas are illustrated in Figure 3-5. The total rated pumping capacity of the well field is 2.20 MGD. The Otis ANG raw water supply well is summarized in Table 3-5. This facility is not considered in the following analysis. (CCC, 1996)

3.2.6 Summary

An analysis of total water supply sources under varying conditions was performed. This analysis includes the total number of water supply facilities, the rated pumping capacity, the pumping capacity with the largest well off-line or out of service, the estimated safe yield of the system, and the Water Management Act (WMA) permitted capacity. These results are summarized in Table 3-6, and are compared to projected demands later in this report.

3.3 Water Treatment, Transmission, and Distribution

As discussed earlier in this report, each town water department is responsible for the provision of their own water supply. The only exception to this is the Town of Mashpee which receives water from its own water department, the Town of Sandwich Water District, and the Town of Falmouth Water Department. All five (5) water districts on West Cape Cod utilize potassium hydroxide to reduce pH. The Town of Falmouth is

Sandwich Public Supply Wells

Massachusetts Military Reservation

Wellhead Protection Area

Public Supply Well

(CCC, 1996)

WATER RESOURCES OF WEST CAPE COD
Figure 3-4: Sandwich Water District

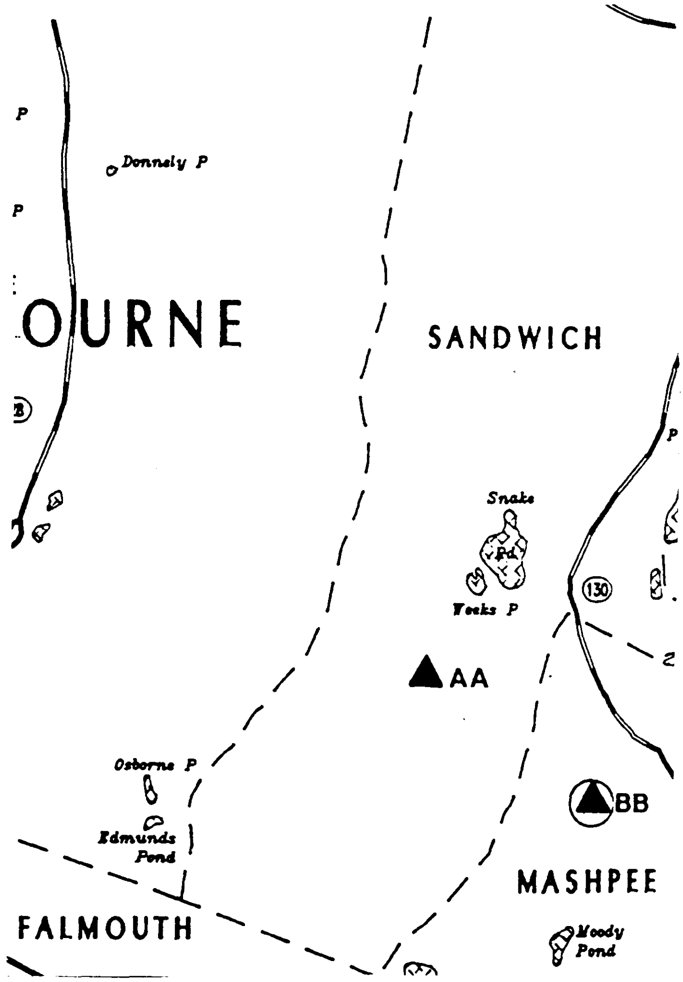
TABLE 3-4

WATER RESOURCES OF WEST CAPE COD

Town of Sandwich - Summary of Raw Water Supply Facilities
1995

Facility	Location of Facility	Pumping Rate (gpm)	Pumping Rate (MGD)
SWD - #1	Tupper Road	abandoned	0.00
SWD - #2	Route 6A	550	0.79
SWD - #3	Route 6A	600	0.86
SWD - #4	Pinkham Road	700	1.01
SWD - #5	Robinwood Circle	700	1.01
SWD - #6	Pinkham Road	700	1.01
SWD - #7	Armstrong Farm Road	700	1.01
SWD - Site #8	Farmersville	700	1.01
SWD - Site #9	n/a	700	1.01
TOTAL		5,350	7.70

Note: Data was supplied by the CCC and Town Water Departments



(DEM, 1994)

WATER RESOURCES OF WEST CAPE COD
Figure 3-5: Otis Air National Guard Base/MMR Water Supply Wells

TABLE 3-5

WATER RESOURCES OF WEST CAPE COD

Otis Air National Guard Base - Summary of Raw Water Supply Facilities
1995

Facility	Location of Facility	Pumping Rate (gpm)	Pumping Rate (MGD)
J Well (1)	Otis ANG	1,530	2.20
TOTAL		1,530	2.20

Notes: Data was supplied by the CCC and the ANG
(1) This well is currently only permitted by the WMA for 0.54 MGD.

TABLE 3-6

WATER RESOURCES OF WEST CAPE COD

Summary of Raw Water Supply Facilities
1995

Town	Total Number Water Supply Facilities	24-Hour Pumping Capacity of Total Wells (MGD)	24-Hour Pumping Capacity With Largest Well Off-Line (MGD)	18-Hour Pumping Capacity of Total Wells (MGD)	18-Hour Pumpin Capacity With Largest Well Off-Line (MGD)	Estimated Safe Yield Capacity for Entity (MGD)	WMA Permitted Capacity (MGD)
Bourne	7	6.51	4.69	4.88	3.52	4.60	1.40
Falmouth	4	14.41	12.41	10.81	9.31	5.50	4.61
Mashpee	4	3.07	2.06	2.30	1.55	2.45	1.20
Sandwich	9	7.70	6.70	5.78	5.03	4.90	2.11
Otis ANG	1	2.20	2.20	1.65	1.65	0.30	0.54
TOTAL	24	33.90	28.06	25.42	21.06	17.75	9.86

Note: Data was supplied by the CCC, Town Water Departments, and ANG currently the only entity that provides chlorine disinfection to their water supply. Eventually all of the water districts will have to disinfect their groundwater supply or obtain a variance from disinfection treatment with the proposed Safe Drinking Water Act (SDWA) Groundwater Disinfection Rule (GWDR) legislation. This is discussed in further detail later in this section.

Public water supply and distribution services within the Town of Bourne include 145 miles of water transmission and distribution mains, 67 miles of which are on West Cape Cod. The Town provides water supply to 8,290 residential service connections, and 519 commercial/municipal connections. The facilities in the Bourne Water District and the South Sagamore Water District account for 5,080 residential connections, and 233 commercial/municipal connections. It is estimated that within the Town of Bourne residential/commercial private wells supply approximately 1,100 homes or businesses with water. This estimate is not available for the individual water districts. (CCC,1996)

Approximately 85-percent of the population of Falmouth is served by public water. The remaining 15-percent of the population of Falmouth utilize private water supply wells. Additional water use is attributed to golf course irrigation, and cranberry bog and other agricultural uses. The Falmouth Water Department pumped an average of 4.172 million gallons per day (MGD) in 1995 from three (3) wells and from Long Pond. Long Pond is currently the only surface water supply system on Cape Cod. Public water supply and distribution services within the Town of Falmouth include 340 miles of water transmission and distribution mains (CCC, 1996; Cape Cod Trends, 1996)

In 1995 the Mashpee Water District water supply system pumped an average of 0.684 MGD. The Town of Mashpee also receives water from Sandwich and Falmouth. The Town of Sandwich provides water to a section of Northern Mashpee, and Falmouth supplies the Tri-Town Circle area. Public water services consist of 94 miles of water distribution and transmission mains, 4,292 residential service connections, and 263 commercial/municipal/industrial service connections. An estimated 3,400 homes or businesses utilize private water supply wells. (CCC, 1996)

The Sandwich Water District water supply wells supplied an average of 1.764 MGD of public water demand in 1995. Public water service assets include 155 miles of water distribution and transmission main, 5,005 residential service connections, and 402 commercial/municipal connections. It is estimated that approximately 3000 non-service area homes or businesses in Sandwich are supplied by private wells. (CCC,1996)

3.4 Historical Water Demand

The analysis of a public water supply system requires the determination of water demand patterns exhibited by the system under various conditions. The Towns of Bourne, Falmouth, Mashpee, and Sandwich have maintained pumping records over the last several years. This data includes water production, and seasonal and daily fluctuations in demand as recorded by the various water districts. Included in this section is a summary of historical water demand, and other demand characteristics of the system.

3.4.1 Average Day Demand

Average water demand has increased dramatically on West Cape Cod over the past ten (10) years. In order to investigate historical water demand trends, the individual and combined demand of the West Cape Cod water districts for the ten year period including 1987 to 1996 was compiled and analyzed. The most recent water demand data was supplied by the environmental consulting firm Earth Tech. This data is summarized in Table 3-7, and illustrated in Figure 3-6.(DEM, 1994; CCC, 1996; Earth Tech, 1997)

3.4.2 Water Demand Variation

Variation in water demand is also reviewed in order to adequately assess the integrity of the existing water supply sources. Variations in water use results in hourly, daily and seasonal shifts in water demand. This study will investigate water demand variations caused by daily or seasonal shifts in water use that reflect seasonal population growth or

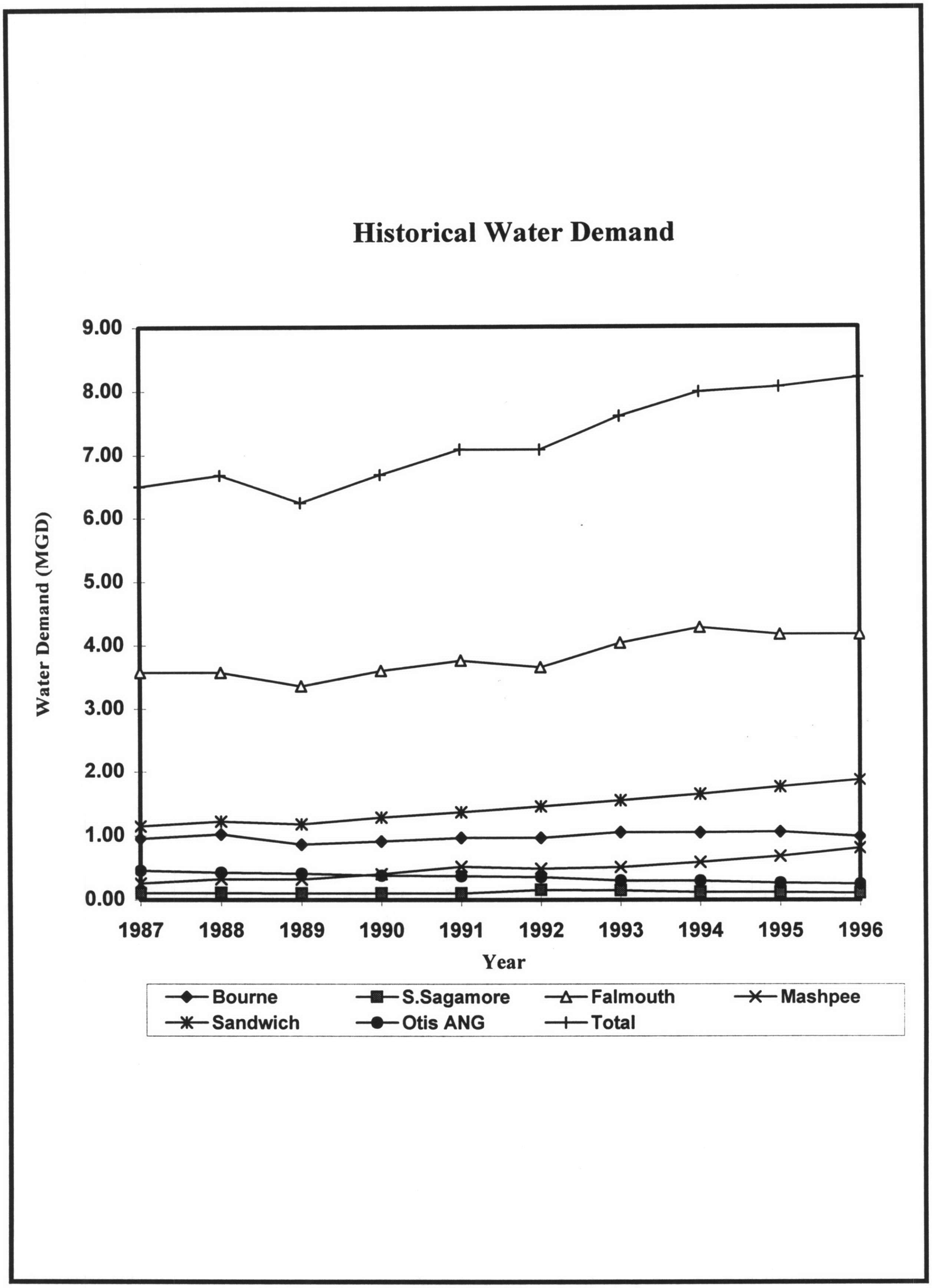
TABLE 3-7

WATER RESOURCES OF WEST CAPE COD

Water Demand Statistics - Annual Average Day Demand (AADD)
(1987-1996)

	Water Districts						
Year	Bourne (MGD)	S. Sagamor (MGD)	Falmouth (MGD) (1)	Mashpee (MGD)	Sandwich (MGD) (2)	Otis ANG (MGD)	Total (MGD)
1987	0.955	0.105	3.575	0.257	1.148	0.459	6.499
1988	1.021	0.108	3.575	0.325	1.223	0.426	6.678
1989	0.867	0.102	3.360	0.322	1.178	0.413	6.242
1990	0.912	0.101	3.605	0.404	1.283	0.381	6.686
1991	0.966	0.102	3.762	0.521	1.366	0.372	7.089
1992	0.968	0.156	3.658	0.490	1.455	0.356	7.083
1993	1.055	0.149	4.039	0.515	1.549	0.301	7.608
1994	1.048	0.123	4.281	0.592	1.650	0.297	7.991
1995	1.060	0.122	4.172	0.684	1.764	0.266	8.068
1996	0.990	0.111	4.172	0.816	1.871	0.251	8.211

Notes: (1) The data listed for 1988 and 1996 are only estimates, due to data deficiencies
(2) The data listed for 1991 through 1994 and 1996 are only estimates based on historical growth rates due to data deficiencies
(3) The data was supplied by Earth Tech



WATER RESOURCES OF WEST CAPE COD

Figure 3-6: Historical Water Demand

seasonal increases in per capita water consumption. The maximum day demand (MDD) is the defined as the water demand that occurred on the day of greatest pumping for a given water district.

Review of historical pumpage reports for the period 1987 through 1996, result in the determination of MDD/AADD factors. The peaking factors were calculated for three (3) of the four (4) communities separately, and then averaged to determine a common factor of demand increase. The MDD/AADD factors are summarized in Table 3-8. The MDD/AADD factors for the Town of Sandwich are not available at this time.

The communities that experienced the greatest shifts during MDD conditions were the Towns of Bourne and Mashpee. Both of these communities experienced peak demand factors of approximately 3.00 for the defined period. The Town of Falmouth peak demand factors have ranged from 2.51 to 1.93, with an average of 2.30 for this time period. The overall West Cape Cod peak demand factor is estimated to be approximately 2.70, assuming the Town of Sandwich's MDDs are similar to MDDs of the communities that surround it.

