PARE PROJECT NO. 07089.03

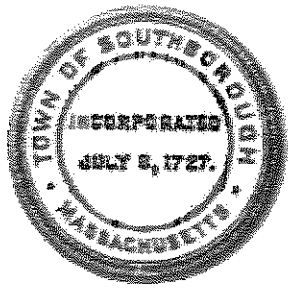
REPORT

TANK SITING ANALYSIS

RELATED TO THE CONSTRUCTION OF A

NEW WATER STORAGE FACILITY

Town of Southborough, Massachusetts



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Submitted January 28, 2008

PARE CORPORATION

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After evaluating the 25 proposed sites with the variety of scenarios, PARE will present herein information relevant to the determination of the most cost effective alternative for the siting of the proposed 2 million gallon water storage facility. See Figure 1 for a Locus Map of the proposed locations.

The cost analysis includes the estimated cost for:

- Site ownership
- 2 million gallon storage pre-cast concrete facility
- Alternatives for installing the tank at grade or burying it
- Pump station requirements for pumped storage scenarios
- Necessary system piping improvements
- Vehicular access to the proposed site
- The extension of 3-phase power if required
- Electrical usage for pumping facilities
- Loss of tax revenue for non-town owned parcels (exclusive of tax liens)

The scope of work, although not directly guided by the previous work performed on tank siting, should include a discussion on the research summary provided by PARE in our September 21, 2007 letter report and is included in Appendix A. The parameters for the location of a tank include: being away from the source water, be located in the high pressure zone, supply water to the system by a gravity feed, and be sized to provide a volume equal to the maximum daily demand and the fire flow volume. Many of the selected sites did not meet these conditions, but the highest rated sites as they directly relate to cost do satisfy these requirements with the exceptions as noted in Table ES-1.

The Town's water system is divided into two pressure zones. Four pressure-reducing valves maintain the division of the high and low service area. Manipulation of the hydraulic model indicated that the pressure reducing valves function somewhat inefficiently. It appears that they were currently designed to open when the pressure difference between the two zones reach a preset level. Due to increases in demands in both pressure zones, the pressure differential is not met because demand in both zones lowers the pressure at a similar rate.

The model also indicated that if they opened when a preset pressure in the low service area was reached, the original intent of augmenting the low service area from the high service area would be met. If this occurred, the model indicates that the previously determined critical fire flow deficiencies would be resolved. Therefore the main thrust of the study was to provide storage in the high service area and less emphasis was placed on satisfying the critical fire flows.

An option that was not considered, involves providing the existing tanks in the low service area with booster pumps and eliminating the two pressure zones with an estimated cost of $1,343,700. This would increase the pressure in the existing low service by approximately 9 psi. It would also allow for an increase of the water in the tanks to be considered useable storage. This would decrease the size of the proposed tank. However, because of the size of the existing tanks in the low service area (735,000 gallons) and the other costs associated with the development of a tank site, the incremental decrease in the size of the proposed tank would not appreciably affect the cost.

Utilizing this information it was determined that the most cost effective site, based on a 20-year present worth analysis is the Tara Road site (Site ID # 2) without a provision for burying the tank or providing a pumped storage option. PARE's opinion of probable cost determined that the development of this site to be $1,237,500. The next lowest at-grade cost was for Site ID # 1 determined to be $1,546,000. Ranked third on costs was Site ID # 18 with an estimate of $1,673,800. Of the 25 sites and three burial options for each site, only three of the alternatives analyzed were within 50% of the cost of Site ID # 2. A site-by-site summary is included in Appendix B.

Our investigation provided a broad-brush approach to the evaluation of the sites. Based on this approach it appears that Site ID # 2 is the most economical alternative. PARE recommends proceeding further with a detailed investigation of the top three sites identified in Table ES-1. Also because certain information was not received we would recommend including Site ID #'s 16C, 20 and 21 in the additional evaluation. The three additional options represent the fourth through sixth most economical options. The detailed investigation would include such factors as

- other design requirements from Massachusetts Highway Department (MHD) as it applies to Site ID # 18 and 20
- a more defined purchase price for land for Site ID # 18
- a more complete site visit for defining site access and layout for all sites
- detailed planning restrictions for all sites
- complete evaluation for the Massachusetts Water Resources Authority (MWRA) tank

availability

- confirmation of an exemption from the FAA for Site ID #16C
- detailed investigation into pump selection and booster station pricing

TABLE ES-1

SITE EVALUATION SUMMARY

Site ID	Description	Gravity Feed	Distance from Source [1]	Piping Improvements Value	20-year Present Worth
2 – At-grade	Tara Road	NO	8,400 ft	$37,500	$1,237,500
1 – At-grade	Fairview Rd.	NO	13,200 ft	$216,000	$1,546,000
18 – At-grade	Flately	NO	9,000 ft	$150,000	$1,673,800
21 – Existing	MWRA	YES	5,000 ft [2]	$1,000,000	$1,910,000
20 – At-grade	Route 495 Interchange	NO	10,200 ft	$675,000	$1,925,000
16C – At-grade	EMC Property	NO	15,600 ft	$66,000	$2,225,000
Average ALL OPTIONS					$3,714,900

1 - Distance to Pressure zone boundary – 18,000 feet

2 – MWRA tank is in the northwest direction and the pressure boundary in to the southeast

PARE was unable to obtain timely information from two sources, MWRA and MHD. We were unable to receive confirmation that the existing storage facility at the John Carroll Water Treatment Facility is available for use by the Town. However, we assumed it was possible and completed an estimate of probable construction cost for a pumped storage system from that location.

Additionally, efforts to obtain written correspondence from MHD regarding the installation of a storage facility within the right-of-way were unsuccessful. It is assumed that they are possible and that land costs will not be incurred.

PARE has completed and forwarded to the Federal Aviation Administration (FAA) Form 7460 requesting a determination of the impact of constructing a water storage facility near the private airport off of Banfill Road. According to the form instructions, an exemption will apply because the airport is privately maintained. Return correspondence from the FAA was not received prior to the report submission.

The file correspondence is included in Appendix C.

PROJECT BACKGROUND

The Town of Southborough retained PARE to perform a peer review of a water system analysis previously performed for the Town of Southborough. Specifically, the review was to research the necessity and logistics of siting a water storage facility. PARE presented its recommendation at a meeting with the DPW Advisory Board on October 24, 2007. At that time, PARE was asked to prepare a proposal to expand the current scope of work to include an evaluation of various scenarios for improving the reliability of the Southborough water system through the review of proposed tank sites, cost analyses and hydraulic model evaluations.

The evaluations of the various tank-siting alternatives will include a logistical and financial analysis. The logistical analysis will include an evaluation of a site to meet the physical parameters set forth by the alternative such as the available size of a site, the elevation of a site, the presence of an existing water system, etc. The logistical analysis will also include an evaluation of piping modifications with the use of the hydraulic model. The financial analysis will be based on the capital and operational costs of the evaluated improvement. Restrictions will be included in the analysis and are listed in the assumptions in the proposal.

The scenarios to be evaluated include:

1. Increasing the capacity of the Boland Pumping Station to provide adequate Critical Fire Flows (CFF) and meet maximum daily demands with no increase in storage. Additional infrastructure improvements would be required for this scenario and will be evaluated using the hydraulic model. This is evaluated as Site ID # 22.
2. Site a tank for gravity service to the service area. This tank would have an overflow elevation of 515.0 feet and be installed in the high service area. Various sites will be evaluated based on the lists of sites provided by the Town and attached to this proposal as Exhibit C in the proposal. System improvements and hydraulic analysis will be limited to those improvements required to connect the proposed site to the system and upgrade certain pipe lengths if necessary to facilitate enhancing system performance. This includes Sites ID # 1, 2, 16A , 16B, 16C, 18, 19 and 20.
3. Site a tank for pumped service to the service area. This pump station would provide pressure equivalent to the current system pressure with a hydraulic grade line equal to 515.0'. The tank would be installed in the high service area. Various sites will be evaluated based on the lists of sites provided by the Town and attached in the proposal as Exhibit C. The capacity of

the pump station will be determined using the hydraulic model. As with the gravity alternative, system improvements and hydraulic analysis will be limited to those improvements required to connect the proposed site to the system and achieve optimum system performance. This includes Site ID # 3, 9, 10, 11 and 16D.

4. Investigate the potential for the Town to utilize the storage facility at the MWRA John Carroll Water Treatment Plant located in the northwest portion of the city for either gravity or pumped storage use. This is evaluated as Site ID # 21
5. Investigate the viability of raising the two existing tank overflow elevations in the low service area to 515.0 feet and combine the systems to provide one service pressure. This would also include the elimination of the five existing pressure-reducing valves and incorporating the modifications into the hydraulic model.
6. Investigate the viability of incorporating pumped storage at the two existing tanks and combine the systems to provide one service pressure. For Site ID's # 8, 17A and 17B, this would also include the elimination of the four existing pressure-reducing valves. A new tank would still be required but would be sized to provide 1,625,000 gallons. By redistricting the low service area, Site ID's # 4, 5, 6, and 7 could be added. For Site ID's # 12, 13 and 14B could be added by adding pumped storage to the Clear Hill tank and redistricting the low service area.

Tables with the complete economic evaluation are included in the back of the report.

In the 2007 Report by H20 (Appendix D), they determined that the size of the proposed storage facility should be 2 million gallons. For the hydraulic analysis performed as part of our work, we assumed this to be true. For the development of the most appropriate cost for burying a tank, we evaluated the cost for various height-to-width figures and determined that a tank 102 feet in diameter and 61 feet high. For the tanks that were to be placed at-grade, the pre-cast concrete tank manufacturer used the maximum height of 85 feet because of design limitations. Because of existing elevations, certain sites allowed for a shorter tank.

Two of the scenarios resulted in a reduced tank size because of an increase in useable storage. Scenario 4 involved raising the tanks. This option would add approximately 275,000 gallons of useable storage to the system and reduce the cost of the tank by $165,000. A tank providing 1,725,000 gallons of useable storage would still be required. The other related costs for a new site including, site purchase, power requirements, access, and piping improvements would still apply. It is estimated to add approximately $1,000,000 to the cost of the scenario and was not considered further.

In a modified version of Scenario 5, modifying the existing low service tanks to provide water through a pumped storage system would also increase the useable storage within the system. It was assumed that a minimum water depth in the tanks should be half of the tank depth. This would allow for a retained storage in the low service of 375,000 gallons that will serve at the reserved fire flow volume. This would add approximately 375,000 gallons to the useable storage and reduce the cost of the tank by approximately $225,000 for Site Id's # 8, 17A and 17B. A tank providing 1,625,000 gallons of useable storage would still be required. The other related costs for a new site including, site purchase, power requirements, access, and piping improvements would still apply

By redistricting the low service area, Site ID's # 12, 13 and 14B could be included, but a pumped storage system would still be required for the Clear Hill Tank. Because of the increase in useable storage at Clear Hill, the proposed tank could be resized to 1,750,000 gallons.

The ownership of a potential site was determined through access of public records with the Board of Assessor's. Applicable Assessor's maps are located in Appendix E Utilizing private property that is delinquent in taxes can reduce the purchase price of a site. The DPW provided PARE with the amount of the tax liens. Site ID's # 8, 12 & 13 included a reduction to the purchase price. Site ID # 14A also had a tax lien, but the property was recently purchased and redevelopment rendered this site not applicable for further review. Site 14B was added due to its vicinity to Site 14A.

Purchase price associated with the cost of a particular Site ID were obtained from the Town Assessor based on current tax value or an estimate based on neighboring parcels.

SITE EVAULATION

The scope of the project involved evaluation of sites that provided a gravity discharge and a pumped discharge of the water from the proposed water storage facility. The scope of work also outlined a maximum height for any new structures. The general site topography obtained from Uniteed State Geologic Survey (USGS) mapping indicated which type of discharge a site would generate, gravity or pumped. To provide a gravity discharge the high water line for the tank would have to meet the existing high service elevation of 515.0'. Subtracting the maximum tank height of 85' yields a minimum elevation of 430' for a gravity discharge. Site ID's # 1, 2, 16A, 16B, 16C, 17A, 17B, 18, 19 & 20 do not require pumping if a tank is located at grade. All sites require pumping if the tank is partially or completely buried.

PUMPING REQUIREMENTS

For the purpose of providing maximum daily demands the proposed pumping station at the tank site should be sized to provide 1,500 gallons per minute. This was determined through the hydraulic model.

Because the sites are located at different elevation, different size pumps are required. Generally, The lower the elevation is for a site, the larger the required pump station and the higher the purchase and operating cost. PARE obtained cost estimates from pre-package booster pump station manufacturers for stations that would meet the conditions expected. Pump curves for various pumping requirements are included in Appendix F. A typical layout of a proposed station is included in Appendix G. The costs for pumping are summarized in Table 2 – Pumping Cost.

Just placing a water tank within the system will not generally solve the shortcomings of the system. In every case, system improvements in the form of new piping were required to meet the fire flow demands, the maximum day demands of the system and reduce system pressure to an appropriate level. PARE utilized the hydraulic model to simulate the piping requirements for a given siting scenario. These results are summarized in Table 3 – Infrastructure Cost.

BURYING OF WATER TANK

The scope of work included evaluating tank sites for partial or complete burial of the tank. Excavation around the site was required to be slightly larger than the tank itself to provide for working room and foundation requirements. The depth of the excavation would be five feet deeper than the tank and the diameter would require 10 feet around the tank.

The evaluation of burying a tank was divided into three categories. The first involved burying the tank half-way. The second involved burying the tank but not the roof. The third option involved completely burying the tank. The third category would require much stronger loads for the roof and is expected to add 40% to the cost of the tank. This can be seen in the "Tank Unit Cost" column in Table 5 – Tank Size and Cost.

To develop excavation costs for the various categories, PARE utilized the "Soil Types of Southern Worcester County" as published by the United States Soil Conservation Service to determine the soil type in the vicinity of a site being evaluated. The description of the soil in an area was used to determine the amount of ledge and excavation conditions that could be expected at a site. Copies of the soil descriptions are included in Appendix H.

ACCESS REQUIREMENTS

Access will be required for each site. Existing roadways and topographic information was used to determine the expected length of an access road. The proposed width of 15 feet will allow for access by DPW vehicles and is considered a standard width. Cost for the road includes clearing, base road construction and paving. Table 4 – Tank Summary includes the expected length of the proposed roadway for each site evaluated.

POWER REQUIREMENTS

Where a pumping station is required, special electrical requirements need to be met. The size of the pumps requires that 3-phase power be available at each site. Consultation with National Grid confirmed the locations were 3-phase power was available and the location of the nearest source in the cases were it was not readily available. National Grid also provided an expected cost for extending 3-phase service. Table 4 – Tank Summary includes the proposed length of 3-phase power that would be required for each site.

Not included in the cost estimate was the added cost of demand charges applied by National Grid. Demand charges are assessed based on the maximum amount of power the station uses in a given period. National Grid assesses the charge because they have to be able to meet your maximum demand at any given time. The amount of the charges varies with the size of the motor and was not included in the analysis. Upon reduction of the number of sites, a more detailed evaluation that included demand charges (if applicable) would be incorporated.

The scope of work outlined that each of the sites was to be evaluated to provide for meeting the fire flow demands and the maximum daily demands of the system. Through the course of the project this has been modified. Since some of the sites are in the low service area, they were not included in Scenario 4. For example, Site 8 on Breakneck Hill Road is too far from the existing high service zone to provide a pumped storage system with two pressure zones. However, in Scenario 5, by creating one pressure zone, it is a viable option.

In our September 21, 2007 letter report, PARE outlined the results of a research of reference material that indicated that a tank should be located away from the source of water (Boland or Hosmer Stations) into the system. Additionally, one of the assumptions was that the tank would be located in the high service area.

As the system is currently constructed, Site ID's # 1, 3, 15, 16A, 16B, 16C & 16D meet the condition of being away from the source water (south of Route 9) and in the high service area. Another option would be to restructure the division line between the high and low service areas. Since updated pressure reducing valves are recommended, relocating them could yield the inclusion of Site ID's # 4, 5, 6, and 7 in the Southville area of Town while still maintaining two pressure zones.

As stated in Proposed Tank Size, Site ID's 12, 13 and 14B could be added if the low service area was restructured with a revised placement of the replacement pressure reducing valves. However, pumped storage would be required for the Clear Hill Tank. This would increase the usable storage and reduce the size of the proposed tank for this option.

Additionally Site ID's 8, 17A and 17B could be added to the evaluation, but both existing tanks would need to be equipped with a pumped storage delivery system. This would further reduce the size of the proposed storage system and eliminate the two pressure zones, but increase overall project costs.

The site evaluation combined all of the data for the potential costs of constructing a tank at a specific site. Capital costs such as the tank; purchase price, access road, excavation, and pumping were evaluated on a present worth basis because the expenditures would occur in Year 1. Annual costs such as operation and maintenance of the pumping station; electricity and lost tax revenue from

purchased private property were also summarized into a present worth cost. The value of the annual cost was set at 5% with a life cycle duration of 20-years.

Table 1 – Cost Summary includes the opinion of estimated costs for each Site. An individual write-up for each ID is included in Appendix B.

11-1.1 Increasing the Capacity of the Boland Pump Station. The scenario (Site ID # 22) involved utilizing the hydraulic model to anticipate the required improvements for only increasing the size of the pump station and not providing additional storage within the system. To meet the maximum daily demand (MDD) and the calculated fire flow (CFF), the pump station was designed to provide 3,500 gpm. When the demands are inputted into the hydraulic model, insufficiencies are noted. They include:

- Increased headloss in the current piping network due to higher water velocities
- Increased losses require heavier duty pumps
- Heavier duty pumps increase localized system pressures to exceed current pressure class rating for certain portions of the system and exceed the Massachusetts Department of Environmental Protection (DEP) guidelines of 100 psi.
- Exceeding the design pressure requires upgrading the pipe design with pipe replacement or increasing the diameter of the existing pipe with replacement.
- Utilizing heavy duty pumps for maximum conditions renders them very inefficient on non-maximum days
- The suction line from the Hultman Aqueduct is comprised of 12-inch pipe. Although it is only a short distance (100-ft +/-); the velocity in the pipe will approach 10 feet per second, which is the upper limit of literature recommendations. Strict parameters exist for available suction head and if it is not available the pump will not function properly and will be damaged.
- Either lowering the demand rate from 3,500 gpm or increasing the size of the suction main from its current size of 12-inch could increase inadequate suction head but was not included in this evaluation.

Using the hydraulic model we estimate that the following improvements will be required if this scenario was implemented. Table 1 includes a summary of the estimated probable construction cost.

- New pumps and motors would be required. We estimate that to meet the design conditions, the pumps would have to be sized with a 350 horsepower motor and would deliver flow at the design rate on an average day at 80% efficiency. Due to the large increase in motor size, we anticipate that all of the electrical components will need to be replaced within the station including a service upgrade.

- To deliver water to the southern part of the system pipe replacement will be necessary to increase the ability of the system to transfer water. The hydraulic model indicates that approximately 2,500 feet of 6-inch and 6,500 feet of 8-inch pipe will need to be replaced with 12-inch pipe.
- With the piping modifications the pressure within the distribution system will be below 150 psi. But it will be necessary to reduce the pressure for services connections where the pressure exceeds 100 psi. PARE did not enumerate the impact of the purchase of pressure reducing valves for individual homes but the area encompasses approximately 20% of the northwest portion of the service area above an approximate elevation of 300 feet.

It should be noted that although this scenario satisfies the requirements for meeting fire flow and maximum daily demands it does not provide for meeting storage requirements outlined in our initial report. Additionally the pumps and motors will be very inefficient at lower flow rates. The minimum flow rate from the expected pump is 1,800 gpm. This flow is greater than the demand for a large part of the year and will result in inefficient start stop cycles for the motors.

11-1-2 Tank Siting with an overflow elevation of 515 ft. Due to the limitations from the tank manufacturer, the maximum height of a tank is 85 ft above grade. To facilitate an overflow elevation of 515 ft, the required ground surface elevation would be 430 ft. To prevent the requirements for extensive additional piping only the sites within the high service area were considered. Our analysis of the sites indicates that only eight sites satisfy this requirement (1, 2, 16A, 16B, 16C, 18, 19 and 20). These sites do not require additional pumping and will feed the system by gravity flow.

11-1-3 Tank siting with an overflow elevation less than 515 ft. As stated in previous text the pumping station would be rated to provide 1,500 gpm. As with a gravity fed tank, the tank sites need to be in the high services area (or in close proximity). This scenario included an evaluation of sites in the high service area (9, 10, 11, 15 and 16D) and in the low service area (Sites 3) For the sites not located in the high service area, additional piping was required to connect them to the high service and is included in the figure in Table 3 – Infrastructure Cost. Redistricting the service area could be performed with the revised placement of new pressure reducing valves and allow for the inclusion of Site ID's # 4, 5, 6, and 7).

11-1-4 Connect to the MWRA tank in Southborough/Marlborough. We attempted to contact the Director of Water Operations at the MWRA on numerous occasions during the course of the study. Response was not received. However, we assumed that it was suitable to connect to the existing tank

at the John Carroll Water Treatment Plant and that connecting to and pumping into the Town water system was a viable option. The option required a pumping station and approximately 5,000 feet of new piping.

11-1-5 Raising the overflow elevation of the existing tanks. Further investigation into the structural stability of the scenario will be required, but the option of raising the elevation of the tanks in the low service area by 22 feet is possible. Additional permitting would also be required through the planning and public hearing process. This Scenario would eliminate the two pressure zones and marginally increase the useable storage provided in the system. Additional storage would still be required but at a smaller magnitude. Eliminating the low service area would also increase the pressure for that part of town approximately 9 psi. This difference would be most noticeable at higher elevations.

11-1-6 Eliminate low service and provide pump stations at existing low service tanks. In lieu of physically raising the elevation of the existing tanks, booster stations could be installed at both sites to provide the additional pressure created by raising them. Because the stations would be relatively small, it is anticipated that they would fit on the existing site in a small enclosure not larger than 10 feet by 20 feet.

Providing booster pumps at the existing tanks would increase the useable storage in the system by making the majority of the water in the tanks available at the system pressure. The tanks could not be completely emptied and a buffer of water would need to be maintained. As with raising the tanks, this will increase the useable storage within the system. However, the tanks in the low service area are relatively small and the need would still exist for additional storage.

The base cost for providing pumped storage for the existing tanks is included in the Tables and estimated to be $1,343,700, for Site ID's 8, 17A and 17B. The additional cost would be $671,850 for Site ID's 12, 13 and 14B, since redistricting of the pressure zones would only dictate that one of the tanks be equipped with a pumped storage system.

HYDRAULIC MODEL RESULTS

The hydraulic model indicates that the pressure reducing valves that create the high and low service zones do not appear to be functioning properly. We anticipated this, but the impact was not completely understood until calibration of the model was attempted. By using the previously complete hydrant flow tests we were able to calibrate the model so that it replicates system pressures and flows to within 5% of actual empirical data.

By manipulating the hydraulic model to where the pressure reducing valves operate in a manner more suitable with the current system conditions, the critical fire flows in the low service area can be achieved. However, it should be understood that the recommendation from our September letter report is still valid, that the water system does not provide adequate storage for maximum daily and fire flow demands.

CONTROL IMPROVEMENTS

The Town currently controls the operation of the pump station with a signal from the tanks indicating their elevation. The Boland and Hosmer pumping stations operate when a preset water level is reached within the tanks in their respective pressure zone. When the tanks are full, the signal dictates that the pump turn off. This is a very simple operation.

Including a pump storage component to the system will require the installation of more up-to-date control system. This system is typically referred to as a SCADA system. SCADA is an acronym for Supervisory Control and Data Acquisition. It involves the installation of programmable logic controllers (PLC's) that utilize data generated by the system to provide the necessary system control.

With the addition of pumped storage, the operation of the system will be more complicated. The tanks will not be able to be filled while the booster pumps are providing water to the system. That is, if allowed to fill during pumping operations, the water would circulate from the booster pump station back into the tank and water would not be added to the system. Operational controls, through the PLC's can be generated to manage the system to insure that it is functioning in its most efficient mode and the system is satisfying the goals of adequate supply, storage, pressure and fire flow.

It is anticipated that an improved SCADA system would be required eventually for the system and it was not included in the costs for the pumped storage scenarios.



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SCALE:	1"=1200'
DESIGNED BY:	KLO
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APPROVED BY:	RPS

DRAWING TITLE:

SITE PLAN FOR PROPOSED TANK SITES

DRAWING NO.:

SHEET NO. 1 OF 1

L:\07089.03 - Southboro Tank Siting Phase II\dwgs\Site Plan.dwg, 1/28/2008 3:31:54 PM, Plotted By RPB

Southborough DPW
Tank Siting Evaluation

TABLE 1
COST EVALUATION SUMMARY

Site ID	Description	Tank Cost ($)	Land purchase price ($)	Lost Annual Tax Revenue ($)	Booster Station Cost ($)	5% O&M Cost ($/yr)	Electric Cost ($/yr)	System Expansion Cost ($)	Total Capital Cost ($)	Total Annual Cost ($/yr)	Present Worth Factor	CAPITAL COST ($)
1	Fairview	$ 1,330,000	$ -	$ -	$ -	$ -	$ -	$ 216,000	$ 1,546,000	$ -	12.4622	$ 1,546,000
	1/2 Buried	$ 2,149,401	$ -	$ -	$ 275,000	$ 13,750	$ 23,472	$ 316,000	$ 2,740,401	$ 37,222	12.4622	$ 3,204,300
	Buried to roof	$ 2,875,157	$ -	$ -	$ 275,000	$ 13,750	$ 46,945	$ 316,000	$ 3,466,157	$ 60,695	12.4622	$ 4,222,500
	Complete bury	$ 3,355,157	$ -	$ -	$ 275,000	$ 13,750	$ 46,945	$ 316,000	$ 3,946,157	$ 60,695	12.4622	$ 4,702,500
2	Tara Road	$ 1,200,000	$ -	$ -	$ -	$ -	$ -	$ 37,500	$ 1,237,500	$ -	12.4622	$ 1,237,500
	1/2 Buried	$ 1,390,819	$ -	$ -	$ 310,000	$ 15,500	$ 23,472	$ 87,500	$ 1,788,319	$ 38,972	12.4622	$ 2,274,000
	Buried to roof	$ 1,559,831	$ -	$ -	$ 310,000	$ 15,500	$ 35,209	$ 87,500	$ 1,957,331	$ 50,709	12.4622	$ 2,589,300
	Complete bury	$ 2,039,831	$ -	$ -	$ 310,000	$ 15,500	$ 35,209	$ 87,500	$ 2,437,331	$ 50,709	12.4622	$ 3,069,300
3	147 Cordaville	$ 1,300,000	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 297,500	$ 1,957,500	$ 76,681	12.4622	$ 2,913,100
	1/2 Buried	$ 1,490,819	$ -	$ -	$ 410,000	$ 20,500	$ 70,417	$ 297,500	$ 2,198,319	$ 90,917	12.4622	$ 3,331,300
	Buried to roof	$ 1,659,831	$ -	$ -	$ 460,000	$ 23,000	$ 93,890	$ 297,500	$ 2,417,331	$ 116,890	12.4622	$ 3,874,000
	Complete bury	$ 2,139,831	$ -	$ -	$ 460,000	$ 23,000	$ 93,890	$ 297,500	$ 2,897,331	$ 116,890	12.4622	$ 4,354,000
4	Highland Street	$ 1,260,000	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 40,000	$ 1,660,000	$ 76,681	12.4622	$ 2,615,600
	1/2 Buried	$ 1,450,819	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 40,000	$ 1,850,819	$ 76,681	12.4622	$ 2,806,400
	Buried to roof	$ 1,619,831	$ -	$ -	$ 460,000	$ 23,000	$ 93,890	$ 40,000	$ 2,119,831	$ 116,890	12.4622	$ 3,576,500
	Complete bury	$ 2,099,831	$ -	$ -	$ 460,000	$ 23,000	$ 93,890	$ 40,000	$ 2,599,831	$ 116,890	12.4622	$ 4,056,500
5	24 Atwood	$ 1,260,000	$ -	$ -	$ 275,000	$ 13,750	$ 35,209	$ 62,500	$ 1,597,500	$ 48,959	12.4622	$ 2,207,600
	1/2 Buried	$ 2,079,401	$ -	$ -	$ 310,000	$ 15,500	$ 46,945	$ 62,500	$ 2,451,901	$ 62,445	12.4622	$ 3,230,100
	Buried to roof	$ 2,805,157	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 62,500	$ 3,227,657	$ 76,681	12.4622	$ 4,183,300
	Complete bury	$ 3,285,157	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 62,500	$ 3,707,657	$ 76,681	12.4622	$ 4,663,300
6	46 Atwood	$ 1,330,000	$ -	$ -	$ 275,000	$ 13,750	$ 35,209	$ 132,500	$ 1,737,500	$ 48,959	12.4622	$ 2,347,600
	1/2 Buried	$ 1,520,819	$ -	$ -	$ 310,000	$ 15,500	$ 46,945	$ 132,500	$ 1,963,319	$ 62,445	12.4622	$ 2,741,500
	Buried to roof	$ 1,689,831	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 132,500	$ 2,182,331	$ 76,681	12.4622	$ 3,137,900
	Complete bury	$ 2,169,831	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 132,500	$ 2,662,331	$ 76,681	12.4622	$ 3,617,900
7	Parkerville Road	$ 1,328,000	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 125,000	$ 1,813,000	$ 76,681	12.4622	$ 2,768,600
	1/2 Buried	$ 1,518,819	$ -	$ -	$ 360,000	$ 18,000	$ 58,681	$ 125,000	$ 2,003,819	$ 76,681	12.4622	$ 2,959,400
	Buried to roof	$ 1,687,831	$ -	$ -	$ 460,000	$ 23,000	$ 93,890	$ 125,000	$ 2,272,831	$ 116,890	12.4622	$ 3,729,500
	Complete bury	$ 2,167,831	$ -	$ -	$ 460,000	$ 23,000	$ 93,890	$ 125,000	$ 2,752,831	$ 116,890	12.4622	$ 4,209,500
8	60 Breakneck Hill Road	$ 1,015,000	$ 212,500	$ 2,822	$ 310,000	$ 15,500	$ 46,945	$ 362,500	$ 1,902,822	$ 65,266	12.4622	$ 2,716,200
	1/2 Buried	$ 1,178,560	$ 212,500	$ 2,822	$ 360,000	$ 18,000	$ 58,681	$ 362,500	$ 2,116,381	$ 79,503	12.4622	$ 3,107,200
	Buried to roof	$ 1,309,407	$ 212,500	$ 2,822	$ 410,000	$ 20,500	$ 70,417	$ 362,500	$ 2,297,229	$ 93,739	12.4622	$ 3,465,400
	Complete bury	$ 1,699,407	$ 212,500	$ 2,822	$ 410,000	$ 20,500	$ 70,417	$ 362,500	$ 2,687,229	$ 93,739	12.4622	$ 3,855,400
9	Clifford-Deerfoot	$ 1,300,000	$ 360,000	$ 4,514	$ 275,000	$ 13,750	$ 35,209	$ 137,500	$ 2,077,014	$ 53,473	12.4622	$ 2,743,400
	1/2 Buried	$ 1,490,819	$ 360,000	$ 4,514	$ 310,000	$ 15,500	$ 46,945	$ 137,500	$ 2,302,834	$ 66,959	12.4622	$ 3,137,300
	Buried to roof	$ 1,659,831	$ 360,000	$ 4,514	$ 360,000	$ 18,000	$ 58,681	$ 137,500	$ 2,521,845	$ 81,195	12.4622	$ 3,533,700
	Complete bury	$ 2,139,831	$ 360,000	$ 4,514	$ 360,000	$ 18,000	$ 58,681	$ 137,500	$ 3,001,845	$ 81,195	12.4622	$ 4,013,700

Southborough DPW
Tank Siting Evaluation

TABLE 1
COST EVALUATION SUMMARY

Site ID	Description	Tank Cost ($)	Land purchase price ($)	Lost Annual Tax Revenue ($)	Booster Station Cost ($)	5% O&M Cost ($/yr)	Electric Cost ($/yr)	System Expansion Cost ($)	Total Capital Cost ($)	Total Annual Cost ($/yr)	Present Worth Factor	CAPITAL COST ($)
10	Northboro Road	$ 1,424,000	$ 225,000	$ 2,822	$ 310,000	$ 15,500	$ 46,945	$ 232,500	$ 2,194,322	$ 65,266	12.4622	$ 3,007,700
	1/2 Buried	$ 1,614,819	$ 225,000	$ 2,822	$ 360,000	$ 18,000	$ 58,681	$ 232,500	$ 2,435,141	$ 79,503	12.4622	$ 3,425,900
	Buried to roof	$ 1,783,831	$ 225,000	$ 2,822	$ 410,000	$ 20,500	$ 70,417	$ 232,500	$ 2,654,153	$ 93,739	12.4622	$ 3,822,300
	Complete bury	$ 2,263,831	$ 225,000	$ 2,822	$ 410,000	$ 20,500	$ 70,417	$ 232,500	$ 3,134,153	$ 93,739	12.4622	$ 4,302,300
11	Ledge Hill Road	$ 1,296,000	$ 250,000	$ 3,135	$ 275,000	$ 13,750	$ 35,209	$ 226,250	$ 2,050,385	$ 52,094	12.4622	$ 2,699,600
	1/2 Buried	$ 1,997,542	$ 250,000	$ 3,135	$ 275,000	$ 13,750	$ 35,209	$ 226,250	$ 2,751,927	$ 52,094	12.4622	$ 3,401,100
	Buried to roof	$ 2,618,908	$ 250,000	$ 3,135	$ 360,000	$ 18,000	$ 58,681	$ 226,250	$ 3,458,293	$ 79,816	12.4622	$ 4,453,000
	Complete bury	$ 3,098,908	$ 250,000	$ 3,135	$ 360,000	$ 18,000	$ 58,681	$ 226,250	$ 3,938,293	$ 79,816	12.4622	$ 4,933,000
12	88 Newton Street	$ 1,080,000	$ 180,000	$ 2,822	$ 360,000	$ 18,000	$ 58,681	$ 40,000	$ 1,662,822	$ 79,503	12.4622	$ 2,653,600
	1/2 Buried	$ 1,249,012	$ 180,000	$ 2,822	$ 410,000	$ 20,500	$ 70,417	$ 40,000	$ 1,881,833	$ 93,739	12.4622	$ 3,050,000
	Buried to roof	$ 1,396,215	$ 180,000	$ 2,822	$ 460,000	$ 23,000	$ 93,890	$ 40,000	$ 2,079,037	$ 119,711	12.4622	$ 3,570,900
	Complete bury	$ 1,816,215	$ 180,000	$ 2,822	$ 460,000	$ 23,000	$ 93,890	$ 40,000	$ 2,499,037	$ 119,711	12.4622	$ 3,990,900
13	55-57 Boston Road	$ 1,180,000	$ 196,000	$ 2,508	$ 360,000	$ 18,000	$ 58,681	$ 192,500	$ 1,931,008	$ 79,189	12.4622	$ 2,917,900
	1/2 Buried	$ 1,627,383	$ 196,000	$ 2,508	$ 410,000	$ 20,500	$ 70,417	$ 192,500	$ 2,428,391	$ 93,425	12.4622	$ 3,592,700
	Buried to roof	$ 2,017,040	$ 196,000	$ 2,508	$ 460,000	$ 23,000	$ 93,890	$ 192,500	$ 2,868,048	$ 119,398	12.4622	$ 4,356,000
	Complete bury	$ 2,437,040	$ 196,000	$ 2,508	$ 460,000	$ 23,000	$ 93,890	$ 192,500	$ 3,288,048	$ 119,398	12.4622	$ 4,776,000
14A	24 Learned Street	$ 1,120,000	$ 200,000	$ 2,508	$ 310,000	$ 15,500	$ 46,945	$ 150,000	$ 1,782,508	$ 64,953	12.4622	$ 2,592,000
14B	Willow Street	$ 1,090,000	$ 200,000	$ 2,508	$ 310,000	$ 15,500	$ 46,945	$ 197,500	$ 1,800,008	$ 64,953	12.4622	$ 2,609,500
	1/2 Buried	$ 1,259,012	$ 200,000	$ 2,508	$ 310,000	$ 15,500	$ 46,945	$ 197,500	$ 1,969,020	$ 64,953	12.4622	$ 2,778,500
	Buried to roof	$ 1,406,215	$ 200,000	$ 2,508	$ 410,000	$ 20,500	$ 70,417	$ 197,500	$ 2,216,223	$ 93,425	12.4622	$ 3,380,500
	Complete bury	$ 1,826,215	$ 200,000	$ 2,508	$ 410,000	$ 20,500	$ 70,417	$ 197,500	$ 2,636,223	$ 93,425	12.4622	$ 3,800,500
15	324 Worcester Turnpike	$ 1,260,000	$ 210,000	$ 2,633	$ 275,000	$ 13,750	$ 35,209	$ 223,750	$ 1,971,383	$ 51,592	12.4622	$ 2,614,300
	1/2 Buried	$ 1,961,542	$ 210,000	$ 2,633	$ 275,000	$ 13,750	$ 35,209	$ 223,750	$ 2,672,926	$ 51,592	12.4622	$ 3,315,900
	Buried to roof	$ 2,582,908	$ 210,000	$ 2,633	$ 360,000	$ 18,000	$ 58,681	$ 223,750	$ 3,379,292	$ 79,314	12.4622	$ 4,367,700
	Complete bury	$ 3,062,908	$ 210,000	$ 2,633	$ 360,000	$ 18,000	$ 58,681	$ 223,750	$ 3,859,292	$ 79,314	12.4622	$ 4,847,700
16A	Southwest Portion	$ 1,740,000	$ 250,000	$ 3,135	$ -	$ -	$ -	$ 210,000	$ 2,203,135	$ 3,135	12.4622	$ 2,242,200
	1/2 Buried	$ 2,441,542	$ 250,000	$ 3,135	$ 275,000	$ 13,750	$ 23,472	$ 460,000	$ 3,429,677	$ 40,357	12.4622	$ 3,932,600
	Buried to roof	$ 3,062,908	$ 250,000	$ 3,135	$ 310,000	$ 15,500	$ 46,945	$ 460,000	$ 4,086,043	$ 65,580	12.4622	$ 4,903,300
	Complete bury	$ 3,542,908	$ 250,000	$ 3,135	$ 310,000	$ 15,500	$ 46,945	$ 460,000	$ 4,566,043	$ 65,580	12.4622	$ 5,383,300
16B	Southwest Portion	$ 1,500,000	$ 850,000	$ 10,659	$ -	$ -	$ -	$ 228,750	$ 2,589,409	$ 10,659	12.4622	$ 2,722,200
	1/2 Buried	$ 2,201,542	$ 850,000	$ 10,659	$ 275,000	$ 13,750	$ 23,472	$ 453,750	$ 3,790,951	$ 47,881	12.4622	$ 4,387,700
	Buried to roof	$ 2,822,908	$ 850,000	$ 10,659	$ 310,000	$ 15,500	$ 46,945	$ 453,750	$ 4,447,317	$ 73,104	12.4622	$ 5,358,400
	Complete bury	$ 3,302,908	$ 850,000	$ 10,659	$ 310,000	$ 15,500	$ 46,945	$ 453,750	$ 4,927,317	$ 73,104	12.4622	$ 5,838,400
16C	Southwest Portion	$ 1,370,000	$ 675,000	$ 8,465	$ -	$ -	$ -	$ 66,000	$ 2,119,465	$ 8,465	12.4622	$ 2,225,000
	1/2 Buried	$ 2,189,401	$ 675,000	$ 8,465	$ 275,000	$ 13,750	$ 23,472	$ 241,000	$ 3,388,866	$ 45,687	12.4622	$ 3,958,200
	Buried to roof	$ 2,915,157	$ 675,000	$ 8,465	$ 310,000	$ 15,500	$ 46,945	$ 241,000	$ 4,149,621	$ 70,909	12.4622	$ 5,033,300
	Complete bury	$ 3,395,157	$ 675,000	$ 8,465	$ 310,000	$ 15,500	$ 46,945	$ 241,000	$ 4,629,621	$ 70,909	12.4622	$ 5,513,300

Southborough DPW
Tank Siting Evaluation

TABLE 1
COST EVALUATION SUMMARY

Site ID	Description	Tank Cost ($)	Land purchase price ($)	Lost Annual Tax Revenue ($)	Booster Station Cost ($)	5% O&M Cost ($/yr)	Electric Cost ($/yr)	System Expansion Cost ($)	Total Capital Cost ($)	Total Annual Cost ($/yr)	Present Worth Factor	CAPITAL COST ($)
16D	Southwest Portion	$ 1,360,000	$ 250,000	$ 3,135	$ 275,000	$ 13,750	$ 35,209	$ 195,000	$ 2,083,135	$ 52,094	12.4622	$ 2,732,300
	1/2 Buried	$ 2,179,401	$ 250,000	$ 3,135	$ 310,000	$ 15,500	$ 46,945	$ 195,000	$ 2,937,536	$ 65,580	12.4622	$ 3,754,800
	Buried to roof	$ 2,905,157	$ 250,000	$ 3,135	$ 360,000	$ 18,000	$ 58,681	$ 195,000	$ 3,713,292	$ 79,816	12.4622	$ 4,708,000
	Complete bury	$ 3,385,157	$ 250,000	$ 3,135	$ 360,000	$ 18,000	$ 58,681	$ 195,000	$ 4,193,292	$ 79,816	12.4622	$ 5,188,000
17A	Pine Hill Road	$ 1,279,000	$ 300,000	$ 3,762	$ -	$ -	$ -	$ 1,800,000	$ 3,382,762	$ 3,762	12.4622	$ 3,429,600
	1/2 Buried	$ 1,880,322	$ 300,000	$ 3,762	$ 275,000	$ 13,750	$ 23,472	$ 1,825,000	$ 4,284,084	$ 40,984	12.4622	$ 4,794,800
	Buried to roof	$ 2,361,379	$ 300,000	$ 3,762	$ 310,000	$ 15,500	$ 46,945	$ 1,825,000	$ 4,800,141	$ 66,207	12.4622	$ 5,625,200
	Complete bury	$ 2,751,379	$ 300,000	$ 3,762	$ 310,000	$ 15,500	$ 46,945	$ 1,825,000	$ 5,190,141	$ 66,207	12.4622	$ 6,015,200
17B	Pine Hill Road	$ 1,245,000	$ 300,000	$ 3,762	$ -	$ -	$ -	$ 1,800,000	$ 3,348,762	$ 3,762	12.4622	$ 3,395,600
	1/2 Buried	$ 1,846,322	$ 300,000	$ 3,762	$ 275,000	$ 13,750	$ 35,209	$ 1,825,000	$ 4,250,084	$ 52,721	12.4622	$ 4,907,100
	Buried to roof	$ 2,327,379	$ 300,000	$ 3,762	$ 310,000	$ 15,500	$ 46,945	$ 1,825,000	$ 4,766,141	$ 66,207	12.4622	$ 5,591,200
	Complete bury	$ 2,717,379	$ 300,000	$ 3,762	$ 310,000	$ 15,500	$ 46,945	$ 1,825,000	$ 5,156,141	$ 66,207	12.4622	$ 5,981,200
18	Near Route 495	$ 1,290,000	$ 200,000	$ 2,508	$ -	$ -	$ -	$ 150,000	$ 1,642,508	$ 2,508	12.4622	$ 1,673,800
	1/2 Buried	$ 1,795,110	$ 200,000	$ 2,508	$ 275,000	$ 13,750	$ 14,083	$ 165,000	$ 2,437,618	$ 30,341	12.4622	$ 2,815,700
	Buried to roof	$ 2,242,494	$ 200,000	$ 2,508	$ 275,000	$ 13,750	$ 35,209	$ 165,000	$ 2,885,002	$ 51,467	12.4622	$ 3,526,400
	Complete bury	$ 2,722,494	$ 200,000	$ 2,508	$ 275,000	$ 13,750	$ 35,209	$ 165,000	$ 3,365,002	$ 51,467	12.4622	$ 4,006,400
19	Route 495 Median	$ 1,290,000	$ -	$ -	$ -	$ -	$ -	$ 1,440,000	$ 2,730,000	$ -	12.4622	$ 2,730,000
	1/2 Buried	$ 1,480,819	$ -	$ -	$ 275,000	$ 13,750	$ 14,083	$ 1,455,000	$ 3,210,819	$ 27,833	12.4622	$ 3,557,700
	Buried to roof	$ 1,649,831	$ -	$ -	$ 275,000	$ 13,750	$ 35,209	$ 1,455,000	$ 3,379,831	$ 48,959	12.4622	$ 3,990,000
	Complete bury	$ 2,129,831	$ -	$ -	$ 275,000	$ 13,750	$ 35,209	$ 1,455,000	$ 3,859,831	$ 48,959	12.4622	$ 4,470,000
20	Route 495 Interchange	$ 1,250,000	$ -	$ -	$ -	$ -	$ -	$ 675,000	$ 1,925,000	$ -	12.4622	$ 1,925,000
	1/2 Buried	$ 1,755,110	$ -	$ -	$ 275,000	$ 13,750	$ 14,083	$ 690,000	$ 2,720,110	$ 27,833	12.4622	$ 3,067,000
	Buried to roof	$ 2,202,494	$ -	$ -	$ 275,000	$ 13,750	$ 35,209	$ 690,000	$ 3,167,494	$ 48,959	12.4622	$ 3,777,600
	Complete bury	$ 2,682,494	$ -	$ -	$ 275,000	$ 13,750	$ 35,209	$ 690,000	$ 3,647,494	$ 48,959	12.4622	$ 4,257,600
21	MWRA Plant	$ -	$ -	$ -	$ 275,000	$ 13,750	$ 35,209	$ 1,025,000	$ 1,300,000	$ 48,959	12.4622	$ 1,910,100
22	Boland PS Expansion	$ -	$ -	$ -	$ 460,000	$ 23,000	$ 82,153	$ 2,040,000	$ 2,500,000	$ 105,153	12.4622	$ 3,810,400
	Eliminate Low Service	$ -	$ -	$ -	$ 550,000	$ 27,500	$ 28,167	$ 100,000	$ 650,000	$ 55,667	12.4622	$ 1,343,700

Average	$ 3,643,494
Lowest	$ 1,237,500
Highest	$ 6,015,200
< lowest + 50%	**$ 1,856,250**
< average+10%	$ 4,007,843

Eliminating Low service requires a new pumping station at both existing low service tanks
Purchase price reduction due to existing tax lien
Property removed from consideration due to recent redevelopment

Southborough DPW
Tank Siting Evaluation

TABLE 2
PUMPING COST SUMMARY

Site ID	Description	Elevation (ft)	Max Tank Height (ft)	Need Pump Sta.	Estimated PS Flow (gpm)	Estimated TDH (ft)	Estimated Motor (hp)	Estimated Usage (hrs/day)	Estimated Power use (kw-hr/yr)	$ 0.115 Estimated Annual Cost ($/yr)
1	Fairview	450	535	NO	-	-	-	-	-	$ -
	1/2 Buried	415	500	YES	1,500	100	50	12	204,108	$ 23,472
	Buried to roof	349	434	YES	1,500	166	100	12	408,216	$ 46,945
	Complete bury	349	434	YES	1,500	166	100	12	408,216	$ 46,945
2	Tara Road	465	550	NO	-	-	-	-	-	$ -
	1/2 Buried	430	515	YES	1,500	100	50	12	204,108	$ 23,472
	Buried to roof	364	449	YES	1,500	151	75	12	306,162	$ 35,209
	Complete bury	364	449	YES	1,500	151	75	12	306,162	$ 35,209
3	147 Cordaville	280	365	YES	1,500	235	125	12	510,270	$ 58,681
	1/2 Buried	245	330	YES	1,500	270	150	12	612,324	$ 70,417
	Buried to roof	179	264	YES	1,500	336	200	12	816,432	$ 93,890
	Complete bury	179	264	YES	1,500	336	200	12	816,432	$ 93,890
4	Highland Street	310	395	YES	1,500	205	125	12	510,270	$ 58,681
	1/2 Buried	275	360	YES	1,500	240	125	12	510,270	$ 58,681
	Buried to roof	209	294	YES	1,500	306	200	12	816,432	$ 93,890
	Complete bury	209	294	YES	1,500	306	200	12	816,432	$ 93,890
5	24 Atwood	380	465	YES	1,500	135	75	12	306,162	$ 35,209
	1/2 Buried	345	430	YES	1,500	170	100	12	408,216	$ 46,945
	Buried to roof	279	364	YES	1,500	236	125	12	510,270	$ 58,681
	Complete bury	279	364	YES	1,500	236	125	12	510,270	$ 58,681
6	46 Atwood	370	455	YES	1,500	145	75	12	306,162	$ 35,209
	1/2 Buried	335	420	YES	1,500	180	100	12	408,216	$ 46,945
	Buried to roof	269	354	YES	1,500	246	125	12	510,270	$ 58,681
	Complete bury	269	354	YES	1,500	246	125	12	510,270	$ 58,681
7	Parkerville Road	300	385	YES	1,500	215	125	12	510,270	$ 58,681
	1/2 Buried	265	350	YES	1,500	250	125	12	510,270	$ 58,681
	Buried to roof	199	284	YES	1,500	316	200	12	816,432	$ 93,890
	Complete bury	199	284	YES	1,500	316	200	12	816,432	$ 93,890
8	60 Breakneck Hill Road	345	430	YES	1,500	170	100	12	408,216	$ 46,945
	1/2 Buried	315	400	YES	1,500	200	125	12	510,270	$ 58,681
	Buried to roof	261	346	YES	1,500	254	150	12	612,324	$ 70,417
	Complete bury	261	346	YES	1,500	254	150	12	612,324	$ 70,417

TABLE 2
PUMPING COST SUMMARY

Site ID	Description	Elevation (ft)	Max Tank Height (ft)	Need Pump Sta.	Estimated PS Flow (gpm)	Estimated TDH (ft)	Estimated Motor (hp)	Estimated Usage (hrs/day)	Estimated Power use (kw-hr/yr)	$ 0.115 Estimated Annual Cost ($/yr)
9	Clifford-Deerfoot	370	455	YES	1,500	145	75	12	306,162	$ 35,209
	1/2 Buried	335	420	YES	1,500	180	100	12	408,216	$ 46,945
	Buried to roof	269	354	YES	1,500	246	125	12	510,270	$ 58,681
	Complete bury	269	354	YES	1,500	246	125	12	510,270	$ 58,681
10	Northboro Road	330	415	YES	1,500	185	100	12	408,216	$ 46,945
	1/2 Buried	295	380	YES	1,500	220	125	12	510,270	$ 58,681
	Buried to roof	229	314	YES	1,500	286	150	12	612,324	$ 70,417
	Complete bury	229	314	YES	1,500	286	150	12	612,324	$ 70,417
11	Ledge Hill Road	400	485	YES	1,500	115	75	12	306,162	$ 35,209
	1/2 Buried	365	450	YES	1,500	150	75	12	306,162	$ 35,209
	Buried to roof	299	384	YES	1,500	216	125	12	510,270	$ 58,681
	Complete bury	299	384	YES	1,500	216	125	12	510,270	$ 58,681
12	88 Newton Street	285	370	YES	1,500	230	125	12	510,270	$ 58,681
	1/2 Buried	254	339	YES	1,500	261	150	12	612,324	$ 70,417
	Buried to roof	196	281	YES	1,500	319	200	12	816,432	$ 93,890
	Complete bury	196	281	YES	1,500	319	200	12	816,432	$ 93,890
13	55-57 Boston Road	280	365	YES	1,500	235	125	12	510,270	$ 58,681
	1/2 Buried	249	334	YES	1,500	266	150	12	612,324	$ 70,417
	Buried to roof	191	276	YES	1,500	324	200	12	816,432	$ 93,890
	Complete bury	191	276	YES	1,500	324	200	12	816,432	$ 93,890
14A	24 Learned Street	350	435	YES	1,500	165	100	12	408,216	$ 46,945
14B	1 Willow Street	360	445	YES	1,500	155	100	12	408,216	$ 46,945
	1/2 Buried	329	414	YES	1,500	186	100	12	408,216	$ 46,945
	Buried to roof	271	356	YES	1,500	244	150	12	612,324	$ 70,417
	Complete bury	271	356	YES	1,500	244	150	12	612,324	$ 70,417
15	324 Worcester Turnpike	400	485	YES	1,500	115	75	12	306,162	$ 35,209
	1/2 Buried	365	450	YES	1,500	150	75	12	306,162	$ 35,209
	Buried to roof	299	384	YES	1,500	216	125	12	510,270	$ 58,681
	Complete bury	299	384	YES	1,500	216	125	12	510,270	$ 58,681
16A	Southwest Portion	450	535	NO	-	-	-	-	-	$ -
	1/2 Buried	415	500	YES	1,500	100	50	12	204,108	$ 23,472
	Buried to roof	349	434	YES	1,500	166	100	12	408,216	$ 46,945
	Complete bury	349	434	YES	1,500	166	100	12	408,216	$ 46,945

Southborough DPW
Tank Siting Evaluation

TABLE 2
PUMPING COST SUMMARY

Site ID	Description	Elevation (ft)	Max Tank Height (ft)	Need Pump Sta.	Estimated PS Flow (gpm)	Estimated TDH (ft)	Estimated Motor (hp)	Estimated Usage (hrs/day)	Estimated Power use (kw-hr/yr)	$ 0.115 Estimated Annual Cost ($/yr)
16B	Southwest Portion	450	535	NO	-	-	-	-	-	$ -
	1/2 Buried	415	500	YES	1,500	100	50	12	204,108	$ 23,472
	Buried to roof	349	434	YES	1,500	166	100	12	408,216	$ 46,945
	Complete bury	349	434	YES	1,500	166	100	12	408,216	$ 46,945
16C	Southwest Portion	450	535	NO	-	-	-	-	-	$ -
	1/2 Buried	415	500	YES	1,500	100	50	12	204,108	$ 23,472
	Buried to roof	349	434	YES	1,500	166	100	12	408,216	$ 46,945
	Complete bury	349	434	YES	1,500	166	100	12	408,216	$ 46,945
16D	Southwest Portion	380	465	YES	1,500	135	75	12	306,162	$ 35,209
	1/2 Buried	345	430	YES	1,500	170	100	12	408,216	$ 46,945
	Buried to roof	279	364	YES	1,500	236	125	12	510,270	$ 58,681
	Complete bury	279	364	YES	1,500	236	125	12	510,270	$ 58,681
17A	Pine Hill Road	460	545	NO	-	-	-	-	-	$ -
	1/2 Buried	430	515	YES	1,500	85	50	12	204,108	$ 23,472
	Buried to roof	376	461	YES	1,500	139	100	12	408,216	$ 46,945
	Complete bury	376	461	YES	1,500	139	100	12	408,216	$ 46,945
17B	Pine Hill Road	440	525	NO	-	-	-	-	-	$ -
	1/2 Buried	410	495	YES	1,500	105	75	12	306,162	$ 35,209
	Buried to roof	356	441	YES	1,500	159	100	12	408,216	$ 46,945
	Complete bury	356	441	YES	1,500	159	100	12	408,216	$ 46,945
18	Near Route 495	500	585	NO	-	-	-	-	-	$ -
	1/2 Buried	465	550	YES	1,500	50	30	12	122,465	$ 14,083
	Buried to roof	399	484	YES	1,500	116	75	12	306,162	$ 35,209
	Complete bury	399	484	YES	1,500	116	75	12	306,162	$ 35,209
19	Route 495 Median	500	585	NO	-	-	-	12	-	$ -
	1/2 Buried	465	550	YES	1,500	50	30	12	122,465	$ 14,083
	Buried to roof	399	484	YES	1,500	116	75	12	306,162	$ 35,209
	Complete bury	399	484	YES	1,500	116	75	12	306,162	$ 35,209
20	Route 495 Interchange	500	585	NO	-	-	-	-	-	$ -
	1/2 Buried	465	550	YES	1,500	50	30	12	122,465	$ 14,083
	Buried to roof	399	484	YES	1,500	116	75	12	306,162	$ 35,209
	Complete bury	399	484	YES	1,500	116	75	12	306,162	$ 35,209
21	MWRA Plant	400	485	YES	1,500	115	75	12	306,162	$ 35,209
22	Boland PS Expansion	270	355	YES	3,500	245	350	6	714,378	$ 82,153
	Elimiate Low Service	490	575	YES	1,500	25	30	24	244,930	$ 28,167

TABLE 3
INFRASTRUCTURE COST

Site ID	Description	Pipe Length (ft)	Unit Cost ($/ft)	Pipe Cost ($)	3-Phase Length (ft)	Unit Cost ($/ft)	3-Phase Cost ($)	Capital Cost ($)
1	Fairview	1,440	$ 150	$ 216,000	-		$ -	$ 216,000
	1/2 Buried	1,440	$ 150	$ 216,000	2,000	$ 50	$ 100,000	$ 316,000
	Buried to roof	1,440	$ 150	$ 216,000	2,000	$ 50	$ 100,000	$ 316,000
	Complete bury	1,440	$ 150	$ 216,000	2,000	$ 50	$ 100,000	$ 316,000
2	Tara Road	250	$ 150	$ 37,500	-		$ -	$ 37,500
	1/2 Buried	250	$ 150	$ 37,500	1,000	$ 50	$ 50,000	$ 87,500
	Buried to roof	250	$ 150	$ 37,500	1,000	$ 50	$ 50,000	$ 87,500
	Complete bury	250	$ 150	$ 37,500	1,000	$ 50	$ 50,000	$ 87,500
3	147 Cordaville	1,650	$ 150	$ 247,500	1,000	$ 50	$ 50,000	$ 297,500
	1/2 Buried	1,650	$ 150	$ 247,500	1,000	$ 50	$ 50,000	$ 297,500
	Buried to roof	1,650	$ 150	$ 247,500	1,000	$ 50	$ 50,000	$ 297,500
	Complete bury	1,650	$ 150	$ 247,500	1,000	$ 50	$ 50,000	$ 297,500
4	Highland Street	200	$ 150	$ 30,000	200	$ 50	$ 10,000	$ 40,000
	1/2 Buried	200	$ 150	$ 30,000	200	$ 50	$ 10,000	$ 40,000
	Buried to roof	200	$ 150	$ 30,000	200	$ 50	$ 10,000	$ 40,000
	Complete bury	200	$ 150	$ 30,000	200	$ 50	$ 10,000	$ 40,000
5	24 Atwood	200	$ 150	$ 30,000	650	$ 50	$ 32,500	$ 62,500
	1/2 Buried	200	$ 150	$ 30,000	650	$ 50	$ 32,500	$ 62,500
	Buried to roof	200	$ 150	$ 30,000	650	$ 50	$ 32,500	$ 62,500
	Complete bury	200	$ 150	$ 30,000	650	$ 50	$ 32,500	$ 62,500
6	46 Atwood	300	$ 150	$ 45,000	1,750	$ 50	$ 87,500	$ 132,500
	1/2 Buried	300	$ 150	$ 45,000	1,750	$ 50	$ 87,500	$ 132,500
	Buried to roof	300	$ 150	$ 45,000	1,750	$ 50	$ 87,500	$ 132,500
	Complete bury	300	$ 150	$ 45,000	1,750	$ 50	$ 87,500	$ 132,500
7	Parkerville Road	500	$ 150	$ 75,000	1,000	$ 50	$ 50,000	$ 125,000
	1/2 Buried	500	$ 150	$ 75,000	1,000	$ 50	$ 50,000	$ 125,000
	Buried to roof	500	$ 150	$ 75,000	1,000	$ 50	$ 50,000	$ 125,000
	Complete bury	500	$ 150	$ 75,000	1,000	$ 50	$ 50,000	$ 125,000
8	60 Breakneck Hill Road	1,500	$ 150	$ 225,000	2,750	$ 50	$ 137,500	$ 362,500
	1/2 Buried	1,500	$ 150	$ 225,000	2,750	$ 50	$ 137,500	$ 362,500
	Buried to roof	1,500	$ 150	$ 225,000	2,750	$ 50	$ 137,500	$ 362,500
	Complete bury	1,500	$ 150	$ 225,000	2,750	$ 50	$ 137,500	$ 362,500

TABLE 3
INFRASTRUCTURE COST

Site ID	Description	Pipe Length (ft)	Unit Cost ($/ft)	Pipe Cost ($)	3-Phase Length (ft)	Unit Cost ($/ft)	3-Phase Cost ($)	Capital Cost ($)
9	Clifford-Deerfoot	750	$ 150	$ 112,500	500	$ 50	$ 25,000	$ 137,500
	1/2 Buried	750	$ 150	$ 112,500	500	$ 50	$ 25,000	$ 137,500
	Buried to roof	750	$ 150	$ 112,500	500	$ 50	$ 25,000	$ 137,500
	Complete bury	750	$ 150	$ 112,500	500	$ 50	$ 25,000	$ 137,500
10	Northboro Road	1,150	$ 150	$ 172,500	1,200	$ 50	$ 60,000	$ 232,500
	1/2 Buried	1,150	$ 150	$ 172,500	1,200	$ 50	$ 60,000	$ 232,500
	Buried to roof	1,150	$ 150	$ 172,500	1,200	$ 50	$ 60,000	$ 232,500
	Complete bury	1,150	$ 150	$ 172,500	1,200	$ 50	$ 60,000	$ 232,500
11	Ledge Hill Road	775	$ 150	$ 116,250	2,200	$ 50	$ 110,000	$ 226,250
	1/2 Buried	775	$ 150	$ 116,250	2,200	$ 50	$ 110,000	$ 226,250
	Buried to roof	775	$ 150	$ 116,250	2,200	$ 50	$ 110,000	$ 226,250
	Complete bury	775	$ 150	$ 116,250	2,200	$ 50	$ 110,000	$ 226,250
12	88 Newton Street	200	$ 150	$ 30,000	200	$ 50	$ 10,000	$ 40,000
	1/2 Buried	200	$ 150	$ 30,000	200	$ 50	$ 10,000	$ 40,000
	Buried to roof	200	$ 150	$ 30,000	200	$ 50	$ 10,000	$ 40,000
	Complete bury	200	$ 150	$ 30,000	200	$ 50	$ 10,000	$ 40,000
13	55-57 Boston Road	1,000	$ 150	$ 150,000	850	$ 50	$ 42,500	$ 192,500
	1/2 Buried	1,000	$ 150	$ 150,000	850	$ 50	$ 42,500	$ 192,500
	Buried to roof	1,000	$ 150	$ 150,000	850	$ 50	$ 42,500	$ 192,500
	Complete bury	1,000	$ 150	$ 150,000	850	$ 50	$ 42,500	$ 192,500
14A	24 Learned Street	750	$ 150	$ 112,500	750	$ 50	$ 37,500	$ 150,000
14B	1 Willow Street	750	$ 150	$ 112,500	1,700	$ 50	$ 85,000	$ 197,500
	1/2 Buried	750	$ 150	$ 112,500	1,700	$ 50	$ 85,000	$ 197,500
	Buried to roof	750	$ 150	$ 112,500	1,700	$ 50	$ 85,000	$ 197,500
	Complete bury	750	$ 150	$ 112,500	1,700	$ 50	$ 85,000	$ 197,500
15	324 Worcester Turnpike	1,125	$ 150	$ 168,750	1,100	$ 50	$ 55,000	$ 223,750
	1/2 Buried	1,125	$ 150	$ 168,750	1,100	$ 50	$ 55,000	$ 223,750
	Buried to roof	1,125	$ 150	$ 168,750	1,100	$ 50	$ 55,000	$ 223,750
	Complete bury	1,125	$ 150	$ 168,750	1,100	$ 50	$ 55,000	$ 223,750
16A	Southwest Portion	1,400	$ 150	$ 210,000	-	$ -	$ -	$ 210,000
	1/2 Buried	1,400	$ 150	$ 210,000	5,000	$ 50	$ 250,000	$ 460,000
	Buried to roof	1,400	$ 150	$ 210,000	5,000	$ 50	$ 250,000	$ 460,000
	Complete bury	1,400	$ 150	$ 210,000	5,000	$ 50	$ 250,000	$ 460,000

TABLE 3
INFRASTRUCTURE COST

Site ID	Description	Pipe Length (ft)	Unit Cost ($/ft)	Pipe Cost ($)	3-Phase Length (ft)	Unit Cost ($/ft)	3-Phase Cost ($)	Capital Cost ($)
16B	Southwest Portion	1,525	$ 150	$ 228,750	-	$ -	$ -	$ 228,750
	1/2 Buried	1,525	$ 150	$ 228,750	4,500	$ 50	$ 225,000	$ 453,750
	Buried to roof	1,525	$ 150	$ 228,750	4,500	$ 50	$ 225,000	$ 453,750
	Complete bury	1,525	$ 150	$ 228,750	4,500	$ 50	$ 225,000	$ 453,750
16C	Southwest Portion	440	$ 150	$ 66,000	-	$ -	$ -	$ 66,000
	1/2 Buried	440	$ 150	$ 66,000	3,500	$ 50	$ 175,000	$ 241,000
	Buried to roof	440	$ 150	$ 66,000	3,500	$ 50	$ 175,000	$ 241,000
	Complete bury	440	$ 150	$ 66,000	3,500	$ 50	$ 175,000	$ 241,000
16D	Southwest Portion	600	$ 150	$ 90,000	2,100	$ 50	$ 105,000	$ 195,000
	1/2 Buried	600	$ 150	$ 90,000	2,100	$ 50	$ 105,000	$ 195,000
	Buried to roof	600	$ 150	$ 90,000	2,100	$ 50	$ 105,000	$ 195,000
	Complete bury	600	$ 150	$ 90,000	2,100	$ 50	$ 105,000	$ 195,000
17A	Pine Hill Road	12,000	$ 150	$ 1,800,000	-	$ -	$ -	$ 1,800,000
	1/2 Buried	12,000	$ 150	$ 1,800,000	500	$ 50	$ 25,000	$ 1,825,000
	Buried to roof	12,000	$ 150	$ 1,800,000	500	$ 50	$ 25,000	$ 1,825,000
	Complete bury	12,000	$ 150	$ 1,800,000	500	$ 50	$ 25,000	$ 1,825,000
17B	Pine Hill Road	12,000	$ 150	$ 1,800,000	-	$ -	$ -	$ 1,800,000
	1/2 Buried	12,000	$ 150	$ 1,800,000	500	$ 50	$ 25,000	$ 1,825,000
	Buried to roof	12,000	$ 150	$ 1,800,000	500	$ 50	$ 25,000	$ 1,825,000
	Complete bury	12,000	$ 150	$ 1,800,000	500	$ 50	$ 25,000	$ 1,825,000
18	Near Route 495	750	$ 200	$ 150,000	-	$ -	$ -	$ 150,000
	1/2 Buried	750	$ 200	$ 150,000	300	$ 50	$ 15,000	$ 165,000
	Buried to roof	750	$ 200	$ 150,000	300	$ 50	$ 15,000	$ 165,000
	Complete bury	750	$ 200	$ 150,000	300	$ 50	$ 15,000	$ 165,000
19	Route 495 Median	1,800	$ 800	$ 1,440,000	-	$ -	$ -	$ 1,440,000
	1/2 Buried	1,800	$ 800	$ 1,440,000	300	$ 50	$ 15,000	$ 1,455,000
	Buried to roof	1,800	$ 800	$ 1,440,000	300	$ 50	$ 15,000	$ 1,455,000
	Complete bury	1,800	$ 800	$ 1,440,000	300	$ 50	$ 15,000	$ 1,455,000
20	Route 495 Interchange	2,250	$ 300	$ 675,000	-	$ -	$ -	$ 675,000
	1/2 Buried	2,250	$ 300	$ 675,000	300	$ 50	$ 15,000	$ 690,000
	Buried to roof	2,250	$ 300	$ 675,000	300	$ 50	$ 15,000	$ 690,000
	Complete bury	2,250	$ 300	$ 675,000	300	$ 50	$ 15,000	$ 690,000
21	MWRA Plant	5,000	$ 200	$ 1,000,000	500	$ 50	$ 25,000	$ 1,025,000
22	Boland PS Expansion	13,600	$ 150	$ 2,040,000	-	$ -	$ -	$ 2,040,000
	Eliminate Low Service	-	$ -	$ -	2,000	$ 50	$ 100,000	$ 100,000

