Final Report

WATER MODELING AND HYDRAULIC EVALUATION

MIDDLEBURY, VERMONT

December 28, 2018

Submitted to:
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Infrastructure Committee
Town of Middlebury
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SECTION 1
EXISTING CONDITIONS
WATER MODELING AND HYDRAULIC EVALUATION REPORT
MIDDLEBURY, VERMONT

General System Description

The Middlebury Water Department Water System (WSID 5004) is supplied by three wells located about 3 miles east of the Town center, off Case Street. Water storage is provided by Chipman Reservoir, a two-cell 1.5 million gallon (mg) tank on Chipman Hill. The system operates as a single pressure zone. The location of the water system components, including the wells, the storage tank and water mains is shown in Figure 1. A full size scale basemap is included in the Appendices.

The system serves a year-round population of approximately 5,800 with 2,200 service connections, as reported in the 2017 Sanitary Survey. Water customers are a mixture of residential, commercial and industrial types. The system's largest user is Middlebury College, served through four interconnection points.

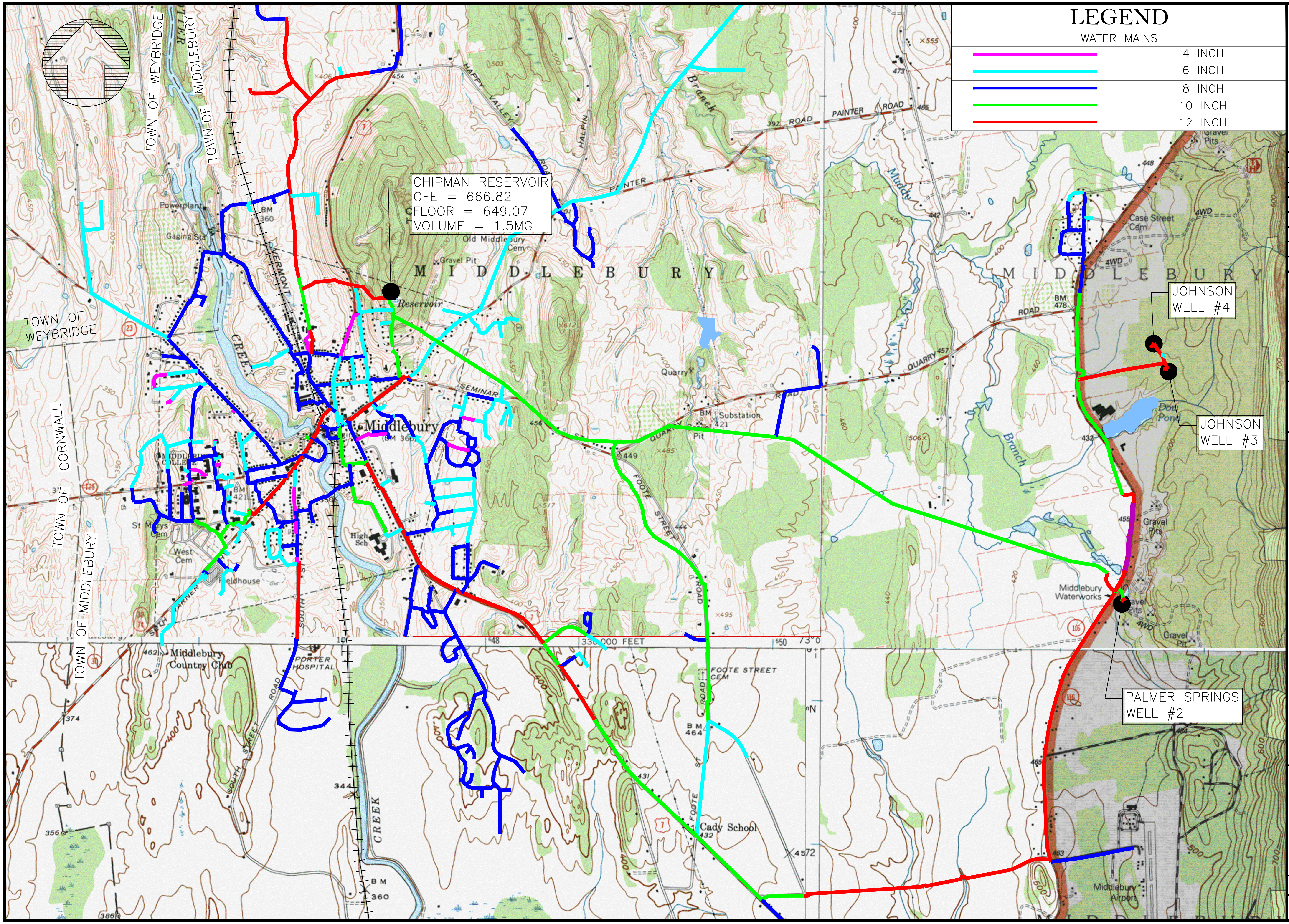
Based on a review of the 2018 metered water usage to date (January 1, 2018 through mid-October 2018) the water supplied to the college represents 18% of the total metered flows for this time period. The college buildings and facilities are individually metered with a total of 156 accounts. The college owns and maintains the distribution system on campus but is not a separate water system.

The water system was originally constructed in 1891 with 7.5 miles of distribution mains, according to the *Manual of American Water-Works Volume 4* published in 1897. Since the original construction, the major system modifications that are currently in service include construction of the Chipman Reservoir in 1978 and construction of the three wells (Wells 2, 3, 4) at individual times.

The water system includes approximately 54 miles of water mains. The characteristics of the water mains are shown in Tables 1, 2, and 3, which summarize installation date, material, and diameter by total length.

The Chipman Reservoir is a cast-in-place concrete structure with two 78'-3" x 77'-8" cells that have a depth of 17.25' to the overflow, which is at elevation 666.84'. The tank does not have an altitude valve.

Well 2 at Palmer Springs, developed in 1978, is the primary source of supply with an original design pumping rate of 1,500 gpm and an authorized rate of 1,550 gpm. The well is controlled to turn on when the Chipman Reservoir level drops to 14 ft and turn off at a level of 16 ft. At the 16 ft level, either Well 3 or Well 4 (the Johnson Wells) will turn on and run until additional supply from Well 2 is required to refill the Chipman Reservoir to above the 14 ft level.



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WATER SYSTEM FACILITIES LOCATION MAP

MIDDLEBURY, VERMONT

FIG 1

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Table 1 Main Installation Date	
Installation Date	Length (miles)
1890-1899	0.72
1900-1909	4.18
1930-1939	3.80
1950-1959	2.08
1960-1969	1.70
1970-1979	3.00
1980-1989	3.48
1990-1999	5.29
2000-2009	5.11
2010-2018	5.52
undetermined	19.13

Table 2 Water Main Material	
Material	Length (miles)
PVC	1.69
Cast Iron	19.48
Asbestos Cement	0.85
HDPE	0.60
Ductile Iron	31.39

Table 3 Water Main Diameter	
Diameter	Length (miles)
2-inch	0.48
3-inch	0.13
4-inch	1.37
6-inch	13.62
8-inch	19.74
10-inch	9.17
12-inch	9.21
24-inch	0.30

Wells 3 and 4 are operated on an alternating basis. Well 3, developed in 1985, supplies about 400 gpm. Well 4, developed in 1997, supplies 450 gpm. The capacity of Well 4 is substantially less than the 800 gpm safe yield for this source. This well has issues with introducing sand to the water system and reported pump cavitation at high flows.

A new Permit to Operate was issued on April 17, 2013, with no expiration date, as is the policy of the Drinking Water and Groundwater Protection Division. The most recent Sanitary Survey was conducted by the Vermont Drinking Water and Groundwater Protection Division staff on September 29, 2017. The survey identified the requirements to continuously monitor disinfectant residual, repair or replace the Chipman Reservoir roof and install security measures for the tank. The Town has addressed these three items.

The Sanitary Survey also identified that Chipman Reservoir provides inadequate storage volume. This water modeling report addresses the requirement, outlined by the Drinking Water and Groundwater Protection Division, to evaluate and plan for providing additional storage capacity, as well as discuss fire flow capabilities and future average day demands.

System Demands

Total water supplied to the Middlebury Water System is measured by flow meters at the three well houses and monitored by the SCADA system. Water Department staff read and manually record the master meters' values daily. If there is any variation in the time of day the meter reading is recorded, the daily values are not representative of supply over a 24-hour period. The source supplies water to meet system demands and maintain storage volume in the Chipman Reservoir.

Water consumption varies from hour to hour and from day to day throughout the year. Average daily demand is the average of the total amount of water used each day during a one-year period. The maximum day demand is defined as the highest total amount of water used during any twenty-four hour period. Typically, the previous three years of data is reviewed to identify the maximum day demand value.

The water supply data for 2007 to 2017 was reviewed to determine water system demands. This data is plotted in Figure 2. The increase in demand in 2015 and subsequent reduction in 2016 is attributed to a significant leak, estimated at 50 gpm, that began in early 2015 and was repaired in November 2016. Table 4 summarizes the Middlebury Water System average and maximum day demands for 2015-2017.

TABLE 4
AVERAGE DAILY DEMAND

Year	Average Day Demand	Maximum Day Demand
2015	1.32 mgd	2.02 mgd
2016	1.26 mgd	1.88 mgd
2017	1.24 mgd	2.00 mgd
Average	1.27 mgd	

Notes:
1. The average day demand is estimated based on water supplied, measured by the master water meters at the well houses and totalized. Water supplied includes consumption and water loss.
2. The MDD dates are 9/1/15, 11/29/16 and 11/2/17.

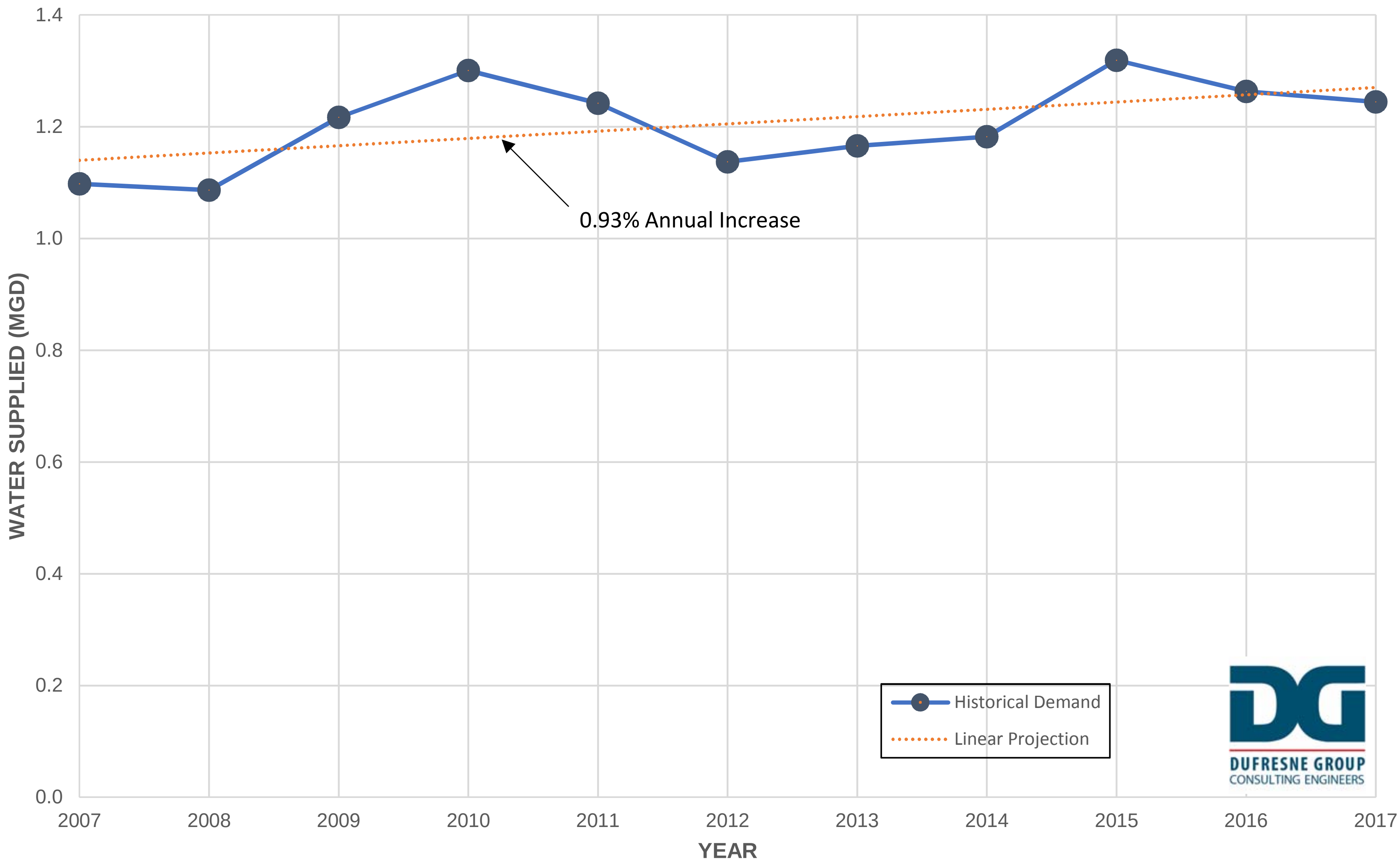
Average Day (ADD), Maximum Day (MDD) and Peak Hour Demands (PHD) are listed in Table 5. The peaking factors reported in Table 2 are the ratios of the maximum day and peak hour demands to the average day demand. These values commonly range from 1.5-3 for the MDD/ADD ratio and from 2.5-5 for the PHD/ADD ratio, according to the *Handbook of Public Water Systems*. The values for Middlebury are at the low end of the range, which indicates that leakage may be significant, as leakage tends to dampen the peaking factors.