Another type of water demand variation is seasonal variation. The influx of seasonal population greatly affects the water supply services on West Cape Cod. The climate of the summer months may also have an effect on customer activities, and associated water use. Tourists and seasonal residents increase water use from anywhere between 100-percent and 200-percent. The seasonal water demand variation is defined in more detail below. (DEM, 1994)

The winter months (September-May) are defined as the Off-Season, while the summer months (June-August) are defined as In-Season. These designations are utilized in several of the population and water demand projection methods. The ratios of Off-Season and In-Season demands were calculated for West Cape Cod utilizing the most recent historical water demand data available. (Earth Tech, 1997)

TABLE 3-8

WATER RESOURCES OF WEST CAPE COD

Water Demand Statistics - Peak Day Demand Factors (PDD/AADD)
(1987-1996)

	Water Districts						
Year	Bourne	S. Sagamore	Falmouth	Mashpee	Sandwich	Otis ANG	Average
1987	3.07	n/a	2.40	3.09	n/a	2.15	2.68
1988	3.22	n/a	n/a	3.19	n/a	2.68	3.03
1989	2.93	n/a	2.36	3.95	n/a	1.94	2.80
1990	3.00	n/a	2.35	2.60	n/a	2.91	2.72
1991	2.75	n/a	2.47	3.07	n/a	2.23	2.63
1992	3.42	n/a	1.93	2.94	n/a	1.93	2.56
1993	3.07	n/a	2.51	3.08	n/a	2.42	2.77
1994	2.75	3.13	2.18	3.12	n/a	2.86	2.81
1995	2.87	2.53	2.20	3.29	n/a	1.97	2.57
1996	2.47	2.11	n/a	n/a	n/a	2.72	2.43
Average	2.96	2.59	2.30	3.15	n/a	2.38	2.70

Notes: Data was supplied by Earth Tech

The ratio of In-Season to Off-Season average water demands in 1996 for the Bourne Water District was calculated to be approximately 1.68. This same ratio for the South Sagamore Water District was calculated to be 1.38. The ratio of In-Season to Off-Season water demands for the Town of Falmouth Water Department was calculated to be 1.55 based on 1995 historical demands. This same ratio for the Mashpee Water District was calculated to be 2.03 based on 1996 historical demands.

As would be expected, the smallest ratio of In-Season to Off-Season demand was calculated for the Otis ANG Water Supply System. This ratio was calculated to be 1.27 using the historical demands recorded in 1996. Ratios calculated in 1986 and 1987 for the base were greater than the 1996 ratio. This is due to the difference in base utilization during that time period.

3.4.3 Water Customers

The majority of water customers on West Cape Cod are residential public water supply customers. Other types of customers are commercial, industrial, municipal, and agricultural. Total freshwater withdrawals for Cape Cod are estimated to consist of 14.8-percent for public supply, 83.6-percent for Domestic/Commercial and 1.6 percent Agricultural. (USGS, 1985) The majority of the agricultural uses are supplied by private wells, and are related to the irrigation of cranberry bogs. Of the actual public water service connections for the Towns of Bourne, Mashpee and Sandwich are divided as follows:

- Residential Connections: 14,377
- Commercial Connections: 799
- Municipal Connections: 97
- Industrial Connections: 2

Similar data for the Town of Falmouth is not available, and therefore the above data only reflects service connections for the Towns of Bourne, Mashpee, and Sandwich. (CCC, 1996)

3.5 Water Quality

The raw water supply source for West Cape Cod is the Sagamore Lens of the Cape Cod Sole Source Aquifer. In general this water supply source provides an excellent quality of water from the Cape Cod Aquifer. The groundwater supply has a naturally low pH, and deficiencies in calcium and magnesium result in a "soft" water supply source. In coastal regions of Cape Cod high levels of sodium chloride have been discovered. This is assumed to be due to the proximity of coastal salt waters. Recently, water quality in this region has become a major area of focus and concern. Groundwater contamination from the MMR, and non-point source contributors, such as residential septic systems, has severely threatened existing residential and public water supply wells. (CCC, 1995)

Federal and State Regulatory agencies request monthly testing of public water supplies for bacteria, nitrates/nitrogen, and several other standards regulated under the Safe Drinking Water Act (SDWA). Water quality results are considered public information, and when water quality contaminant levels are detected above acceptable limits, a public notice is issued. Current water treatment practices consist solely of acidity control. Water quality testing of private water supply wells is considered the responsibility of the resident or property owner. (CCC, 1996) Recently, town and MMR officials have supported the cost of testing private residential wells in some locations because of groundwater contamination concerns. These wells should be tested regularly to ensure quality potable water. Water quality concerns at private wells are color and odor.

3.5.1 Sources of Contamination

As West Cape Cod continues to grow and develop, the provision of an adequate water supply will continue to be under scrutiny. The increased urbanization of West Cape Cod has limited land use areas that can be utilized for the development of pristine water supplies. Another limiting factor has been the availability of good quality water. Several components on West Cape Cod have contributed to the general degradation of water quality of undeveloped potential water supply sources. Possible sources of groundwater contamination in this region consist of residential septic systems, contamination plumes from the MMR, the live fire impact area at the MMR, transmission/distribution lines, and salt water intrusion.

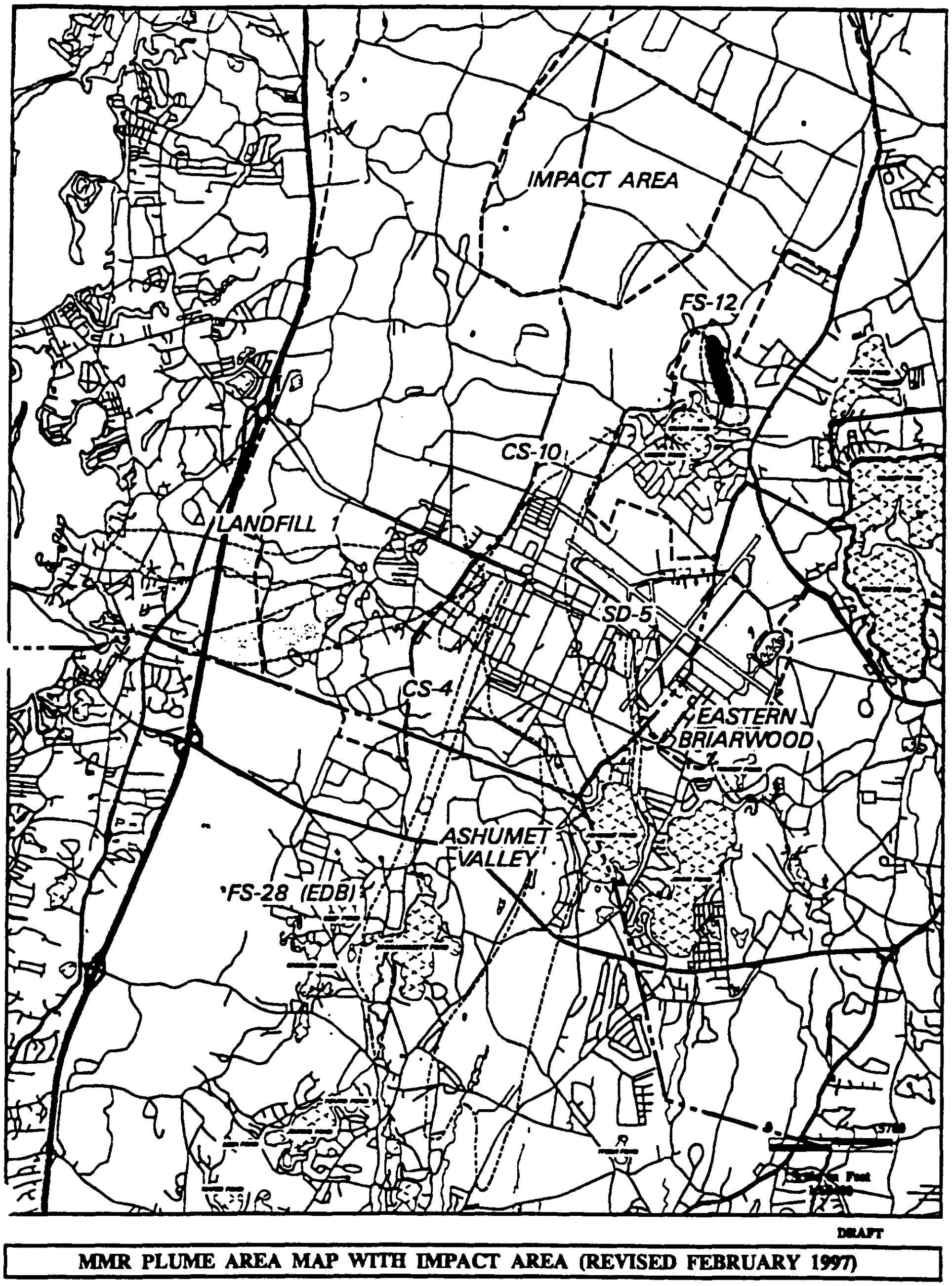
Residential Septic Systems

One of the greatest sources of groundwater contamination on Cape Cod is the disposal of wastewater through residential septic systems. Septic systems release a wastewater that contains high levels of nitrogen into the ground. These septic systems may cause direct contamination of residential water supply wells located on the same property, while large regions of residential septic system users may result in non-point source, nitrogen contamination of regional groundwater supplies. (CCC, 1995) This topic is investigated in more detail by Motolenich-Salas. (Motolenich-Salas, 1997)

Massachusetts Military Reservation Contamination Plumes

The effect of the MMR plumes on public water supplies has been notable. Five (5) public water supply wells have been taken off-line temporarily or permanently. The Falmouth Water District has taken two (2) wells off-line; the Ashumet Valley and Coonamessett Pond Wells based on contamination from the Ashumet Valley Plume. The Bourne Water District has taken Wells #2 and #5 off-line temporarily. They may are still operated during the maximum demand conditions experienced during the In-Season. The final well that was taken off-line was the Weeks Pond Well which is operated by the Sandwich Water District. This well has been taken off-line temporarily for precautionary purposes only. The plumes emanating from the base are illustrated in Figure 3-7.(Town Water Districts, 1997)

These reductions in public water supply will result in the need to develop replacement well sites in non-contaminated areas of these water districts. These water districts are



WATER RESOURCES OF WEST CAPE COD
Figure 3-7: MMR Plume Area Map with Impact Area

investigating the development of new water supply wells on the northwestern corner of the MMR base, where the groundwater has not been affected by contamination.(Bosch, 1996)

Live Fire Impact Area

Recent concern of groundwater contamination on the MMR base has expanded to the effects of the Live Fire Impact Training Area. The possible development of several public potable water supply wells near the live fire impact area has put this facility and its associated activities under close scrutiny. Possible sources of contamination from a live fire impact area are exploded and unexploded munitions used during training sessions. It is debatable whether these possible contaminants ever reach the groundwater supply. Currently, there have been no instances of groundwater contamination resulting from the use of this facility. The live fire impact area is investigated in more detail by Cook. (Cook, 1997)

Transmission/Distribution Lines Transportation

Another possible source of contamination for the public water supplies on West Cape Cod is the transmission and distribution facilities. Water may be contaminated by anaerobic bacterial growth in dead-end lines in the water distribution system. Contamination may also result from corrosion of pipes in the distribution system. Finally, chlorine residuals resulting from chlorine disinfection at the town wells may result in contamination of the public water supply. Although, as mentioned previously, Falmouth is the only water district that chlorinates their water supply.

Saltwater Intrusion

Another possible source of groundwater contamination on Cape Cod is salt water intrusion. Salt water intrusion is most likely to occur on coastal regions, peninsulas, and islands such as Cape Cod. In these regions the fresh water form a layer above the salt water. Salt water intrusion occurs when an aquifer is pumped and salt water begins to replace the fresh water pumped by the supply well. It is estimated that a drawdown of 1 foot in fresh water will correspond to a rise of about 40 feet by salt water. This type of reaction limits the pumping capacity of coastal potable water supply wells. The use of recharge wells or water treatment of the brackish water are possible remedies for this situation. (Viessman, 1977) Currently, these systems are not likely to be implemented based on their high cost, and the existing availability of alternative inland freshwater sources.

3.5.2 Existing Water Quality Regulations

The future planning of the West Cape Cod water supply systems must take into account existing and proposed state and federal regulations that will govern water supply, treatment, and transmission and distribution facilities. Summarized in this section are the rules and regulations that will govern these facilities, and their pertinence to the water supply districts that this report investigates.

The Commonwealth of Massachusetts has established regulatory framework that guide cities and towns to have primary responsibility for the management of land use and water resources. In the Commonwealth of Massachusetts water resource planning and management is primarily guided by the Massachusetts Water Resources Commission (MWRC) and by the Massachusetts Water Resources Authority (MWRA). These entities also implement programs that are initiated by federal agencies. (USGS, 1987)

<u>Safe Drinking Water Act (SDWA) Amendments</u>

The 1986 Amendments to the Safe Drinking Water Act (SDWA) passed by Congress have had a direct impact on the regulation, operation and expansion of the water transmission, distribution, and treatment facilities of West Cape Cod, as well as, communities nationwide. Regulatory requirement updates may take the form of new additional regulated contaminants, more stringent permissible maximum contaminant levels (MCLs), increased monitoring requirements, and/or stricter enforcement penalties. This subsection summarizes some of the directives contained in the SDWA Amendments of 1986 and subsequent regulation updates.

The mandates established by Congress guide the present and new federal and state drinking water regulation programs. The contaminants that are currently regulated are summarized in Table 3-9. An update of these amendments was scheduled for 1996, however, several proposed rules are currently on hold, based on the need for more research on recommended maximum contaminant levels. These amendments to the existing regulations will also be discussed.