Southborough DPW
Tank Siting Evaluation

TABLE 4
TANK COST SUMMARY

Site ID	Description	Road Length (ft)	Unit Cost ($/ft)	Road Cost ($)	Unit Tank Cost	Burial Cost	Tank Cost	Overall Tank Cost
1	Fairview	650	$ 200	$ 130,000	$ 1,200,000	$ -	$ 1,330,000	$ 1,330,000
	1/2 Buried	650	$ 200	$ 130,000	$ 1,200,000	$ 819,401	$ 1,330,000	$ 2,149,401
	Buried to roof	650	$ 200	$ 130,000	$ 1,200,000	$ 1,545,157	$ 1,330,000	$ 2,875,157
	Complete bury	650	$ 200	$ 130,000	$ 1,680,000	$ 1,545,157	$ 1,810,000	$ 3,355,157
2	Tara Road	-	$ 200	$ -	$ 1,200,000	$ -	$ 1,200,000	$ 1,200,000
	1/2 Buried	-	$ 200	$ -	$ 1,200,000	$ 190,819	$ 1,200,000	$ 1,390,819
	Buried to roof	-	$ 200	$ -	$ 1,200,000	$ 359,831	$ 1,200,000	$ 1,559,831
	Complete bury	-	$ 200	$ -	$ 1,680,000	$ 359,831	$ 1,680,000	$ 2,039,831
3	147 Cordaville	500	$ 200	$ 100,000	$ 1,200,000	$ -	$ 1,300,000	$ 1,300,000
	1/2 Buried	500	$ 200	$ 100,000	$ 1,200,000	$ 190,819	$ 1,300,000	$ 1,490,819
	Buried to roof	500	$ 200	$ 100,000	$ 1,200,000	$ 359,831	$ 1,300,000	$ 1,659,831
	Complete bury	500	$ 200	$ 100,000	$ 1,680,000	$ 359,831	$ 1,780,000	$ 2,139,831
4	Highland Street	300	$ 200	$ 60,000	$ 1,200,000	$ -	$ 1,260,000	$ 1,260,000
	1/2 Buried	300	$ 200	$ 60,000	$ 1,200,000	$ 190,819	$ 1,260,000	$ 1,450,819
	Buried to roof	300	$ 200	$ 60,000	$ 1,200,000	$ 359,831	$ 1,260,000	$ 1,619,831
	Complete bury	300	$ 200	$ 60,000	$ 1,680,000	$ 359,831	$ 1,740,000	$ 2,099,831
5	24 Atwood	300	$ 200	$ 60,000	$ 1,200,000	$ -	$ 1,260,000	$ 1,260,000
	1/2 Buried	300	$ 200	$ 60,000	$ 1,200,000	$ 819,401	$ 1,260,000	$ 2,079,401
	Buried to roof	300	$ 200	$ 60,000	$ 1,200,000	$ 1,545,157	$ 1,260,000	$ 2,805,157
	Complete bury	300	$ 200	$ 60,000	$ 1,680,000	$ 1,545,157	$ 1,740,000	$ 3,285,157
6	46 Atwood	650	$ 200	$ 130,000	$ 1,200,000	$ -	$ 1,330,000	$ 1,330,000
	1/2 Buried	650	$ 200	$ 130,000	$ 1,200,000	$ 190,819	$ 1,330,000	$ 1,520,819
	Buried to roof	650	$ 200	$ 130,000	$ 1,200,000	$ 359,831	$ 1,330,000	$ 1,689,831
	Complete bury	650	$ 200	$ 130,000	$ 1,680,000	$ 359,831	$ 1,810,000	$ 2,169,831
7	Parkerville Road	640	$ 200	$ 128,000	$ 1,200,000	$ -	$ 1,328,000	$ 1,328,000
	1/2 Buried	640	$ 200	$ 128,000	$ 1,200,000	$ 190,819	$ 1,328,000	$ 1,518,819
	Buried to roof	640	$ 200	$ 128,000	$ 1,200,000	$ 359,831	$ 1,328,000	$ 1,687,831
	Complete bury	640	$ 200	$ 128,000	$ 1,680,000	$ 359,831	$ 1,808,000	$ 2,167,831
8	60 Breakneck Hill Road	200	$ 200	$ 40,000	$ 975,000	$ -	$ 1,015,000	$ 1,015,000
	1/2 Buried	200	$ 200	$ 40,000	$ 975,000	$ 163,560	$ 1,015,000	$ 1,178,560
	Buried to roof	200	$ 200	$ 40,000	$ 975,000	$ 294,407	$ 1,015,000	$ 1,309,407
	Complete bury	200	$ 200	$ 40,000	$ 1,365,000	$ 294,407	$ 1,405,000	$ 1,699,407

TABLE 4
TANK COST SUMMARY

Site ID	Description	Road Length (ft)	Unit Cost ($/ft)	Road Cost ($)	Unit Tank Cost	Burial Cost	Tank Cost	Overall Tank Cost
9	Clifford-Deerfoot	500	$ 200	$ 100,000	$ 1,200,000	$ -	$ 1,300,000	$ 1,300,000
	1/2 Buried	500	$ 200	$ 100,000	$ 1,200,000	$ 190,819	$ 1,300,000	$ 1,490,819
	Buried to roof	500	$ 200	$ 100,000	$ 1,200,000	$ 359,831	$ 1,300,000	$ 1,659,831
	Complete bury	500	$ 200	$ 100,000	$ 1,680,000	$ 359,831	$ 1,780,000	$ 2,139,831
10	Northboro Road	1,120	$ 200	$ 224,000	$ 1,200,000	$ -	$ 1,424,000	$ 1,424,000
	1/2 Buried	1,120	$ 200	$ 224,000	$ 1,200,000	$ 190,819	$ 1,424,000	$ 1,614,819
	Buried to roof	1,120	$ 200	$ 224,000	$ 1,200,000	$ 359,831	$ 1,424,000	$ 1,783,831
	Complete bury	1,120	$ 200	$ 224,000	$ 1,680,000	$ 359,831	$ 1,904,000	$ 2,263,831
11	Ledge Hill Road	480	$ 200	$ 96,000	$ 1,200,000	$ -	$ 1,296,000	$ 1,296,000
	1/2 Buried	480	$ 200	$ 96,000	$ 1,200,000	$ 701,542	$ 1,296,000	$ 1,997,542
	Buried to roof	480	$ 200	$ 96,000	$ 1,200,000	$ 1,322,908	$ 1,296,000	$ 2,618,908
	Complete bury	480	$ 200	$ 96,000	$ 1,680,000	$ 1,322,908	$ 1,776,000	$ 3,098,908
12	88 Newton Street	150	$ 200	$ 30,000	$ 1,050,000	$ -	$ 1,080,000	$ 1,080,000
	1/2 Buried	150	$ 200	$ 30,000	$ 1,050,000	$ 169,012	$ 1,080,000	$ 1,249,012
	Buried to roof	150	$ 200	$ 30,000	$ 1,050,000	$ 316,215	$ 1,080,000	$ 1,396,215
	Complete bury	150	$ 200	$ 30,000	$ 1,470,000	$ 316,215	$ 1,500,000	$ 1,816,215
13	55-57 Boston Road	650	$ 200	$ 130,000	$ 1,050,000	$ -	$ 1,180,000	$ 1,180,000
	1/2 Buried	650	$ 200	$ 130,000	$ 1,050,000	$ 447,383	$ 1,180,000	$ 1,627,383
	Buried to roof	650	$ 200	$ 130,000	$ 1,050,000	$ 837,040	$ 1,180,000	$ 2,017,040
	Complete bury	650	$ 200	$ 130,000	$ 1,470,000	$ 837,040	$ 1,600,000	$ 2,437,040
14A	24 Learned Street	350	$ 200	$ 70,000	$ 1,050,000	$ -	$ 1,120,000	$ 1,120,000
14B	1 Willow Street	200	$ 200	$ 40,000	$ 1,050,000	$ -	$ 1,090,000	$ 1,090,000
	1/2 Buried	200	$ 200	$ 40,000	$ 1,050,000	$ 169,012	$ 1,090,000	$ 1,259,012
	Buried to roof	200	$ 200	$ 40,000	$ 1,050,000	$ 316,215	$ 1,090,000	$ 1,406,215
	Complete bury	200	$ 200	$ 40,000	$ 1,470,000	$ 316,215	$ 1,510,000	$ 1,826,215
15	324 Worcester Turnpike	300	$ 200	$ 60,000	$ 1,200,000	$ -	$ 1,260,000	$ 1,260,000
	1/2 Buried	300	$ 200	$ 60,000	$ 1,200,000	$ 701,542	$ 1,260,000	$ 1,961,542
	Buried to roof	300	$ 200	$ 60,000	$ 1,200,000	$ 1,322,908	$ 1,260,000	$ 2,582,908
	Complete bury	300	$ 200	$ 60,000	$ 1,680,000	$ 1,322,908	$ 1,740,000	$ 3,062,908
16A	Southwest Portion	2,700	$ 200	$ 540,000	$ 1,200,000	$ -	$ 1,740,000	$ 1,740,000
	1/2 Buried	2,700	$ 200	$ 540,000	$ 1,200,000	$ 701,542	$ 1,740,000	$ 2,441,542
	Buried to roof	2,700	$ 200	$ 540,000	$ 1,200,000	$ 1,322,908	$ 1,740,000	$ 3,062,908
	Complete bury	2,700	$ 200	$ 540,000	$ 1,680,000	$ 1,322,908	$ 2,220,000	$ 3,542,908

TABLE 4
TANK COST SUMMARY

Site ID	Description	Road Length (ft)	Unit Cost ($/ft)	Road Cost ($)	Unit Tank Cost	Burial Cost	Tank Cost	Overall Tank Cost
16B	Southwest Portion	1,500	$ 200	$ 300,000	$ 1,200,000	$ -	$ 1,500,000	$ 1,500,000
	1/2 Buried	1,500	$ 200	$ 300,000	$ 1,200,000	$ 701,542	$ 1,500,000	$ 2,201,542
	Buried to roof	1,500	$ 200	$ 300,000	$ 1,200,000	$ 1,322,908	$ 1,500,000	$ 2,822,908
	Complete bury	1,500	$ 200	$ 300,000	$ 1,680,000	$ 1,322,908	$ 1,980,000	$ 3,302,908
16C	Southwest Portion	850	$ 200	$ 170,000	$ 1,200,000	$ -	$ 1,370,000	$ 1,370,000
	1/2 Buried	850	$ 200	$ 170,000	$ 1,200,000	$ 819,401	$ 1,370,000	$ 2,189,401
	Buried to roof	850	$ 200	$ 170,000	$ 1,200,000	$ 1,545,157	$ 1,370,000	$ 2,915,157
	Complete bury	850	$ 200	$ 170,000	$ 1,680,000	$ 1,545,157	$ 1,850,000	$ 3,395,157
16D	Southwest Portion	800	$ 200	$ 160,000	$ 1,200,000	$ -	$ 1,360,000	$ 1,360,000
	1/2 Buried	800	$ 200	$ 160,000	$ 1,200,000	$ 819,401	$ 1,360,000	$ 2,179,401
	Buried to roof	800	$ 200	$ 160,000	$ 1,200,000	$ 1,545,157	$ 1,360,000	$ 2,905,157
	Complete bury	800	$ 200	$ 160,000	$ 1,680,000	$ 1,545,157	$ 1,840,000	$ 3,385,157
17A	Pine Hill Road	1,520	$ 200	$ 304,000	$ 975,000	$ -	$ 1,279,000	$ 1,279,000
	1/2 Buried	1,520	$ 200	$ 304,000	$ 975,000	$ 601,322	$ 1,279,000	$ 1,880,322
	Buried to roof	1,520	$ 200	$ 304,000	$ 975,000	$ 1,082,379	$ 1,279,000	$ 2,361,379
	Complete bury	1,520	$ 200	$ 304,000	$ 1,365,000	$ 1,082,379	$ 1,669,000	$ 2,751,379
17B	Pine Hill Road	1,350	$ 200	$ 270,000	$ 975,000	$ -	$ 1,245,000	$ 1,245,000
	1/2 Buried	1,350	$ 200	$ 270,000	$ 975,000	$ 601,322	$ 1,245,000	$ 1,846,322
	Buried to roof	1,350	$ 200	$ 270,000	$ 975,000	$ 1,082,379	$ 1,245,000	$ 2,327,379
	Complete bury	1,350	$ 200	$ 270,000	$ 1,365,000	$ 1,082,379	$ 1,635,000	$ 2,717,379
18	Near Route 495	450	$ 200	$ 90,000	$ 1,200,000	$ -	$ 1,290,000	$ 1,290,000
	1/2 Buried	450	$ 200	$ 90,000	$ 1,200,000	$ 505,110	$ 1,290,000	$ 1,795,110
	Buried to roof	450	$ 200	$ 90,000	$ 1,200,000	$ 952,494	$ 1,290,000	$ 2,242,494
	Complete bury	450	$ 200	$ 90,000	$ 1,680,000	$ 952,494	$ 1,770,000	$ 2,722,494
19	Route 495 Median	450	$ 200	$ 90,000	$ 1,200,000	$ -	$ 1,290,000	$ 1,290,000
	1/2 Buried	450	$ 200	$ 90,000	$ 1,200,000	$ 190,819	$ 1,290,000	$ 1,480,819
	Buried to roof	450	$ 200	$ 90,000	$ 1,200,000	$ 359,831	$ 1,290,000	$ 1,649,831
	Complete bury	450	$ 200	$ 90,000	$ 1,680,000	$ 359,831	$ 1,770,000	$ 2,129,831
20	Route 495 Interchange	250	$ 200	$ 50,000	$ 1,200,000	$ -	$ 1,250,000	$ 1,250,000
	1/2 Buried	250	$ 200	$ 50,000	$ 1,200,000	$ 505,110	$ 1,250,000	$ 1,755,110
	Buried to roof	250	$ 200	$ 50,000	$ 1,200,000	$ 952,494	$ 1,250,000	$ 2,202,494
	Complete bury	250	$ 200	$ 50,000	$ 1,680,000	$ 952,494	$ 1,730,000	$ 2,682,494
21	MWRA Plant	-	$ -	$ -	$ -	$ -	$ -	$ -
22	Boland PS Expansion	-	$ -	$ -	$ -	$ -	$ -	$ -
	Eliminate Low Service	-	$ -	$ -	$ -	$ -	$ -	$ -

1 - Cost includes 40% for complete burial with structural roof members

Southborough DPW
Tank Siting Evaluation

TABLE 5
TANK EXCAVATION COSTS

Site ID	Description	Soil Type	Soil Description	Percent Ledge	Percent Loam	Ledge Unit Cost	Loam Unit Cost	Wtd Exc Unit Cost	Tank Volume (gal)	Dia (ft)	Height (ft)	Exc Dia (ft)	Exc Depth (ft)	Exc Volume (cyd)	Tank Unit Cost ($)	Exc Cost ($)	Total Tank Cost
1	Fairview	ChD	15-25%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	ChD	15-25%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	35	11,225	1,200,000	819,401	2,019,401
	Buried to roof	ChD	15-25%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	66	21,167	1,200,000	1,545,157	2,745,157
	Complete bury	ChD	15-25%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	66	21,167	1,680,000	1,545,157	3,225,157
2	Tara Road	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	35	11,225	1,200,000	190,819	1,390,819
	Buried to roof	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,200,000	359,831	1,559,831
	Complete bury	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,680,000	359,831	2,039,831
3	147 Cordaville	WrB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	WrB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	35	11,225	1,200,000	190,819	1,390,819
	Buried to roof	WrB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,200,000	359,831	1,559,831
	Complete bury	WrB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,680,000	359,831	2,039,831
4	Highland Street	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	35	11,225	1,200,000	190,819	1,390,819
	Buried to roof	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,200,000	359,831	1,559,831
	Complete bury	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,680,000	359,831	2,039,831
5	24 Atwood	ChD	15-25%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	ChD	15-25%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	35	11,225	1,200,000	819,401	2,019,401
	Buried to roof	ChD	15-25%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	66	21,167	1,200,000	1,545,157	2,745,157
	Complete bury	ChD	15-25%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	66	21,167	1,680,000	1,545,157	3,225,157
6	46 Atwood	PaC	8-15%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	PaC	8-15%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	35	11,225	1,200,000	190,819	1,390,819
	Buried to roof	PaC	8-15%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,200,000	359,831	1,559,831
	Complete bury	PaC	8-15%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,680,000	359,831	2,039,831
7	Parkerville Road	NgA	0-3%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	NgA	0-3%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	35	11,225	1,200,000	190,819	1,390,819
	Buried to roof	NgA	0-3%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,200,000	359,831	1,559,831
	Complete bury	NgA	0-3%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,680,000	359,831	2,039,831
8	60 Breakneck Hill Road	CaC	8-15%, Deep	10%	90%	$ 80	$ 10	$ 17	1,625,000	63	69	93	-	-	975,000	-	975,000
	1/2 Buried	CaC	8-15%, Deep	10%	90%	$ 80	$ 10	$ 17	1,625,000	75	49	105	30	9,621	975,000	163,560	1,138,560
	Buried to roof	CaC	8-15%, Deep	10%	90%	$ 80	$ 10	$ 17	1,625,000	75	49	105	54	17,318	975,000	294,407	1,269,407
	Complete bury	CaC	8-15%, Deep	10%	90%	$ 80	$ 10	$ 17	1,625,000	75	49	105	54	17,318	1,365,000	294,407	1,659,407
9	Clifford-Deerfoot	CaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	CaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	35	11,225	1,200,000	190,819	1,390,819
	Buried to roof	CaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,200,000	359,831	1,559,831
	Complete bury	CaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,680,000	359,831	2,039,831
10	Northboro Road	WrB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	WrB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	35	11,225	1,200,000	190,819	1,390,819
	Buried to roof	WrB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,200,000	359,831	1,559,831
	Complete bury	WrB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,680,000	359,831	2,039,831
11	Ledge Hill Road	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	35	11,225	1,200,000	701,542	1,901,542
	Buried to roof	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	66	21,167	1,200,000	1,322,908	2,522,908
	Complete bury	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	66	21,167	1,680,000	1,322,908	3,002,908

Southborough DPW
Tank Siting Evaluation

TABLE 5
TANK EXCAVATION COSTS

Site ID	Description	Soil Type	Soil Description	Percent Ledge	Percent Loam	Ledge Unit Cost	Loam Unit Cost	Wtd Exc Unit Cost	Tank Volume (gal)	Dia (ft)	Height (ft)	Exc Dia (ft)	Exc Depth (ft)	Exc Volume (cyd)	Tank Unit Cost ($)	Exc Cost ($)	Total Tank Cost
12	88 Newton Street	MeB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	1,750,000	63	74	93	-	-	1,050,000	-	1,050,000
	1/2 Buried	MeB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	1,750,000	75	53	105	31	9,942	1,050,000	169,012	1,219,012
	Buried to roof	MeB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	1,750,000	75	53	105	58	18,601	1,050,000	316,215	1,366,215
	Complete bury	MeB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	1,750,000	75	53	105	58	18,601	1,470,000	316,215	1,786,215
13	55-57 Boston Road	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	1,750,000	63	74	93	-	-	1,050,000	-	1,050,000
	1/2 Buried	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	1,750,000	75	53	105	31	9,942	1,050,000	447,383	1,497,383
	Buried to roof	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	1,750,000	75	53	105	58	18,601	1,050,000	837,040	1,887,040
	Complete bury	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	1,750,000	75	53	105	58	18,601	1,470,000	837,040	2,307,040
14A	24 Learned Street	PbD	15-25%, Stony	75%	25%	$ 80	$ 10	$ 63	1,750,000	63	74	93	-	-	1,050,000	-	1,050,000
14B	1 Willow Street	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	1,750,000	63	74	93	-	-	1,050,000	-	1,050,000
	1/2 Buried	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	1,750,000	75	53	105	31	9,942	1,050,000	169,012	1,219,012
	Buried to roof	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	1,750,000	75	53	105	58	18,601	1,050,000	316,215	1,366,215
	Complete bury	PaB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	1,750,000	75	53	105	58	18,601	1,470,000	316,215	1,786,215
15	324 Worcester Turnpike	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	35	11,225	1,200,000	701,542	1,901,542
	Buried to roof	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	66	21,167	1,200,000	1,322,908	2,522,908
	Complete bury	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	66	21,167	1,680,000	1,322,908	3,002,908
16A	Southwest Portion	PbB	3-8%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	PbB	3-8%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	35	11,225	1,200,000	701,542	1,901,542
	Buried to roof	PbB	3-8%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	66	21,167	1,200,000	1,322,908	2,522,908
	Complete bury	PbB	3-8%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	66	21,167	1,680,000	1,322,908	3,002,908
16B	Southwest Portion	CcC	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	CcC	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	35	11,225	1,200,000	701,542	1,901,542
	Buried to roof	CcC	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	66	21,167	1,200,000	1,322,908	2,522,908
	Complete bury	CcC	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	2,000,000	75	61	105	66	21,167	1,680,000	1,322,908	3,002,908
16C	Southwest Portion	ChC	3-15%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	ChC	3-15%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	35	11,225	1,200,000	819,401	2,019,401
	Buried to roof	ChC	3-15%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	66	21,167	1,200,000	1,545,157	2,745,157
	Complete bury	ChC	3-15%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	66	21,167	1,680,000	1,545,157	3,225,157
16D	Southwest Portion	ChC	3-15%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	ChC	3-15%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	35	11,225	1,200,000	819,401	2,019,401
	Buried to roof	ChC	3-15%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	66	21,167	1,200,000	1,545,157	2,745,157
	Complete bury	ChC	3-15%, Outcrop	90%	10%	$ 80	$ 10	$ 73	2,000,000	75	61	105	66	21,167	1,680,000	1,545,157	3,225,157
17A	Pine Hill Road	PcB	3-8%, Stony	75%	25%	$ 80	$ 10	$ 63	1,625,000	63	69	93	-	-	975,000	-	975,000
	1/2 Buried	PcB	3-8%, Stony	75%	25%	$ 80	$ 10	$ 63	1,625,000	75	49	105	30	9,621	975,000	601,322	1,576,322
	Buried to roof	PcB	3-8%, Stony	75%	25%	$ 80	$ 10	$ 63	1,625,000	75	49	105	54	17,318	975,000	1,082,379	2,057,379
	Complete bury	PcB	3-8%, Stony	75%	25%	$ 80	$ 10	$ 63	1,625,000	75	49	105	54	17,318	1,365,000	1,082,379	2,447,379
17B	Pine Hill Road	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	1,625,000	63	69	93	-	-	975,000	-	975,000
	1/2 Buried	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	1,625,000	75	49	105	30	9,621	975,000	601,322	1,576,322
	Buried to roof	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	1,625,000	75	49	105	54	17,318	975,000	1,082,379	2,057,379
	Complete bury	PcD	8-15%, Stony	75%	25%	$ 80	$ 10	$ 63	1,625,000	75	49	105	54	17,318	1,365,000	1,082,379	2,447,379
18	Near Route 495	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	2,000,000	75	61	105	35	11,225	1,200,000	505,110	1,705,110
	Buried to roof	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	2,000,000	75	61	105	66	21,167	1,200,000	952,494	2,152,494
	Complete bury	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	2,000,000	75	61	105	66	21,167	1,680,000	952,494	2,632,494

Southborough DPW
Tank Siting Evaluation

TABLE 5
TANK EXCAVATION COSTS

Site ID	Description	Soil Type	Soil Description	Percent Ledge	Percent Loam	Ledge Unit Cost	Loam Unit Cost	Wtd Exc Unit Cost	Tank Volume (gal)	Dia (ft)	Height (ft)	Exc Dia (ft)	Exc Depth (ft)	Exc Volume (cyd)	Tank Unit Cost ($)	Exc Cost ($)	Total Tank Cost
19	Route 495 Median	AgB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	AgB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	35	11,225	1,200,000	190,819	1,390,819
	Buried to roof	AgB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,200,000	359,831	1,559,831
	Complete bury	AgB	3-8%, Deep	10%	90%	$ 80	$ 10	$ 17	2,000,000	75	61	105	66	21,167	1,680,000	359,831	2,039,831
20	Route 495 Interchange	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	2,000,000	63	85	93	-	-	1,200,000	-	1,200,000
	1/2 Buried	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	2,000,000	75	61	105	35	11,225	1,200,000	505,110	1,705,110
	Buried to roof	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	2,000,000	75	61	105	66	21,167	1,200,000	952,494	2,152,494
	Complete bury	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	2,000,000	75	61	105	66	21,167	1,680,000	952,494	2,632,494
21	MWRA Plant	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	-	-	-	-	-	-	-	-	-
22	Boland PS Expansion	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	-	-	-	-	-	-	-	-	-
	Eliminate Low Service	Ud	Disturbed	50%	50%	$ 80	$ 10	$ 45	-	-	-	-	-	-	-	-	-

APPENDIX A

SEPTEMBER 21, 2007 LETTER REPORT

ENGINEERS
SCIENTISTS
PLANNERS

www.parecorp.com

September 21, 2007

Ms. Karen Galligan
Superintendent of Public Works
Town of Southborough
147 Cordaville Road
Southborough, MA 01772

Re: **Water Tank Siting Research Report**
Final Report
PARE Project No. 07089.00

Dear Karen,

In accordance with Pare Corporation (PARE's) Letter Proposal and Agreement dated June 22, 2007, we offer the following results of our research for defining the location and operational characteristics for water storage. Our efforts to date have included two meetings with the Town representatives, research of existing documentation from water service organizations and texts including the American Water Works Association, a review of the "*Water Distribution Study Report*" (H2O Report) completed by H_2O Engineering in January of 2007, performance of six fire flow tests, and a review of the existing water system layout.

SYSTEM SUMMARY

The Town of Southborough water system consists of a High and Low Service pressure zone, three storage tanks (one High and two Low), and two pumping stations (one High and one Low). According to the H_2O Report, the following table summarizes some of the characteristics of the current water system.

TABLE 1
SYSTEM SUMMARY

Characteristic	Current (2005)	Design Year Projections (2020)
Average Day Demand	1.1 mgd	1.6 mgd
Maximum Day Demand	2.7 mgd	3.8 mgd
Fire Flow Demand [1]	0.63 mgd	0.63 mgd
Total Storage	2.04 mg	
Usable Storage	1.20 mg	
Hosmer PS Capacity (Low Service)	1,000 gpm	
Boland PS Capacity (High Service)	1,100 gpm	

Footnotes:
1. The Insurance Services Office lists the maximum fire flow demand at 3,500 gallons per minute for a 3-hour duration or 630,000 gallons.

Identified Concerns
The H_20 Report reported the following concerns with the existing system:

1. The Town experiences water storage shortages in the peak use period of the summer.
2. Because of the lack of storage, inadequate pumping, and/or undersized pipes, certain areas of Town have less than the recommended amount of flow available for fire fighting.
3. The current pumping capacity at the Hosmer and Boland pumping stations will not meet the projected maximum daily demand in the Design Year of 2020.
4. A single tank (Fiddler's Green) serves the High Service Area making servicing the tank difficult.
5. Replacement of old and undersized mains should continue.

Fire flow deficiencies from reports from the Insurance Services Office (ISO) dated 1990 and 2002 and new fire flow information (September 2007) are summarized below. Complete reports and results are included in the Appendix. Since the completion of the fire flow reports by the ISO, the Town has performed system improvements. To confirm the status of the deficient areas, PARE performed six fire flow tests. Four locations from the 2002 report and two locations from the 1990 report that exhibited deficient fire flow capacity. Table 2 is a summary of the historical and recent test results.

TABLE 2
SUMMARY OF FIRE FLOW REPORTING

Location	1990 Needed[1] (gpm)	1990 Available (gpm)	2002 Needed (gpm)	2002 Available (gpm)	2007 Needed (gpm)	2007 Available (gpm)	Comment
Test # 1 Marlboro Road @ St. Marks School			2,500	2,100	2,500	2,532	Sufficient
Test # 2 Trottier School	3,000	1,900			3,000	3,293	Sufficient
Test # 3 Mary E. Finn School			2,250	1,500	2,250	**1,783**	**Inadequate**
Test # 4 Highland Street @ Parkerville Road			1,500	1,200	1,500	**1,328**	**Inadequate**
Test # 5 Mt. Vickery Road @ Cordaville Road			3,500	1,600	3,500	**3,289**	**Inadequate**
Test # 6 Oregon Road @ Woodland Road	1,250	1,100			1,250	2,083	Sufficient

1. ISO sets the value for the "Needed" fire flow based on building age, type of construction, purpose and other factors.

As can be seen from Table 2, although system improvements were completed, fire flow deficiencies still exist in the system in the areas south of the Massachusetts Turnpike in the Low Service Area.

BACKGROUND

The H_2O Report reviewed the existing system and identified three phases of system improvements. The H_2O Report recommended that the Town should implement Phase I of the Report as soon as possible. This work includes:

1. Construction of a 2.0 million gallon water storage facility at the Deerfoot Road site;
2. Increase the capacity of the Boland Street pump station to 1,500 gpm (current 1,100 gpm) servicing the High Serve Area of town; and
3. Conduct various system improvements of water main replacements and extensions

Phase II and III recommendations of the H_2O Report included additional pipeline extensions, connections and replacements and the upgrade of the capacity of the Hosmer Pump Station that serves the Low Service Area to 1,500 gpm (current 1,000 gpm).

SCOPE OF WORK

At a recent Town Meeting, the Town of Southborough voted not to appropriate monies for a new water storage facility. PARE was retained by the Department of Public Works to evaluate a summary of operational characteristics of siting a water storage tank and report the findings to the Town.

PARE's efforts included a review of published American Water Works Association Standards (AWWA), Massachusetts Department of Environmental Protection (DEP) Guidelines and general operational characteristics for the following three conceptual alternatives:

Option 1
Siting a water storage tank with the same overflow elevation as the existing tank in the high service area that would require no additional pumping other than that currently provided at the Boland Pumping Station. The current overflow elevation is 515.00 feet. The Town currently owns a suitable tank site off of Deerfoot Road.

Option 2
Siting a water storage tank with a lower overflow elevation that would require pumping from the tank into the existing high service pressure zone with the use of a new booster pumping station. The Town does not currently own a tank site suitable for this option other than the Deerfoot Road site.

Option 3
Increasing the discharge capacity of the Boland pumping station to provide for additional flow with no provisions for additional storage. This alternative does not require a new site but will likely require an expansion of the building footprint that will trigger unique permitting thresholds.

EXISTING DOCUMENTATION

For this report we compared information related to the design, sizing, operation and location of water storage facilities from the following sources:

A. "Manual M31 – Distribution System Requirements for Fire Protection", by the American Water Works Association, 3rd Edition, 1998.
B. "Rules and Regulations pertaining to Public Drinking Water", by the Massachusetts Department of Environmental Protection, Revised 2001.
C. "Recommended Standards for Water Works" that is commonly referred to as the "Ten States Standards", 2003
D. "Water Resources Engineering" – McGraw Hill, 1979

RESEARCH SUMMARY

For our research summary, we compared the content of the reference documents for guidance on system reliability, tank sizing, location and the ability to supply water. A discussion on each is provided below.

System Reliability
System reliability is the capability of the system to provide for daily water use (domestic and commercial) and fire fighting.

Reference A. Manual M31 defines a reliable system as, "***A water supply system is considered to be fully adequate if it can deliver the required fire flows to all points in the distribution system with the consumption at the maximum daily rate.***" When discussing the capacity of the system to deliver water for fire protection, M31 states, "***The rate of flow from storage must be considered in terms of any limitation of water main capacity.***"

Reference B. Massachusetts Department of Environmental Protection – Rules and Regulations pertaining to Public Drinking Water (DEP) indicates that, "***Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands, and fire flow demands where fire protection is provided.***"

Reference C. In the Recommended Standards for Water Works (Ten States Standards), storage tank sizing should "***meet domestic demand and where fire protection is provided, fire flow demands.***" The statement is not clear if storage sizing is for average or maximum daily demands.

Reference D. Water Resources Engineering – McGraw Hill follows the outline for storage for M31 saying that, ***"The flow required for fire-fighting is added to the average use for the maximum day to determine what is assumed to be the maximum rate of use during a fire."***

Summary:
- A reliable system should meet maximum daily and fire flow demands;

Tank Size
Based on the above statement, the development of the size of a system's available usable storage should be based on the maximum daily demand and the projected fire flow requirement. However, not all of the storage provided in a system is considered "usable". Storage tanks are designed to provide for a minimum pressure within the distribution system. Not all of the depth of a tank provides the minimum pressure. Some of the water is stored at an elevation too low to provide adequate pressure in the system. Usable storage is the amount of storage that provides the minimum pressure. For the Town of Southborough, the H_2O Report defined the current usable storage as 1.2 million gallons.

To meet the recommended guidelines of maximum daily demand plus fire flow, the current and design year 2020 useable storage volume should be 3.33 and 4.43 million gallons respectively. According to the H_2O Report, the Town currently has 1.2 million gallons of usable storage. The deficit in storage is a concern and additional storage should be added to the system.

Tank Location
Reference A. Manual M31 States, ***"It is generally best to locate storage on the opposite side of the major load center from the main source of water. In this way, water can flow toward the most likely fire location from more than one direction. As a rule, elevated storage placed near the main pumping station is the least helpful for either fire fighting or equalization"***

Reference B. No specific recommendation for location

Reference C. No specific recommendation for location

Reference D. The Ten States Standard indicates that, "***Pressure conditions would be improved if the elevated tank were situated in or near the high consumption district.***"

Summary
- A storage tank should be located away from the supply
- Pressure stabilization is improved if the tank is near the system demand

Comment
- The existing site appears to be at an appropriate elevation
- The existing site appears to be at an appropriate location in distribution system

Supply Pumping
Reference A. Manual M31 provides the following description of two types of distribution storage. ***"The two types of distribution storage – ground and elevated have two types of pumping systems. One is a direct pumping system, in which the instantaneous system demand is met by pumping with no elevated storage provided. The second type is an indirect system in which the pumping station lifts water to a reservoir or elevated storage tank, which floats on the system and provides system pressure by gravity.***

Direct Pumping usually involves variable speed pumps or multiple pumps with control based on system pressure. Hydropneumatic tanks at the pump station start provide some storage. These tanks permit the pumping station pumps to start and stop based on a system pressure preset by controls operating the tank. If direct pumping from ground tanks is used such that the water level in the

ground tank is significantly less than the hydraulic grade line elevation near the tank, considerable energy is wasted by filling the tank and repumping the water.

In an indirect system, the pumping station is not associated with the demands of the major load center. It is operated from the water level differences in the reservoir or elevated storage tank, enabling the prescribed range of water levels in the tank to be maintained. Most systems have an elevated storage tank or a reservoir on high ground floating on the system. This arrangement permits the pumping station to operate at a uniform rate, with the storage either making up or absorbing the difference between station discharge and system demand."

Reference B. Not specifically addressed

Reference C. Not specifically addressed

Reference D. Concerning pumping in distribution system, Ten States Standards indicate that, "***Water is pumped into a distribution storage when the demand is low and withdrawn when the demand is high.***" They continue with, ***"Elevated storage may be used advantageously for pressure stabilization"***

See the attached figure from the AWWA Reference that graphically indicates the benefits of a tank location remote from the supply.

Summary:

- Utilizing gravity feed to a system from a tank is more reliable than direct pumping

COMPARISON

Provided below is a comparison of the three options that PARE evaluated for the siting and operational conditions of a new system storage tank. We've included the advantages and disadvantages of each option based on our review of available literature.

Option 1 – Constructing a tank at the existing Site off of Deerfoot Road with an overflow elevation of 515.00 feet provides the most reliable approach to solving the system storage concerns.

Advantages
Utilizes existing tank site off of Deerfoot Road.
Provides for storage away from supply
Increases fire flow capabilities and potentially reduces fire flow deficiencies
Does not require extensive infrastructure improvements

Disadvantages
Affects local residents

Option 2 – Constructing a tank with an overflow elevation lower than the current system gradient elevation of 515.0 feet increases the operational demands of the system and may not provide adequate reliability based on the final location of the tank.

Advantageous
Does not require extensive infrastructure improvements
Maximizes useable storage

Disadvantages
Requires potential for new tank site
Requires pumping water twice
Eliminates gravity-fed system
Creates unique operational restraints
Increases operation and maintenance costs

Option 3 – Increasing Boland pumping station capacity to provide required fire flow will require substantial system piping improvements to eliminate dramatically increasing pressures within the system. Pumping operations will be inefficient due to the requirement to meet a wide variety of flow conditions.

Advantages
No new site required

Disadvantages
Limited by water main size, extensive infrastructure required
Extensive upgrade of Boland station required including unique permitting impacts
System pressure balance difficult to maintain
Daily use of large pumps will be inefficient require an increase in energy costs
Daily use of large pumps will increase system pressure closer to supply
Increase in pipe size will be required to offset pressure increase

RECOMMENDATION

To be consistent with regulatory and independent agencies, and to construct a system that is the most reliable, the Town should construct an elevated storage facility to increase storage to the high service system at the existing tank site off of Deerfoot Road. In addition, the Town should continue to improve the distribution system with the recommended system improvements from Phase I of the H_2O Report.

Utilizing the existing tank site satisfies the recommendation of a central location and eliminates the need for the purchase of an additional tank site. The fact that the system will remain a gravity system also improves the system's overall reliability. The location of the tank should improve fire protection in the areas of need including the Mary Finn School and other areas south of the Massachusetts Turnpike in the Low Service area. Incorporation of the operation of the tank into existing system controls will be facilitated without new control and pumping devices.

Outside of the scope of our work, it also seems essential to increase the capacity of the Hosmer and Boland pumping stations to meet future maximum daily demands. With a pump out-of-service the system cannot meet existing maximum daily demands.

It has been our pleasure to assist you with this effort. Following your review we will meet with you to further discuss the issues. If you have any further questions please do not hesitate to contact me at 401-334-4100.

Very truly yours,

Robert P. Sims, P.E.
Managing Engineer

RPS/abv

Enclosures

L:\07089.00 Southborough Water Tank Siting Review\REPORTS\Final Report.doc

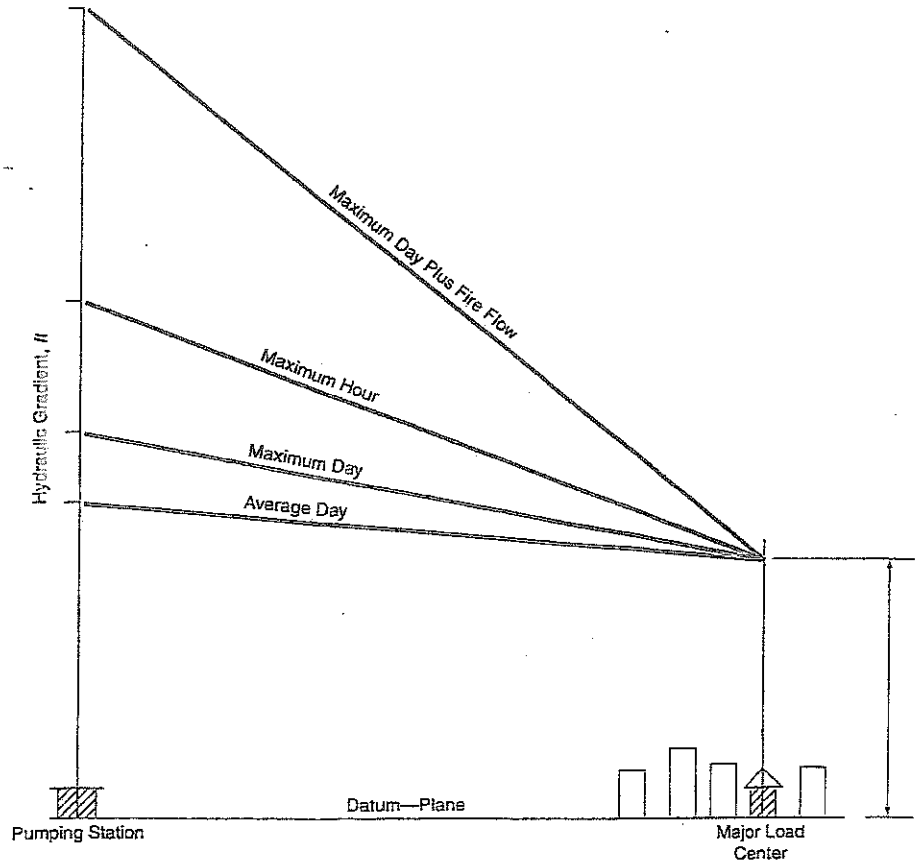


Figure 3-1 System A—hydraulic gradient with no storage

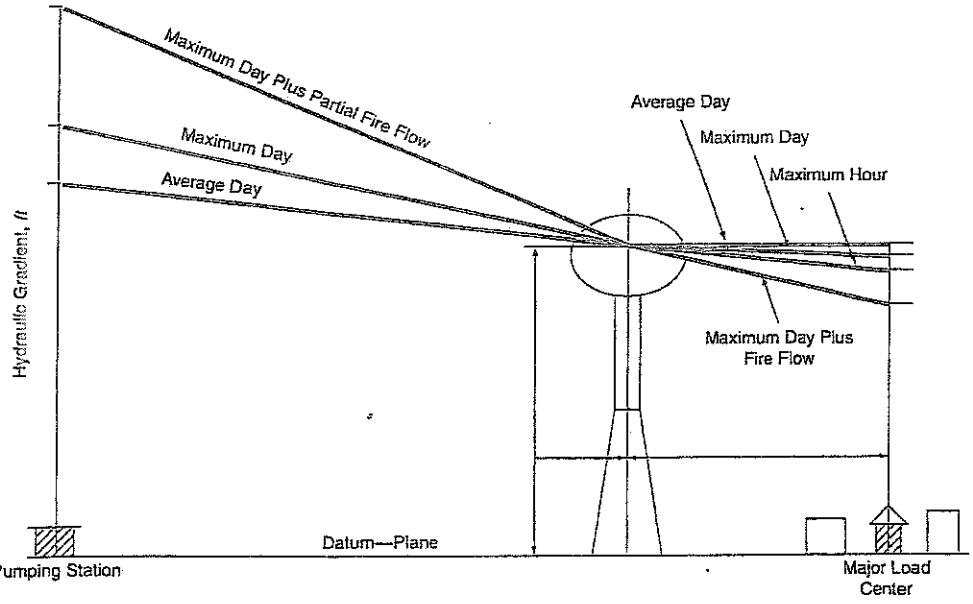


Figure 3-2 System B—hydraulic gradients with storage between pump station and load center

* From AWWA Manaul M31

PARE CORPORATION

HYDRANT FLOW TEST REPORT #1A

Location: St. Mark's School
Southborough, Massachusetts

Date: November 6, 2007

Test Made By: Brandon Blanchard

Start of Test: 1:00 P.M.

Duration of Test: 2 min. +/-

Representative of: Pare Corporation (with assistance from Southborough DPW personnel)

Purpose of Test: Determine available fire flow at 20 psi residual pressure.

Consumption Rate During Test: 1,130 gpm at 2 min = 2,260 gallons +/-

Flow Test Results at Hydrant:

	Flow Hydrant	Residual Hydrant
Flow Rate:	1,130 gpm	
Size Nozzle:	2½ inch	2½ inch
Static Pressure:	69 psi	69 psi
Residual Pressure:	50 psi	58 psi

Note: Residual pressure was gauge monitored at both the flow and residual hydrants, and is provided above. Pressure read from pitot tube gauge corresponding to a flow rate of 1,130 gpm was approximately 45 psi. Friction coefficient of 0.9 is factored into the pitot tube gauge.

Remarks: The results of this flow test are indicative of the conditions of the water system at the time of the test. Other factors, such as available fire reserve (i.e. storage tank volume), the operation of booster pumps, etc., were not considered in this evaluation.

Report prepared by: Brandon Blanchard

PARE CORPORATION

HYDRANT FLOW TEST REPORT #2A

Location: Trottier School
Southborough, Massachusetts

Date: November 6, 2007

Test Made By: Brandon Blanchard

Start of Test: 1:30 P.M.

Duration of Test: 2 min. +/-

Representative of: Pare Corporation (with assistance from Southborough DPW personnel)

Purpose of Test: Determine available fire flow at 20 psi residual pressure.

Consumption Rate During Test: 1,455 gpm at 2 min = 2,910 gallons +/-

Flow Test Results at Hydrant:

	Flow Hydrant	Residual Hydrant
Flow Rate:	1,455 gpm	
Size Nozzle:	2½ inch	2½ inch
Static Pressure:	98 psi	98 psi
Residual Pressure:	78 psi	86 psi

Note: Residual pressure was gauge monitored at both the flow and residual hydrants, and is provided above. Pressure read from pitot tube gauge corresponding to a flow rate of 1,455 gpm was approximately 75 psi. Friction coefficient of 0.9 is factored into the pitot tube gauge.

Remarks: The results of this flow test are indicative of the conditions of the water system at the time of the test. According to Southborough DPW personnel, two (2) booster pumps were running at the time of this test. Other factors, such as available fire reserve (i.e. storage tank volume), were not considered in this evaluation.

Report prepared by: Brandon Blanchard

PARE CORPORATION

HYDRANT FLOW TEST REPORT #2B

Location: Trottier School
Southborough, Massachusetts

Date: November 6, 2007

Test Made By: Brandon Blanchard

Start of Test: 1:45 P.M.

Duration of Test: 2 min. +/-

Representative of: Pare Corporation (with assistance from Southborough DPW personnel)

Purpose of Test: Determine available fire flow at 20 psi residual pressure.

Consumption Rate During Test: 1,400 gpm at 2 min = 2,800 gallons +/-

Flow Test Results at Hydrant:

	Flow Hydrant	Residual Hydrant
Flow Rate:	1,400 gpm	
Size Nozzle:	2½ inch	2½ inch
Static Pressure:	98 psi	98 psi
Residual Pressure:	76 psi	82 psi

Note: Residual pressure was gauge monitored at both the flow and residual hydrants, and is provided above. Pressure read from pitot tube gauge corresponding to a flow rate of 1,400 gpm was approximately 70 psi. Friction coefficient of 0.9 is factored into the pitot tube gauge.

Remarks: The results of this flow test are indicative of the conditions of the water system at the time of the test. According to Southborough DPW personnel, no (0) booster pumps were running at the time of this test. Other factors, such as available fire reserve (i.e. storage tank volume), were not considered in this evaluation.

Report prepared by: Brandon Blanchard

PARE CORPORATION

HYDRANT FLOW TEST REPORT #3

Location: Finn School
Southborough, Massachusetts

Date: November 6, 2007

Test Made By: Brandon Blanchard

Start of Test: 2:05 P.M.

Duration of Test: 2 min. +/-

Representative of: Pare Corporation (with assistance from Southborough DPW personnel)

Purpose of Test: Determine available fire flow at 20 psi residual pressure.

Consumption Rate During Test: 1,050 gpm at 2 min = 2,100 gallons +/-

Flow Test Results at Hydrant:

Flow Hydrant	Residual Hydrant
Flow Rate: 1,050 gpm	
Size Nozzle: 2½ inch	*Size Nozzle:* 2½ inch
Static Pressure: 88 psi	*Static Pressure:* 84 psi
Residual Pressure: 50 psi	*Residual Pressure:* 60 psi

Note: Residual pressure was gauge monitored at both the flow and residual hydrants, and is provided above. Pressure read from pitot tube gauge corresponding to a flow rate of 2,100 gpm was approximately 39 psi. Friction coefficient of 0.9 is factored into the pitot tube gauge.

Remarks: The results of this flow test are indicative of the conditions of the water system at the time of the test. Other factors, such as available fire reserve (i.e. storage tank volume), operation of booster pumps, etc., were not considered in this evaluation.

Report prepared by: Brandon Blanchard

PARE CORPORATION

HYDRANT FLOW TEST REPORT #4

Location: Parkerville Road & Highland Road
Southborough, Massachusetts

Date: November 6, 2007

Test Made By: Brandon Blanchard

Start of Test: 2:20 P.M.

Duration of Test: 2 min. +/-

Representative of: Pare Corporation (with assistance from Southborough DPW personnel)

Purpose of Test: Determine available fire flow at 20 psi residual pressure.

Consumption Rate During Test: 900 gpm at 2 min = 1,800 gallons +/-

Flow Test Results at Hydrant:

Flow Hydrant	Residual Hydrant
Flow Rate: 900 gpm	
Size Nozzle: 2½ inch	*Size Nozzle:* 2½ inch
Static Pressure: 94 psi	*Static Pressure:* 94 psi
Residual Pressure: 44 psi	*Residual Pressure:* 58 psi

Note: Residual pressure was gauge monitored at both the flow and residual hydrants, and is provided above. Pressure read from pitot tube gauge corresponding to a flow rate of 900 gpm was approximately 29 psi. Friction coefficient of 0.9 is factored into the pitot tube gauge.

Remarks: The results of this flow test are indicative of the conditions of the water system at the time of the test. Other factors, such as available fire reserve (i.e. storage tank volume), operation of booster pumps, etc., were not considered in this evaluation.

Report prepared by: Brandon Blanchard

PARE CORPORATION

HYDRANT FLOW TEST REPORT #5

Location: Mt. Vickery Road
Southborough, Massachusetts

Date: November 7, 2007

Test Made By: Brandon Blanchard

Start of Test: 1:45 P.M.

Duration of Test: 2 min. +/-

Representative of: Pare Corporation (with assistance from Southborough DPW personnel)

Purpose of Test: Determine available fire flow at 20 psi residual pressure.

Consumption Rate During Test: 1,150 gpm at 2 min = 2,300 gallons +/-

Flow Test Results at Hydrant:

	Flow Hydrant	Residual Hydrant
Flow Rate:	1,150 gpm	
Size Nozzle:	2½ inch	2½ inch
Static Pressure:	85 psi	83 psi
Residual Pressure:	52 psi	74 psi

Note: Residual pressure was gauge monitored at both the flow and residual hydrants, and is provided above. Pressure read from pitot tube gauge corresponding to a flow rate of 1,150 gpm was approximately 47 psi. Friction coefficient of 0.9 is factored into the pitot tube gauge.

Remarks: The results of this flow test are indicative of the conditions of the water system at the time of the test. Other factors, such as available fire reserve (i.e. storage tank volume), operation of booster pumps, etc., were not considered in this evaluation.

Report prepared by: Brandon Blanchard

PARE CORPORATION

HYDRANT FLOW TEST REPORT #6

Location: Woodland Road
Southborough, Massachusetts

Date: November 7, 2007

Test Made By: Brandon Blanchard

Start of Test: 1:15 P.M.

Duration of Test: 2 min. +/-

Representative of: Pare Corporation (with assistance from Southborough DPW personnel)

Purpose of Test: Determine available fire flow at 20 psi residual pressure.

Consumption Rate During Test: 1,200 gpm at 2 min = 2,400 gallons +/-

Flow Test Results at Hydrant:

Flow Hydrant	Residual Hydrant
Flow Rate: 1,200 gpm	
Size Nozzle: 2½ inch	*Size Nozzle:* 2½ inch
Static Pressure: 73 psi	*Static Pressure:* 70 psi
Residual Pressure: 54 psi	*Residual Pressure:* 52 psi

Note: Residual pressure was gauge monitored at both the flow and residual hydrants, and is provided above. Pressure read from pitot tube gauge corresponding to a flow rate of 1,200 gpm was approximately 51 psi. Friction coefficient of 0.9 is factored into the pitot tube gauge.

Remarks: The results of this flow test are indicative of the conditions of the water system at the time of the test. Other factors, such as available fire reserve (i.e. storage tank volume), operation of booster pumps, etc., were not considered in this evaluation.

Report prepared by: Brandon Blanchard

PARE CORPORATION

PAGE 1 OF 1

PROJECT Southborough, MA Fire Flow Tests PROJECT NUMBER 07089.01
SUBJECT Hydrant Flow Test #1A (St. Mark's School)
COMPUTATIONS BY B. Blanchard DATE 9/7/2007
CHECK BY R. Sims DATE 9/10/2007

Flow Test #1A

$$Q_R = Q_F \times \left[(H_R)^{0.54} \div (H_F)^{0.54} \right]$$

where:

Q_R = *Flow at a residual pressure of 20 psi (gpm)*
Q_F = *Observed flow (gpm)*
H_R = *Pressure drop between static pressure and 20 psi residual pressure*
H_F = *Pressure drop between static pressure and observed residual pressure*

Flow Hydrant		Residual Hydrant	
Static Pressure	69 (psi)	Static Pressure	69 (psi)
Residual Pressure	50 (psi)	Residual Pressure	58 (psi)
Flow	1130 (gpm)		

Flow calculated at 20 psi residual pressure using residual hyd. pressures (gpm): **2532**

PARE CORPORATION

PROJECT Southborough, MA Fire Flow Tests PROJECT NUMBER 07089.01
SUBJECT Hydrant Flow Test #2A (Trottier School)
COMPUTATIONS BY B. Blanchard DATE 9/7/2007
CHECK BY R. Sims DATE 9/10/2007

Flow Test #2A

$$Q_R = Q_F \times \left[\left(H_R \right)^{0.54} \div \left(H_F \right)^{0.54} \right]$$

where:

Q_R = *Flow at a residual pressure of 20 psi (gpm)*
Q_F = *Observed flow (gpm)*
H_R = *Pressure drop between static pressure and 20 psi residual pressure*
H_F = *Pressure drop between static pressure and observed residual pressure*

Flow Hydrant		Residual Hydrant	
Static Pressure	98 (psi)	Static Pressure	98 (psi)
Residual Pressure	78 (psi)	Residual Pressure	86 (psi)
Flow	1455 (gpm)		

Flow calculated at 20 psi residual pressure using residual hyd. pressures (gpm): **3998**

PARE CORPORATION

PROJECT: Southborough, MA Fire Flow Tests — PROJECT NUMBER: 07089.01
SUBJECT: Hydrant Flow Test #2B (Trottier School)
COMPUTATIONS BY: B. Blanchard — DATE: 9/7/2007
CHECK BY: R. Sims — DATE: 9/10/2007

Flow Test #2B

$$Q_R = Q_F \times \left[\left(H_R\right)^{0.54} \div \left(H_F\right)^{0.54} \right]$$

where:

Q_R = *Flow at a residual pressure of 20 psi (gpm)*
Q_F = *Observed flow (gpm)*
H_R = *Pressure drop between static pressure and 20 psi residual pressure*
H_F = *Pressure drop between static pressure and observed residual pressure*

Flow Hydrant	
Static Pressure	98 (psi)
Residual Pressure	76 (psi)
Flow	1400 (gpm)

Residual Hydrant	
Static Pressure	98 (psi)
Residual Pressure	82 (psi)

Flow calculated at 20 psi residual pressure using residual hyd. pressures (gpm): **3293**

PARE CORPORATION

PROJECT	Southborough, MA Fire Flow Tests	PROJECT NUMBER	07089.01
SUBJECT	Hydrant Flow Test #3 (Finn School)		
COMPUTATIONS BY	B. Blanchard	DATE	9/7/2007
CHECK BY	R. Sims	DATE	9/10/2007

Flow Test #3

$$Q_R = Q_F \times \left[(H_R)^{0.54} \div (H_F)^{0.54} \right]$$

where:

Q_R = *Flow at a residual pressure of 20 psi (gpm)*

Q_F = *Observed flow (gpm)*

H_R = *Pressure drop between static pressure and 20 psi residual pressure*

H_F = *Pressure drop between static pressure and observed residual pressure*

Flow Hydrant		Residual Hydrant	
Static Pressure	88 (psi)	Static Pressure	84 (psi)
Residual Pressure	50 (psi)	Residual Pressure	60 (psi)
Flow	1050 (gpm)		

Flow calculated at 20 psi residual pressure using residual hyd. pressures (gpm): **1783**

PARE CORPORATION

PROJECT Southborough, MA Fire Flow Tests PROJECT NUMBER 07089.01
SUBJECT Hydrant Flow Test #4 (Parkerville & Highland)
COMPUTATIONS BY B. Blanchard DATE 9/7/2007
CHECK BY R. Sims DATE 9/10/2007

Flow Test #4

$$Q_R = Q_F \times \left[\left(H_R \right)^{0.54} \div \left(H_F \right)^{0.54} \right]$$

where:

Q_R = *Flow at a residual pressure of 20 psi (gpm)*
Q_F = *Observed flow (gpm)*
H_R = *Pressure drop between static pressure and 20 psi residual pressure*
H_F = *Pressure drop between static pressure and observed residual pressure*

Flow Hydrant	
Static Pressure	94 (psi)
Residual Pressure	44 (psi)
Flow	900 (gpm)

Residual Hydrant	
Static Pressure	94 (psi)
Residual Pressure	58 (psi)

Flow calculated at 20 psi residual pressure using residual hyd. pressures (gpm): **1328**

PARE CORPORATION

PROJECT	Southborough, MA Fire Flow Tests	PROJECT NUMBER	07089.01
SUBJECT	Hydrant Flow Test #5 (Mt. Vickery Road)		
COMPUTATIONS BY	B. Blanchard	DATE	9/7/2007
CHECK BY	R. Sims	DATE	9/10/2007

Flow Test #5

$$Q_R = Q_F \times \left[(H_R)^{0.54} \div (H_F)^{0.54} \right]$$

where:

- Q_R = *Flow at a residual pressure of 20 psi (gpm)*
- Q_F = *Observed flow (gpm)*
- H_R = *Pressure drop between static pressure and 20 psi residual pressure*
- H_F = *Pressure drop between static pressure and observed residual pressure*

Flow Hydrant		Residual Hydrant	
Static Pressure	85 (psi)	Static Pressure	83 (psi)
Residual Pressure	52 (psi)	Residual Pressure	74 (psi)
Flow	1150 (gpm)		

Flow calculated at 20 psi residual pressure using residual hyd. pressures (gpm): **3289**

PARE CORPORATION

PROJECT	Southborough, MA Fire Flow Tests	PROJECT NUMBER	07089.01
SUBJECT	Hydrant Flow Test #6 (Woodland Road)		
COMPUTATIONS BY	B. Blanchard	DATE	9/7/2007
CHECK BY	R. Sims	DATE	9/10/2007

Flow Test #6

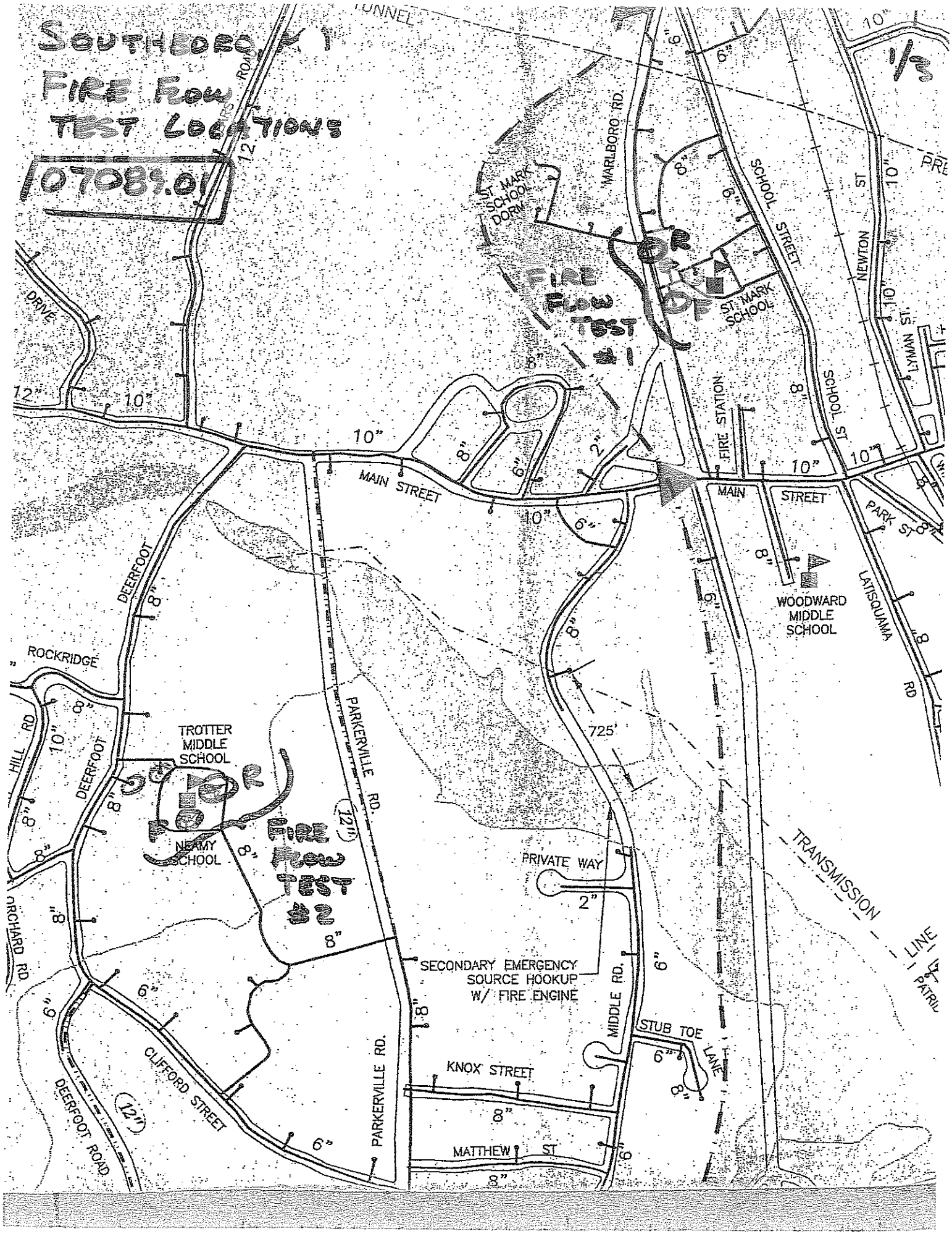
$$Q_R = Q_F \times \left[(H_R)^{0.54} \div (H_F)^{0.54} \right]$$

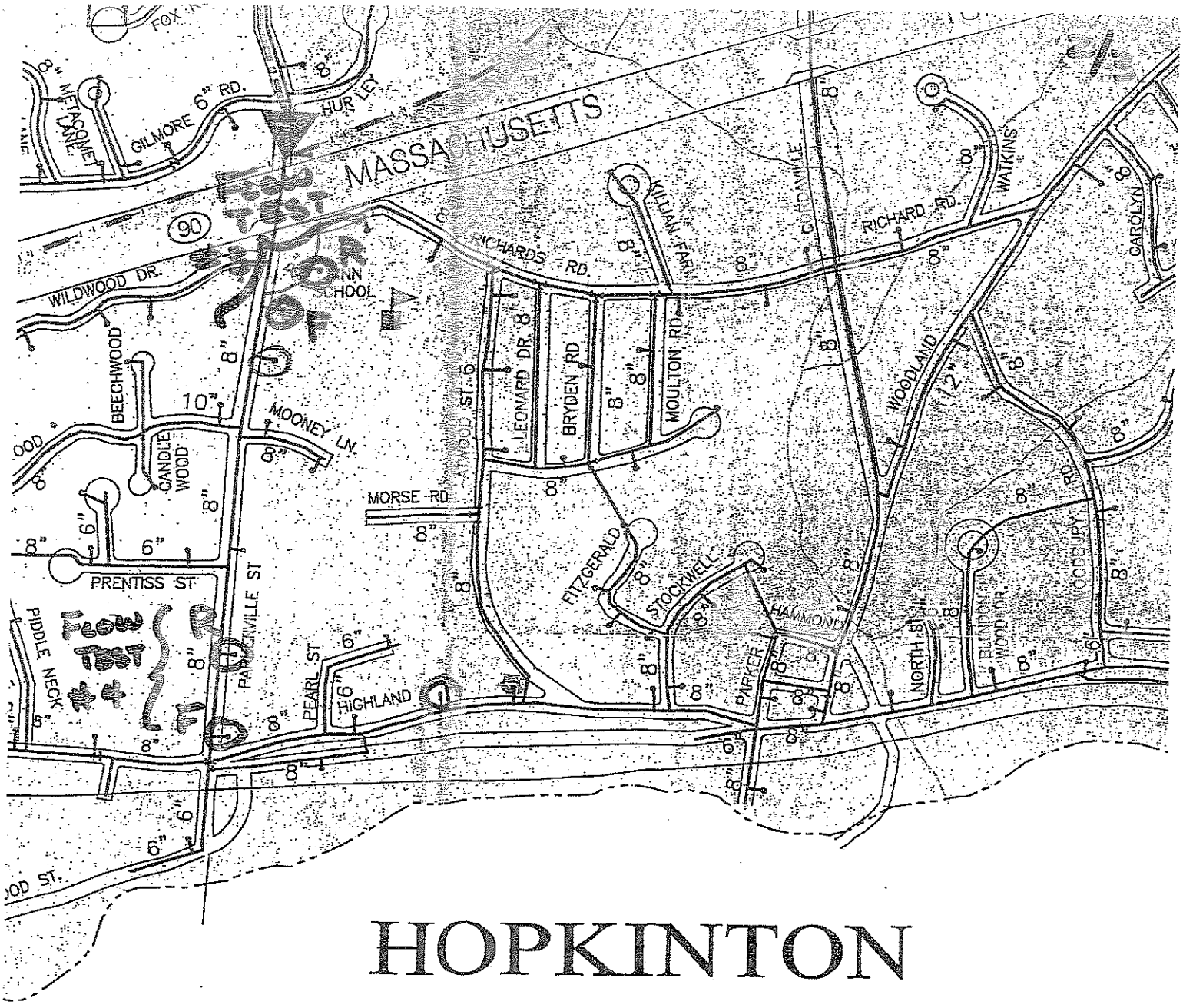
where:

- Q_R = *Flow at a residual pressure of 20 psi (gpm)*
- Q_F = *Observed flow (gpm)*
- H_R = *Pressure drop between static pressure and 20 psi residual pressure*
- H_F = *Pressure drop between static pressure and observed residual pressure*

Flow Hydrant		Residual Hydrant	
Static Pressure	73 (psi)	Static Pressure	70 (psi)
Residual Pressure	54 (psi)	Residual Pressure	52 (psi)
Flow	1200 (gpm)		

Flow calculated at 20 psi residual pressure using residual hyd. pressures (gpm): **2083**

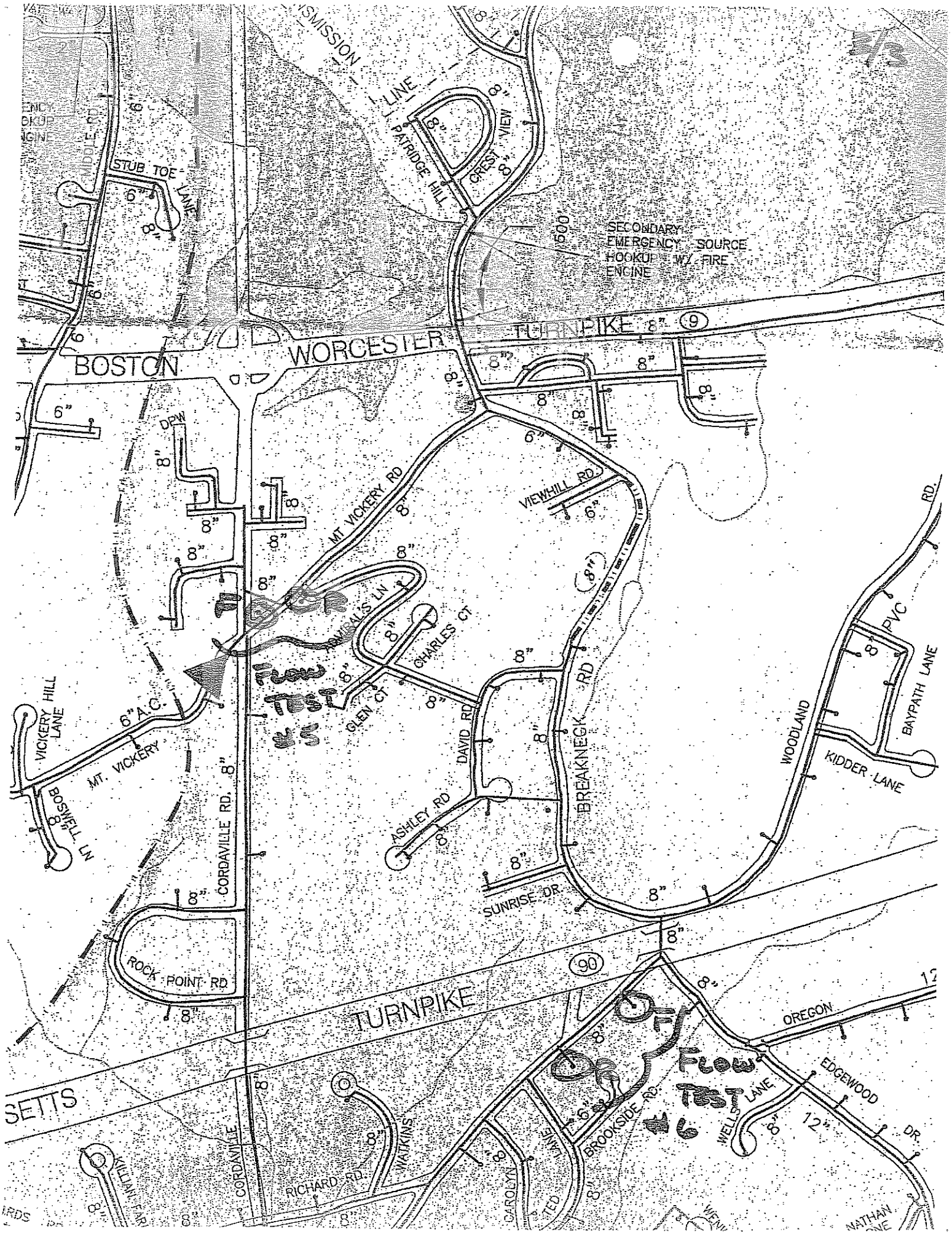

SOUTHBOROUGH
FIRE FLOW
TEST LOCATIONS
07089.01
1/3
MARLBORO RD.
ST. MARK SCHOOL DORM
SCHOOL STREET
NEWTON ST
ST. MARK SCHOOL
FIRE FLOW TEST #1
FIRE STATION
MAIN STREET
LYMAN ST.
PARK ST.
WOODWARD MIDDLE SCHOOL
LATISQUAMA RD
DEERFOOT
ROCKRIDGE
HILL RD
TROTTER MIDDLE SCHOOL
NEARY SCHOOL
FIRE FLOW TEST #2
PARKERVILLE RD.
725'
PRIVATE WAY
TRANSMISSION LINE
SECONDARY EMERGENCY SOURCE HOOKUP W/ FIRE ENGINE
ORCHARD RD
CLIFFORD STREET
DEERFOOT ROAD
KNOX STREET
MIDDLE RD.
STUB TOE LANE
MATTHEW ST



HOPKINTON

0 1000 2000 4000

SCALE IN FEET



2/3
SECONDARY EMERGENCY SOURCE HOOKUP W/ FIRE ENGINE
BOSTON WORCESTER TURNPIKE
9
PATRIDGE HILL
CREST VIEW
STUB TOE LANE
DPW
MT VICKERY RD
VIEWHILL RD
ADMIRAL'S LN
CHARLES CT
GLEN CT
DAVID RD
BREAKNECK RD
ASHLEY RD
SUNRISE DR
VICKERY HILL LANE
MT. VICKERY
BOSWELL LN
CORDAVILLE RD.
ROCK POINT RD
TURNPIKE
90
SETTS
OREGON
EDGEWOOD DR.
WELLS LANE
BROOKSIDE RD.
WATKINS
RICHARD RD.
CAROLYN
TED LANE
KILLIAN FAR
WOODLAND
KIDDER LANE
BAYPATH LANE
PVC
RD.
NATHAN
Flow TEST #5
Flow TEST #6

APPENDIX B

SITE EVALUATION SUMMARY

Site ID # 1 – Fairview Road; Map 27, Lot 40

The site is located in the Fairview Hill area of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 1.23 acres and is currently owned by the Town of Southborough.

