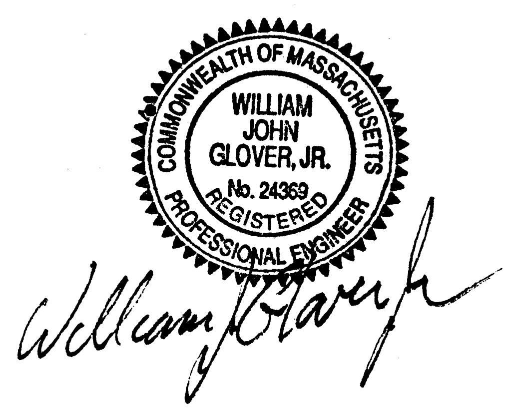
FAY, SPOFFORD & THORNDIKE, INC.
ENGINEERS • PLANNERS • SCIENTISTS

TOWN OF DOUGLAS
MASSACHUSETTS
WATER AND SEWER COMMISSIONERS

WATERWORKS FACILITIES
MASTER PLAN



Fay, Spofford & Thorndike, Inc.

Burlington, MA

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INTRODUCTION

This report presents the results of our tests, investigations, calculations and studies of the water supply and distribution facilities of the Town of Douglas. The results obtained herein are the result of collecting and reviewing various data provided by the Town and local agencies including population, land use and development, zoning, water production and water use. This report was prepared in accordance with our 1994 agreement with the Town of Douglas summarized as follows:

- Review previous studies and reports.
- Prepare a basic plan on which the waterworks system can be shown.
- Determine the present and projected population growth and water requirements through the year 2015.
- Review the zoning bylaw and establish current land usage and potential for development.
- Conduct hydrant flow tests and make calculations to establish flow capacity at strategic locations in the pipe network and to establish the carrying capacity of important existing mains.
- Determine the adequacy of water supply and distribution facilities. Determine the size and location of new storage facilities, if recommended.
- Conduct computer analysis of the existing distribution system to locate inadequacies.
- Conduct computer analysis of the distribution system including recommended improvements, to establish their adequacy under domestic and fire flow conditions projected through the 20 year planning period.
- Develop a sequenced program of construction of recommended improvements based on their priority of importance.
- Prepare project cost estimates for each recommended improvement.
- Prepare a concise report outlining our findings and recommendations.
- Conferences with the Board of Water and Sewer Commissioners as required during the progress of the work.

WATER REQUIREMENTS

The factors which determine a town's water requirements include the population served; domestic, commercial, municipal and industrial usage; unaccounted for usage (leakage, main flushing, etc.); and flows for fire protection service. The improvements proposed in this report are intended to be adequate through the year 2015.

Population Projections

Evaluation of Douglas's water distribution system must take into account future as well as present populations. Any increase in population affects the water supply and distribution needs of the system.

Historic population data was provided by the Town of Douglas and the Massachusetts Census Bureau and is summarized in the following Table 1.

TABLE 1

Population Trends

Year	Population	% Change
1930	2195	---
1940	2617	19%
1950	2624	0.27%
1960	2559	- 2.5%
1970	2947	15%
1980	3721	26%
1990	5438	46%

From 1930 to 1990, the Town of Douglas experienced a population increase of approximately 148%, reaching 5,438 in 1990. From 1930 to 1970, the Town experienced a moderate population increase rising approximately 0.86% per year. However, in the period

1970 to 1990, the Town has experienced rapid growth increasing approximately 84.5% over that period. This corresponds to an average growth rate of 4.23% per year and is nearly five times the rate of growth experienced from 1930 to 1970.

This sudden increase in population is generally due to decentralization from urban life. One of the results of the industrial revolution was the general tendency of people to move in and around large cities. With the expansion of highways and availability of transportation, people have begun to move away from the large cities into rural surroundings. Population data from the Town of Douglas demonstrate this phenomenon.

The rural characteristics attributed to the Town of Douglas make it extremely suitable for residential development. A review of the population data reveals that Douglas is already beginning to be affected by this. The large increase in population that Douglas experienced from 1980 to 1990 is in part due to the vast amounts of open land and forest that is readily available for development in Douglas.

The amount of land available for development was determined based on current zoning. There are about 24,475 acres of land in the Town, divided into seven zoning districts. The seven zoning districts are defined as Rural Agricultural (R-A), Village Residential (VR), Residential Commercial One (RC-1), Residential Commercial Two (RC-2), Central Business (CB), Commercial (COMM) and Industrial (IND). Table 2 below shows a summary of the total useable acreage for each of these zoning districts based on current zoning. Useable acreage is that portion of a given zoning district that has no obvious restrictions that would prohibit development and includes land which is already developed. For the purposes of this report, we have assumed that areas of wetlands and/or 100-year floodplains are not useable. These areas were determined from their representation on the 1982 FIRM Flood Insurance Rate Maps and the 1979 U.S.G.S. quadrangle sheets. Also taken into account when determining useable acreage is protected land which comprises about 19% of the Town of Douglas or 4,650 acres.

TABLE 2

Land Use

(Acres)

Land Use	Zoning District	Useable * Area	% of Total Useable Acreage	
Residence	R-A	13,997	77.01%	
	VR	1,350	7.43%	
	RC-1	98	0.54%	
	RC-2	524	2.88%	87.86%
Business	CB	37	0.21%	
	COMM	201	1.11%	1.32%
Industrial	IND	1,968	10.82%	10.82%
Total Useable Acreage		18,175	100%	

* Useable area includes both developed and undeveloped land.

As can be seen from Table 2, we estimate that approximately 18,175 acres of land in Town are available for development. Of this amount, approximately 16,000 acres are available for residential development.

Under current zoning, the minimum lot sizes for R-A, VR, RC-1 and RC-2 are 90,000 square feet, 20,000 square feet, 20,000 square feet and 90,000 square feet respectively. The total useable land area for R-A zoning is 13,997 acres from Table 2. Conversion from acres to square feet yields approximately 610 million square feet of useable land for zone R-A. Dividing this figure by 90,000 square feet per dwelling unit produces a total of 6,775 potential dwelling units in the R-A zoning district. Repeating this process for VR, RC-1 and RC-2 zoning districts yields 2,940, 213 and 253 potential dwelling units, respectively. This amounts to a total of 10,181 potential residential dwelling units available in the Town of Douglas. Applying the population density for the Town of Douglas obtained from the Central Massachusetts Regional Planning Commission (CMRPC) of 2.87 persons per dwelling to the total number of dwelling units available, we obtain an ultimate or saturation population of 29,220. This saturation population is approximately 5.4 times the current population. These numbers reveal the tremendous potential for growth that the Town of Douglas possesses.

In order to determine the potential rate of population growth within the Town, records from the Town Clerk's Office and Building Department were studied. Figures obtained from the Massachusetts Census Bureau (MCB) indicate that the population in Douglas was 5,438 in 1990. An analysis of building permit records indicates that from 1985 to 1993 approximately 60 dwelling units per year were constructed or permits applied for. If all units were constructed and occupied at the rate of 2.87 persons per unit, the average annual population increase would be 172 people. Applying this number to the 1990 census population for Douglas of 5,438 would yield an average annual increase of 3.16%. The Massachusetts Institute for Social and Economic Research (MISER) projects the population in the Town of Douglas for the year 2000 to be approximately 6467. This results in an annual increase of approximately 103 people or 1.89% through the year 2000. Discrepancies in these results can be accounted for by the fact that some of these dwelling units may not be completed and that in the United States, the average persons per dwelling is slowly decreasing. This parallels the national trend in family size which has been decreasing since the 1960's.

In order to get a better understanding of future population growth in the Town of Douglas, FST used an arithmetic method to make projections. This method is based on the rate of population change experienced in the past. The rate of change is divided by the time over which this rate of change occurred, to obtain a K value. A K value was obtained at ten year increments from 1930 to 1990 for the Town of Douglas. These values were then multiplied based on a factor that was directly related to the year when this change occurred. These weighted K values were then summed to ascertain a total K value for the successive

10 year increments from 1930 to 1990. This K value could then be multiplied by any time in the future and the product added to the present population to obtain a projection. Table 3 shows the results of the steps used to determine a K value for the Town.

TABLE 3

Determination Of K Value

Year	Population	dT	dP	K	Weight Factor	Weighted K
1930	2195	--	--	--	--	--
1940	2617	10	422	42.2	2.5%	1.06
1950	2624	10	7	0.7	2.5%	0.02
1960	2559	10	-65	-6.5	5.0%	-0.33
1970	2947	10	388	38.8	10.0%	3.88
1980	3721	10	774	77.4	40.0%	30.96
1990	5438	10	1717	171.7	40.0%	68.68
				K VALUE		**104.27**

Using the K value determined above in the following equation, we obtained the various projections shown in Table 4 below.

$Pt = Po + Kt$

Where Pt is equal to the population at some time in the future, Po is the present population and t is the period of the projection.

TABLE 4
Population Projections

	2000	2005	2010	2015
FST	6481	7002	7523	8045
MISER	6467	----	7469	----

It is clearly evident from the table above that FST population projections are consistent with those made by Miser. Based on these results, we feel confident that our method is capable of making projections with a fair degree of accuracy. These results will be used to project future water consumption in the Town of Douglas.

Past population data and FST projections are plotted in Figure 1. The graph reveals a rising trend in population. The rapid increases experienced from 1970 to 1990 should begin to decrease as less land is available for development. This type of increasing growth rate can be expected based on the factors addressed previously.