Massachusetts Department of Environmental Protection (MADEP)

The Massachusetts Department of Environmental Protection (MADEP) has a variety of responsibilities related to the development and management of water resources. The MADEP responsibilities include the following:

- Data Collection and Analysis
- Flood Control
- Water Resources Planning and Development
- Licensing
- Cooperative Programs with USGS and other Federal Agencies

The most significant regulations that the Commonwealth of Massachusetts has promulgated are the Massachusetts State Interbasin Transfer Act (1983), and the Massachusetts State Water Management Act (WMA) (1985).(USGS, 1987)

The Interbasin Transfer Act gives the MWRA the authority to control the transfer of surface or groundwater, including wastewater, from one river basin to another. In order for a transfer to occur, all other possible methods of providing an adequate water supply must be investigated. This is important to consider for the planning of future water supplies for West Cape Cod. The WMA was passed to require the permitting of all water withdrawals greater that 100,000 gpd. The MADEP was also granted the authority to be involved with local water emergencies.(USGS, 1987)

TABLE 3-9

WATER RESOURCES OF WEST CAPE COD

Contaminants Regulated By 1986 SDWA Amendments

Inorganic Chemicals:

- Antimony
- Arsenic
- Asbestos
- Barium
- Beryllium
- Cadmium
- Chromium
- Copper
- Cyanide
- Fluoride
- Gross alpha Emitters
- Gross beta Particle and Photon Emitters
- Lead
- Mercury
- Nickel
- Nitrate (as N)
- Nitrite (as N)
- Radium 226 plus 228
- Selenium
- Thallium

Microbiological Contaminants:

Total Coliform Rule
- Total Coliforms
- Fecal Coliforms
- E. Coli

Surface Water Treatment Rule
- Turbidity
- Giardia
- Enteric Viruses
- Legionella
- Heterotrophic Plate Count (HPC)

Disinfection By-Products:

Total Trihalomethanes (THMs)

Information Collection Rule

Disinfection residuals, trihalomethanes, haloacetic acids, haloacetonitriles, haloketones, chloral hydrate, chlorite, chlorate, bromide, bromate, total organic halides (TOX), total organic carbon (TOC), viruses, coliforms, Giardia, Cryptospordium

Organic Chemicals:

Synthetic Organic Compounds
- 2,3,7,8-TCDD (Dioxin)
- 2,4,5-TP (Silvex)
- 2,4-D
- Acrylamide
- Alachlor
- Aldicarb
- Aldicarb Sulfone
- Aldicarb Sulfoxide
- Atrazine
- Carbofuran
- Chlordane
- Dalapon
- Di(2-ethylhexyl)adipate
- Dibromochloropropane (DBCP)
- Diethylhexyl Phthalate
- Dinoseb
- Diquat
- Endothall
- Endrin
- Epichlorohydrin
- Ethylene Dibromide (EDB)
- Gylphosate
- Heptachlor
- Heptachlor Expoxide
- Hexachlorobenzene
- Hexachlorocyclopentadiene
- Lindane
- Methoxychlor
- Oxamyl (Vydate)
- PAHs (Benzo(a)pyrene)
- PCBs
- Pentachlorophenol
- Picloram
- Simazine
- Toxaphene

Volatile Organic Compounds:
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- 1,1-Dichloroethylene
- 1,2,4-Trichlorobenzene
- 1,2-Dichoroethane
- 1,2-Dichoropropane
- Benezene
- Carbon Tetrachloride
- Chlorobenzene
- cis-1,2-Dichlorobenzene
- Dichloromethane
- Ethylbenzene
- othro-Dichlorobenzene
- para-Dichlorobenzene
- Styrene
- Tetrachloroethylene (PCE)
- Toluene
- Trans-1,2-Dichloroethylene
- Trichoroethylene (TCE)
- Vinyl Chloride
- Xylenes (total)

(Source: HDR Engineering, AWWA Journal, 1997)

Groundwater Protection Regulations

There are several parties responsible for the local groundwater protection on West Cape Cod. There have been groundwater regulations developed and enforced at the local, county, and state levels relating to wastewater and hazardous waste. Programs and planning methodologies that have been initiated in West Cape Cod include: groundwater protection overlay districts, large lot zoning, and a thorough review of new developments that may produce excessive amounts of wastewater. (CCC, 1996)

The MMR/AFCEE has also initiated the development of a groundwater protection plan that accounts for the land uses that occur at the MMR military base. The MMR is concerned with the insurance of the a long-term water supply system integrity for those communities that border the military base. The Board of Health also has taken a role in the protection of groundwater resources in this region. These regulations pertain to private wells, stables, underground storage tanks, herbicides/pesticides, and additions to Massachusetts Title 5. (CCC, 1996) A summary of the state, county and individual town groundwater protection regulations is summarized in Table 3-10.

TABLE 3-10

WATER RESOURCES OF WEST CAPE COD

Groundwater Protection Regulations

Regulations	Regulated By: Bourne	Falmouth	Mashpee	Sandwich	State	County
WATER SUPPLY						
oundwater Protection District	Zoning	Zoning	Zoning	Zoning	310 CMR 22.21 (2)	RPP
Private Well	Board of Health	none	Board of Health	Board of Health	none	none
ASTEWATER/NUTRIENTS						
Sewage Disposal Systems	Board of Health	Board of Health	Board of Health	Board of Health	310 CMR 15.00	DRI Review
Vastewater Treatment Plants	Board of Health	Zoning	Board of Health	Brd. Hlth./Zon.	310 CMR 5.00	DRI Review
Nutrient Loading	Zoning	Density/Subdiv.	Zoning	Zoning	310 CMR 22.21/15.00	RPP/DRI Revi
Stables	Brd. Hlth./Zon.	none	Board of Health	Board of Health	none	none
AZARDOUS MATERIALS						
xic and Hazardous Materials	Board of Health	Board of Health	Board of Health	Board of Health	310 CMR 22.21	RPP/DRI Revi
Floor Drains	none	none	none	Board of Health	310 CMR 22.21	none
Jnderground Storage Tanks	Town Bylaw	Board of Health	Board of Health	Board of Health	527 CMR 9.00	none
Herbicides/Pesticides	Board of Health	Brd. Hlth./Zon.	Board of Health	Board of Health	333 CMR	none

rce: Cape Cod Commission, 1996

Section 4: Future Conditions

4.1 Introduction

This section investigates the planning practices utilized for projecting future water demand. Population and water demand projections are derived by a variety of methods to determine water demand needs for the planning period 2000-2020. These projected demands will be compared to available future supplies later in this report to determine overall water supply system deficiencies.

4.2 Population Projections

Population projections are an integral part of water supply system planning. The historical population trends are typically related to historical water demand trends. The one exception to this relationship is the effect of water conservation efforts. Water conservation practices may decrease the per capita water demand, and therefore decrease the total water demand for a public water system.

Mathematical and graphical methods may be utilized to estimate future population. These estimates are generally based on an extension or extrapolation of historical or existing trends. Methods of predicting future population include: uniform growth rate, constant percentage growth rate, decreasing rate of increase, graphical extension, graphical comparison with the growth rate of similar areas, ratio methods, and logistic curves. Population estimates may also include existing and future land use designations, and projected development. (McGhee, 1991)

The existing population projections for West Cape Cod were developed by the Cape Cod Commission and the Massachusetts Institute for Social and Economic Research. These population projections were based on historical population, as well as, future planning strategies. These strategies include analyzing land use, available developable land, and projected service system build out. Build out of a water supply system is the maximum number of users anticipated to have access to the water system. This method of projections is defined as Method 1 for the purpose of this study.

The population projections for West Cape Cod calculated using Method 1 include a forecast of permanent and seasonal population. This variance is extremely important due to the variable population experienced in this region. However, it should be noted that the in-season population projections are based on rough estimates made jointly by Town officials and the Cape Cod Commission. Therefore, there is a large possibility for error in the seasonal projections. The year round and seasonal population projections projected by the Cape Cod Commission by Method 1 are summarized in Table 4-1.

The second method of population projections was based on a linear extrapolation of historical population trends performed for this study. The historical data that was utilized for Method 2 was the historical U.S. Census Bureau Data for 1970-1990. The linear extrapolation of this data is illustrated in Figure 4-1. These projections represent permanent or year round population only. However, seasonal projections may also be calculated using similar data that Cape Cod Commission utilized to estimate the seasonal projections in Method 1. These population projections that were estimated based on a linear extrapolation of historical population are located in Table 4-2.

Given the two projection methods it is determined that Method 1, the population projections determined by the Cape Cod Commission is an adequate estimate of future population. These results are also already divided into Off-Season and In-Season. Since there is a limited amount of developable land on Cape Cod the Commission is more able to estimate these constraints in relation to expected growth rates. When the Method 2 projections are adjusted to represent seasonal populations the total population results are very similar to the Method 1 projections. Therefore, both methods are considered valid. Some of the Method 2 projections are greater than the projections calculated using the first method.

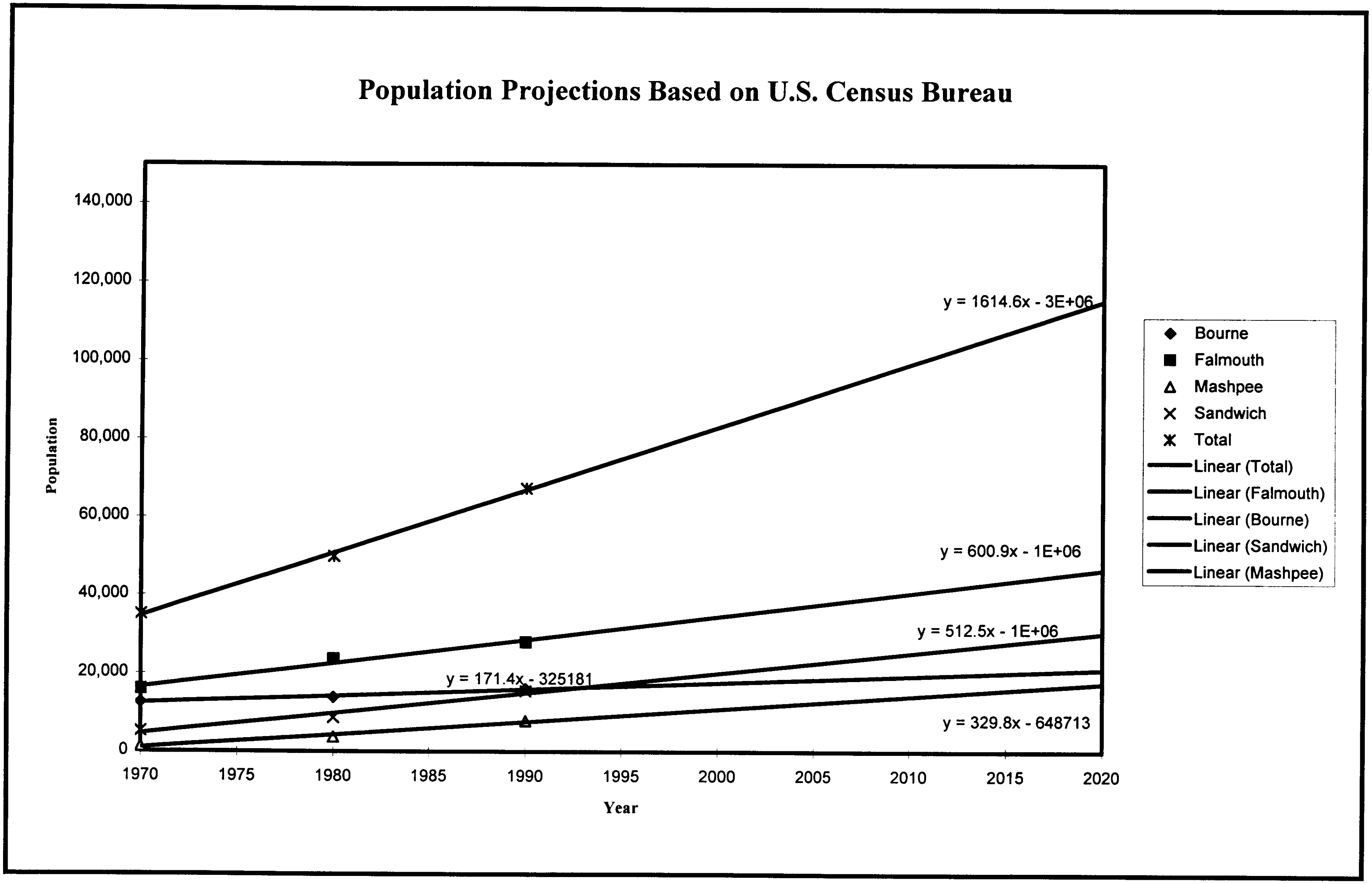
TABLE 4-1

WATER RESOURCES OF WEST CAPE COD

Population Projections
(2000-2020)

Year	Towns									
	Bourne		Falmouth		Mashpee		Sandwich		Total	
	Population	% Growth	Population	% Growth	Population	% Growth	Population	% Growth	Population	% Growth
2000-permanent	17577		28761		10810		17892		75040	
2000-summer	25727		71583		31673		34889		163872	
2010-permanent	17898	1.83%	30204	5.02%	10850	0.37%	17552	-1.90%	76504.07	1.95%
2010-summer	26048	1.25%	75267	5.15%	34829	9.96%	36859	5.65%	173003.2	5.57%
2020-permanent	19642	9.74%	30974	2.55%	10900	0.46%	19471	10.93%	80987.13	5.86%
2020-summer	27792	6.70%	82297	9.34%	34989	0.46%	40889	10.93%	185967.2	7.49%

Notes: Source is DEM, 1994.



WATER RESOURCES OF WEST CAPE COD

Figure 4-1: Population Projections Based U.S. Census Bureau Historical Data

TABLE 4-2

WATER RESOURCES OF WEST CAPE COD

Historical and Projected Population Based on U.S. Census Bureau Data
1970-2020

	Towns				
Year	Bourne	Falmouth	Mashpee	Sandwich	Total
1970	12,636	15,942	1,288	5,239	35,105
1980	13,874	23,640	3,700	8,727	49,941
1990	16,064	27,960	7,884	15,489	67,397
2000	17,778	33,969	11,182	20,614	83,543
2010	19,492	39,978	14,480	25,739	99,689
2020	21,206	45,987	17,778	30,864	115,835

Note: Historical data is taken from U.S. Census Bureau Data for Barnstable County (1970-1990)

Another important consideration that is included in these population projections is the percent of the population that will actually translate into serviced water customers. These percentages were projected by the Cape Cod Commission with the aid of water system managers. The estimation of future service population percentages included the following assumptions. The first assumption was that any system that serviced 100-percent of its population would continue to do so, and any entity that serviced 90-percent or more of its population would increase its percent of serviced population by 5-percent every decade. Those entities with less than 90-percent of their population serviced were analyzed individually with the aid of system water managers. The percentages of serviced population for the four communities are summarized in Table 4-3. These values are utilized in one or more of the water demand projection scenarios provided later in this section.(DEM, 1994)

4.3 Water Demand Factors

For the purpose of water supply planning, it is important to not only estimate the annual average daily demand (AADD), but also the Maximum Day Demand (MDD). In order to estimate these variations in demand it is necessary to determine the ratio between the MDD and the AADD. These ratios are defined as water demand factors. In order to determine appropriate ratios, historical AADD data were examined in comparison to the historical maximum demand variations described above. These historical water demand factors were then analyzed to determine the appropriate future water demand factors.

Historical ratios were calculated for West Cape Cod in the previous section. These water ratios are utilized to increase the projected AADDs of the various water supply systems to calculate the projected MDDs of each system. The water demand factors that are utilized differ for each water district, and range from 2.0 to slightly greater than 3.0.

TABLE 4-3

WATER RESOURCES OF WEST CAPE COD

Projections of Percentage of Population Served
(2000-2020)

Year	Towns			
	Bourne	Falmouth	Mashpee	Sandwich
	% Served	% Served	% Served	% Served
2000	64	95	63	90
2010	64	100	68	95
2020	64	100	73	95

The following peaking factors will be utilized for the projection of MDDs:

- Bourne: 2.90
- Falmouth: 2.20
- Mashpee: 3.20
- Sandwich: 2.00

4.4 Water Demand Projections

The next phase of this investigation is projecting future water demand for the four (4) communities located in West Cape Cod. There are four (4) methods of water demand projections analyzed in this study. The projections span the planning period 2000 through 2020. The first two (2) sets of demand projections are existing projections that are contained in the CCC and DEM planning documents. The second two (2) sets of water demand projections are new projections developed in this study for comparison to or analysis of the existing water demand projections.

The various methods of water demand projections are outlined below. The following subsections will discuss the methodology of, and confidence in the resulting water demand projections. It is important to note that the population projections are adjusted to reflect the number of residents that are serviced by each public water supply system.