The soil is described by the USGS as Soil Type ChD. This is a Charlton stratum with 15-25% slopes and contains rock outcrops. For the analysis of burying the tank we assumed that the soil was approximately 90% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 450'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,440 feet of new piping will be required to provide the required fire flow at the select locations for the gravity discharge alternative and 1,440 feet of new piping if pump-storage is utilized.

Access to the site would be from a new 650-foot long access road off of Deerfoot Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Gravity Discharge - $1,546,000
Cost for Pump-storage with tank partially buried - $3,204,300
Cost for Pump-storage with tank completely except for roof - $4,222,500
Cost for Pump-storage with tank completely buried - $4,702,500

Site ID # 2 – Tara Road: Map 33, Lot 41

The site is located in the western portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 2.0 acres and is currently owned by the Town of Southborough and the existing 1.3 million gallon tank resides at this location.

The soil is described by the USGS as Soil Type PaB. This is a Paxton fine sandy loam with 3-8% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 465'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 74-foot diameter tank with a gravity discharge at this site would be approximately 62-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station. The system required, would be equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 250 feet of new piping will be required to provide the required fire flow at the select locations for the gravity discharge alternative and 250 feet of new piping if pump-storage is utilized.

Access to the site would be from the existing service road off of Tara Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Gravity Discharge - $1,237,500
Cost for Pump-storage with tank partially buried - $2,274,000
Cost for Pump-storage with tank completely except for roof - $2,589,300
Cost for Pump-storage with tank completely buried - $3,069,300

Site ID # 3 – 147 Cordaville Road (DPW); Map 28, Lot 4

The site is located in the central portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 9.45 acres and is currently owned by the Town of Southborough.

The soil is described by the USGS as Soil Type WrB. This is a Woodbridge fine sandy loam with 3-8% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 280'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and power would need to be extended to the site. The cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,650 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 500-foot service road off of Cordaville Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above grade - $2,913,100
Cost for Pump-storage with tank partially buried - $3,331,300
Cost for Pump-storage with tank completely except for roof - $3,874,000
Cost for Pump-storage with tank completely buried - $4,354,000

Site ID # 4 – Highland Street, Arts Center; Map 3, Lot 3

The site is located in the southern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 3.0 acres and is currently owned by the Town of Southborough.

The soil is described by the USGS as Soil Type PaB. This is a Paxton fine sandy loam with 3-8% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 310'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 200 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 300-foot service road off of Highland Street.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,615,600
Cost for Pump-storage with tank partially buried - $2,806,400
Cost for Pump-storage with tank completely except for roof - $3,576,500
Cost for Pump-storage with tank completely buried - $4,056,500

This option would either require the redistricting of the low service system. Additional costs would be incurred with this option. The additional costs were not determined because the option is not cost competitive.

Site ID # 5 – 24 Atwood Drive: Map 8. Lot 2

The site is located in the southern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 1.84 acres and is currently owned by the Town of Southborough.

The soil is described by the USGS as Soil Type ChD. This is a Chatfield-Hollis-Rock complex with 15-25% slopes and contains rock outcrops. For the analysis of burying the tank we assumed that the soil was approximately 90% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 380'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 200 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 300-foot service road off of Atwood Drive.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,207,600
Cost for Pump-storage with tank partially buried - $3,230,100
Cost for Pump-storage with tank completely except for roof - $4,183,300
Cost for Pump-storage with tank completely buried - $4,663,300

This option would either require the redistricting of the low service system. Additional costs would be incurred with this option. The additional costs were not determined because the option is not cost competitive.

Site ID # 6 – 46 Atwood Drive: Map 8, Lot 3

The site is located in the southern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 11.42 acres and is currently owned by the Town of Southborough.

The soil is described by the USGS as Soil Type PaC. This is a Paxton fine sandy loam with 8-15% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 370'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 300 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 650-foot service road off of Atwood Drive.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,347,600
Cost for Pump-storage with tank partially buried - $2,741,500
Cost for Pump-storage with tank completely except for roof - $3,137,900
Cost for Pump-storage with tank completely buried - $3,617,900

This option would either require the redistricting of the low service system. Additional costs would be incurred with this option. The additional costs were not determined because the option is not cost competitive.

Site ID # 7 – Parkerville Road, Mooney Field: Map 7, Lot 23

The site is located in the southern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 6.98 acres and is currently owned by the Town of Southborough.

The soil is described by the USGS as Soil Type NgA. This is a Ninigret fine sandy loam with 0-3% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 300'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 500 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 640-foot service road off of Parkerville Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,768,600
Cost for Pump-storage with tank partially buried - $2,959,400
Cost for Pump-storage with tank completely except for roof - $3,729,500
Cost for Pump-storage with tank completely buried - $4,209,500

This option would either require the redistricting of the low service system. Additional costs would be incurred with this option. The additional costs were not determined because the option is not cost competitive.

Site ID # 8 – 60 Breakneck Hill Road; Map 29, Lot 36

The site is located in the eastern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 3.9 acres and is currently owned by a private party. The property has an existing tax lien in the amount of $12,500 that could be applied to reducing the purchase price.

The soil is described by the USGS as Soil Type CaC. This is a Canton fine sandy loam with 8-15% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 345'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,500 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 200-foot service road off of Breakneck Hill Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,716,200
Cost for Pump-storage with tank partially buried - $3,107,200
Cost for Pump-storage with tank completely except for roof - $3,465,400
Cost for Pump-storage with tank completely buried - $3,855,400

This option would either require the elimination of the low service system. An estimated additional cost of $1,343,700 would be incurred with eliminating the low service and redistricting the low service is estimated to be $671,850 (one pumped system required for the existing Clear Hill Tank. This renders it excessively expensive. See Tables 1 through 5 for a more detailed estimate.

Site ID # 9 – Clifford Road/ Deerfoot Road Property; Map 34. Lot 29

The site is located in the western portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 17.96 acres and is currently owned by a private party. According to Town records, the property also is under the tax protection provided by Chapter 61A (Agricultural exemption).

The soil is described by the USGS as Soil Type CaB. This is a Canton fine sandy loam with 3-8% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 370'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 750 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 500-foot service road off of either Clifford or Deerfoot Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,743,400
Cost for Pump-storage with tank partially buried - $3,137,300
Cost for Pump-storage with tank completely except for roof - $3,533,700
Cost for Pump-storage with tank completely buried - $4,013,700

Site ID # 10 – Northboro Road, Johnson Farm: Map 71, Lot 1.A

The site is located in the northern portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 10.76 acres and is currently owned by a private party.

The soil is described by the USGS as Soil Type WrB. This is a Woodbridge fine sandy loam with 3-8% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 330'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 45 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,150 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 1,120-foot service road off of Northboro Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $3,007,700
Cost for Pump-storage with tank partially buried - $3,425,900
Cost for Pump-storage with tank completely except for roof - $3,822,300
Cost for Pump-storage with tank completely buried - $4,302,300

Site ID # 11 – Ledge Hill Road. St. Marks: Map 74, Lot 6

The site is located in the northern portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 50acres and is currently owned by the St. Marks School.

The soil is described by the USGS as Soil Type PcD. This is a Paxton fine sandy loam with 15-25% slopes and extremely stony. For the analysis of burying the tank we assumed that the soil was approximately 75% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 400'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 775 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 480-foot service road off of Ledge Hill Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,699,600
Cost for Pump-storage with tank partially buried - $3,401,100
Cost for Pump-storage with tank completely except for roof - $4,453,000
Cost for Pump-storage with tank completely buried - $4,933,000

Site ID # 12 – 88 Newton Street; Map 75, Lot 27

The site is located in the northern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 1.34 acres and is currently owned by a private party. The property has an existing tax lien in the amount of $45,000 that could be applied to reducing the purchase price.

The soil is described by the USGS as Soil Type MeB. This is a Merrimac fine sandy loam with 3-8% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 285'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 200 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 150-foot service road off of Newton Street.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,653,600
Cost for Pump-storage with tank partially buried - $3,050,000
Cost for Pump-storage with tank completely except for roof - $3,570,900
Cost for Pump-storage with tank completely buried - $3,990,900

This option would either require the elimination of the low service system. An estimated additional cost of $1,343,700 would be incurred with eliminating the low service and 3redistricting the low service is estimated to be $671,850 (one pumped system required for the existing Clear Hill Tank. This renders it excessively expensive. See Tables 1 through 5 for a more detailed estimate.

Site ID # 13 – 55-57 Boston Road; Map 46, Lot 4

The site is located in the eastern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 5.75 acres and is currently owned by a private party. The property has an existing tax lien in the amount of $4,000 that could be applied to reducing the purchase price.

The soil is described by the USGS as Soil Type Ud. This is an Udorthents that has been disturbed, and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 50% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 280'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,000 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 650-foot service road off of Boston Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,917,900
Cost for Pump-storage with tank partially buried - $3,592,700
Cost for Pump-storage with tank completely except for roof - $4,356,000
Cost for Pump-storage with tank completely buried - $4,776,000

This option would either require the elimination of the low service system. An estimated additional cost of $1,343,700 would be incurred with eliminating the low service and redistricting the low service is estimated to be $671,850 (one pumped system required for the existing Clear Hill Tank. This renders it excessively expensive. See Tables 1 through 5 for a more detailed estimate.

Site ID # 14A – Learned Street; Map 47, Lot 55

The site is located in the eastern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 1.17 acres and is currently owned by a private party. **Because of a recent redevelopment of the property, it was removed from consideration.**

The soil is described by the USGS as Soil Type PbD. This is a Paxton fine sandy loam with 15-25% slopes and is very stony. For the analysis of burying the tank we assumed that the soil was approximately 75% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 350'.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 750 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 350-foot service road off of Learned Street.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Not applicable, site removed from consideration

This option would either require the elimination of the low service system. An estimated additional cost of $1,343,700 would be incurred with this option. This renders it excessively expensive. See Tables 1 through 5 for a more detailed estimate.

Site ID # 14B – End of John Street; Map 48, Lot 1

The site is located in the eastern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 34.45 acres and is currently owned by a private property.

The soil is described by the USGS as Soil Type PaB. This is a Paxton fine sandy loam with 3-8% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 360'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 750 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 200-foot service road off of Willow Street.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Pump-storage with tank above ground - $2,609,500
Cost for Pump-storage with tank partially buried - $2,778,500
Cost for Pump-storage with tank completely except for roof - $3,380,500
Cost for Pump-storage with tank completely buried - $3,800,500

This option would either require the elimination of the low service system. An estimated additional cost of $1,343,700 would be incurred with eliminating the low service and redistricting the low service is estimated to be $671,850 (one pumped system required for the existing Clear Hill Tank. This renders it excessively expensive. See Tables 1 through 5 for a more detailed estimate.

Site ID # 15 – 324 Worcester Street. Avalon: Map 25. Lot 4
The site is located in the western portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 19 acres and is currently owned by a private party.

The soil is described by the USGS as Soil Type PcD. This is a Paxton fine sandy loam with 15-25% slopes and is extremely stony. For the analysis of burying the tank we assumed that the soil was approximately 75% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 400'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,125 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 300-foot service road off of Worcester Turnpike.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY
Cost for Pump-storage with tank above ground - $2,614,300
Cost for Pump-storage with tank partially buried - $3,315,900
Cost for Pump-storage with tank completely except for roof - $4,367,700
Cost for Pump-storage with tank completely buried - $4,847,700

Site ID # 16A – EMC Property, Map 6. Lot 3

The site is located in the southwestern portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 69.49 acres and is currently owned by EMC Corporation.

Because of the proximity to a private airfield, Form 7460 was filed with the Federal Aviation Administration (FAA) seeking an exemption for the construction of the tank. Because the airfield is private, FAA is expected to provide an exemption and the tank site would be approved. However, correspondence confirming this assumption has not been received to date.

The soil is described by the USGS as Soil Type PbB. This is a Paxton fine sandy loam with 3-8% slopes and is very stony. For the analysis of burying the tank we assumed that the soil was approximately 75% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 450'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,400 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 2,700-foot service road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Gravity Discharge - $2,242,200
Cost for Pump-storage with tank partially buried - $3,932,600
Cost for Pump-storage with tank completely except for roof - $4,903,300
Cost for Pump-storage with tank completely buried - $5,383,300

Site ID # 16B – EMC Property, Map 11, Lot 2
The site is located in the southwestern portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 21.5 acres and is currently owned by EMC Corporation.

Because of the proximity to a private airfield, Form 7460 was filed with the FAA seeking an exemption for the construction of the tank. Because the airfield is private, FAA is expected to provide an exemption and the tank site would be approved. However, correspondence confirming this assumption has not been received to date.

The soil is described by the USGS as Soil Type CcC. This is a Canton fine sandy loam with 8-15% slopes and is extremely stony. For the analysis of burying the tank we assumed that the soil was approximately 75% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 450'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,525 feet of new piping will be required to provide the required system performance.

Access to the site would be from a 1,500-foot service road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY
Cost for Gravity Discharge - $2,722,200
Cost for Pump-storage with tank partially buried - $4,387,700
Cost for Pump-storage with tank completely except for roof - $5,358,400
Cost for Pump-storage with tank completely buried - $5,838,400

Site ID # 16C – EMC Property. Map 11. Lot 2
The site is located in the southwestern portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 21.5 acres and is currently owned by EMC Corporation.

Because of the proximity to a private airfield, Form 7460 was filed with the FAA seeking an exemption for the construction of the tank. Because the airfield is private, FAA is expected to provide an exemption and the tank site would be approved. However, correspondence confirming this assumption has not been received to date.

The soil is described by the USGS as Soil Type ChC. This is a Chatfield-Hollis-Rock with 3-15% slopes and contains rock outcrops. For the analysis of burying the tank we assumed that the soil was approximately 90% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 450'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 440 feet of new piping will be required to provide the required system performance.

Access to the site would be from an 850-foot service road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY
Cost for Gravity Discharge - $2,225,000
Cost for Pump-storage with tank partially buried - $3,958,200
Cost for Pump-storage with tank completely except for roof - $5,033,300
Cost for Pump-storage with tank completely buried - $5,513,300

Site ID # 16D – EMC Property, Map 26, Lot 9
The site is located in the southwestern portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 142 acres and is currently owned by EMC Corporation.

The soil is described by the USGS as Soil Type ChC. This is a Chatfield-Hollis-Rock with 3-15% slopes and contains rock outcrops. For the analysis of burying the tank we assumed that the soil was approximately 90% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 380'.

Because of the elevation of the site, the cost of constructing a tank at this site does include a booster pumping station. For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is not currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 600 feet of new piping will be required to provide the required system performance.

Access to the site would be from an 800-foot service road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY
Cost for Pump-storage with tank above ground - $2,732,300
Cost for Pump-storage with tank partially buried - $3,754,800
Cost for Pump-storage with tank completely except for roof - $4,708,000
Cost for Pump-storage with tank completely buried - $5,188,000

Site ID # 17A – Pine Hill Road, Primate Center; Map 95, Lot 1

The site is located in the northeastern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 89 acres and is currently owned by a private party.

The soil is described by the USGS as Soil Type PcB. This is a Paxton fine sandy loam with 3-8% slopes and is extremely stony. For the analysis of burying the tank we assumed that the soil was approximately 75% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 460'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 12,000 feet of new piping will be required to provide the required fire flow at the select locations for the gravity discharge alternative and 12,000 feet of new piping if pump-storage is utilized.

Access to the site would be from a 1,520-foot service road off of Pine Hill Road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Gravity Discharge - $3,429,600
Cost for Pump-storage with tank partially buried - $4,794,800
Cost for Pump-storage with tank completely except for roof - $5,625,200
Cost for Pump-storage with tank completely buried - $6,015,200

This option would either require the elimination of the low service system. An estimated additional cost of $1,343,700 would be incurred with this option. This renders it excessively expensive. See Tables 1 through 5 for a more detailed estimate.

Site ID # 17B – Rousseau Property; Map 87, Lot 1

The site is located in the northeastern portion of the Town in the current Low Service area. See Figure 1 for actual location. The site is approximately 122.03 acres and is currently owned by a private party.

The soil is described by the USGS as Soil Type PcD. This is a Paxton fine sandy loam with 15-25% slopes and is extremely stony. For the analysis of burying the tank we assumed that the soil was approximately 75% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 440'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 12,000 feet of new piping will be required to provide the required fire flow at the select locations for the gravity discharge alternative and 12,000 feet of new piping if pump-storage is utilized.

Access to the site would be from a 1,350-foot service road off of Pine Hill Road.

The modeling results and detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Gravity Discharge - $3,395,600
Cost for Pump-storage with tank partially buried - $4,907,100
Cost for Pump-storage with tank completely except for roof - $5,591,200
Cost for Pump-storage with tank completely buried - $5,981,200

This option would either require the elimination of the low service system. An estimated additional cost of $1,343,700 would be incurred with this option. This renders it excessively expensive. See Tables 1 through 5 for a more detailed estimate.

Site ID # 18 – Near Route 495, Map 24, Lot 3
The site is located in the western portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 8.96 acres and is currently owned by a private party.

The soil is described by the USGS as Soil Type Ud. This is an Udorthents that has been disturbed, and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 50% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 500'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 750 feet of new piping will be required to provide the required fire flow at the select locations for the gravity discharge alternative and 750 feet of new piping if pump-storage is utilized.

Access to the site would be from a 450-foot service road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY
Cost for Gravity Discharge - $1,673,800
Cost for Pump-storage with tank partially buried - $2,815,700
Cost for Pump-storage with tank completely except for roof - $3,526,400
Cost for Pump-storage with tank completely buried - $4,006,400

Site ID # 19 – Route 495 Median

The site is located in the western portion of the Town in the current High Service area. See Figure 1 for actual location. The site is currently owned by the Commonwealth of Massachusetts.

The soil is described by the USGS as Soil Type AgB. This is an Agawam fine sandy loam with 3-8% slopes and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 10% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 500'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 1,800 feet of new piping will be required to provide the required fire flow at the select locations for the gravity discharge alternative and 1,800 feet of new piping if pump-storage is utilized.

Access to the site would be from a 450-foot service road.

The detailed cost analysis can be found in Tables 1 through 5

COST SUMMARY

Cost for Gravity Discharge - $2,730,000
Cost for Pump-storage with tank partially buried - $3,557,700
Cost for Pump-storage with tank completely except for roof - $3,990,000
Cost for Pump-storage with tank completely buried - $4,470,000

Site ID # 20 – Route 495 & Route 9 Interchange

The site is located in the western portion of the Town in the current High Service area. See Figure 1 for actual location. The site is located in Westborough and is currently owned by the Commonwealth of Massachusetts.

The soil is described by the USGS as Soil Type Ud. This is an Udorthents that has been disturbed, and is very deep. For the analysis of burying the tank we assumed that the soil was approximately 50% ledge. The complete description from the USGS can be found in Appendix H. The general site elevation is approximately 500'.

Because of the elevation of the site, the cost of constructing a tank at this site does not necessarily need to include a booster pumping station. A 76-foot diameter tank with a gravity discharge at this site would be approximately 78-feet above grade that includes 12-feet allowance for a roof.

For the analysis we also evaluated the partial and full burial requirements for the site. Based on the results of the hydraulic model, a pump-storage system would require the installation of a booster pumping station equipped with pumps capable of providing 1,500 gpm of discharge. The size of the pumping station requires that 3-phase power be available. This site is currently serviced by 3-phase power and the cost analysis includes extending the electrical system to support the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

The dimensions of the tank affect the burial cost. A more efficient size was selected on excavation costs for the buried tank option. For burying a tank, the dimensions changed to 75 feet in diameter and 61 feet high. The cost analysis includes three options for burying a tank:

- Burying half of the tank
- Burying the tank but leaving the roof exposed
- Completely burying the tank and providing internal structural support

Based on the analysis of the hydraulic model it is anticipated that approximately 2,250 feet of new piping will be required to provide the required fire flow at the select locations for the gravity discharge alternative and 2,250 feet of new piping if pump-storage is utilized.

Access to the site would be from a 250-foot service road.

The detailed cost analysis can be found in Tables 1 through 5.

COST SUMMARY

Cost for Gravity Discharge - $1,925,000
Cost for Pump-storage with tank partially buried - $3,067,000
Cost for Pump-storage with tank completely except for roof - $3,777,600
Cost for Pump-storage with tank completely buried - $4,257,600

Site ID # 21 – MWRA Water Storage Tank: Map 49. Lot 9

The scope of work included evaluating the feasibility of connecting the Town water system to the water storage facility at the James Carroll Water Treatment Facility in Southborough owned and operated by the Massachusetts Water Resources Authority (MWRA). See Figure 1 for actual location. The parcel is 159.58 acres and is owned by the MWRA.

PARE attempted to contact the MWRA to discuss the viability of this option. The attempts were unsuccessful. For the sake of our work we assumed that it was a valid option and proceeding with the development of a cost opinion.

Because the overflow elevation of the facility is below the Southborough hydraulic gradient, pumping would be required. Additional costs would be incurred associated with the pump station including the potential for, access, property acquisition, power costs and other system improvements. It is assumed that the pumping station would be located at the existing site of the Boland Pumping Station. This site is currently serviced by 3-phase power. We have also included an annual cost to operate and maintain the pump station of 5%.

Based on the analysis of the hydraulic model it is anticipated that approximately 5,000 feet of new piping will be required to connect to the existing tank.

The detailed cost analysis can be found in Tables 1 through 5.

COST SUMMARY

Cost for Pump-storage with existing tank - $1,910,100

Site ID # 22 – Boland Pump Station Expansion; Map 61, Lot 3
The site is located in the western portion of the Town in the current High Service area. See Figure 1 for actual location. The site is approximately 8.82 acres and is currently owned by the MWRA.

The scope of work included the scenario of not providing any additional storage and only meeting the fire flow demands and system pressure through the expansion of the pumping capabilities of the Boland Pump Station. To meet the demand, the capacity of the station would have to be increased to 3,500 gallons per minute. For the analysis we assumed that the MWRA system has the ability to provide 3,500 gpm without negatively impacting their system.

This site is currently serviced by 3-phase power and the cost analysis includes upgrading the electrical system to support the increased size of the pumping station. We have also included an annual cost to operate and maintain the pump station of 5%.

Based on the analysis of the hydraulic model it is anticipated that approximately 13,600 feet of new piping will be required to provide the reduce pressure to an acceptable range (< 150 psi) within the system. According to the hydraulic model, approximately 20% of the northwestern part of the service area would exhibit pressures in excess of 100 psi. Additional costs ($100 per connection) would be incurred to reduce domestic pressures below 100 psi, but they were not included at this time.

Access to the site would be from the existing service road.

The detailed cost analysis can be found in Tables 1 through 5.

COST SUMMARY
Cost for Pump-storage with existing tank - $3,810,400

Although the proposed improvement meets the fire flow demands, it does not provide for additional storage discussed in out letter report of September 24, 2007.

APPENDIX C
CORRESPONDENCE

PARE
CORPORATION

MEMORANDUM

DATE: January 3, 2008

TO: FAA Obstruction Evaluations

CC: Karen Galligan, Southborough
New England Regional Office

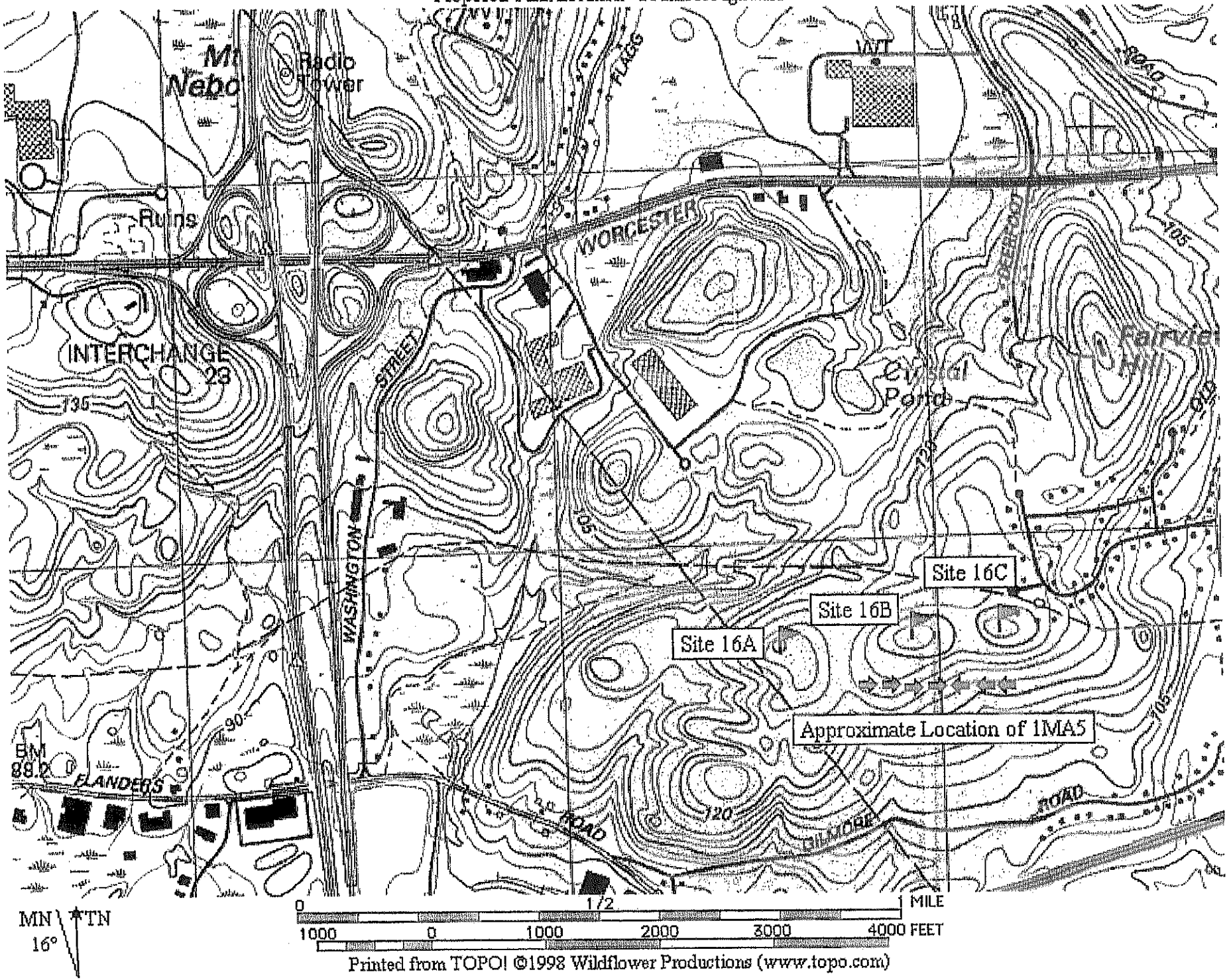
FROM: Robert P. Sims, P.E., PARE RS

RE: **Form 7460-1 for Three Sites**
Proposed Tank Location
PARE Project No. 07089.03

Pare Corporation (PARE) has been retained by the Town of Southborough Department of Public Works Department to investigate potential locations for a new water storage facility. A few of the locations are in the vicinity of an Unknown Field Airport identified by the FAA as 1MA5 at 42-16-44.35N 071-32-52.233W in the southwest portion of Southborough. The website www.airnav.com lists the estimated elevation as 432 ft. The proposed overflow elevation of the 2 million gallon water storage facility is 515.0 feet. The roof would add approximately 10 more feet to create an overall elevation of 525.0 feet.

Please find enclosed forms 7460-1 for the three sites and a map indicating the proposed locations of the tank. Because we are in the site evaluation phase, we are gathering information to rank the viability of the various sites. Does the proximity to this airport impinge on the ability of the Town to locate a tank at these sites? If so, what restrictions or design issues would be reasonable to include in our evaluation?

Proposed Tank Location - Southborough MA



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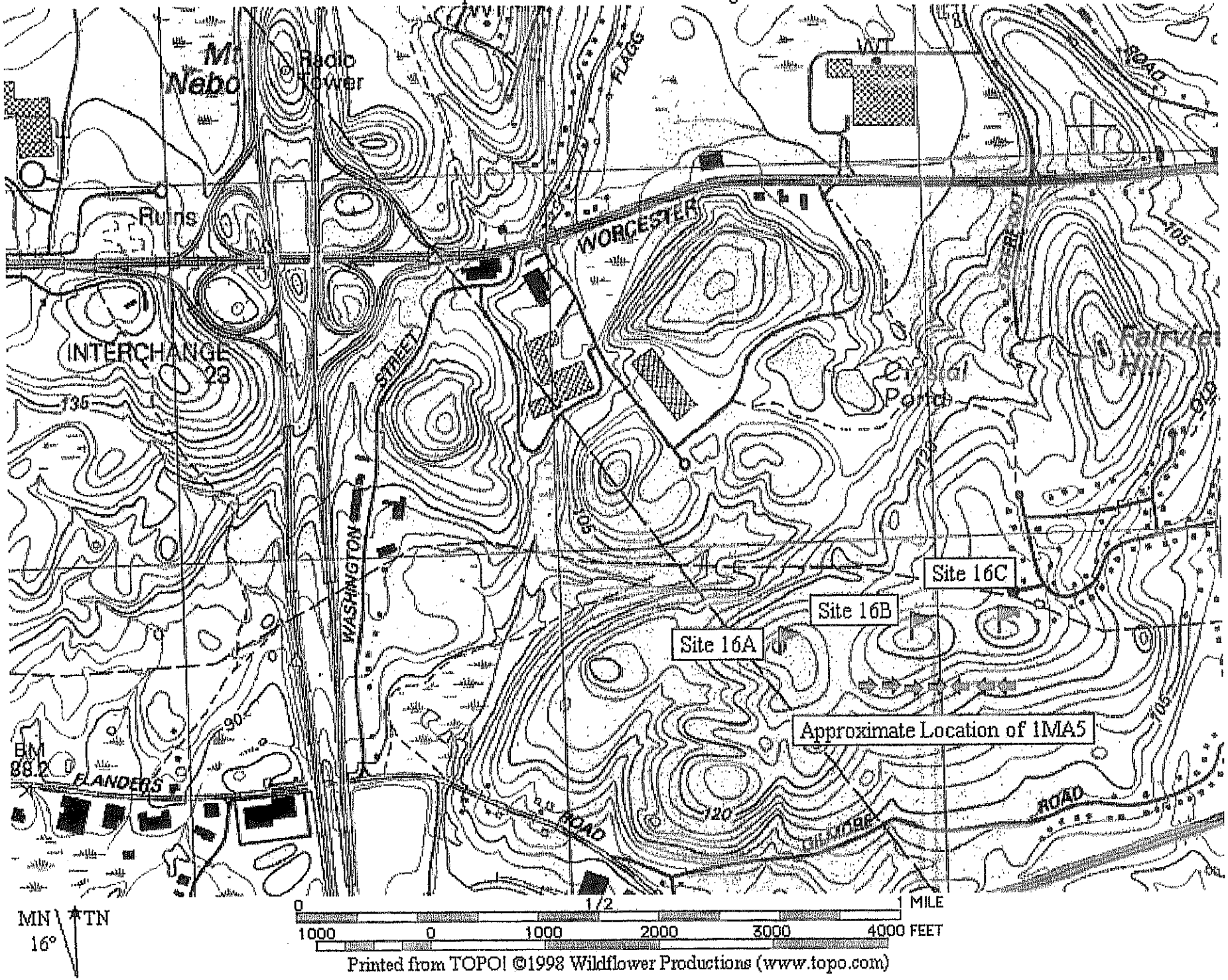
Proposed Tank Location - Southborough MA



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Please Type or Print on This Form

Form Approved OMB No. 2120-0001

U.S. Department of Transportation
Federal Aviation Administration

Failure To Provide All Requested Information May Delay Processing of Your Notice

Notice of Proposed Construction or Alteration

FOR FAA USE ONLY
Aeronautical Study Number
- - -

1. Sponsor *(person, company, etc. proposing this action)* :
Attn. of: Town of Southborough DPW
Name: Ms. Karen Galligan
Address: 147 Cordaville Road
City: Southborough State: MA Zip: 01772
Telephone: 508-485-1210 Fax:

2. Sponsor's Representative *(if other than #1)* :
Attn. of: Pare Corporation
Name: Robert P. Sims, P.E.
Address: 8 Blackstone Valley Place
City: Lincoln State: RI Zip: 02865
Telephone: 401-334-4100 Fax: 401-334-4108

3. Notice of: ☒ New Construction ☐ Alteration ☐ Existing

4. Duration: ☒ Permanent ☐ Temporary (months, days)

5. Work Schedule: Beginning March 2009 End Aug 2009

6. Type: ☐ Antenna Tower ☐ Crane ☐ Building ☐ Power Line
☐ Landfill ☒ Water Tank ☐ Other

7. Marking/Painting and/or Lighting Preferred:
☐ Red Lights and Paint ☐ Dual - Red and Medium Intensity White
☐ White - Medium Intensity ☐ Dual - Red and High Intensity White
☐ White - High Intensity ☒ Other no preference

8. FCC Antenna Structure Registration Number *(if applicable)*:

9. Latitude: 42° 16' 45.____"

10. Longitude: 71° 33' 04.____"

11. Datum: ☒ NAD 83 ☐ NAD 27 ☐ Other

12. Nearest: City: Southborough State: MA

13. Nearest Public-use (not private-use) or Military Airport or Heliport:
Marlboro Airport

14. Distance from #13. to Structure: 4.2 miles

15. Direction from #13. to Structure: 024

16. Site Elevation *(AMSL)*: 440 ft.

17. Total Structure Height *(AGL)*: 85 ft.

18. Overall height (#16. + #17.) *(AMSL)*: 525 ft.

19. Previous FAA Aeronautical Study Number (if applicable):

20. Description of Location: (Attach a USGS 7.5 minute Quadrangle Map with the precise site marked and any certified survey.)
See Attached for Site 16A

21. Complete Description of Proposal:

The Town is evaluating sites for the potential construction of a 2 million gallon water storage tank. The sites are near a PRIVATE airfield (1MA5). The input from the FAA will assist the town in prioritizing their site evaluation.

Frequency/Power (kW)	

Notice is required by 14 Code of Federal Regulations, part 77 pursuant to 49 U.S.C., Section 44718. Persons who knowingly and willingly violate the notice requirements of part 77 are subject to a civil penalty of $1,000 per day until the notice is received, pursuant to 49 U.S.C., section 46301 (a).

I hereby certify that all of the above statements made by me are true, complete, and correct to the best of my knowledge. In addition, I agree to mark and/or light the structure in accordance with established marking and lighting standards as necessary.

Date	Typed or Printed name and Title of Person Filing Notice	Signature

Please Type or Print on This Form

Form Approved OMB No. 2120-0001

U.S. Department of Transportation
Federal Aviation Administration

Failure To Provide All Requested Information May Delay Processing of Your Notice

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Address: 147 Cordaville Road
City: Southborough State: MA Zip: 01772
Telephone: 508-485-1210 Fax:

2. Sponsor's Representative *(if other than #1)* :
Attn. of: Pare Corporation
Name: Robert P. Sims, P.E.
Address: 8 Blackstone Valley Place
City: Lincoln State: RI Zip: 02865
Telephone: 401-334-4100 Fax: 401-334-4108

3. Notice of: ☒ New Construction ☐ Alteration ☐ Existing

4. Duration: ☒ Permanent ☐ Temporary (months, days)

5. Work Schedule: Beginning March 2009 End Aug 2009

6. Type: ☐ Antenna Tower ☐ Crane ☐ Building ☐ Power Line
☐ Landfill ☒ Water Tank ☐ Other

7. Marking/Painting and/or Lighting Preferred:
☐ Red Lights and Paint ☐ Dual - Red and Medium Intensity White
☐ White - Medium Intensity ☐ Dual - Red and High Intensity White
☐ White - High Intensity ☒ Other no preference

8. FCC Antenna Structure Registration Number *(if applicable)*:

9. Latitude: 42° 16' 46.____"

10. Longitude: 71° 32' 48.____"

11. Datum: ☒ NAD 83 ☐ NAD 27 ☐ Other

12. Nearest: City: Southborough State: MA

13. Nearest Public-use (not private-use) or Military Airport or Heliport:
Marlboro Airport

14. Distance from #13. to Structure: 4.2 miles

15. Direction from #13. to Structure: 024

16. Site Elevation *(AMSL)*: 450 ft.

17. Total Structure Height *(AGL)*: 75 ft.

18. Overall height (#16. + #17.) *(AMSL)*: 525 ft.

19. Previous FAA Aeronautical Study Number (if applicable):

20. Description of Location: (Attach a USGS 7.5 minute Quadrangle Map with the precise site marked and any certified survey.)
See Attached for Site 16B

21. Complete Description of Proposal:

The Town is evaluating sites for the potential construction of a 2 million gallon water storage tank. The sites are near a PRIVATE airfield (1MA5). The input from the FAA will assist the town in prioritizing their site evaluation.

Frequency/Power (kW)	

Notice is required by 14 Code of Federal Regulations, part 77 pursuant to 49 U.S.C., Section 44718. Persons who knowingly and willingly violate the notice requirements of part 77 are subject to a civil penalty of $1,000 per day until the notice is received, pursuant to 49 U.S.C., section 46301 (a).

I hereby certify that all of the above statements made by me are true, complete, and correct to the best of my knowledge. In addition, I agree to mark and/or light the structure in accordance with established marking and lighting standards as necessary.

Date	Typed or Printed name and Title of Person Filing Notice	Signature

Please Type or Print on This Form

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Attn. of: Pare Corporation
Name: Robert P. Sims. P.E.
Address: 8 Blackstone Valley Place
City: Lincoln State: RI Zip: 02865
Telephone: 401-334-4100 Fax: 401-334-4108

3. **Notice of:** ☒ New Construction ☐ Alteration ☐ Existing

4. **Duration:** ☒ Permanent ☐ Temporary (months, days)

5. **Work Schedule:** Beginning March 2009 End Aug 2009

6. **Type:** ☐ Antenna Tower ☐ Crane ☐ Building ☐ Power Line
☐ Landfill ☒ Water Tank ☐ Other

7. **Marking/Painting and/or Lighting Preferred:**
☐ Red Lights and Paint ☐ Dual - Red and Medium Intensity White
☐ White - Medium Intensity ☐ Dual - Red and High Intensity White
☐ White - High Intensity ☒ Other no preference

8. **FCC Antenna Structure Registration Number** *(if applicable)*:

9. **Latitude:** 42° 16' 46." N

10. **Longitude:** 71° 32' 39." W

11. **Datum:** ☒ NAD 83 ☐ NAD 27 ☐ Other

12. **Nearest:** City: Southborough State: MA

13. **Nearest Public-use** (not private-use) or Military Airport or Heliport:
Marlboro Airport

14. **Distance from #13. to Structure:** 4.2 miles

15. **Direction from #13. to Structure:** 024

16. **Site Elevation** *(AMSL)*: 450 ft.

17. **Total Structure Height** *(AGL)*: 75 ft.

18. **Overall height (#16. + #17.)** *(AMSL)*: 525 ft.

19. **Previous FAA Aeronautical Study Number** (if applicable):

20. **Description of Location:** (Attach a USGS 7.5 minute Quadrangle Map with the precise site marked and any certified survey.)
See Attached for Site 16C

21. **Complete Description of Proposal:**

The Town is evaluating sites for the potential construction of a 2 million gallon water storage tank. The sites are near a PRIVATE airfield (1MA5). The input from the FAA will assist the town in prioritizing their site evaluation.

Frequency/Power (kW)	

Notice is required by 14 Code of Federal Regulations, part 77 pursuant to 49 U.S.C., Section 44718. Persons who knowingly and willingly violate the notice requirements of part 77 are subject to a civil penalty of $1,000 per day until the notice is received, pursuant to 49 U.S.C., section 46301 (a).

I hereby certify that all of the above statements made by me are true, complete, and correct to the best of my knowledge. In addition, I agree to mark and/or light the structure in accordance with established marking and lighting standards as necessary.

Date	Typed or Printed name and Title of Person Filing Notice	Signature

Robert P. Sims

07089.03

From: cliff.vacirca@faa.gov
Sent: Wednesday, January 02, 2008 9:14 AM
To: Robert P. Sims
Subject: Re: Question about Engineering

Hi Robert,
Sorry for the late response, I have been out of the office. Please feel free to contact me at 781-238-7627
Cliff

rsims@parecorp.com

12/18/2007 03:36 PM

To Cliff Vacirca/ANE/FAA@FAA
cc
Subject Question about Engineering

This email was sent through the Federal Aviation Administration's public website.
You have been contacted via an email link on the following page:
http://www.faa.gov/airports_airtraffic/airports/regional_guidance/new_england/construction/index.cfm

Message:

Mr. Vacirca,
We are evaluating sites for a proposed water tank in Southborough MA. Three of the sites are near 1MA5. Could you please contact me regarding the impact of the airport to our evaluation.

Robert

Robert P. Sims

From: Hodgson, Chris [chodgson@Natgun.com]
Sent: Monday, December 10, 2007 8:57 AM
To: Robert P. Sims
Subject: Southborough Pricing

~~07073.00~~
07089.03

Hi Robert,

Here are the current estimated tank prices for Southborough. These are for standard Natgun tanks, in accordance with AWWA D110, Type III, with floor, footings, walls, concrete dome (or flat slab where shown), basic piping and accessories. Site work and additional work are extra. These are for comparison purposes for the various site options. The prices are for 2008 construction and are conservative at this time.

1.5 MG tank with concrete dome roof. (all tanks can be exposed or partially buried. Full bury to the top of the wall, for tanks up to and including 30 ft swd)

113 ft diam x 20 ft swd, $865,000
101 ft diam x 25 ft swd, $840,000
92 ft diam x 30 ft swd. $835,000
80 ft diam x 40 ft swd, $825,000
72 ft diam x 50 ft swd, $825,000
65 ft diam x 60 ft swd, $880,000
60 ft diam x 70 ft swd, $975,000
58 ft diam x 75 ft swd, $1,025,000
56 ft diam x 80 ft swd, $1,085,000
55 ft diam x 85 ft swd, $1,150,000

1.5 MG tank with column supported flat slab roof. (for full bury condition)

113 diam x 20 ft swd, $1,100,000

I will check back with you and discuss.

Chris

Christopher C. Hodgson
Natgun Corporation
781-246-1133-Office
617-510-0320-Cell
chodgson@natgun.com

;

Attention:

The information contained in this message and or attachments is intended only for the person or entity to which it is addressed and may contain confidential and/or privileged material. Any review, retransmission, dissemination or other use of, or taking of any action in reliance upon, this information by persons or entities other than the intended recipient is prohibited. If you received this in error, please contact the sender and delete the material from any system and destroy any copies.

Any views expressed in this message are those of the individual sender, except where the message states otherwise and the sender is authorized to state them to be the views of any such entity.

Thank You.

19089.03

Robert P. Sims

From: Brian Ballantine [bballantine@southboroughma.com]
Sent: Friday, December 07, 2007 10:51 AM
To: Robert P. Sims
Subject: RE: Tax Liens & Water Tanks

Hi Robert - Please see below....

29-36	12,535.35
75-27	45,478.68
46-4	4,330.81
34-29	0
71-1A	0

Hope this helps.

-----Original Message-----
From: Robert P. Sims [mailto:RSims@parecorp.com]
Sent: Friday, December 07, 2007 10:02 AM
To: Brian Ballantine
Cc: Karen Galligan
Subject: Tax Liens & Water Tanks

Mr. Ballantine,
I sent the following e-mail to the Town Acct. and I think I should have sent it to you.

We are working with Karen @ DPW on a water tank siting study. One of the options would be to foreclose or buy a property with a tax lien to reduce the cost of the land purchase. We have identified a few sites and would like to know how much is owed so that the amount can be deducted from the estimated assessed value we obtained from the assessor. The properties are:
1. 60 Breakneck Hill Road; Map 29 Lot 36
2. 88 Newton Street; Map 75 Lot 27
3. 55-57 Boston Road Map 46 Lot 4

There are two that I'm not sure if taxes are owed, if they are could you please provide that too?
4. Open Land; Map 34 Lot 29
5. Open Land; Map 71 Lot 1A

Thank you very much for the help.

Robert

Robert P. Sims, P.E.
Managing Engineer
Pare Corporation
8 Blackstone Valley Place
Lincoln, RI 02865
401-334-4100
401-334-4108 fax
508-320-4767 cell

"Look not mournfully into the past; it returns no more: wisely improve the present, and go forth into the shadowy future without fear and with a strong heart"...Ralph Waldo Emerson.

Robert P. Sims

07089.03

From: Dustin Diedrich [ddiedrich@engineeredfluid.com]
Sent: Thursday, December 06, 2007 4:32 PM
To: timbezler@att.net; Robert P. Sims
Subject: RE: Southborough

Mr. Sims,

Please find the following ballpark cost estimations as requested. Be advised that I got together with a couple of people and based these estimates on HP and experience alone. We figured two pumps in each case at their respective condition listed below. We can work up a good estimate once the pump conditions are known.

	1000 GPM	1500 GPM	2000 GPM
H<150	$200,000	$275,000	$325,000
150<H<200	$225,000	$310,000	$375,000
200<H<250	$260,000	$360,000	$440,000

Please let me know if this did not come through clearly.

Thanks,
Dustin Diedrich
EFI Applications
618-533-1351

From: timbezler@att.net [mailto:timbezler@att.net]
Sent: Monday, December 03, 2007 1:38 PM
To: Robert P. Sims
Cc: Dustin Diedrich
Subject: Re: Southborough

Robert,

I'm on vacation this week, but I copied Dustin at EFI. I'll call you on 12/10.

Regards, Tim

---------- Original message from "Robert P. Sims" <RSims@parecorp.com>: ----------

Tim,
I know I mentioned this but Southborough MA is about to give us an assignment for evaluating pumped storage. We are currently finalizing a hydraulic model, but I expect the proposed size will be 1,000 to 2,000 gpm with TDH's from 150' to 250'. I'd like to be able to generate a cost matrix based on flow and head. This would ease our work to create an evaluation of the 24 sites that they have proposed.

I was thinking something along the lines of

	1000	1500	2000

h<150	$	$	$
150<h<200	$	$	$
200<h<250	$	$	$

Please give me a call or let's arrange for a visit.

Robert

Robert P. Sims, P.E.
Managing Engineer
Pare Corporation
8 Blackstone Valley Place
Lincoln, RI 02865
401-334-4100
401-334-4108 fax
508-320-4767 cell

"Look not mournfully into the past; it returns no more: wisely improve the present, and go forth into the shadowy future without fear and with a strong heart"...Ralph Waldo Emerson.

-----Original Message-----
From: Tim Bezler [mailto:timbezler@att.net]
Sent: Tuesday, November 27, 2007 2:20 PM
To: Robert P. Sims
Subject: KCWA Mishnock Tank BPS

Bob,

Attached are performance curves for EFI's initial pump selections for the three conditions you requested. Ingersoll Dresser vertical turbine pumps were selected because of their high efficiency, but this could change depending on customer preference and eventual chosen conditions:

- 1000 GPM @ 180' TDH (3 stage, 75 HP motor)
- 1500 GPM @ 180' TDH (4 stage, 100 HP motor)
- 2000 GPM @ 180' TDH (4 stage, 125 HP motor)

Please contact me with any questions.

Sincerely,

Tim Bezler - Connecticut Office
David F. Sullivan & Associates
178 Glengarry Road
Fairfield, CT 06825
203-373-9261 Fax 9262
Cell 203-731-4318
<<...>>

This message contains confidential information and is intended only for the individual named. If you are not the named addressee you should not disseminate, distribute or copy this e-mail. Please notify the sender immediately by e-mail if you have received this e-mail by mistake and delete this e-mail from your system. E-mail transmission cannot be guaranteed to be secure or error-free as information could be intercepted, corrupted, lost, destroyed, arrive late or incomplete, or contain viruses. The sender therefore does not accept liability for any errors or omissions in the contents of this

APPENDIX D

JANUARY 2007 H_2O REPORT

H_2O ENGINEERING CONSULTING ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS

TOWN OF
SOUTHBOROUGH

Department Public Works
Water Division

TOWN OF

SOUTHBOROUGH

Department Public Works
Water Division

WATER DISTRIBUTION SYSTEM

STUDY REPORT

2007

Prepared by:
H_2O Engineering Consulting Associates, Inc.
2 Alfred Circle, Bedford, MA. 01730
January 15, 2007

H_2O Engineering Consulting Associates, Inc.
水利工程顧問
2 ALFRED CIRCLE * BEDFORD, MA 01730
781-275-7714 (TELEPHONE) H2OENG275@AOL.COM 781-275-7604 (FAX)

January 15, 2007

Ms. Karen Galligan
Town of Southborough
Department of Public Works
147 Cordaville Road
Southborough, MA 01772

Dear Ms. Galligan:

In accordance with our agreement, H2O Engineering Consulting Associates Inc., is pleased to submit the attached report entitled "Water Distribution System Study Report" for the Town of Southborough, Massachusetts. This report includes the evaluation of existing system facilities, estimates of existing and projected future system requirements and recommendations relative to system improvements.

The report contains a Water System Master Plan and three Phases of recommendations for the Town to improve the existing distribution system to meet the requirements. The cost estimations for Phase I and Phase II improvements are also included in the report.

H_2O Engineering Consulting Associates, Inc. appreciates the opportunity to serve the Town of Southborough. We would to thank you for your assistance in providing data and information relative to the water system and its operation.

Very truly yours,

T. T. Chiang

Edward T.T. Chiang, Ph.D., P.E.
President

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Appendix

Recommended Water Distribution System Map

I. INTRODUCTION

The Town of Southborough's Water Supply System Master Plan needs to be updated and revised due to recent changes put upon the system.

The Town of Southborough has experienced more growth in recent years than was expected. Its water demand is growing at a faster rate than population growth. This is due to many large homes being constructed in the Town of Southborough and those households use much more water per capita than the average home. With the fast growth and the change of demand patterns, a review of the projected demand and the water supply system has become necessary.

In addition, the Massachusetts Water Resources Authority's (MWRA) Metro West Water Supply Tunnel (MWWST) project has constructed some water main extensions to an area in Southborough where the private wells may be impacted by the tunnel project. This project enables those private well users to connect to the Town of Southborough's water supply system.

These water main extensions have not only provided public water supply to some residents who currently are using private wells, but also increased the available land along the water main route to be developed because the water supply is available and ready to use.

This report includes: population, water consumption and growth trends. A Distribution System analysis by digital computer to identify system weaknesses under present demands and projected future demands is also included. The necessary system improvements have been evaluated and a program of improvements formulated, identifying the pipe reinforcements and extensions required; the storage facilities to be added and pump station expansions.

These improvements have been grouped into two categories to indicate their urgency: Phase I (immediate, includes some improvements needed by 2010) and Phase II (improvements needed by 2015).

II. POPULATION

A. Past and Present

In general, water consumption increases with population growth, but in recent years, the rate of growth of water consumption does not correspond to the rate of population growth. This is especially true in the so-called "Nine Bedroom Communities", such as the Town of Southborough.

Population growth is usually affected by the regional economic development, land available, taxes, industrial presence, transportation convenience, etc.

The Town's population history between 1975 and 2005 is listed in Table 1. Between 1975 and 1990 the population of Southborough grew very slowly with no significant changes and had experienced some negative growth in 1978 and 1990. From 1985 to 1994, the population increased steadily at about 1% annually with a short no growth period from 1989 to 1991. From 1994 to 1997, the population increased from 6,972 to 7,768, an 11.42% increase in four years which is more than the previous decade's growth. From 1997 to 2005, the population increased from 7,768 to 9,580, a 23.3% increase in less than 10-years. Currently, the new subdivisions and new homes being built in the Town indicate this fast growth is slowing down but will continue.

TABLE 1 - Past, Present and Estimated Future Population.

Year	Population
1975	6,326
1976	6,324
1977	6,377
1978	6,299
1979	6,389
1980	6,412
1981	6,421
1982	6,392
1983	6,429
1984	6,405
1985	6,334
1986	6,431
1987	6,444
1988	6,534
1989	6,636
1990	6,628
1991	6,657
1992	6,783
1993	6,893
1994	6,972
1995	7,297
1996	7,432
1997	7,768
2000	8,781
2005	9,580
2010	10,700*
2020	11,800*
2030	12,500*

*: estimated

B. Population Projection

In order to analyze the water supply system and to determine the future water consumption, the future population of the area to be served must be established for the target year. This is usually obtained by using selected mathematical techniques to analyze previous figures for population. This, however, is a very unreliable method, as the future population is a function of many unpredictable and indiscernible events.

To minimize the possibility of error, therefore, the future population for the Town of Southborough was estimated by considering only those areas of the Town considered buildable. Then, the zoning regulations which applied to each of these areas were considered to determine the maximum number of dwellings which could be built in the Town under current zoning laws.

It is a well known fact that communities surrounding large metropolitan areas always grow with the large metropolitan, especially for those so-called "Nine Bedroom Communities". As less land becomes available, the growth rate slows down until the area has met its "saturated" or "ultimate" density. When this density will occur in Southborough is impossible to predict; however, the year 2030 is used in this report.

The Town of Southborough is located between two major large metropolitan areas, Boston and Worcester; with interstate 495 and the Massachusetts Turnpike passing through the Town. With their excellent public services and school system, and land available, the Town of Southborough has experienced steady growth through out the Nineties even when other surrounding communities' growth had slowed down due to the Massachusetts economical downturn during the late Eighties and early Nineties.

The saturation population for Southborough was estimated to be approximately 12,500. It was further assumed that this figure will be reached shortly after the year 2030. Table 1 shows the Town's population history, and projected population. Currently, the Town of Southborough does not have a public sewer system. If public sewer were available, the population could increase when currently un-buildable land would become buildable.

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III. EXISTING SOURCES OF SUPPLY

A. Sources of Water Supply and Pumping Facilities

At present the Town of Southborough obtains its water from the Massachusetts Water Resources Authority's Metro-West Water Supply Tunnel (MWWST) through two pump stations, the Thomas J. Boland pump station and the Arthur L Hosmer pump station (see Table 2). These two pump Stations used to obtain their supply from the Hultman Aqueduct until the completion of the MWWST. Based on the MWRA supply system, the Town of Southborough can obtain its source of supply from either the MWWST or the Hultman Aqueduct. But the quantity of water withdrawn will always be governed by a contract between the Town of Southborough and the MWRA which is renewed periodically. Currently, the two pump stations can pump 2,000 gallons per minute into the Southborough water supply piping system. The 2,000 gpm rate is higher than the allowed contract withdrawal amount (Average 1,400 gpm approximately) if the pumps were operated 24 hours per day. The following are brief description of these two pump stations.

1. The Thomas J. Boland Pump Station is located northwest of the Town, off Northborough Road. This pump station has two 50-horse power Gould pumps and has a capacity of 1,000 gallons per minute (gpm). It supplies the water for the west and southwest areas of the Town and fills the Fiddlers Green Reservoir which is located on Tara Road.

2. The Authur L. Hosmer Pump Station, built in 1977, is located in the northeast quarter of the Town. This pump station was connected to the MWRA supply system near the Shaft No.3 of the MWRA Hultman Aqueduct. A new supply line from the MWRA's MWWST has been constructed to connect to the suction line of the Hosmer pump station. It is equipped with one 60-horse power and one 40-

horse power Marthon electric pumps with a capacity of approximately 1,000 gallons per minute (gpm). This pump station serves the remaining sections of Town and fills the Clear Hill and the Oak Hill Stand Pipes.

In addition to the MWRA water source, some areas of the Town of Southborough rely on private wells. These private well users have no connection to the Town's water system; however, the Town's water system may have to be expanded to supply some of the areas if these private wells become inadequate. For this purpose, demand in some locations has been scaled up in the computer model to represent these likely future connections.

Table 2 – Existing Pumping Facilities in Southborough, MA

Pump Station	Boland	Hosmer
Location	Northborough Road	Shaft No.3, MWRA Hultman Aqueduct
Source	MWRA transmission	MWRA transmission
No. of pump	2	2
Capacity & Head	pump #1 – 550 gpm @3560 rpm, TDH 275 ft pump #2 – 550 gpm @3500 rpm, TDH 275 ft	pump #1 – 600 gpm @1750 rpm, TDH 250 ft pump #2 – 400 gpm @3500 rpm, TDH 250 ft

B. Storage Facilities

The Town of Southborough has three water storage facilities (see Table 3), the Fiddlers Green Reservoir, the Clear Hill Stand Pipe and the Oak Hill Stand Pipe. The total storage capacity of these facilities is 2 million gallons. The Fiddlers Green Reservoir has the highest overflow elevation. A physical description of the three (3) storage facilities follows.

Table 3 - Existing Storage Facilities in Southborough, MA

Name	Fiddlers Green Reservoir	Clear Hill Stand Pipe	Oak Hill Stand Pipe
Diameter (ft)	67	40	25
Height (ft)	48	42.5	75
Capacity (gallons)	1,300,000	460,000	275,000
Overflow Elev.	515.0	493.3	492.7
Base Elev.	467	451	418
High Water Elev.	511	489.5	480
High water Level Capacity (gallons)	1,192,000	362,000	264,000
Telemeter Gradient	511 ft.	486.6 ft.	487 ft.
Normal daily Min.	40 ft. 1,083,000 gallons	28.5 ft. 268,000 gallons	62 ft. 227,000 gallons

1. The Fiddlers Green Reservoir is located on Tara Road in the northwest section of the Town. It is about 7,500 feet south of the Boland Pump Station. This reservoir's overflow elevation is at 515.0 feet USGS mean sea level and has an approximate storage capacity of 1.3 million gallons. The water main connecting from the Boland Pump Station to the Tara Reservoir is a 12-inch pipe.

2. The Clear Hill Stand Pipe, located about 4,700 feet northwest of Hosmer Pump Station, is connected to the pump station by 10-inch and 12-inch pipes. Its overflow elevation is 493.3 ft. USGS mean sea level and its storage capacity is about 0.46 million gallons.

3. The Oak Hill Stand Pipe is located about 8,000 feet south of Hosmer Pump Station. This stand pipe is filled by the Hosmer Pump Station through the water mains on Central Street and Oak Hill Road. The water main which fills the Oak Hill Stand Pipe was upgraded to a 12-inch main at the end of 1993, except for a section of the old 8-inch pipe from Boston Road to Learned Street and a piece under the railroad. The Oak Hill Stand Pipe's capacity is about 0.28 million gallons with an overflow at 492.7 ft USGS mean sea level. Due to its limited storage capacity, this stand pipe will only help the water demand in the local area.

Prior to 1990, the water distribution system had a small elevated tank at Atwood Street. This tank had a storage capacity of 150,000 gallons. The Water Division removed this tank in 1990 because it was not cost effective to maintain such an old, small elevated tank.

C. Distribution System

Southborough's water distribution system has more than 62 miles of pipeline in the system. Pipe sizes range from 6 to 12 inches in diameter, except for a short section of 16-inch from the MWRA Hultman Aqueduct shaft No.3 to Hosmer Pump Station. Pipe materials include unlined cast iron, cement-lined cast iron, cement-lined ductile iron, and asbestos-cement. Geographically the Southborough distribution system can be separated into three sections by using Route 9 and Route 90 as dividers; north, middle and south. Both the Boland and Hosmer Pump Stations are located in the north and raise the system pressure in that section. The water is introduced into the system in the north section and flows south.

1. The northern section, north of Route 9, includes Southborough's downtown area and includes more than half of the service area of the Town. Although the Sudbury Reservoir occupies approximately 1/5 of the area in this section, it has the highest demand in the distribution system. The Boland and Hosmer Pumping Stations and the Clear Hill Stand Pipe are all located in this area; therefore, the

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water service to this northern section is adequate.

2. The middle section includes the area between Route 9 and Route 90. It has two high ground areas, e.g., Fair View Hill on the west and Oak Hill on the east. The low area is a valley in the vicinity of Cordaville Road. The Oak Hill Stand Pipe feeds the easterly high point. The Fiddlers Green Reservoir feeds the westerly high point. The water pressure and volume of flow in this section of the Town are marginally adequate. The service pressure for some of the high ground areas is low even when the system pressure reaches its maximum. This is because the ground elevation is too high to be served by the system.

3. The southern section, south of Route 90, is the furthest area from the storage facilities and pump stations. The Town's distribution system map indicates only three 8-inch water mains cross Route 90 and continuing to the south, until recently when a 12-inch main was installed from Walnut Drive to Oregon Road. It appears that Route 90 becomes a bottleneck in servicing the southern section of the Town. Fortunately, this section of the Town does not have high ground, therefore its' domestic water supply is adequate but, the large fire flow needed at the Finn School area is not adequate.

The Town of Southborough has more than its share of main highways, railroads, large storage reservoirs and aqueducts crossing through the Town. It is difficult and costly to manage a complex water supply network like this. Some of the problems in this system include undersized pipes running under railroads, Massachusetts Turnpike (Route 90), Route 9 and crossing a water body and aqueduct. Because of their location, the pipes referenced here are costly to replace, besides the cost, it is difficult to obtain the permits required to install these new pipes. There are many dead ends in the system, and most of them are difficult to eliminate.

In 1997, the MWRA through the Department of Public Works of the Town of Southborough installed water mains along Sears Road, Valley Road, Bigelow Road, Pinehill Road, Johnson Road and Main Street. Most of these areas' residents are using private wells.

IV. WATER REQUIREMENT

A. General

In order to predict the future water supply needs of a community it is necessary to take into account the trends in the use of water as well as the character of the community itself.