TABLE 5
CURRENT SYSTEM DEMANDS

Period	Demand	Peaking Factor to Average Day
Average Day	1.24 mgd	
Maximum Day	2.02 mgd	1.69
Peak Hour	2,000 gpm	2.3

Notes:
1. Master meter records for 2015-2017 were reviewed to determine the maximum day demand (MDD), which is reported as the highest MDD value during the three year period.
2. The average day demand is the value for calendar year 2017.
3. The maximum day demands were 2.02, 1.88, 2.00 mgd during 2015, 2016 and 2017 respectively.
4. The peak hour flow was estimated by a review of well production and tank level fluctuations during a maximum day. For the day analyzed, well production was 1,700 gpm average.

FIGURE 2
WATER SYSTEM HISTORICAL DEMAND
MIDDLEBURY, VERMONT



An analysis of large water users was conducted during the preparation of a computer model for the Middlebury Water System. The ten accounts with the highest historical consumption were identified and the average day demand for the computer model nodes at the account locations was assigned from metered usage provided by the Town. These ten highest use accounts have a total average daily consumption of 314,000 gpd or about 25% of the system metered demand.

System Pressures and Surges

Water pressure for the distribution system is set by the Chipman Reservoir. The lowest elevation areas in the center of town have static pressure of about 135 psi. Many customers have individual pressure reducing valves.

The Town Water Department and the Middlebury College Facilities Services staff report that there is a water hammer issue in the system. Pressure gauges interior to some college buildings have measured pressures of 180-260 psi as documented by photographs taken by College Facilities Services staff on January 10, 2018. Normal static levels in this area are 100-110 psi.

Fire Flow Requirements

The most recent Insurance Services Office (ISO) testing was performed September 25, 2013. As shown in the tabulated results contained in Table 6, the majority of the ISO Needed Fire Flows (NFF) are satisfied. At two locations, the Available Fire Flow (AFF) was less than the NFF. These locations are Foote Street/Dorey Lane and Route 116 at Specialty Filaments, shown in Figure 3.

Table 6

INSURANCE SERVICES OFFICE, INC.

HYDRANT FLOW DATA SUMMARY

City Middlebury

County Vermont(Addison), State VERMONT (44) Witnessed by: Insurance Services Office Date: Sep 25, 2013

TEST NO.	TYPE DIST.*	TEST LOCATION	SERVICE	FLOW - GPM $Q=(29.83(C(d^2)p^{0.5}))$ INDIVIDUAL HYDRANTS			TOTAL	PRESSURE PSI STATIC	RESID.	FLOW -AT 20 PSI NEEDED **	AVAIL.	REMARKS***	MODEL TYPE
1		Rte 7 and Schoolhouse Rd	Middlebury Water Department	1590	0	0	1590	110	105	2000	7600	(B)-(1534 gpm)	
10		South St. Last Hydrant	Middlebury Water Department	1270	0	0	1270	120	75	500	2000		
11		Main St and S. Main St	Middlebury Water Department	2850	0	0	2850	128	125	2000	19700	(B)-(1534 gpm)	
12		Elm St and N. Pleasant St	Middlebury Water Department	2850	0	0	2850	120	55	3500	3600	(C)-(1534 gpm)	
13		Washington St and High St	Middlebury Water Department	2850	0	0	2850	110	85	2500	5700	(A)-(2250.0 gpm)1 (B)-(1534 gpm)	
14		Seminary and Foote St	Middlebury Water Department	1300	0	0	1300	90	70	500	2600		
15		Foote St and Dowling Lane	Middlebury Water Department	1190	0	0	1190	105	70	3500	1900	(C)-(1534 gpm)	
16		Main St and Lower Plains St	Middlebury Water Department, East Middlesbury	0	0	0	0	50	20	2500	700	(B)-(1841 gpm)	
17		Piper Rd near School House Hill	Middlebury Water Department, East Middlesbury	0	0	0	0	60	12	1000	550		
18		Main St and Rte 116	Middlebury Water Department, East Middlesbury	0	0	0	0	80	20	2500	650	(B)-(1841 gpm)	
18A		Main St and Rte 116	Middlebury Water Department, East Middlesbury	0	0	0	0	80	20	1000	650		
19		Rte 125 Near Livestock Sales	Middlebury Water Department, East Middlesbury	670	0	0	670	85	15	3000	650	(C)-(1323 gpm)	
2		Rte 7 S. Of Cady Rd	Middlebury Water Department	1010	0	0	1010	120	100	1750	2400	(B)-(1534 gpm)	
3		Rte 116 @ Specialty Filaments	Middlebury Water Department	1300	0	0	1300	120	75	3500	2000	(C)-(1534 gpm)	
4		Painter and Painter Hills	Middlebury Water Department	580	0	0	580	115	34	500	650		
5		Exhange St at End	Middlebury Water Department	1400	0	0	1400	120	100	2250	3300	(B)-(1534 gpm)	

THE ABOVE LISTED NEEDED FIRE FLOWS ARE FOR PROPERTY INSURANCE PREMIUM CALCULATIONS 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.

*** (A)-Limited by available hydrants to gpm shown. Available facilities limit flow to gpm shown plus consumption for the needed duration of (B)-2 hours, (C)-3 hours or (D)-4 hours.

Table 6

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INSURANCE SERVICES OFFICE, INC.

HYDRANT FLOW DATA SUMMARY

City MIDDLEBURY, VT. State IL Zip 5753 Witnessed by Insurance Services Office, Inc. Date 4/25 AND 4/26/2000

TEST NO.	TYPE DIST.*	TEST LOCATION	SERVICE	FLOW - GPM INDIVIDUAL HYDRANTS			FLOW - GPM TOTAL	PRESSURE PSI STATIC	PRESSURE PSI RESID.	FLOW AT 20 PSI NEEDED **	FLOW AT 20 PSI AVAIL.	REMARKS
1	Comm	RTE 7 AND SCHOOLHOUSE RD	Main	1590			1590	110	105	2000	7600	
2	Comm	RTE 7 S. OF CADY RD	"	1010			1010	120	100	1750	2400	
3	Comm	RTE 116 @ SPECIALTY FILAMENTS	"	1300			1300	120	75	3000	2000	
4	Comm	PAINTER AND PAINTER HILLS	"	580			580	115	34	500	650	
5	Comm	EXCHANGE ST AT END	"	1400			1400	120	100	2250	3300	
6	Comm	EXCHANGE ST @ V.F.W.	"	1640			1640	135	125	2250	6100	
7	Comm	WEYBRIDGE AND GORHAM ST	"	1210			1210	130	105	750	2700	
8	Comm	COURT ST AND CHARLES ST	"	1430			1430	130	45	3500	1600	
9	Comm	MERCHANTS ROW	"	2850			2850	125	120	3500	14800	
10	Comm	SOUTH ST LAST HYDRANT	"	1270			1270	120	75	750	2000	
11	Comm	MAIN ST AND S. MAIN ST	"	2850			2850	128	125	2000	19700	
12	Comm	ELM ST AND N. PLEASANT ST	"	2850			2850	120	55	3500	3600	
13	Comm	WASHINGTON ST AND HIGH ST	"	2850			2850	110	85	2500	5700	
14	Comm	SEMINARY AND FOOTE ST	"	1300			1300	90	70	500	2600	
15	Comm	FOOTE ST AND DOWLING LANE	"	1190			1190	105	70	3500	1900	
1	Comm	MAIN ST AND LOWER PLAINS ST	"	690			690	50	20	2500	700	

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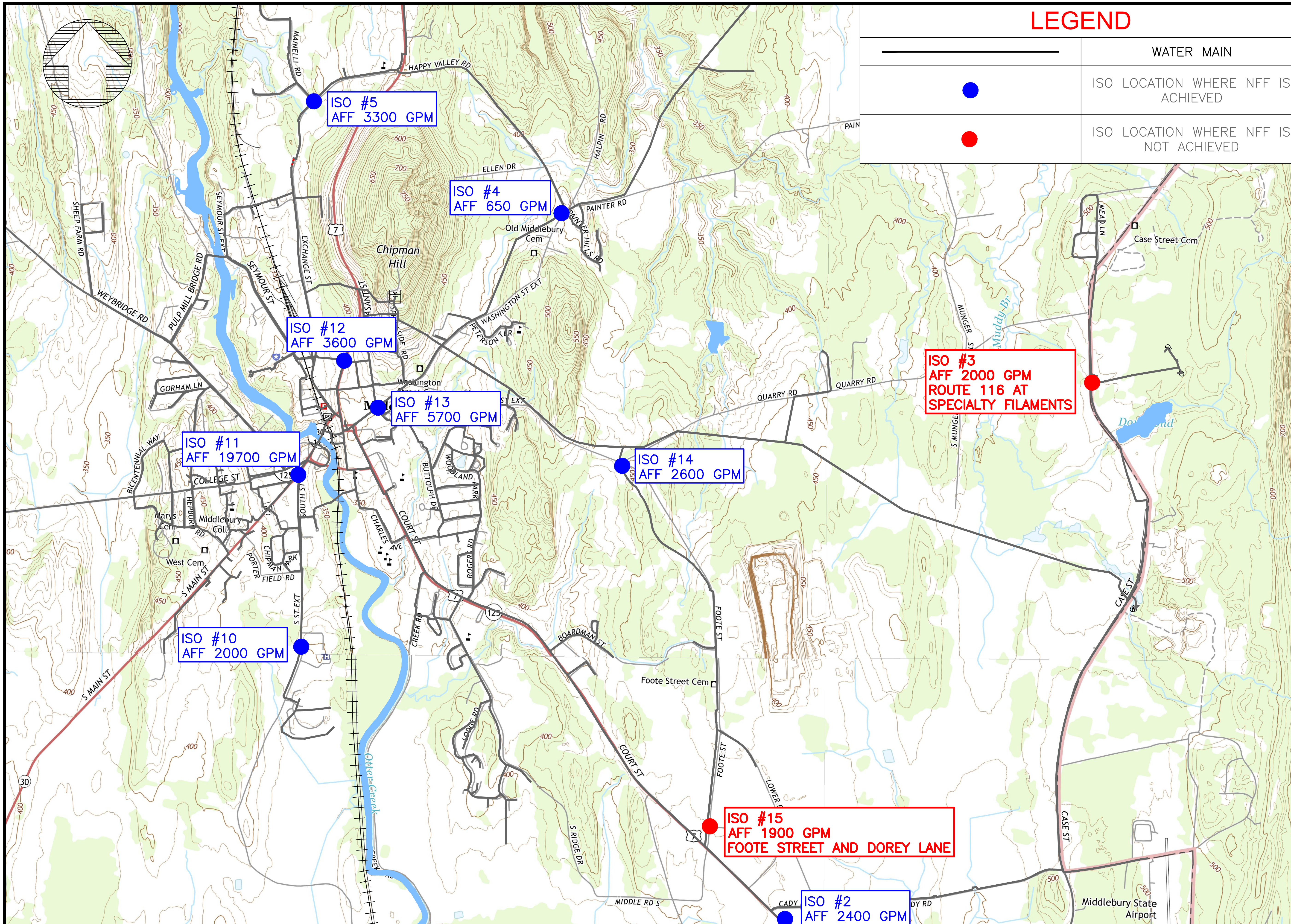
**Needed is the rate of flow for a specific duration for a full credit condition. Needed Fire Flows greater than 3,500 gpm are not considered in determining the classification of the city when using the Fire Suppression Rating Schedule.