4.4.1 Method 1 - CCC (1994)

The first method of water demand projections was provided in 1994 by the Cape Cod Commission. The CCC projected future demands for the planning year 2020. The CCC utilized the WMA permitted AADD well capacities to represent the 1995 AADD. The next step included increasing these water demands by a Maximum Day Factor of 2.50. These MDDs were then increased by various percentages to represent the projected increase in water demand. These percentages of demand increase were based on historical water demands and discussions with town water managers. The projected

MDDs for the planning year 2020 are summarized in Table 4-4, and illustrated in Figure 4-2.(CCC, 1994)

These water demand projections are not very well founded. Utilizing the permitted ADDs does not necessarily reflect the existing water usage in 1995, but rather only the water usage limited by permit, and therefore the resulting demands are probably slightly high. It is also questionable to utilize the same MDD factor for each of the four (4) communities when historical data does not warrant this assumption. Finally, the percent increase in water demand seems somewhat arbitrary. For the four (4) entities, the percentage of water demand increase is a standard 10-percent increase for the 25-year period.(CCC, 1994)

For the above reasons there is not much confidence found in this method of demand projections. In fact since the time of these projections the Cape Cod Commission has adopted the water demand projections that were estimated in the DEM Water Resources Report in 1994. This method of projections is detailed in the following subsection.(CCC,1996)

4.4.2 Method 2 - DEM (1994)

The next method of water demand projections was provided by the DEM in 1994. This method of projecting future water demands involved an analysis of historical data. The DEM investigated historical permanent and seasonal water demands individually. Method 2 first calculated the average historical water demands for the period 1986-1990. The DEM termed this historical average the "base" demand. The four (4) communities were given an Off-Season and an In-Season base demand. (DEM, 1994)

From these base demands the DEM projected water demands through the planning year 2020. The rate of growth that was utilized for each entity was determined based on historical data, and recommendations from the public water system managers. The final step of this forecasting method was adjusting the permanent and seasonal water demand

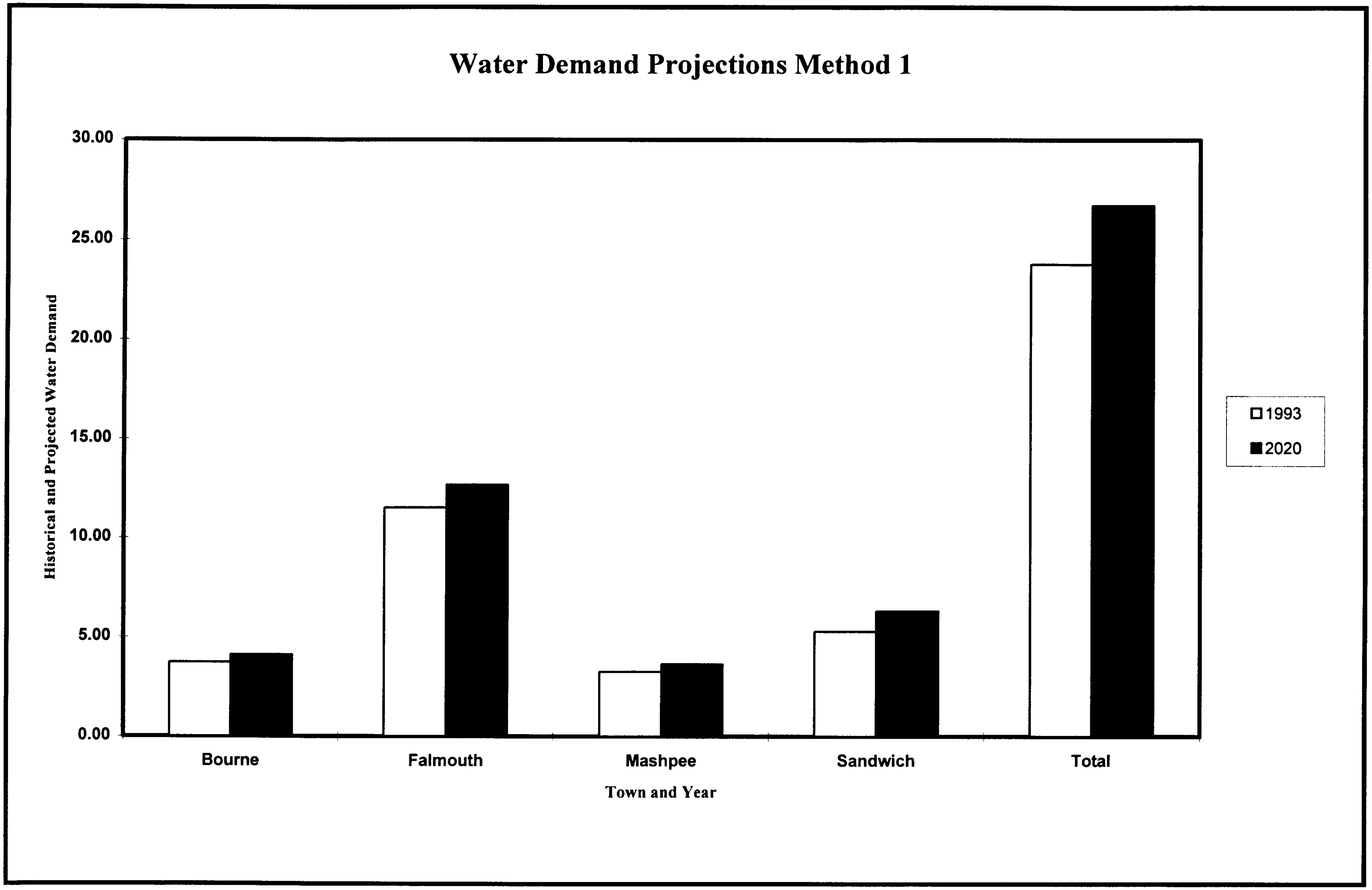
TABLE 4-4

WATER RESOURCES OF WEST CAPE COD

Water Demand Projections - Method 1 - CCC
(2000-2020)

Year	Towns				
	Bourne	Falmouth	Mashpee	Sandwich	Total
WMA Permit Reg.	1.49	4.61	1.30	2.11	9.51
MDD Ratio	2.50	2.50	2.50	2.50	2.50
Estimated Existing	3.73	11.53	3.25	5.28	23.78
Maximum Demand					
25-Year Growth	0.38	1.15	0.63	0.53	2.69
@ 10%					
2020 MDD	4.11	12.68	3.63	6.31	26.73

Notes: Source is CCC, 1994



WATER RESOURCES OF WEST CAPE COD

Figure 4-2: Water Demand Projections - Method 1

projections to represent annual average water needs. This was done by utilizing the following equation:

Annual Water Needs = [(Off-Season demand x 7) + (In-Season demand x 5)] / 12

The annual average water demand projections based on this methodology are summarized in Table 4-5, and are illustrated in Figure 4-3.(DEM, 1994)

This method of population projections has more of a foundation than Method 1. First, the DEM utilizes the "base demand" which incorporates actual historical water usage for a 5-year period. The use of 5-years of data reduces the possibility of a significant one-year event affecting future water projections. Examples of such an event could include a particularly dry/wet season or a large fire. The 5-year base demand provides a valid historical average that facilitates the projection of realistic water demands.

Another benefit of this method of water demand projections is the separate consideration of permanent and seasonal water demand. This provides different growth rates for Off-Season and In-Season water demand projections. This may be a more realistic interpretation of forecasting methods since for the most part the permanent and seasonal water demands do not seem to be related. As mentioned above, the Cape Cod Commission has altered its water supply/demand analysis using these water demand projections instead of their original projections.(CCC, 1997)

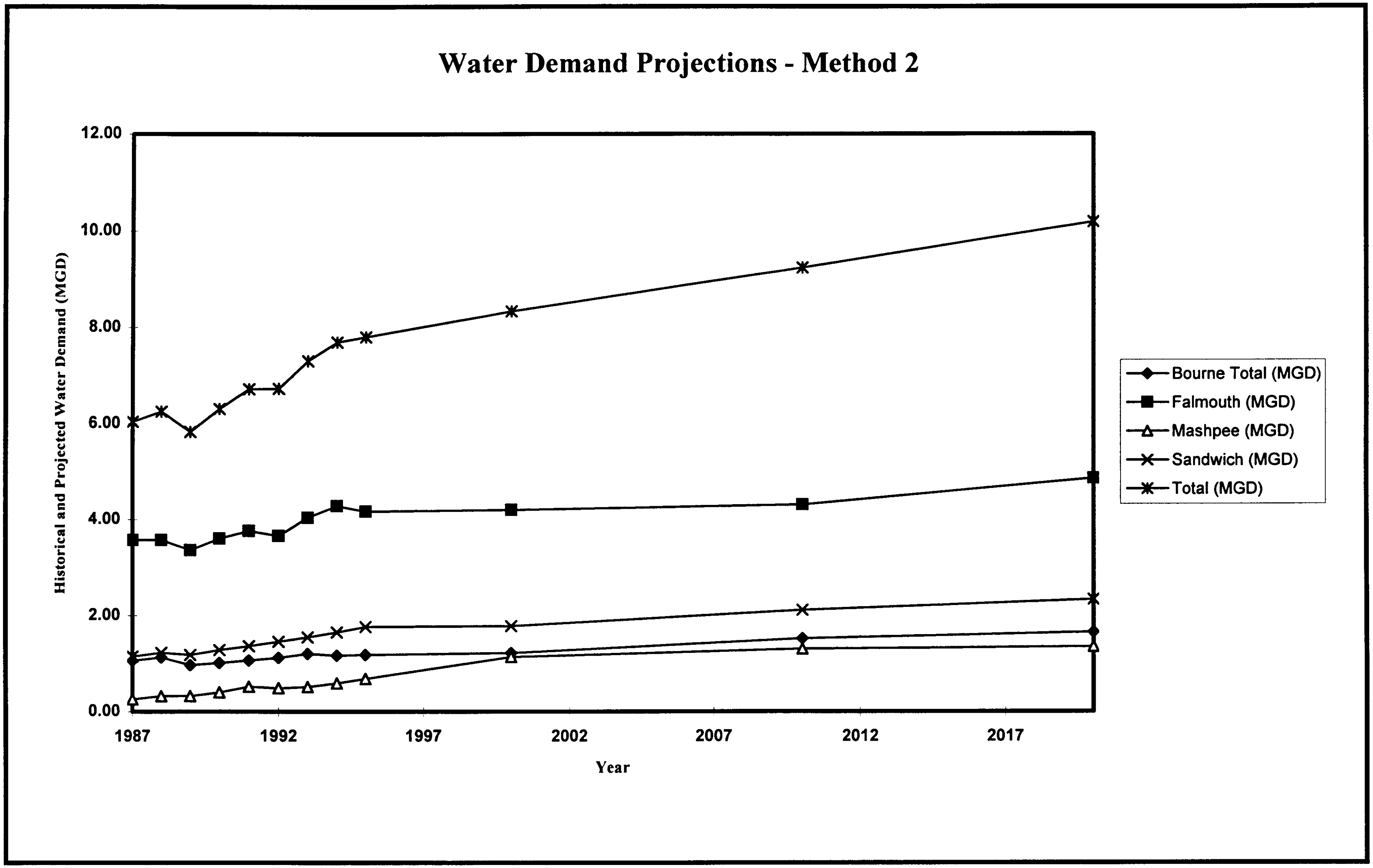
TABLE 4-5

WATER RESOURCES OF WEST CAPE COD

Water Demand Projections - Method 2
(2000-2020)

Year	Towns									
	Bourne		Falmouth		Mashpee		Sandwich		Total	
	Demand (mgd)	% Growth	Demand (mgd)	% Growth	Demand (mgd)	% Growth	Demand (mgd)	% Growth	Demand (mgd)	% Growth
2000	1.22		4.2		1.14		1.78		8.34	
2010	1.52		4.31		1.3		2.11		9.24	
		24.59%		2.62%		14.04%		18.54%		10.79%
2020	1.65		4.86		1.35		2.33		10.19	
		8.55%		12.76%		3.85%		10.43%		10.28%

Note: These water demand projections are provided by Office of Water Resources, DEM, 1994



WATER RESOURCES OF WEST CAPE COD

Figure 4-3: Water Demand Projections - Method 2

4.4.3 Method 3 - Per Capita Projections

Method 3 of the water demand projections was derived for the purpose of this study. This method is utilized to evaluate Methods 1 and 2, since these methods seems to have some inconsistencies. The water demand projections for Method 3 were calculated using population projections and historical consumption trends. The historical per capita consumption rates for the year 1990 were determined for each of the four (4) communities earlier in this report. These consumption rates were further refined by allocating an Off-Season and In-Season per capita consumption rate for each entity. The historical per capita consumption rates vary from 60 to 125 gpcd.

This analysis utilizes the Method 1 population projections calculated earlier in this report. These projected populations are then multiplied by the estimated water consumption rates (gpcd) for each water supply entity. The resulting water demand projections utilizing this methodology are summarized in Table 4-6 and illustrated in Figure 4-4.

The benefit of this type of water demand projections is that it accounts for actual increases in population. The extrapolation of historical water demand may not reflect an increase in population based on a new development of a community or a decrease in population based on stagnation of growth in a community which is not attracting new residents. The possible disadvantages to this method are the possibility of error related to the population projections, and the error related to estimating future per capita consumption rates based solely on one set of historical data in 1990.

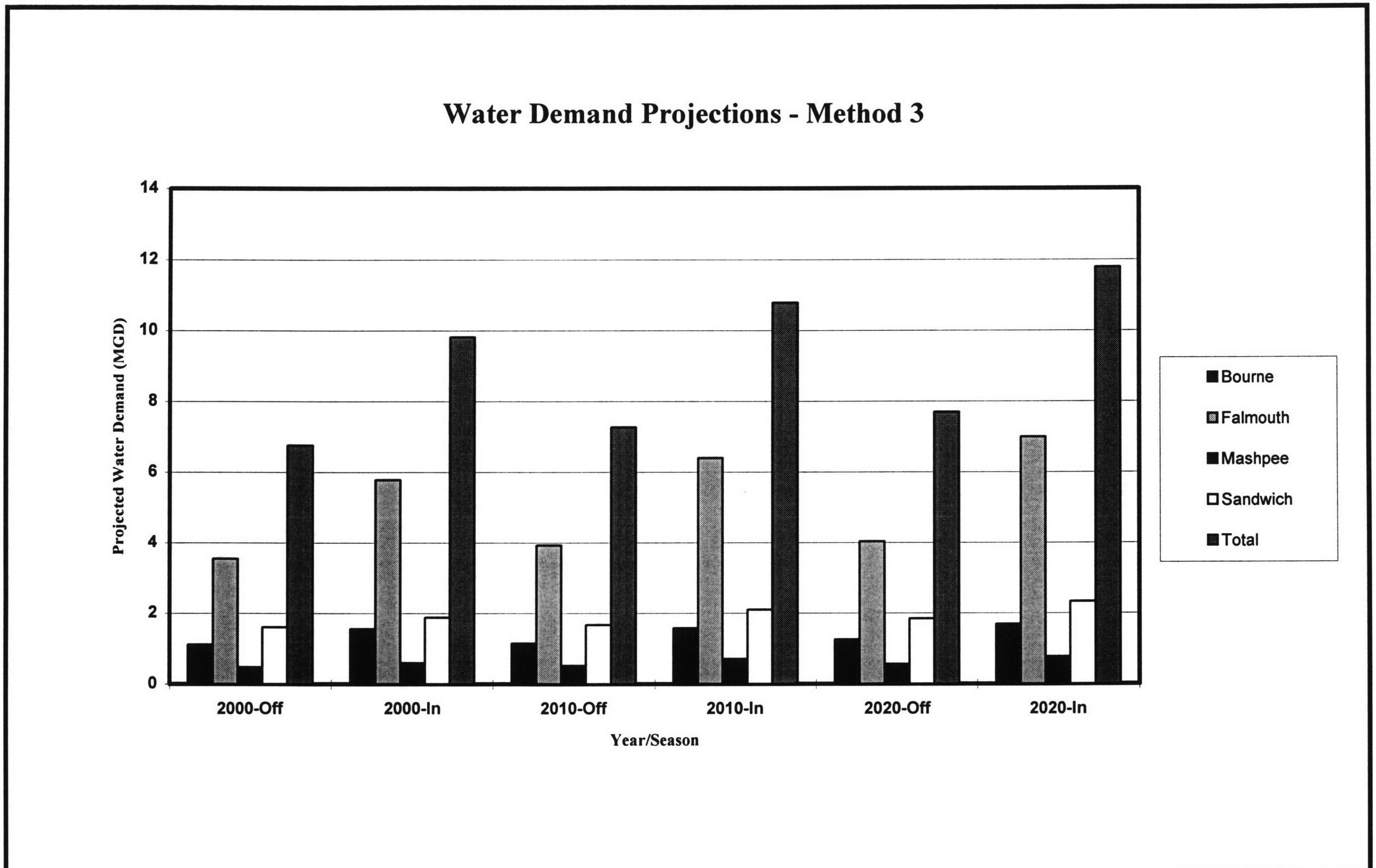
TABLE 4-6

WATER RESOURCES OF WEST CAPE COD

Population Projections - Method 3
(2000-2020)