Water demand is the sum of water consumed by customers and lost through the water distribution system, such as fire protection, hydrant flushing and testing, and leakage. In a non-industrial community there are two major types of metered water consumers; domestic and commercial. Within a community, the domestic use of water will vary depending on lot size, water cost, family income and the adequacy of the distribution system. The amount of water consumed by commercial users is dependent upon the type of business.

The Town of Southborough's water source is metered from the MWRA. Therefore, the total water demand in this system is based on the total metered water volume from the Town's pump stations. The historical records of the yearly volumes of water pumped out from MWRA's aqueduct are shown in Figure 1.

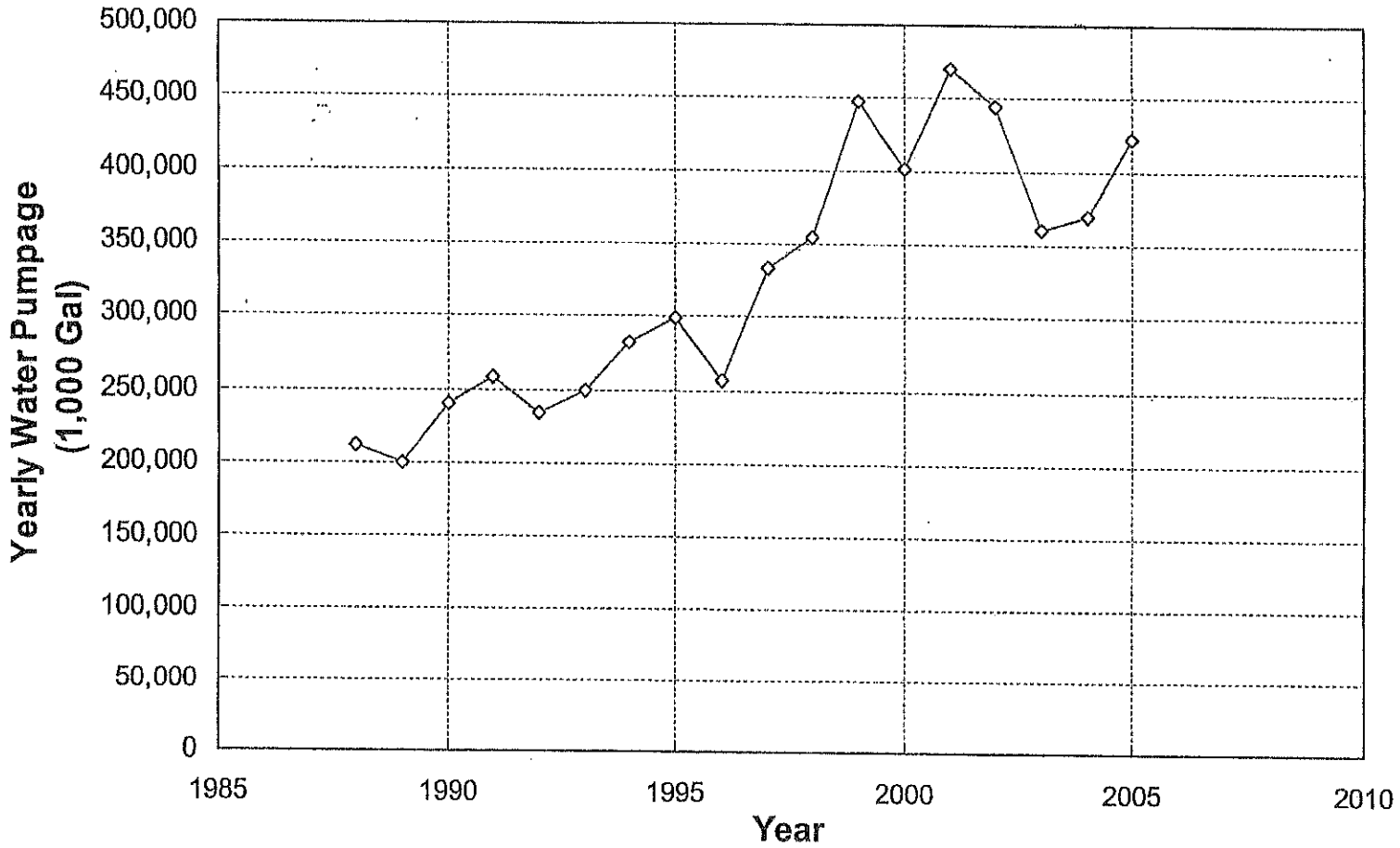
B. Water Demand

Presently the Town of Southborough accommodates very few industrial and commercial properties in addition to its residential water consumers. The Southborough Water Department records indicate that the total annual pumpage has generally increased over the years Figure 2 shows the past, present and future annual pumpage.

Average Day Demand

The 2005 average daily water consumption for the Town of Southborough was 1.15 million gallons per day (MGD). The average daily water consumption has increase from 0.57 MGD in 1988 to 0.96MGD in 1998, a 68.4% increase in 10 years. It increased to

Figure 1
Historical Yearly Water Pumpage for Southborough, MA



1.29 MGD in 2001, another 34.4% increase. Since 2001 this consumption has been reduced to 1.15 MGD in 2005. From 1988 to 2005 the average water consumption has more than doubled. Figure 2. shows the past, present and projected future average water consumption. The daily water consumption can be separated into domestic water consumption and commercial and industrial consumption

Domestic Demand

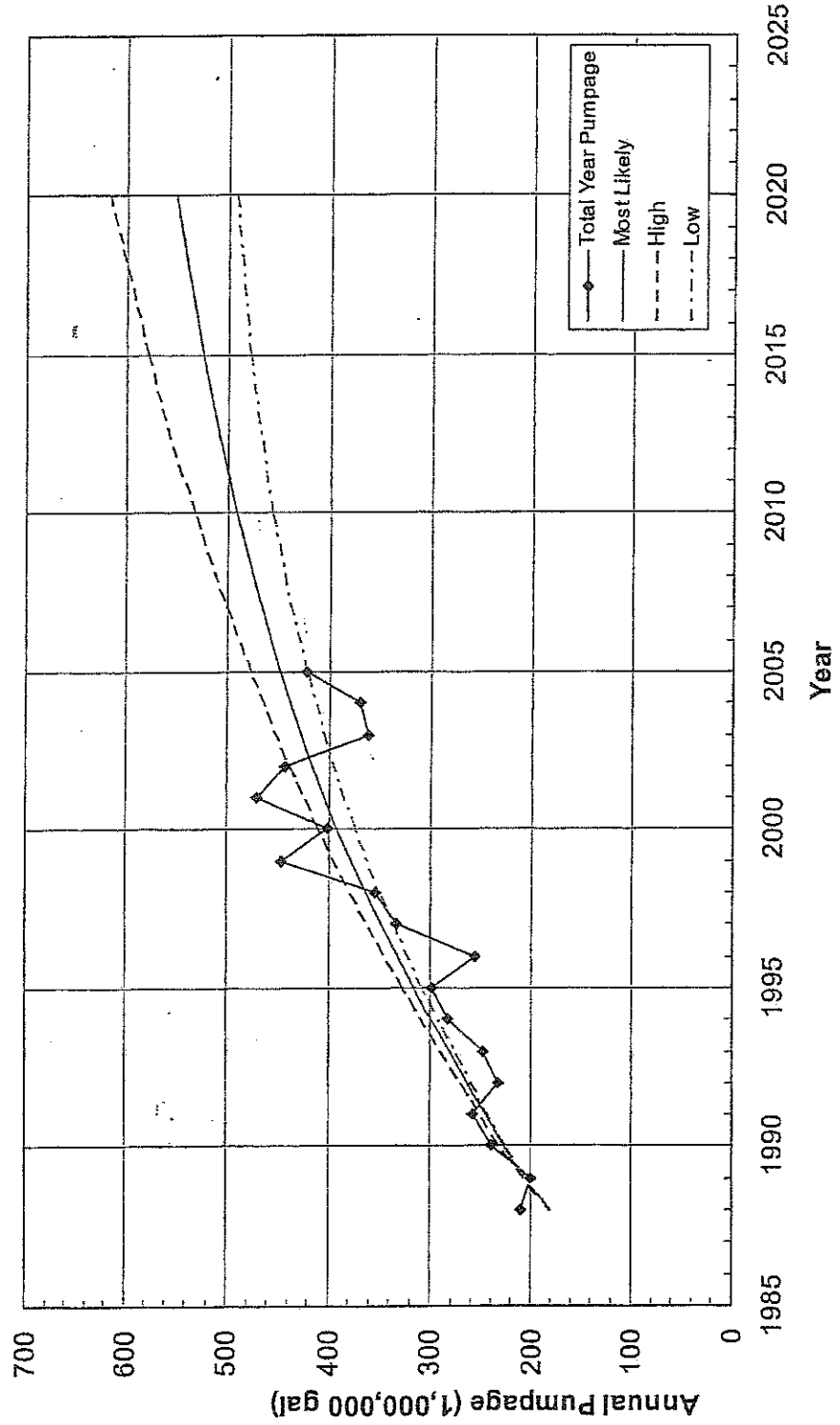
In general, for the so-called Bedroom Communities, the domestic demand for water is the major portion of the community's demand and it has been increasing at a faster rate than the rate of population growth since the Sixties. This demand has been primarily caused by the ever increasing use of such water operated appliances as automatic dishwashing machine, garbage disposal units and automatic lawn sprinklers, as well as backyard swimming pools. High value residential areas are inclined to be in areas of large lots with large grass areas with houses having more water using appliances. However, this trend of water consumption increasing faster than the population increases has been changing in recent years due to the conservation measures and the reduction of irrigation use.

Domestic water consumption is the major water demand in the Town of Southborough. In the nineties, this consumption had steadily increased faster than the rate of population. From 1990 through 1997, the total population increased 17.2% but the average daily water consumption had increased by 38.7%. In Southborough, some of the new homes constructed in recent years are on private wells, otherwise the domestic demand would increase much faster. From 1997 through 2001, the average daily water consumption increased by 42.4%. From 2001 the Southborough water consumption decreased from 1.29 MGD to 0.99 MGD (2003), but has since increased back to 1.15 MGD in 2005. With the fast population growth of the Town of Southborough, even if the per capita consumption does not increase the total water demand will be increased.

Commercial and Industrial Demand

It is extremely difficult to estimate the water requirements for future industrial and commercial areas in the Town of Southborough. Currently, Southborough does not have

Figure 2
Annual Pumpage Projection for Southborough, MA



D. Estimated Future Demand

One consideration in determining the adequacy of a water system involves the comparison of the maximum daily consumption with the available supply sources and the system carrying capacity. Therefore, to estimate the maximum daily consumption is necessary.

It is very difficult to estimate accurately the average daily water demand, and it is more difficult to estimate accurately the maximum daily demand. This is because the maximum daily demand is dependant on the weather much more than other factors. To reduce the magnitude of error, therefore, the population projection, per capita consumption projection and the water consumption trend all have to be considered.

After analyzing the past data of populations, per capita consumption, water consumption trends and the ratio of maximum daily consumption to the average demand, the trend curves for the maximum daily demand is established.

Figure 3 shows that the maximum daily demand in the eighteen year history was 3,005,000 gallons per day in August 2, 1999. The projected maximum daily demand for the year of 2020 is about 3,750,000 gallons per day. The increase is about 25%. Figure 5 shows the history and projected average daily demand. The largest daily demand is 1.29 million gallons per day in 2001. The projected average daily demand for the year of 2020 is about 1.51 million gallons per day. The increase is about 13%. These projected demands will be applied in the computer model of the distribution system to determine recommended future system improvements.

It should be pointed out that future demand depends on many variables, such as zoning, land availability, public sewer availability and economic development. It should also be noted that any change to the above variables will affect the projected demands especially if a public sewer system were available. Therefore, upgrading the model periodically is recommended.

Table 4 - Per Capita Consumption

Year	GPCD
1990	100
1991	106
1992	109
1993	111
1994	112
1995	113
1996	114
1997	114
2000	124
2005	120

Maximum Demand

Another factor requiring consideration during demand analysis is that of seasonal fluctuations in consumption rates. During the summer months, the demand placed on the Southborough water system is far greater than that at any other period of the year. Since this increased consumption occurs annually, the system design has to be able to provide this higher demand.

Table 5 indicated that the ratio of the maximum daily demand to the average daily demand of Town of Southborough varied from 2.03 to 2.74 during 1990 through 2005. This variation is due to the variation of rainfall and temperature of each year, as well as the use of lawn sprinklers.

Table 5 - Water Usage Per Person Per Day for Southborough, MA

Year	Pumpage (gal)	Population	gpcd
1990	240,460,000	6628	99.40
1991	258,009,000	6657	106.19
1992	233,434,000	6783	94.29
1993	248,955,000	6893	98.95
1994	285,858,000	6972	112.33
1995	305,998,000	7297	114.89
1996	259,010,000	7432	95.48
1997	333,413,000	7768	117.59

C. Past Water Consumption

Figure 3 and Figure 4 show the history and the estimated maximum daily demand and the maximum weekly demand. The numbers clearly show that the demands are increasing yearly. The increases are not only due to an increase of the population, but also an increase in the per capita consumption. In recent years, homes constructed in Southborough are the large and expensive type. Therefore, water consumption has increased rapidly, especially the maximum daily demand. Due to the location of the Town of Southborough, land cost in the future could be very expensive; therefore, any home construction in the future would be a highly priced type. With the possibility that some of the homes currently on private wells may change to the public water supply, the water consumption trend will continue to grow faster than the population growth in the Town of Southborough.

large shopping malls and major water consuming industry. Most of the commercial and industry businesses in Southborough are neighborhood commercial and office type industry. Therefore, water consumption for those areas has not been separated out from the total water demand. Based on a recent document, the proposed EMC Complex will obtain their water supply from the Town of Westborough and private wells. Otherwise it would become a major industrial demand.

Per Capita Consumption

The Per Capita Consumption is the average daily consumption divided by the total population. Southborough Water Department records show that the total water demand increases at a rate faster than the increase in population, the per capita consumption in Southborough (Table 4) having increased from 99 gallons per capita per day (gpcd) in 1990 to nearly 118 gpcd in 1997 and to 125 gpcd in 2000. This per capita consumption leveled off after the year 2000 and slowly reduced to 120 gpcd in 2005. This may be due to conservation or that some new connections to the Southborough system have their own well for lawn and garden irrigation and that some of the new homes are using private well water. If all new homes were using the public water supply, the Per Capita Consumption of water will be higher.

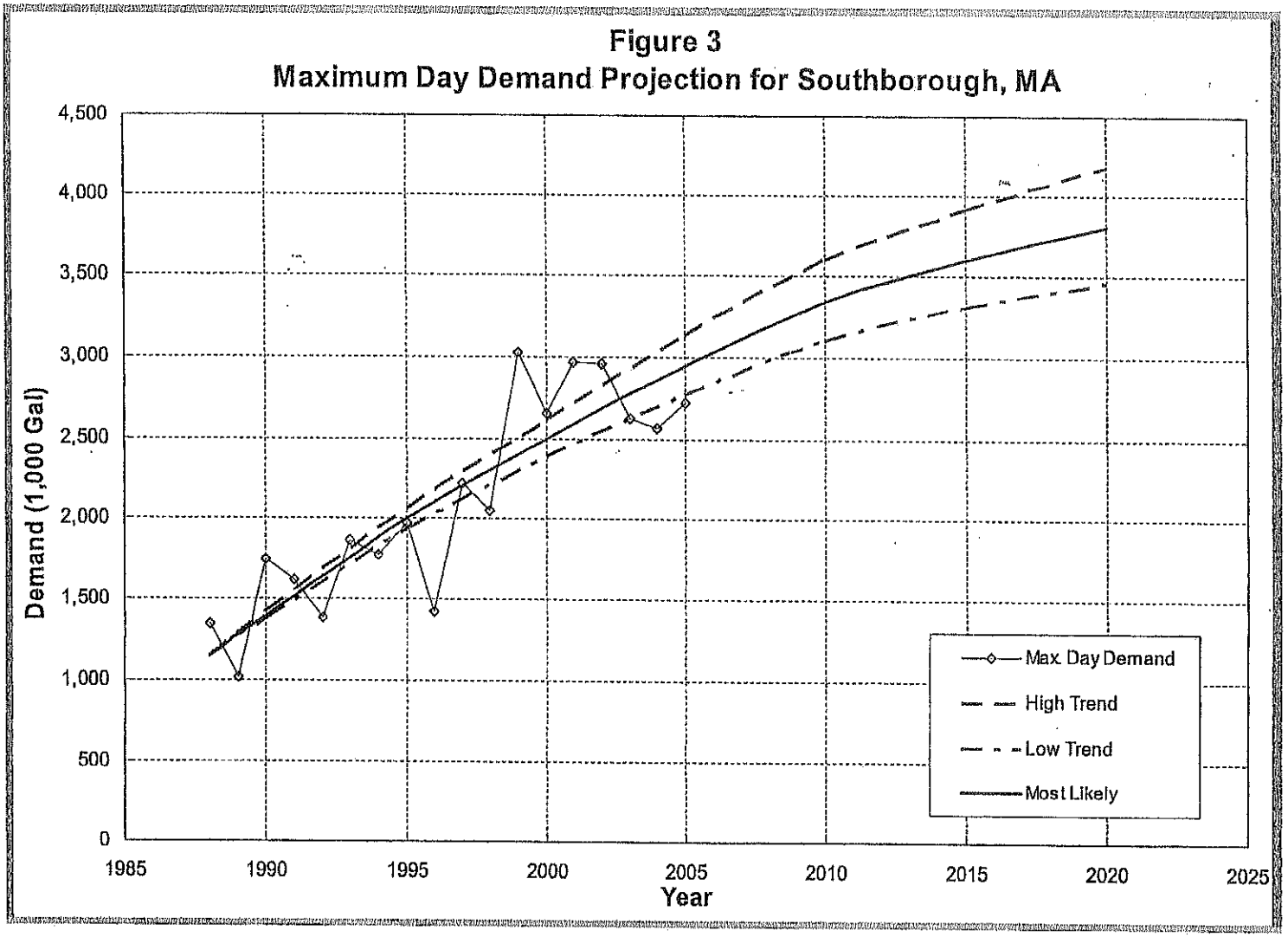


Figure 3
Maximum Day Demand Projection for Southborough, MA
Demand (1,000 Gal)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year
Max. Day Demand
High Trend
Low Trend
Most Likely

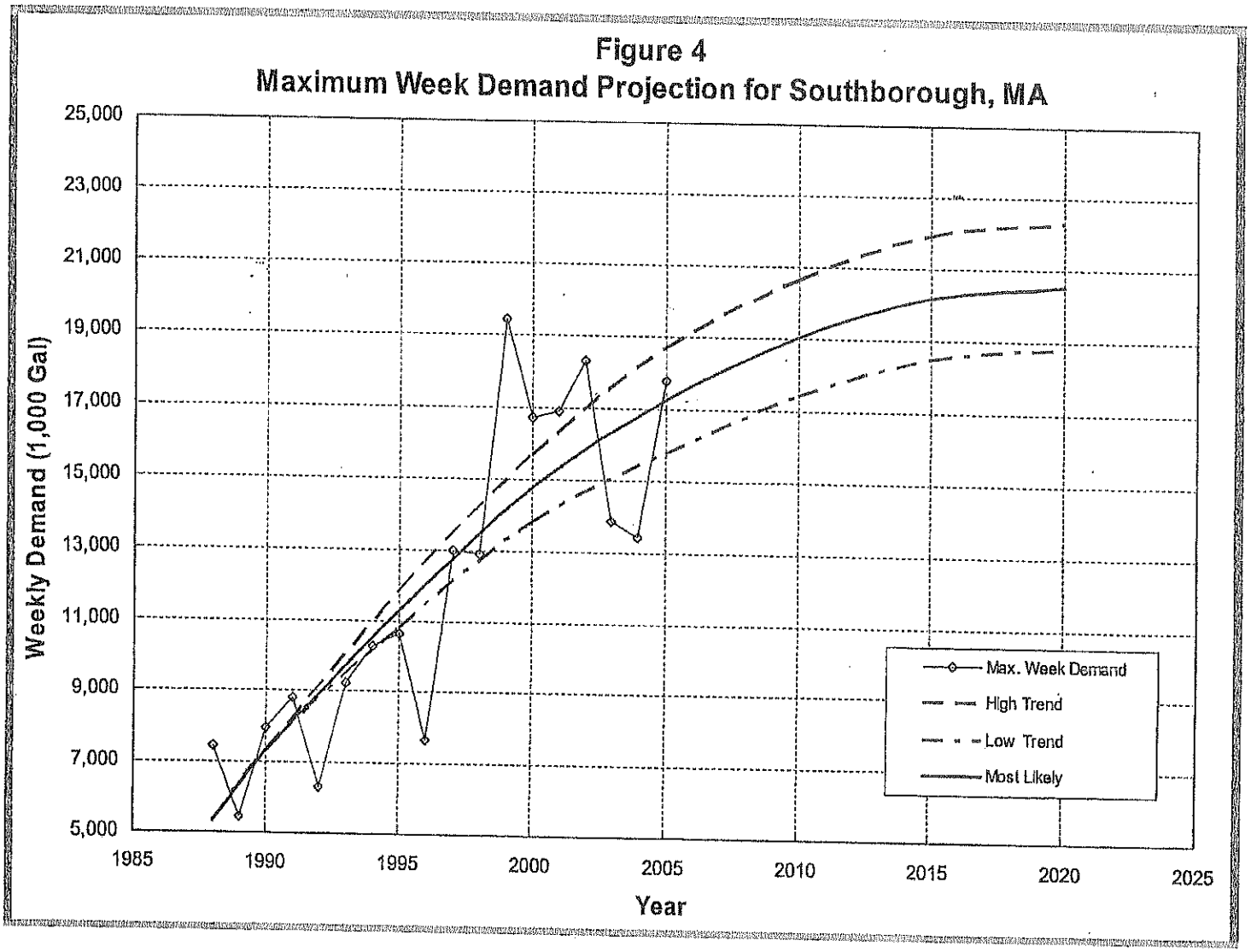


Figure 4
Maximum Week Demand Projection for Southborough, MA
Weekly Demand (1,000 Gal)
25,000
23,000
21,000
19,000
17,000
15,000
13,000
11,000
9,000
7,000
5,000
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year
Max. Week Demand
High Trend
Low Trend
Most Likely

E. Fire Flow Demand

The Insurance Service Office (ISO), formerly called the Fire Underwriter, has adopted new standards for determining required fire flow and duration. These new standards call for increased available flow rates with shorter duration as compared to the old standards. Therefore, the total required usable system storage is approximately the same, but the distribution system carrying capacity must be greater.

Based on the building density, size and building materials, the typical single family residential areas of the Town would require no more than 1,000 gallons per minute (gpm) fire flow. Areas where multi-family dwellings, schools, shopping malls and industries are located would need fire flow of about 2,500 to 3,500 gpm.

In March 1990, the ISO conducted several fire flow tests within the Town of Southborough and set the fire flow requirement. Table 6 shows the test results. Four locations (Tests 4, 5, 8 & 10) found the test flow under the required flow. All other locations had acceptable test flow.

The ISO flow testing showed the maximum available fire flow around the Parkerville Road area was about 3,000 gallons per minute in steady state (see Table 6 - Hydrant Flow Data Summary Table, Test No. 12 & No. 11). At the time of the test, the Atwood Elevated Tank was still in service. It should be noted that the fire flow test was done in a very short time period. With the limited storage capacity of the Atwood Elevated Tank, the fire flow would empty this tank in less than one hour. The system model's fire flow is 3,500 gallons per minute for three hours continuously and reduced to half the required fire flow for the next three hours. This demand is much higher than the existing system can provide and creates a critical condition for the existing system.

Figure 5
Average Daily Demand Projection for Southborough, MA

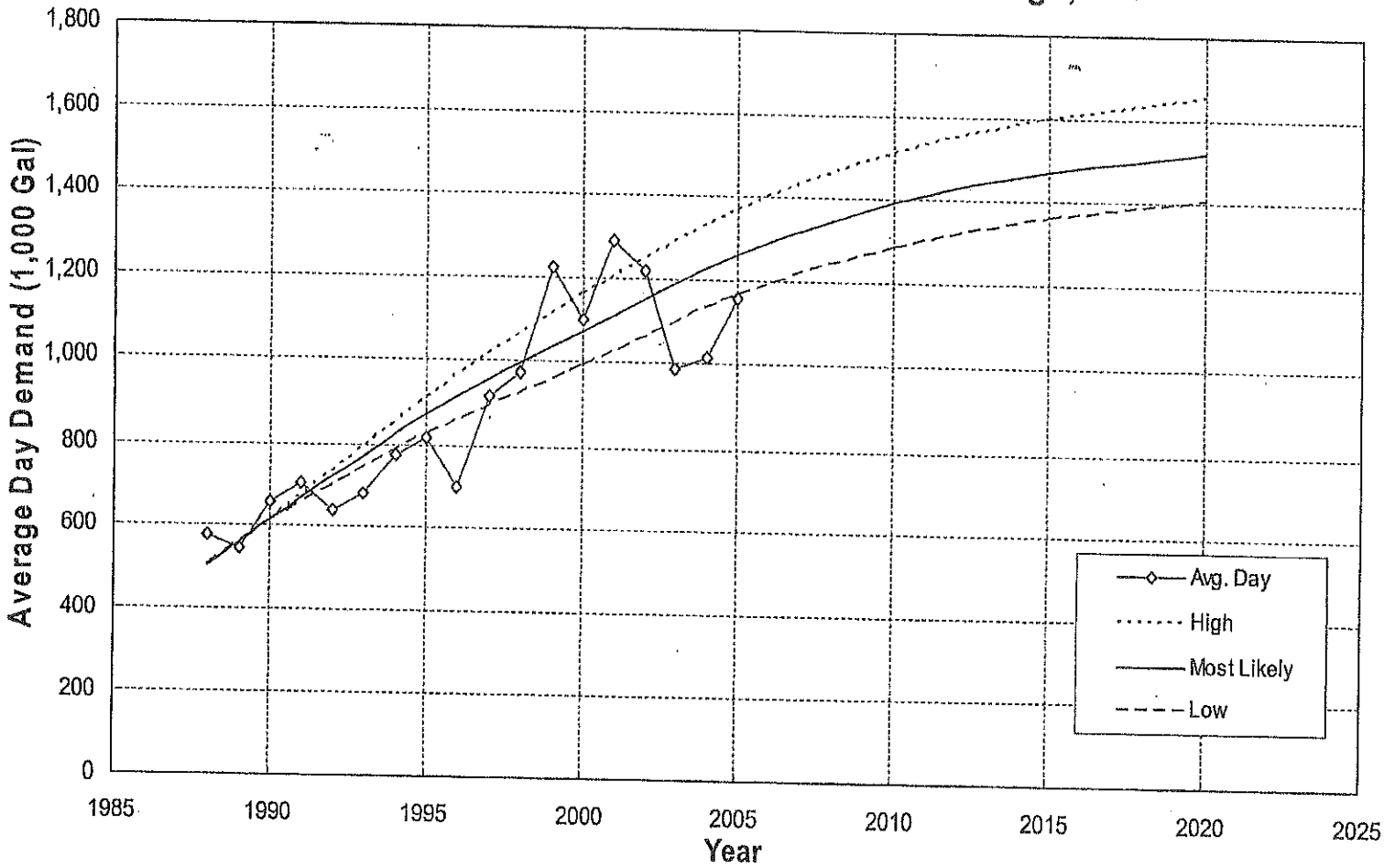


Table 7 - Hydrant Flow Data Summary for Town Of Southborough
Conducted by ISO Commercial Risk Services, Inc.

City Southborough State MA Zip 01772 Witnessed by A. Lagadinos Date 3-9-00

TEST NO.	TYPE DIST.*	TEST LOCATION	SERVICE	FLOW-GPM				PRESSURE PSI		FLOW AT 20 PSI		REMARKS
				INDIVIDUAL HYDRANTS			TOTAL	STATIC	RESID.	NEEDED **	AVAIL.	
1	Res	Presidential & Sears	Main	1140			1140	40	30	500	1400	
2	Res	6 Maple Crest Dr.	"	1570			1570	80	42	750	2000	
3	Comm	Main St. at Fay School	"	2050			2050	76	55	3000	3500	
4	Comm	150 Cordaville Rd	"	1380			1380	96	73	3000	2700	
5	Comm	Cor. Rte 9 & Willow St	"	1200			1200	90	22	3500	1200	
6	Comm	337 Turnpike Rd-Rt 9	"	2060			2060	66	55	2500	4500	
7	Res	Lynnbrook at CUL DE SAC	"	2820			2820	86	75	500	7400	
8	Comm	Neary School-Front Yard	"	1690			1690	90	34	3000	1900	
9	Comm	21 Boston Rd.	"	2150			2150	78	48	1500	3100	
10	Comm	17 Oregon Rd.	"	1280			1280	60	8	1250	1100	
11	Comm	Parkerville Rd.near Gilmore	"	1160			1160	80	62	2250	2200	
12	Res	151 Southville Rd	"	1980			1980	92	58	750	3000	
13	Comm	Southville Rd.at North St	"	1950			1950	102	50	2250	2500	
14	Comm	10 Southville Rd.	"	2220			2220	105	48	1250	2800	

THE ABOVE LISTED NEEDED FIRE FLOWS ARE FOR INSURANCE RATING PURPOSES ONLY AND ARE NOT INTENDED TO PREDICT THE MAXIMUM AMOUNT OF WATER REQUIRED FOR A LARGE SCALE FIRE CONDITION. THE AVAILABLE FLOWS ONLY INDICATE THE CONDITIONS THAT EXISTED AT THE TIME AND AT THE LOCATION WHERE TESTS WERE WITNESSED.

* Comm = Commercial; Res = Residential.

** Needed is the rate of flow for a specific duration for a full credit condition. Needed Fire Flows greater than 3,500 gpm are not considered in determining the classification of the city when using the Fire Suppression Rating Schedule.

IV. SYSTEM ANALYSIS

A. General

The purpose of a distribution system analysis is to evaluate the adequacy of the system's pipe network, storage facilities, source supply and pumping capacities under present and project future water demand conditions along with assessing the adequacy of fire protection.

The computer analysis of the existing water system and evaluation of proposed improvement in Southborough, Massachusetts, was accomplished by means of a high speed computer. The computer programs used were the Hardy Cross Method of distribution analysis and the Newton Raphson iteration technique. To put the water system on the computer, the distribution system was schematically drawn to include all water mains that transmitted significant quantities of water. Ideally, for this analysis, 6-inch diameter water mains and larger were included.

Simulating the present system by means of a mathematical model was necessary to evaluate the present and determine the proposed water distribution system. The proper boundary conditions such as the system demands, sources of supply, pipe characteristic (length, size, and "C" value), and water levels in the storage tanks were entered into the computer model.

After inputting the boundary conditions into the computer model, actual system operating data were used for the model's calibration. The distribution system model should be calibrated over a range of system operating conditions to insure that the computer model response closely matches the actual system response. Field fire flow test data including pressure, pumping flow data, and storage tank water levels were utilized in the model calibration. The model has been calibrated by using flow test data obtained through the years.

Once the water distribution system model was calibrated, the future demands were placed into the computer model to analyze the steady state condition of the system, and the requirements to meet these demands were determined from the program output.

Conditions that might develop throughout the water distribution system were analyzed by superimposing required fire flows on projected maximum system demands with elongated time. This dynamic analysis was done by assigning required pressure (20 psi) to a node at a particular location and checking for the adequacy of the flow rate along the time variation at that location. Water levels in storage facilities were adjusted along the time variation. As a result, the analysis presents the system adequacy for the specified location with the variation of the available flow along the time, and the water levels in the tanks fluctuating throughout the simulated period. This data was analyzed to determine the capacity to meet the projected future demands and was also used to recommend proposed improvements.

B. System Analysis Results

Generally, the existing system can provide a marginally adequate service to meet maximum daily demand. Some areas were found to have low service pressure due to the high ground elevation, such as Atwood Street, Harris Road, Richard Road, High Ridge Road and Fairview Drive. The Southborough Water Supply System has been designed to serve the areas where the ground elevations are lower than elevation 400 feet (ft) (U.S.G.S.). Any location where the ground elevation is between 400 ft and 430 ft will experience unacceptable low pressures. Some areas located between elevation 300 ft and 400 ft would encounter pressure problems during fire fighting if the pipe line is undersized.

The following several paragraphs discuss some of the computer results. There are many to be considered which may not be discussed in detail hereafter, but are included in the recommendations.

Fiddlers Green Reservoir, Clear Hill Standpipe, Boland Pump Station and Hosmer Pump Station are all located north of Route 9 and are capable of providing adequate service to this portion except for the high ground areas.

However, in March 1990, ISO made a flow test at the intersection of Route 9 and Willow Street and found the available flow was 1,200 gpm where 3,500 gpm is required. A previous computer model had confirmed this problem, but the problem has been solved with the installation of a 12-inch water main along Valley Road and Willow Street. But inadequate fire flow is still a problem along Route 9 between Willow Street and Oakhill Road. This is due to the old and under sized 6-inch water main along Route 9. Also water main and services lines at this area frequently have leaking problems. To correct this problem, it is necessary to replace the old main. Also, due to the heavy traffic, having a service line cross Route 9 is a problem. Therefore it would be better to have two supply lines along Route 9 to supply this section of the commercial area. However, the cost to install a new watermain on Route 9 is expensive. Therefore utilizing an easement from private land along Route 9 may be a better solution.

In the middle section, the ground elevation at both the east and west areas are high. Fortunately, the west area is not far away from the Fiddlers Green Reservoir and the Boland Pump Station, and the east area has the Oak Hill Standpipe. Both areas are able to maintain a reasonably adequate water service. When Fiddlers Green Reservoir is maintained at its high level, the distribution system can maintain adequate service along Parkerville Road where the ground elevation is below 390 ft. There are areas with dead end piping that lack adequate fire fighting flow. Elimination of some dead end pipes should be considered.

The southern section, south of Route 90, is at the end of the distribution system. Because this section of the Town does not have a high ground elevation, the water system has no problem providing maximum daily demand, but can only provide approximately 1,600 gpm of fire flow. A 3,000 gpm fire flow at the Finn School is needed. At the intersection of Parkerville Road and Richards Road the indicated available fire flow on average is

less than 1,600 gpm. The computer model indicates that the high head loss is caused by the undersized pipes crossing the bottleneck at Route 90. During 2004-2005 a 12-inch water main was installed from Walnut Drive to Oregon Road by using the existing the 12-inch water main which was installed many years ago under the Massachusetts Turnpike. This water main improved the fire flow at the Finn School area to 2,200 gpm. In order to provide adequate fire flow to the Finn School area and this part of Town, the distribution system in this section of Town still needs to be improved.

For system stability and reliability, the Town needs to provide storage and improve the piping system. This work can be divided into two phases to complete the required improvement. One phase is to install a water tank on Fairview Hill near the end of Skylar Drive and also improve some pipes on Parkerville Road (between Route 9 and Richards Road). This tank shall be fed by installing a 12-inch water main along Deerfoot Road and a 16-inch water main to the tank.

This storage tank has been recommended for many years, but has not been constructed yet due to the possibility of two construction sites. One site is at Fairview Hill and the other is the Fiddlers Green Reservoir. Both sites have pros and cons, but based on the analysis, it is recommended that this storage facility be located at the Fairview Hill area.

Table 7 lists the pro and con of the two sites.

No computer analysis has been performed for the Pine Hill Area which currently does not have public water supply from Southborough. To supply water to this area, a storage tank and 12-inch loop will be required. It may also require a booster pumping station to supply the area.

A 12-inch water main along Central Street and Oak Hill Road was installed in the early Nineties. There is a short section of 8-inch pipe under the railroad that has not been replaced. This short section of 8-inch pipe should be replaced to complete the 12-inch water main along Central Street to Boston Road.

Table 7 - Pro and Con of the Two Tank Sites

Description	Fiddlers Green	Fairview Hill
Safety	Poor	Good
Hydraulic Control	Very Good	Good
System Hydraulic	Good	Very Good
Size	Limited to 1.3MG	Can construct up to 2.5MG
Construction Cost	Relatively Low	Relatively High Due to access road requirement

C. Inadequate Storage Capacity

The existing storage facilities in the Town of Southborough have a total capacity of about 2.0 Million Gallons (MG). But the total usable storage is less than 1.2 MG assuming all three storage facilities are filled to the overflow level. This 1.2 MG usable storage just about meets the peak hourly demand variation, which usually last three to three and a half hours (between 6:30 AM to 10:00 AM), and a three hour fire flow. But the fire fighting generally last longer than three hours (usually six hours). Therefore, the usable storage is not adequate. If the tank was not full at the beginning, then the usable storage definitely is not adequate. Also, another emergency condition could occur at the same time, such as pump equipment break down, pipe line break, etc., then the usable storage would not be adequate to meet the Town's demand, especially during the summer months. Generally, storage facilities should be capable of providing the additional water required for demand equalization and emergency situations such as fire flow demands, pipe line breaks, etc.

The other problem is that the Town of Southborough Water Division can not take Fiddlers Green Reservoir out of service for maintenance without a risk, as there is no storage to provide for fire flow and the maximum daily demand. Eventually, the Fiddlers Green Reservoir has to be taken out of service for painting; therefore an additional storage facility is needed.

D. Inadequate Pumping Capacity

Currently, the maximum pumping capacity of both pumping stations is 1,000 gpm but the maximum daily demand has increased to over 2,000 gpm since 1997. In the summer time, during the maximum weekly demand, the variation of demand from day to day varies very little. To make up the pump deficiency, water would have to come from storage facilities, which will make the system storage more inadequate. Increasing pumping capacity therefore is necessary. The first pump station that should be renovated to increase the pumping capacity is the Boland Pump Station. It is recommended that the pumping capacity of this pump station be increased from the current 1,000 gpm to about 1,500 gpm, and before the year 2015, the Hosmer Pump Station should be renovated to increase its capacity from the current 1,000 gpm to about 1,200 gpm.

V. WATER SYSTEM MASTER PLAN

A. General

Because there are several major highways, a railroad, a large water supply aqueduct and a reservoir located in the Town, and varying ground elevations throughout town, it is difficult and costly to develop a water supply system which would provide adequate supply at sufficient pressure to all areas in the Town of Southborough.

The recommended Master Plan in this Report intends to provide a feasible and practical development of the water distribution system considering the Town of Southborough's existing system capabilities. In general, the following criteria were considered in the Master Plan Development:

1. Maximum utilization of existing water distribution system and storage facilities.

2. Location and sizing of the reinforcing mains throughout the Town to minimize construction costs, avoid paralleling large size mains along a street and avoiding construction in "high" value streets.

The Master Plan was designed based on projections of future growth under current zoning. The Town should, however, review their demands and distribution system periodically to allow for any unusual growth patterns or demands placed on the system. Minor modifications may be required due to some unforeseen events, such as a new residential complex, a high water consumer or construction of an industrial complex in the remote areas of the system.

The design of the system is meant to satisfy future demands by concentrating on the major mains and major improvements involving large expenditures of time and money which would require more than Town labor. As for minor improvements, these will be covered under the section of general recommendations which will be discussed later in this Report.

B. Source of Supply and Pumping Facilities

The Town of Southborough's source of water supply is from the MWRA's MWWST

Tunnel which has had no problem supplying the Town of Southborough's water needs. Because the present contract between Southborough and the MWRA expired in 1997, the Town of Southborough and the MWRA are in the process of discussing a new contract. In accordance with the existing contract, Southborough is limited to pump only two million gallons per day by the MWRA. In our previous System Study Report, we predicted that the demand will grow over the 2 MGD rate in 1997. In 1997, the maximum day demand did go over the 2.0 MGD. It is strongly recommended that when Southborough negotiates a future MWRA contract the Town requests the 2.0 MGD limit be upgraded to a higher limit, preferably 4.0 MGD, which is just higher than the projected 2020 maximum daily demand of 3.8 MGD, including obtaining water from a neighboring MWRA community.

The capacity of the two existing pumping stations can adequately handle a flow rate of about 2.8 MGD. Considering the age of each pumping station, we strongly recommend the equipment in each station be thoroughly inspected, repaired and/or replaced, including chlorinators, pumps and motors as well as electrical wires and panels. The capacity and equipment of Boland pump station should be improved and expended to 3.8 MGD before 2010 – after the construction of a new storage reservoir.

C. Storage Facilities

The storage facilities within a water system are one of the most essential elements of a water supply distribution system. The purpose of water storage in a distribution system is to increase the capacity and efficiency of the water as follows:

1. Provide adequate flow for fighting fires

2. Meet maximum and peak hourly demand variations

3. Provide more uniform pressures within the system 24 hours a day

4. Provide water to meet system demands at emergency conditions such as mechanical failure, periodic maintenance of pumping facilities or water main breaks

5. Provide a safety outlet in the system to attenuate the effects of pressure surges known as water hammer

The primary purpose of storage is to provide a source of pressure and a standby supply that will result in a more balanced system pressure and in an equalization of system supply and demand. Storage "rides" on the hydraulic gradient of the distribution systems so power outages do not affect the immediate ability of the storage facilities to supply the water distribution system.

In addition, if a system had no storage, the water supply pumping facilities would have to be capable of supplying the maximum, instantaneous rate of consumption, regardless of how infrequent this rate occurred.

The required storage volume of a water supply system can be analyzed in detail based on the hourly demand variation of a maximum daily demand, and based on maximum fire protection requirements to determine the required fire flow storage. However, it is quite difficult to determine the required emergency storage which varies with the type of emergency.

It is a "rule of thumb" that a system should have, as a minimum, a usable storage equal to its maximum daily demand, especially for small systems. Many small systems have storage equal to 5 times its maximum daily demand. The Town's projected maximum daily demand is about 3.8 MGD for the year 2020. The existing gross storage is 1.97 MG, but the existing usable storage is only 1.2 MG with each storage reservoir filled to its overflow elevation (This is based on 30 psi service pressure for ground elevation 400 ft.). This is approximately 2.4 MG less than the 3.8 MG of usable required storage. This emphasizes the need for additional storage in Southborough.

We recommend constructing a new two million gallon storage facility which would provide another 1.4 million gallons of usable storage. With the above improvements, the total usable storage would be about 2.6 MGD. This total usable storage is less than the projected maximum daily demand by about 1.2 MG, but it will help the system tremendously. Some time in the future, a new storage tank could be added to the low pressure zone, or a larger tank could be constructed to replace the Clear Hill Tank and /or the Oak Hill standpipe. Mt. Vickery area has

ground elevation of about 430 ft.USGS, which may be a possible tank site but, would require a long transmission water main.

D. Distribution System Improvement

The existing Southborough Water Supply System has already been changed to a two pressure zone system. The overflow elevations of the storage facilities in the low pressure zone are about 493 ft USGS. The high pressure zone controlled by the Fiddlers Green Reservoir, its overflow elevation is about 515 ft USGS. Using the overflow elevations of the storage facilities, the required service pressure and the approximate highest service elevation in the system can be determined.

There are several Pressure Regulating Valves installed between the two pressure zones, so that water can flow from the high pressure zone to the low pressure zone in case that the low pressure zone is in need of water. This is the reason why it is recommended that the new storage facility be constructed in the high pressure zone, so it can benefit both pressure zones.

The Massachusetts Department of Environmental Protection (DEP) Guidelines for Public Water Systems recommend a minimum service pressure of 35 pounds per square inch (psi). In the low pressure zone system, even when the storage facilities are full, any area with a ground elevation higher than elevation 413 ft will not have the recommended minimum service pressure of 35 psi, even neglecting the pipe friction losses within the system. When pipeline head losses are considered, areas where the system can provide 35 psi would have a ground elevation below 400 ft USGS. However, the Fiddlers Green Reservoir has an overflow elevation of 515 ft USGS. When the Fiddlers Green Reservoir is full, it can help to provide adequate service pressure for areas with ground elevation between 400 to 430 ft USGS. But for areas in high pressure zones, when the ground level is higher than 430 ft USGS, it will not have adequate service pressure. The high pressure zone is controlled by the Fiddlers Green Reservoir and the lower pressure zone is

controlled by the Oak Hill Storage stand pipe and the Clear Hill Tank.

To minimize low pressure problems on the Fairview Hill area, we recommend construction of a storage facility on Fairview Hill along with related pipeline improvements. This storage facility should have a capacity of 2.0 MG with an overflow elevation 515 ft USGS.

Presently, the Pine Hill area, located north of the Sudbury Reservoir, is not being served by Southborough's Water System. To serve this area would require the installation of a long pipeline from Old Boston Road to the Pine Hill area. It will require the construction of a booster pumping station and a storage tank. Also, the pipe from the Old Boston Road line must pass through the MWRA facility below the Sudbury Reservoir. Therefore, obtaining the easement would be extremely difficult and construction economically unrealistic.

To supply water to the Pine Hill area from the Town of Southborough water s ystem will be very costly. It appears that it would be more feasible to obtain water from the Town of Framingham's high service area. Framingham's high service zone has one pumping station (Grove Street P.S.), a one million gallon pre-stressed concrete tank, along with an old 300,000 gallon steel tank which may be out of service. The supply of Framingham's high service system is limited by the Grove Street Pumping Station's one million gallon per day pumping capacity, therefore, a storage facility will be needed for this area. There is another possible way to supply the Pine Hill area and that is to obtain the right from MWRA for another supply point from the the MWRA water main near the Pine Hill area such as Pleasant Street in Framingham and construct a small booster pump and a storage tank. However, we recommend that the system storage capacity and the pipe line and how to supply this area be evaluated once this area needs the water supply. The Town of Southborough should warn those who build their house at this area that there is no fire protection and emergency water supply.

Another area that requires immediate attention is the section located south of the

EPA and DEP drinking water standards except for bacteria and corrosiveness.

Because raw water quality meets most DEP and EPA drinking water standards, it is not surprising that past treatment was limited to disinfection in Southborough. Aggressive water corrodes distribution system piping and plumbing, causing leaching of pipe materials into the water supply. This results in increasing concentrations of these metals to above the drinking water standards. Recently, the MWRA has constructed a corrosion control facility at Shaft C in Marlborough. Southborough is located very close to this MWRA Corrosion Control Facility. Therefore, corrosion treatment for the Southborough Water Supply may not be required.

Also, the MWRA has constructed the water treatment plant at Shaft C area. This new plant is expected to solve the corrosion problem and other water quality problems for all MWRA communities. Therefore, we recommended that Southborough take no immediate action for corrosion control.

There are many miles of AC pipes in the water system. They should be slowly replaced by D.I. pipe, especially the dead end AC pipes which should be replaced as soon as financially feasible.

F. System Reliability

The 12-inch pipe from Boland pumping station along Northborough Road and the access road to Main Street which delivers more than half of the system supply, with a total length over 3000 feet, is not only under high pressure but also high velocity. After the Boland Pump Station is upgraded this condition will worsen. It is a vulnerable situation. Also, due to the high head losses, the pump has to pump at a higher head and waste energy. It is recommended that either a 12-inch connection pipe under the railroad from Fisher Road to Presidential Drive be installed or a 12-inch pipe along Chestnut Hill Road be installed to connect to the existing 12-inch water main at Main Street. This will not only provide reliability to the system, but also reduced the pumping head by about 3 psi.

If both pipes are installed, the pumping head can be reduced by more than 5 psi. It would save energy costs and reduce the extra pressure on the pipe line located at low ground elevation.

VII. RECOMMENDATIONS AND COST ESTIMATES

A. General Recommendations

The water system improvements discussed below are general in nature and in some cases may be performed by the Town's own labor force. The suggested improvements described below should be conducted on a continual basis and should be included in design considerations for future system growth.

Where future extension of the water distribution system is needed or when existing lines are being replaced, consideration should be given to its effect on the over all water distribution system. Extensions should be made to create looped connections and with pipe sizes large enough to carry the required domestic and fire flows for future demands.

It should become standard practice, within the Town, that all water mains serving hydrants should be a minimum of 8-inch in diameter.

An old pipe replacement program should be put in place to replace all old under sized (6-inch) pipe, especially the AC pipes. Any replacement pipe should be a minimum of 8-inch in diameter.

It is recommended that in the future, any new development should submit the following to the Town's Public Works Department for review to determine the effect on the water system:

1. Plans of subdivisions should be submitted to the Town's Department of Public Works for review and approval.

2. Record plans should be submitted to the Public Works Department for all projects affecting the water system.

3. Large projects such as condominiums, industries, etc., should be investigated with respect to fire requirements, prior to approval.

B. Specific Recommended Improvements

As a result of the computer model analysis of the Southborough Water System, it was concluded that the distribution system can adequately meet consumer demands except for a few high elevation areas with inadequate pressure, but can not satisfy required fire flow demands in many areas. Among the reasons for this are the undersized and limited numbers of transmission mains within the Town, along with many "dead-end" pipes which result in a lack of necessary reinforcing "loops" within the system. Another major problem is the low pressures existing in the sections of Southborough which are at high ground elevations.

To overcome the low pressure problem on those areas with high ground elevation, it is recommended that any building constructed in Low Pressure Zone on land with an elevation above 380 ft USGS should provide a domestic water booster pump, and that any building constructed in High Pressure Zone on land with elevation above 410 ft USGS should also provide a domestic water booster pump. This will not eliminate the inadequate pressure problem completely, but will help some domestic supply pressure issues. There are some undeveloped areas which are economically infeasible to supply at present. This condition should be considered carefully before developing those areas. Therefore, several solutions are presented to further minimize the pressure problems in high ground areas:

1. Prohibit all developments above elevation 400 ft USGS in the low service zone, and above elevation 430 ft USGS in the high service zone.

2. Request developers to construct necessary water tanks and booster systems to provide required pressure in the high elevation areas.

The above facts led to the compilation of a series of proposed improvements which have been broken into three phases. Phase I involves all measures that should be taken immediately to improve the water system and completed by the year 2010. All

recommended improvements are shown on the system map in the Appendix.

Phase II improvements should be considered promptly and completed by the year 2015. Both Phase I and Phase II reinforce the existing system and upgrade the Southborough water supply system to bring the Town much closer to meeting the existing required standards. Therefore, the work recommended in Phase I and Phase II should be completed as soon as possible. Phase III improvements would depend upon the progress of land development and economical conditions. Phase III's timing is difficult to predict. Some items may be developed in the near future and some items may be developed in the more distant future.

Phase I

1. Construction of a storage tank and associated pipes:

   Construct a 2.0 MG water storage tank at the hill between Deerfoot Road and Sarsen Stone Way and install the necessary pipeline. It is estimated that a minimum 800 feet of 16-inch diameter and 700 feet of 12-inch diameter pipe would need to be installed.

2. Renovate Boland Pump Station to increase its capacity to 1,500 gpm and install about 700 feet of 12-inch pipe from Fisher Road to Presidential Drive. This water main has a railroad crossing, therefore its cost would be very high. Another alternative is to install a 12-inch main along Chestnut Hill Road as described in Phase II - 3.

3. To increase the available flow to the Finn School and the Southville area, install a 12-inch water main from Deerfoot Road to Fairview Drive and install a 12-inch pipe along Parkerville Road from the intersection of Fairview Drive and Parkerville Road to Richards Road. The estimated length of this alternative route is about 5,900 feet and requires an easement from EMC Inc. The estimated length can vary because the easement route is unknown.

4. Extend the 12-inch main recently installed at Willow Street along Route 9 replacing the 6-inch and 8-inch water main along Route 9. The estimated length is 2,400 feet between the new 12-inch water main near Brook Lane and Pleasant Street. Should funding become an issue, this item can be deferred to Phase II

Phase II

1. Install 1,600 feet of 12-inch diameter pipe on Deerfoot Road from Route 9 northerly to the intersection of Deerfoot Road and Clifford Street. This includes the replacement of the 600 ft of 6-inch line.
2. Increase the capacity of Hosmer Pumping Station from the existing 1,000 gpm to 1,300 - 1,400 gpm.
3. Install a 12-inch water main along Chestnut Hill Road. The length of this main is about 5,700 feet. This main has to cross the MWRA pressure aqueduct, investigation of the aqueducts' exact location and elevation should be conducted.
4. Install approximately 1,600 feet of a 12-inch diameter main to replace the existing 8-inch main on Central Street from Boston Road to Learned Street including a 60 foot section under the Railroad track which was not previously completed.
5. Connect the 8-inch water main on Middle Road between Mt. Vickery Road and Route 9 with a 12-inch main. The estimated length is 1,700 feet.
6. Install a 12-inch main on Parkerville Road from Main Street to the Neary School driveway.
7. Connect the 8-inch main on Breakneck Hill Road between Davis Road and Viewhill Road. The estimated length is approximately 1.300 feet

Phase III

The recommendations in this phase include pipes that shall form an efficient transmission looping system for the Town of Southborough. The recommended time for the installation of many of these water mains in this phase depends upon future subdivisions. However, each subdivision is responsible for installing the proper size water mains through the subdivision to abutting lands.

1. In general, in any new main in future developments or extension of water mains along existing streets, a minimum of an 8-inch diameter water main should be installed. Any

recommended improvements are shown on the system map in the Appendix.

Phase II improvements should be considered promptly and completed by the year 2015. Both Phase I and Phase II reinforce the existing system and upgrade the Southborough water supply system to bring the Town much closer to meeting the existing required standards. Therefore, the work recommended in Phase I and Phase II should be completed as soon as possible. Phase III improvements would depend upon the progress of land development and economical conditions. Phase III's timing is difficult to predict. Some items may be developed in the near future and some items may be developed in the more distant future.

Phase I

1. Construction of a storage tank and associated pipes:

   Construct a 2.0 MG water storage tank at the hill between Deerfoot Road and Sarsen Stone Way and install the necessary pipeline. It is estimated that a minimum 800 feet of 16-inch diameter and 700 feet of 12-inch diameter pipe would need to be installed.

2. Renovate Boland Pump Station to increase its capacity to 1,500 gpm and install about 700 feet of 12-inch pipe from Fisher Road to Presidential Drive. This water main has a railroad crossing, therefore its cost would be very high. Another alternative is to install a 12-inch main along Chestnut Hill Road as described in Phase II - 3.

3. To increase the available flow to the Finn School and the Southville area, install a 12-inch water main from Deerfoot Road to Fairview Drive and install a 12-inch pipe along Parkerville Road from the intersection of Fairview Drive and Parkerville Road to Richards Road. The estimated length of this alternative route is about 5,900 feet and requires an easement from EMC Inc. The estimated length can vary because the easement route is unknown.

4. Extend the 12-inch main recently installed at Willow Street along Route 9 replacing the 6-inch and 8-inch water main along Route 9. The estimated length is 2,400 feet between the new 12-inch water main near Brook Lane and Pleasant Street. Should funding become an issue, this item can be deferred to Phase II

new main without a loop and longer than 1,500 feet, such as streets which may end at wetlands, State and Interstate Highways, and water bodies, which are difficult to loop, should require a 12-inch diameter water main for adequate fire flow. Also, dead end water mains should be avoided.

2. During development of the Pine Hill area, purchasing water from the Town of Framingham's high service zone would be the most feasible supply solution. However, since Framingham's high service system supply is limited by the Grove Street Pumping Station, Framingham may not be willing to sell water to the Town of Southborough.

   Another option is to purchase water from Framingham's low service zone at the Pine Hill Road and Waveney Road intersection area. Also, this can be accomplished by obtaining a permit from MWRA to add a new take-out point from the MWRA transmission main by tapping one 12-inch pipe to the MWRA 24-inch pipe which connects the Valve Chamber off the Hultman Aqueduct and Pleasant Street Pumping Station in Framingham. In those cases, a booster pumping station will need to be constructed.

   The third option is to obtain an easement from the Town of Framingham to install a 12-inch diameter pipe along Pleasant Street and Pine Hill Road from the existing 12-inch diameter main at Boston Road in (Southborough) to the Pine Hill area. The cost for this long pipe is infeasible. Pipe size at the Pine Hill area should have a 12-inch diameter loop with 8-inch diameter sub-loops. No 6-inch diameter pipes should be used due to the high ground elevation. A storage tank is required if this area becomes fully developed.

3. A 12-inch loop transmission main should be installed from Crystal Pond Road and Coslin Drive area southerly toward the Gilmore Road area. This area is currently under the EMC proposed development which may obtain their water supply from the Town of Westborough.

4. For high ground areas, large size watermain such as a 12-inch pipe should be used for reducing the friction loss. Especially, since the Southborough water system can not provide adequate pressure for an area higher than 400 ft USGS, especially for areas

farther away from the pumping stations and storage tanks.

5. For pipe line replacement, it is recommended that the minimum pipe size should be an 8-inch diameter.

6. A 12-inch loop from Lynbrook Road to Tara Road should be installed when this area becomes developed.

C. Cost Estimation

The cost estimate for Phase I and II is based on the current cost estimation and is shown on the next two pages. This does not include the cost of land acquisition, right of way, appraisal and survey, site preparation, or new access roads, (which in some cases, the new purchase of land may be required). This is a preliminary estimate for alternative comparison only.

Phase I Recommendations:

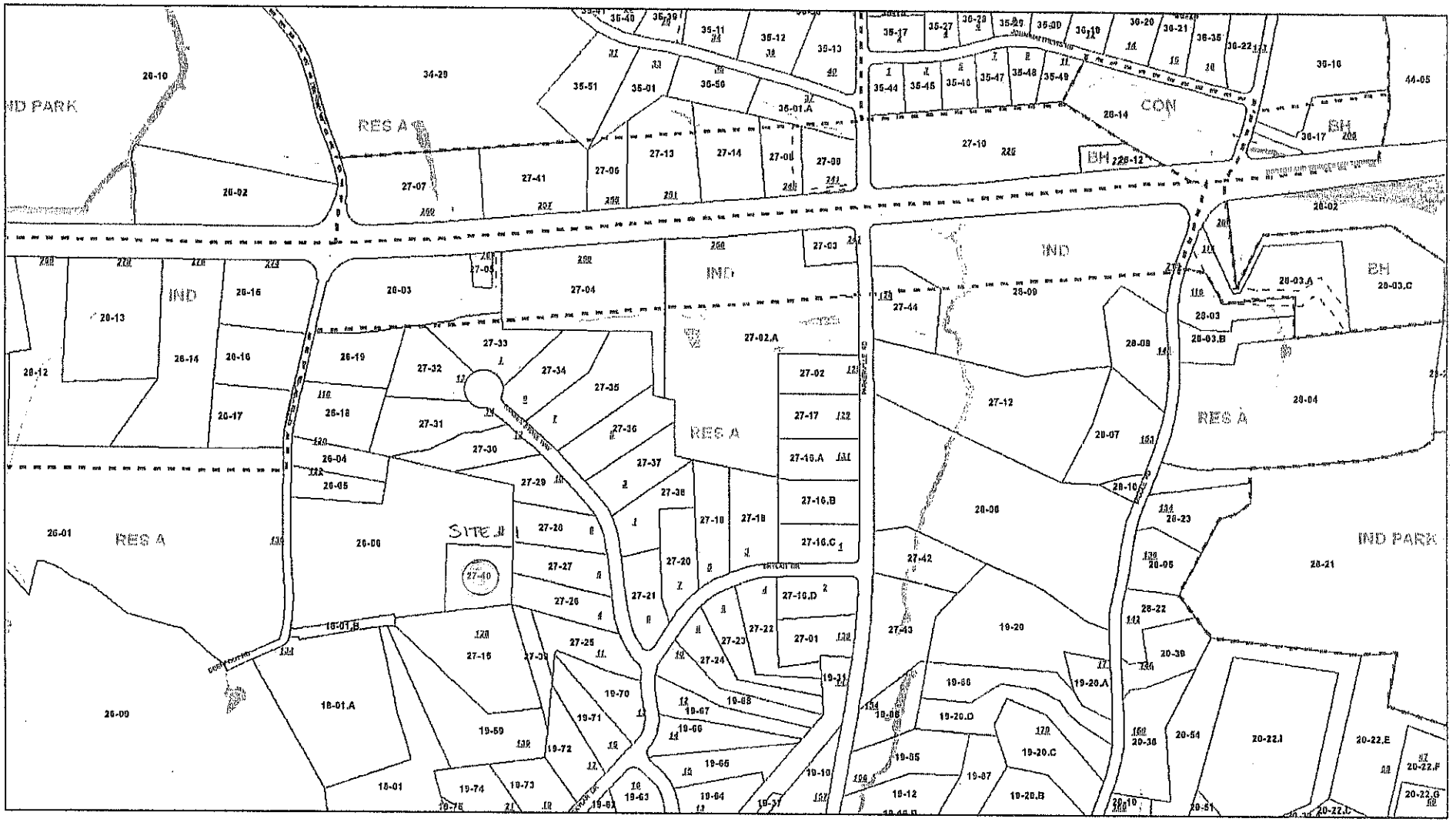
1	Construct 2.0 MG New Tank		$1,230,000
	Control Valve & Site Work, Foundation		$460,000
	16-inch diameter water main from reservoir to distribution system with access road	800 ft	$149,000
	Install a 12-inch diameter water main on Deerfoot Rd.	700 ft	$80,000
	Sub-Total		**$1,919,000**
2.	Renovate Boland Pump Station to increase its capacity from 1,000 gpm to 1,500 gpm		$471,000
	Install 700ft of 12-inch line include Railroad crossing from Fisher Road to Presidential Drive		$145,000
	Sub-Total		**$616,000**
3.	Install a 12-inch water main from Deerfoot Rd to High Ridge Road (through EMC site) and along Parkerville Rd. from Fairview Drive to Richard Rd.	5,000 ft	$517,000
4.	Replace 6-inch diameter pipe along Route 9 with a 12-inch diameter pipe	2,400 ft	$305,000
		Total	**$3,357,000**

Phase II Recommendation:

1.	Install an 8-inch water main on Deerfoot Rd. from Rt. 9 to Clifford St.	1,600 ft	$147,000
2.	Increase the capacity of Hosmer P.S. from 1,000 gpm to 1,300 – 1,400 gpm, excluding standby pump		$287,000
3.	Install a 12-inch water main along Chestnut Hill Road	5,700 ft	$655,000
4.	Replace the existing 8-inch main on Central Street including Railroad Crossing from Boston Road to Learned Street.	1,600 ft	$338,000
5.	Connect an 8-inch diameter water main along Middle Road between Mt. Vickery Road and Route 9.	1,700 ft	$173,000
6.	Install a 12-inch water main on Pakerville Road from Main Street to the Neary School driveway.	3,600 ft	$373,000
7.	Connect the 8-inch and 6-inch water main along Breakneck Hill Road between Davis Road and Viewhill Road with an 8-inch main.	1,300 ft	$131,000
		Total	***$2,104,000***

APPENDIX E

ASSESSORS MAPS



Parcel Boundary
Hydrographic Feature
Zoning Boundary
House Number

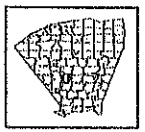
PROPERTY MAP

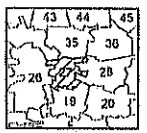
TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

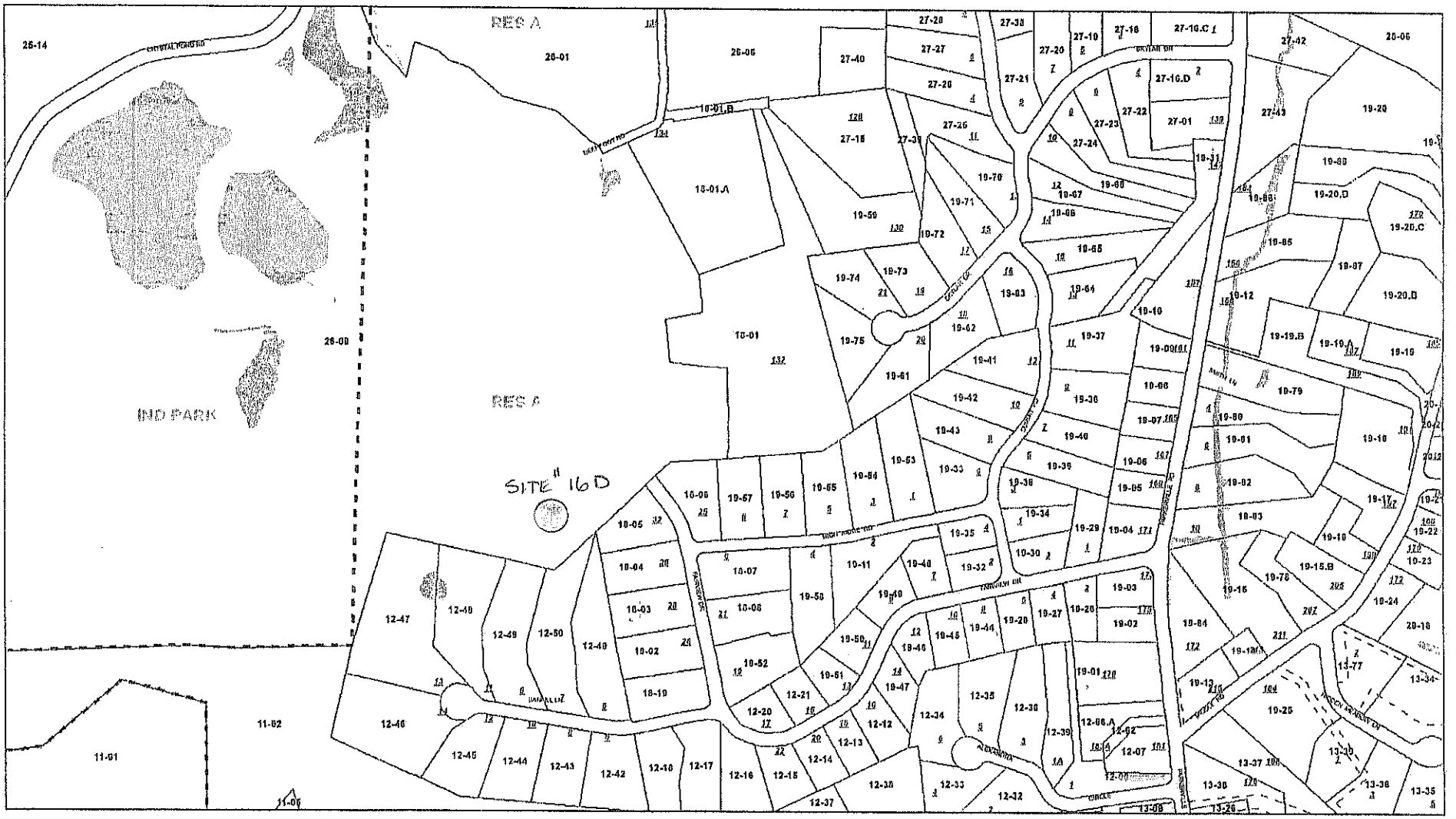
0 137.5 275 550 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.





MAP 27 OF 99



Parcel Boundary
Hydrographic Features
Zoning Boundary
Lineal Number

PROPERTY MAP

TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 100 200 400 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY. NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH. NOT TO BE USED FOR CONVEYANCES.