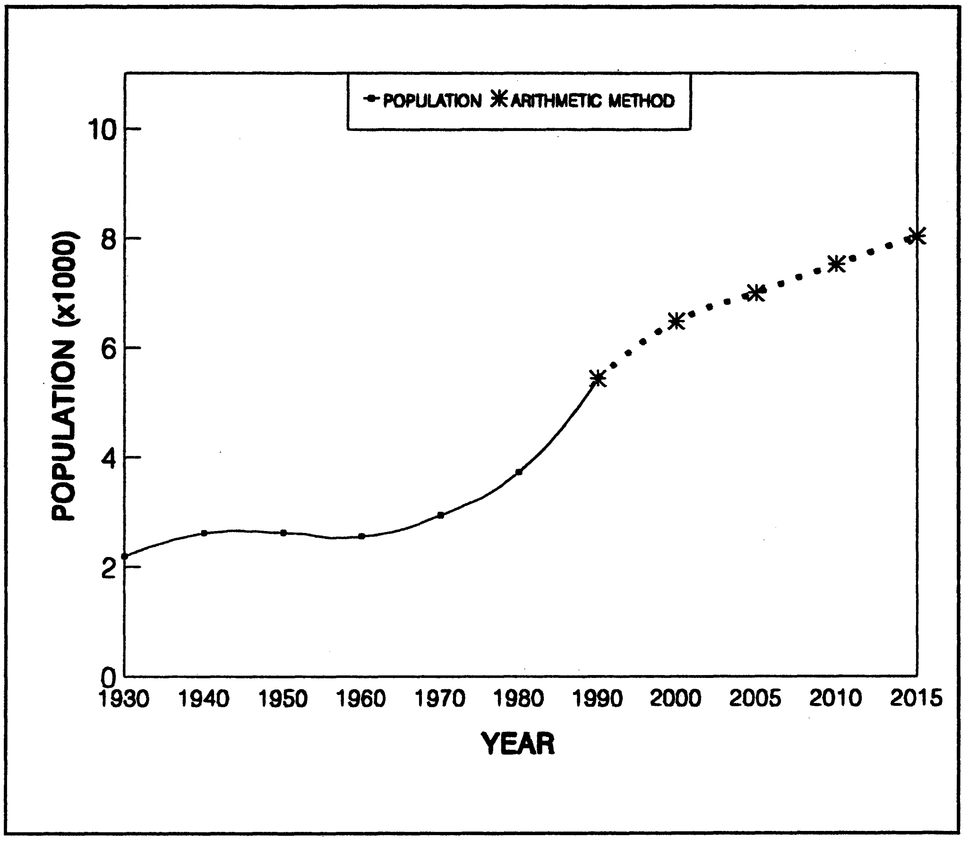


Figure 1
Population Projections

Service Ratio

To make projections on water consumption, we need to look at the percentage of the population that is served. Since the Town doesn't provide public water to all its citizens, a service ratio must be determined. A service ratio can be calculated by dividing the number of residential service connections by the total number of housing units in the Town. In 1990, 899 water services were in use. Dividing this number by the total number of housing units in Town in 1990, we obtain a service ratio of 0.42. If this service ratio is multiplied by the Town population at any time, an estimation of the population served can be determined. This procedure assumes that the population distribution is uniform throughout the Town, so if the Town serves a percentage of the housing, then it serves the same percentage of the population. To properly project the population served, an average of service ratios over the last ten years is calculated in Table 5 below.

TABLE 5
Estimation Of Service Ratio

Year	Total Units Served	Total Housing Units*	Service Ratio
1985	724	1589	0.46
1986	744	1649	0.45
1987	762	1709	0.45
1988	764	1769	0.43
1989	744	1829	0.41
1990	800	1889	0.42
1991	869	1949	0.45
1992	845	2009	0.42
1993	854	2069	0.41
1994	871	2129	0.41

* Values calculated based on 60 new houses per year.

Taking an average of the results presented above yields a service ratio for the Town of Douglas of 0.43. Table 5 also reveals that although the number of units being serviced has been steadily increasing, the percentage of population served with public water has remained fairly stable due to the decrease in the average household size. This historic data suggests that the service ratio method should closely project the future consumption of the water supplied by the Town.

Projections

Projections of population served by the Town provides the basis for projecting water consumption and assessing system needs. Projections for the Town of Douglas are made by applying the average service ratio, determined above, to the projections determined by

FST which were previously presented. Results of projections for population served at five year increments through the year 2015 are presented in Table 6 below. These results show that a considerable increase in population served can be expected in the Town of Douglas in the future. Provisions to the Town's water supply, distribution and storage facilities need to be made so this anticipated future demand can be met.

TABLE 6

Projected Population Served

Year	Townwide* Population	Service Ratio	Estimated Population Served
2000	6481	0.43	2787
2005	7002	0.43	3011
2010	7523	0.43	3235
2015	8045	0.43	3460

* FST projected numbers

Water Consumption

Town water consumption may be separated into various classes, as follows:

Domestic: water used in residences and apartments, for drinking, bathing, sanitation and lawn watering.

Commercial: water used in restaurants, service stations and retail establishments.

Industrial: water used in manufacturing and warehousing facilities.

Municipal: water used by Town owned facilities.

Unaccounted for: water which includes all unmetered uses, such as system leakage, hydrant flow for fire protection and other uses and meter inaccuracy.

Domestic Water Consumption

Population, land use restrictions and water consumption habits collectively influence the domestic water consumption. Since it is primarily dependent on the population served, domestic water consumption is often expressed in terms of gallons per capita per day (GPCD). The following Table 7 lists residential consumption records, population served and average water consumption per resident from 1991 to 1994. Average daily water consumption per resident is expressed in GPCD and was determined by dividing the total residential consumption gallons per day (GPD) by the population served.

TABLE 7

Domestic Water Consumption

Year	Gallons	GPD	Population Served	GPCD
1991	64,214,880	175,931	2,383	74
1992	66,948,660	183,421	2,429	75
1993	61,760,280	169,206	2,473	68
1994	62,827,850	172,135	2,518	68

In projecting domestic water requirements, we have adopted a per capita water consumption of 71 gallons per capita per day through the year 2015. The following Table 8 shows our projected population and average daily domestic water consumption through the year 2015.

TABLE 8

Town of Douglas Domestic Water Requirements

Year	Service Population	GPCD	Consumption (GPD)
2000	2787	71	197,877
2005	3011	71	213,781
2010	3235	71	229,685
2015	3460	71	245,660

Commercial Water Consumption

The level of commercial development is difficult to project because of the many factors involved. An analysis of the historical data indicates an increasing trend in commercial consumption, rising approximately 117% from 1991 to 1994. Since commercial establishments often serve the general public, it is reasonable to deduce that an increase in population would correspond to an increase in commercial water usage. Data indicates that commercial consumption currently accounts for approximately 4% of the total water consumption. The best approach for making commercial water consumption projections appears to be to approximate commercial usage in terms of the relationship between commercial activity and the population which sustains it. The approach used, therefore, is based on a residential to commercial consumption ratio. Over the historic period, we have found that commercial consumption has been approximately 5% of the residential consumption. We will assume that this value will remain constant throughout the planning period. Table 9 shows the projected average daily commercial water consumption through the year 2015.

TABLE 9

**Projected Commercial Water Consumption
Gallons**

Year	Consumption (GPD)
2000	9,894
2005	10,689
2010	11,484
2015	12,283

Industrial Water Consumption

Industrial consumption is less dependent upon population than domestic or commercial consumption and is influenced more by available water supply, access to transportation corridors and the state of the economy. Industrial consumption in Douglas from 1991-1994 shows a 426% increase in consumption rising to nearly 4% of the total water consumption. Conversations with Town Representatives indicated that the large increase in industrial usage was due to the fact that Guilford Industries, the only industrial user in Town, began receiving their water from the Town supply. Previously, Guilford Industries was using their own well supply as a source of water. The recent addition of a second full-time shift at Guilford Industries, was also accountable for their increased water consumption. The fact that only a small part of the available land in Douglas is zoned for industrial use, leads us to believe that industrial water consumption will remain fairly stable in the future. One approach for industrial use projections is the relationship between industrial activity and the population which sustains it. The method used to make these projections is based on the ratio of industrial to residential consumption. For purposes of projecting industrial consumption we have adopted 5.5% as the historical ratio between industrial consumption and residential consumption. We have assumed that this ratio will remain constant over the 20 year planning period. The following Table 10 shows our projected average daily industrial water consumption through the year 2015.

TABLE 10

**Projected Industrial Water Consumption
Gallons**

Year	Consumption (GPD)
2000	10,833
2005	11,758
2010	12,633
2015	13,511

Municipal Water Consumption

Municipal water consumption includes the facilities and offices that use water and are owned by the Town. Municipal consumption generally accounts for only a small portion of the total demand. Using the same methodology as previously described, we have found that municipal consumption is approximately 6% of the residential consumption over the historic period. For the purposes of the 20 year planning period, we have assumed that this ratio will remain constant. Table 11 shows the projected average daily municipal water consumption through the year 2015.