Year	Towns																		
	Bourne				Falmouth				Mashpee				Sandwich				Total		
	Population	%Serviced	Serviced	Demand	Population	%Serviced	Serviced	Demand	Population	%Serviced	Serviced	Demand	Population	%Serviced	Serviced	Demand	Population	Serviced	Demand
				(mgd)				(mgd)				(mgd)				(mgd)			(mgd)
2000	17577	0.64	11249	1.12	28761	0.95	27323	3.55	10810	0.63	6810	0.48	17892	0.90	16103	1.61	75040	61485	6.76
	25727	0.64	16465	1.56	71583	0.95	68004	5.78	31673	0.63	19954	0.60	34889	0.90	31400	1.88	163872	135823	9.83
2010	17898	0.64	11455	1.15	30204	1.00	30204	3.93	10850	0.68	7378	0.52	17552	0.95	16674	1.67	76504	65711	7.26
	26048	0.64	16671	1.58	75267	1.00	75267	6.40	34829	0.68	23684	0.71	36859	0.95	35016	2.10	173003	150637	10.79
2020	19642	0.64	12571	1.26	30974	1.00	30974	4.03	10900	0.73	7957	0.56	19471	0.95	18497	1.85	80987	69999	7.69
	27792	0.64	17787	1.69	82297	1.00	82297	7.00	34989	0.73	25542	0.77	40889	0.95	38845	2.33	185967	164470	11.78

Notes: The top line and bottom line for each year listed represents Off-Season and In-Season Results, respectively



WATER RESOURCES OF WEST CAPE COD
Figure 4-4: Water Demand Projections - Method 3

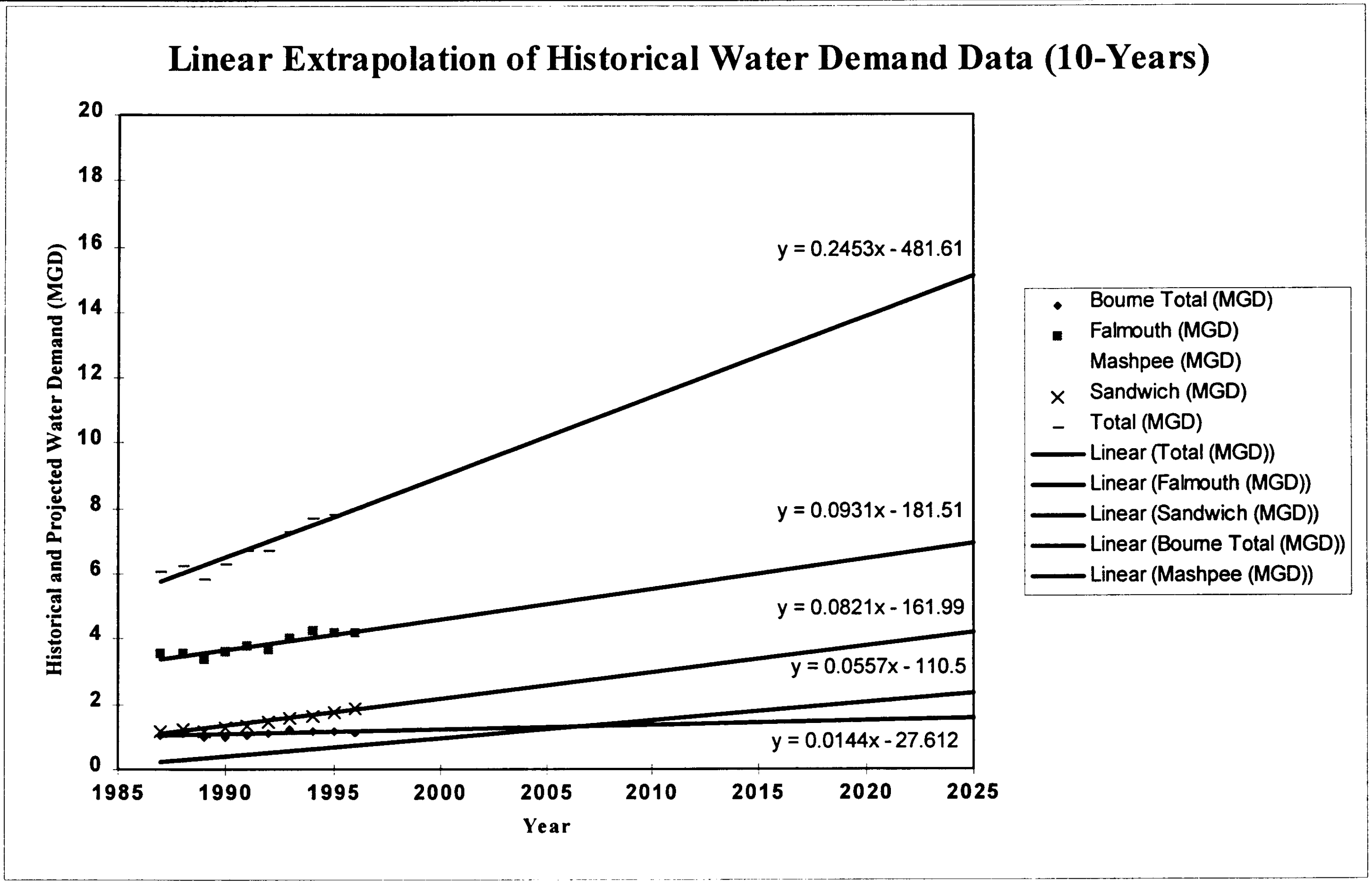
4.4.4 Method 4 - Graphical Method

Method 4 of this water demand projection section is the final method of projections that will be utilized for this study. The method utilized for this set of projections included the use of historical water demands provided by Earth Tech that were outlined earlier in this section of the report. The historical water demands represent actual historical AADD, and, therefore, they do not require seasonal adjustments.

The projection method utilized for Method 4 includes the use of three (3) graphical methods that are illustrated in Figures 4-5 through 4-7. The first method involves a linear extrapolation of historical water demands from the ten (10) year period spanning 1987-1996. The second graphical method also involved a linear extrapolation. However, the historical water demands used in this projection were limited to the most recent 5-years of data. The final graphical method includes a logarithmic extrapolation of the historical water demands from the same 10-year period described above.

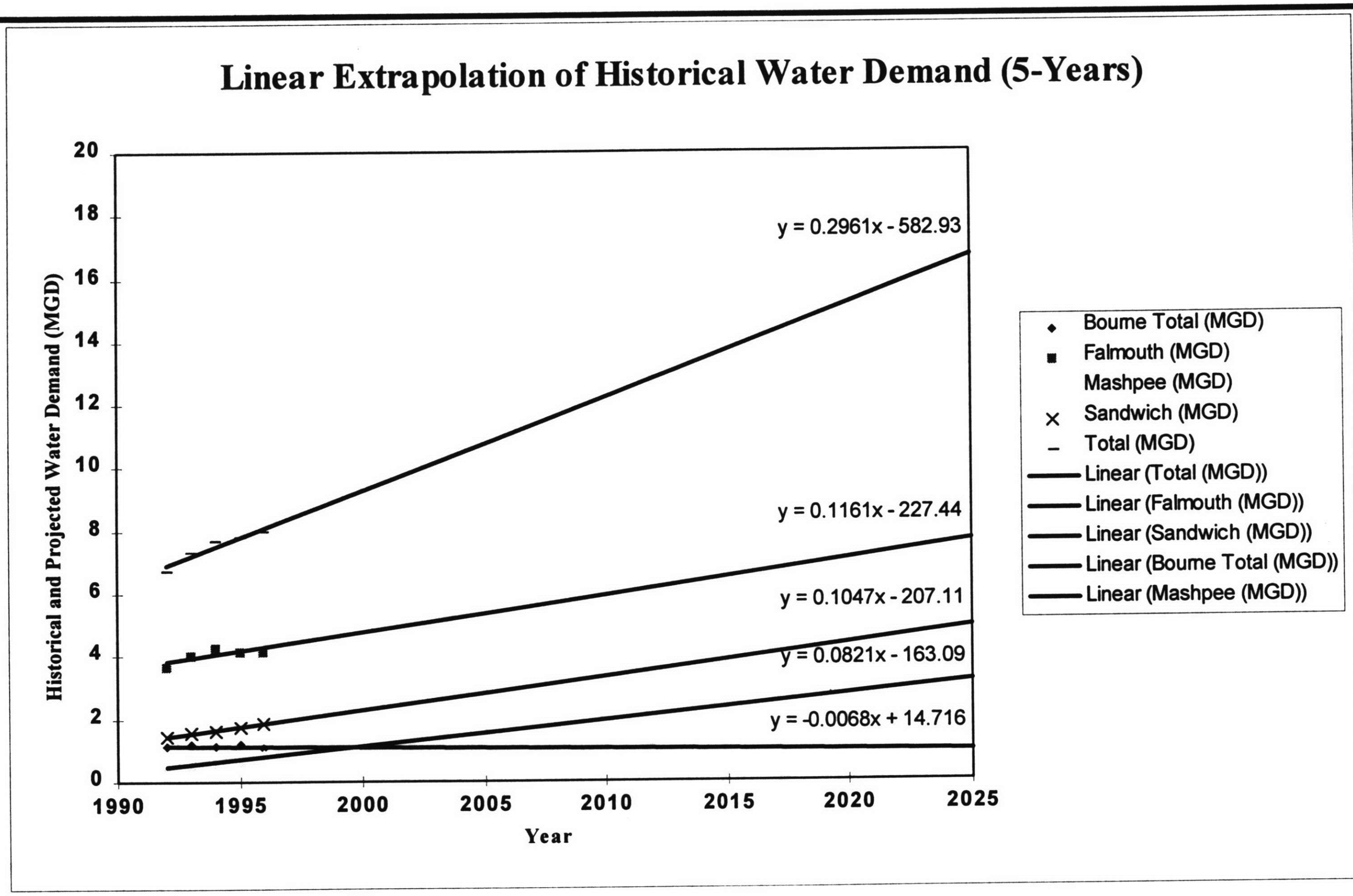
The linear extrapolation method is chosen to be the most effective method of water demand projection. The exponential extrapolation method does not reflect a significant increase in water usage. This graphical method is more suitable for older communities that are close to build out, and therefore lack developable land and/or future customers. The linear extrapolation method that utilizes the most recent five years of historical water demand data is also considered inadequate. This may overestimate future demands due to large growth rates experienced in recent years. The linear extrapolation of the 10-year data better represents the growth rates that West Cape Cod could expect through 2020, as it evaluates and includes 10-years of historical water demands. (McGhee, 1991)

It should be noted that the historical water demands for the Town of Sandwich already represent a linear extrapolation for the years 1991-1994 and 1996, due to an earlier adjustment of data due to deficiencies explained in an earlier section of this report. The Method 4 demand projections using the linear extrapolation of ten years of historical water demand data are summarized in Table 4-7.

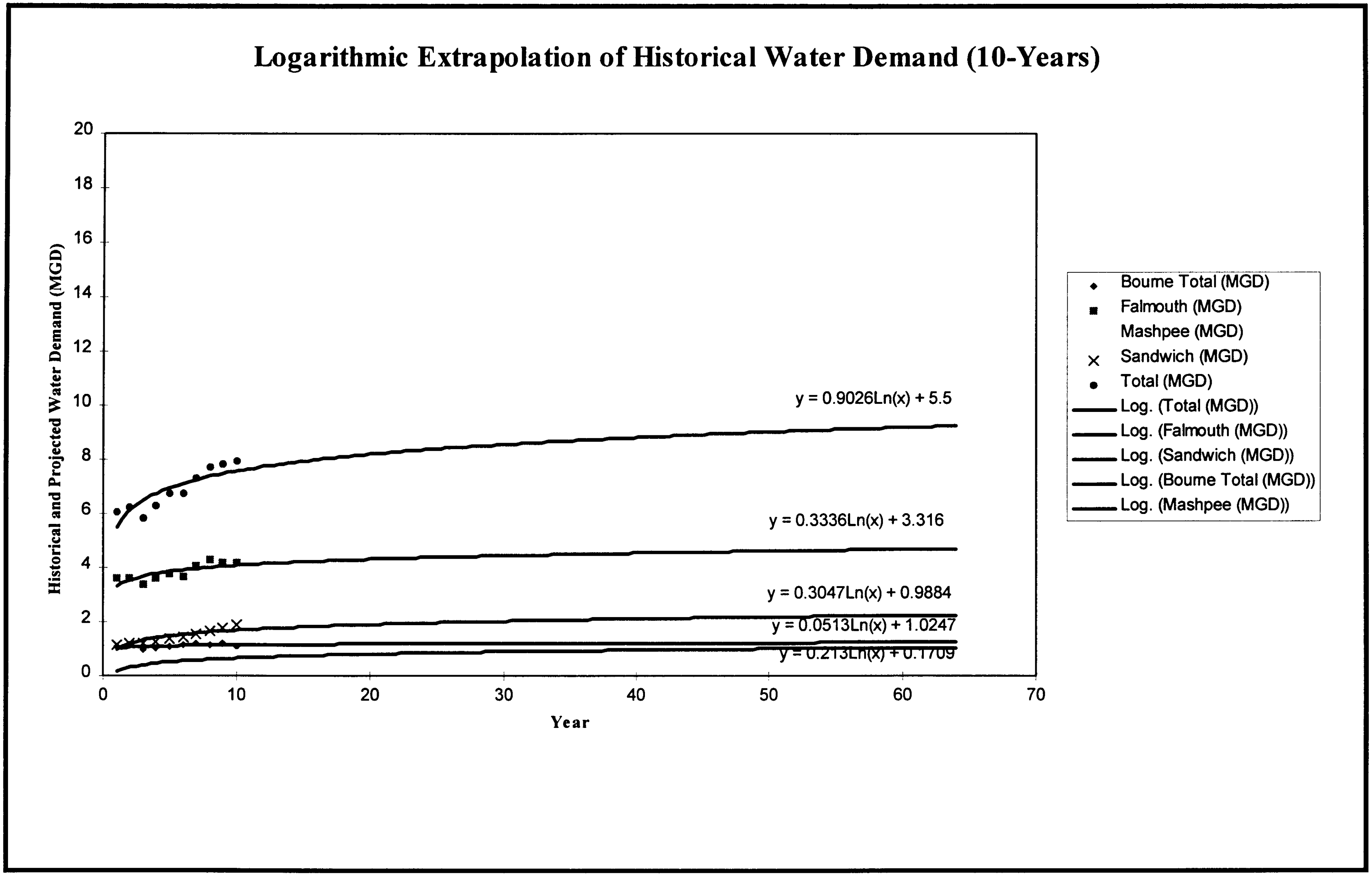


WATER RESOURCES OF WEST CAPE COD

Figure 4-5: Water Demand Projections - Method 4a



WATER RESOURCES OF WEST CAPE COD
Figure 4-6: Water Demand Projections - Method 4b



WATER RESOURCES OF WEST CAPE COD

Figure 4-7: Water Demand Projections - Method 4c

TABLE 4-7

WATER RESOURCES OF WEST CAPE COD

Water Demand Projections - Method 4 - Linear Extrapolation (10-Years)
(2000-2020)

Year	Towns (MGD)				
	Bourne	Falmouth	Mashpee	Sandwich	Total
1995-ADD	1.182	4.172	0.684	1.764	7.802
1995-MDD	3.428	9.178	2.189	3.528	18.323
2000-ADD	1.254	4.638	0.963	2.175	9.029
2000-MDD	3.637	10.203	3.080	4.349	21.268
2010-ADD	1.398	5.569	1.520	2.996	11.482
2010-MDD	4.054	12.251	4.862	5.991	27.158
2020-ADD	1.542	6.500	2.077	3.817	13.935
2020-MDD	4.472	14.299	6.645	7.633	33.049

The Method 4 projections that are the result of a graphical linear extrapolation represent a solid method for water demand projections. Some error may result from using ten (10) years of data. However, the benefit of this method over Method 2 is that it includes the historical data up to 1996, where the DEM Method 2 only utilizes 5-years of data up to and including 1990. It is interesting to note, however, that the Method 4 results for future water demand projections are very similar to those presented by Method 2. This correlation gives some level of confidence or credence to both forms of the water demand projections.