MAP 18 OF 66



Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP

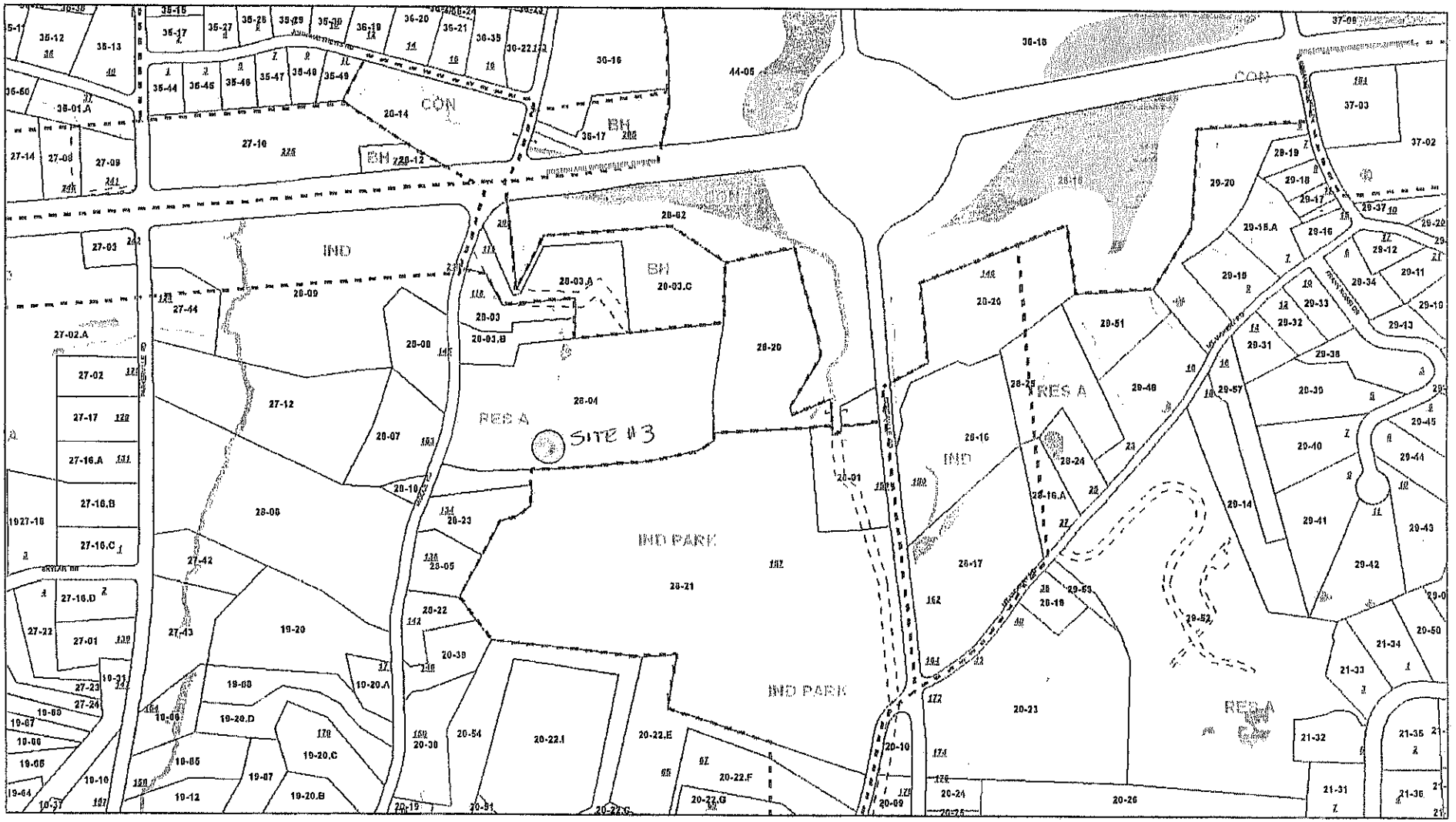
TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 135 270 540 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

MAP 33 OF 66



Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP

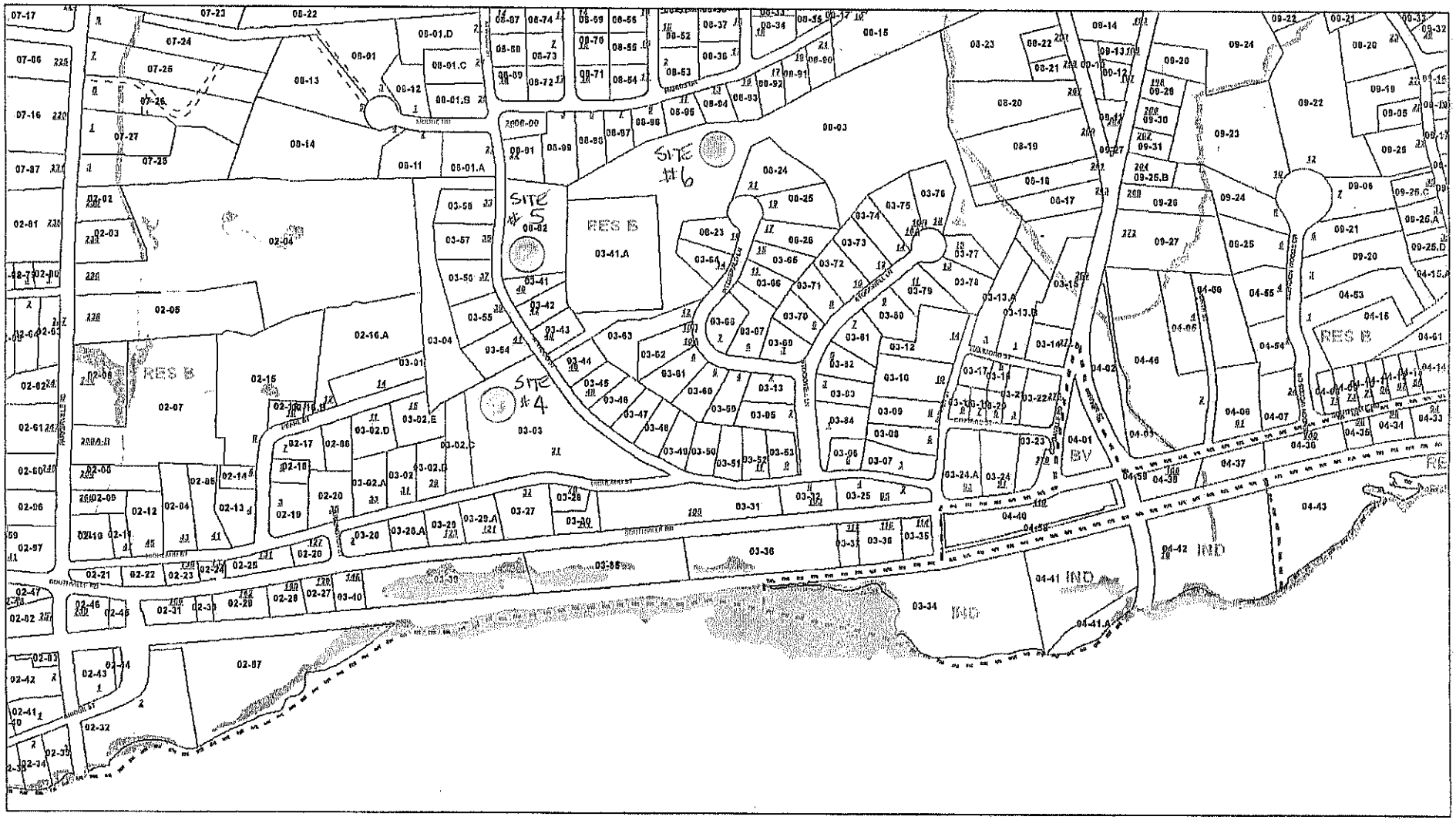
TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 140 280 560 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

MAP 28 OF 90



Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP

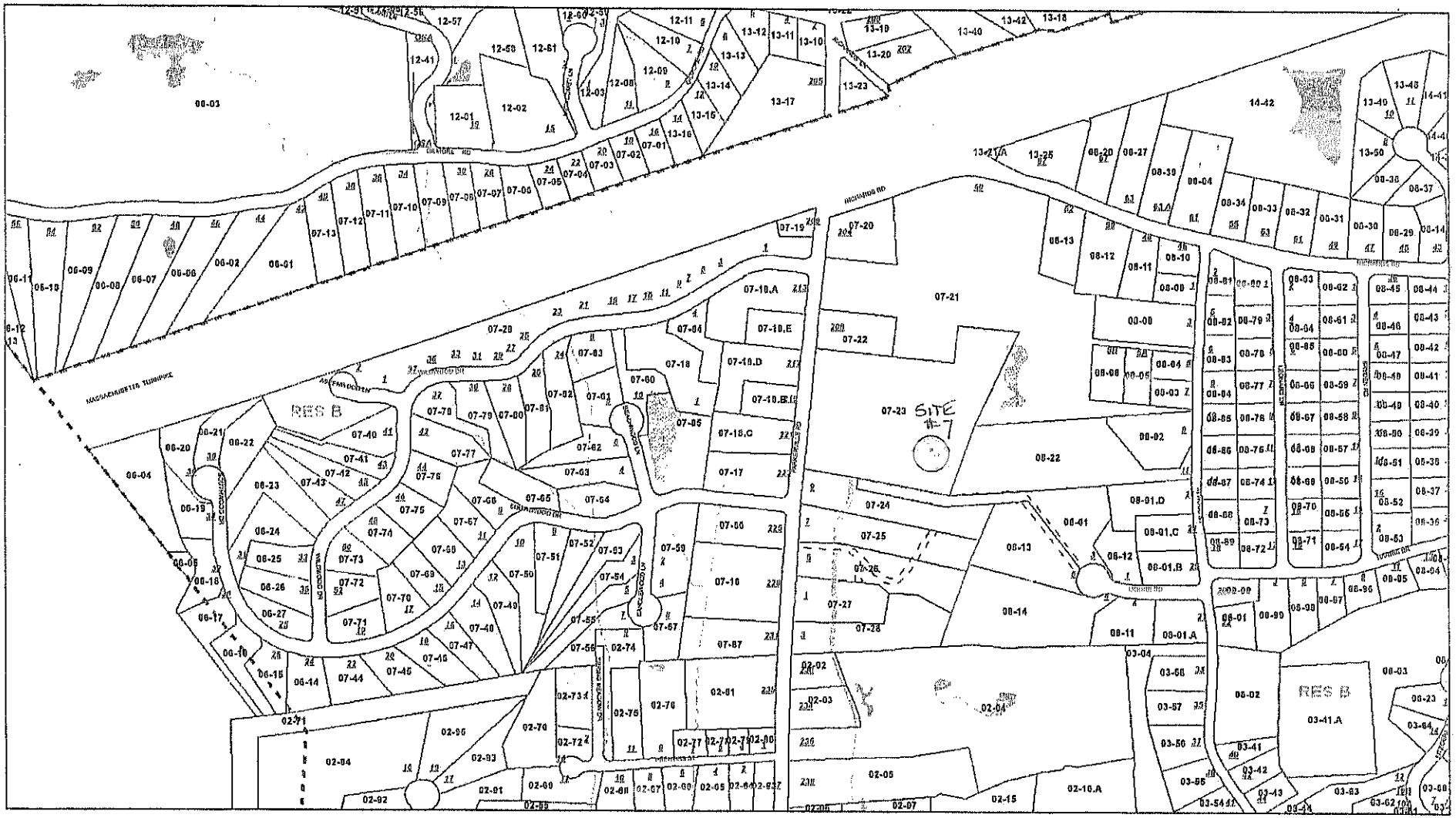
TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 137.5 275 550 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

MAP 3 OF 96



Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP

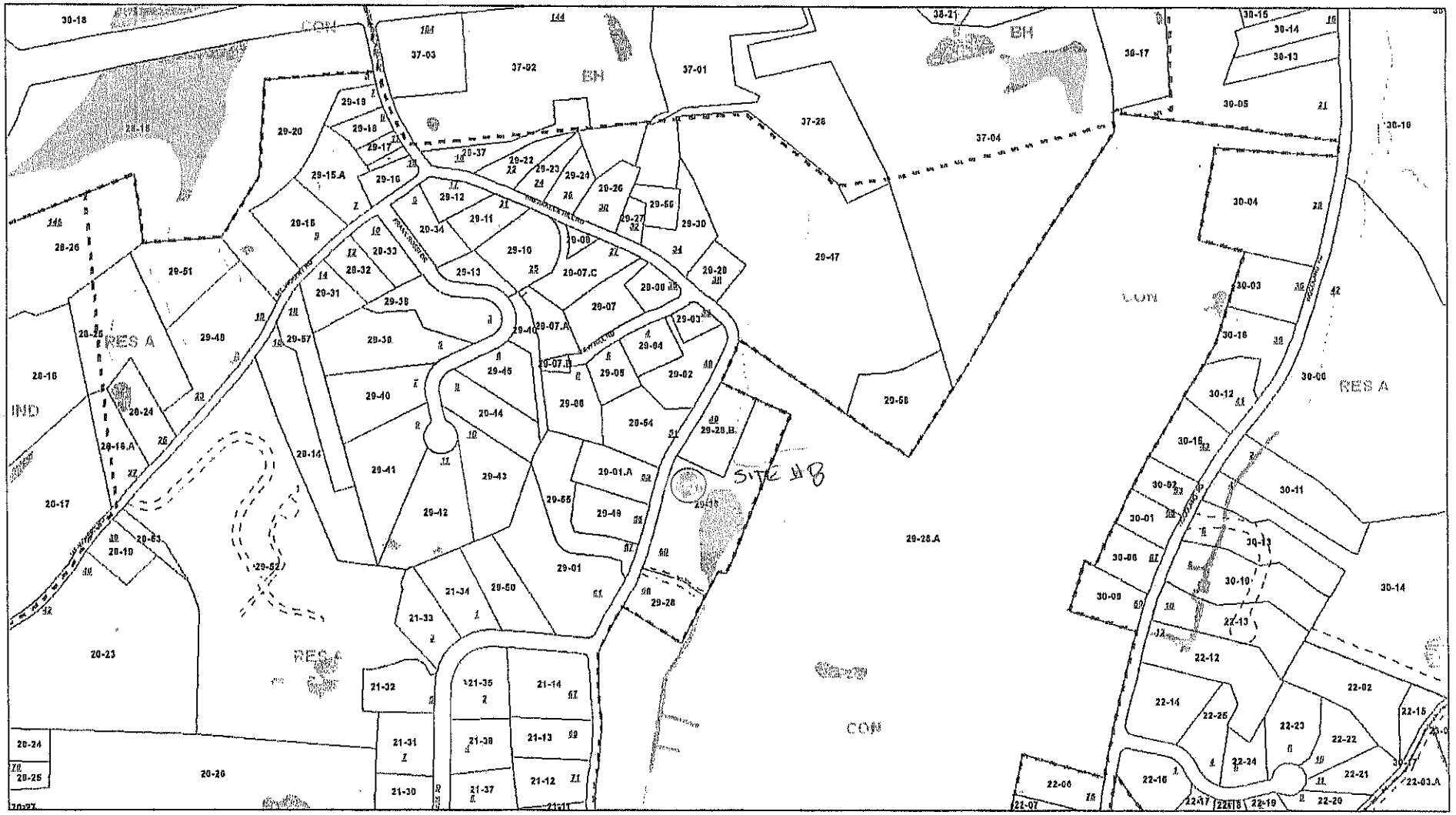
TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 110 220 440 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

MAP 7 OF 90



Parcel Boundary
Hydrographic Features
Zoning Boundary
Lease Number

PROPERTY MAP

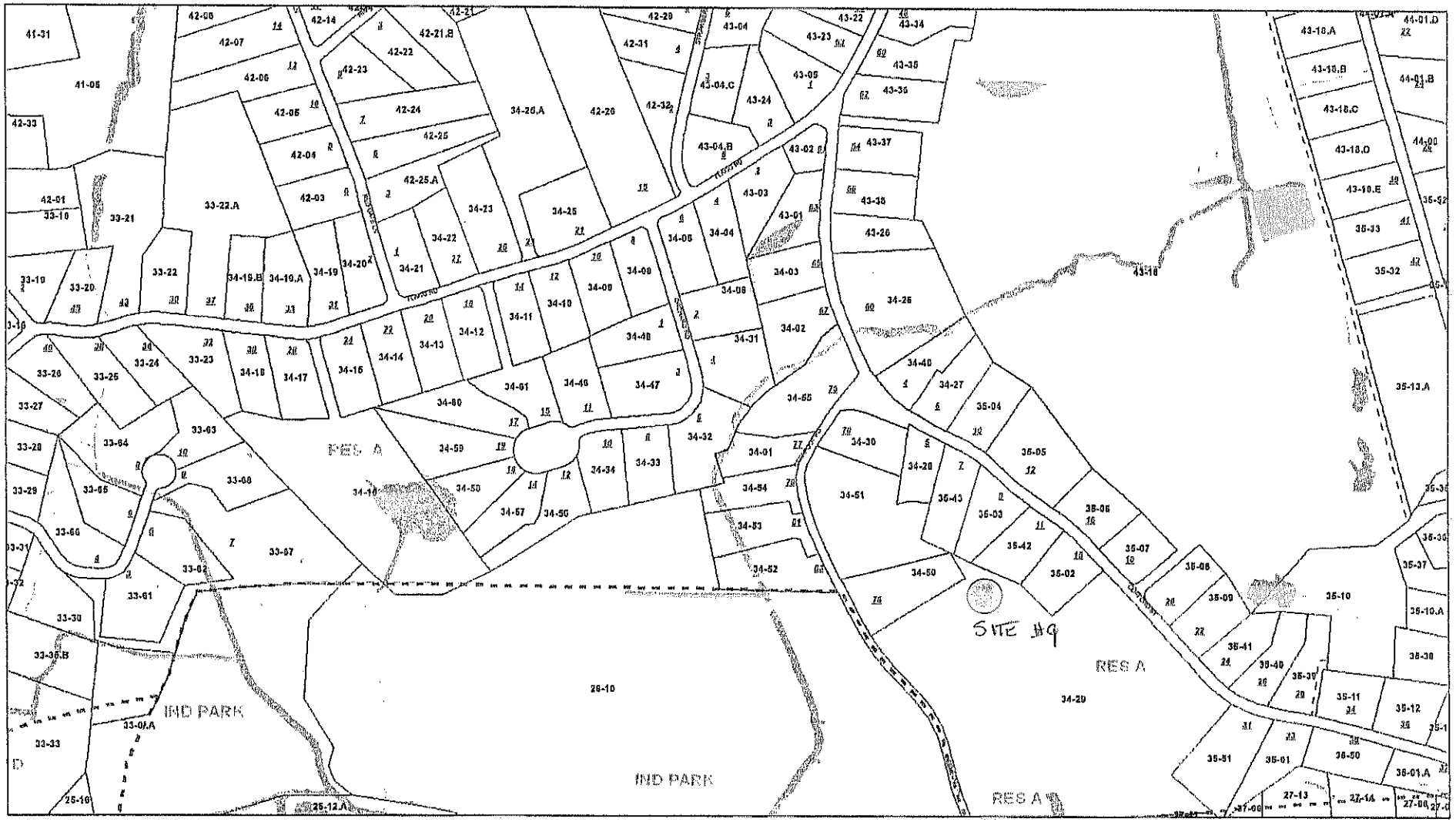
TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 100 200 500 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

MAP 29 OF 06



Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP

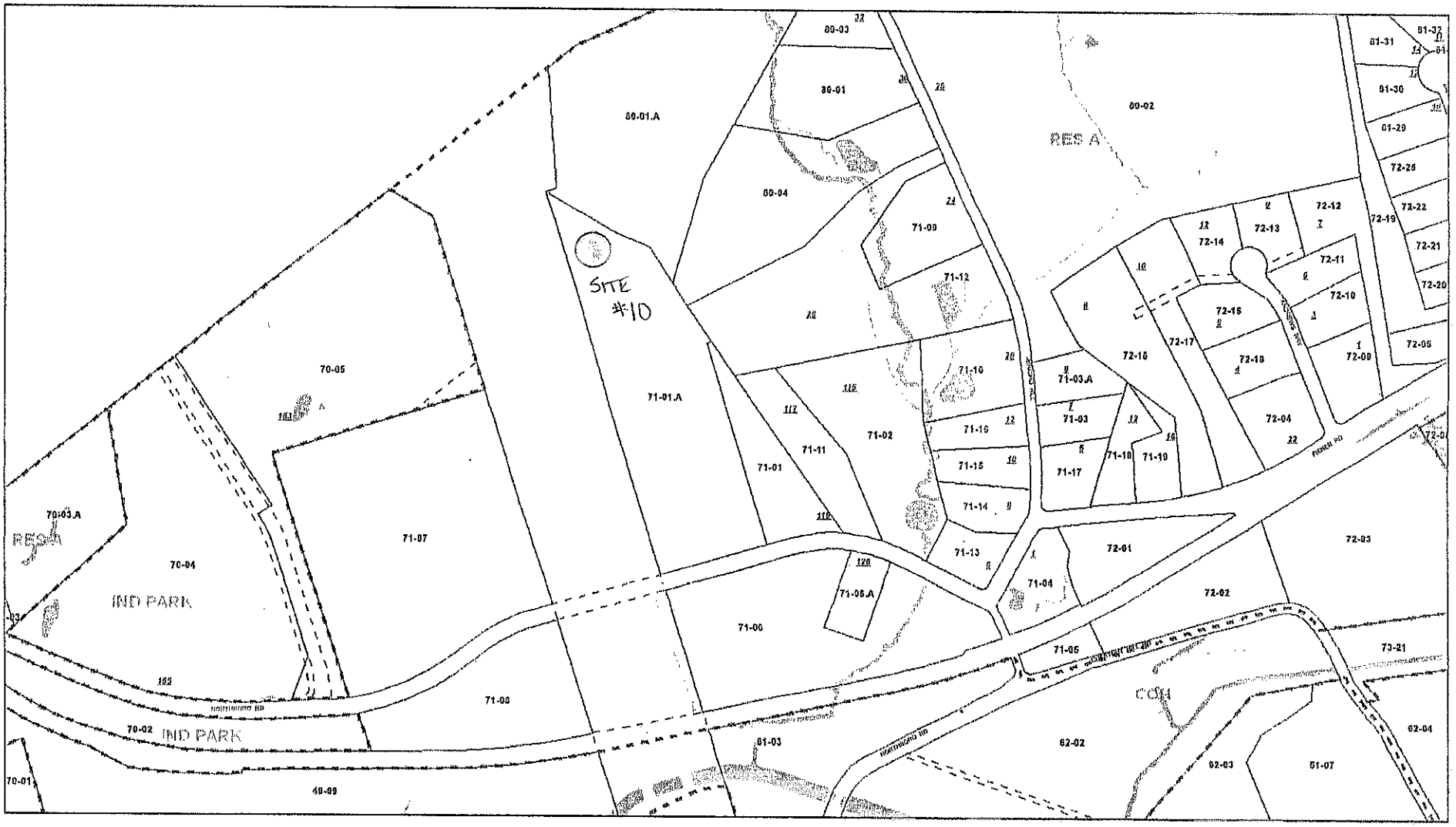
TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 135 270 540 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

MAP 34 OF 96

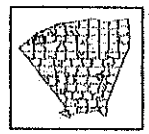


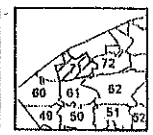
Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP
TOWN OF SOUTHBOROUGH
WORCESTER COUNTY, MASSACHUSETTS

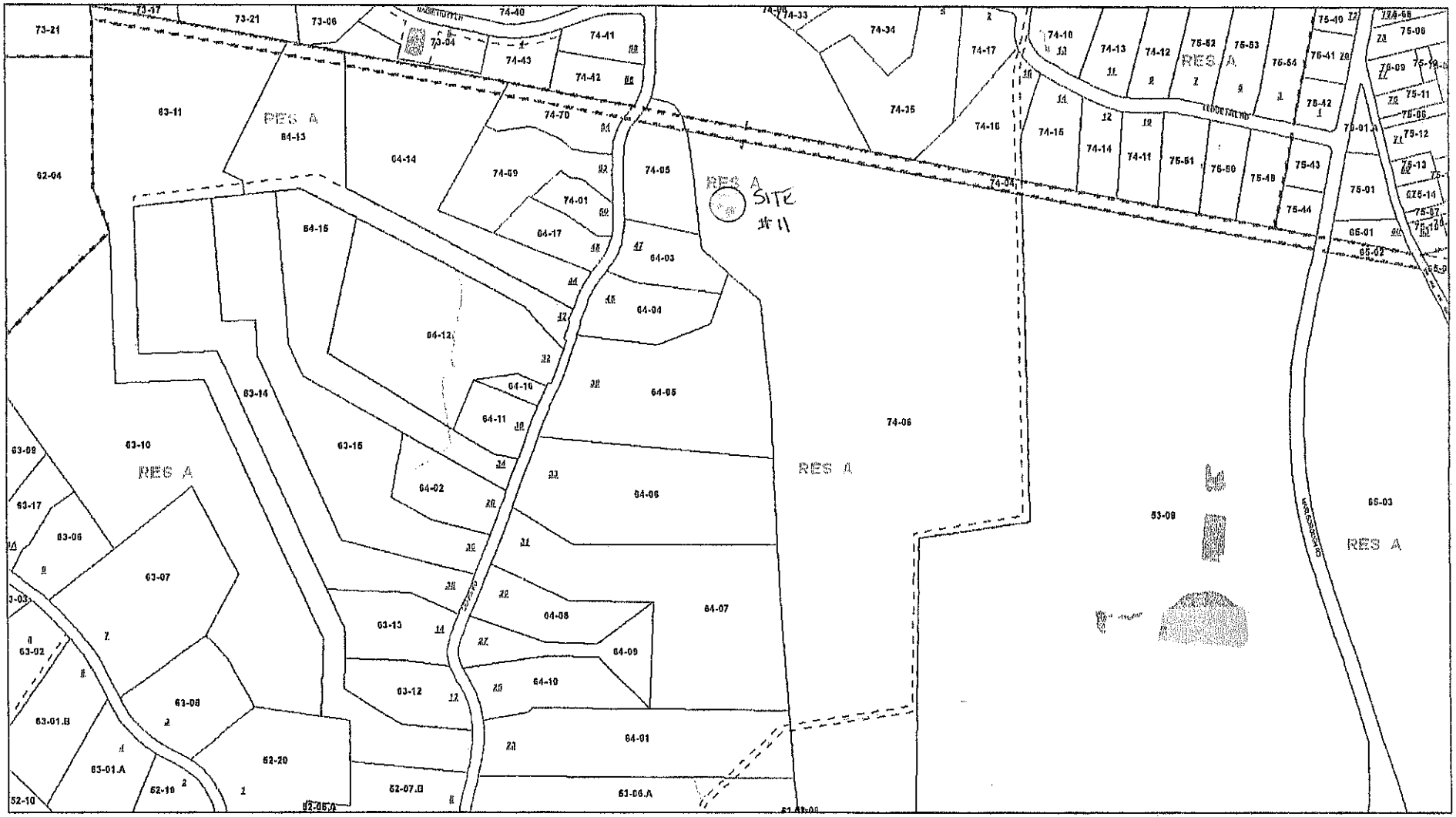
0 110 220 440 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY. NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH. NOT TO BE USED FOR CONVEYANCES.





MAP
71
OF 98



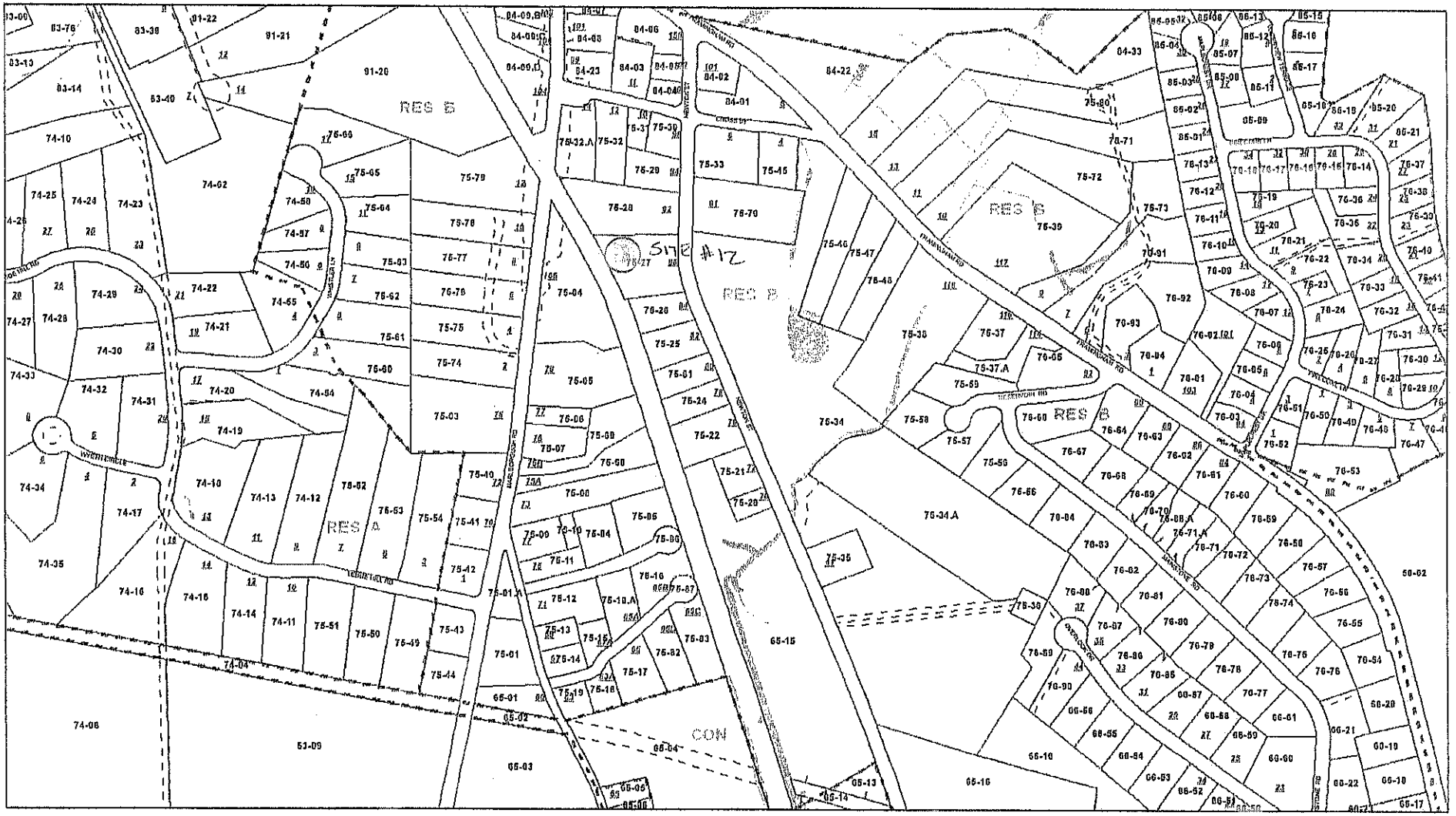
Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP
TOWN OF SOUTHBOROUGH
WORCESTER COUNTY, MASSACHUSETTS

0 110 220 440 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

MAP
64
OF 96



PROPERTY MAP

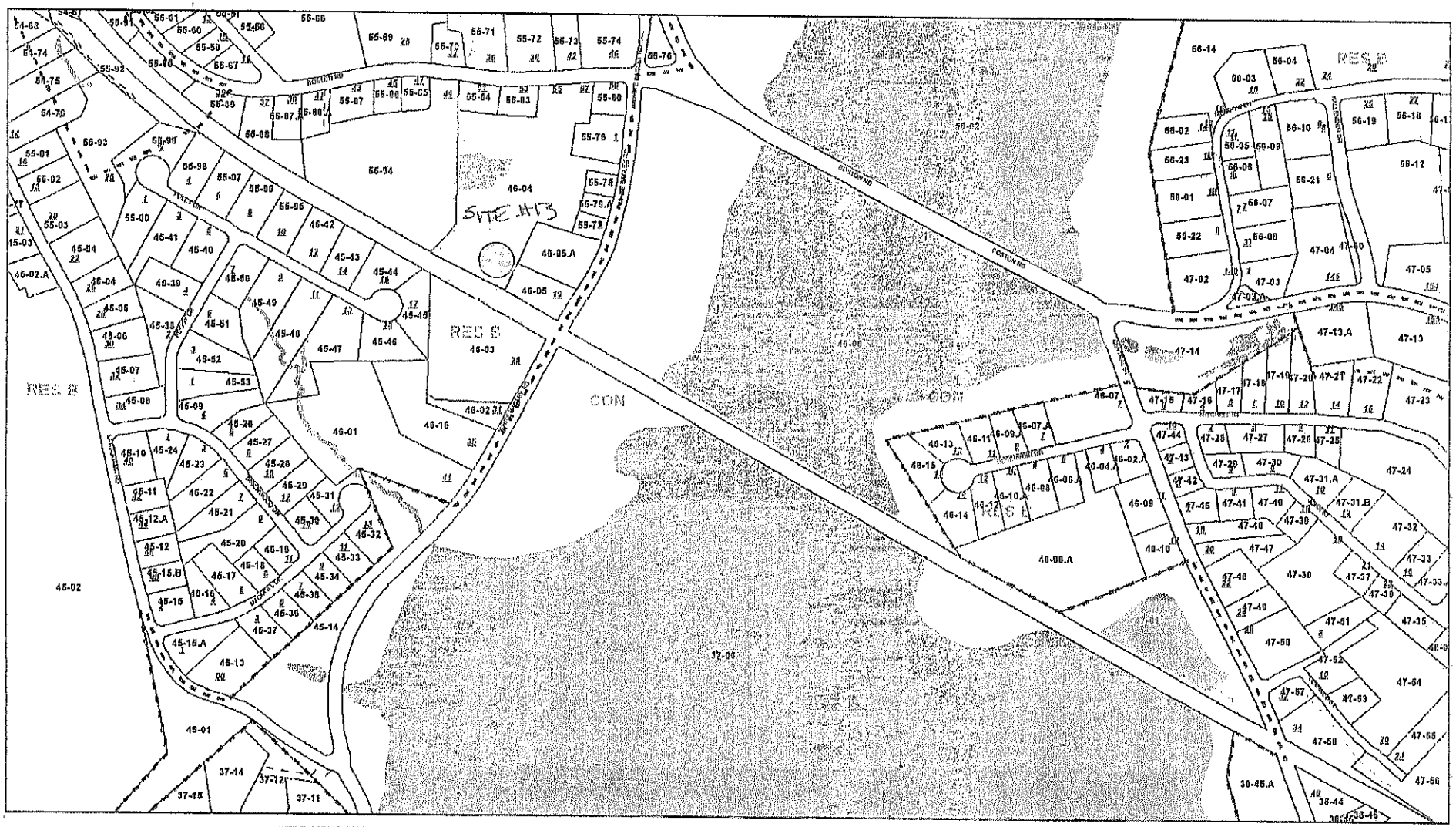
TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 110 220 440 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

MAP 75 OF 96


SITE #13
RES B
COM
RES B
COM
RES B
RES B
46-04
46-03
46-01
46-02
46-06
46-06.A
46-05.A
46-05
46-16
46-10.A
46-12
46-14
46-09
46-10
46-08
46-07
46-13
46-15
46-11
46-09.A
46-04.A
46-02.A
47-01
47-00
47-14
47-13.A
47-13
47-24
47-32
47-33
47-35
47-54
47-55
47-56
47-53
47-52
47-51
47-50
47-49
47-48
47-47
47-46
47-45
47-44
47-43
47-42
47-41
47-40
47-39
47-38
47-37
47-36
47-31.A
47-31.B
47-30
47-29
47-28
47-27
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47-25
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47-22
47-21
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47-19
47-18
47-17
47-16
47-15
47-12
47-11
47-10
47-09
47-08
47-07
47-06
47-05
47-04
47-03
47-03.A
47-02
56-14
56-04
56-03
56-02
56-23
56-01
56-22
56-05
56-09
56-10
56-19
56-18
56-12
56-21
56-08
56-07
56-06
56-00
47-04
47-05
46-45.A
46-44
46-43
46-42
46-41
46-40
46-39
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46-36
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46-22
46-21
46-20
46-19
46-18
46-17
46-16
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46-11
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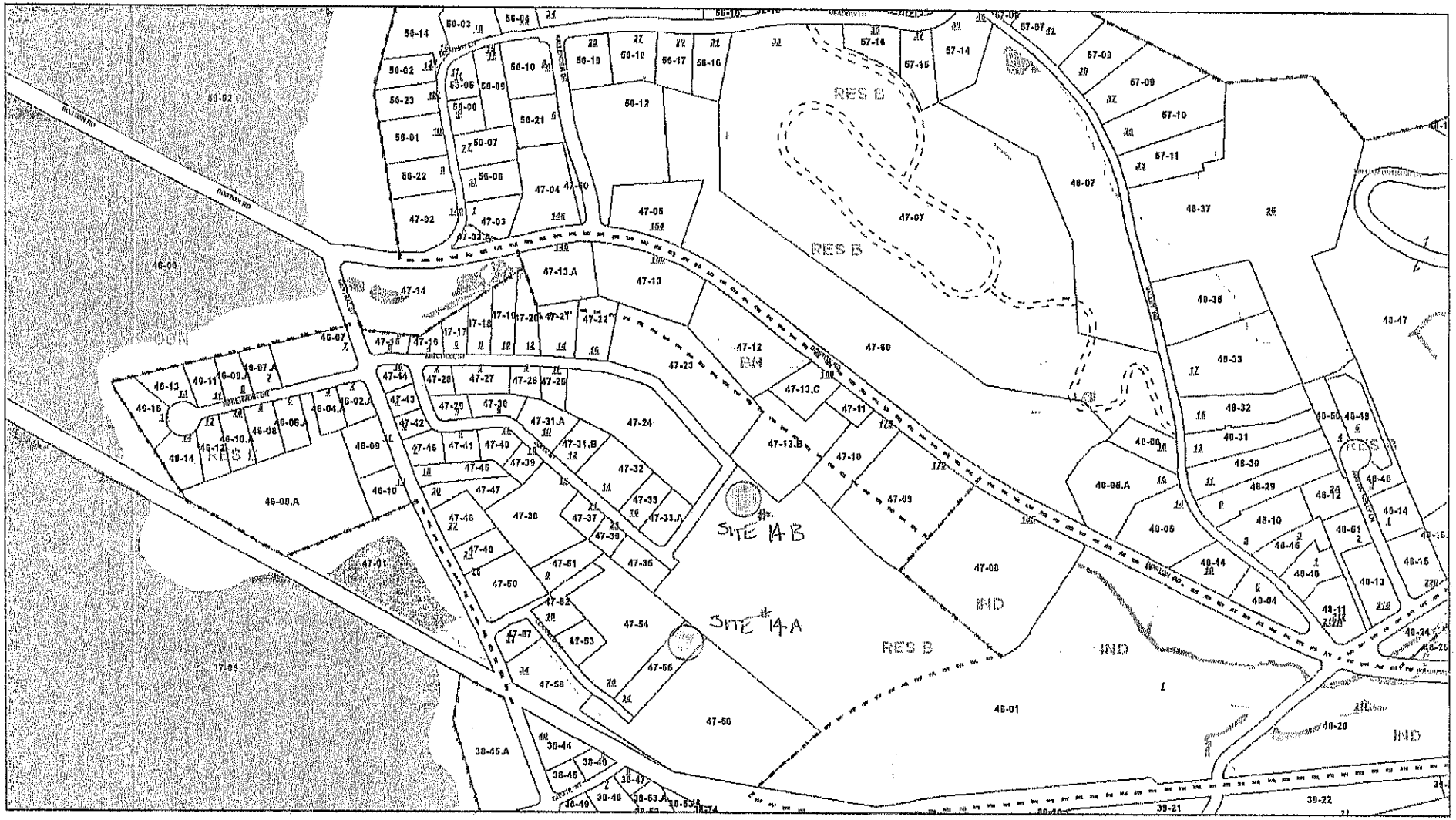
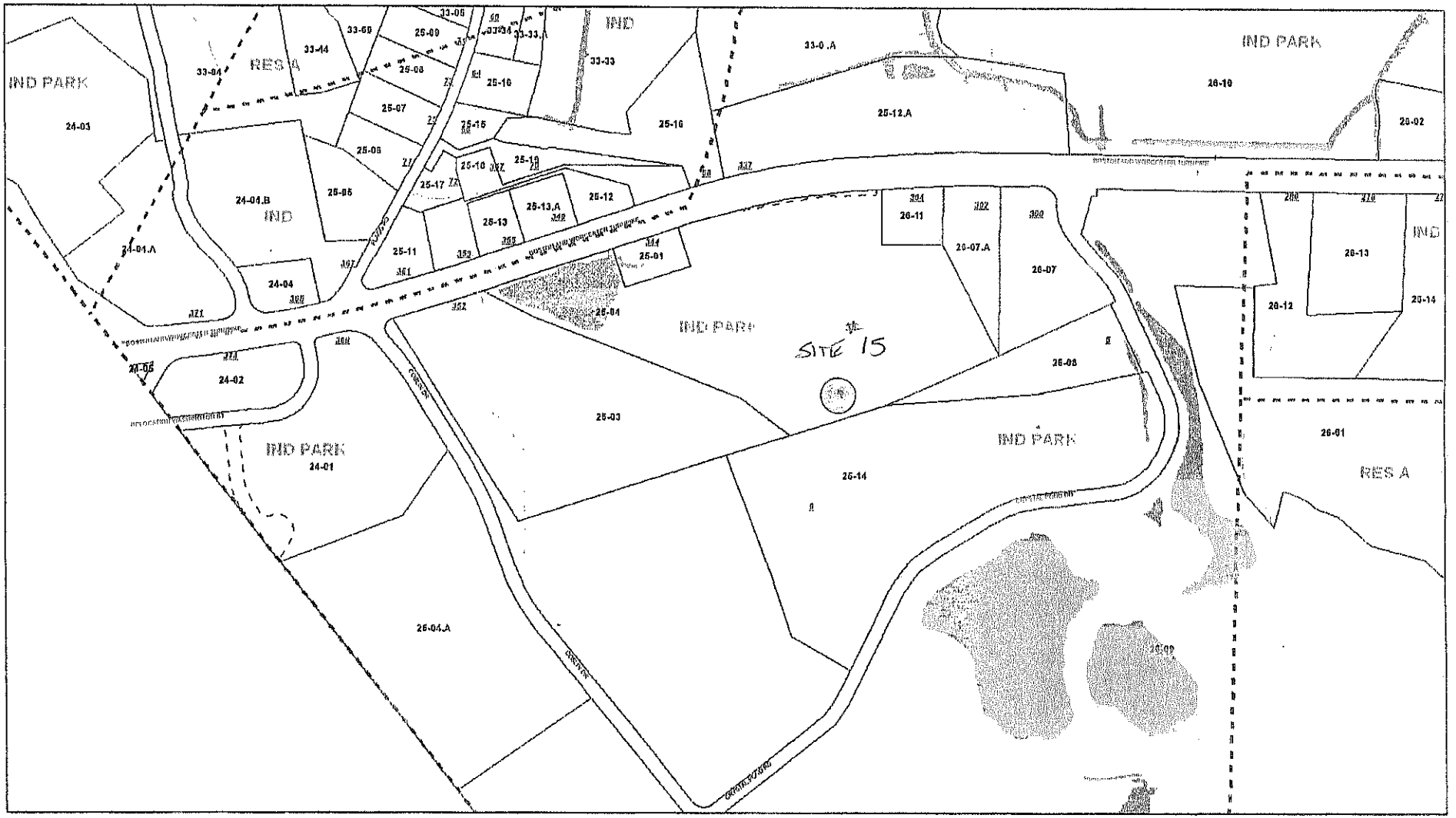
46-08
46-07
46-06
46-05
46-04
46-03
46-02
46-01
45-16.A
45-15.B
45-15
45-14
45-13
45-12.A
45-12
45-11
45-10
45-09
45-08
45-07
45-06
45-05
45-04
45-03
45-02
45-01
38-46.A
38-44
38-45
37-14
37-12
37-11
37-10
55-94
55-93
55-92
55-91
55-90
55-89
55-88
55-87
55-86
55-85
55-84
55-83
55-82
55-81
55-80
55-79
55-78
55-78.A
55-77
55-76
55-75
55-74
55-73
55-72
55-71
55-70
55-69
55-68
55-67
55-66
54-79
54-78
54-77
54-76
54-75
54-74
54-73
54-72
54-71
54-70
54-69
54-68
WILLIAM RD
WILLIAM RD
OCEAN RD
OCEAN RD
MEADOW RD
MEADOW RD
MEADOW


RES B
RES B
RES B
IND
IND
IND
SITE 14-B
SITE 14-A
RES A
RES A
RES

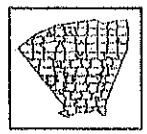


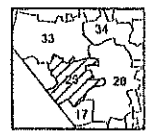
Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP
TOWN OF SOUTHBOROUGH
WORCESTER COUNTY, MASSACHUSETTS

0 140 280 560 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.





MAP
25
OF 96



Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP

TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 155 310 620 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
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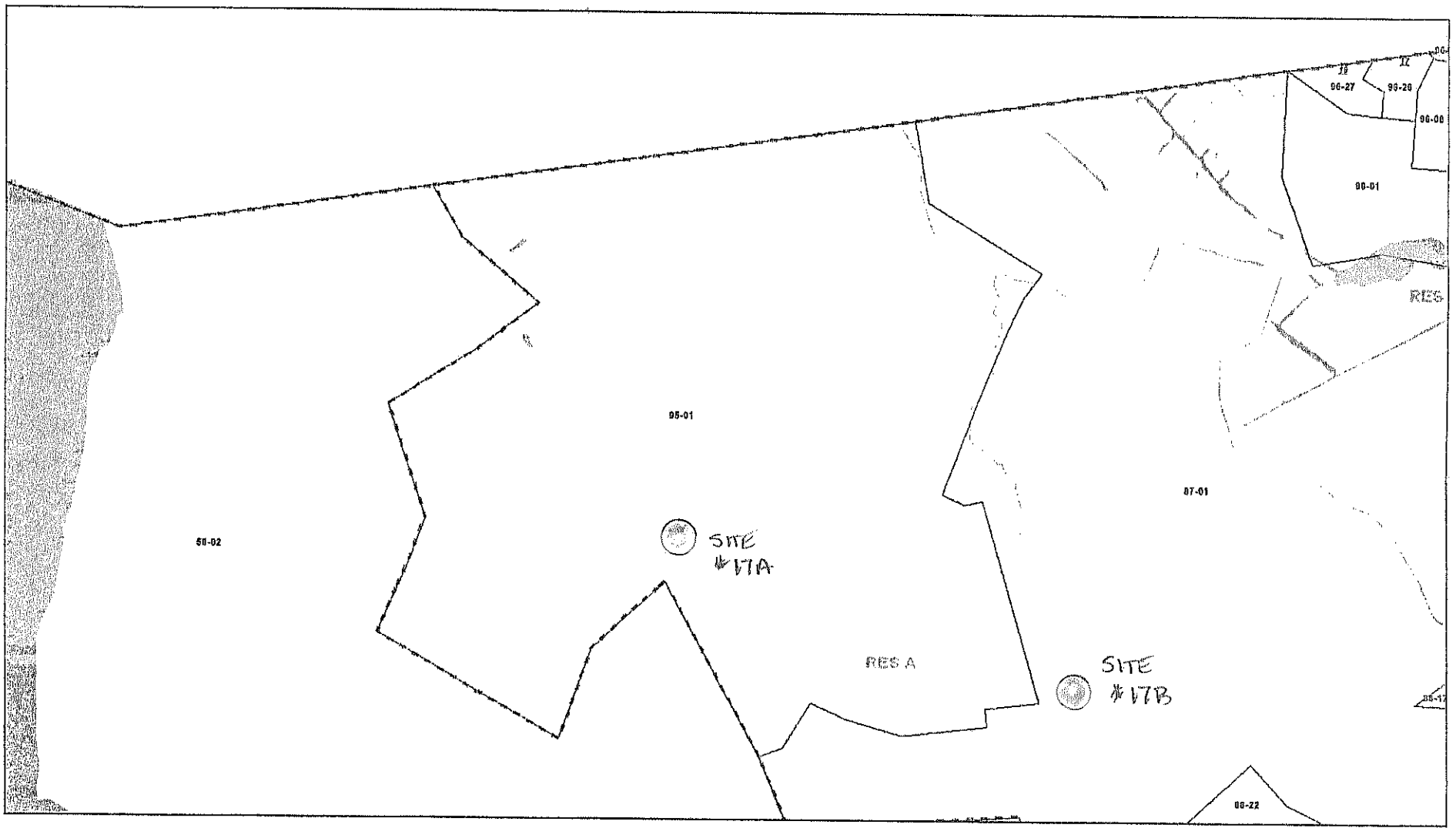
NOT TO BE USED FOR CONVEYANCES.

MAP 12 OF 96



Parcel Boundary
Hydrographic Features
Zoning Boundary
House Number

PROPERTY MAP

TOWN OF SOUTHBOROUGH

WORCESTER COUNTY, MASSACHUSETTS

0 95 100 300 Feet

INFORMATION SHOWN HEREON IS FOR ASSESSING PURPOSES ONLY.
NO LIABILITY FOR ERROR IS ASSUMED BY THE TOWN OF SOUTHBOROUGH.
NOT TO BE USED FOR CONVEYANCES.

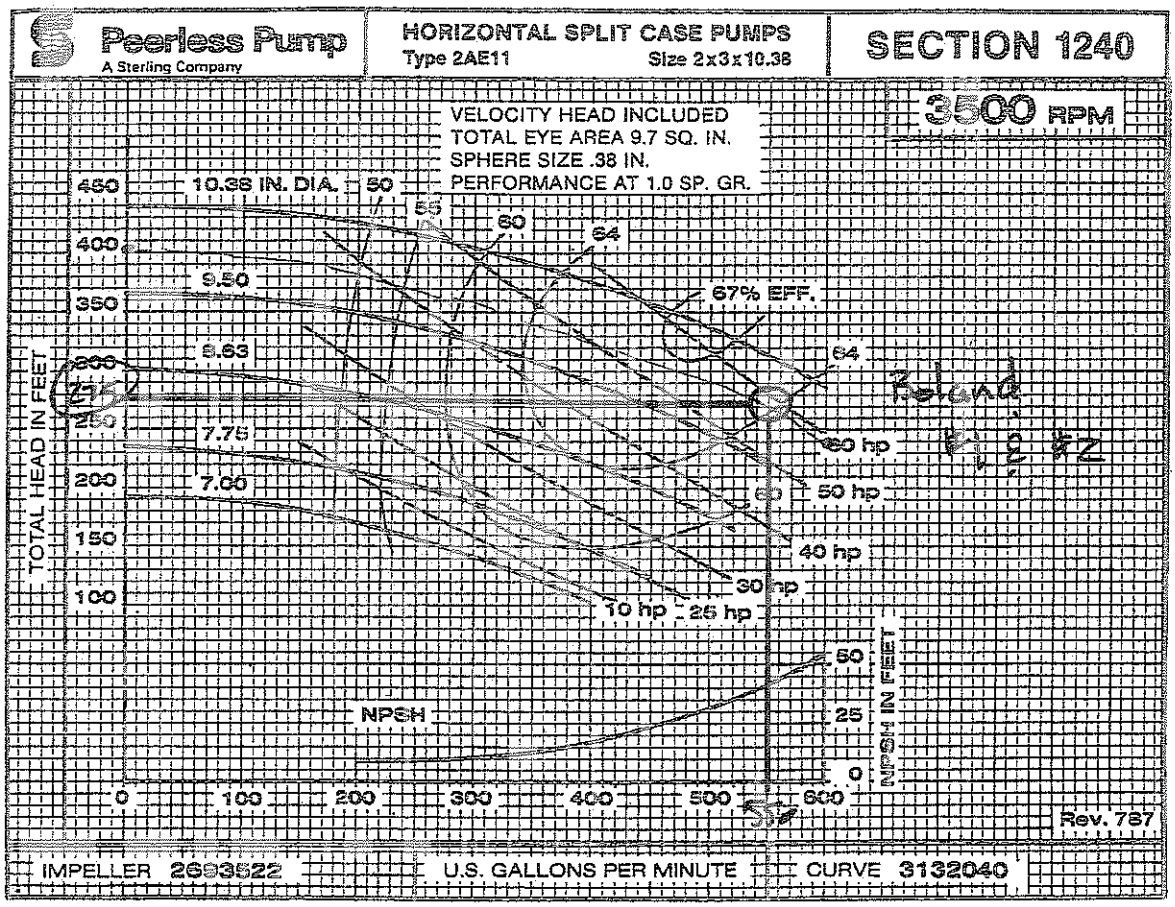
04	05	06
06	07	08
77	78	79

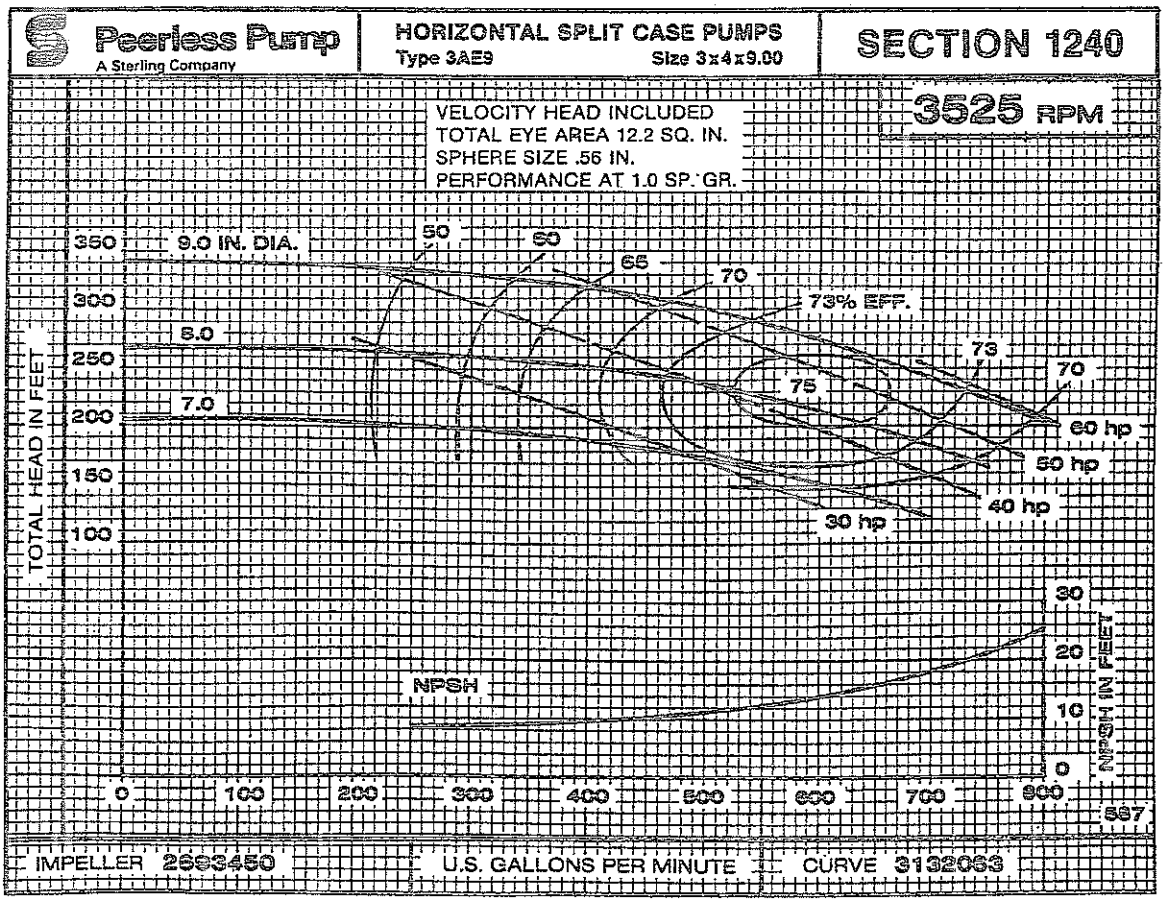
MAP **95** OF 96

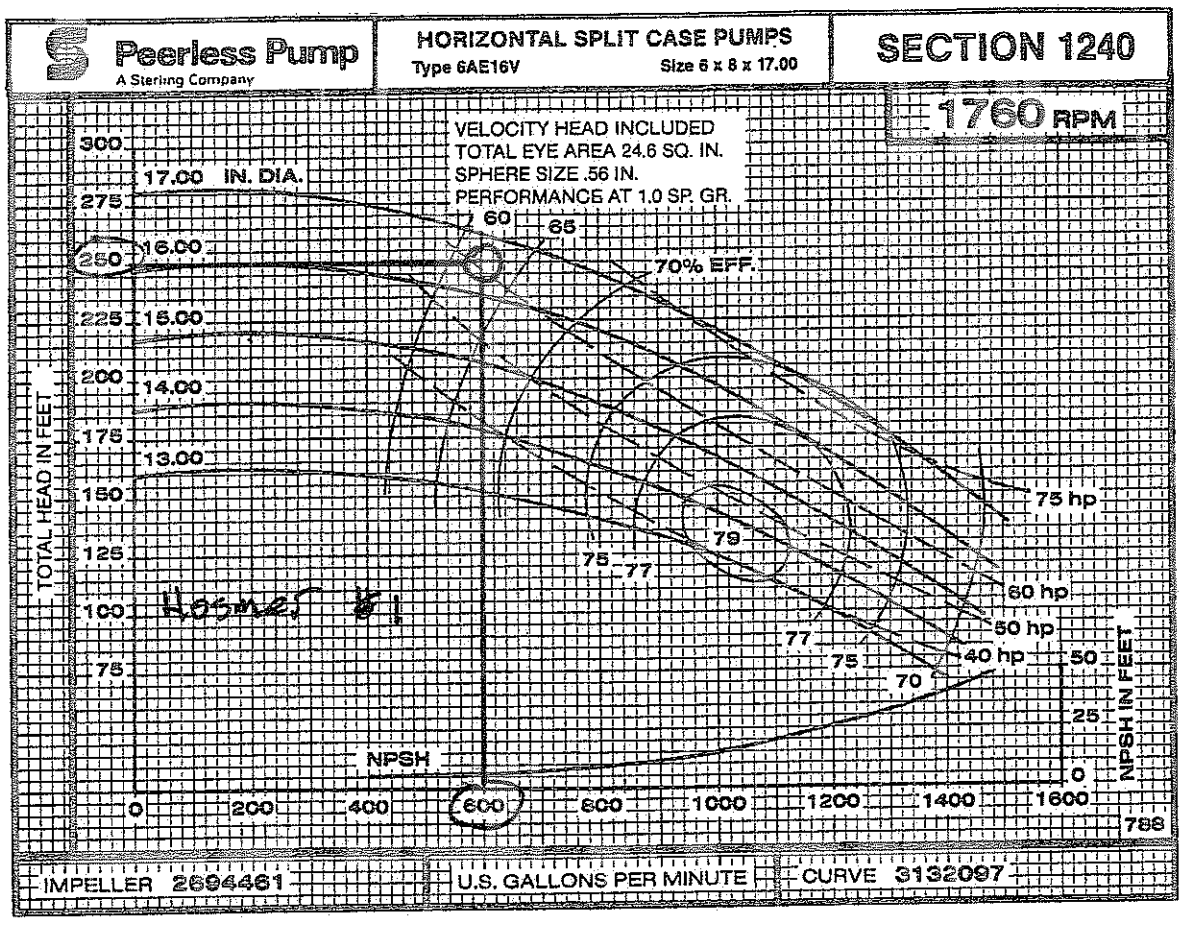
APPENDIX F

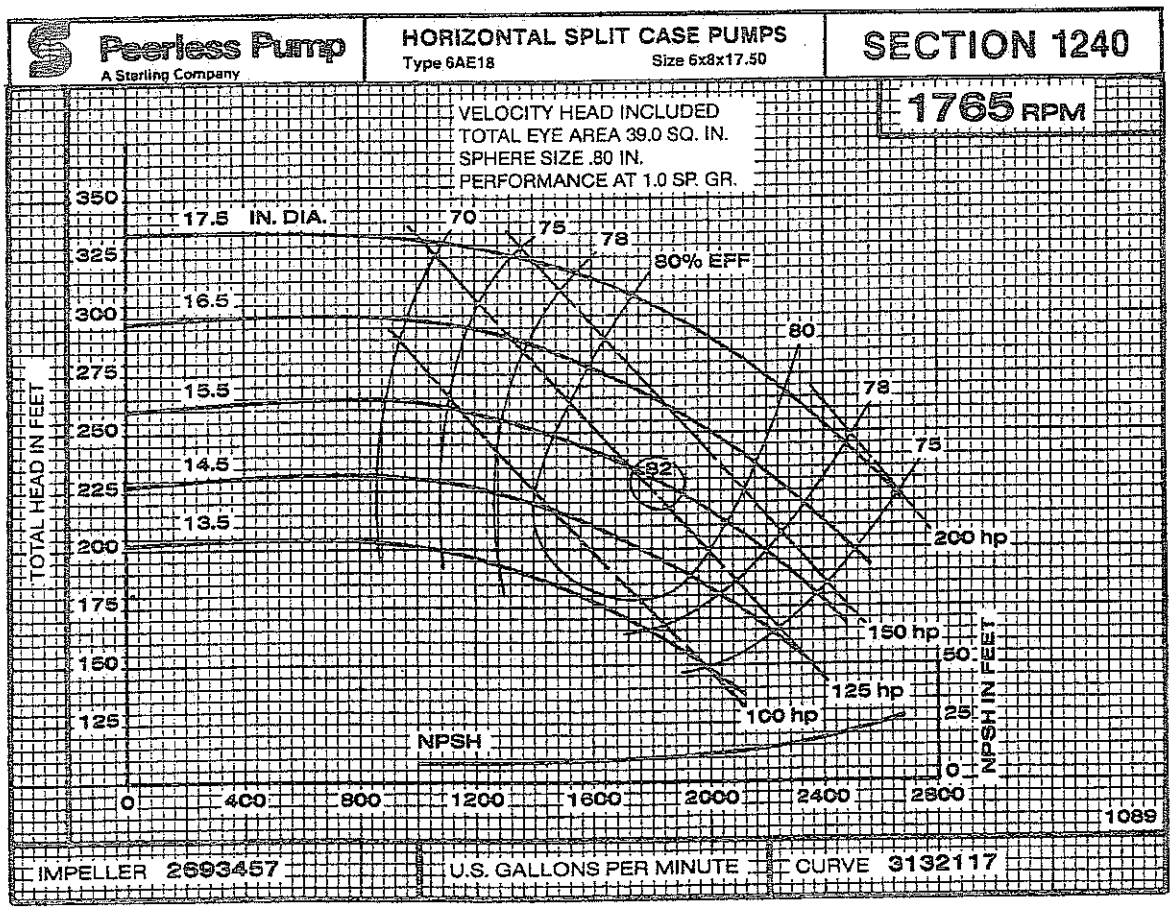
PUMP CURVES

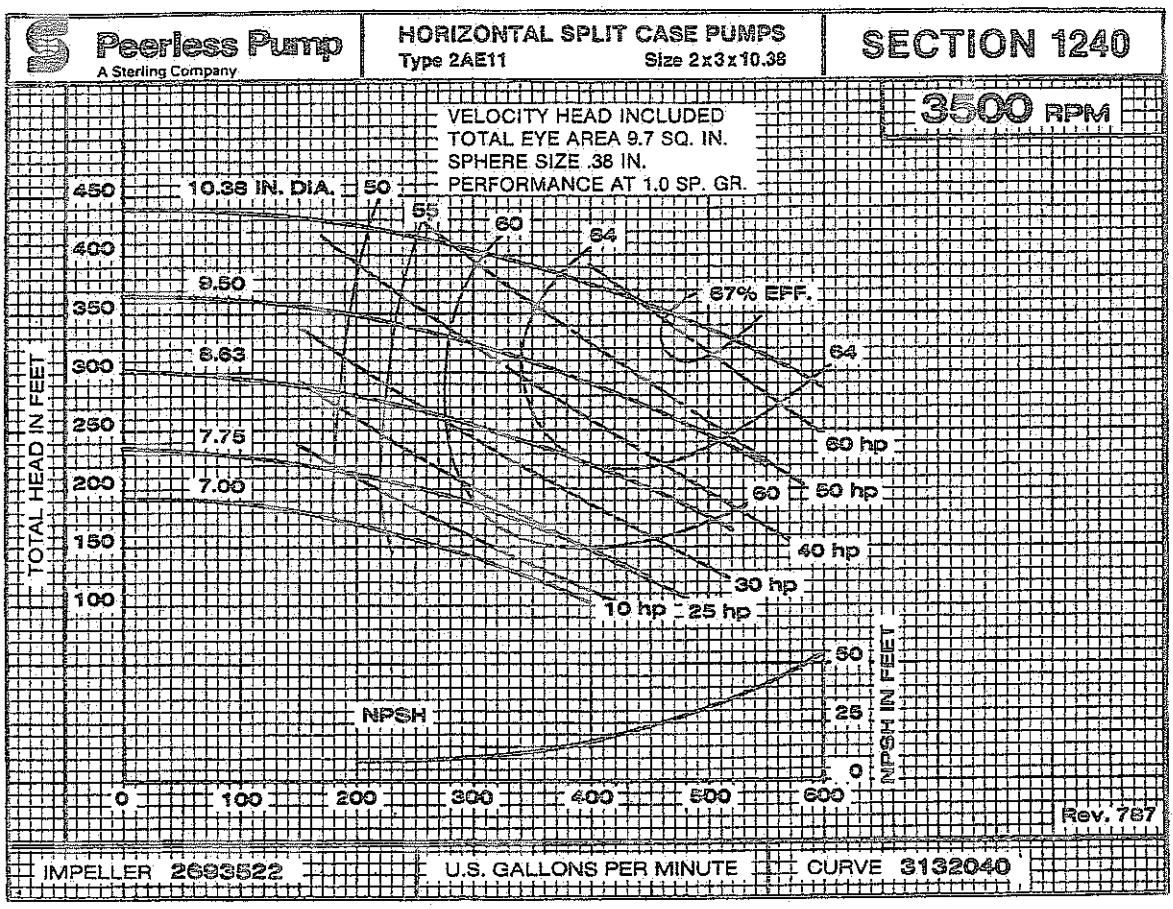
EXISTING PUMPS

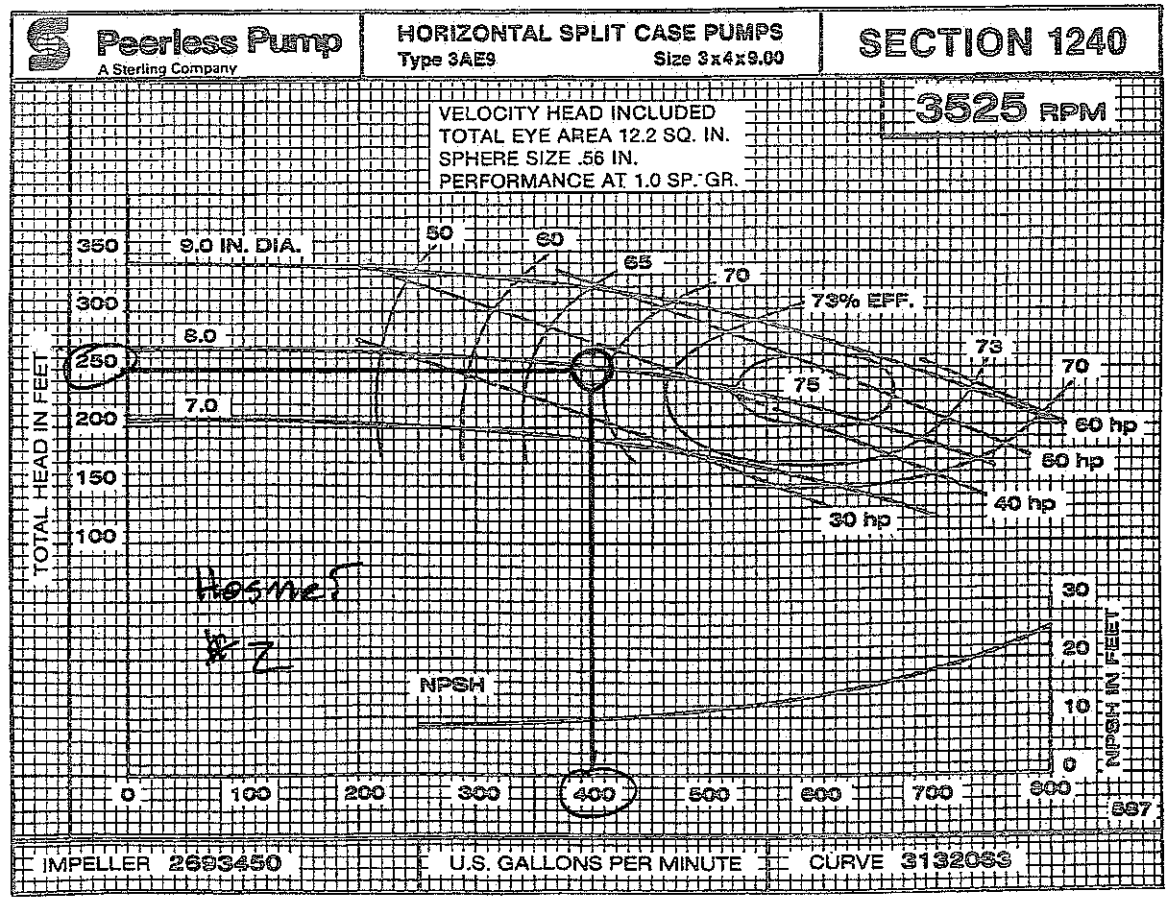

Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 2AE11
Size 2x3x10.38
SECTION 1240
3500 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 9.7 SQ. IN.
SPHERE SIZE .38 IN.
PERFORMANCE AT 1.0 SP. GR.
10.38 IN. DIA.
9.50
8.63
7.75
7.00
67% EFF.
60 hp
50 hp
40 hp
30 hp
25 hp
NPSH
TOTAL HEAD IN FEET
NPSH IN FEET
Rev. 7-87
IMPELLER 2693522
U.S. GALLONS PER MINUTE
CURVE 3132040


Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 3AE9
Size 3x4x9.00
SECTION 1240
3525 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 12.2 SQ. IN.
SPHERE SIZE .56 IN.
PERFORMANCE AT 1.0 SP. GR.
9.0 IN. DIA.
8.0
7.0
73% EFF.
60 hp
50 hp
40 hp
30 hp
NPSH
TOTAL HEAD IN FEET
NPSH IN FEET
5-87
IMPELLER 2693450
U.S. GALLONS PER MINUTE
CURVE 3132063


Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 6AE16V
Size 6 x 8 x 17.00
SECTION 1240
1760 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 24.6 SQ. IN.
SPHERE SIZE .56 IN.
PERFORMANCE AT 1.0 SP. GR.
17.00 IN. DIA.
16.00
15.00
14.00
13.00
70% EFF.
75 hp
60 hp
50 hp
40 hp
NPSH
TOTAL HEAD IN FEET
NPSH IN FEET
Homer #1
IMPELLER 2694461
U.S. GALLONS PER MINUTE
CURVE 3132097
788


Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 6AE18
Size 6x8x17.50
SECTION 1240
1765 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 39.0 SQ. IN.
SPHERE SIZE .80 IN.
PERFORMANCE AT 1.0 SP. GR.
17.5 IN. DIA.
16.5
15.5
14.5
13.5
80% EFF
200 hp
150 hp
125 hp
100 hp
NPSH
TOTAL HEAD IN FEET
NPSH IN FEET
IMPELLER 2693457
U.S. GALLONS PER MINUTE
CURVE 3132117
1089


Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 2AE11 Size 2x3x10.38
SECTION 1240
3500 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 9.7 SQ. IN.
SPHERE SIZE .38 IN.
PERFORMANCE AT 1.0 SP. GR.
10.38 IN. DIA.
9.50
8.63
7.75
7.00
67% EFF.
60 hp
50 hp
40 hp
30 hp
25 hp
10 hp
NPSH
TOTAL HEAD IN FEET
NPSH IN FEET
Rev. 7-87
IMPELLER 2693522
U.S. GALLONS PER MINUTE
CURVE 3132040

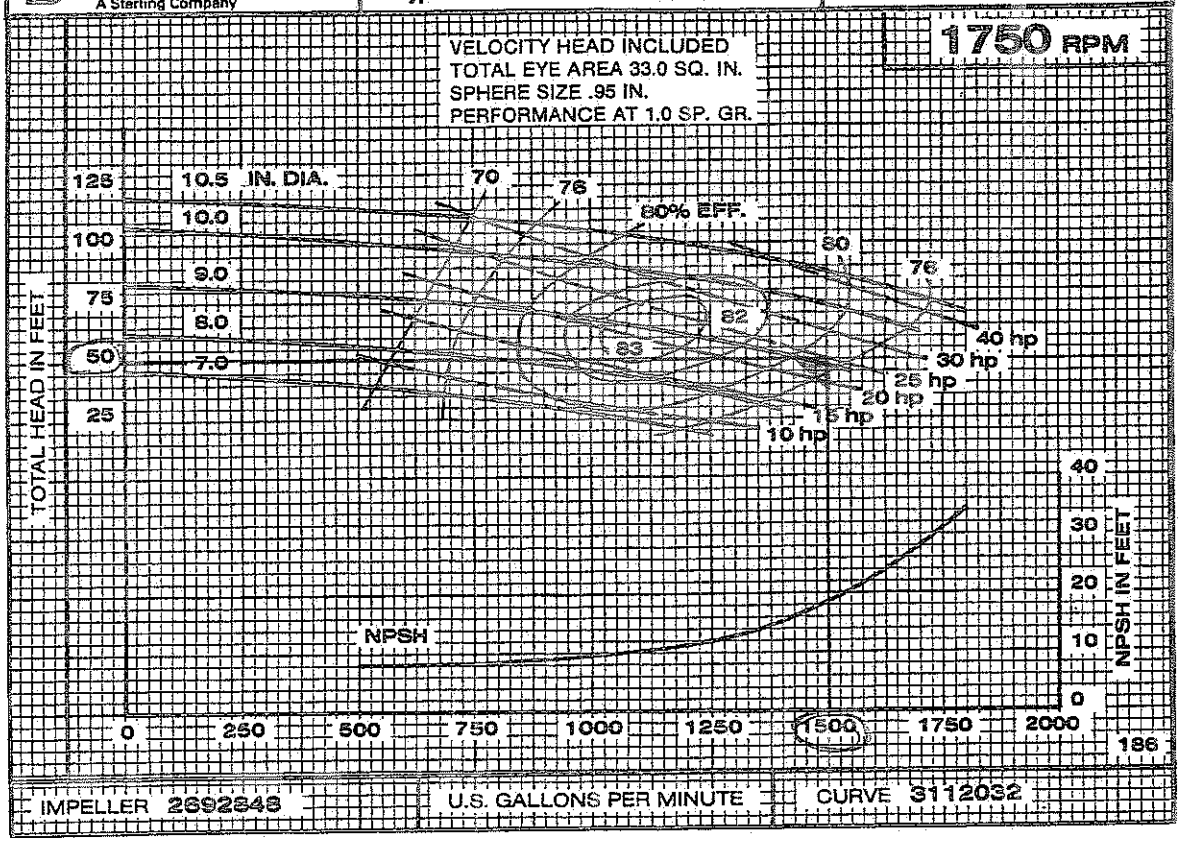

Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 3AE9 Size 3x4x9.00
SECTION 1240
3525 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 12.2 SQ. IN.
SPHERE SIZE .56 IN.
PERFORMANCE AT 1.0 SP. GR.
9.0 IN. DIA.
8.0
7.0
73% EFF.
60 hp
50 hp
40 hp
30 hp
NPSH
TOTAL HEAD IN FEET
NPSH IN FEET
Hosmer
#7
IMPELLER 2693450
U.S. GALLONS PER MINUTE
CURVE 3132033

PROPOSED PUMPS

Peerless Pump
A Sterling Company

HORIZONTAL SPLIT CASE PUMPS
Type 6AE11 Size 6x6x10.50

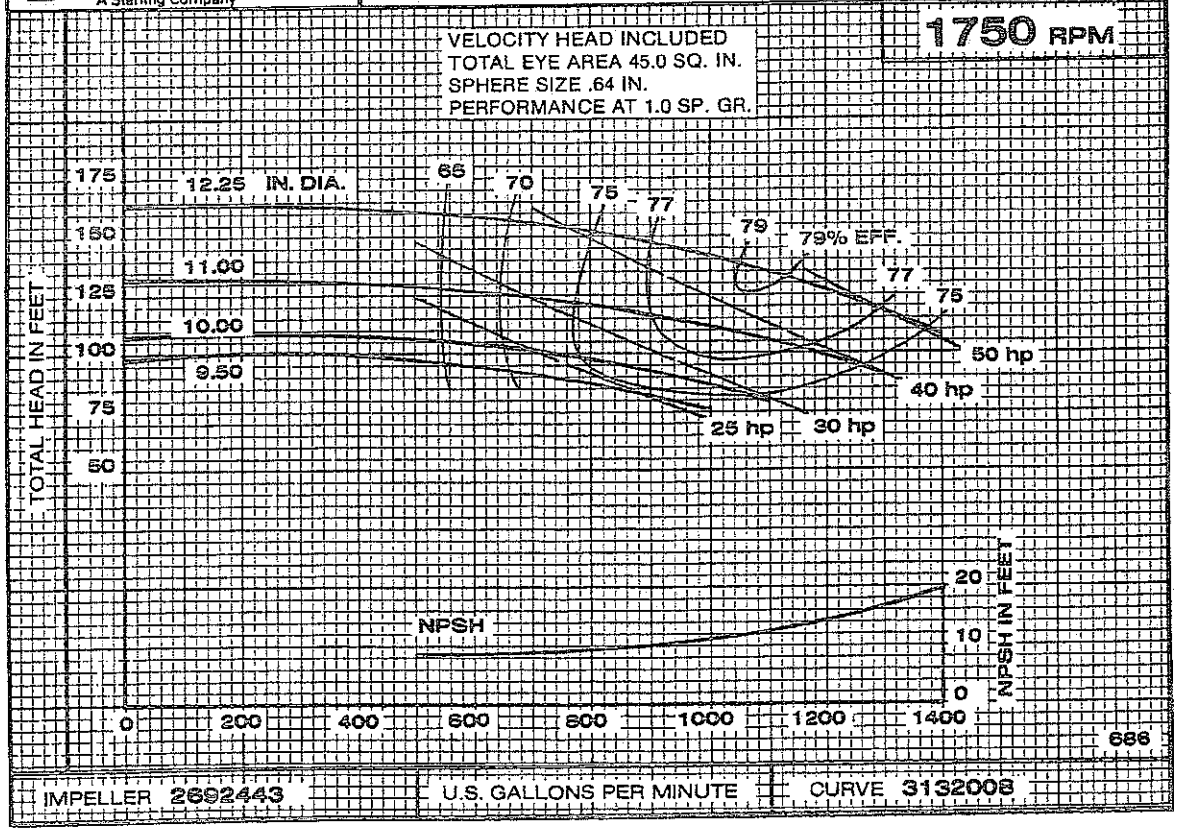
SECTION 1240

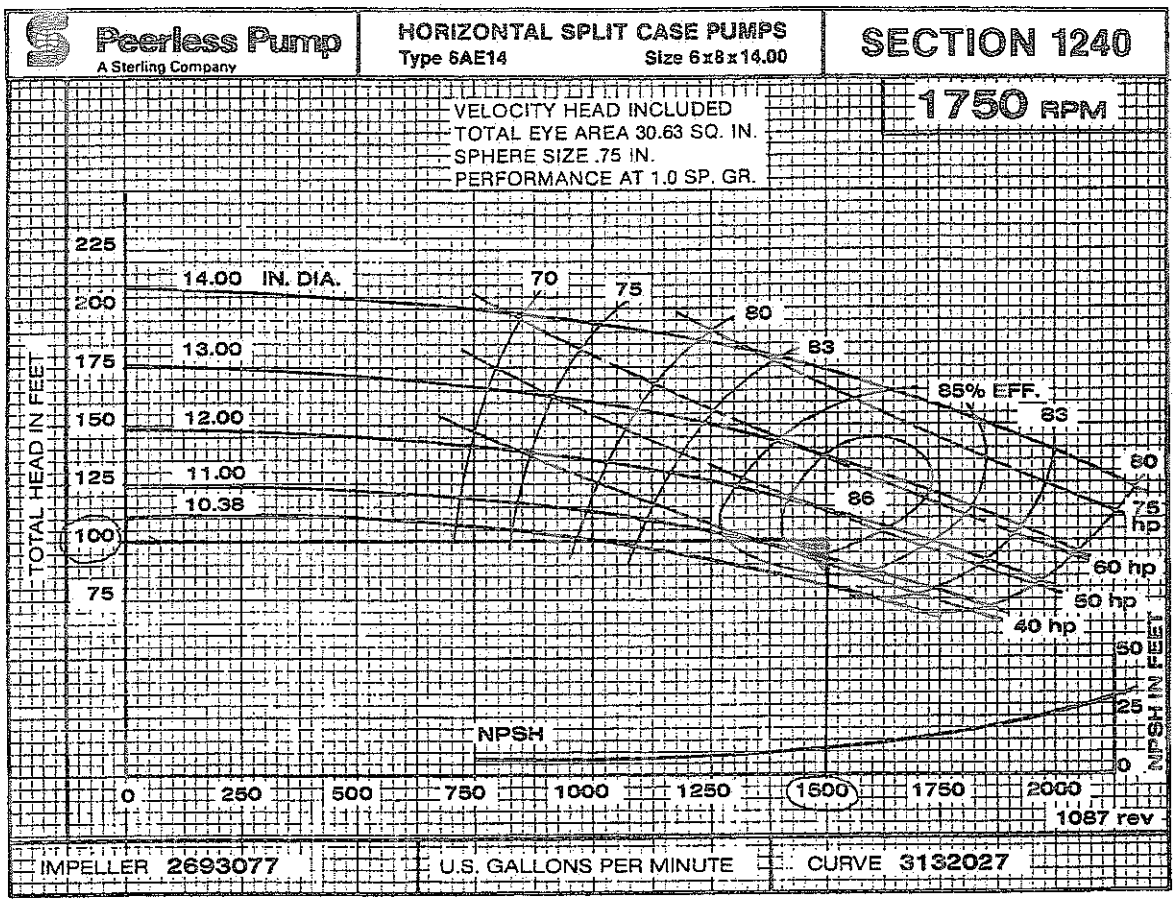


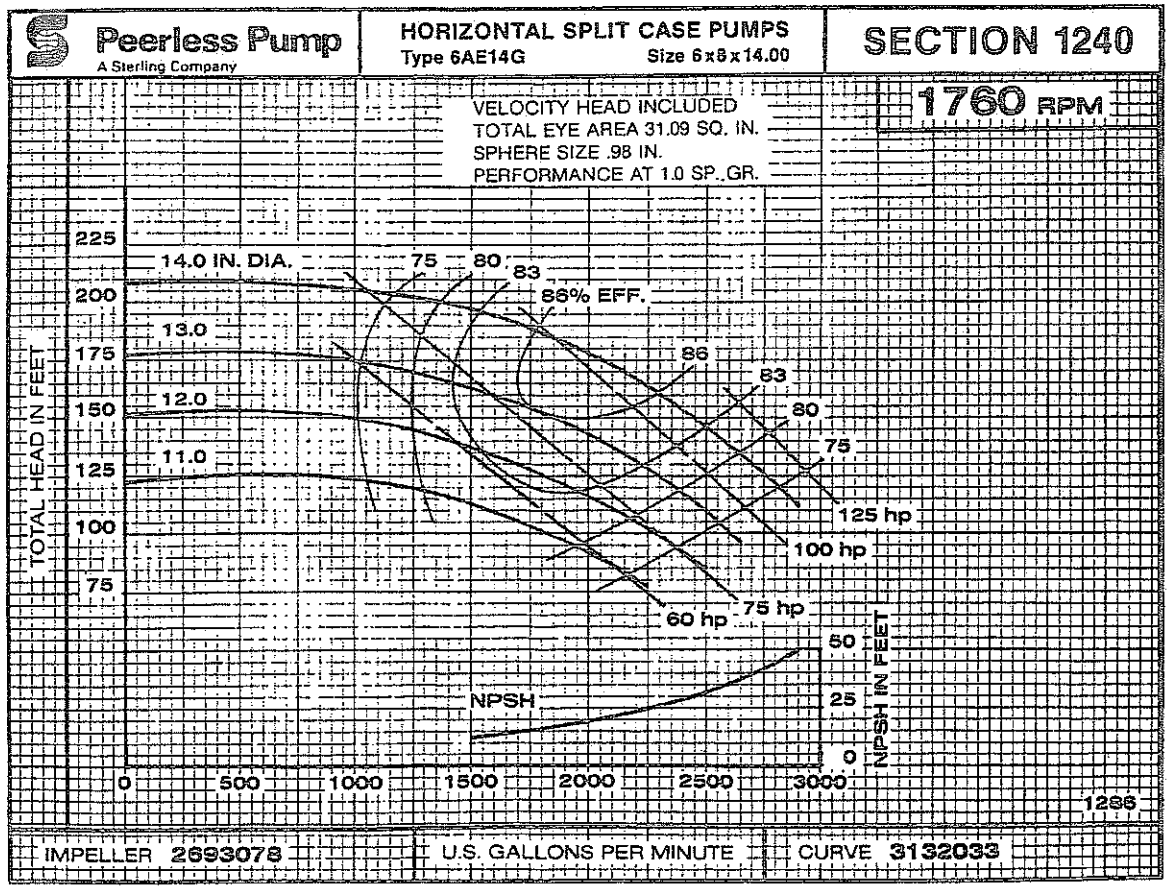
Peerless Pump
A Sterling Company

HORIZONTAL SPLIT CASE PUMPS
Type 6AE12 Size 6x8x12.25

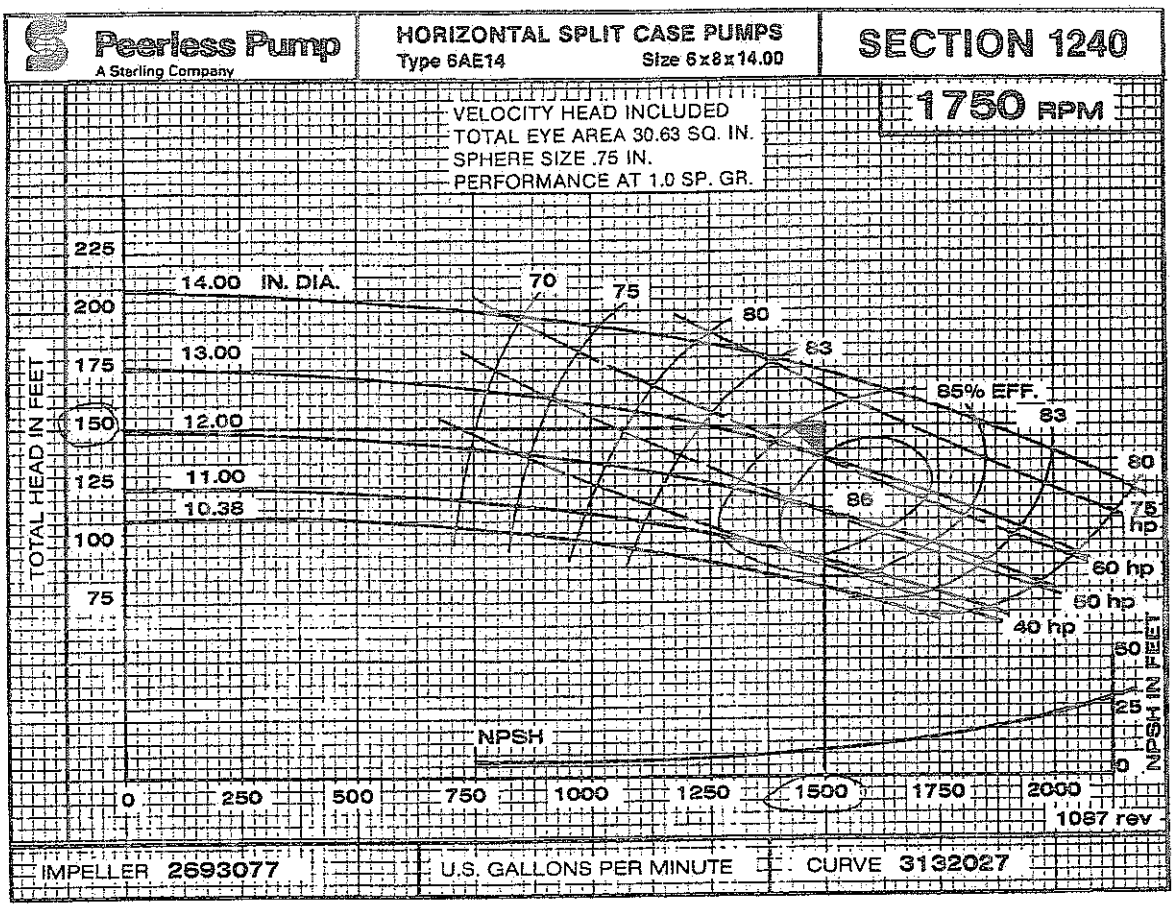
SECTION 1240

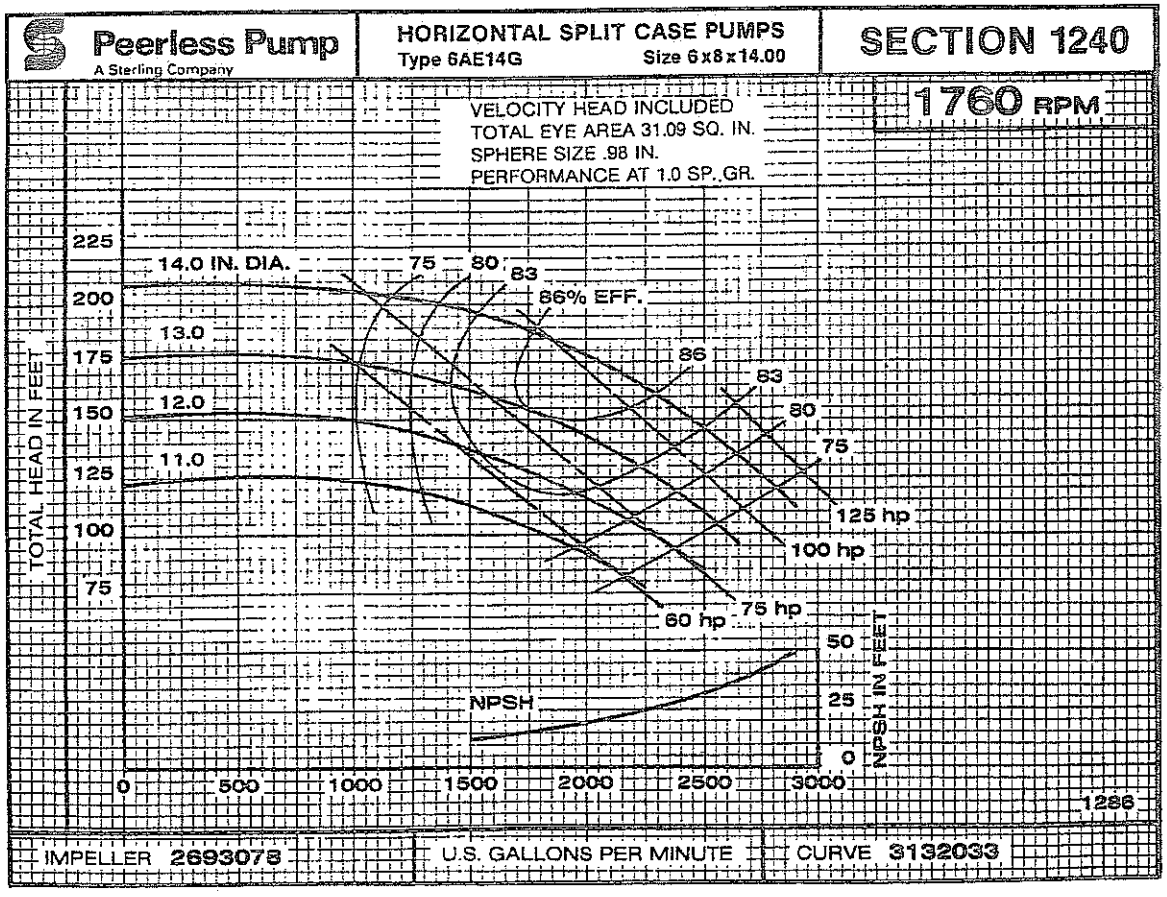


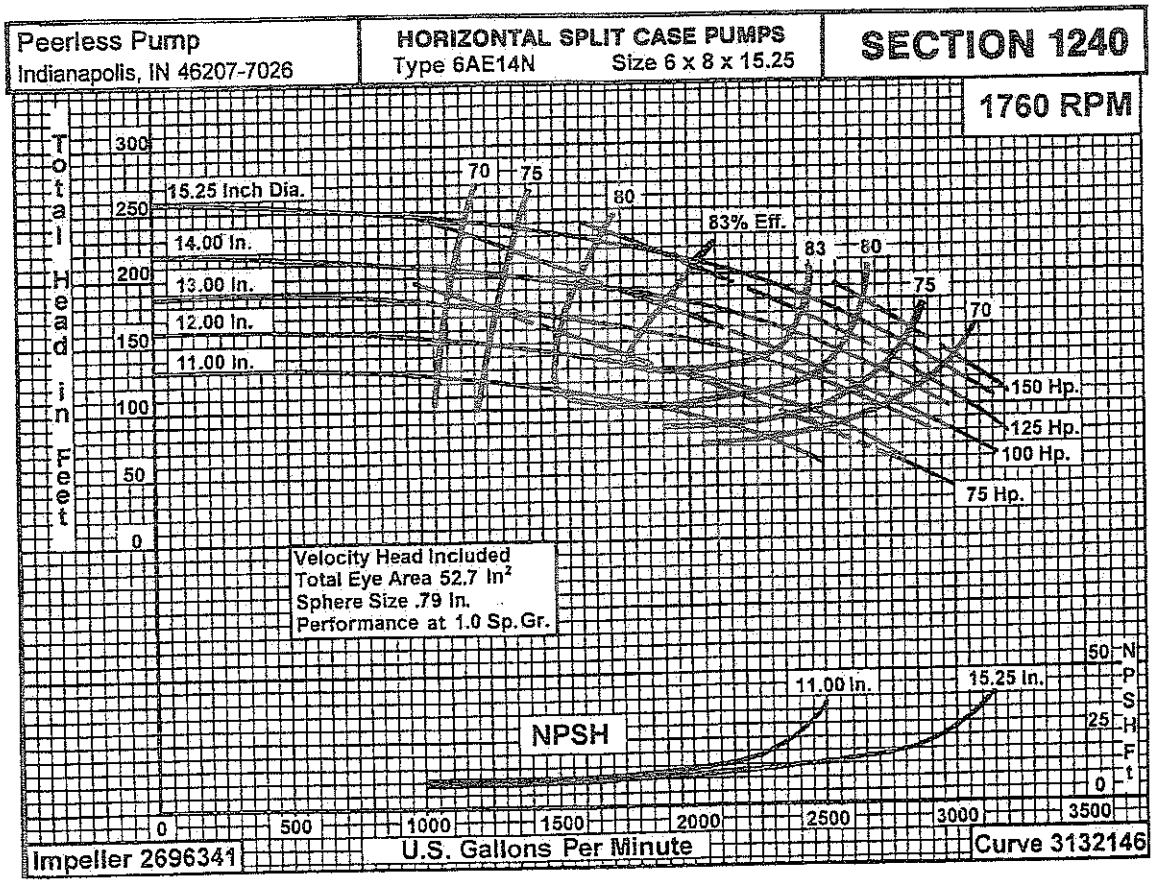

Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 6AE14
Size 6x8x14.00
SECTION 1240
1750 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 30.63 SQ. IN.
SPHERE SIZE .75 IN.
PERFORMANCE AT 1.0 SP. GR.
TOTAL HEAD IN FEET
225
200
175
150
125
100
75
14.00 IN. DIA.
13.00
12.00
11.00
10.38
70
75
80
83
85% EFF.
83
80
86
75 hp
60 hp
50 hp
40 hp
NPSH
NPSH IN FEET
50
25
0
0
250
500
750
1000
1250
1500
1750
2000
1087 rev
IMPELLER 2693077
U.S. GALLONS PER MINUTE
CURVE 3132027

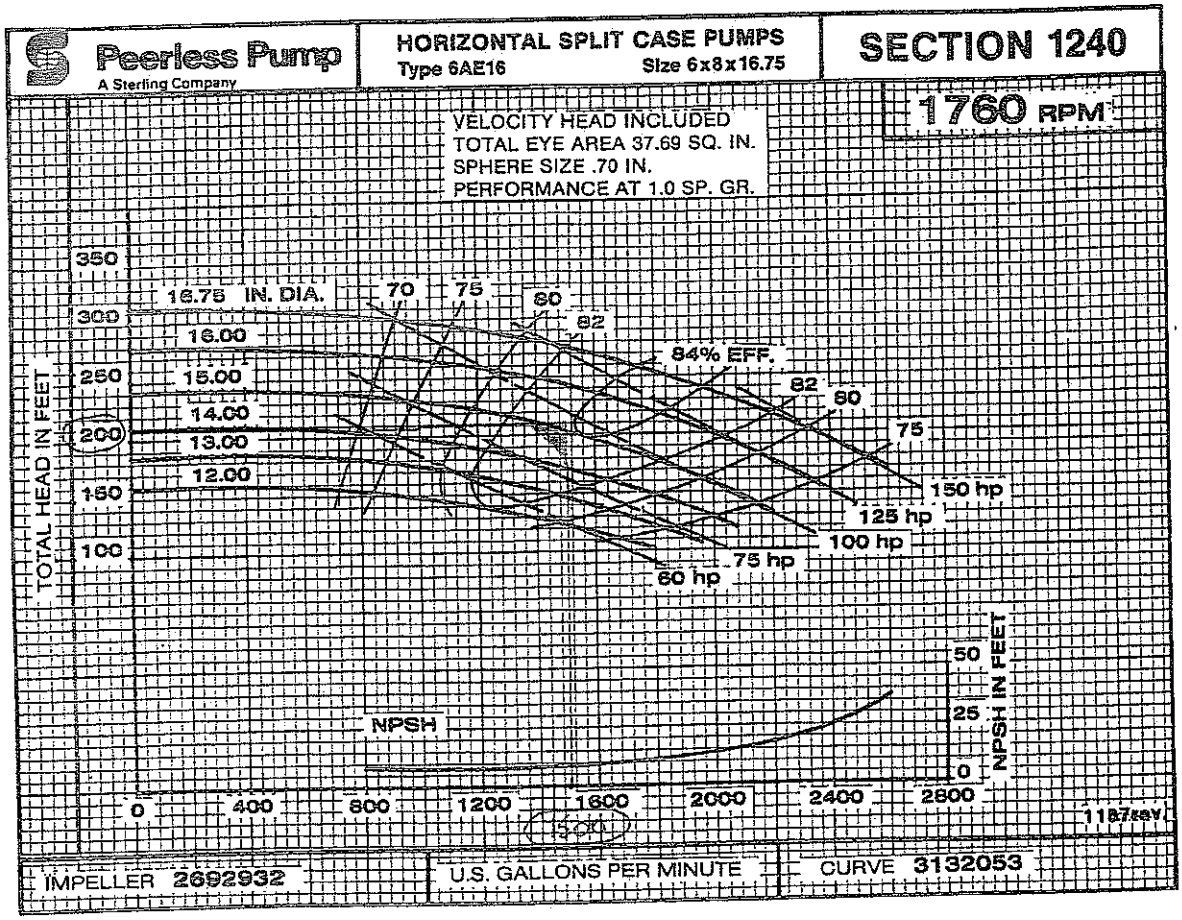

Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 6AE14G
Size 6x8x14.00
SECTION 1240
1760 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 31.09 SQ. IN.
SPHERE SIZE .98 IN.
PERFORMANCE AT 1.0 SP. GR.
TOTAL HEAD IN FEET
225
200
175
150
125
100
75
14.0 IN. DIA.
13.0
12.0
11.0
75
80
83
86% EFF.
86
83
80
75
125 hp
100 hp
75 hp
60 hp
NPSH
NPSH IN FEET
50
25
0
0
500
1000
1500
2000
2500
3000
1286
IMPELLER 2693078
U.S. GALLONS PER MINUTE
CURVE 3132033

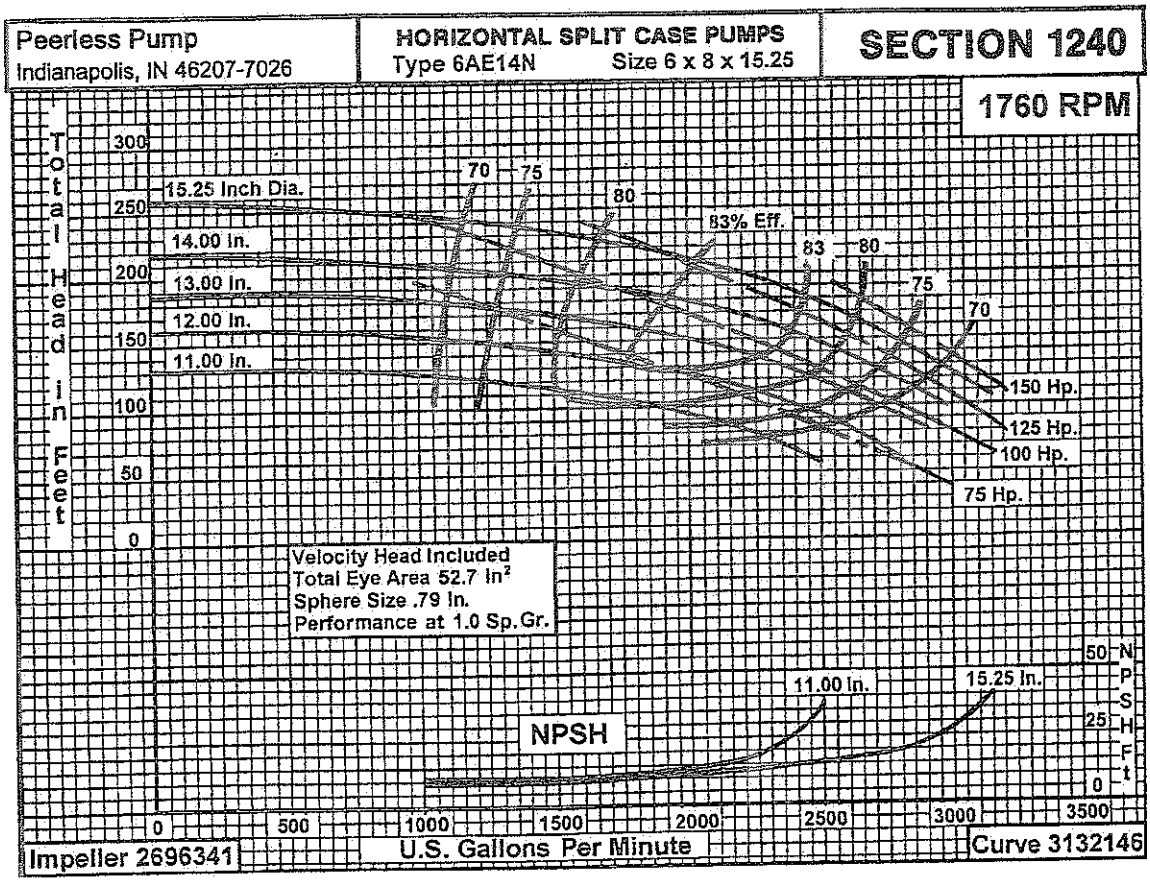
1750 RPM

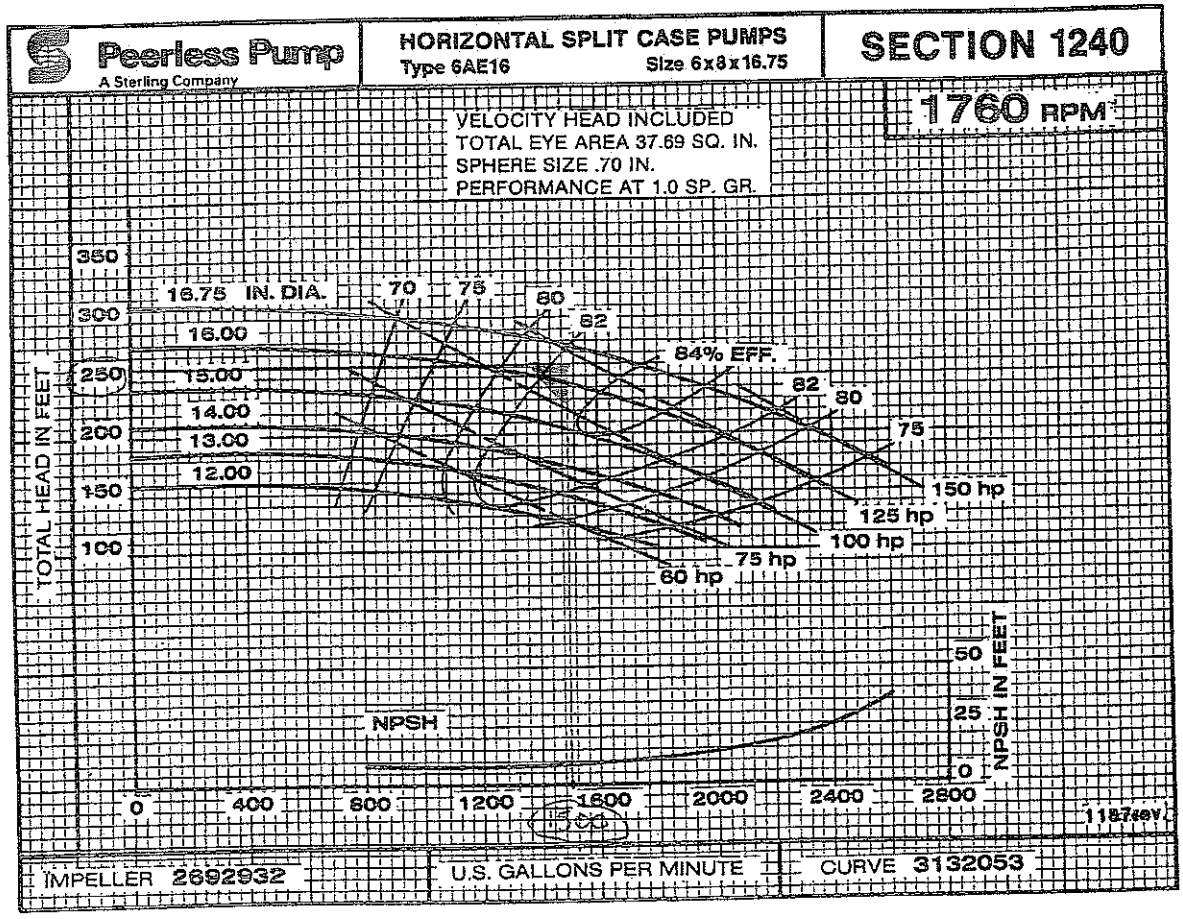

Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 6AE14 Size 6x8x14.00
SECTION 1240
1750 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 30.63 SQ. IN.
SPHERE SIZE .75 IN.
PERFORMANCE AT 1.0 SP. GR.
TOTAL HEAD IN FEET
225
200
175
150
125
100
75
14.00 IN. DIA.
13.00
12.00
11.00
10.38
70
75
80
83
85% EFF.
83
80
86
75 hp
60 hp
50 hp
40 hp
NPSH
NPSH IN FEET
50
25
0
0
250
500
750
1000
1250
1500
1750
2000
1087 rev
IMPELLER 2693077
U.S. GALLONS PER MINUTE
CURVE 3132027

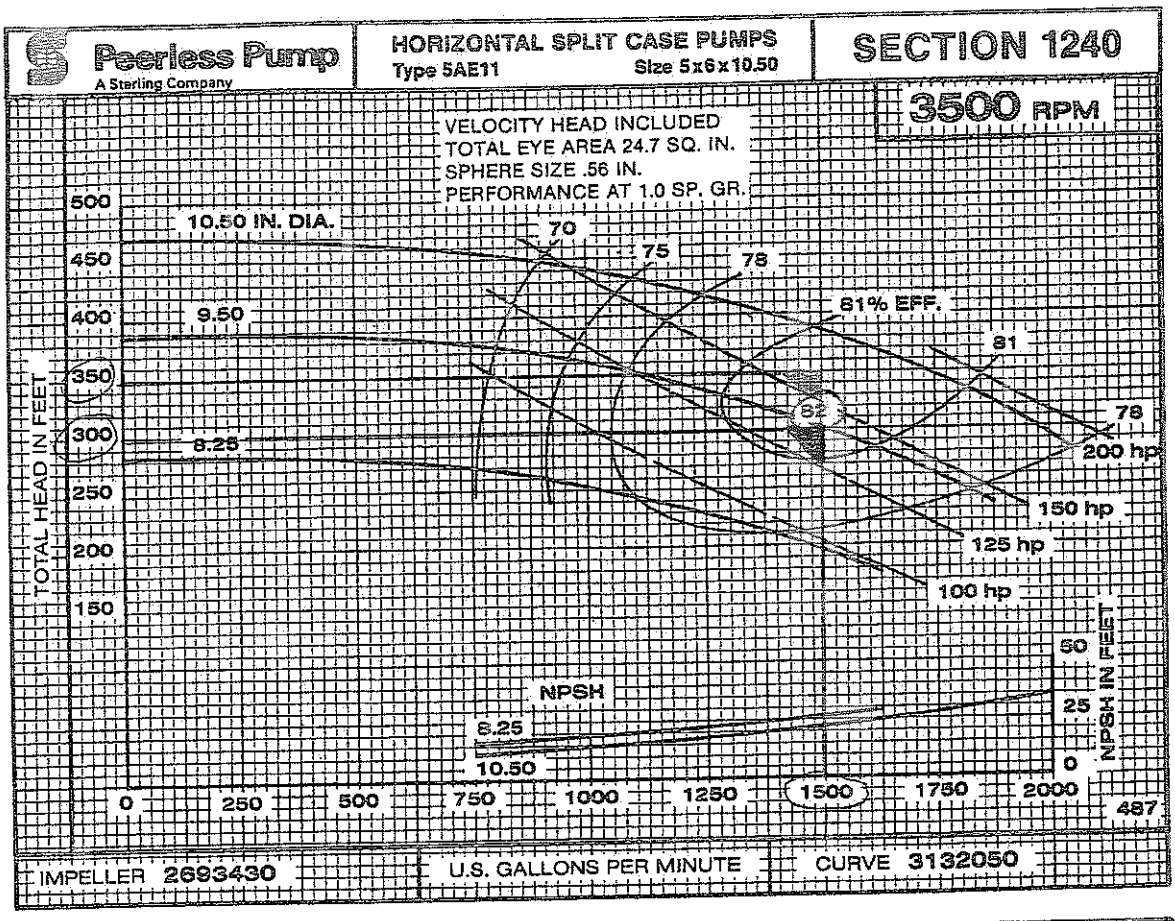

Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 6AE14G Size 6x8x14.00
SECTION 1240
1760 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 31.09 SQ. IN.
SPHERE SIZE .98 IN.
PERFORMANCE AT 1.0 SP. GR.
TOTAL HEAD IN FEET
225
200
175
150
125
100
75
14.0 IN. DIA.
13.0
12.0
11.0
75
80
83
86% EFF.
86
83
80
75
125 hp
100 hp
75 hp
60 hp
NPSH
NPSH IN FEET
50
25
0
0
500
1000
1500
2000
2500
3000
1286
IMPELLER 2693078
U.S. GALLONS PER MINUTE
CURVE 3132033

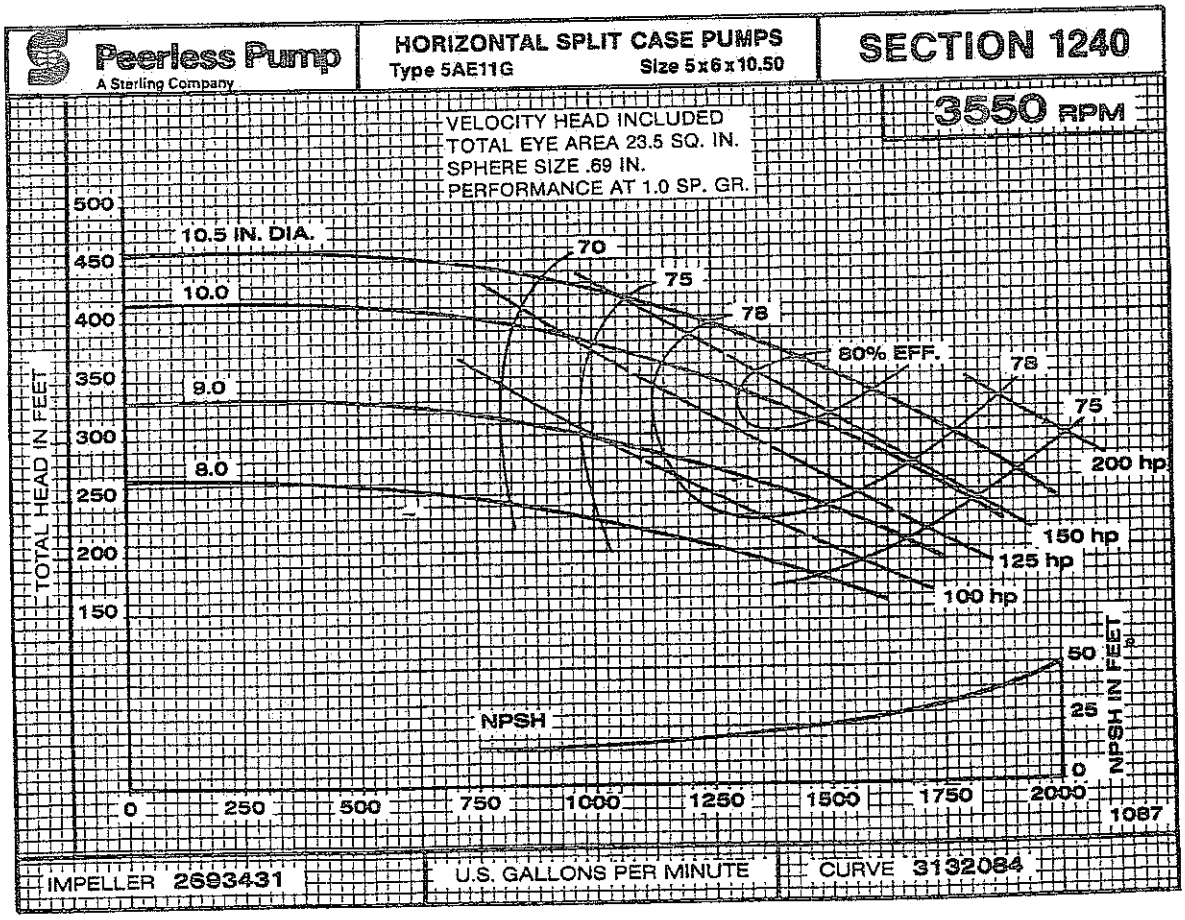

Peerless Pump
Indianapolis, IN 46207-7026
HORIZONTAL SPLIT CASE PUMPS
Type 6AE14N Size 6 x 8 x 15.25
SECTION 1240
1760 RPM
Total Head in Feet
15.25 Inch Dia.
14.00 In.
13.00 In.
12.00 In.
11.00 In.
83% Eff.
150 Hp.
125 Hp.
100 Hp.
75 Hp.
Velocity Head Included
Total Eye Area 52.7 In²
Sphere Size .79 In.
Performance at 1.0 Sp.Gr.
NPSH
NPSH Ft
U.S. Gallons Per Minute
Impeller 2696341
Curve 3132146

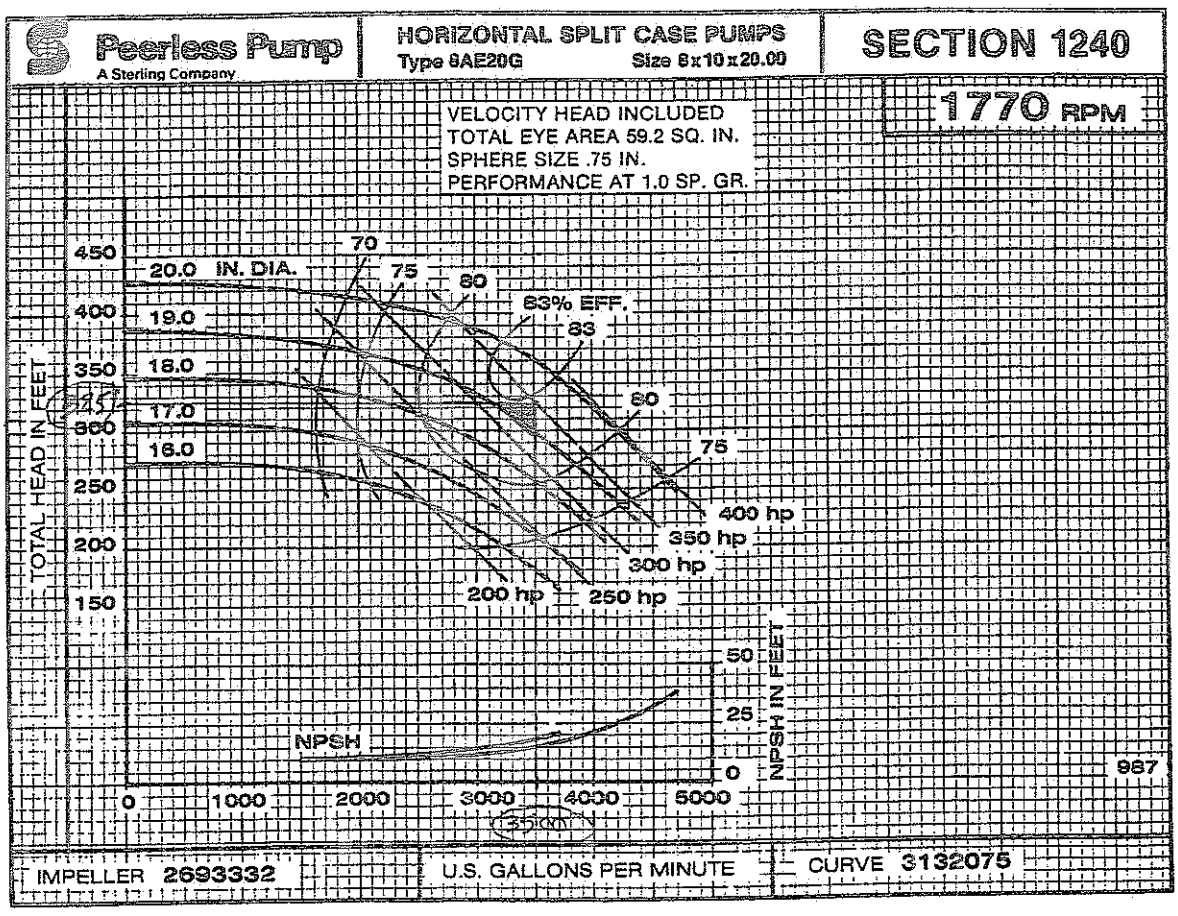

Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 6AE16 Size 6x8x16.75
SECTION 1240
1760 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 37.69 SQ. IN.
SPHERE SIZE .70 IN.
PERFORMANCE AT 1.0 SP. GR.
TOTAL HEAD IN FEET
16.75 IN. DIA.
16.00
15.00
14.00
13.00
12.00
84% EFF.
150 hp
125 hp
100 hp
75 hp
60 hp
NPSH
NPSH IN FEET
IMPELLER 2692932
U.S. GALLONS PER MINUTE
CURVE 3132053

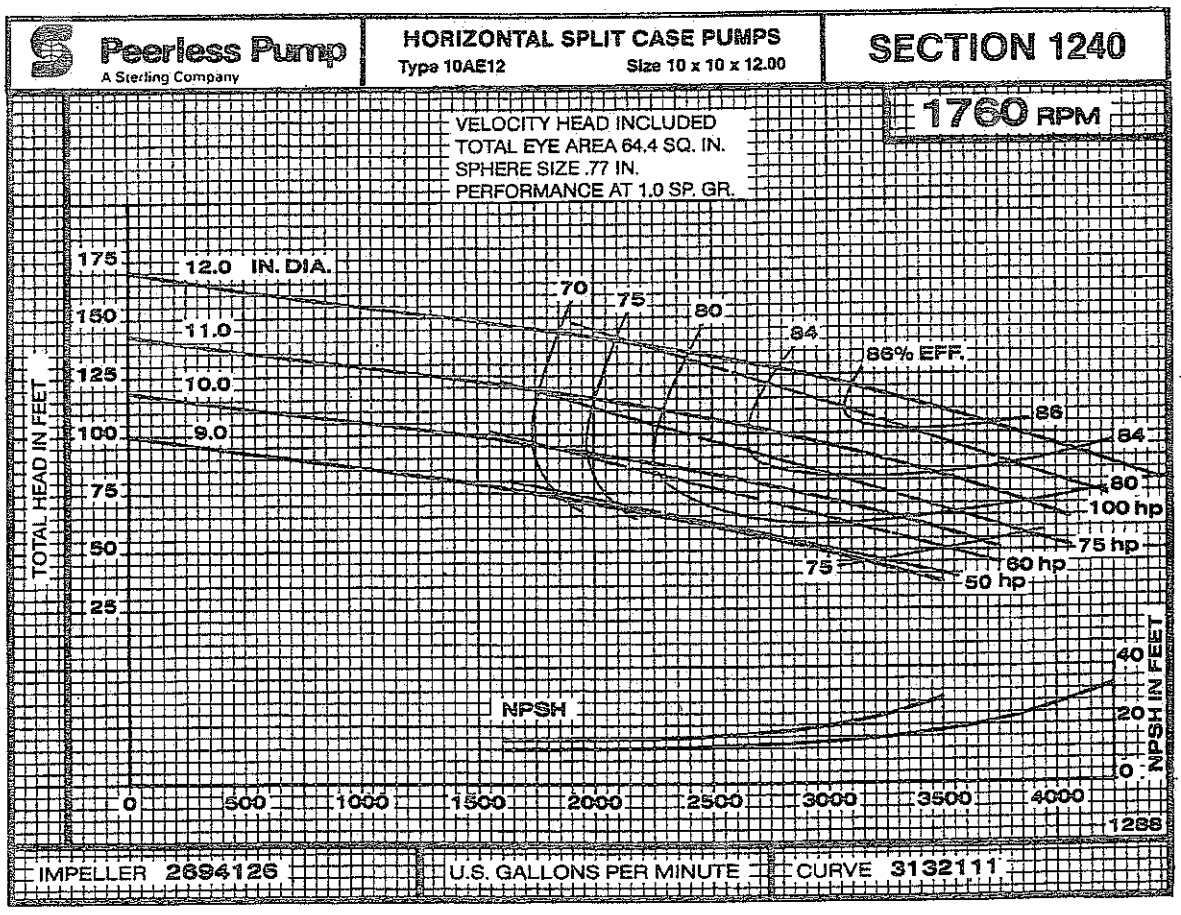

Peerless Pump
Indianapolis, IN 46207-7026
HORIZONTAL SPLIT CASE PUMPS
Type 6AE14N Size 6 x 8 x 15.25
SECTION 1240
1760 RPM
Total Head in Feet
15.25 Inch Dia.
14.00 in.
13.00 in.
12.00 in.
11.00 in.
83% Eff.
150 Hp.
125 Hp.
100 Hp.
75 Hp.
Velocity Head Included
Total Eye Area 52.7 in²
Sphere Size .79 in.
Performance at 1.0 Sp.Gr.
NPSH
NPSH Ft
Impeller 2696341
U.S. Gallons Per Minute
Curve 3132146


Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 6AE16 Size 6x8x16.75
SECTION 1240
1760 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 37.69 SQ. IN.
SPHERE SIZE .70 IN.
PERFORMANCE AT 1.0 SP. GR.
TOTAL HEAD IN FEET
16.75 IN. DIA.
16.00
15.00
14.00
13.00
12.00
84% EFF.
150 hp
125 hp
100 hp
75 hp
60 hp
NPSH
NPSH IN FEET
IMPELLER 2692932
U.S. GALLONS PER MINUTE
CURVE 3132053


Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 5AE11
Size 5x6x10.50
SECTION 1240
3500 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 24.7 SQ. IN.
SPHERE SIZE .56 IN.
PERFORMANCE AT 1.0 SP. GR.
10.50 IN. DIA.
9.50
8.25
70
75
78
81% EFF.
81
82
78
200 hp
150 hp
125 hp
100 hp
NPSH
8.25
10.50
TOTAL HEAD IN FEET
NPSH IN FEET
500
450
400
350
300
250
200
150
50
25
0
0
250
500
750
1000
1250
1500
1750
2000
487
IMPELLER 2693430
U.S. GALLONS PER MINUTE
CURVE 3132050

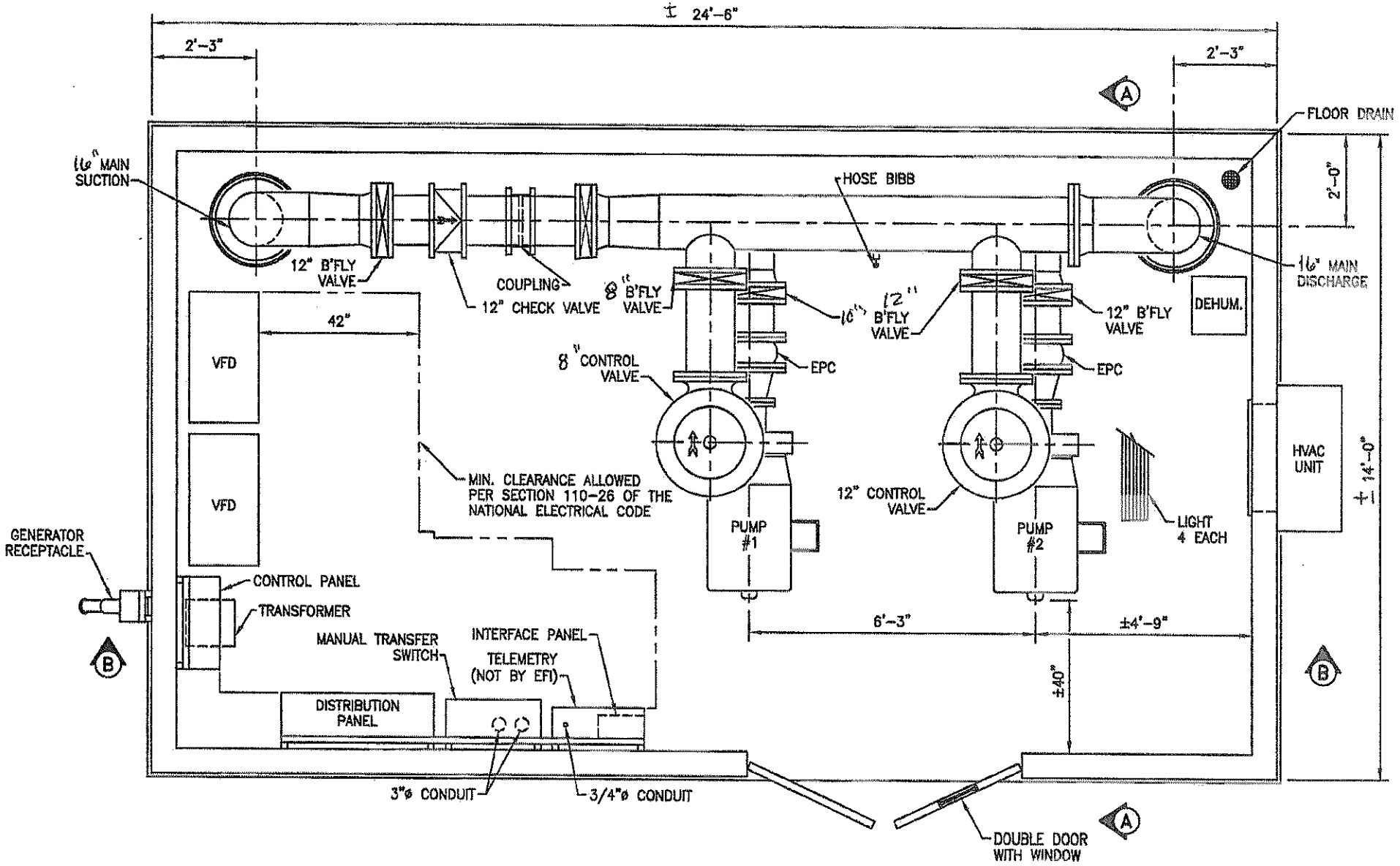

Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 5AE11G
Size 5x6x10.50
SECTION 1240
3550 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 23.5 SQ. IN.
SPHERE SIZE .69 IN.
PERFORMANCE AT 1.0 SP. GR.
10.5 IN. DIA.
10.0
9.0
8.0
70
75
78
80% EFF.
78
75
200 hp
150 hp
125 hp
100 hp
NPSH
TOTAL HEAD IN FEET
NPSH IN FEET
500
450
400
350
300
250
200
150
50
25
0
0
250
500
750
1000
1250
1500
1750
2000
1087
IMPELLER 2693431
U.S. GALLONS PER MINUTE
CURVE 3132084


Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 8AE20G
Size 8x10x20.00
SECTION 1240
1770 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 59.2 SQ. IN.
SPHERE SIZE .75 IN.
PERFORMANCE AT 1.0 SP. GR.
TOTAL HEAD IN FEET
20.0 IN. DIA.
19.0
18.0
17.0
16.0
83% EFF.
400 hp
350 hp
300 hp
250 hp
200 hp
NPSH
NPSH IN FEET
987
IMPELLER 2693332
U.S. GALLONS PER MINUTE
CURVE 3132075


Peerless Pump
A Sterling Company
HORIZONTAL SPLIT CASE PUMPS
Type 10AE12
Size 10 x 10 x 12.00
SECTION 1240
1760 RPM
VELOCITY HEAD INCLUDED
TOTAL EYE AREA 64.4 SQ. IN.
SPHERE SIZE .77 IN.
PERFORMANCE AT 1.0 SP. GR.
TOTAL HEAD IN FEET
12.0 IN. DIA.
11.0
10.0
9.0
86% EFF.
100 hp
75 hp
60 hp
50 hp
NPSH
NPSH IN FEET
1288
IMPELLER 2694126
U.S. GALLONS PER MINUTE
CURVE 3132111

APPENDIX G

TYPICAL PUMP STATION


24'-6"
2'-3"
2'-3"
A
FLOOR DRAIN
16" MAIN SUCTION
HOSE BIBB
2'-0"
16" MAIN DISCHARGE
12" B'FLY VALVE
COUPLING
12" CHECK VALVE
8" B'FLY VALVE
12" B'FLY VALVE
12" B'FLY VALVE
DEHUM.
42"
VFD
VFD
8" CONTROL VALVE
EPC
EPC
MIN. CLEARANCE ALLOWED PER SECTION 110-26 OF THE NATIONAL ELECTRICAL CODE
12" CONTROL VALVE
PUMP #1
PUMP #2
LIGHT 4 EACH
HVAC UNIT
14'-0"
GENERATOR RECEPTACLE
CONTROL PANEL
TRANSFORMER
MANUAL TRANSFER SWITCH
INTERFACE PANEL
TELEMETRY (NOT BY EFI)
DISTRIBUTION PANEL
6'-3"
±4'-9"
±40"
B
B
3"ø CONDUIT
3/4"ø CONDUIT
DOUBLE DOOR WITH WINDOW
A

PLAN

APPENDIX H

SOIL MAPS & SOILS DESCRIPTION

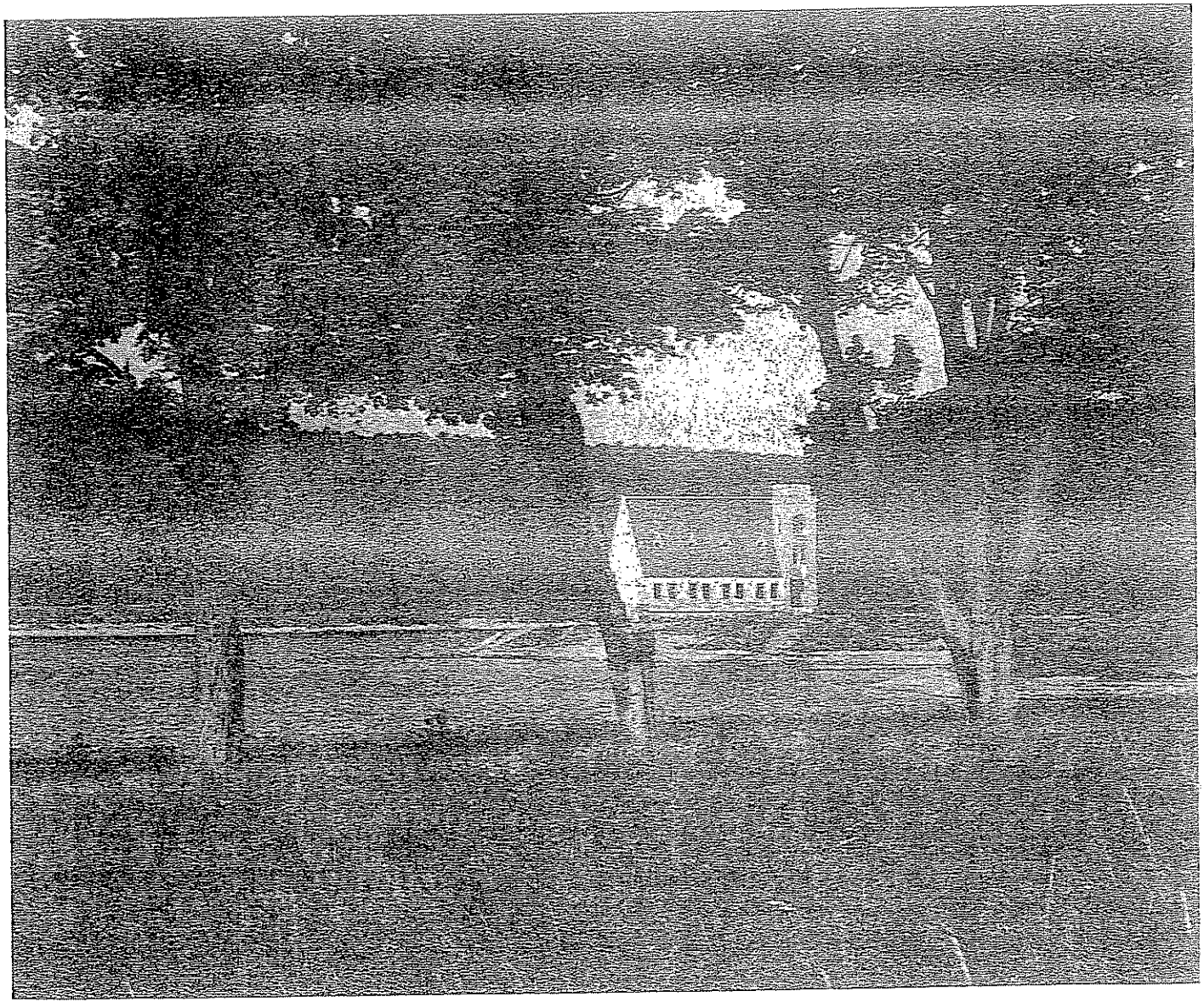
United States Department of Agriculture

Soil Conservation Service

In cooperation with Massachusetts Agricultural Experiment Station

Soil Survey of Worcester County Massachusetts

Northeastern Part



SOIL LEGEND

Publication symbols consist of letters. The first letter, always a capital, is the initial letter of the soil name. The second letter is lower case and separates map units, except those that are slope phases, having names that begin with the same letter. The third letter, always a capital A, B, C, D, or E, indicates the class of slope. Symbols without a slope letter are for nearly level soils, soils named for higher categories, or for miscellaneous areas.