TABLE 11

Projected Municipal Water Consumption Gallons

Year	Consumption (GPD)
2000	11,873
2005	12,827
2010	13,781
2015	14,740

Unaccounted For Water

Unaccounted for usage is determined by comparing the volume of water passing through the customer's meters with the volume of water supplied to the system. Typically, unaccounted for water usage ranges from 15 to 25 percent of the total volume supplied. Conversations with Town personnel have indicated that unaccounted for water in Douglas typically is about 20 percent of the total water produced. We have assumed that this value will remain constant throughout the planning period. Table 12 shows the projections made for unaccounted for water through the year 2015.

TABLE 12

Projected Unaccounted For Water Consumption Gallons

Year	Consumption (GPD)
2000	46,095
2005	49,811
2010	53,517
2015	57,239

Total Water Requirements

Total water requirements are the summation of all the water used. For the Town of Douglas, residential consumption accounts for the majority of the water used. Commercial, industrial, municipal and unaccounted for water are the remaining elements that make up the total water requirements in Town. Table 13 shows the projected average daily water requirements by category of user for the Town.

TABLE 13

**Average Daily Water Requirements
Gallons Per Day**

User Category	1994	2000	2005	2010	2015
Domestic	172,135	197,877	213,781	229,685	245,660
Commercial	8,562	9,894	10,689	11,484	12,283
Industrial	9,520	10,833	11,758	12,633	13,511
Municipal	10,315	11,873	12,827	13,781	14,740
Unaccounted	40,106	46,095	49,811	53,517	57,239
Total	240,638	276,572	298,866	321,100	343,433

Maximum daily rates of consumption are used to determine the adequacy of the supply source and pumping facilities. Maximum hourly rates of consumption along with maximum daily rates of consumption plus fire flows are used to determine the adequacy of distribution storage facilities, transmission mains and distribution mains.

The maximum daily consumption is the largest volume of water used over a single 24 hour period during the year. It is determined from records and is expressed as a ratio of the average day, typically ranging from 1.4 to 2.5. In addition, this ratio is also a function of the relative importance of each component of the total demand: domestic, commercial and industrial. The ratio of maximum to average daily consumption is generally higher for domestic than for industrial and commercial users. Industry normally uses water at a relative constant rate each day. Domestic consumers, however, can easily double or triple their average daily consumption by such activities as lawn watering, car washing and swimming pool filling. Analysis of the Town's water consumption records for the last nine years indicates that the maximum daily consumption rates average about 1.8 times the average daily rates.

The maximum hourly consumption is the maximum volume of water used over a single 60 minute period. Like maximum daily demand, peak hourly consumption is usually projected by calculating the ratio of peak hourly to average daily demand and multiplying it by the projected average daily consumption. Our calculations and observations indicate that the maximum hourly consumption is 2.3 times the average rate of consumption for the day. Generally, the maximum hour consumption occurs during the maximum day. Table 14 shows the current and projected water consumption rates we have adopted.

TABLE 14

Water Consumption Rates
(Gallons Per Day)

	Percent of Annual Daily Average	2000	2005	2010	2015
Average Day	100	276,572	298,866	321,100	343,433
Maximum Day	180	497,830	537,959	577,980	618,179
Maximum Hour	230	636,116	687,392	738,530	789,896

Conclusions

Water supply facilities, transmission and pumping facilities supplying the Town of Douglas should be capable of supplying the future maximum day requirement of 618,179 gallons per day by the year 2015. Distribution mains and storage plus transmission facilities should be capable of supplying the future maximum hourly requirement of 789,896 gallons per day.

WATER SUPPLY SYSTEM

Water Supply Facilities

The Town of Douglas currently obtains its water from two groundwater sources situated about 1000 feet from each other on opposite sides of West Street. These wells are in an aquifer that extends over much of east-central Douglas. The Main Wellfield consists of eleven 2 1/2-inch wells and two 6-inch wells. The pump station uses a suction header attached to two centrifugal pumps to draw water out of these wells and pump it to the distribution system. The Main Wellfield produces approximately 240 gallons per minute (gpm). The other well is a 12-inch by 24-inch gravel packed well with a six stage verticle turbine pump. Historical data indicates that the gravel packed well produces approximately 200 gpm.

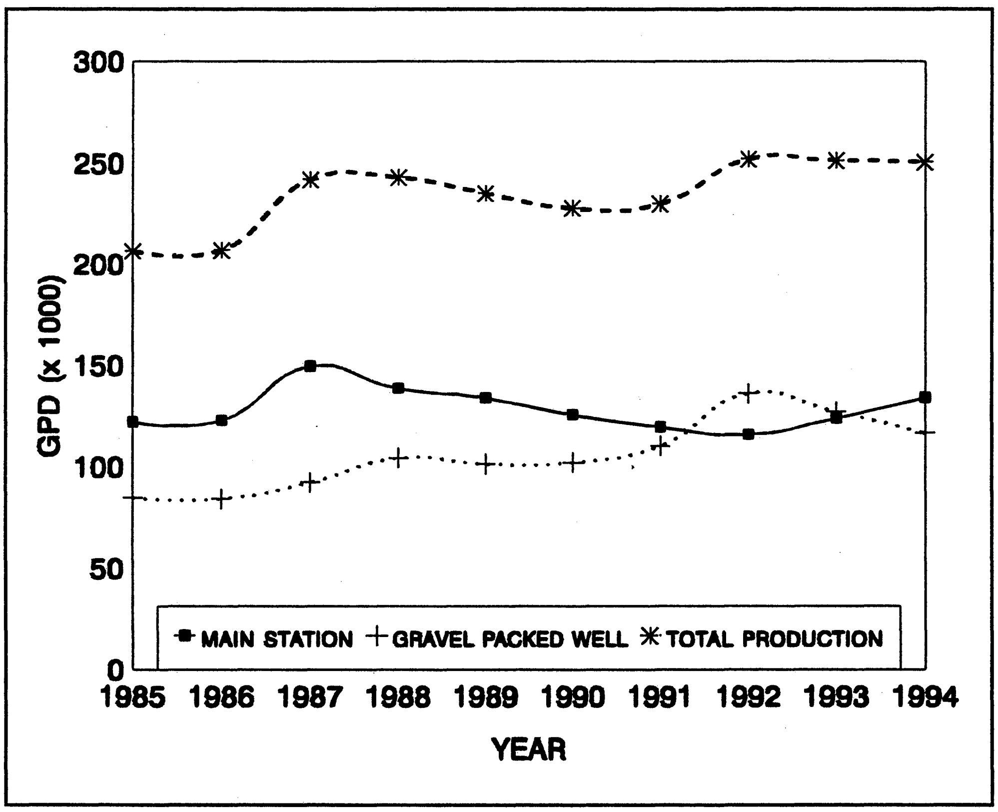


Figure 2
Historic Water Production

Figure 2 shows the historical water production from each source and the total amount produced per day by the current Town of Douglas supply facilities. The graph reveals an increasing trend in water production. With the increase in population that Douglas has experienced, this increasing trend should be expected. In 1994, the Town water supply facilities pumped approximately 250,000 gallons of water per day.

The Town of Douglas has recently begun construction of new wells and a pump station off Glen Road which are scheduled to go on line in 1995. This new pumping station consists of a 24-inch x 48-inch diameter well and a 10-inch x 16-inch diameter well. The pump for Well #1 (24-inch well) will consist of a deep well turbine pump designed to produce 135 gpm. The pump for Well #2 (10-inch well) will be a submersible well pump designed to produce 160 gpm. This new source will supply approximately 295 gpm into the system.

The locations of these water supply facilities are shown on the Master Plan located at the back of this report. Water supply sources are tabulated below:

TABLE 15

Sources of Supply

Description	Operating Status	Type	Rated Pump Capacity
Main Wellfield	Active	Tubular	240 gpm (0.35 MGD)
Gravel-Packed Well	Active	Gravel-Packed	200 gpm (0.29 MGD)
Glen St. Well #1	Inactive (Under Const.)	Gravel-Packed	135 gpm (0.19 MGD)
Glen St. Well #2	Inactive (Under Const.)	Gravel-Packed	160 gpm (0.23 MGD)
		Active=	0.64 MGD
		Inactive=	0.42 MGD
		Total=	1.06 MGD

Adequacy of Water Supply

The adequacy of a water supply source, pumping and transmission facilities is determined by their ability to supply the maximum daily flow while maintaining storage levels full. The ability of supply to deliver the required flows is dependent upon the size and condition of the transmission mains and hydraulic grade line elevation at the supply source.

The water consumption trends and projections of the Town have been analyzed and documented in a previous section of this report. Based on these projections, it appears the

Town can meet its increases in demands for this planning period with its current supply sources and the new Glen Road wells. Once these new wells are completed the rated pumping capacity of the system will be approximately 735 gpm (1.06 MGD). This is well above the projected 2015 average day, maximum day and peak hour water demands.

Conclusions

With the addition of the new Glen Road well supply, the Town of Douglas has adequate capacity to meet its 2015 projected demands. It is desirable for a water supply system to be able to provide its maximum day while pumping only 18 hours per day. This provides a margin of safety for the system and allows the sources to be put offline for regeneration or maintenance. For an 18 hour pumping period, the Town supplies are capable of pumping 793,800 gallons per day. With this supply capacity, the Town is still capable of meeting future demands while operating pumps for only 18 hour periods. Sources currently produce excellent quality water with little chemical treatment needed. These reasons lead us to believe that the Town supply is sufficient and no new provisions for water supply need to be considered at this time.