4.4.5 Recommendation of Water Demand Projections

Based on the above analysis the water demand projections from Method 2 and Method 4 best represent historical and projected future trends. The correlation between these two (2) sets of results increases the overall confidence in these projection methods. The final part of this analysis will involve the comparison of supply and demand for the four (4) communities during the planning year 2020.

The supply/demand analysis involves the investigation of two (2) existing analyses performed by the Cape Cod Commission, and one analysis performed for this study. The first two (2) analyses include the use of the water demand projections presented in Method 2. The third analysis will utilize the water demand projections outlined in Method 4. Even though the results of these two (2) methods are very similar, the use of Method 2 projected water demands in the demand/supply analysis will preserve the original presentation of the original Cape Cod Commission analyses. The investigation of future water resources includes an evaluation of quality as well as quantity. The following subsections provide an overview of future regulatory conservation and quality requirements that may have some effect on the operations of these four (4) water supply systems.

4.5 Water Conservation Strategies

The water projections recommended above do not reflect future water use impacts based on conservation or reuse programs. Recent changes in federal and state water policy have placed a greater emphasis on conservation, and reuse of reclaimed water to ease withdrawals from ground water supplies. Investigation of reuse alternatives for West Cape Cod has indicated that water reuse at this time is not economically feasible. (Bosch, 1996) Water conservation, however, can have an effect on water usage with minimal economic investment.

The Water Resources Commission adopted revised water conservation standards in 1992. These standards are included with the WMA permitting process, and require the implementation of certain conservation programs in order to obtain a WMA permit. The effects of these programs on existing water demand has not yet been investigated, although, similar programs have resulted in system water conservation. The effect of such water conservation methods is discussed later in this report.(DEM, 1994)

The Office of Water Resources at the DEM has conducted an analysis of current water conservation practices for West Cape Cod. This analysis investigates the following conservation practices: determination of unaccounted for water, public education programs, leak detection systems, metering methods, pricing methods, retrofitting with conservation devices, plumbing code, emergency supply plans, water audits, and official conservation plans. The water conservation program status of the four (4) towns and their associated five (5) water districts is presented in Table 4-8. (DEM, 1994) The possible benefits from conservation programs are outlined later in this report.

4.6 Future Regulations

Water supply planning does not only require an assessment of future water supply needs, but it should also address future water supply and treatment regulations. A list of proposed SDWA regulations to be regulated is located in Table 4-9. Future regulations that may affect the provision of water within the West Cape Cod water districts are

TABLE 4-8

WATER RESOURCES OF WEST CAPE COD

Water Conservation Status

Community	% Unc. Water	Pub. Ed.	Leak Det.	Metering: % meter	Metering: Reg. Test.	Metering: Times Read*	Pricing: Rate Struct.	Pricing: Full Cost	Residential Use: Retro. Devic.	Residential Use: Plumb. Code	Public Use: Retro. Devic.	Public Use: Plumb. Code	Supply Management: Emerg. Plan**	Supply Management: Water Audit	Supply Management: Cons. Plan
Barnstable															
Barnstable FD	4	yes	annual	100	yes	2/y;4/y	incr.	yes	yes	yes	no	yes	yes	yes	yes
Barnstable WC	20	yes	(1)	81	yes	4/y;1/m	decr.	yes	(2)	yes	(4)	yes	no	yes	yes
COMM FD	9	yes	2 yrs	100	yes	2/y	incr.	yes	(3)	yes	(5)	yes	yes	yes	yes
Cotuit FD	16	yes	2 yrs	100	yes	1/y	incr.	yes	(3)	yes	na(6)	yes	yes	yes	yes
Bourne															
S. Sagamore WD	(0)	yes	survey	100	yes	1/y	incr.	no	(3)	yes	(3)	yes	yes	no	no
Bourne WD	8	yes	3 yrs	100	yes	2/y	flat	yes	(3)	yes	(0)	yes	yes	yes	yes
Brewster	8	yes	no (7)	100	yes	2/y	flat	yes	yes	yes	no	yes	yes	yes	yes
Chatham	23	yes	5 yrs	100	yes	4/y	incr.	yes	(3)	(8)	no	(8)	yes	yes	yes
Dennis	10	yes	ongoing	100	yes	2/y	incr.	yes	no	yes	yes	yes	no	no	yes
Falmouth	20(0)	yes	survey	100	yes	2/y	incr.	yes	yes	yes	yes	yes	yes	yes	yes
Harwich	11.5	yes	ongoing	100	yes	2/y	incr.	(9)	yes	yes	yes	yes	yes	yes	yes
Mashpee WD	6%	yes	5 yrs	100	yes	2/y	incr.	yes	(3)	yes	no	yes	yes	yes	yes
Orleans	17.5	yes	5 yrs	100	yes	2/y	incr.	no	no	yes	no	yes	no	yes	yes
Provincetown	14-20	yes	5 yrs	100	yes	2/y	incr.	yes	yes	(8)	yes	(8)	no	no	yes
Sandwich	4.2	yes	ongoing	100	yes	2/y	incr.	yes	(3)	yes	yes	yes	yes	yes	yes
Yarmouth	22	yes	ongoing	100	yes	1/y	incr.	yes	no	yes	no	yes	yes	yes	yes

DEM Office of Water Resources

* Where two time periods are given, first indicates smaller customers; second indicates large or commercial meters;

** If no, water supplier has informal agreements with neighboring communities to assist during water supply emergencies

(1) Leak detection program began 10/18/93; frequency of future leak detection surveys will depend on results

(2) Have devices available for distribution, but haven't started program

(3) Cooperative program with the Cape and Islands Self-Reliance Corp. or the Barnstable County Water Utilities Association

(4) Town plumbing inspector has been installing in town buildings

(5) COMM Fire District does not serve entire town of Barnstable; retrofit devices installed in all public buildings within the District

(6) There are no public buildings within the Cotuit Fire District

(7) System is less than 20 years old; planning on instituting formal program in 5-7 years.

(8) The Board of Health or Building/Plumbing Inspector is responsible for enforcing plumbing code

(9) Covers all but bond payments

(0) Not able to update

TABLE 4-9

WATER RESOURCES OF WEST CAPE COD

SDWA Contaminants to be Regulated

Proposed Regulations:	*Name of Contaminant:*	*Maximum Contaminant Level: (mg/L unless noted)*
Arsenic Rule	Arsenic	0.002 to 0.020
Radionuclides	Gross alpha Emitters	15 pCi/L
	Gross beta Particle and Photon Emitters	4mRem ede/yr
	Radium-226	20 pCi/L
	Radium-228	20 pCi/L
	Radon	300 pCi/L
	Uranium	30 pCi/L
Sulfate Rule	Sulfate	500
Disinfectant/Disinfection Byproduct Rule (D/DBP)	Disinfectants	
	Chlorine	4-MDRL
	Chloramine	4-MDRL
	Chlorine Dioxide	0.8-MDRL
	Byproducts	
	Total Trihalomethanes (THMs)	0.08
	Haloacetic Acids (HAA5)	0.06
	Bromate	0.01
	Chlorite	1
Enhanced Surface Water Treatment Rule (ESWTR)	Cryptosporidium	Treatment Technology (MCLG=0)
	Giardia	Treatment Technology (MCLG=0)
	Viruses	Treatment Technology (MCLG=0)
Groundwater Disinfection Rule (GWDR)	Viruses	Treatment Technology (MCLG=0)
	Legionella	Treatment Technology (MCLG=0)
	Hetrotrophic Plate Count (HPC)	Treatment Technology (MCLG=0)
Filter Backwash Recycling Rule	Cryptosporidium	Treatment Technology
	Giardia	
Source Water Protection Rule	All potential drinking water contaminants	
Chemical Monitoring Reform	64 Primary Drinking Water Standards	No change in MCLs
New Contaminant Selection/ Determination to Regulate	5 New Contaminants every 5 years	To Be Determined
Consumer Confidence Reports Rule (CCR)	None (data reporting only)	

(Source: HDR Engineering, AWWA Journal, 1997) summarized in this section. These future regulations may impact current and future water supply decisions. The inclusion of future water quality concerns into current water planning strategies may reduce future water district allocations of efforts and monies. The future regulations that may be pertinent to West Cape Cod are groundwater disinfection/disinfection by-products (D/DBP), radionuclides, and sulfates.

The amended SDWA of 1986 mandates the United States Environmental Protection Agency (USEPA) to set disinfection requirements for all public water systems. The Surface Water Treatment Rule (SWTR) was the first rule enacted to address these disinfection requirements. The final SWTR published in July 1989 set disinfection requirements for surface supply sources and those groundwater sources under the direct influence of surface water. A draft proposal of the Groundwater Disinfection Rule (GWDR) was published in July 1992. (AWWA, 1997)

Due to resource shortages within the USEPA administration, the promulgation of this rule has been delayed. The GWDR rule is expected to require the disinfection of all water systems using groundwater supplies unless they meet certain criteria to obtain a variance. The draft rule would require a minimum disinfectant residual of 0.2 mg/L be maintained at the point of entry and a detectable residual or heterotrophic plate count (HPC) less than 500 count/ml in the distribution system. (AWWA, 1997)

Currently, only the Town of Falmouth disinfects its raw water supply. Disinfection facilities are provided at Long Pond, a surface water supply source, and at some of the groundwater supply sources. With the future implementation of GWDR the remaining communities will need to provide disinfection to their raw water supplies, or obtain variances based on the quality of the raw water supply. In any case the GWDR will affect each of the communities located in West Cape Cod to some degree.

The D/DBP rule is a very controversial element of future SDWA regulations for the USEPA. This rule would govern the contaminant levels of Total Trihalomethanes

(TTHMs), Total Haloacetic Acids (THAAs), chlorites, bromates, chloramines, chlorine, and chlorine dioxide. The most significant aspect of this rule is the reduction in TTHMs contaminant level from 0.10 mg/L to 0.08 mg/L. Promulgation of the D/DBP rule is expected in 1998. (AWWA, 1997) The promulgation of the D/DBP rule could affect the Town of Falmouth facilities that are providing chlorine disinfection. The rule would also affect the other three (3) communities if they installed chlorine disinfection facilities for the treatment of their raw water supplies.

The USEPA proposed the rule to govern radionuclides in July, 1991. Currently, the USEPA and several associated entities are performing studies of the relation of radon exposure levels to health characteristics. There is a great deal of controversy regarding the appropriate maximum contaminant level (MCL). This rule will regulate contaminant levels for radon-222, radium-226, radium-228, natural uranium, beta particles, and photon emitters. (AWWA, 1997)

The maximum allowable sulfate contaminant level may be increased with future regulations. The re-proposed rule for sulfates regulation sets the MCL for this contaminant at 500 mg/L. The USEPA is still accepting public comment on this proposal. (AWWA, 1997) This future ruling may affect the West Cape Cod communities that may have wells in the path of the Ashumet Valley Plume which contains some concentration of sulfates.

Section 5: Water Supply Planning

5.1 Introduction

This section develops the investigation of the various methods of projecting supply and demand, and compares supply/demand to determine excesses and deficits in supply. As has been shown throughout the study; projections of population, water demand and water supply, are only predictions which are limited by the data and methods used to calculate them. In order to plan for a water supply system or systems the projections should be updated as often as feasible to reflect changes in recent historical trends. Below is a summary of three (3) forms of supply and demand analysis.

5.2 Water Supply/Demand Analysis

The water supply and demand analyses consist of three (3) different investigations. Two (2) of the investigations were performed by the Cape Cod Commission, and the final analysis is an original investigation performed for this study. Each of the three (3) analyses have similar components, and most of the differences reflect a difference in interpretation of existing supply and demand, rather than factual discrepancies. Each of three (3) analyses are valid interpretations of the existing data, but the purpose of this study is to identify the best interpretation for the provision of an adequate water supply for West Cape Cod. A methodology and discussion of results is provided below for each for of analysis.

5.2.1 Analysis 1 -CCC(1994)

The first analysis of water supply and demand that will be discussed is the analysis performed by the Cape Cod Commission.(CCC, 1994) The water demand projections that were utilized in this analysis were developed by the Cape Cod Commission, and were outlined in the previous section as Method 1 water demand projections. The demand projections are adjusted to include a margin of error for estimation, and a volume of water supply for emergency reserve as recommended by the MDEP. (CCC, 1994)

The supply projections utilize a safe yield pumping capacity that is reduced to reflect 18-hour pumping instead of 24-hour pumping. The CCC has also included possible future water supply sources to its total projected supply in its 1994 analysis. The final adjustment is made based on plume contamination to the Town of Bourne's water supply wells. This adjustment is calculated as a reduction of 1.70 MGD to the total supply of the Town of Bourne. The total deficiencies calculated by this analysis are equal to 10.73 MGD for these four communities. This water supply and demand analyses is detailed in Table 5-1.

There are several components of this analysis that lessen confidence for the final results. The first issue is the use of the WMA permitted capacities as the historical AADD. It would have been better strategy to use actual historical water demands for this purpose. The MDD factors in this analysis are also questionable. This analysis utilizes a common MDD/AADD factor of 2.5 for all four (4) communities. Although, for this analysis there is not a significant difference between using a common peaking factor and weighted peaking factors for projections, this could change in the future as water demand increases. As shown earlier in this report, these factors vary between 2.0 and 3.2 for the four (4) communities.

From the water supply side there are also a few concerns with Analysis 1. One concern is the exclusion of the water supply wells from Bourne that are not utilized during AADD conditions, but are brought on-line for MDD conditions. Since this analysis investigates a comparison of MDD and maximum day supply, these wells should be included in this comparison. Eventually these wells may be taken off-line permanently. However, the wells do not currently exceed the MCL of any regulated contaminant and should remain part of this analysis until they are completely removed from service.