SYMBOL	NAME
AgA	Agawam fine sandy loam, 0 to 3 percent slopes
AgB	Agawam fine sandy loam, 3 to 8 percent slopes
AgC	Agawam fine sandy loam, 8 to 15 percent slopes
AmB	Amostown and Belgrade soils, 3 to 8 percent slopes
CaB	Canton fine sandy loam, 3 to 8 percent slopes
CaC	Canton fine sandy loam, 8 to 15 percent slopes
CbB	Canton fine sandy loam, 3 to 8 percent slopes, very stony
CbC	Canton fine sandy loam, 8 to 15 percent slopes, very stony
CcB	Canton fine sandy loam, 3 to 8 percent slopes, extremely stony
CcC	Canton fine sandy loam, 8 to 15 percent slopes, extremely stony
CcD	Canton fine sandy loam, 15 to 25 percent slopes, extremely stony
CcE	Canton fine sandy loam, 25 to 35 percent slopes, extremely stony
ChC	Chatfield-Hollis-Rock outcrop complex, 3 to 15 percent slopes
ChD	Chatfield-Hollis-Rock outcrop complex, 15 to 25 percent slopes
De	Deerfield sandy loam
Fm	Freetown muck
Fp	Freetown muck, ponded
HaA	Hadley very fine sandy loam
HgA	Hinckley sandy loam, 0 to 3 percent slopes
HgB	Hinckley sandy loam, 3 to 8 percent slopes
HgC	Hinckley sandy loam, 8 to 15 percent slopes
HgD	Hinckley sandy loam, 15 to 25 percent slopes
HgE	Hinckley sandy loam, 25 to 35 percent slopes
HkB	Hinckley sandy loam, 3 to 8 percent slopes, very stony
HkC	Hinckley sandy loam, 8 to 15 percent slopes, very stony
HuC	Hinckley-Urban land complex, 0 to 15 percent slopes
HwB	Hinesburg loamy sand, 3 to 8 percent slopes
Lm	Limerick silt loam
MeA	Merrimac fine sandy loam, 0 to 3 percent slopes
MeB	Merrimac fine sandy loam, 3 to 8 percent slopes
MeC	Merrimac fine sandy loam, 8 to 15 percent slopes
MeD	Merrimac fine sandy loam, 15 to 25 percent slopes
NgA	Ninigret fine sandy loam, 0 to 3 percent slopes
PaB	Paxton fine sandy loam, 3 to 8 percent slopes
PaC	Paxton fine sandy loam, 8 to 15 percent slopes
PaD	Paxton fine sandy loam, 15 to 25 percent slopes
PbB	Paxton fine sandy loam, 3 to 8 percent slopes, very stony
PbC	Paxton fine sandy loam, 8 to 15 percent slopes, very stony
PbD	Paxton fine sandy loam, 15 to 25 percent slopes, very stony
PcB	Paxton fine sandy loam, 3 to 8 percent slopes, extremely stony
PcC	Paxton fine sandy loam, 8 to 15 percent slopes, extremely stony
PcD	Paxton fine sandy loam, 15 to 25 percent slopes, extremely stony
PcE	Paxton fine sandy loam, 25 to 35 percent slopes, extremely stony
PdC	Paxton-Urban land complex, 8 to 15 percent slopes
Pg	Pits, gravel
Pm	Pits, quarry
PoB	Poquonock loamy sand, 3 to 8 percent slopes
PoC	Poquonock loamy sand, 8 to 15 percent slopes
PsB	Poquonock loamy sand, 3 to 8 percent slopes, very stony

SYMBOL	NAME
QnA	Quonset loamy sand, 0 to 3 percent slopes
QnB	Quonset loamy sand, 3 to 8 percent slopes
QnC	Quonset loamy sand, 8 to 15 percent slopes
QnD	Quonset loamy sand, 15 to 25 percent slopes
Ra	Raynham silt loam
RdA	Ridgebury fine sandy loam, 0 to 3 percent slopes
RdB	Ridgebury fine sandy loam, 3 to 8 percent slopes
RsA	Ridgebury fine sandy loam, 0 to 3 percent slopes, extremely stony
RsB	Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony
Sa	Saco silt loam
Sc	Scarboro mucky fine sandy loam
SdA	Sudbury fine sandy loam, 0 to 3 percent slopes
SdB	Sudbury fine sandy loam, 3 to 8 percent slopes
Su	Suncook loamy fine sand
Sw	Swansea muck
Ud	Udorthents, smoothed
Ur	Urban land
Wa	Walpole fine sandy loam
Wg	Whitman loam
Wh	Whitman loam, extremely stony
WnA	Windsor loamy fine sand, 0 to 3 percent slopes
WnB	Windsor loamy fine sand, 3 to 8 percent slopes
WnC	Windsor loamy fine sand, 8 to 15 percent slopes
WnD	Windsor loamy fine sand, 15 to 25 percent slopes
Wo	Winooski very fine sandy loam
WrA	Woodbridge fine sandy loam, 0 to 3 percent slopes
WrB	Woodbridge fine sandy loam, 3 to 8 percent slopes
WrC	Woodbridge fine sandy loam, 8 to 15 percent slopes
WsB	Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony
WsC	Woodbridge fine sandy loam, 8 to 15 percent slopes, very stony
WtB	Woodbridge fine sandy loam, 0 to 8 percent slopes, extremely stony
WtC	Woodbridge fine sandy loam, 8 to 15 percent slopes, extremely stony
W	Water

CULTURA

BOUNDARIES

National, state or

County or parish

Minor civil divisic

Reservation (nati
state forest or
and large airpc

Land grant

Limit of soil surv

Field sheet matcl

AD HOC BOUNDA

Small airport, air
cemetery, or f

STATE COORDINA

LAND DIVISION C
(sections and lan

ROADS

Divided (median
if scale permi

Other roads

Trail

ROAD EMBLEM &

Interstate

Federal

State

County, farm or

RAILROAD

POWER TRANSM
(normally not sl

PIPE LINE
(normally not s

FENCE
(normally not s

LEVEES

Without road

With road

With railroad

DAMS

Large (to scale)

Medium or sma

PITS

Gravel pit

Mine or quarry

CONVENTIONAL AND SPECIAL SYMBOLS LEGEND

L FEATURES

rovince

ai forest or park,
rk,

(label)

ne & neatline

(label)

Hedley Airstrip

d, park, oilfield,
od pool

FLOOD POOL LINE

E TICK

RNERS
rants)

own

ESIGNATIONS

21

172

13

1233

ON LINE
n)

n)

n)

ck

MISCELLANEOUS CULTURAL FEATURES

Farmstead, house (omit in urban areas)

Church

School

Indian mound (label) — Indian Mound

Located object (label) — Tower

Tank (label) — Gas

Wells, oil or gas

Windmill

Kitchen midden

WATER FEATURES

DRAINAGE

Perennial, double line

Perennial, single line

Intermittent

Drainage end

Canals or ditches

Double-line (label) — CANAL

Drainage and/or irrigation

LAKES, PONDS AND RESERVOIRS

Perennial — water, w

Intermittent — int, i

MISCELLANEOUS WATER FEATURES

Marsh or swamp

Spring

Well, artesian

Well, irrigation

Wet spot

water

w

SPECIAL SYMBOLS FOR SOIL SURVEY

SOIL DELINEATIONS AND SYMBOLS — CnB, WaC2

ESCARPMENTS

Bedrock (points down slope)

Other than bedrock (points down slope)

SHORT STEEP SLOPE

GULLY

DEPRESSION OR SINK

SOIL SAMPLE SITE (normally not shown) — S

MISCELLANEOUS

Blowout

Clay spot

Gravelly spot

Gumbo, slick or scabby spot (sodic)

Dumps and other similar non soil areas

Prominent hill or peak

Rock outcrop (includes sandstone and shale)

Saline spot

Sandy spot

Severely eroded spot

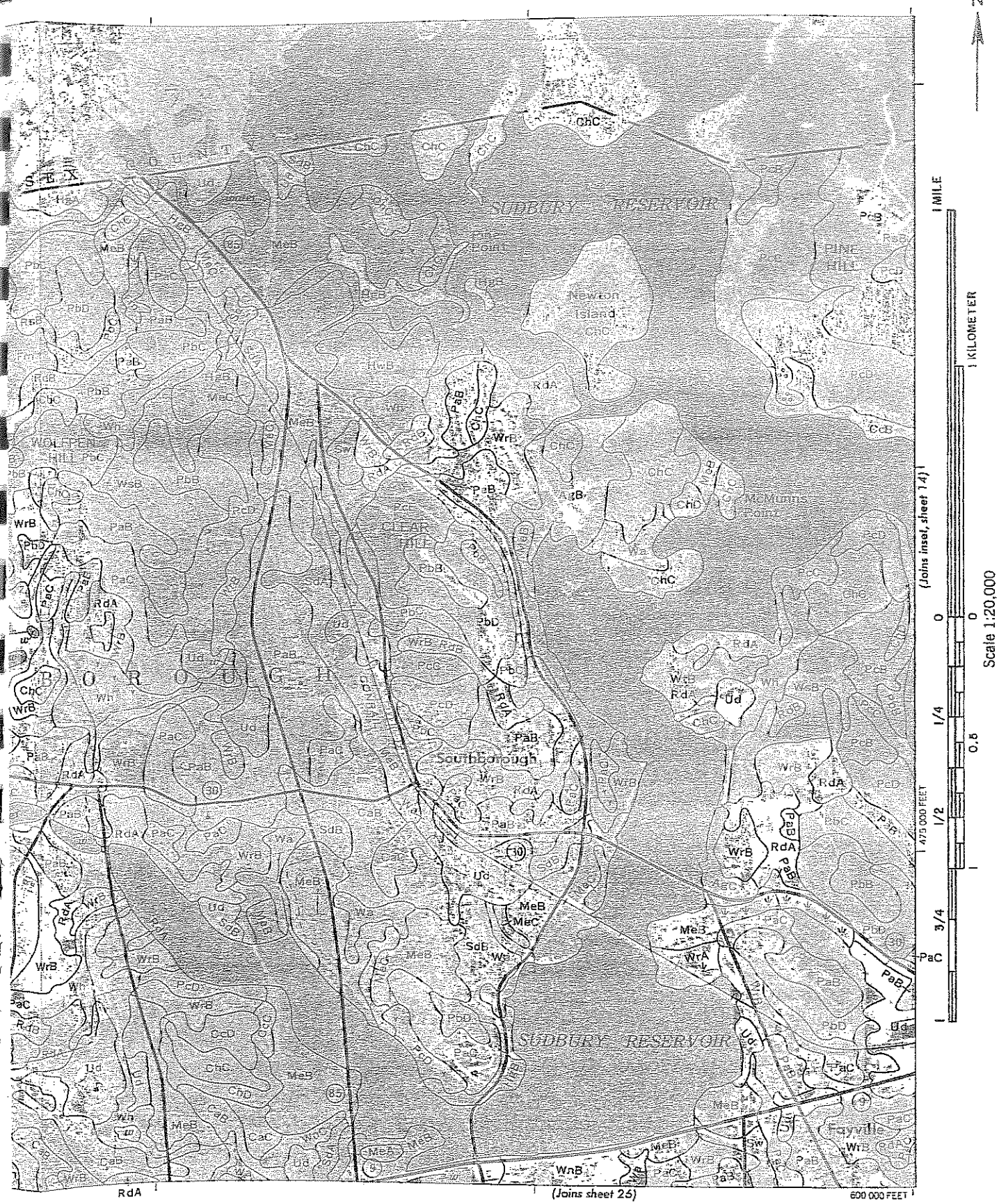
Slide or slip (tips point upslope)

Stony spot, very stony spot

Stripped land

SOIL SURVEY WORCESTER COUNTY, MASSACHUSETTS, NORTHEASTERN PART — SHEET NUMBER 23



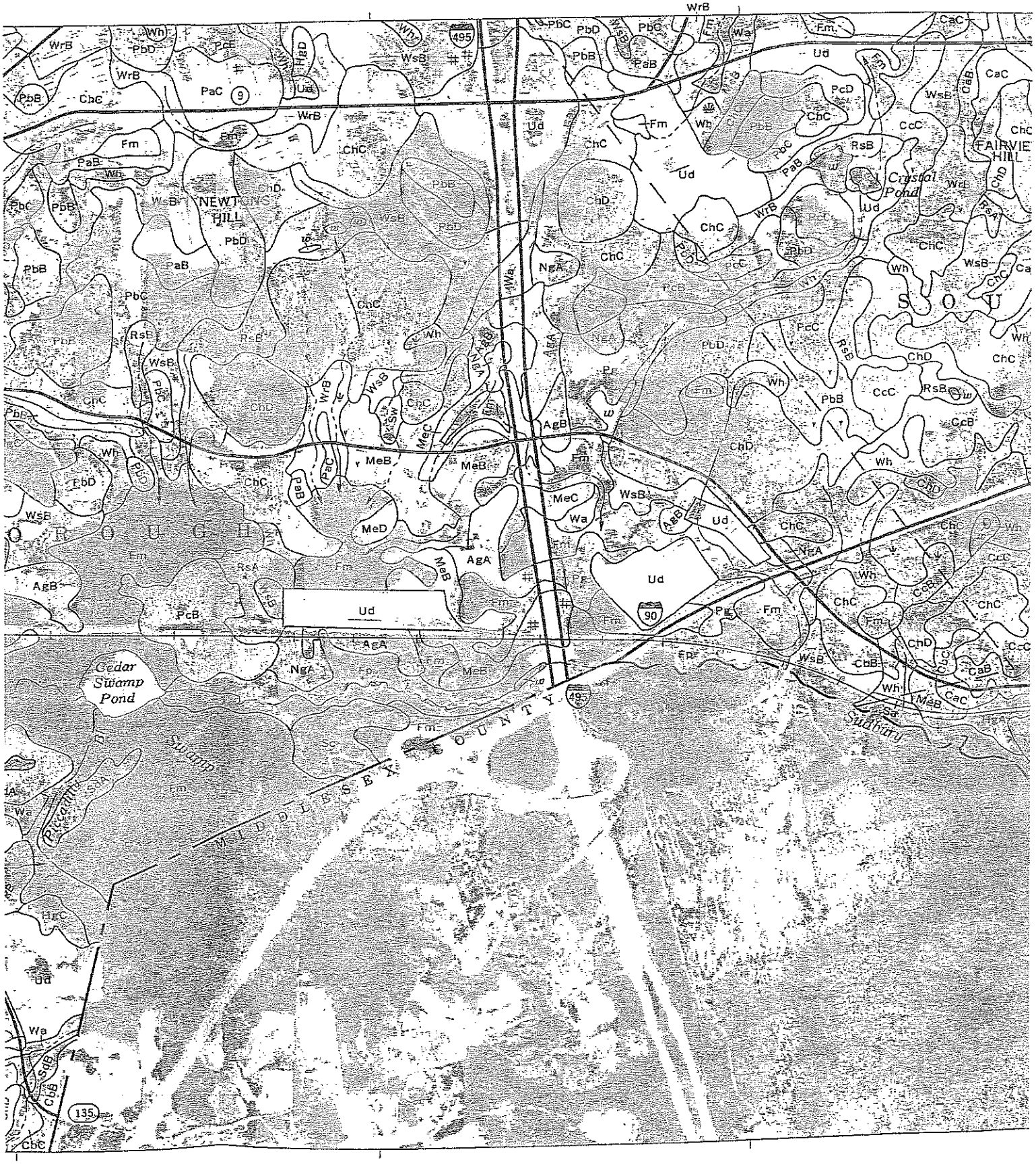

N
SUDBURY RESERVOIR
Newton Island
PINE HILL
WOLFPEN HILL
CLEAR HILL
McMurrins Point
Southborough
Fayville
SUDBURY RESERVOIR
(Joins inset, sheet 14)
(Joins sheet 26)
475 000 FEET
600 000 FEET
1 MILE
1 KILOMETER
Scale 1:20,000
0
1/4
1/2
3/4
0.5

RT — SHEET NUMBER 26

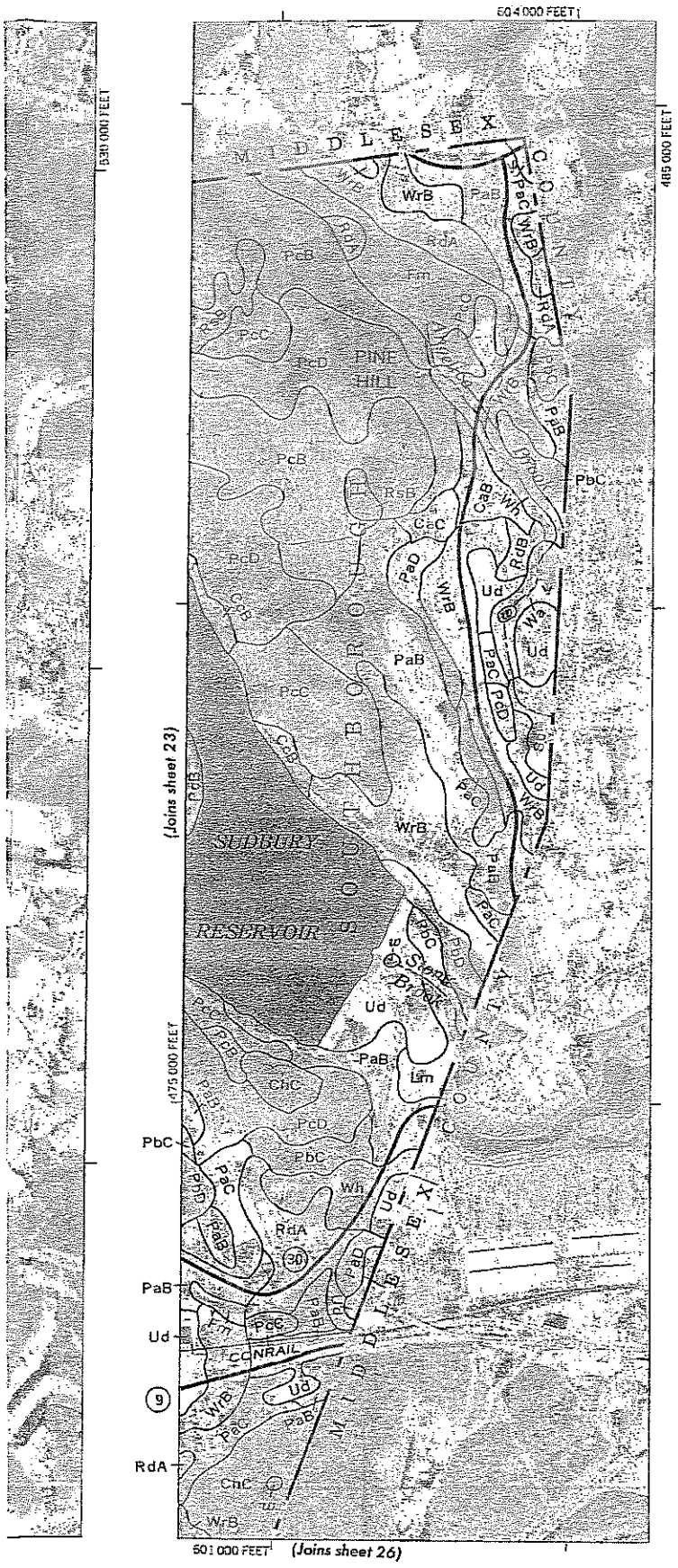
(Joins sheet 23) | (Joins inset, sheet 14)



SOIL SURVEY WORCESTER COUNTY, MASSACHUSETTS, NORTHEASTERN PA



NUMBER 14



3000 AND 5000-FOOT GRID TICKS

Detailed Soil Map Units

The map units on the detailed soil maps at the back of this survey represent the soils in the survey area. The map unit descriptions in this section, along with the soil maps, can be used to determine the suitability and potential of a soil for specific uses. They also can be used to plan the management needed for those uses. More information on each map unit, or soil, is given under "Use and management of the soils."

Each map unit on the detailed soil maps represents an area on the landscape and consists of one or more soils for which the unit is named.

A symbol identifying the soil precedes the map unit name in the soil descriptions. Each description includes general facts about the soil and gives the principal hazards and limitations to be considered in planning for specific uses.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer or of the underlying material, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer or of the underlying material. They also can differ in slope, stoniness, salinity, wetness, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Canton stony fine sandy loam, 3 to 8 percent slopes, is one of several phases in the Canton series.

Some map units are made up of two or more major soils. These map units are called soil complexes or undifferentiated groups.

A *soil complex* consists of two or more soils in such an intricate pattern or in such small areas that they cannot be shown separately on the soil maps. The pattern and proportion of the soils are somewhat similar in all areas. Chatfield-Hollis-Rock outcrop complex, 3 to 15 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils in a mapped area are not uniform. An area can be made up of only one of the major soils, or it can be made up of all of them. Amostown and Belgrade soils, 3 to 8 percent slopes, is an undifferentiated group in this survey area.

Most map units include small scattered areas of soils other than those for which the map unit is named. Some of these included soils have properties that differ substantially from those of the major soil or soils. Such differences could significantly affect use and management of the soils in the map unit. The included soils are identified in each map unit description. Some small areas of strongly contrasting soils are identified by a special symbol on the soil maps.

This survey includes *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Pits, quarry, is an example. Miscellaneous areas are shown on the soil maps. Some that are too small to be shown are identified by a special symbol on the soil maps.

Table 4 gives the acreage and proportionate extent of each map unit. Other tables (see "Summary of tables") give properties of the soils and the limitations, capabilities, and potentials for many uses. The Glossary defines many of the terms used in describing the soils.

Soil Descriptions

AgA—Agawam fine sandy loam, 0 to 3 percent slopes. This soil is very deep, nearly level, and well drained. It is in broad areas and in narrow areas adjacent to strongly sloping soils. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 40 acres, but most are about 10 acres.

Typically, the surface layer is dark yellowish brown fine sandy loam about 7 inches thick. The subsoil is yellowish brown fine sandy loam 18 inches thick. The substratum extends to a depth of 60 inches or more. It is yellowish brown gravelly loamy coarse sand in the upper part and light olive brown and light yellowish brown very gravelly coarse sand in the lower part.

Included with this soil in mapping are small areas, less than 3 acres each, of Merrimac, Ninigret, and Windsor soils. Also included are soils that have more silt in the surface layer and subsoil than this Agawam soil. Included areas make up about 15 percent of the unit.

The permeability of this Agawam soil is moderately rapid in the subsoil and rapid in the substratum.

Available water capacity is high. Reaction ranges from very strongly acid to slightly acid.

Most areas of this soil are used for residential development. Some areas are used for cultivated crops. A few areas are covered with trees, and the soil is well suited to trees.

This soil is well suited to cultivated crops, hay, and pasture. Incorporating crop residue into the soil increases the organic matter content. The use of proper stocking rates, deferred grazing, and rotational grazing help to maintain the desirable pasture plant species.

This soil has no major limitation as a site for dwellings with basements or for local roads and streets. The soil is a poor filter for septic tank absorption fields, however, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability class: I.

AgB—Agawam fine sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and well drained. It is in areas that are long and narrow or irregular in shape. The areas range from 5 to 80 acres, but most are about 20 acres.

Typically, the surface layer is dark yellowish brown fine sandy loam about 7 inches thick. The subsoil is yellowish brown fine sandy loam 18 inches thick. The substratum extends to a depth of 60 inches or more. It is yellowish brown gravelly loamy coarse sand in the upper part and light olive brown and light yellowish brown very gravelly coarse sand in the lower part.

Included with this soil in mapping are small areas, less than 3 acres each, of Merrimac, Ninigret, and Windsor soils. Also included are areas of Agawam soils with slopes of 0 to 3 percent and soils that have more silt in the surface layer and subsoil than this Agawam soil. Included areas make up about 15 percent of the unit.

The permeability of this Agawam soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to slightly acid.

Most areas of this soil are used for residential development. Some areas are used for cultivated crops. A few areas are covered with trees, and the soil is well suited to trees.

This soil is well suited to cultivated crops, hay, and pasture. Maintaining a plant cover and using crop residue, conservation tillage, and contour farming are practices that help to reduce the hazard of erosion.

This soil has no major limitation as a site for dwellings with basements or for local roads and streets. The soil is a poor filter for septic tank absorption fields, however, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIe.

AgC—Agawam fine sandy loam, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and well drained. It is in long and narrow or irregularly shaped areas. The areas range from 5 to 60 acres, but most areas are about 10 acres.

Typically, the surface layer is dark yellowish brown fine sandy loam about 7 inches thick. The subsoil is yellowish brown fine sandy loam 18 inches thick. The substratum extends to a depth of 60 inches or more. It is yellowish brown gravelly loamy coarse sand in the upper part and light olive brown and light yellowish brown very gravelly coarse sand in the lower part.

Included with this soil in mapping are small areas, less than 3 acres each, of Merrimac, Ninigret, and Windsor soils. Also included are areas of Agawam soils with slopes of 3 to 8 percent and soils that have more silt in the surface layer and subsoil than this Agawam soil. Included areas make up about 10 percent of the unit.

The permeability of this Agawam soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to slightly acid.

Most areas of this soil are covered with trees, and the soil is well suited to trees. Some areas are used for residential development, and a few areas are in cropland.

This soil is suited to cultivated crops, hay, and pasture. Slope is the main limitation for farming. Maintaining a plant cover and using crop residue, stripcropping, conservation tillage, and contour farming are practices that help reduce the erosion hazard.

Slope is a limitation of the soil as a site for dwellings with basements or for local roads and streets. Using a special design, grading and filling, and using retaining walls are ways of overcoming the slope limitation for building sites. Constructing local roads and streets on the contour will help avoid steep cuts, on which plant cover is difficult to maintain. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIe.

AmB—Amostown and Belgrade soils, 3 to 8 percent slopes. These soils are very deep, gently sloping, and moderately well drained. They are in irregularly shaped areas. The areas range from 5 to 50 acres, but most are about 10 acres. The total acreage of the unit is about 40 percent Amostown soils, 30 percent Belgrade soils, and 30 percent other soils. Some areas are mostly Amostown soils, some are mostly Belgrade soils, and some are both. The soils were mapped together because they have no major differences in use and management.

Typically, the Amostown soils have a surface layer of dark brown fine sandy loam about 8 inches thick. The subsoil is light olive brown fine sandy loam 22 inches thick. The substratum extends to a depth of 60 inches or more. It is light olive brown loamy sand in the upper part

and olive gray stratified silt and loamy fine sand in the lower part.

Typically, the Belgrade soils have a surface layer of dark brown silt loam about 10 inches thick. The subsoil is yellowish brown silt loam and light olive brown silt loam 26 inches thick. The substratum is light olive brown silt loam to a depth of 60 inches or more.

Included with this unit in mapping are small areas, less than 3 acres each, of Raynham soils. Also included are nearly level and strongly sloping areas of Amostown and Belgrade soils and areas that are well drained.

The permeability of these Amostown soils is moderately rapid in the subsoil and slow to very slow in the substratum. The permeability of these Belgrade soils is moderate in the subsoil and slow to moderately rapid in the substratum. Available water capacity in both soils is high. Reaction ranges from strongly acid to neutral in the Amostown soils and from very strongly acid to neutral in the Belgrade soils. The root zone is restricted by the seasonal high water table at a depth of 1 1/2 to 3 feet.

Some areas of this unit are covered with trees, and the unit is well suited to trees. Some areas are in cropland, and a few are used for building sites.

This unit is well suited to cultivated crops, hay, and pasture. Drainage is needed in some areas, and using conservation tillage and contour farming helps to reduce erosion.

Wetness, low strength, and a frost-action potential are limitations of these soils as a site for dwellings and local roads and streets. Some form of drainage is needed for homesites with basements. Using a suitable base material and grading and filling help to improve the suitability of the soils as a site for local roads and streets. These soils are poor material for septic tank absorption fields because of the wetness and the permeability in the substratum of the Amostown soils.

Capability subclass: IIe.

CaB—Canton fine sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and well drained. It is on the lower slopes of hills. The areas are irregular in shape. They range from 5 to 25 acres, but most are about 15 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is 22 inches thick. The upper 3 inches is strong brown fine sandy loam, and the lower 19 inches is yellowish brown fine sandy loam and gravelly fine sandy loam. The substratum is grayish brown gravelly loamy sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, less than 3 acres each, of Paxton and Woodbridge soils. Also included are soils that have more sand in the subsoil than this Canton soil, soils with slopes of 0 to 3 percent, and soils that have more silt in the substratum than this Canton soil. Included areas make up about 25 percent of the unit.

The permeability of this Canton soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are covered with trees, and the soil is well suited to trees. Some areas are in cropland, and a few are used for residential development.

This soil is well suited to cultivated crops, hay, and pasture. Maintaining a plant cover and using crop residue, conservation tillage, stripcropping, and contour farming are practices that help to reduce erosion.

This soil has essentially no limitation as a site for dwellings or for local roads and streets; however, the sides of excavations in this soil are unstable, and steep sides commonly collapse. Thus, some form of shoring is needed in deep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIe.

CaC—Canton fine sandy loam, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and well drained. It is on the upper slopes of hills. The areas are irregular in shape. They range from 5 to 30 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is 22 inches thick. The upper 3 inches is strong brown fine sandy loam, and the lower 19 inches is yellowish brown fine sandy loam and gravelly fine sandy loam. The substratum is grayish brown gravelly loamy sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, less than 3 acres each, of Paxton and Woodbridge soils. Also included are areas that have more sand in the subsoil than this Canton soil and areas that have more silt in the substratum. Included areas make up about 20 percent of the unit.

The permeability of this Canton soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are covered with trees, and the soil is well suited to trees. Some areas are in cropland, and a few are used for residential development.

This soil is suited to cultivated crops, hay, and pasture. Maintaining a plant cover and using crop residue, conservation tillage, stripcropping, and contour farming are practices that help to reduce erosion.

Slope is the main limitation of this soil as a site for dwellings and roads and streets. Special design, grading and filling, and using retaining walls are practices that

help to overcome the slope limitation. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Placing local roads and streets on contours is needed to avoid steep cuts, on which plant cover is difficult to maintain. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIe.

CbB—Canton fine sandy loam, 3 to 8 percent slopes, very stony. This soil is very deep, gently sloping, and well drained. It is on the lower slopes of hills. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this unit are irregular in shape. They range from 10 to 125 acres, but most are about 50 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is 22 inches thick. The upper 3 inches is strong brown fine sandy loam, and the lower 19 inches is yellowish brown fine sandy loam and gravelly fine sandy loam. The substratum is grayish brown gravelly loamy sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, less than 3 acres each, of Paxton and Woodbridge soils. Also included are soils that have more sand in the subsoil than this Canton soil, soils with slopes of 0 to 3 percent, and soils that have more silt in the substratum than this Canton soil. Included areas make up about 20 percent of the unit.

The permeability of this Canton soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are covered with trees, and the soil is well suited to trees. Some areas have been cleared for pasture, and a few areas are used for residential development.

The stones on the surface make this soil poorly suited to cultivated crops, hay, and pasture. The soil is well suited to those uses if the stones are removed. Cultivation of this soil increases the hazard of erosion. Maintaining a plant cover and using crop residue, conservation tillage, and contour stripcropping are practices in cultivated areas that help to reduce erosion.

This soil has essentially no limitation as a site for dwellings and local roads and streets. Sides of excavations in these soils are unstable, however, and the steeper sides commonly collapse. Thus, shoring is needed in steep cuts. This soil is a poor filter for septic tank absorption fields and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIs.

CbC—Canton fine sandy loam, 8 to 15 percent slopes, very stony. This soil is very deep, strongly sloping, and well drained. It is on the sides of hills and the tops of ridges. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this unit are irregular in shape. They range from 10 to 100 acres, but most are about 40 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is 22 inches thick. The upper 3 inches is strong brown fine sandy loam, and the lower 19 inches is yellowish brown fine sandy loam and gravelly fine sandy loam. The substratum is grayish brown gravelly loamy sand to a depth of 60 inches or more.

Included in mapping are small areas, less than 3 acres each, of Paxton and Woodbridge soils. Also included are areas of soils that have more sand in the subsoil than this Canton soil and areas that do not have stones on the surface. Included areas make up about 15 percent of the unit.

The permeability of this Canton soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are covered with trees, and the soil is well suited to trees. Some areas have been cleared and are used for pasture, and a few areas are used for residential development.

Slope and the stones on the surface make this soil poorly suited to cultivated crops, hay, and pasture. Maintaining a plant cover and using crop residue, conservation tillage, contour farming, and stripcropping are practices in cultivated areas that help to reduce erosion.

Slope is the main limitation of this soil as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, some form of shoring is needed when steep cuts are made. Locating roads and streets on the contour will help to avoid steep cuts, on which plant cover is difficult to maintain. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIs.

CcB—Canton fine sandy loam, 3 to 8 percent slopes, extremely stony. This soil is very deep, gently sloping, and well drained. It is on the lower slopes of hills. Stones that are 2 to 5 feet apart cover 3 to 15 percent of the surface. The areas of this unit are irregular in shape. They range from 10 to 160 acres, but most are about 40 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is 22

nches thick. The upper 3 inches is strong brown fine sandy loam, and the lower 19 inches is yellowish brown ine sandy loam and gravelly fine sandy loam. The substratum is grayish brown gravelly loamy sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, less than 3 acres each, of Paxton and Woodbridge soils. Also included are areas of soils that have more sand in the subsoil than this Canton soil, areas of Canton soils with slopes of 0 to 3 percent, and areas where stones cover less than 3 percent of the surface. Included areas make up about 20 percent of the unit.

The permeability of this Canton soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are covered with trees. A few areas are used for residential development.

The stones on the surface make this soil poorly suited to cultivated crops, hay, and pasture. Erosion is a hazard. Maintaining a plant cover and using crop residue, conservation tillage, contour farming, and stripcropping are practices that help to reduce erosion in cultivated areas.

This soil is suited to trees. The stones on the surface limit the use of some types of woodland equipment.

Although clearing of stones is necessary in some areas, the soil essentially has few or no limitations as a site for dwellings or local roads and streets. The sides of excavations in this soil are unstable, however, and the steeper sides commonly collapse. Thus, some form of shoring is needed. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water pollution.

Capability subclass: VIIs.

CcC—Canton fine sandy loam, 8 to 15 percent slopes, extremely stony. This soil is very deep, strongly sloping, and well drained. It is on the sides of hills and the tops of ridges. Stones that are 2 to 5 feet apart cover 3 to 15 percent of the surface. The areas of this unit are irregular in shape. They range from 10 to 100 acres, but most are about 50 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is 22 inches thick. The upper 3 inches is strong brown fine sandy loam, and the lower 19 inches is yellowish brown fine sandy loam and gravelly fine sandy loam. The substratum is grayish brown gravelly loamy sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, less than 3 acres each, of Paxton and Woodbridge soils. Also included are areas of soils that have more sand in the subsoil than this Canton soil and areas where stones cover less than 3 percent of the surface. Included areas make up about 15 percent of the unit.

The permeability of this Canton soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are covered with trees. A few areas are used for residential development.

Slope and the stones on the surface make this soil poorly suited to cultivated crops, hay, and pasture. Maintaining a plant cover and using crop residue, conservation tillage, contour farming, and stripcropping are practices that help to reduce erosion in cultivated areas.

This soil is suited to trees. The stones on the surface limit the use of some types of equipment.

Slope is the main limitation of this soil as a site for dwellings and local roads and streets. Stone removal is needed in some areas. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, some form of shoring is needed in deep cuts. Constructing roads and streets on the contour will help to avoid steep cuts, on which plant cover is difficult to maintain. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIIs.

CcD—Canton fine sandy loam, 15 to 25 percent slopes, extremely stony. This soil is very deep, moderately steep, and well drained. It is on the sides of hills and the tops of ridges. Stones that are 2 to 5 feet apart cover 3 to 15 percent of the surface. The areas of this unit are irregular in shape. They range from 10 to 75 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is 22 inches thick. The upper 3 inches is strong brown fine sandy loam, and the lower 19 inches is yellowish brown fine sandy loam and gravelly fine sandy loam. The substratum is grayish brown gravelly loamy sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, less than 3 acres each, of Chatfield, Paxton, and Woodbridge soils. Also included are areas of soils that have more sand in the subsoil than this Canton soil and areas where stones cover less than 3 percent of the surface. Included areas make up about 15 percent of the unit.

The permeability of this Canton soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid throughout the soil.

Slope and the stones on the surface make this soil poorly suited to cultivated crops, hay, and pasture.

Maintaining a plant cover and using crop residue, conservation tillage, contour farming, and stripcropping are practices that help to reduce erosion in cultivated areas.

Most areas of this soil are covered with trees, and the soil is suited to trees. The stones on the surface limit the use of some types of equipment.

Slope is the main limitation of this soil as a site for dwellings, local roads and streets, and septic tank absorption fields. Stone removal is needed in some areas. Special design, retaining walls, and grading and filling are needed in some areas to overcome the slope. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, some form of shoring is needed. Placing roads and streets on the contour will help to avoid steep cuts, on which plant cover is difficult to maintain. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water pollution.

Capability subclass: VIIs.

CcE—Canton fine sandy loam, 25 to 35 percent slopes, extremely stony. This soil is very deep, steep, and well drained. It is on the sides of hills and the tops of ridges. Stones that are 2 to 5 feet apart cover 3 to 15 percent of the surface. The areas of this unit are long and narrow or irregular in shape. They range from 10 to 80 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is 22 inches thick. The upper 3 inches is strong brown fine sandy loam, and the lower 19 inches is yellowish brown fine sandy loam and gravelly fine sandy loam. The substratum is grayish brown gravelly loamy sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, less than 3 acres each, of Chatfield, Paxton, and Woodbridge soils. Also included are areas of soils that have more sand in the subsoil than this Canton soil and areas where stones cover less than 3 percent of the surface. Included areas make up about 20 percent of the unit.

The permeability of this Canton soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid throughout the soil.

Slope and the stones on the surface make this soil poorly suited to cultivated crops, hay, and pasture. The soil is suited to trees, and most areas are wooded. The stones and slope limit the use of some types of equipment.

Slope and the stones on the surface are major limitations of this soil as a site for dwellings and septic tank absorption fields and nearly preclude use of the soil as a site for local roads and streets. Special design, retaining walls, and grading and filling are needed for some building sites. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, shoring is needed in deep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIIs.

ChC—Chatfield-Hollis-Rock outcrop complex, 3 to 15 percent slopes. This unit consists of well drained to somewhat excessively drained soils on hills and ridges. Stones that are 5 to 30 feet apart cover less than 1 percent to 3 percent of the surface. The areas of this unit are irregular in shape. They range from 10 to 100 acres, but most are about 20 acres. This unit consists of 45 percent moderately deep Chatfield soils, 25 percent shallow Hollis soils, 15 percent Rock outcrop, and 15 percent other soils. The Chatfield and Hollis soils and Rock outcrop are so intermingled that it was not practical to map them separately.

Typically, the Chatfield soils have a surface layer of very dark grayish brown fine sandy loam about 3 inches thick. The subsoil is fine sandy loam 27 inches thick. The upper 5 inches of the subsoil is yellowish brown, the next 16 inches is light olive brown, and the lower 6 inches is light yellowish brown. Bedrock is at a depth of 30 inches.

Typically, the Hollis soils have a surface layer of very dark brown and brown fine sandy loam about 4 inches thick. The subsoil is 13 inches thick. The upper 8 inches is dark brown and yellowish brown fine sandy loam, and the lower 5 inches is yellowish brown gravelly fine sandy loam. Bedrock is at a depth of 17 inches.

Included with this unit in mapping are small areas, less than 3 acres each, of Canton, Paxton, and Woodbridge soils. Also included are areas where stones cover more than 3 percent of the surface.

The permeability in these Chatfield and Hollis soils is moderate or moderately rapid throughout. Available water capacity is moderate in the Chatfield soils and very low in the Hollis soils. Reaction in both soils ranges from very strongly acid through moderately acid. The depth to bedrock ranges from 20 to 40 inches in the Chatfield soils and 10 to 20 inches in the Hollis soils.

Most areas of these soils are covered with trees. Some areas are in pasture, and a few areas are used for cropland or residential development.

The stones on the surface, slope, the areas of rock outcrop, and the depth to bedrock make this unit poorly suited to farming. The unit is suited to trees. The stones and rock outcrop on the surface limit the use of some types of equipment, and the very low available water capacity of the Hollis soils causes a high rate of seedling mortality.

The rock outcrop and the depth to bedrock limit the use of these soils as a site for dwellings or local roads

and streets, and the depth to rock is a limitation of the unit as a site for septic tank absorption fields.

Capability subclass: VIs.

ChD—Chatfield-Hollis-Rock outcrop complex, 15 to 25 percent slopes. This unit consists of well drained to somewhat excessively drained soils on hills and ridges (fig. 4). Stones that are 2 to 5 feet apart cover 3 to 15 percent of the surface. The areas of this unit are irregular in shape. They range from 10 to 150 acres, but most are about 40 acres. This unit consists of 40 percent moderately deep Chatfield soils, 25 percent shallow Hollis soils, 20 percent Rock outcrop, and 15 percent other soils. The Chatfield and Hollis soils and Rock outcrop are so intermingled that it was not practical to map them separately.

Typically, the Chatfield soils have a surface layer of very dark grayish brown fine sandy loam about 3 inches thick. The subsoil is fine sandy loam 27 inches thick. The upper 5 inches of the subsoil is yellowish brown, the next 16 inches is light olive brown, and the lower 6 inches is light yellowish brown. Bedrock is at a depth of 30 inches.

Typically, the Hollis soils have a surface layer of very dark brown and brown fine sandy loam about 4 inches thick. The subsoil is 13 inches thick. The upper 8 inches is dark brown and yellowish brown fine sandy loam, and the lower 5 inches is yellowish brown gravelly fine sandy loam. Bedrock is at a depth of 17 inches.

Included in mapping are small areas, less than 3 acres each, of Canton, Paxton, and Woodbridge soils. Also included are areas of soils that have sandy subsoil and areas where stones cover less than 3 percent of the surface.

The permeability in these Chatfield and Hollis soils is moderate or moderately rapid throughout. Available water capacity is moderate in the Chatfield soils and very low in the Hollis soils. Reaction in both soils ranges from very strongly acid through moderately acid. The depth to bedrock ranges from 20 to 40 inches in the Chatfield soils and 10 to 20 inches in the Hollis soils.

The stones on the surface, slope, the areas of rock outcrop, and the depth to bedrock make this unit poorly suited to farming. The unit is suited to trees, and most areas are wooded. The stones and rock outcrop on the surface limit the use of some types of equipment, and the very low available water capacity of the Hollis soils causes a high rate of seedling mortality.

The rock outcrop, slope, and depth to bedrock are the main limitations of the unit as a site for dwellings and local roads and streets. Slope and the depth to bedrock also limit the unit as a site for septic tank absorption fields.

Capability subclass: VIIs.

De—Deerfield sandy loam. This soil is very deep, nearly level, and moderately well drained. It is on flats and in slight depressions. The areas of this unit are long and narrow or irregular in shape. They range from 5 to 50 acres, but most are about 10 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is black sandy loam about 2 inches thick. The subsoil is about 22 inches thick. The upper 6 inches of the subsoil is dark brown sandy loam, and the lower 16 inches is strong brown and yellowish brown loamy fine sand. The substratum extends to a depth of 60 inches or more. It is light brownish gray and light olive gray fine sand.

Included with this soil in mapping are small areas, less than 3 acres each, of Windsor soils. Also included are areas that have more silt in the surface layer and subsoil than this Deerfield soil and areas of Deerfield soils with slopes of 3 to 8 percent. Included soils make up about 20 percent of this unit.

The permeability of this Deerfield soil is rapid in the subsoil and very rapid in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to medium acid throughout the soil. The root zone is restricted by a seasonal high water table at a depth of 1 foot to 3 feet.

Most areas of this soil are wooded. Some are used for building sites, and a few areas are used for cropland.

This soil is suited to cultivated crops, hay, and improved pasture. The available water capacity is the main limitation of the soil for crops. Irrigating, adding organic matter, and using cover crops are practices that help to increase the suitability of the soil for farming. The seasonal high water table limits the use of equipment and restricts the root zone of some types of plants.

This soil is suited to trees, but the available water capacity causes a high rate of seedling mortality and makes drought-tolerant species more suitable.

The seasonal high water table is the main limitation of this soil as a site for dwellings and septic tank absorption fields, and makes drainage necessary in some areas. The soil is suitable as a site for local roads and streets, but the sides of excavations are unstable and the steeper sides commonly collapse. The soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIw.

Fm—Freetown muck. This soil is very deep, nearly level, and very poorly drained. It is in depressional areas and old glacial lakes. The areas of this unit are irregular in shape. They range from 5 to 250 acres, but most are about 20 acres. Slopes range from 0 to 2 percent.

Typically, the soil consists of black and dark reddish brown layers of highly decomposed organic material to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Scarboro, Swansea,

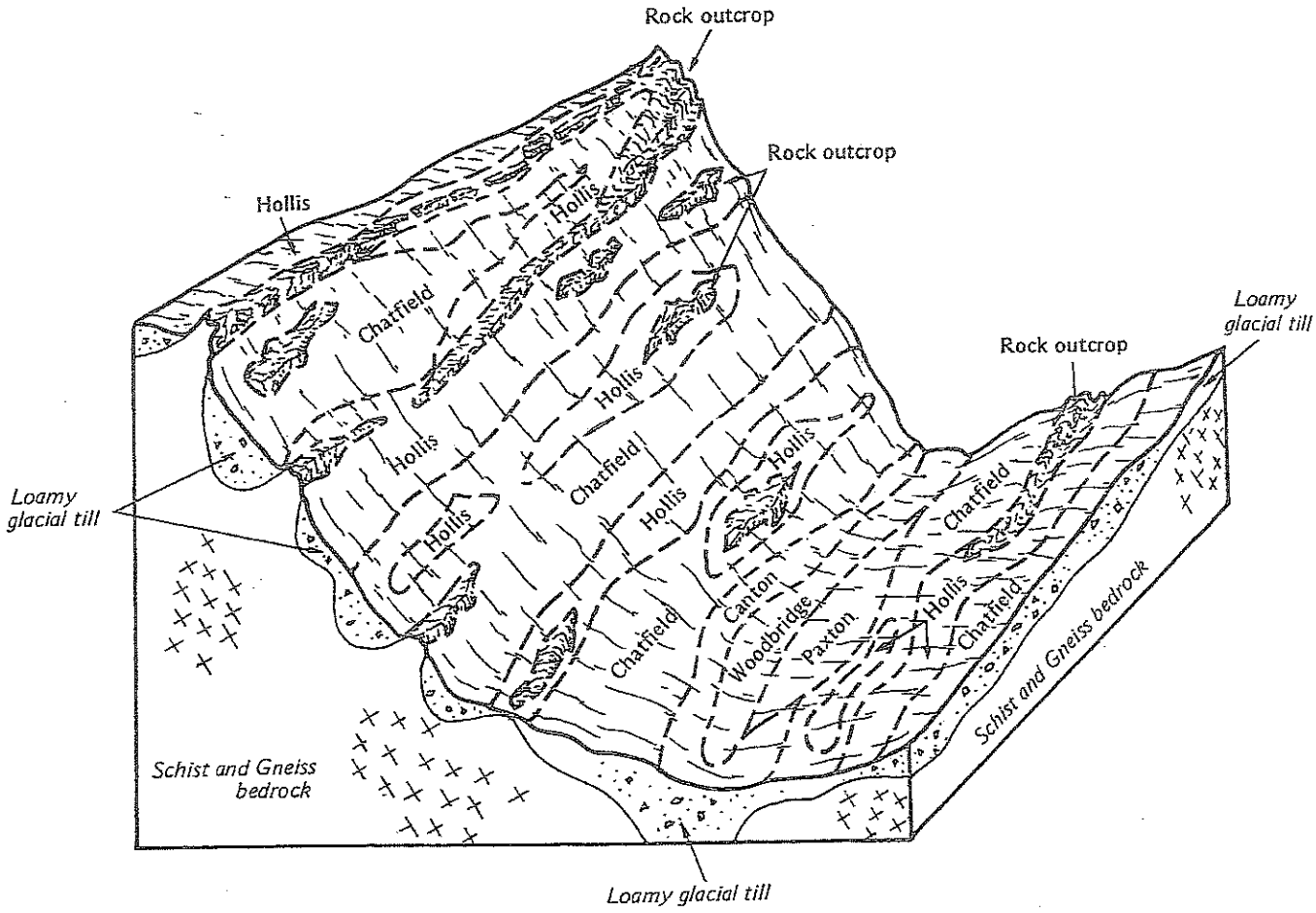


Figure. 4—Typical pattern of soils and underlying material in the Chatfield-Hollis-Rock outcrop complex, 15 to 25 percent slopes.

Saco, and Walpole soils. Included areas make up about 25 percent of this unit.

The permeability of this Freetown soil is moderate in the upper part and moderately rapid in the lower part. Available water capacity is high. Reaction is extremely acid throughout the soil. The root zone is restricted by a high water table between the surface and a depth of 1 foot.

Most areas of this soil are covered with water-tolerant shrubs and tree species.

The high water table makes this soil poorly suited to farming and woodland. Drained and limed areas, however, are suitable for vegetables and hay. The high water table restricts rooting, making trees susceptible to uprooting during windy periods, and it causes a high rate of seedling mortality and limits the use of equipment.

The water table and low strength limit the soil as a site for dwellings and local roads and streets. The water table further limits the soil as a site for septic tank absorption fields and makes ground-water contamination a hazard in areas used as sites for septic tanks.

Capability subclass: Vw.

Fp—Freetown muck, ponded. This soil is very deep, nearly level, and very poorly drained. It is in depressional areas and old glacial lakes covered with up to 2 feet of water. The areas of this unit are irregular in shape. They range from 5 to 100 acres, but most are 10 acres. Slopes range from 0 to 1 percent.

Typically, the soil consists of black and dark reddish brown layers of highly decomposed organic material to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Saco, Scarboro, and Swansea soils. Included areas make up about 20 percent of this unit.

The permeability of this Freetown soil is moderate to moderately rapid. Available water capacity is high.

Reaction is extremely acid throughout the soil. The root zone is restricted by water at or on the surface.

The water on the surface of this soil is a major limitation for most uses, including farming, woodland, and community development. A few areas are used for wildlife habitat, and some areas are covered by low-quality, water-tolerant shrubs.

Capability subclass: VIIw.

HaA—Hadley very fine sandy loam. This soil is very deep, nearly level, and well drained. It is on flood plains. The areas of this unit are irregular in shape. They range from 5 to 100 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown very fine sandy loam about 8 inches thick. The substratum is light olive brown and olive very fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Winooski soils. Also included are areas of Suncook soils and areas that are sand, fine sandy loam, or sandy loam throughout. Included areas make up about 15 percent of this unit.

The permeability of this Hadley soil is moderate or moderately rapid throughout. Available water capacity is high. Reaction ranges from very strongly acid through mildly alkaline throughout.

Most areas of this soil are used for crops. A few areas are in native vegetation.

This soil is well suited to cultivated crops, hay, pasture, and trees. Occasional, brief flooding is a limitation, but protected areas are suitable for farming.

Flooding also is the main limitation of this soil as a site for dwellings, local roads and streets, and septic tank absorption fields.

Capability class: I.

HgA—Hinckley sandy loam, 0 to 3 percent slopes. This soil is very deep, nearly level, and excessively drained. It is on broad areas on outwash plains. The areas of this unit are irregular in shape. They range from 5 to 80 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown sandy loam about 3 inches thick. The subsoil is yellowish brown and is 18 inches thick. The upper 9 inches is gravelly loamy sand, and the lower 9 inches is gravelly sand. The substratum is light olive brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Deerfield, Merrimac, and Windsor soils. Included areas make up about 20 percent of the unit.

The permeability of this Hinckley soil is rapid in the subsoil and very rapid in the substratum. Available water capacity is low. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are in brushland. Some are used for building sites, and a few areas are covered with trees.

This soil is suited to cultivated crops, hay, and pasture. Droughtiness and a low nutrient content are the main limitations for cultivated crops. Irrigating, fertilizing, using cover crops, and mixing crop residue and manure into the plow layer are practices that help to improve the suitability of the soil for crops. Droughtiness and the low nutrient content are concerns but not major limitations of the soil for hay and pasture. The major pasture management concern is the prevention of overgrazing.

This soil is poorly suited to trees. The droughtiness and low nutrient content cause a high seedling mortality rate.

This soil has essentially no limitations as a site for dwellings or local roads and streets. The sides of excavations in this soil are unstable, however, and steep sides commonly collapse. Thus, some form of shoring is needed in deep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIs.

HgB—Hinckley sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and excessively drained. It is on rolling areas on outwash plains. The areas of this unit are irregular in shape. They range from 10 to 150 acres, but most areas are about 20 acres.

Typically, the surface layer is very dark grayish brown sandy loam about 3 inches thick. The subsoil is yellowish brown and is 18 inches thick. The upper 9 inches is gravelly loamy sand, and the lower 9 inches is gravelly sand. The substratum is light olive brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Deerfield, Merrimac, and Windsor soils. Included areas make up about 20 percent of the unit.

The permeability of this Hinckley soil is rapid in the subsoil and very rapid in the substratum. Available water capacity is low. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are in brushland. Some are used for building sites, and a few areas are covered with trees.

This soil is suited to cultivated crops, hay, and pasture. Erosion, droughtiness, and a low nutrient content are the main limitations for cultivated crops. Fertilizing, using cover crops, and mixing crop residue and manure into the plow layer are practices that help to improve the suitability of the soil for crops. Droughtiness and low nutrient content are concerns but not major limitations for hay and pasture.

This soil is poorly suited to trees. The droughtiness and low nutrient content cause a high seedling mortality rate.

This soil has essentially no limitations as a site for dwellings or local roads and streets. The sides of excavations in this soil are unstable, however, and steep sides commonly collapse. Thus, some form of shoring is needed in deep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIs.

HgC—Hinckley sandy loam, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and excessively drained. It is on the sides of kames and on the side slopes of flat outwash plains. The areas of this unit are long and narrow or irregular in shape. They range from 5 to 100 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown sandy loam about 3 inches thick. The subsoil is yellowish brown and is 18 inches thick. The upper 9 inches is gravelly loamy sand, and the lower 9 inches is gravelly sand. The substratum is light olive brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Merrimac and Windsor soils. Included areas make up about 20 percent of the unit.

The permeability of this Hinckley soil is rapid in the subsoil and very rapid in the substratum. Available water capacity is low. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are in brushland. Some are used for building sites, and a few areas are covered with trees.

This soil is suited to cultivated crops, hay, and pasture. Erosion, droughtiness, and a low nutrient content are the main limitations for cultivated crops. Fertilizing, using cover crops, and mixing crop residue and manure into the plow layer are practices that help to improve the suitability of the soil for crops. Droughtiness and the low nutrient content are concerns but not major limitations for hay and pasture.

This soil is poorly suited to trees. The droughtiness and low nutrient content cause a high seedling mortality rate.

Slope is the main limitation of this soil as a site for buildings and local roads and streets. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, some form of shoring is needed when deep cuts are made. Placing roads on the contour of the landscape helps to avoid steep excavations, on which plant cover is difficult to establish. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IVs.

HgD—Hinckley sandy loam, 15 to 25 percent slopes. This soil is very deep, moderately steep, and excessively drained. It is on ridges on outwash plains. The areas of this unit are irregular in shape. They range from 10 to 70 acres, but most are about 15 acres.

Typically, the surface layer is very dark grayish brown sandy loam about 3 inches thick. The subsoil is yellowish brown and is 18 inches thick. The upper 9 inches is gravelly loamy sand, and the lower 9 inches is gravelly sand. The substratum is light olive brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Merrimac and Windsor soils. Included areas make up about 20 percent of the unit.

The permeability of this Hinckley soil is rapid in the subsoil and very rapid in the substratum. Available water capacity is low. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are in brushland. Some areas are covered with trees.

Droughtiness, erosion, and a low nutrient content make this soil poorly suited to farming. Stripcropping, using cover crops, and mixing crop residue and manure into the plow layer help to control erosion in cultivated areas.

This soil is poorly suited to trees. The droughtiness and low nutrient content cause a high seedling mortality rate.

Slope is the major limitation of this soil as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, some form of shoring is needed. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIs.

HgE—Hinckley sandy loam, 25 to 35 percent slopes. This soil is deep, steep, and excessively drained. It is on ridges of eskers. The areas of this unit are irregular in shape. They range from 5 to 40 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown sandy loam about 3 inches thick. The subsoil is yellowish brown and is 18 inches thick. The upper 9 inches is gravelly loamy sand, and the lower 9 inches is gravelly sand. The substratum is light olive brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres, of Windsor soils and soils where stones cover 1 to 3 percent of the surface.

The permeability of this Hinckley soil is rapid in the subsoil and very rapid in the substratum. Available water

capacity is low. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are in brushland. Some areas are covered with trees.

Droughtiness, slope, and a low nutrient content make this soil poorly suited to farming and woodland. The droughtiness and low nutrient content cause a high seedling mortality rate, and the slope limits the use of some types of woodland equipment.

Slope is the major limitation of this soil as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, some form of shoring is needed. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIIs.

HkB—Hinckley sandy loam, 3 to 8 percent slopes, very stony. This soil is very deep, gently sloping, and excessively drained. It is on rolling areas on outwash plains. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this unit are irregular in shape. They range from 5 to 20 acres, but most areas are about 10 acres.

Typically, the surface layer is very dark grayish brown sandy loam about 3 inches thick. The subsoil is yellowish brown and is 18 inches thick. The upper 9 inches is gravelly loamy sand, and the lower 9 inches is gravelly sand. The substratum is light olive brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton, Merrimac, and Windsor soils. Included areas make up about 15 percent of the unit.

The permeability of this Hinckley soil is rapid in the subsoil and very rapid in the substratum. Available water capacity is low. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are in brushland. Some areas are covered with trees, and some are used for commercial and residential development.

Droughtiness, the stones on the surface, and a low nutrient content make this soil poorly suited to cultivated crops, hay, and improved pasture. Fertilizing, using cover crops, and mixing crop residue and manure into the plow layer are practices that help to improve the suitability of the soil for crops.

This soil is poorly suited to trees. Droughtiness and the low nutrient content cause a high seedling mortality rate.

This soil has essentially no limitations as a site for dwellings or local roads and streets. The sides of excavations in this soil are unstable, however, and steep sides commonly collapse. Thus, some form of shoring is needed in deep cuts. This soil is a poor filter for septic tank absorption fields and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIs.

HkC—Hinckley sandy loam, 8 to 15 percent slopes, very stony. This soil is very deep, strongly sloping, and excessively drained. It is on the sides of terraces, kames, and outwash plains. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this unit are irregular in shape. They range from 5 to 15 acres, but most areas are about 10 acres.

Typically, the surface layer is very dark grayish brown sandy loam about 3 inches thick. The subsoil is yellowish brown and is 18 inches thick. The upper 9 inches is gravelly loamy sand, and the lower 9 inches is gravelly sand. The substratum is light olive brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton, Merrimac, and Windsor soils. Also included are areas of Hinckley soils with slopes of 15 to 25 percent. Included areas make up about 20 percent of the unit.

The permeability of this Hinckley soil is rapid in the subsoil and very rapid in the substratum. Available water capacity is low. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this soil are in brushland. Some areas are covered with trees, and some are used for urban development.

Droughtiness, the stones on the surface, slope, and a low nutrient content make this soil poorly suited to cultivated crops, hay, and improved pasture. Erosion is a hazard. Fertilizing, using cover crops, and mixing crop residue and manure into the plow layer are practices that help to improve the suitability of the soil for crops.

This soil is poorly suited to trees. Droughtiness and the low nutrient content cause a high seedling mortality rate.

This soil has essentially no limitations as a site for dwellings or local roads and streets. The sides of excavations in this soil are unstable, however, and steep sides commonly collapse. Thus, some form of shoring is needed in deep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIs.

HuC—Hinckley-Urban land complex, 0 to 15 percent slopes. This unit is on outwash plains. It consists of very deep, nearly level to strongly sloping, excessively drained soils and areas that have been altered by filling or grading for buildings, parking lots, and other urban structures. The areas of the unit are rectangular or irregularly shaped and range from 10 to

100 acres, but most are about 30 acres. The areas consist of about 45 percent Hinckley soils, 35 percent urbanized areas, and 20 percent other soils. The Hinckley soils and urbanized areas are so intermingled that it was not practical to map them separately.

Typically, the surface layer of the Hinckley soils is very dark grayish brown sandy loam about 3 inches thick. The subsoil is yellowish brown and is 18 inches thick. The upper 9 inches is gravelly loamy sand, and the lower 9 inches is gravelly sand. The substratum is light olive brown stratified sand and gravel to a depth of 60 inches or more.

Included with this unit in mapping are small areas of Udorthents and Agawam, Merrimac, and Windsor soils. Also included are soils with slopes of more than 15 percent and moderately well drained soils.

The permeability of these Hinckley soils is rapid in the subsoil and very rapid in the substratum. Available water capacity is low. Reaction ranges from extremely acid to moderately acid throughout the soil.

Most areas of this unit are used for residential and commercial use. A few areas are in native vegetation.

The lack of open space is the major limitation of this unit for cultivated crops or woodland, and the Hinckley soils are droughty and have a low content of nutrients. The unit is generally suitable as a site for dwellings and local roads and streets, but the sides of excavations in the Hinckley soils are unstable and the steeper sides commonly collapse. The Hinckley soils are a poor filter for septic tank absorption fields. Seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: not assigned.

HwB—Hinesburg loamy sand, 3 to 8 percent slopes. This soil is very deep, gently sloping, and well drained. It is on broad areas and old lakebeds. The areas of this unit are irregular in shape. They range from 5 to 40 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown loamy sand about 7 inches thick. The subsoil is 21 inches thick. The upper 11 inches is yellowish brown loamy sand, and the lower 10 inches is light yellowish brown fine sand. The upper 3 inches of the substratum is grayish brown fine sand. The lower part is olive silt loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Deerfield and Windsor soils. Also included are areas that have a surface layer and subsoil of silt loam, areas of soils with slopes of 0 to 3 percent, and areas of soils that are mottled in the subsoil. Included areas make up about 25 percent of the unit.

The permeability of this Hinesburg soil is rapid in the subsoil and moderately slow in the substratum. Available water capacity is low. Reaction ranges from moderately acid to slightly acid in the surface layer and subsoil and from strongly acid to neutral in the substratum.

Most areas of this soil are covered with trees or brush, and the soil is well suited to trees.

This soil is well suited to cultivated crops, hay, and improved pasture. The low available water capacity and a low content of nutrients are the main limitations for crops, and erosion is a hazard. Farming on the contour and using tillage methods that leave large amounts of crop residue on the surface are practices that help to control erosion in cultivated areas.

Low strength and a frost-action potential are the main limitations of this soil as a site for buildings and local roads and streets. Compaction of the soil or using fill material will help to overcome the low strength and frost-action potential. The permeability of the substratum limits the soil as a site for septic tank absorption fields.

Capability subclass: IIs.

Lm—Limerick silt loam. This soil is very deep, nearly level, and poorly drained. It is on flood plains. The areas of this unit are irregular in shape. They range from 5 to 30 acres, but most are about 15 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is dark grayish brown silt loam about 9 inches thick. The substratum is olive gray and extends to a depth of 60 inches or more. It is silt loam in the upper part and very fine sandy loam in the lower part.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Saco and Winooski soils. Also included are areas of soils that are more sandy than this Limerick soil. Included areas make up about 20 percent of the unit.

The permeability of this Limerick soil is moderate throughout. Available water capacity is high. Reaction ranges from strongly acid to neutral to a depth of 40 inches and from moderately acid to neutral below a depth of 40 inches. The seasonal high water table is at a depth of 6 to 18 inches.

This soil is suited to cultivated crops, hay, and improved pasture, and some areas are farmed. The main limitations for farming are frequent, brief flooding and the seasonal high water table.

Flooding and the seasonal high water table make this soil poorly suited to trees. They limit the use of equipment, cause a high rate of seedling mortality, and restrict rooting. They also are the main limitations for most types of urban development.

Capability subclass: IIIw.

MeA—Merrimac fine sandy loam, 0 to 3 percent slopes. This soil is very deep, nearly level, and somewhat excessively drained. It is on broad areas on outwash plains. The areas of this unit are long and narrow or irregular in shape. They range from 5 to 80 acres, but most are about 15 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 2 inches thick. The subsoil is 22 inches thick. The upper 13 inches is yellowish brown fine sandy loam, and the lower 9 inches is a light olive brown gravelly sandy loam. The substratum is light yellowish brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley, Sudbury, and Windsor soils. Also included are areas of soils with a surface layer of sandy loam. Included areas make up about 15 percent of this unit.

The permeability of this Merrimac soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid.

Most areas of this soil are used for cropland. Some areas are used for building sites.

This soil is well suited to cultivated crops, hay, and improved pasture. Droughtiness is a limitation. Using irrigation and increasing the organic matter content of the soil are the main farming management concerns. Use of proper stocking rates and deferred and rotational grazing are pasture management practices that help to maintain desirable plant species.

This soil is well suited to trees. The available water capacity causes a moderate rate of seedling mortality. Mulching and increasing the organic matter content of the soil are practices that help to increase the moisture content of the soil.

This soil has essentially no major limitations as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, however, and the steeper sides commonly collapse, making some form of shoring necessary in steep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIs.