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Project Mgr.	TPK
Design	N/A
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Checked by	NRJ
Date	10/3/2018
Scale	1"=2000'
Approved by	NRJ

2013 ISO AFF FIRE FLOW DATA

MIDDLEBURY, VERMONT

FIG 3

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SECTION 2
EVALUATION
WATER MODELING AND HYDRAULIC EVALUATION REPORT
MIDDLEBURY, VERMONT

Demand Projections

Based on a 20-year planning period, future average day demand is estimated for the year 2038 by linearly projecting the current average day demand using an annual increase of 0.93%. This growth rate is equal to the historical system demand rate of increase over the 2007-2017 period. Based on this projection, the future average day demand in 2038 is estimated at 1.54 mgd.

The projected future demands are shown in Table 7. The future maximum day demand of 2.60 mgd is estimated by applying a peaking factor of 1.69 to the future average day demand. Peak hour demand is estimated using a peaking factor of 2.3 for the peak hour to average day ratio.

TABLE 7
FUTURE WATER SYSTEM DEMANDS

Period	Future (2038)
Average Day	1.53 mgd
Maximum Day	2.60 mgd
Peak Hour	2,460 gpm

Notes:

1. The average day demand was 1.27 mgd for the period 2015-2017 based on total water production records.
2. Future average demands are calculated using an annual growth rate of 0.93%, equal to the historical demand increase trend over 2007-2017.
3. Maximum day demand is calculated using a peaking factor of 1.69 for average day to maximum day. Peak hour demand is calculated using a peaking factor of 2.3.

Water System Service Area

A water system service area represents the land that can be serviced at acceptable pressure without boosted pressure zones. Delineation of the practical upper limits of the service area for the Town of Middlebury was determined by an evaluation of the topography of the region and the following minimum pressure criteria in accordance with the Vermont Water Supply Rule (WSR):

- 20 psi minimum pressure at ground level throughout the distribution system at all flow conditions.
- 35 psi minimum normal working pressure.

The upper limit of the service area is usually defined as the maximum elevation where the minimum working pressure (35 psi) is maintained. The static pressure is usually set by adjacent distribution storage tanks and depends on storage tank levels. Typically, a low tank level is assumed for calculating the elevation corresponding to 35 psi (approximately 80 feet) below the lowest working level to allow for "active" storage tank level. Development above the elevation that corresponds to the defined service area limit is usually prohibited to ensure that users receive water at adequate pressures.

The overflow elevation of the existing 1.5 mg Chipman Reservoir storage tank sets the hydraulic gradeline for all customers served by gravity flow from this tank and defines the topographic limits that can be served by the proposed water system without pumping. The limit of the areas that can be served by gravity, based on the tank low level criteria, is elevation 580 ft. The service area limit calculation is presented in Table 8 and shown in Figure 4.

Connection of future customers in the water system should be restricted to the 580 ft service area elevation. Customers above this elevation should not be serviced by the water system without use of municipal style water booster stations. As shown in Figure 4, there is one user on Springside Road that is just above the service area limit at elevation 595 ft. The normal static pressure at this location is 30 psi.

TABLE 8
MAXIMUM GRAVITY
SERVICE AREA LIMITS

Item	Value
Maximum Hydraulic Gradeline	666.8 ft
Tank Low Level Alarm from Overflow	-4 ft
Minimum Working Pressure (35± psi)	- 80.9 ft
Service Area Maximum Limit (approximately)	580 ft

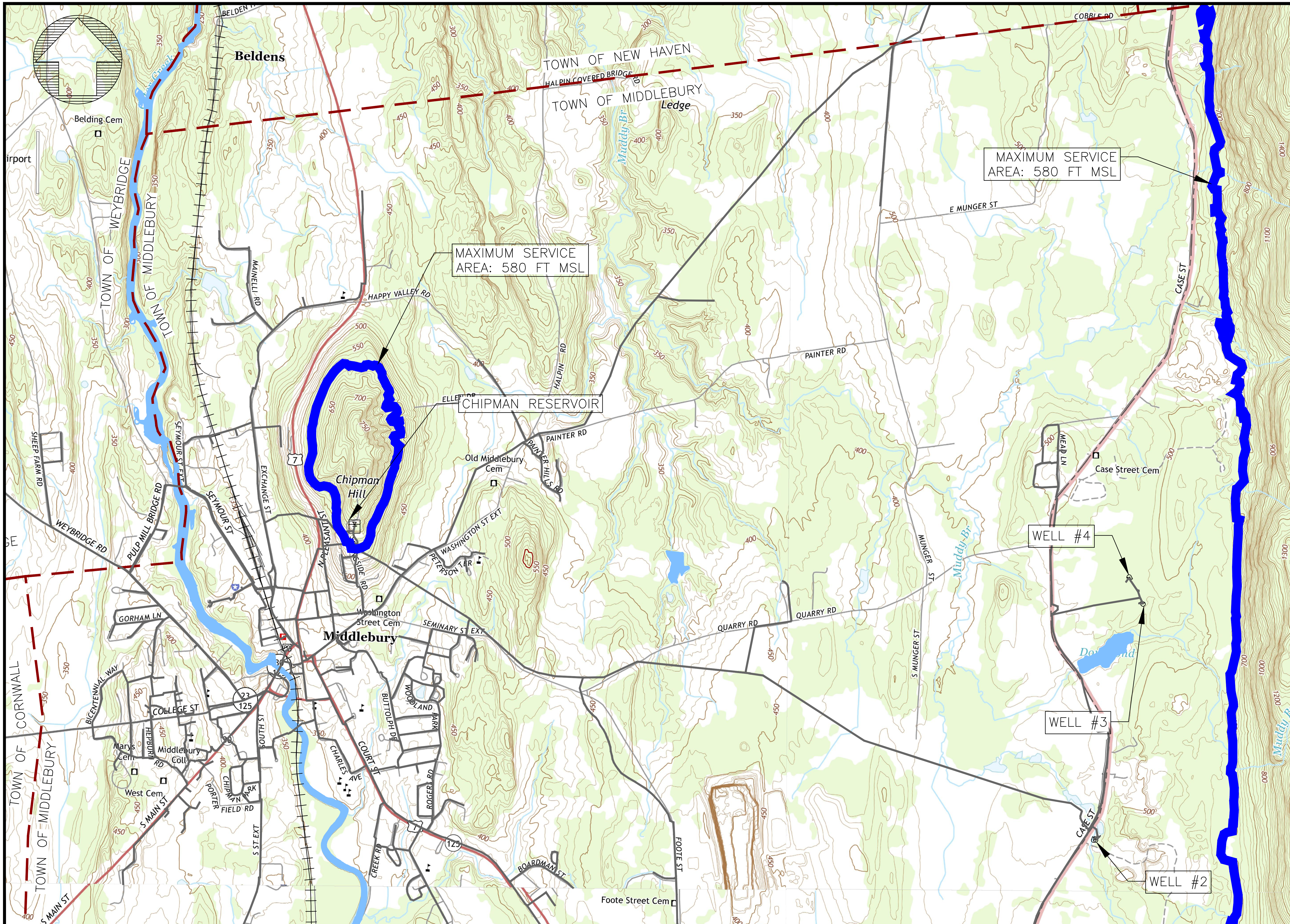
Notes:

1. The maximum hydraulic gradeline is set by the overflow elevation of the existing Chipman Reservoir storage tank.
2. Tank level fluctuation is based on a level of 13.25 ft in the storage tank, 0.75' below the normal Well 2 control "On" setting of 14 ft.
3. Minimum working pressure is defined by the Vermont Water Supply Rule.

Storage Volume Requirements

The Vermont Water Supply Rule provides criteria for sizing finished water storage facilities for systems providing fire protection as the volume necessary to meet the following:

- Fire flow demands of a minimum of 500 gpm for two hours with consideration for fire flows established by the Insurance Services Office (ISO) or the local fire department.
- Average daily domestic demands.



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MAXIMUM WATER SYSTEN SERVICE AREA

MIDDLEBURY, VERMONT

FIG 4

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The criteria does not include a requirement for peak flow equalization volume. In addition, this criteria does not address or consider that a portion of the tank may be unusable or require “dead storage” to maintain minimum system pressure for protection of high elevation customers.

Prior to defining the storage components, the following functions of storage facilities should be considered:

1. Storage tanks cannot compensate for inadequate source capacity. The only water available from a tank during the day is the quantity that can be replenished at night. If daily demands exceed the source capacity for an extended period, the storage tanks will eventually be empty regardless of the tank size.
2. Water storage tanks provide water to meet system demand during emergency periods when sources of supply are not available.
3. Peak hourly and fire flow demand usually exceeds total source capacity and is generally provided from water storage, which is replenished during low demand periods.
4. Storage facilities stabilize the system’s hydraulic gradeline providing steady pressures to areas adjacent to the tanks during variable demand conditions.
5. Water storage tanks should be located at an elevation at least 80 feet above the highest customer to provide a minimum pressure of 35 psi to the highest user at the tank low operating level.
6. Storage tank sizing should consider the effect of oversized tanks on increased detention times and potential water quality issues.

In considering the functions listed above, the storage volume for a single tank generally consists of the following components:

<u>Peak Flow Equalization:</u>

Water storage facilities should be designed to provide equalization between average day and peak hourly demands, with water withdrawn from storage during peak demand hours and replenished during nighttime, low demand periods. If there is not adequate storage to provide peak hour demands, source facilities must meet the peak flow requirements.

The amount of water produced that should be stored for equalization depends on the individual system and typical operations. For example, in a system where pumps are operated continually to meet the average demand for the day, many references refer to a general rule of providing 10-25% of maximum day demand exclusively for the peak flow equalization volume component.

<u>Emergency Storage:</u>

Emergency storage is provided in order to maintain continuous water service during short periods without source availability due to equipment maintenance or transmission main disruption and repair. Typically, this volume is equal to one day of average day system demand, but it is usually greater for systems with a vulnerable water supply. The volume of emergency storage is larger for systems with few sources and no auxiliary power supply, compared to systems with multiple sources and backup power.

Fire Flow Protection:

The rates of flow to be available for fire suppression concurrently with normal system usage are typically far in excess of source and/or treatment capacity. Generally, it is much less expensive to construct water storage facilities to provide fire flows than to construct high capacity source facilities, which would otherwise be required.

In accordance with the Water Supply Rule, the amount of fire flow storage for individual systems should consider ISO criteria. However, this requirement does not provide for a quantified design criterion. Historically, ISO has developed fire flow rates for selected individual buildings but does not set fire flow durations. However, the National Fire Protection Association does provide fire flow durations, which can be used to estimate fire flow volumes in conjunction with the ISO fire flows. Interpretation by the local fire chief is usually required to quantify a required volume and to confirm the required fire flow for the community.

The Town of Middlebury Fire Chief has established the local fire flow requirement is the ISO fire flows, which include Needed Fire Flows (NFF) of 3,500 gpm.

Dead Storage:

Dead storage volume is the water that must remain in a tank to ensure customer pressures are at least 35 psi during normal conditions or at least 20 psi under all flow conditions including a fire situation. This volume is variable for each tank depending on the highest customer in the tank service area, the tank elevation and the tank configuration. Typically, this volume is most significant in tall standpipe tanks.

There is one user above the maximum service area set by the 35 psi minimum pressure criteria at elevation 580 feet. Even with a full tank, this user has just 31 psi water pressure. Therefore, there is no benefit to maintaining a partially full tank just to keep high elevation users above 35 psi.