TABLE 5-1

WATER RESOURCES OF WEST CAPE COD

Water Supply/Demand Analysis - Analysis 1

Characteristics	Towns				
	Bourne	Falmouth	Mashpee	Sandwich	Total
SUPPLY (MGD)					
Safe Yield					
Existing (18 hrs.)	4.91	5.50	2.45	4.90	17.76
Future Sources	1.00	2.00	1.35	2.00	6.35
Plume Contamination	-1.70	0.00	0.00	0.00	-1.70
Total Supply (2020)	4.21	7.50	3.80	6.90	22.41
DEMAND (MGD)					
WMA Permitted	1.49	4.61	1.30	2.11	9.51
1993 MDD/ADD	2.50	2.50	2.50	2.50	10.00
Ratio					
Projected MDD	3.73	11.53	3.00	5.28	23.54
(2020)					
Adjusted 10% MDD	0.38	1.15	0.63	0.53	2.69
Error					
Emergency Reserve	1.61	1.00	1.00	3.30	6.91
Adjusted MDD	5.72	13.68	4.63	9.11	33.14
(2020)					
SUMMARY (MGD)					
Total Difference of	-1.51	-6.18	-0.83	-2.21	-10.73
Supply-Demand					

The supply analysis also includes future water supply wells. At this point in time, the location or actual rated capacity of these wells has not yet been determined Since these wells are not yet developed or rated it seems improper to include them in this analysis. However, if they are to be included they should at least be consistent with the rest of the analysis. The existing water supply sources have been reduced to reflect 18-hours of pumping, while the future sources are not similarly adjusted.

For system reliability this analysis has also given an emergency supply allocation of 3.0 MGD to the Town of Sandwich since their distribution system operates in three (3) pressure zones. It is anticipated under emergency conditions, however, that these pressure zones would not affect the transmission of this emergency supply. Therefore, an emergency supply of 1.00 MGD would be adequate. The Cape Cod Commission has since revisited this analysis. The results of the revised analysis conducted in 1996 are located in the following section for Analysis 2.

5.2.2 Analysis 2 - CCC(1996)

Analysis 2 was also performed by the Cape Cod Commission.(CCC, 1996) This analysis, however, utilizes the water demand projection developed by the DEM in 1994. These water demand projections were discussed earlier in this section, and were defined as Method 2 water demand projections. The Cape Cod Commission incorporated the DEM water demand projections in their updated analysis, as they more adequately represented probable future demands. (CCC, 1997)

This analysis by the Cape Cod Commission is much more thorough and appropriate than the 1994 analysis. The water demand projections utilize actual historical water demand data instead of WMA permitted capacities, and the MDD/AADD factors are based on historical water demand data specific to the individual community. The projected water demands are also adjusted to represent an allowable 10-percent error in projections, and include demand reserves for each entity to satisfy emergency conditions. The demand reserves in this analysis are adjusted to reflect 18-hour and 24-hour pumping scenarios.

The water supply analysis includes 18-hour and 24-hour pumping scenarios for 1995 and 2020. The water supply estimated for the planning year 2020 includes estimates of future water supply wells. The total available water supply projected for 2020 is differentiated into available AADD supply and MDD supply based on 18-hour and 24-hour pumping rates, respectively. The total deficiencies calculated by this water supply and demand analysis is summarized in Table 5-2.

This analysis still has some areas of concern, but is a significant improvement from the previous 1994 analysis. On the supply side it is probably not proper to include future water supply wells as similarly discussed under Analysis 1. The supply projections are fairly reasonable with the exception of this inclusion. In the demand analysis the provision of 10-percent error is probably rather conservative considering the conservatism that is already reflected in the peaking factors and emergency reserve. The emergency reserve discussed in this analysis is also slightly misleading. Under an emergency condition with an ADD demand scenario, it is not likely that the water supply pumps would be limited to 18 hours of operation. It should instead be assumed that under any emergency condition the pumps would operate to their full 24-hour production capacity. The minor concerns associated with this analysis are addressed in Analysis 3.

5.2.3 Analysis 3

The final analysis is an original analysis based on revised interpretations of water supply and demand projections presented in Analyses 1 and 2. The water demand projections that are utilized for this analysis are those presented in the previous section of this report entitled Method 4 water demand projections. These water demand projections were based on the linear extrapolation of 10-years of historical data as recommended in Section 4 of this report.

TABLE 5-2

WATER RESOURCES OF WEST CAPE COD

Water Supply/Demand Analysis - Analysis 2

Characteristics	Towns				
	Bourne	Falmouth	Mashpee	Sandwich	Total
SUPPLY (MGD)					
Existing (1995)					
24-hr Pumping	6.51	5.21	3.07	7.70	22.49
18-hr Pumping	4.88	3.91	2.31	5.78	16.88
Future (estimated)					
24-hr Pumping	0.00	1.01	2.52	2.02	5.55
18-hr Pumping	0.00	0.76	1.89	1.51	4.16
Total Supply (2020)					
MDD	6.51	6.22	5.59	9.72	28.04
ADD	4.88	4.66	4.20	7.29	21.03
DEMAND (MGD)					
Existing (1995)					
MDD	3.35	9.17	2.25	3.64	18.41
ADD	1.18	4.17	0.68	1.76	7.79
Ratio	2.84	2.20	3.29	2.07	10.40
Future (2020)					
MDD	4.69	10.68	4.44	4.81	24.62
ADD	1.65	4.86	1.35	2.33	10.19
Adjusted 10%					
MDD error	0.47	1.07	0.44	0.48	2.46
ADD error	0.17	0.49	0.14	0.23	1.03
Demand Reserve					
24-hr Pumping	1.47	1.01	1.01	1.01	4.50
18-hr Pumping	1.10	0.76	0.76	0.76	3.38
Adjusted (2020)					
MDD	6.63	12.75	5.89	6.30	31.57
ADD	2.92	6.10	2.24	3.32	14.58
SUMMARY (MGD)					
MDD Excess/Deficit	-0.12	-6.53	-0.30	3.42	
ADD Excess/Deficit	1.96	-1.44	1.96	3.97	

The determination of future supply included the utilization of existing 24-hour and 18-hour pumping capacity from Analysis 2. However, the total supply was then adjusted to reflect the largest well at each water supply entity being out of service or off-line. This replaces the "emergency reserve" allocation utilized in the previous water supply/demand analyses. The analysis would be different if the four (4) communities were interconnected, then only the largest well for the entire system would be considered out of service for this calculation. For this analysis it was assumed that the remaining wells that are on-line are operating for 24 hours during AADD and MDD scenarios. The total projected MDD supply for 2020 was calculated based on the total 24-hour supply reduced by the reduction of the largest well capacity.

The total projected AAD supply was calculated by determining both the 18-hour pumping capacity and the 24-hour pumping capacity with the largest well out of service. The pumping capacity that most limits AAD production is chosen as the total available AAD supply. The total supply deficits calculated by this method are summarized in the water supply and demand analysis for Analysis 3 detailed in Table 5-3.

5.3 Water Supply Solutions and Alternatives

The above analyses are only beneficial if they are utilized for future water supply management. Future water supply facility deficiencies should be calculated and targeted for technically and economically feasible remedies. There are several methods of preserving adequate water service to West Cape Cod.

The first, and most obvious, method is the development of new raw water supply wells. This alternative is currently being investigated in all four (4) communities. The greatest concern for the development of these wells is proposed location. As discussed earlier in this report, there are several concerns associated with the location of future water supply wells on the MMR at the Live Fire Impact Area. Per this investigation it does not appear that the historical or existing use of the Live Fire Impact Area should affect the

TABLE 5-3

WATER RESOURCES OF WEST CAPE COD

Water Supply/Demand Analysis - Analysis 3

Characteristics	Towns				
	Bourne	Falmouth	Mashpee	Sandwich	Total
SUPPLY (MGD)					
Existing (1995)					
24-hr Pumping	6.51	14.41	3.07	7.70	31.69
18-hr Pumping	4.88	10.81	2.30	5.78	23.77
Largest Well Off-line					
24-hr Pumping	4.69	12.41	2.06	6.70	25.86
24-hr Pumping	4.69	12.41	2.06	6.70	25.86
Total Supply (2020)					
MDD	4.69	12.41	2.06	6.70	25.86
ADD	4.69	10.81	2.06	5.78	23.34
DEMAND (MGD)					
Existing (1995)					
MDD	3.35	9.17	2.25	3.64	18.41
ADD	1.18	4.17	0.68	1.76	7.79
Ratio	2.84	2.20	3.29	2.07	10.40
Projected (2020)					
MDD	4.47	14.30	6.65	7.63	33.05
ADD	1.54	6.50	2.08	3.82	13.94
SUMMARY (MGD)					
MDD Excess/Deficit	0.22	-1.89	-4.59	-0.93	
ADD Excess/Deficit	3.15	4.31	-0.02	1.96	

development of future raw water supply wells.(Cook, 1997) A greater concern may be nitrate contamination of potential private and public groundwater supplies.(Motolenich-Salas, 1997)

Another consideration is the effect of water conservation methods. A list of existing conservation programs was outlined in a previous section. If an aggressive strategy for water conservation is developed, than there may be some noticeable effects on water usage. It has been estimated that aggressive conservation programs can reduce water usage by 10 gpcd with retrofit devices such as flow restrictors and toilet dams, and by up to 15 gpcd using originally installed devices and appliances, such as low flush toilets and low water use washing machines. (Metcalf & Eddy, 1991)

With a total service population of approximately 120,000 customers by the year 2020, and a per capita day reduction of 10 gpcd, this could equate to 1.20 MGD reduction. This would significantly reduce the shortages projected for the planning year 2020, but would necessitate an aggressive strategy for promoting such voluntary efforts of the customer. It should also be noted that the existing programs that are in place may already include a fraction of the possible 1.20 MGD reduction.

Another way of reducing future water supply needs, is the provision of water storage reservoirs. These reservoirs or storage tanks could eliminate future deficiencies in two (2) capacities. The first is a supply allocation for peak demand conditions. The second is a supply allocation for emergency demand conditions. The current emergency reserve supply is provided by allocating a fraction of each community's total water supply well capacity to emergency supply. Therefore, the total calculated well capacity for each community is in essence decreased by 1.0 MGD to ensure the availability of this emergency reserve capacity.

When storage tanks are provided the emergency reserve can be withdrawn during AADD conditions, and be available at any time for emergency purposes. The addition of storage facilities could also be used to dampen MDD or PDD conditions. The implementation of water supply storage could be incorporated with possible future treatment facilities. Based on MADEP requirements the needed volume of storage would be approximately 1 million gallons (MG) per water supply district. Additional pump capacity would also be necessary under this scenario. If the rated well capacities could be increased the addition of pump capacity could alone remedy the estimated deficiencies.

The final option or consideration should be the implementation of a regional water supply authority. This authority could take on two different forms. One would be the design and construction of an actual integrated transmission/distribution system. The other is the development of an integrated water supply source system. An integrated water transmission/distribution system would increase system reliability, by creating several water supply locations for a singular integrated water supply system. It has also been shown that larger systems experience smaller maximum day peaking factors. This may not be a significant reduction on West Cape Cod as the land usage is fairly homogeneous between the four (4) communities. Another benefit of an interconnected system is service reliability.(AWWA, 1997)

Regionalization through facility interconnects will need further investigation, as the expense of providing system connections between the existing utility systems may by greater than the actual benefits of doing so. However, this alternative may provide a longer term solution. (AWWA, 1997) A smaller scale regional method could also consist of basic system interconnects to be used solely for emergency conditions. These could replace the emergency reserve allocations discussed above.

The other possible regionalization method would be the regionalization of supply sources for West Cape Cod. This would allow each water supply utility to retain its identity, while securing a fair allocation of future water supply sources. The concept behind this alternative is that the authority would manage possible new public water supply wells. When water supply entities begin to anticipate water supply shortages they would make a request to the authority for additional supply. This alternative would allow the authority to optimize the reduction of deficits with supply allocations. This alternative may produce some political tensions, but is a viable "regional" solution, that is not as expensive as the complete regional alternative presented above. All of the summarized alternatives are valid and should be investigated more thoroughly as water usage increases, and water supply deficits occur.

5.4 Conclusion

It is apparent from the review of the various water supply analyses, that West Cape Cod is in need of an aggressive and consistent water supply planning strategy. The existing water supply and demand projections do not accurately represent the existing facilities, and future needs for Bourne, Falmouth, Mashpee, and Sandwich. This report attempts another water supply/demand analysis to be used as a comparison to the existing analyses. However, the West Cape Cod communities and the MMR IRP must communicate and work together to determine where their efforts should be focused. One of the goals of the MMR IRP is the provision of an adequate drinking water supply. This commitment should not be lost amongst the remediation efforts at the base. Instead, efforts should be integrated to best accomplish the goals of the Installation Restoration Program (IRP), and the goals of the surrounding communities.

Groundwater contamination has not drastically reduced the public water supply sources of these four (4) communities to date. Although, at this time groundwater contamination has limited public well production in the Towns of Bourne, Falmouth, and Sandwich. Plume contamination has perhaps had a more significant impact on possible future public well sites, or private well supplies, such as the residential wells located in neighborhoods such as Hatchville. (LRWS-JPAT, 1997) The threats experienced with residential wells may result in a higher customer demand for public water supply hook-ups. There are several public water system expansion efforts that are underway that will be able to satisfy these customer needs.

From a planning standpoint, the issues of available land use for well development, and increased water usage based on future growth trends and future increases in service population, may represent a more significant change in water needs and supplies, than plume contamination. However, future contamination of the groundwater supply may continue to affect available land or groundwater supplies for the development of future wells. For this reason the four (4) communities should continue to support efforts at the MMR for the containment and remediation of the existing groundwater containment plumes, as they continue to develop new public water supply services so that all individuals residing on West Cape Cod may be supplied with a safe and adequate water supply.

With this discussion it is important to understand the degree of estimation that is involved in the projection of water demand. Although there are some deficits in supply located in the Towns of Falmouth, Mashpee, and Sandwich by 2020, the majority of the deficiencies are estimated to occur at maximum day demand conditions, and therefore, may be more of a pumping capacity issue, rather than an issue of inadequate supply. The only community that has a estimated deficiency in average day supply by 2020 is the Town of Mashpee. The volume of the deficiency is very minimal, and should not be a concern. However, as discussed earlier in the facility inventory, there are already future water supply wells planned for this water supply system, as well as others. The communities that are projected to experience deficiencies during maximum day demand scenarios will need to improve system supply or pumping capacity by the planning year 2020, by implementing one or more of the strategies outlined above. The Long Range Water Supply JPAT must not solely provide oversight to water supply management, but rather leadership to the West Cape Cod communities, to ensure the provision of an adequate water supply for the future.

Currently, no single entity has taken the challenge of providing a detailed water supply/demand analysis for West Cape Cod. Recently, the consulting firm, Earth Tech, has been contracted to provide a water master plan that includes such an analysis. This analysis will be completed by the end of this year. This master plan will provide the West Cape communities with some direction for future water supply management. While this study is being completed the individual entities of West Cape Cod must learn to cooperate in order to accurately assess their future water supply needs.

Demand projections that are calculated without appropriate methodology, will not allow the West Cape to forecast future facility deficiencies. Earnest consideration should also be given to water treatment alternatives, system regionalization, storage, and expansion of pumping facilities that are discussed above. The preservation and development of future water supply sources will not solely depend on the success of remediation alone, but rather on an understanding that the provision of an adequate water supply for West Cape Cod is a multi-dimensional problem. The remedy to this problem will demand commitment and support from the various municipal entities associated with West Cape Cod, but more importantly it will require an element of leadership.