MeB—Merrimac fine sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and somewhat excessively drained. It is on broad areas on outwash plains. The areas of this unit are long and narrow or irregular in shape. They range from 10 to 160 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 2 inches thick. The subsoil is 22 inches thick. The upper 13 inches is yellowish brown fine sandy loam, and the lower 9 inches is light olive brown gravelly sandy loam. The substratum is light yellowish brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley, Sudbury, and Windsor soils. Also included are areas of soils with a surface layer of sandy loam. Included areas make up about 15 percent of this unit.

The permeability of this Merrimac soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid.

Most areas of this soil are used for cropland (fig. 5). Some areas are used for building sites.

This soil is well suited to cultivated crops, hay, and improved pasture. Erosion is a hazard, and droughtiness is a limitation. Using irrigation and increasing the organic matter content of the soil are practices that help to increase the moisture content of this soil. Stripcropping, planting on the contour, and using conservation tillage help to reduce the hazard of erosion. Using proper stocking rates and deferred and rotational grazing are pasture management practices that help to maintain desirable plant species.

This soil is well suited to trees. The available water capacity causes a moderate rate of seedling mortality. Mulching and increasing the organic matter content of the soil are practices that help to increase the moisture content of the soil.

This soil has essentially no major limitations as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, however, and the steeper sides commonly collapse, making some form of shoring necessary in steep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIs.

MeC—Merrimac fine sandy loam, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and somewhat excessively drained. It is on the side slopes of ridges and the sides of broad areas on outwash plains. The areas of this unit are long and narrow or irregular in shape. They range from 10 to 100 acres, but most are about 15 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 2 inches thick. The subsoil is 22 inches thick. The upper 13 inches is yellowish brown fine sandy loam, and the lower 9 inches is a light olive brown gravelly sandy loam. The substratum is light yellowish brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley and Windsor soils. Also included are areas of soils with a surface layer of sandy loam. Included areas make up about 15 percent of this unit.

The permeability of this Merrimac soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid.

Typically, the surface layer is very dark grayish brown fine sandy loam about 2 inches thick. The subsoil is 22 inches thick. The upper 13 inches is yellowish brown fine sandy loam, and the lower 9 inches is a light olive brown gravelly sandy loam. The substratum is light yellowish brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley, Sudbury, and Windsor soils. Also included are areas of soils with a surface layer of sandy loam. Included areas make up about 15 percent of this unit.

The permeability of this Merrimac soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid.

Most areas of this soil are used for cropland. Some areas are used for building sites.

This soil is well suited to cultivated crops, hay, and improved pasture. Droughtiness is a limitation. Using irrigation and increasing the organic matter content of the soil are the main farming management concerns. Use of proper stocking rates and deferred and rotational grazing are pasture management practices that help to maintain desirable plant species.

This soil is well suited to trees. The available water capacity causes a moderate rate of seedling mortality. Mulching and increasing the organic matter content of the soil are practices that help to increase the moisture content of the soil.

This soil has essentially no major limitations as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, however, and the steeper sides commonly collapse, making some form of shoring necessary in steep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIs.

MeB—Merrimac fine sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and somewhat excessively drained. It is on broad areas on outwash plains. The areas of this unit are long and narrow or irregular in shape. They range from 10 to 160 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 2 inches thick. The subsoil is 22 inches thick. The upper 13 inches is yellowish brown fine sandy loam, and the lower 9 inches is light olive brown gravelly sandy loam. The substratum is light yellowish brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley, Sudbury, and Windsor soils. Also included are areas of soils with a surface layer of sandy loam. Included areas make up about 15 percent of this unit.

The permeability of this Merrimac soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid.

Most areas of this soil are used for cropland (fig. 5). Some areas are used for building sites.

This soil is well suited to cultivated crops, hay, and improved pasture. Erosion is a hazard, and droughtiness is a limitation. Using irrigation and increasing the organic matter content of the soil are practices that help to increase the moisture content of this soil. Stripcropping, planting on the contour, and using conservation tillage help to reduce the hazard of erosion. Using proper stocking rates and deferred and rotational grazing are pasture management practices that help to maintain desirable plant species.

This soil is well suited to trees. The available water capacity causes a moderate rate of seedling mortality. Mulching and increasing the organic matter content of the soil are practices that help to increase the moisture content of the soil.

This soil has essentially no major limitations as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, however, and the steeper sides commonly collapse, making some form of shoring necessary in steep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIs.

MeC—Merrimac fine sandy loam, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and somewhat excessively drained. It is on the side slopes of ridges and the sides of broad areas on outwash plains. The areas of this unit are long and narrow or irregular in shape. They range from 10 to 100 acres, but most are about 15 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 2 inches thick. The subsoil is 22 inches thick. The upper 13 inches is yellowish brown fine sandy loam, and the lower 9 inches is a light olive brown gravelly sandy loam. The substratum is light yellowish brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley and Windsor soils. Also included are areas of soils with a surface layer of sandy loam. Included areas make up about 15 percent of this unit.

The permeability of this Merrimac soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid.



Figure 5.—Corn in an area of Merrimac fine sandy loam, 3 to 8 percent slopes.

Most areas of this soil are used for cropland. Some areas are used for building sites.

This soil is suited to cultivated crops, hay, and improved pasture. Erosion is a hazard, and slope and droughtiness are the main limitations. Stripcropping, conservation tillage, and increasing the organic matter content of the soil are the main farming management practices. Using proper stocking rates and deferred and rotational grazing are pasture management practices that help to maintain desirable plant species.

This soil is well suited to trees. The available water capacity causes a moderate rate of seedling mortality. Mulching and increasing the organic matter content of the soil are practices that help to increase the moisture content of the soil.

Slope is the main limitation of this soil as a site for dwellings and local roads and streets. Using retaining walls, grading, and constructing roads and streets on the contour are ways of overcoming the slope. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse, making some form of shoring necessary in steep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIe.

MeD—Merrimac fine sandy loam, 15 to 25 percent slopes. This soil is very deep, moderately steep, and somewhat excessively drained. It is on ridges on outwash plains. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 80 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 2 inches thick. The subsoil is 22 inches thick. The upper 13 inches is yellowish brown fine sandy loam, and the lower 9 inches is a light olive brown gravelly sandy loam. The substratum is light yellowish brown stratified sand and gravel to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley and Windsor soils. Also included are areas of soils with a surface layer of sandy loam. Included areas make up about 15 percent of this unit.

The permeability of this Merrimac soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from extremely acid to moderately acid.

Most areas of this soil are covered with trees and brush.

This soil is suited to cultivated crops, hay, and improved pasture. Erosion is a hazard, and slope and droughtiness are the main limitations. Stripcropping, conservation tillage, and increasing the organic matter content of the soil are the main farming management practices. Using proper stocking rates and deferred and rotational grazing are pasture management practices that help to maintain desirable plant species.

This soil is well suited to trees. The available water capacity causes a moderate rate of seedling mortality. Mulching and increasing the organic matter content of the soil are practices that help to increase the moisture content of the soil.

Slope is the main limitation of this soil as a site for dwellings and local roads and streets. Using retaining walls, grading, and constructing roads and streets on the contour are ways of overcoming the slope. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse, making some form of shoring necessary in steep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IVe.

NgA—Ninigret fine sandy loam, 0 to 3 percent slopes. This soil is very deep, nearly level, and moderately well drained. It is on broad areas on outwash plains. The areas of this unit are irregular in shape. They range from 5 to 40 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 9 inches thick. The subsoil is yellowish brown fine sandy loam 12 inches thick. The substratum is light olive brown and extends to a depth of 60 inches or more. It is loamy fine sand in the upper part and gravelly loamy sand in the lower part.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Agawam, Deerfield, Merrimac, and Windsor soils. Also included are areas of soils that have more silt in the surface layer and subsoil than this Ninigret soil and areas of soils with slopes of 3 to 8 percent. Included areas make up about 15 percent of the unit.

The permeability of this Ninigret soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is moderate. Reaction ranges from moderately acid to very strongly acid throughout the soil. A seasonal high water table is at a depth of 1 1/2 to 3 feet.

Most areas of this soil are in cropland. Some areas have been developed for residential use.

This soil is well suited to cultivated crops, hay, and improved pasture and to woodland. Incorporating crop residue into the soil increases the organic matter content. The use of proper stocking rates and deferred and rotational grazing help to maintain the desirable pasture plant species.

The seasonal high water table during the winter and early spring is the main limitation of the soil as a site for dwellings or local roads and streets. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIw.

PaB—Paxton fine sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and well drained. It is on drumlins and drumlinlike areas. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 50 acres, but most are about 15 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Woodbridge soils. Also included are areas that have stones on the surface, areas of soils that have more sand in the substratum than this Paxton soil, and areas of soils with slopes of 0 to 3 percent. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are used for cropland. Some have been developed for residential use. A few areas are covered with trees, and the soil is well suited to trees.

This soil is well suited to cultivated crops, hay, and improved pasture. Erosion is a hazard. Conservation tillage, using cover crops, and stripcropping help to reduce erosion.

The seasonal high water table and a frost-action potential are the main limitations of the soil as a site for dwellings or local roads and streets. The slow or very slow permeability of the substratum limits the use of this soil for septic tank absorption fields.

Capability subclass: IIe.

PaC—Paxton fine sandy loam, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and well drained. It is on drumlins and drumlinlike areas. The areas of this unit are long and narrow or irregular in shape. They range from 5 to 50 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Woodbridge soils. Also included are stony areas. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees, and the soil is well suited to trees. Some areas have been developed for residential use, and a few areas are used for cropland.

This soil is suited to cultivated crops, hay, and improved pasture. Slope is the major limitation, and erosion is a hazard. Conservation tillage, using cover crops, and stripcropping help to reduce erosion in cultivated areas.

Slope, the seasonal high water table, and a frost-action potential are the main limitations of this soil as a site for dwellings and local roads and streets. The slow or very slow permeability of the substratum is a limitation of the soil for septic tank absorption fields.

Capability subclass: IIIe.

PaD—Paxton fine sandy loam, 15 to 25 percent slopes. This soil is deep, moderately steep, and well drained. It is on drumlins. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 80 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Woodbridge soils. Also included are areas that have stones on the surface and areas that have more sand in the substratum than this Paxton soil. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees or are in pasture.

This soil is suited to cultivated crops, hay, and improved pasture. Slope is the major limitation and erosion is a hazard. Conservation tillage, using cover crops, and stripcropping help to reduce erosion.

This soil is well suited to growing trees. Slope limits the use of some types of equipment.

Slope is the major limitation of this soil as a site for dwellings or local roads and streets. The slow or very slow permeability in the substratum limits the use of this soil for septic tank absorption fields.

Capability subclass: IVe.

PbB—Paxton fine sandy loam, 3 to 8 percent slopes, very stony. This soil is very deep, gently sloping, and well drained. It is on drumlins and drumlinlike areas. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this soil are irregular in shape. They range from 5 to 80 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Woodbridge soils. Also included are areas that have more sand in the substratum than this Paxton soil and areas of soils with slopes of 0 to 3 percent. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees, and the soil is well suited to trees. Some areas are used for pasture, and a few areas are used for residential development.

The stones on the surface and an erosion hazard make this soil poorly suited to cultivated crops, hay, and improved pasture. The soil is well suited to these uses if the stones are removed. Conservation tillage, cover crops, and stripcropping help to reduce erosion in cultivated areas.

The seasonal high water table and a frost-action potential are the main limitations of the soil as a site for

dwellings or local roads and streets. The slow or very slow permeability and the firmness of the substratum limit the use of this soil for septic tank absorption fields.

Capability subclass: VIs.

PbC—Paxton fine sandy loam, 8 to 15 percent slopes, very stony. This soil is very deep, strongly sloping, and well drained. It is on drumlins and drumlinlike areas. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this soil are irregular in shape. They range from 5 to 50 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Woodbridge soils. Also included are areas that have more sand in the substratum than this Paxton soil and areas of soils with slopes of 3 to 8 percent. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees, and the soil is well suited to trees. Some areas are used for pasture.

The stones on the surface and an erosion hazard make this soil poorly suited to cultivated crops, hay, and improved pasture. Conservation tillage, cover crops, and stripcropping help to reduce erosion in cultivated areas.

The seasonal high water table and a frost-action potential are the main limitations of the soil as a site for dwellings or local roads and streets. The slow or very slow permeability and the firmness of the substratum limit the use of this soil for septic tank absorption fields.

Capability subclass: VIs.

PbD—Paxton fine sandy loam, 15 to 25 percent slopes, very stony. This soil is very deep, moderately steep, and well drained. It is on drumlins. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this unit are long and narrow or irregular in shape. They range from 5 to 100 acres, but most are about 25 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Woodbridge soils. Also included are areas that have more sand in the substratum than this Paxton soil and areas of soils with slopes of 8 to 15 percent. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees. A few areas are used for pasture.

The stones on the surface and an erosion hazard make this soil poorly suited to cultivated crops, hay, and improved pasture. Conservation tillage, cover crops, and stripcropping help to reduce erosion in cultivated areas.

This soil is well suited to trees. Slope limits the use of some types of equipment.

Slope, the seasonal high water table, and a frost-action potential are the main limitations of this soil as a site for dwellings or local roads and streets. The slow or very slow permeability in the substratum limits the use of this soil for septic tank absorption fields.

Capability subclass: VIs.

PcB—Paxton fine sandy loam, 3 to 8 percent slopes, extremely stony. This soil is very deep, gently sloping, and well drained. It is on drumlins and drumlinlike areas. Stones that are 2 to 5 feet apart cover from 3 to 15 percent of the surface. The areas of this soil are irregular in shape. They range from 15 to 150 acres, but most are about 50 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Woodbridge soils. Also included are areas of soils that have more sand in the substratum than this Paxton soil, areas where stones cover less than 3 percent of the surface, and areas of Paxton soils with slopes of 0 to 3 percent. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees. A few areas are used for pasture.

The stones on the surface and an erosion hazard make this soil poorly suited to cultivated crops, hay, and improved pasture. The soil is well suited to these uses if the stones are removed. Conservation tillage, cover crops, and stripcropping help to reduce erosion in cultivated areas.

This soil is well suited to trees. The stones on the surface limit the use of some types of equipment.

The seasonal high water table and a frost-action potential are the main limitations of the soil as a site for dwellings or local roads and streets. The slow or very slow permeability of the substratum limits the use of this soil for septic tank absorption fields.

Capability subclass: VIIs.

PcC—Paxton fine sandy loam, 8 to 15 percent slopes, extremely stony. This soil is very deep, strongly sloping, and well drained. It is on drumlins and drumlinlike areas. Stones that are 2 to 5 feet apart cover from 3 to 15 percent of the surface. The areas of this unit are irregular in shape. They range from 5 to 100 acres, but most are about 25 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Woodbridge soils. Also included are areas where stones cover less than 3 percent of the surface and areas of soils that have more sand in the substratum than this Paxton soil. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

The stones on the surface and an erosion hazard make this soil poorly suited to cultivated crops, hay, and improved pasture. Conservation tillage, cover crops, and stripcropping help to reduce erosion in cultivated areas.

This soil is well suited to trees, and most areas are wooded. The stones on the surface limit the use of some types of equipment.

The seasonal high water table and a frost-action potential are the main limitations of the soil as a site for dwellings or local roads and streets. The slow or very slow permeability of the substratum limits the use of this soil for septic tank absorption fields.

Capability subclass: VIIs.

PcD—Paxton fine sandy loam, 15 to 25 percent slopes, extremely stony. This soil is very deep, moderately steep, and well drained. It is on drumlins. Stones that are 2 to 5 feet apart cover from 3 to 15 percent of the surface. The areas of this unit are long and narrow or irregular in shape. They range from 10 to 80 acres, but most are about 40 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Chatfield soils. Also included are areas of soils that have more sand in the substratum than this Paxton soil and areas where stones cover less than 3 percent of the surface. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

The stones on the surface and an erosion hazard make this soil poorly suited to cultivated crops, hay, and improved pasture. Conservation tillage, cover crops, and stripcropping help to reduce erosion in cultivated areas.

This soil is well suited to trees, and most areas are wooded. Slope and the stones on the surface limit the use of some types of equipment.

Slope, the seasonal high water table, and a frost-action potential are the main limitations of this soil as a site for dwellings or local roads and streets. The slow or very slow permeability in the substratum limits the use of this soil for septic tank absorption fields.

Capability subclass: VIIs.

PcE—Paxton fine sandy loam, 25 to 35 percent slopes, extremely stony. This soil is very deep, steep, and well drained. It is on drumlins. Stones that are 2 to 5 feet apart cover from 3 to 15 percent of the surface. The areas of this unit are long and narrow or irregular in shape. They range from 10 to 80 acres, but most are about 15 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Canton and Chatfield soils. Also included are areas of soils that have more sand in the substratum than this Paxton soil and areas where stones cover less than 3 percent of the surface. Included areas make up about 15 percent of this unit.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Slope and the stones on the surface make this soil poorly suited to cultivated crops, hay, and improved pasture.

This soil is well suited to trees, and most areas are wooded. Slope and the stones on the surface limit the use of some types of equipment.

Slope, the seasonal high water table, and a frost-action potential are the main limitations of this soil as a site for dwellings or local roads and streets. The slow or very slow permeability in the substratum limits the use of this soil for septic tank absorption fields.

Capability subclass: VIIs.

PdC—Paxton-Urban land complex, 8 to 15 percent slopes. This unit is on uplands. It consists of very deep, gently sloping and strongly sloping, well drained soils and areas that have been altered by filling or grading for buildings, parking lots, and other urban structures. The areas of this unit are long and narrow or irregular in shape and range from 20 to 100 acres, but most are about 40 acres. The areas consist of about 45 percent Paxton soils, 30 percent urbanized areas, and 25 percent other soils. The Paxton soils and urbanized areas are so intermingled that it was not practical to map them separately.

Typically, the surface layer of the Paxton soils is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is yellowish brown fine sandy loam about 22 inches thick. The substratum is very firm, grayish brown gravelly fine sandy loam to a depth of 60 inches or more.

Included with this unit in mapping are small areas, mainly less than 3 acres each, of Udorthents and Woodbridge, Ridgebury, and Canton soils.

The permeability of this Paxton soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this unit are in residential or commercial use. The lack of open space is the main limitation of the unit for cultivated crops or woodland. The Paxton soils are well suited to trees, shrubs, and small gardens. The seasonal high water table and a frost-action potential in the Paxton soils are the main limitations of the unit as a site for dwellings or local roads and streets. The slow or very slow permeability of the substratum is a limitation for septic tank absorption fields.

Capability subclass: not assigned.

Pg—Pits, gravel. This unit consists of areas from which gravel has been removed for use in construction. The excavations mainly are in areas of sandy glacial outwash. Some excavations are in areas of loose, sandy glacial till. The pits are 3 to 50 feet deep and mainly have steep sides and a nearly level floor. Piles of stones and boulders commonly are scattered on the pit floor, and small pools of water are in some pits. The excavations commonly are irregular in shape, depending on the nature of the deposits and ownership boundaries. The pits range from 2 to 100 acres, but most are about 10 acres.

The pits have very low available water capacity. Permeability varies, but it mainly is moderately rapid to very rapid.

Most of these units are devoid of plants, but some older excavations have growths of bushes, grasses, and annuals. The very low available water capacity and steep sides make the unit poorly suited to farming or woodland. The potential for wildlife habitat is poor, but some birds inhabit these areas. The sandy material is a poor filter, and use of the unit for waste disposal facilities causes a hazard of ground-water contamination.

Capability subclass: not assigned.

Pm—Pits, quarry. This unit consists of areas that have been excavated for rock. The areas typically are on the sides and tops of ridges that range from nearly level to very steep. The areas consist of layers of exposed bedrock. The walls are mainly vertical, and the bottom generally is excavated in steps. Small pools of water are at the bottom of many quarries, and some areas have small piles of broken granite at the bottom of and along the edges.

The lack of soil material and difficulty of excavation hinder reclamation of these areas, and very few have been reclaimed. Very little vegetation grows in or around the quarries. The areas have poor potential for most uses because of exposed bedrock, a high percentage of small stone fragments, and very low available water capacity. Onsite investigation is necessary to determine the suitability of the unit for any proposed use.

Capability subclass: not assigned.

PoB—Poquonock loamy sand, 3 to 8 percent slopes. This soil is very deep, gently sloping, and well drained. It is on the toe slopes of uplands and in areas bordering fluvial terraces. The areas of this unit are long and narrow or irregular in shape. They range from 5 to 50 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown loamy sand about 7 inches thick. The subsoil is about 27 inches thick. The upper 4 inches of the subsoil is yellowish brown loamy fine sand. The lower 23 inches is light olive brown loamy sand. The substratum is firm, olive fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Merrimac, Paxton, and Windsor soils. Also included are areas of moderately well drained soils, soils where stones cover from less than 1 percent to 3 percent of the surface, and Poquonock soils with slopes of 0 to 3 percent. Included areas make up about 25 percent of the unit.

The permeability of this Poquonock soil is rapid or very rapid in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees. Some areas are used for residential and commercial development, and a few areas are used for cropland.

This soil is well suited to cultivated crops, hay, and improved pasture. Conservation tillage, using cover crops, and contour farming are practices that help to reduce an erosion hazard.

This soil is well suited to trees. The seedling mortality rate is moderate because the soil is droughty at times and low in natural fertility. Fertilizing and mulching are practices that help to increase the fertility and moisture content of the soil.

This soil has no major limitations as a site for dwellings or local roads and streets. The sides of excavations in this soil are unstable, however, and the steeper sides commonly collapse. The seasonal high water table is a limitation in winter and early spring, making drainage necessary in some areas. The slow or very slow permeability of the substratum is a limitation of the soil as a site for septic tank absorption fields.

Capability subclass: IIs.

PoC—Poquonock loamy sand, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and well drained. It is on the lower slopes of the uplands and in areas bordering fluvial terraces. The areas of this unit are long and narrow or irregular in shape. They range from 5 to 40 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown loamy sand about 7 inches thick. The subsoil is about 27 inches thick. The upper 4 inches of the subsoil is yellowish brown loamy fine sand. The lower 23 inches is light olive brown loamy sand. The substratum is firm, olive fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Merrimac, Paxton, and Windsor soils. Also included are areas of moderately well drained soils and soils where stones cover from less than 1 percent to 3 percent of the surface. Included areas make up about 25 percent of the unit.

The permeability of this Poquonock soil is rapid or very rapid in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees. Some areas are used for residential and commercial development.

This soil is suited to cultivated crops, hay, and improved pasture. Slope is the main limitation, and erosion is a hazard. Conservation tillage, using cover crops, and contour farming help to reduce erosion.

This soil is well suited to trees. The seedling mortality rate is moderate because the soil is droughty at times and low in natural fertility. Fertilizing and mulching are practices that help to increase the fertility and moisture content of the soil.

Slope and the seasonal high water table are the main limitations of this soil as a site for dwellings or local roads and streets. The slow or very slow permeability in the substratum is a limitation of the soil as a site for septic tank absorption fields.

Capability subclass: IIIe.

PsB—Poquonock loamy sand, 3 to 8 percent slopes, very stony. This soil is very deep, gently sloping, and well drained. It is on the toe slopes of uplands and in areas bordering fluvial terraces. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this unit are irregular in shape. They range from 5 to 60 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown loamy sand about 7 inches thick. The subsoil is about 27 inches thick. The upper 4 inches of the subsoil is yellowish brown loamy fine sand. The lower 23 inches is light olive brown loamy sand. The substrautm is firm, olive fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Merrimac and Paxton soils. Also included are areas where stones cover more than 3 percent of the surface, areas of moderately well drained soils, and areas where slopes are less than 3 percent or more than 8 percent. Included areas make up about 20 percent of the unit.

The permeability of this Poquonock soil is rapid or very rapid in the subsoil and slow or very slow in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. A seasonal high water table is perched at a depth of 1 1/2 to 2 1/2 feet.

Most areas of this soil are covered with trees. Some areas are used for residential and commercial development.

This soil is poorly suited to cultivated crops, hay, and improved pasture. The stones on the surface are a limitation, and erosion is a hazard. The soil is well suited to these uses if the stones are removed. Conservation tillage, using cover crops, and contour farming help to reduce erosion.

This soil is well suited to trees. The seedling mortality rate is moderate because the soil is droughty at times and low in natural fertility. Fertilizing and mulching are practices that help to increase the fertility and moisture content of the soil.

The seasonal high water table is the main limitation of this soil as a site for dwellings or local roads and streets. The slow or very slow permeability in the substratum limits the soil as a site for septic tank absorption fields.

Capability subclass: VIs.

QnA—Quonset loamy sand, 0 to 3 percent slopes. This soil is very deep, nearly level, and excessively drained. It is on terraces and outwash plains. The areas of this unit are long and narrow or irregular in shape. They range from 10 to 50 acres, but most are about 20 acres.

Typically, the surface layer is very dark brown loamy sand about 3 inches thick (fig. 6). The subsoil is dark yellowish brown and is 15 inches thick. The upper 3 inches is channery loamy sand, and the lower 12 inches is very channery loamy sand. The substratum is olive brown and light olive brown very channery coarse sand to a depth of 60 inches or more.



Figure 6.—Typical soil profile of Quonset loamy sand, 0 to 3 percent slopes.

Included with this soil in mapping are small areas, mainly less than 2 acres each, of Deerfield, Hinckley, and Windsor soils. Also included are areas that have more silt in the surface layer and subsoil than this Quonset soil. Included areas make up about 20 percent of this unit.

The permeability of this Quonset soil is moderately rapid or rapid in the subsoil and very rapid in the substratum. Available water capacity is very low. Reaction is very strongly acid or strongly acid in the surface layer and subsoil and ranges from strongly acid to slightly acid in the substratum.

Most areas of this soil are in brushland. Some areas are used for dwellings, and a few areas are being mined for sand and gravel.

This soil is suited to cultivated crops, hay, and improved pasture. Droughtiness and a low nutrient content are the main limitations. The rapid permeability causes some of the nutrients from fertilizer application to readily pass through the soil. Using cover crops and mixing crop residue and manure into the surface layer are practices that will help maintain the organic matter content and improve the tilth of the soil.

This soil is poorly suited to trees. The droughtiness and low nutrient content causes a high seedling mortality rate. Mulching, mixing crop residue into the soil, and fertilizing are means of reducing the mortality rate.

This soil has no major limitations as a site for dwellings or local roads and streets. The side slopes of excavations in this soil are unstable, however, and the steep sides commonly collapse. Some form of shoring is needed when steep cuts are made. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIs.

QnB—Quonset loamy sand, 3 to 8 percent slopes. This soil is very deep, gently sloping, and excessively drained. It is on terraces, eskers, and outwash plains. The areas of this unit are irregular in shape. They range from 10 to 150 acres, but most areas are about 20 acres.

Typically, the surface layer is very dark brown loamy sand about 3 inches thick. The subsoil is dark yellowish brown and is 15 inches thick. The upper 3 inches is channery loamy sand, and the lower 12 inches is very channery loamy sand. The substratum is olive brown and light olive brown very channery coarse sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 2 acres each, of Deerfield, Hinckley, and Windsor soils. Also included are areas that have more silt in the surface layer and subsoil than this Quonset soil. Included areas make up about 20 percent of this unit.

The permeability of this Quonset soil is moderately rapid or rapid in the subsoil and very rapid in the substratum. Available water capacity is very low. Reaction is very strongly acid or strongly acid in the surface layer and subsoil and ranges from strongly acid to slightly acid in the substratum.

Most areas of this soil are in brushland. Some areas are used for dwellings, and a few areas are being mined for sand and gravel.

This soil is suited to cultivated crops, hay, and improved pasture. Droughtiness and a low nutrient

content are the main limitations, and erosion is a hazard. The rapid permeability causes some of the nutrients from fertilizer application to readily pass through the soil. Using cover crops, stripcropping, conservation tillage, and mixing crop residue and manure into the surface layer are practices that will help maintain the organic matter content and reduce erosion.

This soil is poorly suited to trees. The droughtiness and low nutrient content cause a high seedling mortality rate. Mulching, mixing crop residue into the soil, and fertilizing are means of reducing the mortality rate.

This soil has no major limitations as a site for dwellings or local roads and streets. The side slopes of excavations in this soil are unstable, however, and the steep sides commonly collapse. Some form of shoring is needed when steep cuts are made. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIs.

QnC—Quonset loamy sand, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and excessively drained. It is on terraces, eskers, and outwash plains. The areas of this soil are irregular in shape. They range from 10 to 100 acres, but most are about 15 acres.

Typically, the surface layer is very dark brown loamy sand about 3 inches thick. The subsoil is dark yellowish brown and is 15 inches thick. The upper 3 inches is channery loamy sand, and the lower 12 inches is very channery loamy sand. The substratum is olive brown and light olive brown very channery coarse sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley and Windsor soils. Also included are areas of soils that have more silt in the surface layer and subsoil than this Quonset soil. Included areas make up about 20 percent of this unit.

The permeability of this Quonset soil is moderately rapid or rapid in the subsoil and very rapid in the substratum. Available water capacity is very low. Reaction is very strongly acid or strongly acid in the surface layer and subsoil and ranges from strongly acid to slightly acid in the substratum.

Most areas of this soil are in brushland. Some areas are used for dwellings, and a few areas are being mined for sand and gravel.

This soil is suited to cultivated crops, hay, and improved pasture. Droughtiness and a low nutrient content are the main limitations, and erosion is a hazard. The rapid permeability causes some of the nutrients from fertilizer application to readily pass through the soil. Using cover crops, stripcropping, conservation tillage, and mixing crop residue and manure into the surface layer are practices that will help maintain the organic matter content and reduce erosion.

This soil is poorly suited to trees. The droughtiness and low nutrient content cause a high seedling mortality rate. Mulching, mixing crop residue into the soil, and fertilizing are means of reducing the mortality rate.

Slope is the main limitation of this soil as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, some form of shoring is needed when steep cuts are made. Placing roads and streets on the contour helps to avoid deep cuts, on which vegetation is difficult to establish. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IVs.

QnD—Quonset loamy sand, 15 to 25 percent slopes. This soil is very deep, moderately steep, and excessively drained. It is on terraces, eskers, and outwash plains. The areas of this unit are irregular in shape. They range from 10 to 70 acres, but most are about 15 acres.

Typically, the surface layer is very dark brown loamy sand about 3 inches thick. The subsoil is dark yellowish brown and is 15 inches thick. The upper 3 inches is channery loamy sand, and the lower 12 inches is very channery loamy sand. The substratum is olive brown and light olive brown very channery coarse sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley and Windsor soils. Included areas make up about 15 percent of this unit.

The permeability of this Quonset soil is moderately rapid or rapid in the subsoil and very rapid in the substratum. Available water capacity is very low. Reaction is very strongly acid or strongly acid in the surface layer and subsoil and ranges from strongly acid to slightly acid in the substratum.

Most areas of this soil are in brushland. Some areas are being mined for sand and gravel.

Slope, droughtiness, and a low nutrient content make this soil poorly suited to cultivated crops, hay, and improved pasture. The rapid permeability causes some of the nutrients from fertilizer application to readily pass through the soil. Conservation tillage, stripcropping, using cover crops, and mixing crop residue and manure into the surface layer will help maintain the organic matter content of the soil and help reduce erosion.

This soil is poorly suited to trees. The droughtiness and low nutrient content cause a high seedling mortality rate. Mulching, mixing crop residue into the soil, and fertilizing are means of reducing the mortality rate.

Slope is the main limitation of this soil as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse. Thus, some form of shoring is

needed when steep cuts are made. Placing roads and streets on the contour helps to avoid deep cuts, on which vegetation is difficult to establish. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIs.

Ra—Raynham silt loam. This soil is very deep, nearly level, and poorly drained. It is on old lake plains. The areas of this soil are irregular in shape. They range from 5 to 30 acres, but most are about 5 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is very dark brown silt loam about 3 inches thick. The subsoil is silt loam about 21 inches thick. The upper 9 inches is light olive brown, and the lower 12 inches is a light olive gray. The substrautm is olive silt loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Amostown and Belgrade soils. Also included are soils with slopes of 3 to 8 percent. Included areas make up about 20 percent of this unit.

The permeability of this Raynham soil is moderate or moderately slow in the subsoil and slow in the substratum. Available water capacity is high. Reaction is strongly acid to slightly acid in the surface layer and subsoil and moderately acid to neutral in the substratum. The seasonal high water table is at a depth of 6 inches to 2 feet during the winter and early spring.

This soil is suited to cultivated crops, hay, and improved pasture, but some form of drainage is necessary. Mixing crop residue and manure into the plow layer improves the tilth and increases the organic matter content of the soils.

This soil is poorly suited to trees. Some areas are wooded. The seasonal high water table limits the use of equipment and causes a high seedling mortality rate. The water table also restricts rooting, and many trees are subject to uprooting during windy periods.

The seasonal high water table is the major limitation of the soil as a site for dwellings, local roads and streets, and septic tank absorption fields. A frost-action potential is a further limitation.

Capability subclass: IIIw.

RdA—Ridgebury fine sandy loam, 0 to 3 percent slopes. This soil is very deep, nearly level, and poorly drained. It is in low-lying areas and depressions. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 15 acres, but most are about 5 acres.

Typically, the surface layer is black fine sandy loam about 9 inches thick. The subsoil is about 14 inches thick. The upper 5 inches is dark grayish brown fine sandy loam, and the lower 9 inches is olive gray gravelly fine sandy loam. The substratum is olive and olive gray fine sandy loam to a depth of 60 inches or more. It is very firm in the upper part and firm in the lower part.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Whitman and Woodbridge soils. Also included are areas of poorly drained soils that are friable to a depth of more than 30 inches. Included areas make up about 15 percent of this unit.

The permeability of this Ridgebury soil is moderate or moderately rapid in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout the soil. The seasonal high water table is between the surface and a depth of 1 1/2 feet during the winter and early spring.

Most areas of this soil are in woodland. Some areas are used for pasture.

This soil is suited to cultivated crops, hay, and improved pasture. The seasonal high water table is the main limitation. Installing drainage and the proper timing of farming operations are the main management concerns.

This soil is poorly suited to trees. The seasonal high water table limits the use of equipment and causes a high rate of seedling mortality. It also limits rooting, and some trees are subject to uprooting during windy periods.

The seasonal high water table and a frost-action potential limit this soil as a site for dwellings and local roads and streets. Some form of drainage is necessary to overcome the wetness. The water table and the slow or very slow permeability in the substratum are limitations of the soil as a site for septic tank absorption fields.

Capability subclass: IIIw.

RdB—Ridgebury fine sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and poorly drained. It is in low-lying areas and depressions. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 30 acres, but most are about 10 acres.

Typically, the surface layer is black fine sandy loam about 9 inches thick. The subsoil is about 14 inches thick. The upper 5 inches is dark grayish brown fine sandy loam, and the lower 9 inches is olive gray gravelly fine sandy loam. The substratum is olive and olive gray fine sandy loam to a depth of 60 inches or more. It is very firm in the upper part and firm in the lower part.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Whitman and Woodbridge soils. Also included are areas of poorly drained soils that are friable to a depth of more than 30 inches. Included areas make up about 20 percent of this unit.

The permeability of this Ridgebury soil is moderate or moderately rapid in the subsoil and slow or very slow in

the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout the soil. The seasonal high water table is between the surface and a depth of 1 1/2 feet during the winter and early spring.

Most areas of this soil are in woodland. Some areas are used for pasture.

This soil is suited to cultivated crops, hay, and improved pasture. The seasonal high water table is the main limitation. Installing drainage and the proper timing of farming operations are the main management concerns.

This soil is poorly suited to trees. The seasonal high water table limits the use of equipment and causes a high rate of seedling mortality. It also limits rooting, and some trees are subject to uprooting during windy periods.

The seasonal high water table and a frost-action potential limit this soil as a site for dwellings and local roads and streets. Some form of drainage is necessary to overcome the wetness. The water table and the slow or very slow permeability in the substratum are limitations of the soil as a site for septic tank absorption fields.

Capability subclass: IIIw.

RsA—Ridgebury fine sandy loam, 0 to 3 percent slopes, extremely stony. This soil is very deep, nearly level, and poorly drained. It is in low-lying areas and depressions. Stones that are 2 to 5 feet apart cover 3 to 15 percent of the surface. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 25 acres, but most are about 5 acres.

Typically, the surface layer is black fine sandy loam about 9 inches thick. The subsoil is about 14 inches thick. The upper 5 inches is dark grayish brown fine sandy loam, and the lower 9 inches is olive gray gravelly fine sandy loam. The substratum is olive and olive gray fine sandy loam to a depth of 60 inches or more. It is very firm in the upper part and firm in the lower part.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Whitman and Woodbridge soils. Also included are areas where stones cover less than 3 percent of the surface and poorly drained soils that are friable to a depth of more than 30 inches. Included areas make up about 25 percent of this unit.

The permeability of this Ridgebury soil is moderate or moderately rapid in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout the soil. The seasonal high water table is between the surface and a depth of 1 1/2 feet during the winter and early spring.

This soil is poorly suited to cultivated crops, hay, and improved pasture. The stones on the surface and the seasonal high water table are the main limitations. Installing drainage, proper timing of farming operations, and clearing of stones are the main management concerns.

This soil is poorly suited to trees. Most areas are wooded. The seasonal high water table limits the use of equipment and causes a high rate of seedling mortality. It also limits rooting, and some trees are subject to uprooting during windy periods.

The seasonal high water table and a frost-action potential limit this soil as a site for dwellings and local roads and streets. Some form of drainage is necessary to overcome the wetness. The water table and the slow or very slow permeability in the substratum are limitations of the soil as site for septic tank absorption fields.

Capability subclass: VIIs.

RsB—Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony. This soil is very deep, gently sloping, and poorly drained. It is in low-lying areas and depressions. Stones that are 2 to 5 feet apart cover 3 to 15 percent of the surface. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 50 acres, but most are about 10 acres.

Typically, the surface layer is black fine sandy loam about 9 inches thick. The subsoil is about 14 inches thick. The upper 5 inches is dark grayish brown fine sandy loam, and the lower 9 inches is olive gray gravelly fine sandy loam. The substratum is olive and olive gray fine sandy loam to a depth of 60 inches or more. It is very firm in the upper part and firm in the lower part.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Whitman and Woodbridge soils. Also included are areas where stones cover less than 3 percent of the surface and poorly drained soils that are friable to a depth of more than 30 inches. Included areas make up about 25 percent of this unit.

The permeability of this Ridgebury soil is moderate or moderately rapid in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout the soil. The seasonal high water table is between the surface and a depth of 1 1/2 feet during the winter and early spring.

This soil is poorly suited to cultivated crops, hay, and improved pasture. The stones on the surface and the seasonal high water table are the main limitations. Installing drainage, proper timing of farming operations, and clearing of stones are the main management concerns.

This soil is poorly suited to trees. Most areas are wooded. The seasonal high water table limits the use of equipment and causes a high rate of seedling mortality. It also limits rooting, and some trees are subject to uprooting during windy periods.

The seasonal high water table and a frost-action potential limit this soil as a site for dwellings and local roads and streets. Some form of drainage is necessary to overcome the wetness. The water table and the slow or very slow permeability in the substratum are limitations of the soil as a site for septic tank absorption fields.

Capability subclass: VIIs.

Sa—Saco silt loam. This soil is very deep, nearly level, and very poorly drained. It is on flood plains. The areas of this soil are irregular in shape. They range from 5 to 30 acres, but most are about 5 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is very dark gray silt loam about 12 inches thick. The substratum extends to a depth of 60 inches or more. The upper part is very dark gray and gray very fine sandy loam, and the lower part is gray and dark gray silt loam.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Limerick and Swansea soils. Also included are soils that have more sand in the substratum than this Saco soil. Included areas make up about 15 percent of the unit.

The permeability in the substratum of this Saco soil is moderate in the upper part and rapid or very rapid in the lower part. Available water capacity is high. Reaction ranges from strongly acid to slightly acid in the upper 30 inches of the soil and from moderately acid to neutral below a depth of 30 inches. The seasonal high water table is between the surface and a depth of 6 inches during winter and early spring.

Frequently, brief flooding and the seasonal high water table make this soil poorly suited to farming and woodland and are the major limitations for community development. Most areas of the soil are in native vegetation.

Capability subclass: VIw.

Sc—Scarboro mucky fine sandy loam. This soil is very deep, nearly level, and very poorly drained. It is in low-lying areas and depressions on outwash plains. The areas of this soil are irregular in shape. They range from 5 to 50 acres, but most are about 10 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is covered with about 8 inches of organic material. The surface layer is black mucky fine sandy loam about 6 inches thick. The substratum is grayish brown and extends to a depth of 60 inches or more. The upper part is loamy sand, the middle part is sand, and the lower part is gravelly sand.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Swansea and Walpole soils. Also included are poorly drained, sandy soils. Included areas make up about 20 percent of this unit.

The permeability of this Scarboro soil is rapid or very rapid throughout. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid. The water table is between the surface and a depth of 1 foot during most of the year.

Most areas of this soil are covered with brush and trees.

The high water table makes this soil poorly suited to farming and woodland and is the main limitation for community development. The water table restricts the root zone of trees, limits the use of equipment, and causes a high rate of seedling mortality.

Capability subclass: Vw.

SdA—Sudbury fine sandy loam, 0 to 3 percent slopes. This soil is very deep, nearly level, and moderately well drained. It is in slight depressions on outwash plains. The areas of this soil are irregular in shape. They range from 10 to 30 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 9 inches thick. The subsoil is yellowish brown and is about 16 inches thick. The upper 9 inches is fine sandy loam, and the lower 7 inches is gravelly loamy sand. The substratum is light olive brown gravelly sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Agawam, Merrimac, Ninigret, and Walpole soils. Included areas make up about 20 percent of the unit.

The permeability of this Sudbury soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is high. Reaction ranges from extremely acid to moderately acid throughout. The seasonal high water table is at a depth of 1 1/2 to 3 feet.

Most areas of this soil are used for cropland. Some are used for residential or commercial development.

This soil is well suited to woodland, cultivated crops, hay, and improved pasture. The main farming management concerns are providing drainage where needed and maintaining the organic matter content. Using proper stocking rates and rotational grazing are pasture management practices that help to maintain desirable plant species.

The seasonal high water table is a limitation of this soil as a site for dwellings or local roads and streets, and drainage is needed. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse, making some form of shoring necessary. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIw.

SdB—Sudbury fine sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and moderately well drained. It is in slight depressions on outwash plains. The areas of this soil are irregular in

shape. They range from 10 to 50 acres, but most are about 15 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 9 inches thick. The subsoil is yellowish brown and is about 16 inches thick. The upper 9 inches is fine sandy loam, and the lower 7 inches is gravelly loamy sand. The substratum is light olive brown gravelly sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Agawam, Merrimac, Ninigret, and Walpole soils. Included areas make up about 20 percent of the unit.

The permeability of this Sudbury soil is moderately rapid in the subsoil and rapid in the substratum. Available water capacity is high. Reaction ranges from extremely acid to moderately acid throughout. The seasonal high water table is at a depth of 1 1/2 to 3 feet.

Most areas of this soil are used for cropland. Some are used for residential or commercial development.

This soil is well suited to woodland, cultivated crops, hay, and improved pasture. The seasonal high water table is a limitation for farming, and erosion is a hazard. Providing drainage where needed and maintaining the organic matter content are the main farming management concerns. Farming on the contour and using tillage methods that leave large amounts of crop residue on the surface help to control erosion in cultivated areas. Use of proper stocking rates and rotational grazing are pasture management practices that help to maintain desirable plant species.

The seasonal high water table is a limitation of this soil as a site for dwellings or local roads and streets, and drainage is needed. The sides of excavations in this soil are unstable, and the steeper sides commonly collapse, making some form of shoring necessary. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIe.

Su—Suncook loamy fine sand. This soil is very deep, nearly level, and excessively drained. It is on flood plains bordering the stream channel. The areas of this soil are circular, long and narrow, or irregular in shape. They range from 5 to 60 acres, but most are about 10 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is dark brown loamy fine sand about 9 inches thick. The substratum is dark yellowish brown and yellowish brown sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres in size, of Hadley soils. Also included are soils with slopes of more than 3 percent. Included areas make up about 15 percent of this unit.

The permeability of this Suncook soil is rapid or very rapid in the substratum. Available water capacity is low. Reaction is very strongly acid to slightly acid throughout the soil.

Most areas of this soil are idle. A few areas are used for cropland.

This soil is suited to woodland, cultivated crops, hay, and improved pasture. Occasional, brief flooding and the low available water capacity are the main limitations. Mixing crop residue and manure into the surface layer helps to improve tilth and increase organic matter content in cultivated areas.

Flooding is the major limitation to use of this soil as a site for dwellings and local roads and streets. This soil is unstable, and sides of excavations commonly collapse. Thus, some form of shoring is needed where steep cuts are made. The rapid permeability in the substratum causes a hazard of ground-water contamination in areas that are used for waste disposal.

Capability subclass: IIIs.

Sw—Swansea muck. This soil is very deep, nearly level, and very poorly drained. It is in bogs and depressions on outwash plains and glacial till uplands. The areas of this soil are round or irregular in shape. They range from 5 to 80 acres, but most are about 10 acres. Slopes range from 0 to 3 percent.

Typically, the upper layers are black organic material to a depth of about 36 inches. The substratum is olive gray sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Freetown, Saco, Scarboro, and Whitman soils. Also included are soils that have a loamy substratum. Included areas make up about 20 percent of this unit.

The permeability of this Swansea soil is moderate or moderately rapid in the organic material and very rapid in the substratum. Available water capacity is high. Reaction is extremely acid throughout the soil. The water table is between the surface and a depth of 1 foot for most of the year.

Most areas of this soil support a growth of water-tolerant species of brush and grass. A few areas are covered with trees.

The water table makes this soil poorly suited to woodland, cultivated crops, hay, and improved pasture. The water table causes a high rate of seedling mortality, limits the use of equipment, and restricts rooting, making trees susceptible to uprooting during windy periods.

The high water table, the content of organic matter in the soil, and low strength are the main limitations of the soil as a site for dwellings, local roads and streets, and waste-disposal facilities. The permeability of the soil causes a hazard of ground-water contamination in areas used for waste disposal.

Capability subclass: Vw.

Ud—Udorthents, smoothed. The soils in this unit are very deep, nearly level to steep, and excessively drained

to moderately well drained. The soil material has been excavated or has been deposited from nearby areas. The areas of this unit are long and narrow or irregular in shape. They range from 3 to 30 acres. The depth of excavation or fill material ranges from 2 to 20 feet. Commonly, the soil is olive gray fine sandy loam at least 60 inches thick.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of urban land and areas that are sandier than Udorthents. Also included are areas that have been filled with trash and an area of coal dust and slag adjacent to Route 146 in the southeastern part of Worcester. Included areas make up about 20 percent of this unit.

The range in the properties and characteristics of this unit is so wide that onsite investigation is needed to determine the suitability of the unit for any use.

Capability subclass: not assigned.

Ur—Urban land. This unit consists mainly of buildings, shopping centers, roads, and parking lots. Most areas are in the built-up parts of cities and some of the densely populated suburbs. The vegetation commonly is limited to lawns and ornamental trees and shrubs. Determination of the suitability of these areas for any use requires onsite investigation.

Capability subclass: not assigned.

Wa—Walpole fine sandy loam. This soil is very deep, nearly level, and poorly drained. It is in low-lying areas and depressions on outwash plains. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 60 acres, but most are about 10 acres. Slopes range from 0 to 3 percent.

Typically, the surface is covered with 2 inches of organic matter. The surface layer is very dark grayish brown fine sandy loam about 6 inches thick. The subsoil is dark grayish brown and olive sandy loam about 16 inches thick. The substratum is light olive brown gravelly loamy sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Scarboro and Sudbury soils that make up about 20 percent of the unit.

The permeability of this Walpole soil is moderately rapid in the subsoil and rapid or very rapid in the substratum. Available water capacity is high. Reaction ranges from very strongly acid to moderately acid throughout the soil. The seasonal high water table is between the surface and a depth of 1 foot.

Most areas of this soil are covered with trees. A few areas have been drained and are used for cropland.

This soil is suited to cultivated crops, hay, and improved pasture. The seasonal high water table is the main limitation. It restricts the root zone of some plants and limits the use of equipment, and some form of drainage is needed to overcome its effects.

The seasonal high water table makes the soil poorly suited to trees. It limits the use of equipment and causes a high rate of seedling mortality. The seasonal high water table also limits the root zone of trees, causing a hazard of uprooting during windy periods.

The water table and a frost-action potential are the main limitations of this soil as a site for dwellings and local roads and streets. The water table also limits the soil as a site for waste disposal, and the rapid permeability in the substratum causes a hazard of ground-water contamination in areas used for waste disposal.

Capability subclass: IIIw.

Wg—Whitman loam. This soil is very deep, nearly level, and very poorly drained. It is in low-lying areas on uplands. The areas of this unit are long and narrow or irregular in shape. They range from 5 to 20 acres, but most are about 5 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is black loam about 10 inches thick. The subsoil is gray fine sandy loam about 8 inches thick. The substratum is light gray and olive, firm fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Ridgebury and Swansea soils. Also included are areas of Whitman soils with slopes of 3 to 8 percent. Included areas make up about 30 percent of the unit.

The permeability of this Whitman soil is moderate or moderately rapid in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to slightly acid. The seasonal high water table is between the surface and a depth of 6 inches.

The seasonal high water table makes this soil poorly suited to woodland, cultivated crops, hay, and improved pasture. Most areas are wooded, but the water table limits the use of equipment and causes a high rate of seedling mortality.

The seasonal high water table and a frost-action potential limit this soil as a site for dwellings and local roads and streets. The water table and the slow or very slow permeability in the substratum limit the soil as a site for septic tank absorption fields.

Capability subclass: Vw.

Wh—Whitman loam, extremely stony. This soil is very deep, nearly level, and very poorly drained. It is in low-lying areas on uplands. Stones that are 2 to 5 feet apart cover 3 to 15 percent of the surface. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 20 acres, but most are about 5 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is black loam about 10 inches thick. The subsoil is gray fine sandy loam about 8

inces thick. The substratum is light gray and olive, firm fine sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Ridgebury and Swansea soils. Also included are areas of Whitman soils with slopes of 3 to 8 percent and Whitman soils where stones cover less than 3 percent of the surface. Included areas make up about 30 percent of the unit.

The permeability of this Whitman soil is moderate or moderately rapid in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to slightly acid. The seasonal high water table is between the surface and a depth of 6 inches.

This soil is poorly suited to woodland, cultivated crops, hay, and improved pasture. The stones on the surface and the water table are the main limitations for farming, and the water table limits the use of woodland equipment and causes a high rate of seedling mortality.

The water table and a frost-action potential limit this soil as a site for dwellings and local roads and streets. The seasonal high water table and the slow or very slow permeability in the substratum limit the soil as a site for septic tank absorption fields.

Capability subclass: VIIs.

WnA—Windsor loamy fine sand, 0 to 3 percent slopes. This soil is very deep, nearly level, and excessively drained. The areas of this soil are irregular in shape. They range from 10 to 100 acres, but most are about 20 acres.

Typically, the surface layer is dark yellowish brown loamy fine sand about 10 inches thick. The subsoil is about 20 inches thick. The upper 6 inches is brown loamy fine sand, and the lower 14 inches is light yellowish brown fine sand. The substratum is olive and light olive gray fine sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Agawam, Deerfield, and Hinckley soils. Included areas make up about 20 percent of the unit.

The permeability of this Windsor soil is rapid or very rapid throughout. Available water capacity is low. Reaction ranges from moderately acid to very strongly acid throughout the soil.

Most areas of this soil are in brushland or poor-quality woodland. Some areas are used for residential and commercial development, and a few areas are used for cropland.

This soil is suited to cultivated crops, hay, and improved pasture. Droughtiness is the main limitation. The main management concerns are providing irrigation and fertilizer and increasing organic matter content by mixing crop residue and manure into the surface layer.

This soil is poorly suited to trees. Droughtiness causes a high rate of seedling mortality for all but drought-tolerant species.

This soil has essentially no limitations as a site for dwellings and local streets and roads. The sides of excavations in this soil are unstable, however, and steep sides commonly collapse. Thus, some form of shoring is needed in steep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIs.

WnB—Windsor loamy fine sand, 3 to 8 percent slopes. This soil is very deep, gently sloping, and excessively drained. It is on broad areas and rolling hills. The areas of this soil are irregular in shape. They range from 20 to 150 acres, but most are about 30 acres.

Typically, the surface layer is dark yellowish brown loamy fine sand about 10 inches thick. The subsoil is about 20 inches thick. The upper 6 inches is brown loamy fine sand, and the lower 14 inches is light yellowish brown fine sand. The substratum is olive and light olive gray fine sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Agawam, Deerfield, and Hinckley soils. Included areas make up about 20 percent of the unit.

The permeability of this Windsor soil is rapid or very rapid throughout. Available water capacity is low. Reaction ranges from moderately acid to very strongly acid throughout the soil.

Most areas of this soil are in brushland or poor-quality woodland. Some areas are used for residential and commercial development, and a few areas are used for cropland.

This soil is suited to cultivated crops, hay, and improved pasture. Droughtiness is the main limitation, and erosion is a hazard. Conservation tillage and increasing organic matter content by mixing crop residue and manure into the surface layer are practices that help to reduce the erosion hazard.

This soil is poorly suited to trees. Droughtiness causes a high rate of seedling mortality for all but drought-tolerant species.

This soil has essentially no limitations as a site for dwellings and local streets and roads. The sides of excavations in this soil are unstable, however, and steep sides commonly collapse. Thus, some form of shoring is needed in steep cuts. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IIIs.

WnC—Windsor loamy fine sand, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and excessively drained. It is on sides of eskers and areas bordering sand plains. The areas of this soil are irregular in shape. They range from 10 to 100 acres, but most are about 20 acres.

Typically, the surface layer is dark yellowish brown loamy fine sand about 6 inches thick. The subsoil is about 20 inches thick. The upper 6 inches is brown loamy fine sand, and the lower 14 inches is light yellowish brown fine sand. The substratum is olive and light olive gray fine sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Agawam, Hinckley, and Merrimac soils. Included areas make up about 20 percent of the unit.

The permeability of this Windsor soil is rapid or very rapid throughout. Available water capacity is low. Reaction ranges from moderately acid to very strongly acid throughout the soil.

Most areas of this soil are in brushland or poor-quality woodland. Some areas are used for residential and commercial development, and a few areas are used for cropland.

This soil is suited to cultivated crops, hay, and improved pasture. Droughtiness is the main limitation. The main management concerns are providing irrigation and fertilizer and increasing organic matter content by mixing crop residue and manure into the surface layer.

This soil is poorly suited to trees. Droughtiness causes a high rate of seedling mortality for all but drought-tolerant species.

Slope is the main limitation to use of this soil as a site for dwellings and local roads and streets. The sides of excavations in this soil are unstable, and the steep sides commonly collapse. Excavating and grading and using retention walls are practices used to overcome the slope. Roads and streets should be built on the contour instead of making steep cuts, on which vegetation is difficult to establish. Some form of shoring is needed where steep cuts are made. This soil is a poor filter for effluent in a septic tank absorption field, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: IVs.

WnD—Windsor loamy fine sand, 15 to 25 percent slopes. This soil is very deep, moderately steep, and excessively drained. It is on ridges on outwash plains. The areas of this soil are long and narrow or irregular in shape. They range from 5 to 30 acres, but most are about 5 acres.

Typically, the surface layer is dark yellowish brown loamy fine sand about 4 inches thick. The subsoil is about 20 inches thick. The upper 6 inches is brown loamy fine sand, and the lower 14 inches is light yellowish brown fine sand. The substratum is olive and light olive gray fine sand to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hinckley soils that make up about 15 percent of the unit.

The permeability of this Windsor soil is rapid or very rapid throughout. Available water capacity is low. Reaction ranges from moderately acid to very strongly acid throughout the soil.

Most areas of this soil are in brushland or poor-quality woodland.

This soil is poorly suited to cultivated crops, hay, and improved pasture. Slope and droughtiness are the major limitations, and erosion is a hazard. The main management concerns are providing irrigation and increasing organic matter content by mixing crop residue and manure into the surface layer. Stripcropping and conservation tillage help to control erosion.

This soil is poorly suited to trees. Droughtiness causes a high rate of seedling mortality for all but drought-tolerant species.

Slope is the main limitation of this soil as a site for dwellings or local roads and streets. The sides of excavations in this soil are unstable, and the steep sides commonly collapse. Excavating and grading and using retention walls are practices used to overcome the slope. Placing roads and streets on the contour helps to avoid steep cuts, on which vegetation is difficult to establish, and some form of shoring is needed where steep cuts are made. This soil is a poor filter for septic tank absorption fields, and seepage of the effluent through the substratum causes a hazard of ground-water contamination.

Capability subclass: VIs.

Wo—Winooski very fine sandy loam. This soil is very deep, nearly level, and moderately well drained. It is on flood plains. The areas of this soil are irregular in shape. They range from 5 to 100 acres, but most are about 15 acres. Slopes range from 0 to 3 percent.

Typically, the surface layer is very dark grayish brown very fine sandy loam about 8 inches thick. The substratum is multicolored and extends to a depth of 60 inches or more. It is very fine sandy loam in the upper part and loamy very fine sand in the lower part.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Hadley and Limerick soils. Also included are soils with a sandy surface layer and subsoil. Included areas make up about 20 percent of this unit.

The permeability of this Winooski soil is moderate to moderately rapid throughout. Available water capacity is moderate. Reaction ranges from very strongly acid to neutral above a depth of 35 inches and from moderately acid to neutral below a depth of 35 inches. The seasonal

high water table is at a depth of 1 1/2 to 3 feet during winter and early spring.

Most areas of this soil are idle. Some areas are used for cropland.

This soil is well suited to woodland, cultivated crops, hay, and improved pasture. The main limitation is occasional, brief flooding.

Flooding is the major limitation of the soil as a site for dwellings or local roads and streets. The soil is a poor filter for septic tank absorption fields.

Capability subclass: IIw.

WrA—Woodbridge fine sandy loam, 0 to 3 percent slopes. This soil is very deep, nearly level, and moderately well drained. It is on the tops of drumlins and in areas on glacial till uplands (fig. 7). The areas of this soil are irregular in shape or long and narrow. They range from 3 to 20 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 9 inches thick. The subsoil is dark yellowish brown and light olive brown sandy loam about 13 inches thick. The substratum is very firm, grayish brown sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Paxton and Ridgebury soils. Also included are areas of soils that are friable to a depth of 30 inches or more. Included areas make up about 15 percent of this unit.

The permeability of this Woodbridge soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout the soil. The seasonal high water table is at a depth of 1 1/2 to 3 feet.

Most areas of this soil are used for cropland. Some are used for residential development, and a few are covered with trees.

This soil is well suited to woodland, cultivated crops, hay, and improved pasture. This soil is wet until late spring, which restricts the use of heavy equipment and makes drainage a farming management concern.

The seasonal high water table and frost-action potential are the main limitations of the soil as a site for dwellings and local roads and streets. Using drainage will help overcome those limitations. This soil is a poor filter for septic tank absorption fields and most other sanitary facilities because of the slow or very slow permeability in the substratum.

Capability subclass: IIw.

WrB—Woodbridge fine sandy loam, 3 to 8 percent slopes. This soil is very deep, gently sloping, and moderately well drained. It is on the tops of drumlins on glacial till uplands. The areas of this soil are irregularly shaped or rectangular. They range from 5 to 30 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 9 inches thick. The subsoil is dark yellowish brown and light olive brown sandy loam about 13 inches thick. The substratum is very firm, grayish brown sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Paxton and Ridgebury soils. Also included are areas of soils that are friable to a depth of 30 inches or more. Included areas make up about 15 percent of this unit.

The permeability of this Woodbridge soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout. The seasonal high water table is at a depth of 1 1/2 to 3 feet.

Most areas of this soil are used for cropland. Some areas are used for residential development, and a few are wooded.

This soil is well suited to woodland, cultivated crops, hay, and improved pasture. Erosion is a hazard in cultivated areas. This soil is wet until late spring, which restricts the use of heavy equipment and makes drainage a farming management concern.

The seasonal high water table and frost-action potential are the main limitations of the soil as a site for dwellings and local roads and streets. Using drainage will help overcome those limitations. This soil is a poor filter for septic tank absorption fields and most other sanitary facilities because of the slow or very slow permeability in the substratum.

Capability subclass: IIw.

WrC—Woodbridge fine sandy loam, 8 to 15 percent slopes. This soil is very deep, strongly sloping, and moderately well drained. It is on the side slopes of drumlins on glacial till uplands. The areas of this soil are irregularly shaped or rectangular. They range from 5 to 25 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 9 inches thick. The subsoil is dark yellowish brown and light olive brown sandy loam about 13 inches thick. The substratum is very firm, grayish brown sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Paxton soils. Also included are areas of soils that are friable to a depth of 30 inches or more. Included areas make up about 15 percent of this unit.

The permeability of this Woodbridge soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout. The seasonal high water table is at a depth of 1 1/2 to 3 feet.



Figure 7.—An area of Woodbridge fine sandy loam, 0 to 3 percent slopes.

Most areas of this soil are used for cropland. Some are used for community development, and a few areas are wooded.

This soil is suited to cultivated crops, hay, and improved pasture and is well suited to woodland. The seasonal high water table and slope are the main limitations for farming, and erosion is a hazard. Installing drainage is a management concern. Stripcropping, conservation tillage, and contour farming are practices that help reduce erosion in cultivated areas.

The seasonal high water table and frost-action potential are the main limitations of the soil as a site for dwellings and local roads and streets. Using drainage will help overcome those limitations. This soil is a poor filter for septic tank absorption fields and most other sanitary facilities because of the slow or very slow permeability in the substratum.

Capability subclass IIIe.

WsB—Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony. This soil is very deep, nearly level to gently sloping, and moderately well drained. It is on the top of drumlins and on toe slopes of glacial till uplands. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this soil are irregularly shaped or rectangular. They range from 5 to 80 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 5 inches thick. The subsoil is dark yellowish brown and light olive brown sandy loam about 13 inches thick. The substratum is very firm, grayish brown sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Paxton and Ridgebury soils. Also included are areas of very stony Woodbridge soils and soils that are friable to a depth of 30 inches or more. Included areas make up about 15 percent of this unit.

The permeability of this Woodbridge soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges

from very strongly acid to moderately acid throughout. The seasonal high water table is at a depth of 1 1/2 to 3 feet.

Most areas of this soil are covered with trees, and the soil is well suited to woodland. Some areas are used for pasture, and a few are used for residential development.

The stones on the surface and the seasonal high water table make this soil poorly suited to cultivated crops, hay, and improved pasture. The soil is well suited to these uses if the stones are removed. Providing drainage is a management concern in some areas, and erosion is a hazard.

The seasonal high water table and frost-action potential are the main limitations of the soil as a site for dwellings and local roads and streets. Using drainage will help overcome those limitations. This soil is a poor filter for septic tank absorption fields and most other sanitary facilities because of the slow permeability in the substratum.

Capability subclass: VIs.

WsC—Woodbridge fine sandy loam, 8 to 15 percent slopes, very stony. This soil is very deep, strongly sloping, and moderately well drained. It is on the sides of drumlins on glacial till uplands. Stones that are 5 to 30 feet apart cover from less than 1 percent to 3 percent of the surface. The areas of this soil are irregularly shaped. They range from 5 to 50 acres, but most are about 10 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is dark yellowish brown and light olive brown sandy loam about 13 inches thick. The substratum is very firm, grayish brown sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Paxton soils. Also included are areas of soils that are friable to a depth of 30 inches or more. Included areas make up about 15 percent of this unit.

The permeability of this Woodbridge soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout. The seasonal high water table is at a depth of 1 1/2 to 3 feet.

Most areas of this soil are covered with trees, and the soil is well suited to trees.

Slope, the seasonal high water table, and the stones on the surface make this soil poorly suited to cultivated crops, hay, and improved pasture. Providing drainage in some areas is a management concern, and erosion is a hazard. Conservation tillage, using cover crops, contour farming, and stripcropping are practices that help to reduce erosion in cultivated areas.

Slope, the seasonal high water table, and a frost-action potential are the main limitations of this soil as a site for dwellings or local roads and streets. The soil is a poor filter for septic tank absorption fields because of the slow or very slow permeability in the substratum.

Capability subclass: VIs.

WtB—Woodbridge fine sandy loam, 0 to 8 percent slopes, extremely stony. This soil is very deep, nearly level and gently sloping, and moderately well drained. It is on the tops of drumlins and on toe slopes on glacial till uplands. Stones that are 2 to 5 feet apart cover from 3 to 15 percent of the surface. The areas of this soil are irregular in shape. They range from 10 to 80 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is dark yellowish brown and light olive brown sandy loam about 13 inches thick. The substratum is very firm, grayish brown sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Paxton and Ridgebury soils. Also included are areas of Woodbridge soils where stones cover less than 3 percent of the surface and soils that are friable to a depth of 30 inches or more. Included soils make up about 15 percent of this unit.

The permeability of this Woodbridge soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout. The seasonal high water table is at a depth of 1 1/2 to 3 feet.

The stones on the surface and the seasonal high water table make this soil poorly suited to cultivated crops, hay, and improved pasture. The soil is well suited to these uses if the stones are removed. Providing drainage is a management concern in some areas, and erosion is a hazard.

This soil is well suited to trees, and most areas are wooded. The stones on the surface restrict the use of some types of equipment.

The seasonal high water table and frost-action potential are the main limitations of the soil as a site for dwellings and local roads and streets. Using drainage will help to overcome those limitations. This soil is a poor filter for septic tank absorption fields and most other sanitary facilities because of the slow or very slow permeability in the substratum.

Capability subclass: VIIs.

WtC—Woodbridge fine sandy loam, 8 to 15 percent slopes, extremely stony. This soil is very deep, strongly sloping, and moderately well drained. It is on sides of drumlins on glacial till uplands. Stones that are 2 to 5 feet apart cover from 3 to 15 percent of the surface. The areas of this soil are irregular in shape. They range from 10 to 100 acres, but most are about 20 acres.

Typically, the surface layer is very dark grayish brown fine sandy loam about 4 inches thick. The subsoil is dark

yellowish brown and light olive brown sandy loam about 13 inches thick. The substratum is very firm, grayish brown sandy loam to a depth of 60 inches or more.

Included with this soil in mapping are small areas, mainly less than 3 acres each, of Paxton soils. Also included are areas where stones cover less than 3 percent of the surface and soils that are friable to a depth of 30 inches or more. Included areas make up about 15 percent of this unit.

The permeability of this Woodbridge soil is moderate in the subsoil and slow or very slow in the substratum. Available water capacity is moderate. Reaction ranges from very strongly acid to moderately acid throughout the soil. The seasonal high water table is at a depth of 1 1/2 to 3 feet.

Slope, the seasonal high water table, and the stones on the surface make this soil poorly suited to cultivated crops, hay, and improved pasture. Providing drainage in some areas is a management concern, and erosion is a hazard. Conservation tillage, using cover crops, contour farming, and stripcropping are practices that help to reduce erosion in cultivated areas.

This soil is well suited to trees, and most areas are wooded. The stones on the surface limit the use of some types of equipment.

Slope, the seasonal high water table, and a frost-action potential are the main limitations of this soil as a site for dwellings or local roads and streets. The soil is a poor filter for septic tank absorption fields because of the slow or very slow permeability in the substratum.

Capability subclass: VIIs.