Table 9 presents an analysis of required storage tank volume based on current demands. However, it would not be cost efficient to build a water storage tank to meet existing conditions only. Storage tanks can last for decades and in most cases, it makes economic sense to build larger tanks to meet future conditions. Therefore, the analysis also presents the future scenario based on future demands.

The analysis shows that 2.78 mg of storage is required for the system to provide the storage volume components of equalization, emergency and fire flow protection based on a 3,500 gpm fire flow and future demand projections. In comparison to the required 2.78 mg, the storage provided by the existing 1.5 mg tank is deficient, with a difference of 1.28 mg between available and required storage volume.

TABLE 9
STORAGE TANK VOLUME ANALYSIS

Component	Current Scenario Volume (mg)	Future Scenario Volume (mg)
Existing Tank Storage	1.50	1.50
- Dead Storage	-0.00	-0.00
Available Storage	1.50	1.50
Peak Flow Equalization	+0.52	+0.62
Emergency Storage	+1.24	+1.53
Fire Flow Protection	+0.63	+0.63
Total Storage Recommended	2.39	2.78
Storage Surplus (+) or Deficit (-)	0.89	1.28

Notes:

1. Peak flow equalization = 25% of Maximum Day Demand.
2. Emergency storage = 100% of ADD.
3. Fire flow protection = 3,500 gpm for 3 hours.
4. Dead storage is zero since existing users have insufficient pressure even with a full tank and providing a dead storage volume has no benefit.

In addition to the individual volume components discussed above, there are other considerations in selecting the storage volume for this project. In some systems with disinfection byproduct (DBP) issues, there is concern of providing too much storage due to water age and the related disinfection byproduct formation potential. In those situations, mixing and other techniques are used to reduce DBP formation. Although Middlebury has not experienced DPB issues, incorporating mixing techniques should be considered for the tank design. This may be as simple as a separate inlet, elevated above the outlet at the tank floor, or installing a mechanical mixer such as the GridBee system.

<u>Distribution System Hydraulic Evaluation</u>

A model of the water system was developed using Bentley Haestad Methods WaterGEMS® computer software. GIS files for the system water pipes provided by the Town were used to create the water model. The pipes included attribute data for pipe diameter, material and age. Additional information was added to the pipe data to define roughness coefficients. Other model input included system demands, pump characteristics curves, tank geometry and elevations.

The model was calibrated to actual field testing by Dufresne Group in July 2018. A calibration report, which documents the model development and calibration procedures is included in the Appendices.

The computer model was used to identify existing areas of inadequate pressure based on the Water Supply Rule criteria that a minimum pressure of 20 psi shall be maintained at all points under all conditions of flow and a minimum pressure of 35 psi under normal conditions.

The calibrated computer model of the water system was also used to simulate existing conditions during average day demand (normal conditions) and the system design flow. The design flow represents the limiting condition, which is the greater of peak hour demand or a fire flow during maximum day demand. For the Town of Middlebury, the limiting condition is system maximum day demand in conjunction with fire flow demand. Fire flow demands were based on the Insurance Services Office (ISO) fire flows.

During present and future average day and maximum day demand conditions, without a fire flow, there are no pressure problems. During simulations of a 500 gpm minimum required fire flow during present system maximum day demand, there are only a few locations where a 500 gpm fire flow cannot be satisfied. These locations, shown in Figure 5, are:

- The end of the 4-inch diameter main west of South Main Street.
- Painter Hills Road and Happy Valley Road region.
- Munger Street.

The water model was used to simulate the 2013 Needed Fire Flows. During simulations of the fire flows during future maximum day demand, there are two locations where the flow cannot be achieved while maintaining a minimum of 20 psi at all locations in the distribution system that are normally above 35 psi.

These locations are on Case Street and Foote Street. The Foote Street fire flow does not adversely affect areas in the distribution by causing pressures to drop below 20 psi. The needed fire flows at Painter Road/Painter Hills Road and Case Street are the only ISO locations that have NFFs which cause pressures below 20 psi. Figure 6 depicts the water model node locations that fall below 20 psi during the simulated Needed Fire Flows.

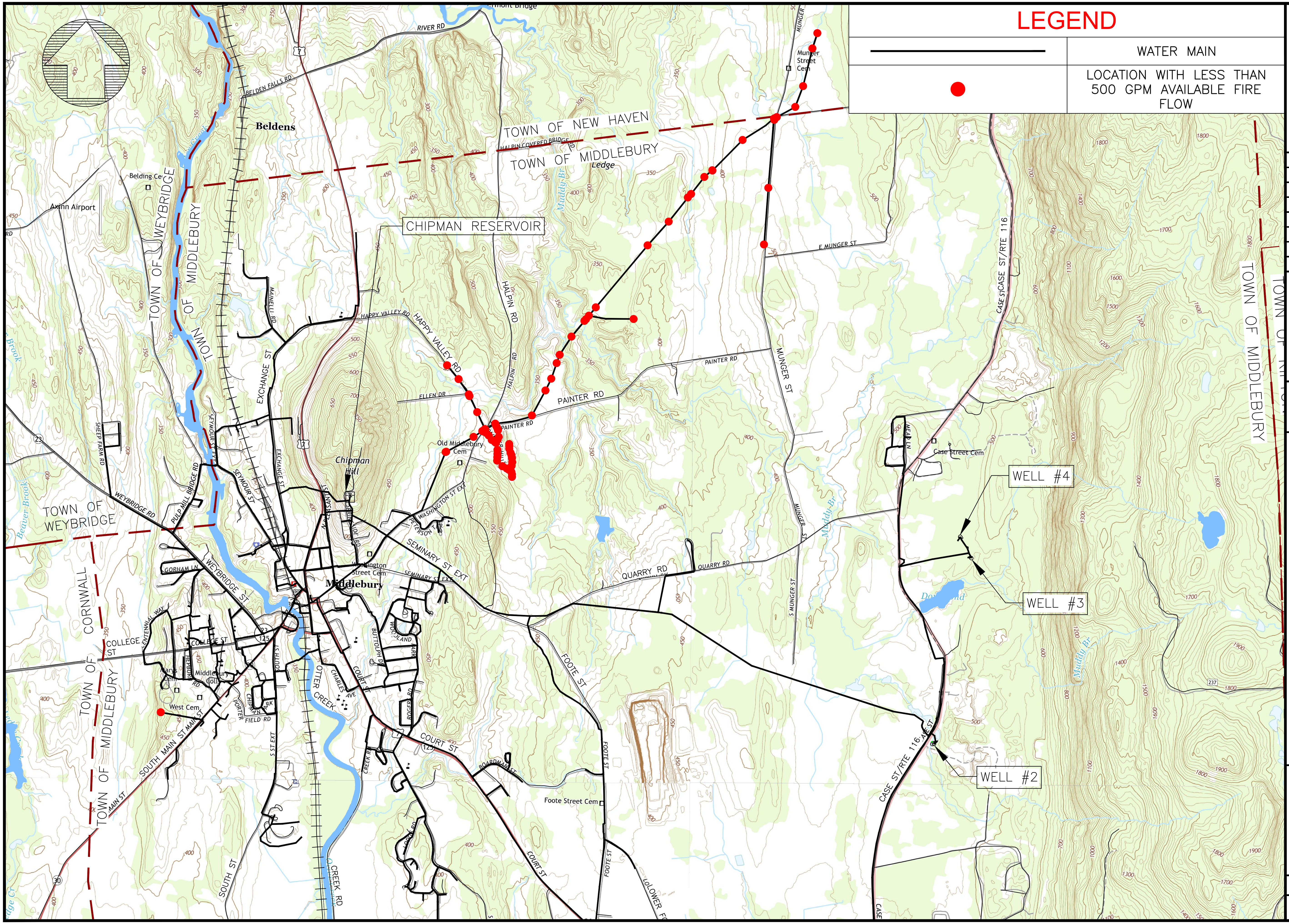
Potential for Microelectric Generation

There is no excess available head within the hydraulic gradeline from the sources to distribution system to allow for hydroelectric generation from the existing system. If there were pressure reducing valves (PRVs) that reduced the gradeline from one pressure zone to a second zone, that situation would provide the opportunity to use the wasted head from pressure reduction for hydroelectric generation. However, there are no PRVs in the Middlebury system.

Surge

Pressure recording data shows that two significant pressure fluctuations occurred during five weeks of monitoring in June and July 2018, with drops of about 50 psi. These two events were on June 13, 2018 at 10 a.m. and June 14, 2018 at 8 a.m. A copy of the chart is included in the Appendices.

The pressure recordings do not show high pressure swings that would occur in the event of a water hammer. The well operation data for these two days was reviewed to assess if well pump on/off operation coincided with the pressure fluctuation. The data shows the on/off times do not correspond to the time of the pressure drops.



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Project Mgr.	TPK
Design	N/A
Drawn	MCB
Checked by	NRJ
Date	10/3/2018
Scale	1"=2500'
Approved by	NRJ

LOCATIONS WITH LESS THAN 500 GPM AVAILABLE FIRE FLOW

MIDDLEBURY, VERMONT

FIG 5

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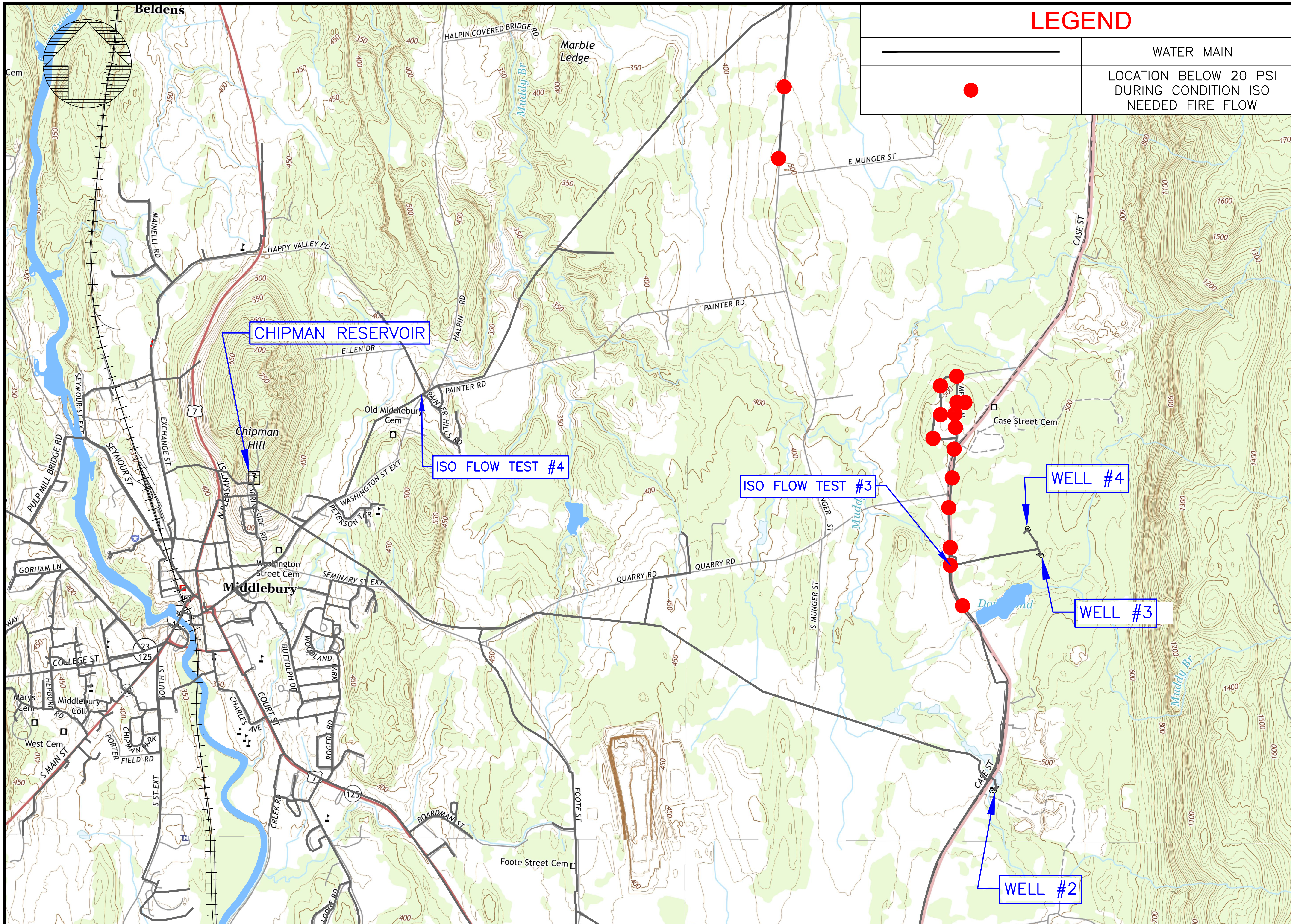

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Scale	1"=2000'
Approved by	NRJ

ISO MODELING RESULTS

MIDDLEBURY, VERMONT

FIG 6

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SHEET 1 OF 1

On-line meter records were reviewed for customers with large diameter meters including the college and Vermont Apple Cider. The records show no major changes at the time of the pressure drop when compared to values throughout the June 13-14 time period.