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Appendix

WATER SUPPLY STATISTICS FOR

BOURNE WATER DISTRICT
PUBLIC WATER SUPPLY
IDENTIFICATION NO. 4036000

Month	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Water Pumped from Own Sources:										
January	18,299,950	21,770,350	19,815,990	22,704,790	19,413,210	23,185,460	21,810,370	25,971,200	21,365,540	21,026,130
February	17,768,810	19,588,090	16,976,170	17,516,120	16,917,630	19,966,370	23,706,610	23,275,995	19,530,220	19,465,510
March	18,302,040	22,847,790	18,031,810	19,674,300	19,268,950	20,819,900	23,880,600	24,177,955	21,552,360	20,318,100
April	18,626,270	23,725,170	19,665,750	21,903,150	21,083,400	21,582,110	22,096,350	24,643,755	23,523,514	24,071,790
May	28,735,430	29,996,290	25,685,460	25,799,940	32,660,830	36,052,680	30,608,490	29,742,890	29,219,430	30,629,160
June	39,180,870	47,067,900	32,137,370	33,415,950	45,365,690	45,038,700	45,622,360	43,432,800	42,067,630	42,607,850
July	60,142,590	55,561,530	44,111,330	48,406,200	53,822,530	46,523,360	61,856,540	66,497,330	62,526,650	52,022,930
August	53,263,650	53,843,830	38,476,470	46,256,420	41,566,750	39,391,250	59,481,050	45,133,364	56,921,330	47,962,830
September	27,995,060	32,111,970	28,090,670	31,779,750	29,676,360	31,235,260	32,548,400	31,147,439	42,250,350	29,415,440
October	24,305,700	25,309,860	27,049,640	23,309,780	25,410,590	23,432,500	23,655,290	26,062,370	25,458,878	27,380,950
November	22,188,000	19,893,940	20,216,890	22,138,800	23,237,470	22,548,270	19,238,330	21,760,670	21,248,470	23,452,070
December	19,879,760	20,927,510	26,147,600	19,868,240	24,221,740	23,589,310	20,412,610	20,684,950	21,217,410	23,100,480
Total Pumpage	**348,688,130**	**372,644,230**	**316,405,150**	**332,773,440**	**352,645,150**	**353,365,170**	**384,917,000**	**382,530,718**	**386,881,782**	**361,453,240**
Annual Average Day Demand	**955,310**	**1,020,943**	**866,863**	**911,708**	**966,151**	**968,124**	**1,054,567**	**1,048,029**	**1,059,950**	**990,283**
Peak Day Demand (PDD)	**2,933,130**	**3,284,200**	**2,535,700**	**2,735,850**	**2,653,700**	**3,306,920**	**3,238,730**	**2,879,700**	**3,042,140**	**2,446,650**
Peak Week Demand (PWD)	--	--	--	13,896,540	15,915,270	13,534,340	16,097,680	15,929,870	--	13,524,900
PDD/ADD	**3.07**	**3.22**	**2.93**	**3.00**	**2.75**	**3.42**	**3.07**	**2.75**	**2.87**	**2.47**

(1) Shaded quantities are quantities which are different than those shown on the Well Pumping Records.

Prepared by Earth Tech

WATER SUPPLY STATISTICS FOR
TOWN OF FALMOUTH WATER DEPARTMENT
PUBLIC WATER SUPPLY IDENTIFICATION NO. 4096000

Month	1987	1988	1989	1990	1991	1992	1993	1994	1995
Water Pumped From Own Sources:									
January	79,148,000	No Data	73,937,000	88,139,000	81,479,300	84,254,000	80,995,700	100,242,500	93,173,000
February	75,713,000	Available	65,119,000	75,318,000	74,374,300	77,700,000	74,269,800	84,601,500	81,739,000
March	79,011,000	for 1988	74,890,000	82,738,000	80,473,600	81,982,000	83,743,400	94,898,700	92,849,000
April	79,285,000		77,691,000	80,595,000	85,200,700	80,565,000	82,817,800	94,725,200	95,154,000
May	99,891,000		98,542,000	98,036,000	122,353,100	126,513,000	116,796,300	119,731,000	116,626,000
June	137,591,000		114,900,000	131,799,000	169,247,400	159,735,000	162,448,400	169,661,000	151,339,000
July	195,204,000		172,132,000	184,988,000	204,982,100	180,691,000	229,219,600	245,317,300	225,587,000
August	191,573,000		159,507,000	186,816,000	170,716,500	162,912,000	216,309,000	200,339,500	212,506,000
September	105,993,000		115,031,000	129,561,000	121,958,100	121,077,000	142,648,700	140,188,300	159,111,000
October	95,379,000		95,309,000	97,565,000	100,870,500	97,973,000	107,001,100	111,922,000	113,433,000
November	82,784,000		86,325,000	80,380,000	75,086,000	80,063,000	91,450,500	97,716,700	91,669,000
December	83,447,000		92,844,000	79,986,000	86,322,300	81,829,000	86,360,400	103,230,400	89,751,000
Total Pumpage	**1,305,019,000**	**0**	**1,226,227,000**	**1,315,921,000**	**1,373,063,900**	**1,335,294,000**	**1,474,060,700**	**1,562,574,100**	**1,522,937,000**
Average Day Demand (ADD)	**3,575,395**	**0**	**3,359,526**	**3,605,263**	**3,761,819**	**3,658,340**	**4,038,522**	**4,281,025**	**4,172,430**
Peak Day Demand (PDD)	**8,565,400**	**--**	**7,934,200**	**8,461,200**	**9,306,500**	**7,067,700**	**10,118,200**	**9,334,500**	**9,167,000**
Peak Week Demand (PWD)	**--**	**--**	**44,365,000**	**49,443,700**	**53,172,000**	**45,943,200**	**58,520,300**	**59,972,700**	**52,364,000**
PDD/ADD	**2.40**		**2.36**	**2.35**	**2.47**	**1.93**	**2.51**	**2.18**	**2.20**

(1) Pumpage Records for 1991, 1993, 1994 and 1995 are gathered from DEP Annual Statistical Reports.
(2) Pumpage Records for 1980 through 1990 and 1992 are gathered from Town Annual Reports.

Prepared by Earth Tech

WATER SUPPLY STATISTICS
MASHPEE WATER DISTRICT
PUBLIC WATER SUPPLY

Month	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Water Pumped From Own Sources:										
January	2,897,100	3,268,000	3,969,170	6,272,420	12,701,900	8,189,040	7,700,170	11,574,100	10,731,760	12,321,480
February	3,013,530	3,502,670	3,088,480	4,716,650	6,160,000	9,947,560	8,926,470	11,862,420	8,652,870	14,465,170
March	2,340,410	4,394,890	3,941,030	5,764,640	6,600,900	9,678,210	8,458,890	9,283,130	10,854,840	15,103,960
April	2,055,400	5,513,670	4,900,440	5,834,580	7,573,300	9,641,190	8,522,930	13,443,340	12,028,470	17,216,400
May	6,750,680	8,515,970	9,276,770	8,405,530	15,082,800	16,721,010	16,047,490	17,006,790	18,349,670	27,683,160
June	12,354,020	15,668,870	13,058,140	12,142,680	20,631,300	24,123,200	21,714,010	26,517,890	26,792,070	38,586,590
July	18,538,370	23,179,610	21,910,750	21,566,070	35,130,020	29,570,250	33,002,240	41,905,690	42,261,930	47,270,270
August	20,388,550	22,697,400	20,893,960	24,479,170	32,867,410	26,671,950	32,236,810	31,242,450	41,455,030	45,600,600
September	10,981,010	11,744,570	13,826,110	16,002,390	17,455,890	16,291,680	20,536,810	19,541,060	28,310,590	31,454,630
October	6,589,860	7,425,250	9,181,380	13,987,520	12,080,030	11,717,620	13,327,310	15,953,530	20,399,970	18,587,600
November	4,855,750	5,246,210	5,502,300	14,608,730	15,274,630	7,931,000	8,458,610	6,922,040	17,475,530	14,999,400
December	2,995,830	7,301,670	7,933,750	13,664,930	8,629,290	8,385,830	8,992,960	10,952,060	12,414,760	14,534,340
Total Pumpage	**93,760,510**	**118,458,780**	**117,482,280**	**147,445,310**	**190,187,470**	**178,868,540**	**187,924,700**	**216,204,500**	**249,727,490**	**297,823,600**
Average Day Demand (ADD)	**256,878**	**324,545**	**321,869**	**403,960**	**521,062**	**490,051**	**514,862**	**592,341**	**684,185**	**815,955**
Peak Day Demand (PDD)	**795,000**	**1,034,250**	**1,270,840**	**1,049,960**	**1,598,390**	**1,439,100**	**1,588,000**	**1,847,130**	**2,249,400**	--
Peak Week Demand (PWD)	**5,062,720**	**6,181,660**	**5,492,900**	**6,312,360**	**8,643,829**	**7,621,310**	**9,015,000**	**10,732,820**	**10,421,320**	--
PDD/ADD	**3.09**	**3.19**	**3.95**	**2.60**	**3.07**	**2.94**	**3.08**	**3.12**	**3.29**	**#VALUE!**

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WATER SUPPLY STATISTICS FOR
SANDWICH WATER DEPARTMENT
PUBLIC WATER SUPPLY IDENTIFICATION NO.

Month	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Total Pumpage	1.1475	1.2225	1.1775	1.2825	1.366	1.455	1.549	1.650	1.757	1.871
		6.5%	-3.7%	8.9%						1.764
Peak Day Demand (PDD)				3.9%	5.5					
Peak Week Demand (PWD)										

WATER SUPPLY STATISTICS FOR
OTIS ANG BASE WATER DEPARTMENT
PUBLIC WATER SUPPLY IDENTIFICATION NO. 4096001

Month	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Water Pumped From Own Sources:										
January	12,757,000	13,516,400	12,684,100	11,467,800	11,522,700	10,818,000	8,948,900	8,593,100	7,593,600	6,784,100
February	11,448,700	10,355,000	13,950,400	9,322,800	8,817,000	9,286,600	7,660,800	6,869,000	7,081,000	6,886,100
March	11,393,800	11,243,000	15,776,300	10,771,900	9,474,400	10,414,500	8,093,000	7,498,400	6,610,000	7,947,300
April	11,684,300	10,613,000	11,688,200	9,662,300	9,653,300	9,539,400	8,180,600	7,733,000	6,806,700	7,428,700
May	13,443,200	11,803,000	12,985,400	10,762,600	11,938,000	11,732,600	9,684,500	9,946,900	7,881,500	8,927,000
June	14,734,400	16,653,000	14,781,200	12,981,200	16,065,300	14,330,800	12,585,000	11,815,100	9,105,600	10,451,200
July	22,223,500	17,786,400	15,475,100	14,278,500	16,453,300	13,536,100	14,380,100	14,034,300	11,844,200	10,429,200
August	23,755,300	16,599,800	13,400,100	14,066,600	13,134,200	10,934,300	11,190,900	10,601,900	10,429,800	9,484,000
September	11,776,000	11,111,700	9,627,800	10,658,800	11,362,000	11,889,600	8,321,900	8,101,000	9,480,400	7,450,000
October	11,250,800	11,898,600	10,713,200	9,787,100	9,347,500	10,550,500	6,984,800	8,389,700	6,840,900	8,819,800
November	11,408,200	10,714,600	9,585,400	9,907,500	8,815,300	8,677,100	6,811,100	7,149,800	6,822,400	6,930,800
December	11,551,600	13,024,200	10,133,100	15,504,100	9,453,900	8,101,500	7,196,000	7,735,800	6,501,000	
Total Pumpage	**167,426,800**	**155,318,700**	**150,800,300**	**139,171,200**	**136,036,900**	**129,811,000**	**110,037,600**	**108,468,000**	**96,997,100**	**91,538,200**
Average Day Demand (ADD)	**458,704**	**425,531**	**413,152**	**381,291**	**372,704**	**355,647**	**301,473**	**297,173**	**265,745**	**250,790**
Peak Day Demand (PDD)	**984,600**	**1,139,900**	**812,200**	**1,107,700**	**832,800**	**686,400**	**728,300**	**851,000**	**523,400**	**683,300**
Peak Week Demand (PWD)	--	--	--	--	**4,148,700**	--	**4,000,000**	**3,800,000**	**2,866,300**	--
PSS/ADD	**2.15**	**2.68**	**1.97**	**2.91**	**2.23**	**1.93**	**2.42**	**2.86**	**1.97**	**2.72**

Prepared by Earth Tech

WATER SUPPLY
STATISTICS FOR
SOUTH SAGAMORE
WATER DISTRICT
PUBLIC WATER SUPPLY
IDENTIFICATION NO.
4036003

Month	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Water Pumped From Own Sources:										
January	3,067,300	2,125,100	2,571,400	2,249,400	2,188,100	3,176,000	4,876,300	2,943,800	4,086,300	2,716,190
February	2,740,400	2,171,300	2,677,400	2,363,900	2,411,700	3,368,500	3,799,600	2,514,700	2,889,000	2,335,690
March	2,082,700	3,013,500	3,162,300	2,845,800	3,067,200	4,828,700	3,796,300	2,839,900	2,731,500	2,816,870
April	2,084,200	2,536,300	2,890,500	2,632,700	2,153,600	2,772,600	4,110,500	2,864,000	2,796,300	2,816,330
May	3,534,400	2,698,200	3,198,400	2,353,300	2,781,300	4,522,800	4,222,000	3,389,800	3,079,015	3,530,960
June	4,886,600	4,702,700	3,467,100	4,250,500	5,244,000	4,512,100	4,584,500	4,928,500	4,190,220	4,671,529
July	3,856,100	5,092,400	4,043,800	4,421,200	4,868,300	5,842,500	5,827,500	6,809,700	5,768,300	4,746,031
August	5,775,400	4,498,400	4,576,100	5,286,400	4,550,500	7,369,100	7,306,400	5,491,900	5,623,420	4,425,571
September	2,622,600	4,078,700	3,116,900	3,137,100	2,427,800	5,492,400	4,374,800	3,639,500	4,052,210	3,335,743
October	2,641,100	2,848,500	2,727,100	2,586,000	2,337,200	5,769,600	5,185,100	3,115,000	3,476,076	3,448,250
November	2,818,400	2,757,200	2,512,500	2,409,500	2,380,900	4,691,600	3,372,100	2,863,000	2,916,953	2,891,230
December	2,313,300	2,726,800	2,420,200	2,183,400	2,711,000	4,673,200	2,907,000	3,539,200	2,831,524	2,881,430
Total Pumpage	**38,422,500**	**39,249,100**	**37,363,700**	**36,719,200**	**37,121,600**	**57,019,100**	**54,362,100**	**44,939,000**	**44,440,818**	**40,615,824**
Average Day Demand	**105,267**	**107,532**	**102,366**	**100,601**	**101,703**	**156,217**	**148,937**	**123,121**	**121,756**	**111,276**
Peak Day Demand (PDD)	--	--	--	--	--	--	--	**385,300**	**307,500**	**234,770**
Peak Week Demand (PWD)	--	**1,584,300**	**1,191,300**	**1,370,100**	**1,435,200**	**1,728,400**	**1,686,900**	**1,811,100**	**1,407,390**	**1,215,415**
PDD/ADD								**3.13**	**2.53**	**2.11**

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