WATER DISTRIBUTION SYSTEM

General

The water distribution system is made up of the pipe network, booster stations and storage facilities. The distribution system should be capable of delivering the maximum rates of flow, including required fire flows, while maintaining suitable pressure within the system. The Department of Environmental Protection (DEP) guidelines for Public Water Systems recommend the normal working pressure in the distribution system should not be less than 35 pounds per square inch (psi).

In the case of fire flows, the Insurance Services Office (ISO), the agency responsible for grading a municipality's fire fighting capabilities, requires fire flows to be available at a residual pressure of 20 psi.

Distribution Piping

The distribution piping consists of approximately 20 miles of pipe of various diameters through 12-inch. About 26% of the piping is 6-inches or less in diameter. The system contains a majority of 8-inch pipe accounting for nearly 65% of the entire distribution system. The larger 10 and 12-inch mains form the remaining portion of the distribution system comprising about 9% of the system. Piping in the system consists of mostly old cast iron pipe with some ductile iron and transite pipe scattered in various locations. New construction of mains and sound engineering has helped to loop some areas but in general many dead end mains exist. Much of the cast iron pipe was installed nearly 80 years ago and is unlined. The backbone of the distribution system is the 8-inch main in Main Street. This pipe connects the high and low service pressures zones and generally experiences the highest flow capacities. Much of the unlined cast-iron pipe had diminished in carrying capacity over the years.

Distribution Water Storage

In the evaluation of a municipal water system, present as well as future storage requirements must be considered. Some of the major advantages of providing storage within a distribution system are:

1. Storage helps to dampen hourly demand fluctuations at pumping stations, thus reducing operational costs.

2. Storage helps to meet required fire flows, thus reducing pumping station capacity and cost.

3. Storage provides a volume of water for emergencies in case of a pipeline break, mechanical equipment malfunction or power failure.

4. Storage, if properly located, helps to equalize pressure throughout the system.

It is necessary to maintain storage levels as near to full as possible in order to maintain maximum available pressure in the distribution system and maximize availability.

Currently, there are two water storage tanks in the Town's distribution system. The Common Street Standpipe, located off of Common Street, has a capacity of 250,000 gallons at overflow elevation 714.5, Mean Sea Level Datum (MSL) and serves the high service area. The Franklin Street Concrete Tank, located off of Franklin Street, has a capacity of 234,000 gallons at an overflow elevation of 572 MSL and serves the low service area. The Common Street Tank is supplied from a manually operated booster station located on Main Street near Glen Road. The Franklin Street Tank is supplied from the existing pump stations on West Street and the new Glen Road wells when they are put into service.

The volume of water required for storage is dependent upon the equalizing storage requirement and storage needed for fire protection. Our experience indicates that equalizing storage, which is the volume of water necessary to satisfy hourly fluctuations in water consumption, generally amounts to about 20 percent of the total water consumption of any given day. For this report, we will assume that this value will remain constant through the planning period. The current equalizing storage required is 76,500 gallons or 20 percent of the maximum day consumption. In the year 2015, the equalizing storage requirement is projected to be 20 percent of 618,179 (2015 max day) or approximately 123,636 gallons.

The Main Street Booster Station is the only source of supply to the Common Street Tank. Records from this station indicate that it pumps approximately 72,000 gallons of water into the high service system per day. This amounts to approximately 29% of the total water produced in the Town of Douglas. To properly evaluate the equalizing storage requirement for the high and low service tanks, this value will be used. Multiplying current and future equalizing storage volumes by 29% amounts to 22,185 and 36,000 gallons needed for equalizing storage for the Common Street Tank. Subtracting these values from the total equalizing storage requirement gives us the needed storage volume for the Franklin Street Tank. The current and projected year 2015 values for equalizing storage for the low service Franklin Street Tank amount to 54,315 and 87,600 gallons respectively.

Differences in fire flow requirements for the two service zones are due to the fact that different building types exist in each service area. The high service zone consists mostly of residential housing units. We have adopted a fire flow volume requirement of 90,000 gallons for the high service area. This was developed in accordance with the Insurance Services Office (ISO) requirements and is based on a 750 gpm fire flow for a two hour duration. The low service area serves the center of Town and all the schools. For the low service area, we have adopted a fire flow volume of 630,000 gallons. This is based on a 3500 gpm fire flow for a three hour duration. For the purposes of this report we have assumed that the year 2015 fire flow requirements will remain the same. Addition of these water requirements yields the total storage requirements for the high and low service areas. These storage requirements are shown in Table 16 below.

TABLE 16
Water Storage Requirements

	Equalizing Storage		Fire Flow Storage		Total Storage Required		Total Storage Available
	1995	2015	1995	2015	1995	2015	1995
High Service	22,185	36,000	90,000	90,000	112,185	126,000	250,000
Low Service	54,314	87,600	630,000	630,000	684,314	717,600	234,000
				Totals	796,499	843,600	484,000

Adequacy of Distribution Storage

As shown in Table 16, the total storage facilities in Town amount to 484,000 gallons. Control valves were recently installed in Main Street and West Street which will open at predetermined pressure settings and allow water from the high service area to be utilized in the low service area during fire flow and high demand conditions. We have determined that the total volume of water in the high and low service tanks is useable during fires while maintaining the required 20 psi in the system.

Table 16 indicates that the high service storage tank provides an adequate volume of water for current and future fire flow and equalizing storage conditions. The availability of storage in the low service zone has recently been enhanced by the installation of the previously mentioned control valves. However, we will determine low storage availability based on the Franklin Street Tank capacity only. Currently, there is a total useable volume of 234,000 gallons for fire flow and equalizing storage in the low service area. Current and projected 2015 requirements will far exceed the storage that is available in the low service system. Fire flow and equalizing storage requirements for 2015 amount to 717,600 gallons while the available storage amounts to 234,000 gallons. Since the current tank is not capable of providing adequate storage, additional storage is required. Also, the Franklin Street Tank is over 90 years old and is in need of repairs to remain in service. The construction of a new 0.75 MG storage tank to replace the existing concrete tank will allow the current as well as future storage requirements to be met. This new tank should help maintain storage levels at or near overflow which will result in increased pressures throughout the system under all consumption conditions.

Hydrant Flow Tests and Pressure Observations

Hydrant flow tests and observations of system pressures were made on October 13, 1994 by personnel from FST, assisted by personnel from the Douglas Water Department. The purpose of these tests and observations was to observe the normal system operation as well as system operation under stress; that is, under various fire flow conditions. The results of these tests were used to evaluate the distribution system strength, to determine the location of deficiencies and to assist in the calibration of the computer model of the distribution system.

Flow tests were conducted by measuring the rate of discharge from selected hydrants while observing the resulting drops in system pressure. Pressure recorders were set up throughout the system and supply facilities were monitored during the tests to help us understand the system's strengths and weaknesses. Hydrant elevations were obtained and used to determine the hydraulic gradeline (HGL) elevations. The gradeline elevations were compared to the HGL elevations at the tanks and were also compared to each other. The difference in HGL elevation between locations provides the driving force for moving water through the distribution system.

A summary of hydrant flow tests and pressure observations conducted in October, 1994 is shown in Table 17. Data tabulated for each test includes observed static and residual pressures, calculated static and residual HGL elevation, measured hydrant discharge, calculated discharge that would be available at 20 psi and estimated fire flow requirements. Hydrant flow test locations are shown on the enclosed Master Plan.

TABLE 17

Hydrant Flow Tests

October 13, 1994

Location	Static Pressure psi	Residual Pressure psi	Static HGL feet	Residual HGL feet	Hydrant Discharge gpm	Hydrant Discharge @20 psi gpm	Required Fire Flow gpm
1. Southwest Main St.	39	26	682	652	594	729	750
2. Southeast Main St. @ Yew St.	64	56	704	685	986	2,474	750
3. Riedell St.	100	45	704	577	728	891	750
4. Main St. (high service)	68	57	702	677	921	2,040	2,000
5. Main St. @ West St.	65	54	600	575	728	1,558	2,500
6. Depot St. @ Martin Rd.	50	38	566	538	579	950	2,500
7. Manchaug St. @ Caswell Ct.	74	45	577	510	420	588	2,250
8. North St.	85	48	596	511	637	864	1,000
9. North St. @ Hayward Landing	79	43	530	447	786	1,027	3,500
10. N.E. Main St. @ Monroe St.	92	48	588	486	532	694	750
11. Towle Ct.	45	4	560	465	441	337	750

The quantity of water available at a flow test location may be shown graphically by a hydrant discharge curve. This curve shows the relationship between hydraulic gradeline elevation, or pressure, plotted on the vertical axis, and flow available, plotted on the horizontal axis. Hydrant discharge curves are generated by extrapolating the observed data of a single flow test using the formula:

$$\left(\frac{\Delta H_1}{\Delta H_2}\right)^{0.54} = \frac{Q_1}{Q_2}$$

Where Q_1 is the measured flow and ΔH_1 is the observed difference between the static HGL and the residual HGL. Q_2 is the flow computed for any difference in HGL, ΔH_2.

Hydrant discharge curves have been prepared for the flow tests performed. The curves are used to illustrate the capacity of the existing system and also the anticipated effects of improvements on the system capacity. Hydrant discharge curves can be found in the Appendix.

Adequacy of Distribution System

Given the operating hydraulic gradeline of the water system, distribution piping can be considered adequate if fire flows can be satisfied anywhere in the system and a residual of 20 psi can be maintained at ground level during a period of maximum daily consumption.