As described previously, pressure spikes to 260 psi have been documented on the college campus. This is a significant issue to be resolved. Continued pressure monitoring should occur in an effort to identify the time of day of the surges and potential causes. Since there were no surges in the June-July monitoring period, it appears the water hammer events occur when college is in session. Dufresne Group can provide a pressure chart recorder for further investigations of pressure fluctuations.

Summary of Deficiencies

The water system modeling results, analysis of water storage and review of existing system characteristics identified the following deficiencies:

1. One water customer at 19 Springside Road is above the existing service area and has normal working pressure below the required 35 psi minimum.

2. The required minimum 500 gpm fire flow is not achieved at the following locations:
    a. The end of the 4-inch diameter main west of South Main Street.
    b. Painter Hills Road and Happy Valley Road region.
    c. Munger Street.

3. During ISO fire flow conditions, 20 psi minimum pressure is not maintained at the following locations:
    a. Case Street (during 3,500 gpm NFF at 3406 Case St)
    b. Painter Hills Road, Happy Valley Road and Munger Street (during 500 gpm NFF at Painter Rd. and Painter Hills Rd.)

4. The Needed Fire Flows at Case Street and Foote Street are not available.

5. The storage tank volume is inadequate to provide current or future average day demand plus fire flow volume. The deficit is 1.3 mg for the future demand condition.

6. Water hammer is causing high pressure surges in excess of 250 psi.

Assessment of Improvements

Middlebury Water Department staff have developed a list of priority water main replacement projects. The projects are identified as high priority to address areas of known leakage, undersized pipes and aged infrastructure. Table 10 presents the 13 projects identified by the Town. These projects are shown in Figure 7.

TABLE 10
TOWN PRIORITY PROJECTS

Town Priority Rank	Location	Proposed Diameter (in)	Length (ft)
1	Route 7/Cady Road/Court St.	12	6,750
2	Court Square, Court St. and Washington Street	12	5,325
3	Exchange Street, Mainelli Road, Pond Lane	12	7,100
4	South Street	12	2,150
5	Gorham and South Gorham Lane	8	5,200
6	Foote Street	12	2,600
7	Woodland Park, Meadow Way, Swanage Court	8	2,700
8	Seminary Street Ext. and cross country	12	18,600
9	Charles Avenue	8	450
10	Sheep Farm Rd and Weybridge Street	8	5,200
11	Colonial Drive	8	300
12	Washington St Ext	8	4,375
13	Happy Valley Road	8	3,450

The water main replacement projects were simulated in the water model to evaluate the effect of the improvements on existing system deficiencies. Since there are few pressure deficiencies, the effect of the improvements to resolve the problem areas is limited. The effects are summarized as follows:

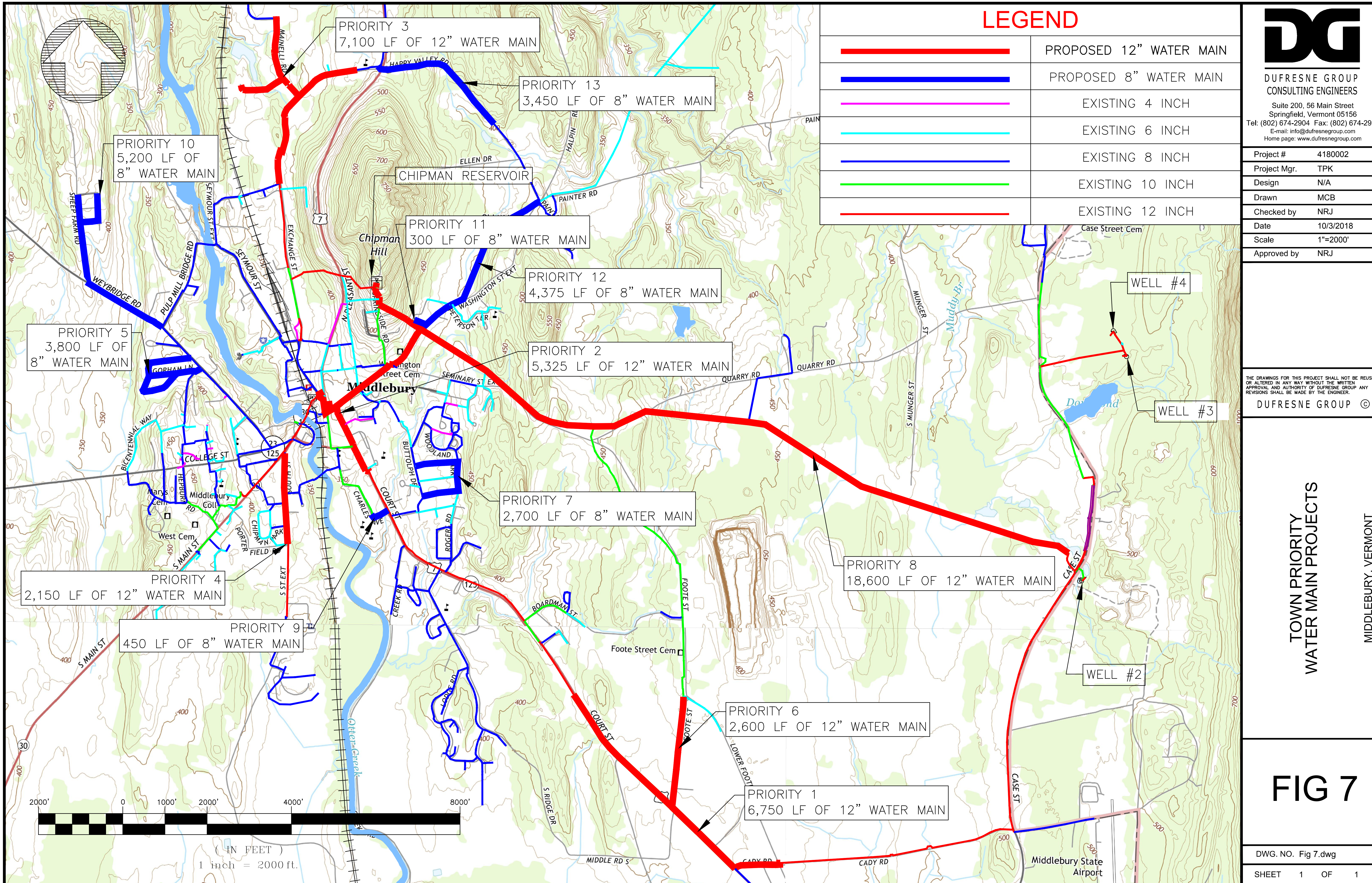
1. Priority projects 1 and 6 (Route 7/Court Street and Foote Street): increases the available fire flow and resolves the deficient fire flow condition at Foote Street.

2. Priority project 12 (replace the 6-inch main cross country off Washington Street extension with 8-inch diameter pipe): increases the available fire flows in the Painter Hills Road region and the 500 gpm minimum fire flows are achieved.

3. Priority project 13 (Happy Valley Road loop): increases the available fire flows in the Painter Hills Road region and the 500 gpm minimum fire flows are achieved.

The modeled AFFs with all improvements are shown in Figure 8.

In addition to an assessment of improved fire flows, the proposed project to loop Happy Valley Road to Exchange Street and the proposed project to improvement North and South Pleasant Street mains with abandonment of the Merchants Row main were evaluated to assess effects on reliability of service. The results are summarized below:



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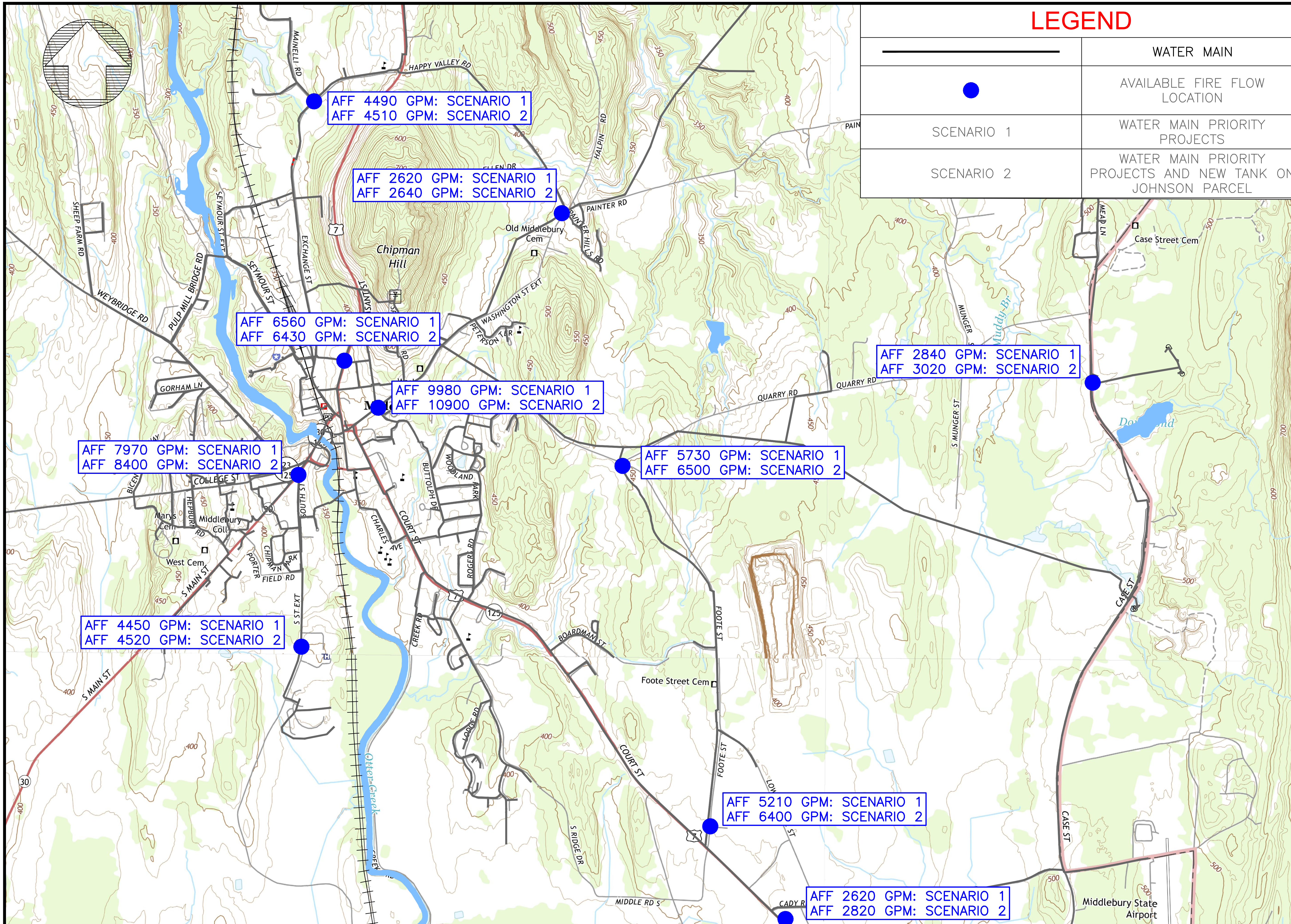

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Project Mgr.	TPK
Design	N/A
Drawn	MCB
Checked by	NRJ
Date	10/3/2018
Scale	1"=2000'
Approved by	NRJ

IMPROVED SYSTEM FIRE FLOWS AVAILABLE AT 20 PSI

MIDDLEBURY, VERMONT

FIG 8

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Evaluation of connecting Happy Valley Road to Exchange Street:

- The connecting 8-inch diameter loop provides a hydraulic benefit by improving fire flows, including resolving deficiencies in the Painter Hills area and northeast region
- The loop increases reliability; however, depending on the location of repair work with a water main shutdown, the loop may not assure continued service. The water main project on and north of Exchange Street will be valuable to replace the deficient piping.
- The connection allows continued service to Mainelli Road in the event that the 12-inch diameter Exchange Street main is closed south of Mainelli Road. Available fire flow in this situation is 460 gpm at the intersection of Exchange Street and Happy Valley Road. Under normal demand conditions with the 12" main closed and the loop in place, the pressure reduces from 120 psi to 113 psi at the intersection of Exchange Street and Happy Valley Road.