System pressures observed during the flow tests show that on days of average consumption, distribution pressures are higher than 35 psi, on the order of 39 to 100 psi. The exception to this is in areas of high elevation, particularly areas close to the water storage tanks. Pressure variations within each service area are due primarily to the elevation differences within the service area and in smaller measures due to the capacity of the distribution system. With a water storage level of 714.5 feet in the Common Street Tank, a static pressure of 35 psi could be maintained to ground elevation 634 in the high service area. In the low service area, a static pressure of 35 psi could be maintained to ground elevation 491, with water surface level at 572 in the Franklin Street Tank. The actual elevation at which 35 psi could be maintained in each service area would be slightly below elevation 634 and 491 as a result of normal system friction losses and variations in tank water levels. The Town should not consider any new developments located in areas above these elevations without provisions for booster pumping.

Large pressure drops experienced in various locations during the hydrant flow tests indicate that the system piping is not functioning very efficiently. Dead end mains and decreasing pipe capacities are generally the most accountable factors for such high pressure drops. The fact that much of the piping in Douglas is very old and that many dead ends do exist, confirm our findings.

As previously mentioned, fire flow requirements are determined by ISO for purposes of grading a municipality's fire fighting capabilities. Required fire flows are based upon such items as building size, type of occupancy, materials of construction, exposure to other buildings and existence of sprinklers. The flow tests conducted on October 13, 1994, were used as the basis for determining system adequacy. Required fire flows in areas of 1 and 2 family dwellings not exceeding 2 stories in height are as follows:

Distance Between Buildings (Feet)	Required Fire Flow (gpm)
Over 100	500
31 - 100	750
11 - 30	1000
10 or less	1500

Fire flow requirements for commercial and industrial establishments generally are quite higher. For the purposes of this report, FST has established 3500 gpm as the required fire flow for industrial developments. Residential Zoning By-Laws for the Town of Douglas generally require a minimum distance between buildings of 25 feet. Therefore, in most residential locations we have adopted a value of 750 gpm as the fire flow requirement.

Of the eleven flow tests that FST conducted in October 1994, eight were deficient. Hydrant flow tests showed that only a few areas of the system could support the requirements needed to properly fight a fire. The fire flows available in areas of large fire flow demands (schools, apartments, industry, etc.) were inadequate due to the large fire flows required for these types of buildings.

One method which was used to identify deficiencies within the distribution system involved using the computer model to analyze the occurrence of a fire flow during maximum day demand conditions. A fire flow may severely stress an isolated portion of the distribution system. Our calibrated model allowed us to look at fire flow availabilities at any point in the system, while maintaining a specified residual pressure throughout the system. This function helped us to identify deficient areas under a variety of demand conditions.

Much of the old unlined cast iron pipe in Douglas have lost their carrying capacity due to tuberculation and age. One problem area is located around Gilboa Street and Manchaug Street. Another problem area is North Street and the developments off of North Street. Analysis of this area reveals that large pressure drops are experienced any time a large demand is experienced anywhere in the low service system. This area is situated at a high elevation that is distant from any supply source. The limited pressure available in this area is due to the elevation and the headloss that is experienced from the system as water travels from the supply to this area. The fact that the only supply to this area comes from an old 8-inch unlined cast iron pipe enhances these problems. The improvements to the system that we recommend have been determined by looking at the ability that these improvements have to correct these problems. The hydrant discharge curves shown in Figures 3 and 4 illustrate the effects of these proposed improvements.

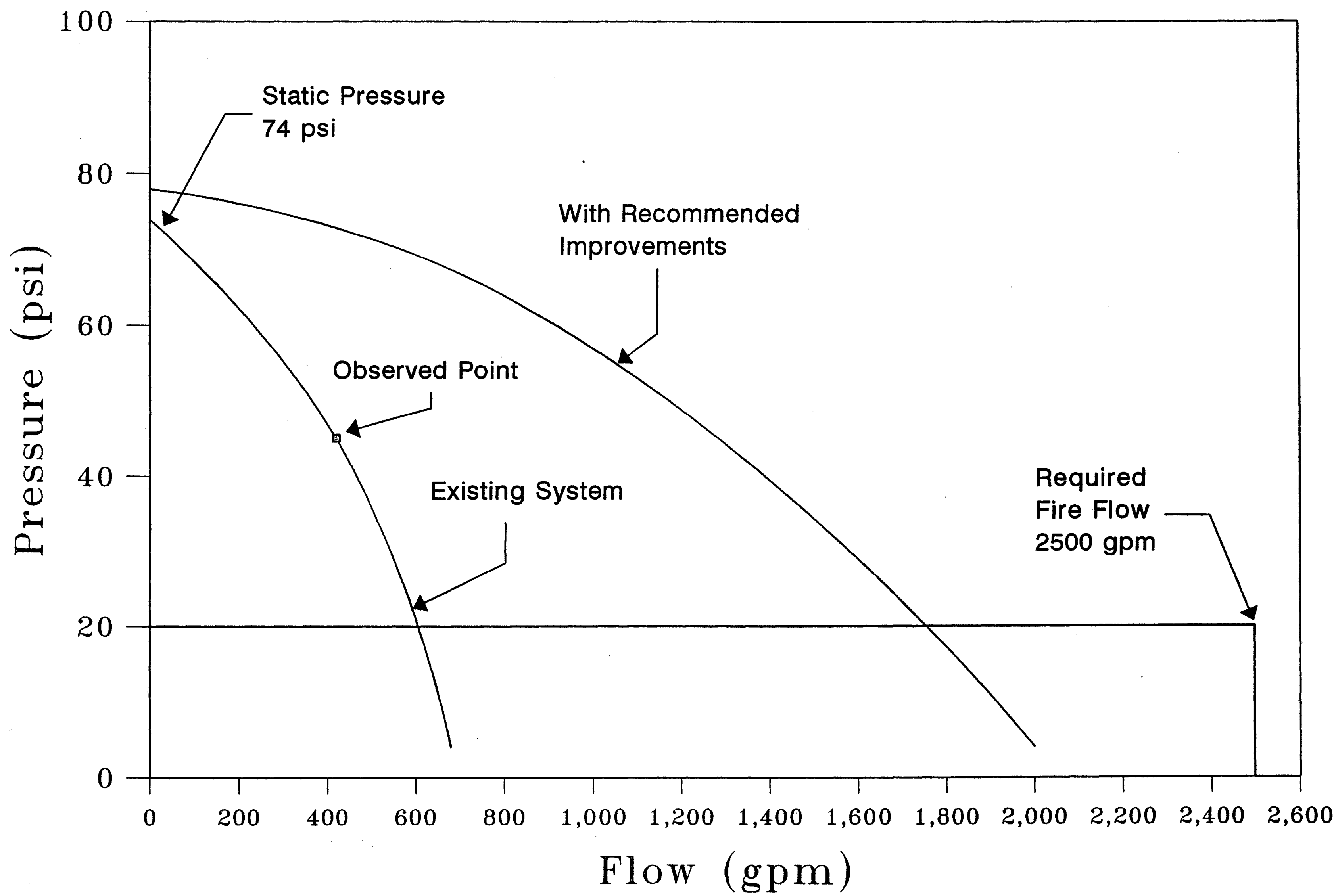


Figure 3
Hydrant Discharge Curve
Manchaug Street at Caswell Court

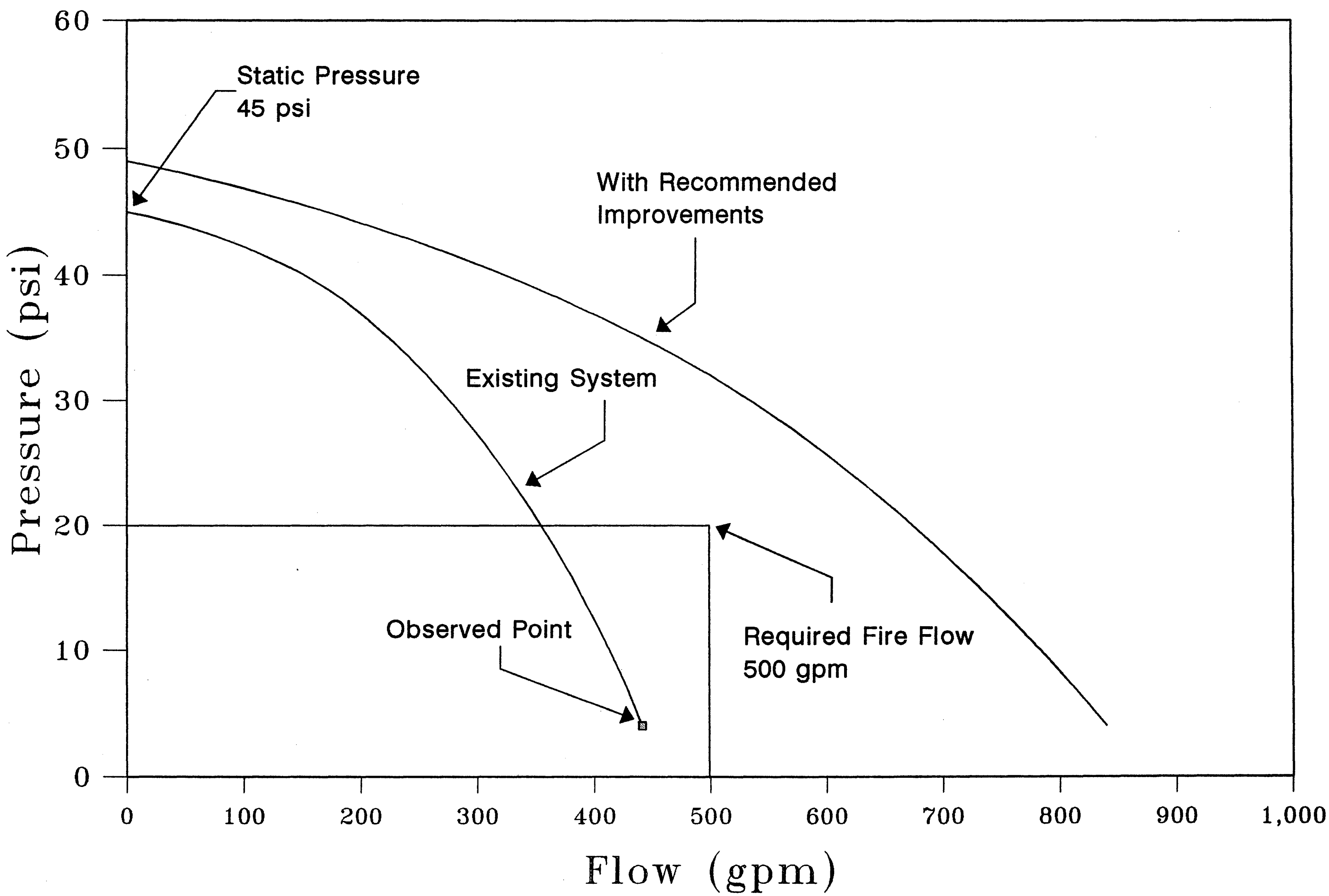


Figure 4
Hydrant Discharge Curve
Towle Court

Distribution System Operation

In order for the system to properly function, pumps must be capable of supplying the maximum day rate, storage tanks must have sufficient capacity to balance supply rates with consumption demands while maintaining a storage reserve for emergencies. The distribution pipe network must have sufficient capacity to distribute water during periods of maximum consumption while maintaining suitable pressures.

The current high service area is supplied from a booster station that is manually operated for about 8 hours per day. This is generally an adequate amount of time to keep the high service tank near its overflow. The existing tank and booster station have enough capacity to provide water on days of maximum and peak hour demand while still maintaining the storage level in the tank at least half full. A problem does occur, however, if a large fire demand is required in the high or low service area after the booster station has been shut down for the night. If this flow requirement drains the high service tank, then water will only be available in the high service area if someone from the Town goes out after the fire and turns on the booster station. We recommend that the booster station be automated to turn on and off manually based on some preset tank level. This would allow the assurance that the tank level is monitored automatically on a 24 hr basis.

The Franklin Street Tank is supplied from the two existing pump stations on West Street These stations are automatically turned on and off based on the water level in the Franklin Street Tank. Pumps turn on when the level in the tank falls three feet from 17 ft to 14 ft. Pumps at the station shut down when the water level in the tank rises to 16 ft. This allows fluctuations in the tank level over the course of the day during average day conditions. Some fluctuation in tank levels should be experienced to keep water from becoming stagnant within the tank. This will assure that the water quality doesn't degrade from sitting in the tank for long periods of time. The West Street Main Station is also equipped with an alarm set to go off at a high water elevation of 16.75 ft or a low water elevation of 11.5 ft. We have also determined that during maximum day conditions the system is not capable of supplying enough water into the system while maintaining the required storage levels. The addition of the new Glen Road wells and pump station, which will also supply the Franklin Street Tank, will correct this problem. Our computer model revealed that a large fire flow in the low service area will most likely completely drain the Franklin Street Tank, even with all supply sources running. As previously mentioned, a new 0.75 MG storage tank will give adequate capacity to fight such a fire.

FINDINGS AND RECOMMENDATIONS

1. Historically, the population in the Town of Douglas has been steadily increasing. Over the last 20 years, the Town's population has nearly doubled.

2. Under current zoning regulations, the Town's ultimate service population would be approximately 12,565 indicating that growth potential is significant.

3. The water supply available to the Town is adequate for current and projected average day, maximum day and peak hour requirements. The addition of the new Glen Road well to augment the existing supplies allows these requirements to be met.

4. Much of the distribution piping is old and consists of unlined cast iron main. System improvements have helped to loop certain areas of the distribution system, but in general many dead end mains exist. The reduced carrying capacity of these mains and the fact that many areas are not adequately looped, causes poor fire fighting capabilities in many areas of the system. These dead end mains could also be the source of poor water quality issues. A looped system provides reliability and is preferred over a dead ended system, since looped pipe can supply water for consumption and fire protection from more than one direction and also prevents water from stagnating as may occur in a dead ended pipe, where circulation is limited.

5. Distribution storage is currently provided by the Common Street and Franklin Street storage tanks. The storage volume of the Common Street Tank is more than adequate to meet the requirements of the high service area. The Franklin Street Tank is old and doesn't provide the needed capacity for equalizing and fire flow requirements. Replacement of this tank with a new 0.75 MG storage tank will provide the needed storage volumes.

6. Results of hydrant flow tests conducted by FST in October of 1994 indicate that many fire flow deficiencies exist throughout the system, particularly in the low service area.

7. Reinforcement and replacement of distribution piping is needed in key areas to eliminate fire flow deficiencies and help maintain pressures and provide reliable service.

8. The Town cannot adequately serve development above elevation 634 in the high service area and elevation 491 in the low service area without booster pumping facilities.

9. To provide reliable supply to the high service area, the existing booster station should be automated to run off of tank levels from the Common Street Tank.

10. A program for annual valve and hydrant replacement should be budgeted for and implemented.

11. All supply sources should be metered and supply meters should be calibrated on an annual basis.

12. Unaccounted for consumption is approximately 20% of the total volume supplied. A leakage study and water audit should be conducted to determine what steps are needed to reduce this percentage.

13. The Master Plan should be reviewed and updated by the Town every five years.

RECOMMENDED IMPROVEMENT PROGRAM

The following program of improvements, when completed, will provide adequate distribution and supply facilities though the year 2015. Our sequence for construction and estimated 1995 construction costs are shown on the following pages. Cost estimates include allowances for pavement replacement, rock excavation and other items usually involved in water works construction. The estimates include a 15 percent allowance for engineering and contingencies assuming the work will be performed under competitive bid construction contracts. The estimates do not include legal fees, land and easement costs or Town administrative costs.

Phase I improvements are designed to increase the adequacy of distribution storage in the low service area and to provide for increased flow from the new storage tank on Franklin Street. Phase II improvements will increase pipe capacity for future flows and improve current deficiencies in fire flows. Phase III improvements will increase system reliability in localized areas by eliminating some of the dead ended mains in the system and will also improve deficiencies in fire flows.

RECOMMENDED IMPROVEMENT PROGRAM

PHASE I

ITEM NO. AND SEQUENCE		DESCRIPTION	ESTIMATED COST
1		Increase storage capacity and provide for improved flow from the new storage tank. Also to provide for replacement of hydrants and valves in the distribution system:	
	√ A.	Demolish the existing Franklin Street Tank and construct a new 0.75 MG prestressed concrete storage tank at the same site.	$650,000
	√ B.	Install about 3,000 ft of 12-inch DI water main in Franklin Street.	$245,000
	√ C.	Begin a 5-year annual program of valve and hydrant replacement.	*$250,000
		TOTAL PHASE I IMPROVEMENTS	$1,145,000

* Cost to be spread out over five years.

RECOMMENDED IMPROVEMENT PROGRAM

PHASE II

ITEM NO. AND SEQUENCE	DESCRIPTION		ESTIMATED COST
2	Improve distribution system capacity to provide adequate fire flow capabilities and eliminate deficiencies in fire flows. Also, to provide a reliable water supply to the high service area:		
	A.	Install about 5,100 feet of 12-inch DI water main in Main Street from Franklin Street to Charles Street.	$400,000
	B.	Install about 2,700 feet of 12-inch DI water main in Main Street from Franklin Street to the existing booster station near Glen Road.	$200,000
	C.	Automate the existing booster station on Main Street to operate on Common Street Tank water levels.	$75,000
		TOTAL PHASE II IMPROVEMENTS	$675,000

RECOMMENDED IMPROVEMENT PROGRAM

PHASE III

ITEM NO. AND SEQUENCE	DESCRIPTION		ESTIMATED COST
3	Improve distribution system capacity and provide improved fire flows in localized areas:		
	A.	Install about 4,500 feet of 8-inch DI water main in Mechanic Street, Manchaug Street and Gilboa Street.	$310,000
	B.	Install about 1,500 feet of 12-inch DI water main in North Street from Gilboa Street to Main Street.	$125,000
	C.	Install about 200 feet of 8-inch DI water main connecting Towle Court off Pond Street with Towle Court off Colonial Estates. Install about 720 feet of 8-inch DI water main in Depot Street from Railroad Avenue to Maple Street. Install about 1,300 feet of 8-inch DI water main in Maple Street from Depot Street to Martin Street.	$160,000
		TOTAL PHASE III IMPROVEMENTS	$595,000
	TOTAL PHASE I, II AND III IMPROVEMENTS		$2,415,000

ACKNOWLEDGMENTS

We are pleased to record our appreciation for the cooperation and valued assistance received from Mr. Anthony Gressak, Superintendent of the Douglas Water-Sewer Department, and other members of the Department.