Evaluation of eliminating Merchants Street main and South Pleasant Street water main replacement (as shown in Figure 9):

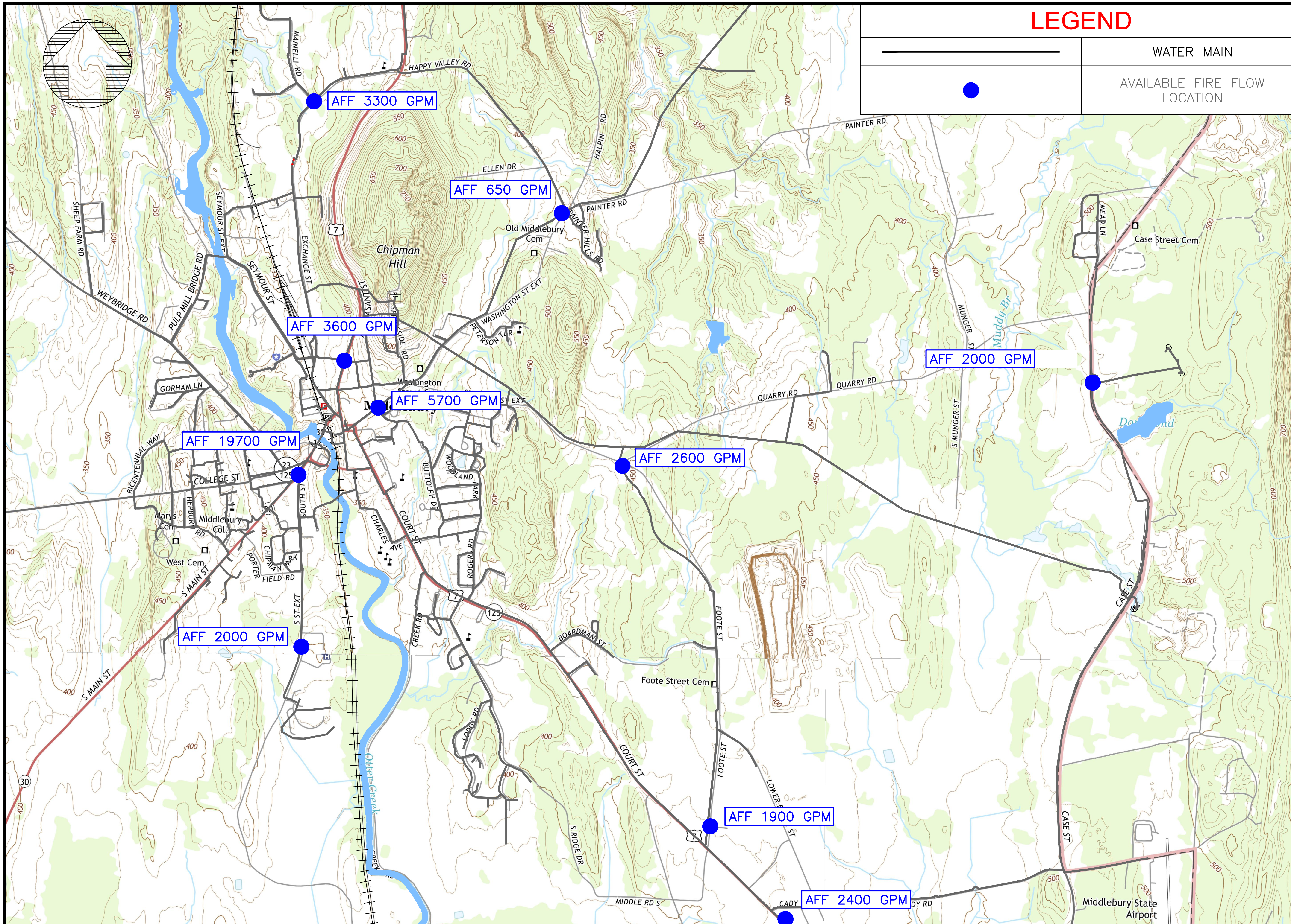
- Water mains and other deficient utilities should be replaced prior to, or in conjunction with, planned roadway improvements projects. Replacing the 6-inch and 8-inch mains on S. Pleasant St. improves the Available Fire Flow by 2,000 gpm. The abandonment of the Merchants St. main has no adverse effects due to the existing looped water mains.

With all of the proposed improvements on the Town's list incorporated into the water system, the following distribution system hydraulic deficiencies remain:

- A 3,500 gpm fire flow at 3406 Case Street causes pressures to fall below 20 psi north of the fire flow location.
- A minimum fire flow of 500 gpm cannot be achieved at Munger Street.

System hydraulics may be improved with the construction of a second water storage tank, which has been identified as a needed improvement. There are two general locations in Middlebury that have adequate elevation to site a ground level storage tank. The first location is Chipman Hill and the second is east of Case Street. Additional storage on Chipman Hill would address the storage deficit but not resolve the fire flow issue on Case Street.

The Town has previously identified the parcel owned by A. Johnson Co., LLC off School House Hill Road, east of Case Street, as a potential water storage tank site. The Johnson site is shown in Figure 10. The suitable elevation of a tank on the east side of the water system, near the well sources of supply, is dependent on the characteristics of the well pumps and the transmission mains. The tank must be low enough to be filled by the well pumps and high enough to maintain adequate gradeline for the system when the wells are off.



DG

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AVAILABLE AT 20 PSI

MIDDLEBURY, VERMONT

FIG 9

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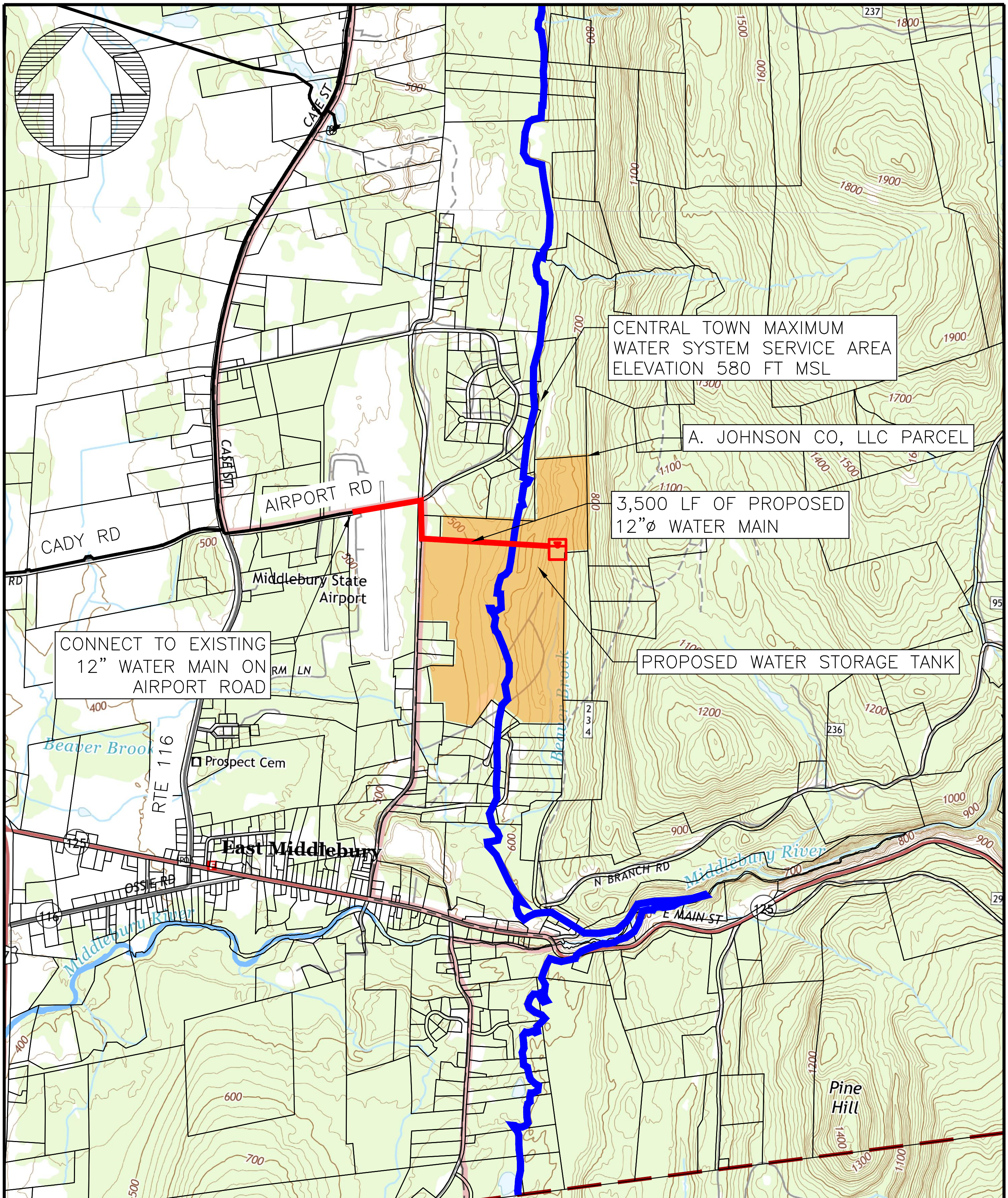

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FIGURE 10

POTENTIAL SITE
WATER STORAGE TANK
JOHNSON PARCEL

MIDDLEBURY, VERMONT

PROJECT NO.	4180002
PROJECT MJR.	TPK
SCALE	1"=2000'
DATE	10/3/2018
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The 580 ft service area limit defined by the Chipman Reservoir bisects this parcel from north to south. But, this limit is set by the Chipman Reservoir remotely located from the potential new tank site. Due to the distance of the potential new site from the distribution system and the resulting headloss in the transmission main, the tank must be located above elevation 580 ft.

A proposed tank on the Johnson parcel was simulated to assess the effect on system pressures during fire flow conditions in the north Case Street area. Based on preliminary modeling using Extended Period Simulation techniques, the proposed tank was simulated with a floor elevation of 680 ft and an overflow elevation of 700 ft. The tank improved the available fire flow at 3046 Case Street to 3,020 gpm but did not resolve the pressure deficiencies during the fire flow condition. Resolution of the Case Street pressure issues would be resolved with construction of a tank closer to the fire flow location to reduce the pressure drop during a 3,500 gpm fire flow. A review of topographic mapping shows there are no locations with elevation around 700 ft that provide a substantial wide, level area for a potential tank site as is available on the Johnson parcel. There is a sizeable pond adjacent to the fire flow location that has the potential for use as a source during a fire event.

The existing water system provides an AFF of 2,000 gpm according to ISO testing. Although this is less than the NFF, this is not considered a system deficiency considering AWWA guidance for water systems providing fire protection, as well the specifics of fire protection facilities at the Earth Waste System/former Specialty Filaments property.

The facility has a booster fire pump system and is sprinklered but the current abilities of the system are unknown. Although it is not clear if the facility can obtain sufficient fire flow from the pond, the existence of a fire pump indicates that historically the property has assumed responsibility for their individual fire protection.