Respectfully Submitted

FAY, SPOFFORD & THORNDIKE, INC.

By

William J. Glover, Jr., P.E.
Senior Vice President

APPENDIX

HYDRANT DISCHARGE CURVES

HYDRANT FLOW TEST REPORT

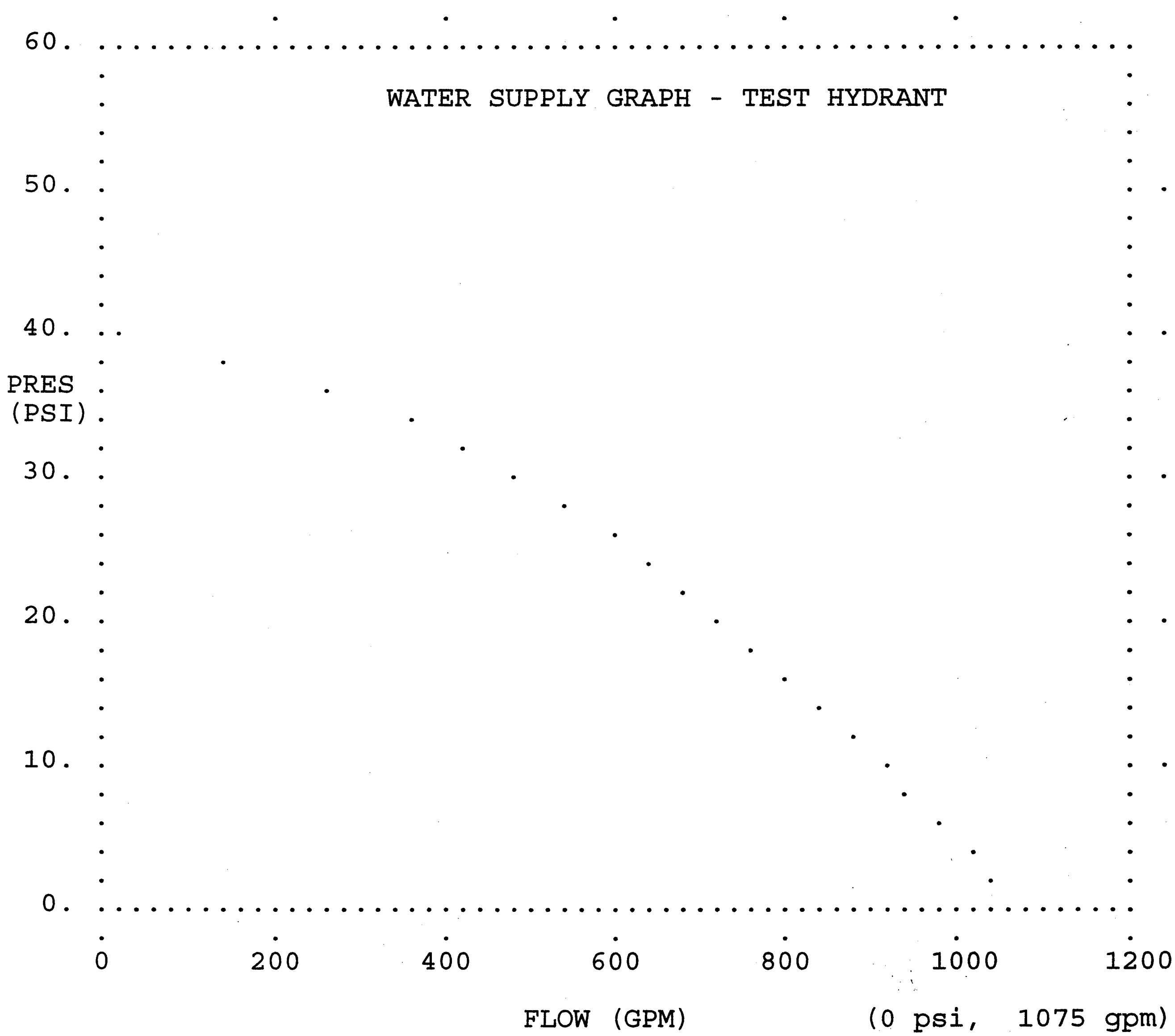
Test Hydrant: Date: 10/13/1994 Time: 11:38 FRESH
Location:
SOUTHWEST MAIN ST
Elevation: 592 ft Tester: DPB,BPK
Remarks:

Gage: 1503 Static Pressure: 39.0 psi Residual Pressure: 26.0 psi

-FLOW HYDRANT	GAGE	DIAMETER	COEFFICIENT	PITOT	FLOW
		2- 4/16 in	0.880	20.0 psi	594 gpm

Total Flow: 594 gpm

Flow @20 psi: 729 gpm Flow @10 psi: 917 gpm



HYDRANT FLOW TEST REPORT

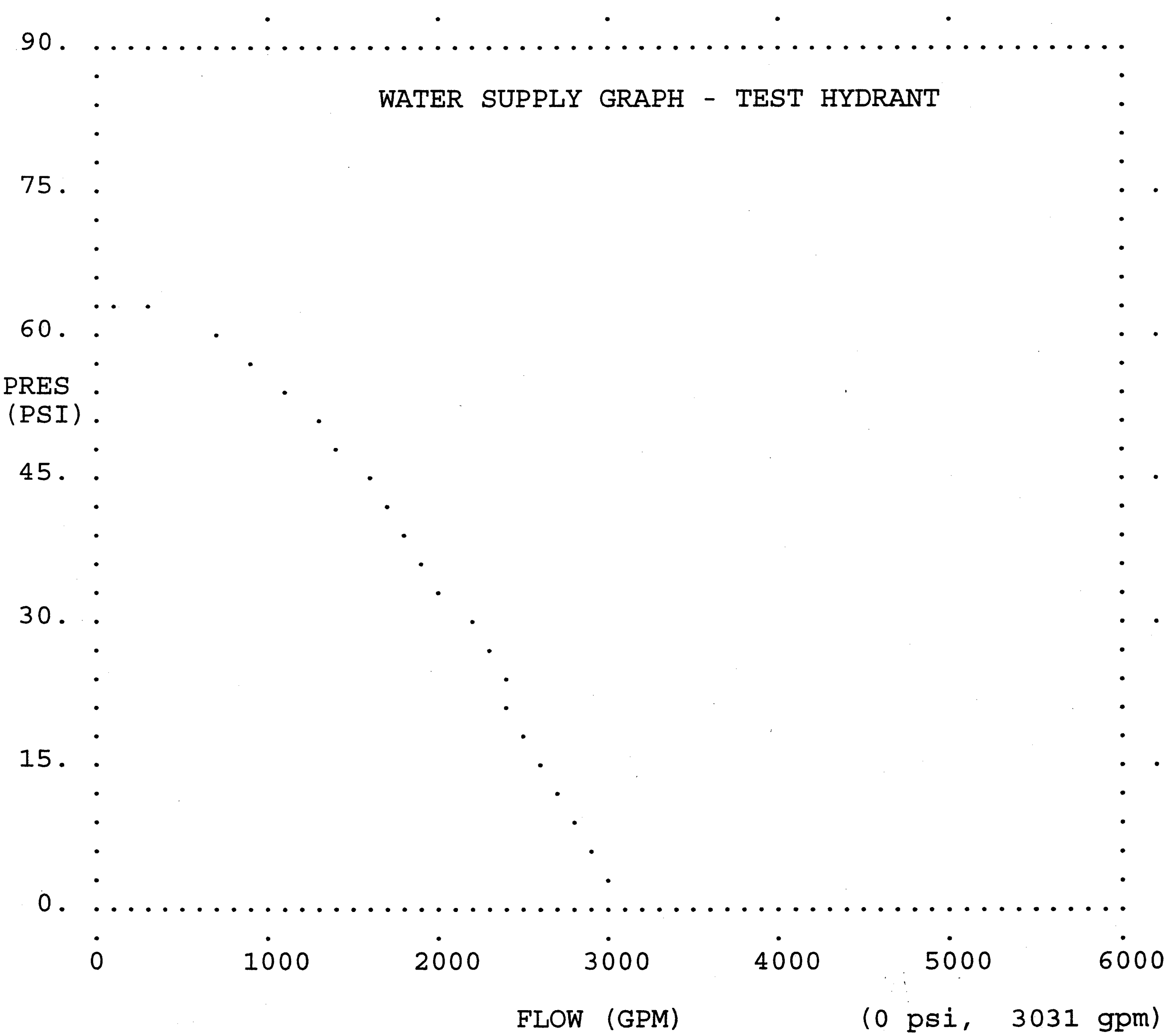
Test Hydrant: Date: 10/13/1994 Time: 11:50 FRESH
Location:
SOUTHEAST MAIN ST @ YEW ST
Elevation: 556 ft Tester: DPB,BPK
Remarks:

Gage: 1503 Static Pressure: 64.0 psi Residual Pressure: 56.0 psi

-FLOW HYDRANT	GAGE	DIAMETER	COEFFICIENT	PITOT	FLOW
		2- 4/16 in	0.880	55.0 psi	986 gpm

Total Flow: 986 gpm

Flow @20 psi: 2474 gpm Flow @10 psi: 2764 gpm



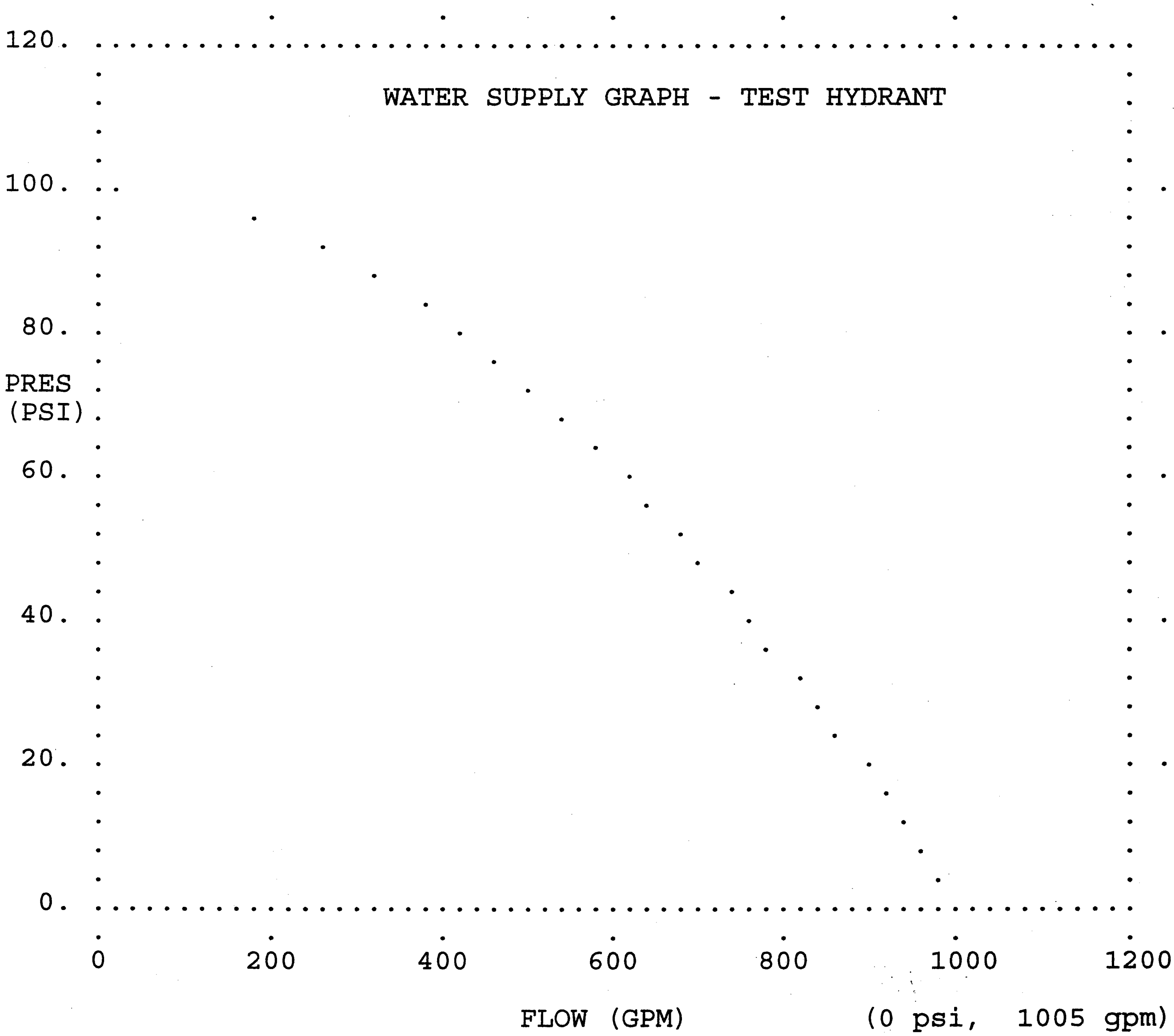
HYDRANT FLOW TEST REPORT

Test Hydrant: Date: 10/13/1994 Time: 01:44 FRESH
Location:
RIEDELL ST
Elevation: 473 ft Tester: DPB,BPK
Remarks:

Gage: 1503 Static Pressure: 100.0 psi Residual Pressure: 45.0 psi

-FLOW HYDRANT-	-GAGE-	-DIAMETER-	-COEFFICIENT-	-PITOT-	-FLOW-
		2- 4/16 in	0.880	30.0 psi	728 gpm

Total Flow: 728 gpm
Flow @20 psi: 891 gpm Flow @10 psi: 950 gpm



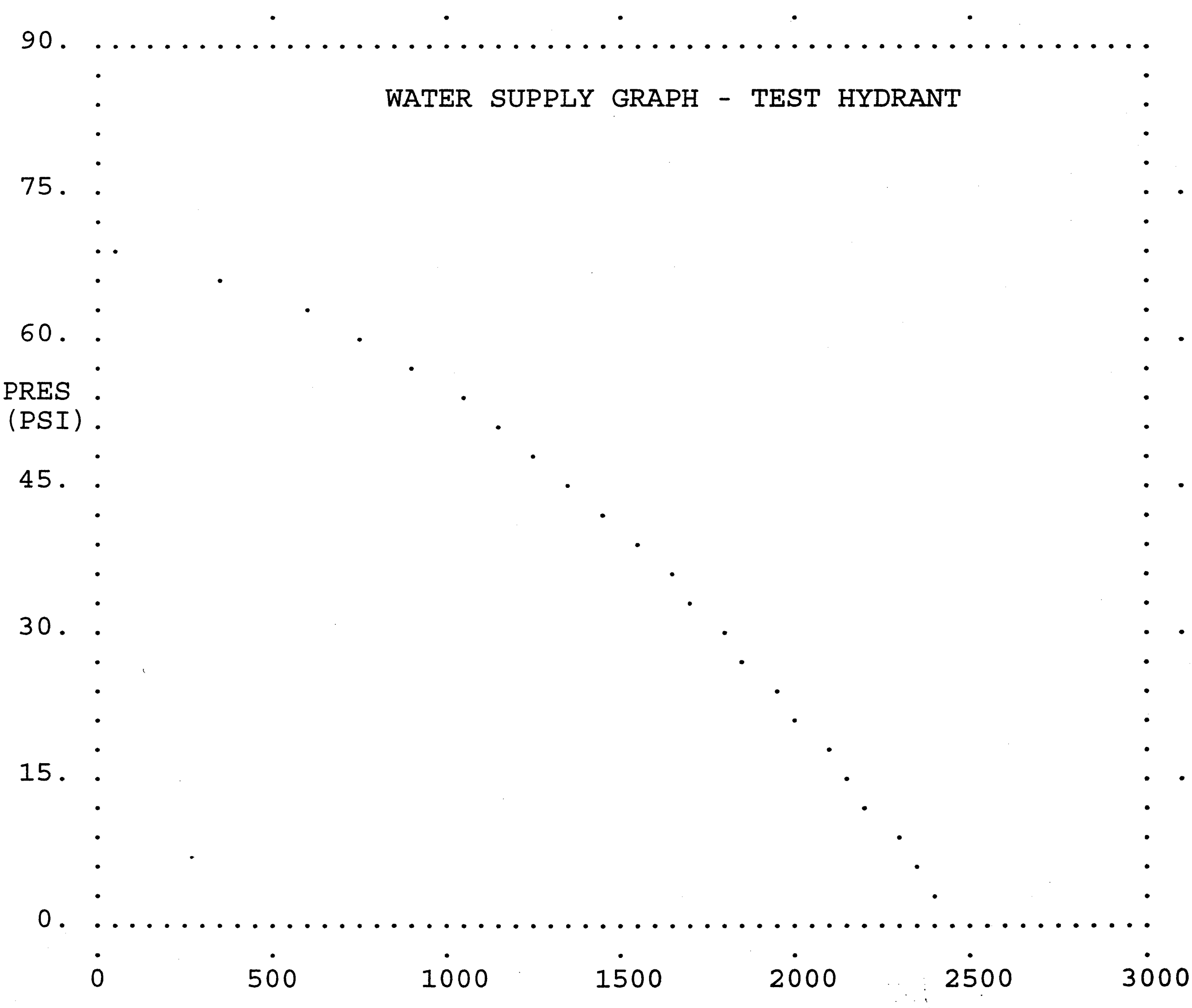
HYDRANT FLOW TEST REPORT

Test Hydrant: Date: 10/13/1994 Time: 02:00 FRESH
Location:
MAIN ST (HIGH SERVICE)
Elevation: 545 ft Tester: DPB,BPK
Remarks:

Gage: 1503 Static Pressure: 68.0 psi Residual Pressure: 57.0 psi

FLOW HYDRANT	GAGE	DIAMETER	COEFFICIENT	PITOT	FLOW
		2- 4/16 in	0.880	48.0 psi	921 gpm

Total Flow: 921 gpm
Flow @20 psi: 2040 gpm Flow @10 psi: 2260 gpm



(0 psi, 2463 gpm)

TOWN OF DOUGLAS

OFFICE OF THE SELECTMEN
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Fax: 508-476-1070
TTY 508-476-1619

November 15, 2007

John M. Goggins
Attorney at Law
34 Mechanic Street
Worcester, MA 01618

Dear Attorney Goggins:

Please be advised that, with the exception of limited transportation services offered by Elderbus for senior citizens in Douglas, there is no public transportation offered in the Town of Douglas.

Sincerely,

Michael J. Guzinski
Executive Administrator