AWWA Manual 31 provides guidance for water systems providing fire protection as follows:

- It is very unusual for an existing water distribution system to be capable of providing every NFF within its service area.
- Inability of the system to fully deliver NFF should not be considered a failure of the system.

Although a tank at the Johnson site improves the fire flow at the Earth Waste property, its benefits to improving fire flows in the central portion of the water system are minimal. Figure 8, presented previously, includes the results of AFFs with the Johnson tank online. A tank at the Johnson site also provides improved water storage reliability but, due to the remote location, source control improvements may be needed to ensure the tank has active exchange.

The alternative location for a new tank on the Chipman Hill parcel is shown in Figure 11. The Chipman Hill site reduces the length of needed access road and water transmission main and the total project cost, for a new water storage tank.

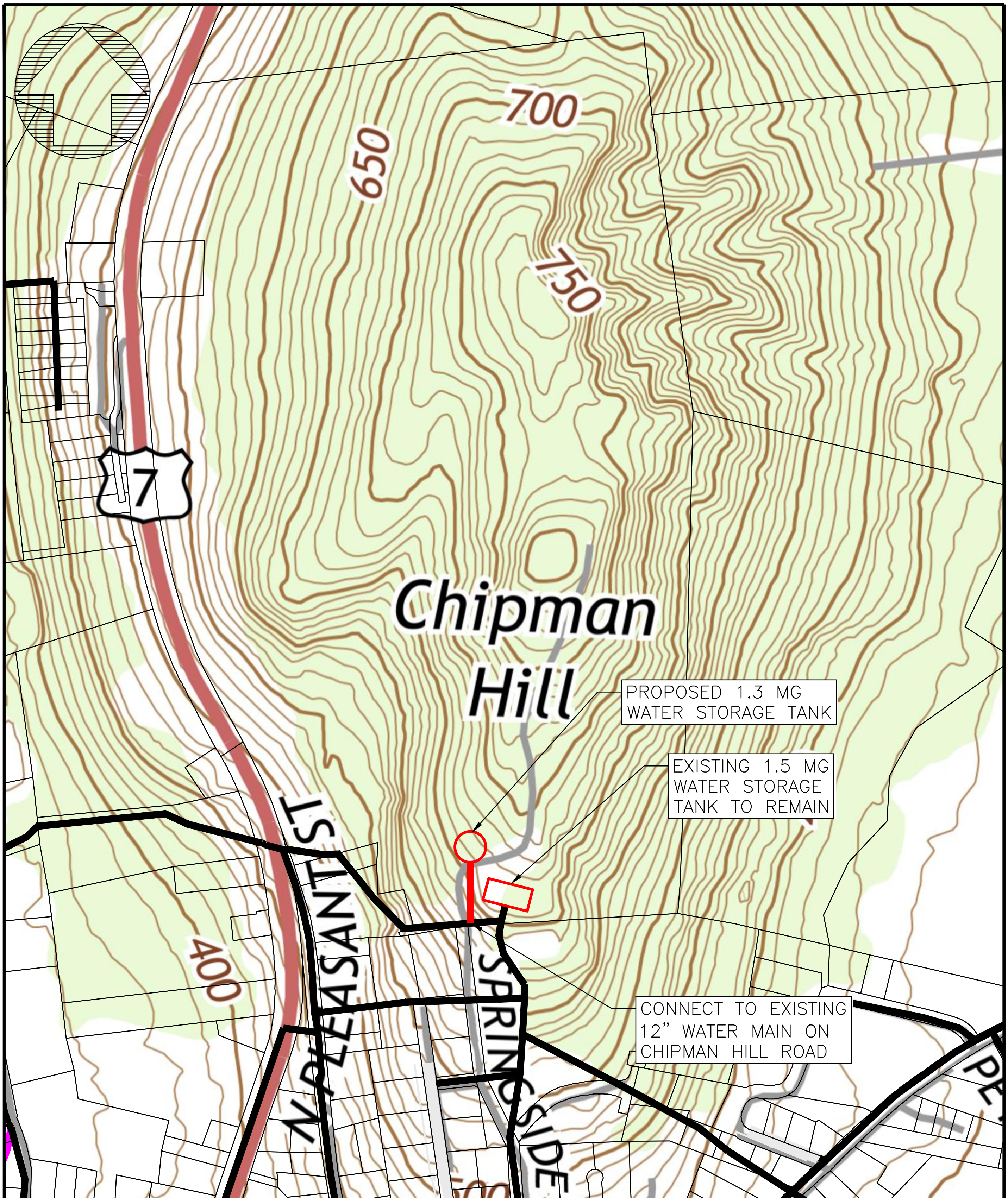

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FIGURE 11

POTENTIAL SITE
WATER STORAGE TANK
CHIPMAN HILL PARCEL

MIDDLEBURY, VERMONT

PROJECT NO.	4180002
PROJECT MJR.	NRJ
SCALE	1"=500'
DATE	12/11/2018
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Regarding the remaining distribution system deficiencies, the computer modeling was used to develop the following findings:

1. The Munger Street pressure deficiencies are resolved by replacing all the 6-inch diameter pipe on Washington Street and the cross country route with 8-inch diameter main, a total length of about 15,000 ft.
2. Replacement of the section of 4-inch main west of South Main Street increases the available fire flow to a minimum of 500 gpm.

Considerations for Project Planning and Cost Estimates

The Town's list of planned water main replacement projects was developed to address known leakage, undersized pipes, deficient materials and aged infrastructure. The Town Water Department routinely repairs more than 20 pipe breaks each year, therefore replacement of the pipes prone to leaks is high priority.

Pipe condition has been a major factor in assigning priority to the replacement projects. Since fire flow availability is generally good, replacement to address hydraulic issues has been a lesser factor in recent project planning. One of the objectives of the system modeling is to identify hydraulic issues that may revise the original priority for water main projects.

Another factor that was considered in the distribution system evaluation is the ability of the system to provide for projected growth. As described by Town representatives and also discussed in the Town Plan, the primary area for potential growth is the industrial area off Exchange Street. The priority 3 project provides a strong water main connection to this area, with all 12-inch diameter water main except for one segment of 10-inch diameter piping on Route 7.

Based on the results of the distribution hydraulic evaluation, there are no recommendations for revising the priority ranking for water main replacement projects. The improvements described above to improve hydraulics for the Munger Street area during the fire flow conditions are not included as recommended capital improvements, primarily because the expense does not appear justified compared to the relatively minor benefit. Replacement of the 4-inch main is also not a priority project since there are hydrants in the vicinity that may serve the area with adequate flow. However, a new water storage tank and transmission main is added to the list of planned capital improvements. The priority of this project will be reviewed by Town staff, but the priority is considered high and in the top three projects.

The construction and capital costs for the water improvements projects are shown in Tables 11 and 12. Table 12 presents the cost for both tank alternative sites. These costs are based on current construction prices and must be inflated for future years.

TABLE 11
PROPOSED WATER MAIN REPLACEMENT PROJECTS ESTIMATED COSTS

Location	Existing Pipe	Proposed Diameter (inches)	Length (ft)	Cost Per Foot	Estimated Construction Cost	Total Project Cost
Route 7/Cady Rd./Court St.	6-10” CI	12	6,750	$250	$1,687,500	$2,379,000
Court Square and Washington St.	6-12” CI and DI	12	5,325	$250	$1,331,250	$1,877,000
Exchange St, Mainelli Rd, Pond Lane	12” DI	12	7,100	$250	$1,775,000	$2,503,000
South St.	4-6” CI	12	2,150	$250	$537,500	$758,000
Gorham Lane and South Gorham Lane	2-6” Universal	8	3,800	$225	$855,000	$1,206,000
Foote St.	6” CI	12	2,600	$250	$650,000	$917,000
Woodland Park, Meadow Way, Swanage Court	6” AC	8	2,700	$225	$607,500	$857,000
Seminary St. Ext. and cross country	10” CI	12	5,200	$250	$1,300,000	$1,833,000
	10” CI	12	13,400	$200	$2,680,000	$3,779,000
Charles Avenue	6” CI	8	450	$225	$101,250	$143,000
Sheep Farm Road and Weybridge St	6” CI	8	5,200	$225	$1,170,000	$1,650,000
Colonial Drive	2” PVC	8	300	$250	$75,000	$106,000
Washington St. Ext.	6” CI	8	4,375	$225	$984,375	$1,388,000
Happy Valley Road	None	8	3,450	$225	$776,250	$1,095,000

Notes:

1. Unit prices are based on manufacturers’ quotes, RS Means pricing and bid tabulations for recent projects. The estimates are made without the benefit of final design and actual costs may vary substantially. The cost estimates are dated October 2018, ENR = 10,900.
2. The project on Seminary St. and a cross country rate includes 13,400 lf of cross country main. This section has a reduced cost per foot since pavement restoration is not required. The cost assumes pavement restoration is trench patch, not full width overlay.
3. Costs per foot include complete construction of water main and appurtenances, surface restoration (with trench patch in paved areas) traffic control and contractor overhead/profit.
4. The total project cost consists of construction cost plus administrative, engineering and contingency costs. Administrative, engineering and contingency costs are all estimated as a percentage of construction, with values of 3%, 23% and 15% respectively.

TABLE 12
PROPOSED WATER TANK ESTIMATED CONSTRUCTION COSTS

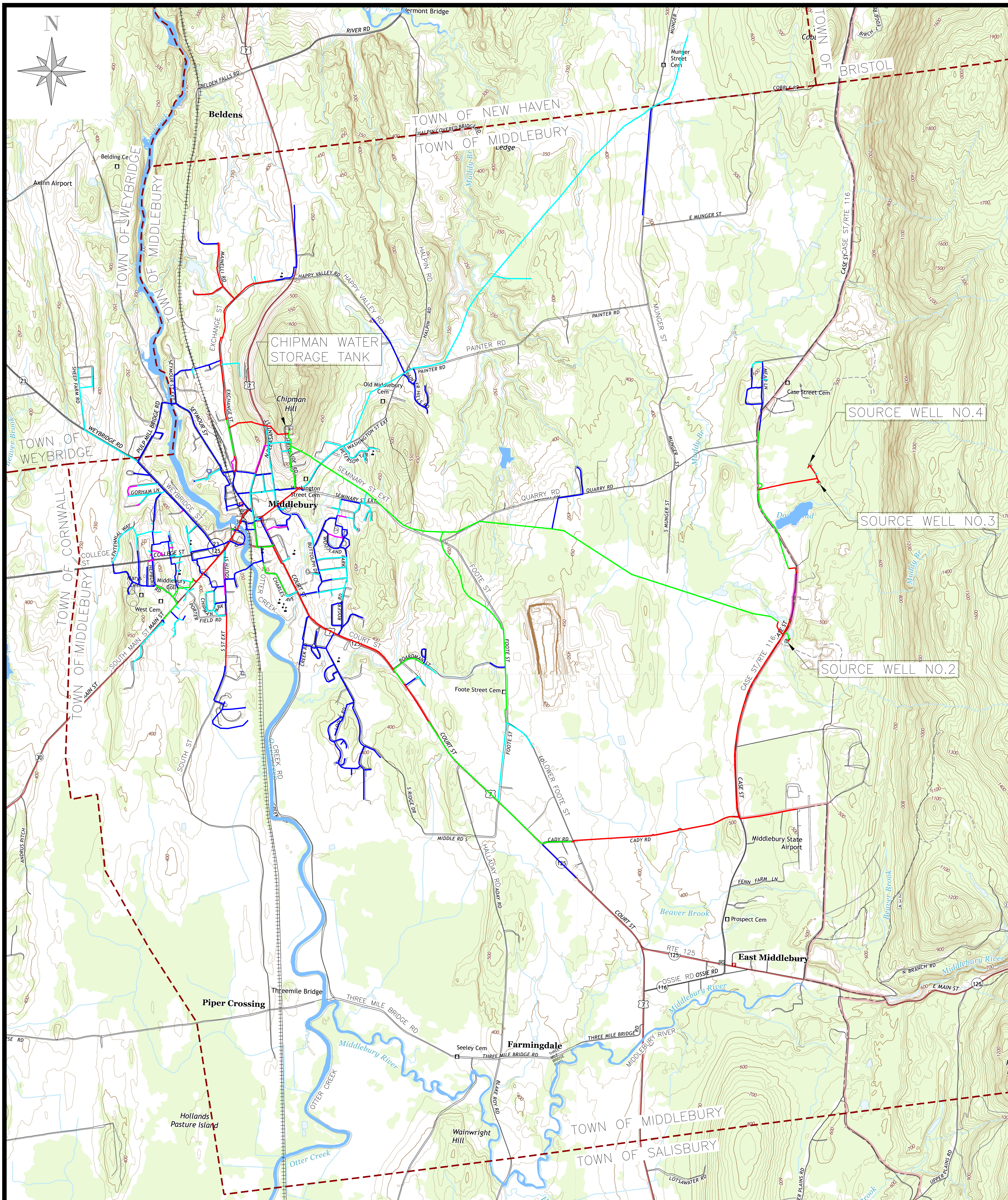
Item	Quantity	Units	Alt. 1 Johnson Site	Alt. 2 Chipman Hill Site
1.3 mg Tank	1	LS	$1,000,000	$1,000,000
Tank Accessories	1	LS	$35,000	$35,000
Site Work and Yard Piping	1	LS	$150,000	$150,000
Geotechnical Investigation	1	LS	$10,000	$10,000
Access Road	1	LS	$200,000	$10,000
Transmission Main	1	LS	$790,000	$50,000
Miscellaneous Work and Cleanup	1	LS	$325,000	$188,000
Total Construction Cost			**$2,500,000**	**$1,440,000**
Total Project Cost			**$3,525,000**	**$2,030,000**

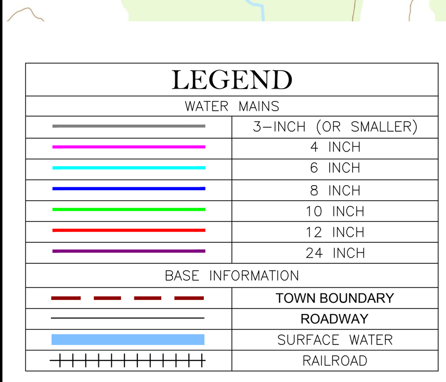
Notes:

1. Unit prices are based on bid tabulations for recent projects, cost estimates in RS Means and pricing from DN Tanks received October 2018 for a 30' high, 86' diameter precast-prestressed concrete tank. The estimates are made without the benefit of final design and actual costs may vary substantially. The cost estimates are dated October 2018, ENR = 10,900.
2. The 1.3 mg tank concept is a precast-prestressed tank with an 86 ft diameter and 30 ft water depth. The cost for tank and accessories is based on an October 2018 quote from DN Tanks. Glass-fused-to-steel tanks are also feasible, economical and recommended for consideration.
3. The Johnson site – Alternative 1, includes 2,000 lf of access road and 3,500 lf of transmission main. The Chipman Hill Site – Alternative 2, includes 100 lf of access road and 225 lf of transmission main.
4. The total project cost consists of construction cost plus administrative, engineering and contingency costs. Administrative, engineering and contingency costs are all estimated as a percentage of construction, with values of 3%, 23% and 15% respectively.

APPENDICES:

Appendix A	Water System Basemap
Appendix B	Calibration Report
Appendix C	Inventory Photos
Appendix D	June 12, 2018 Pressure Recorder Chart
Appendix E	2017 Sanitary Survey
Appendix F	Project Scope





NOTE:

BASE INFORMATION FOR THIS MAP INCLUDING ROADS AND SURFACE WATER WERE OBTAINED FROM THE STATE OF VERMONT CENTER FOR GEOGRAPHICAL INFORMATION.

WATER PIPE INFORMATION, INCLUDING SIZE AND LOCATION, IS BASED ON INFORMATION PROVIDED BY THE TOWN OF MIDDLEBURY.

1000 0 500 1000 2000 4000

(IN FEET)
1 inch = 1000ft.

MIDDLEBURY, VT
WATER SYSTEM BASEMAP
LAST UPDATED: APRIL 25, 2018

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WATER COMPUTER MODEL
CALIBRATION REPORT
MIDDLEBURY, VERMONT
July 6, 2018

General

The Middlebury, VT computerized water system model was developed using available information for the water system, provided by Middlebury Public Works officials, and additional field data obtained by Dufresne Group (DG). The procedures used for model calibration are described herein and a comparison of actual field conditions compared to calibrated model simulation results has been prepared.

Preliminary Model Development

The computerized water system model was developed using Bentley® WaterGEMS® V8i software using the following sources of information:

1. GIS water main data provided by Middlebury officials.
2. General knowledge of the water system from Middlebury officials.
3. Field information obtained by Dufresne Group on July 25, 2018.

The water main GIS ShapeFiles provided by the Middlebury Public Works Department were used as the basis for the water model. The GIS data included water main attribute data including installation date, material, and diameter, which was assigned to the water mains in the water model.

Using topographic 20-foot contour data available through the Vermont Center for Geographic Information (VCGI), approximate elevations were assigned to all junctions (or “nodes”) in the water model. A field survey was performed by DG to obtain elevations for the water storage tank floor and overflow, source building elevations, and hydrants used during field testing. This detailed elevation data was incorporated into the model.

Pump curves available from the manufacturer for the well pumps were assigned to source well pumps in the water model.

Roughness coefficients, or “C-values”, were assigned to water mains based on age and material as determined from the available water system data and input from the Water Department staff. The initial C-values were set in the model based on the pipe characteristics as summarized in Table 1.

TABLE 1 INITIAL C-VALUE ASSIGNMENT MIDDLEBURY, VERMONT September 25, 2018	
Pipe Description (material, installation date)	C-Value
Cast Iron, unknown age	60
Cast Iron – Lined, any age	120
Ductile Iron, unknown age	120
Ductile Iron, 1960-1990	120
Ductile Iron, 1990 to present	130
PVC or Plastic, any age	140
Asbestos Cement (AC), any age	140

Water supply records for 2015-2017 were reviewed to create a base model to simulate an average day demand of 1,275,000 gallons per day (1.275 mgd). The total demand assigned and distributed equally to the computer junctions. This method of assigning demands distributes any system leakage or other unaccounted for water uniformly across the system, a common practice in water system computer modeling.

Water storage tank characteristics including horizontal dimensions, floor elevation, and overflow elevation were initially obtained from tank construction plans and adjusted based on field information as described under the Field Data Collection section of this report.

Field Data Collection

The following information was obtained during a field survey performed by Dufresne Group on June 8, 2018 and July 25, 2018, which included the use of GPS methods:

- Finish floor elevation at Wellhouse 2, 3, and 4.
- Water storage tank floor and overflow elevations.
- Elevation of outlet nozzles at hydrants used during field flow tests.

Field Testing:

Fire flow testing was conducted with the assistance of the Middlebury Water Department on July 25, 2018. The data obtained from the fire flow tests are summarized in Table 6. Fire flow locations are shown in Figure 1 and are as follows:

1. Morningside Street
2. Industrial Avenue
3. Munger Street
4. Mead Lane
5. Meadow Glen Drive
6. Wilson Road
7. Golf Course Road
8. Adirondack View
9. Cedar Court
10. Harrow Way
11. Lucius Shaw Way
12. Shannon Street
13. Airport Road

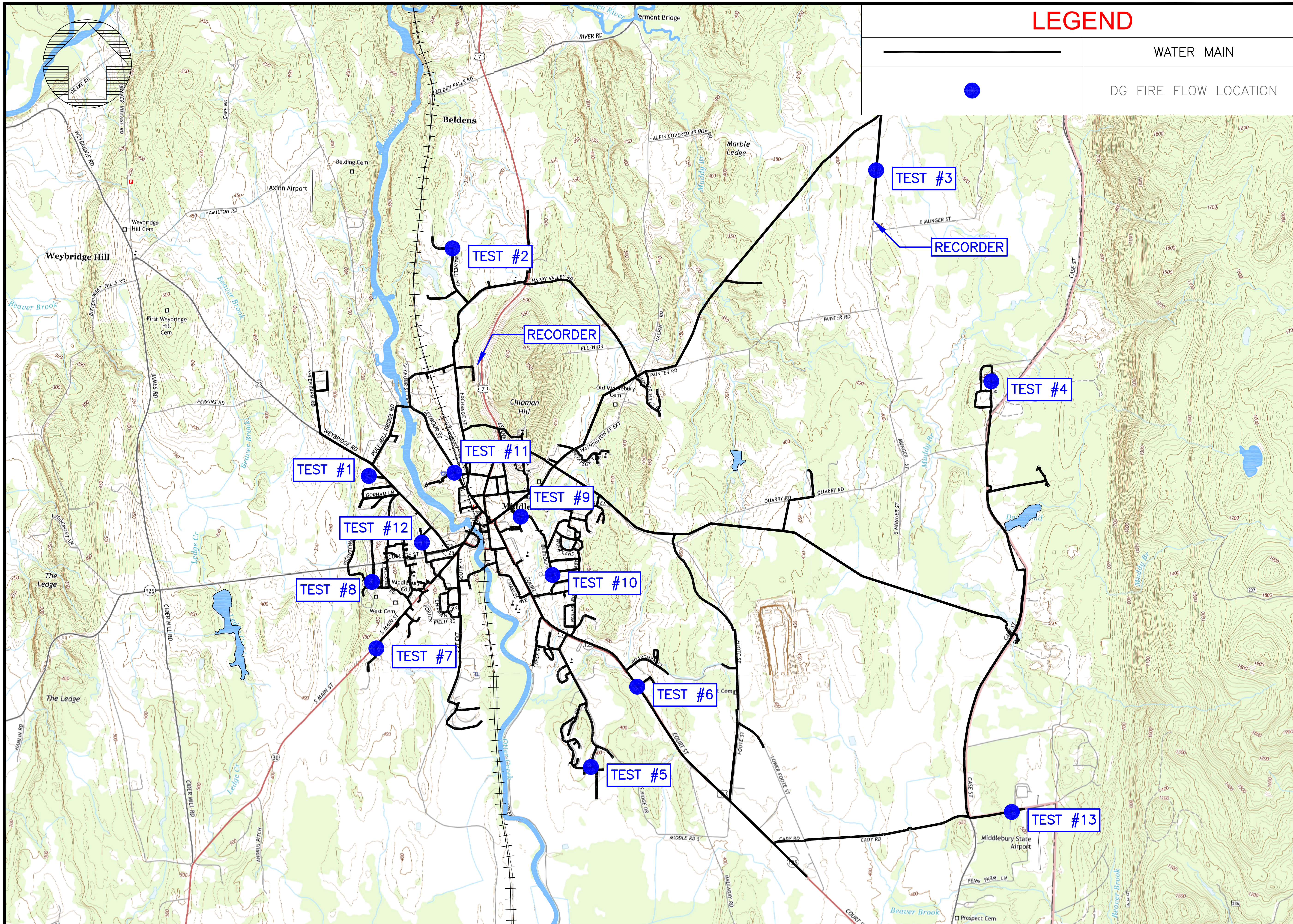
In addition to providing data for calibrating the computer model, the fire flow testing is useful to assess the ability of the water system to supply fire flows.

Continuous Pressure Monitoring:

To supplement the flow test data, pressure recorders were used at two locations in the water system to monitor system pressure under normal conditions and during field work. The locations of the recorders are shown in Figure 1 and the data collected at each of the locations is shown in Figures 2 and 3. The locations are as follows:

- Munger Street
- Grandview Street

The pressure data is reviewed under the calibration section of this report.



LEGEND

———	WATER MAIN
●	DG FIRE FLOW LOCATION

DUFRESNE GROUP
CONSULTING ENGINEERS
Suite 200, 56 Main Street
Springfield, Vermont 05156
Tel: (802) 674-2904 Fax: (802) 674-2913
E-mail: info@dufresnegroup.com
Home page: www.dufresnegroup.com

Project #	4180002
Project Mgr.	TPK
Design	N/A
Drawn	MCB
Checked by	NRJ
Date	10/3/2018
Scale	1"=3000'
Approved by	NRJ

DG FIRE FLOW TEST LOCATIONS

MIDDLEBURY, VERMONT

FIG 1

DWG. NO. FIRE FLOW TEST LOCA

SHEET 1 OF 1

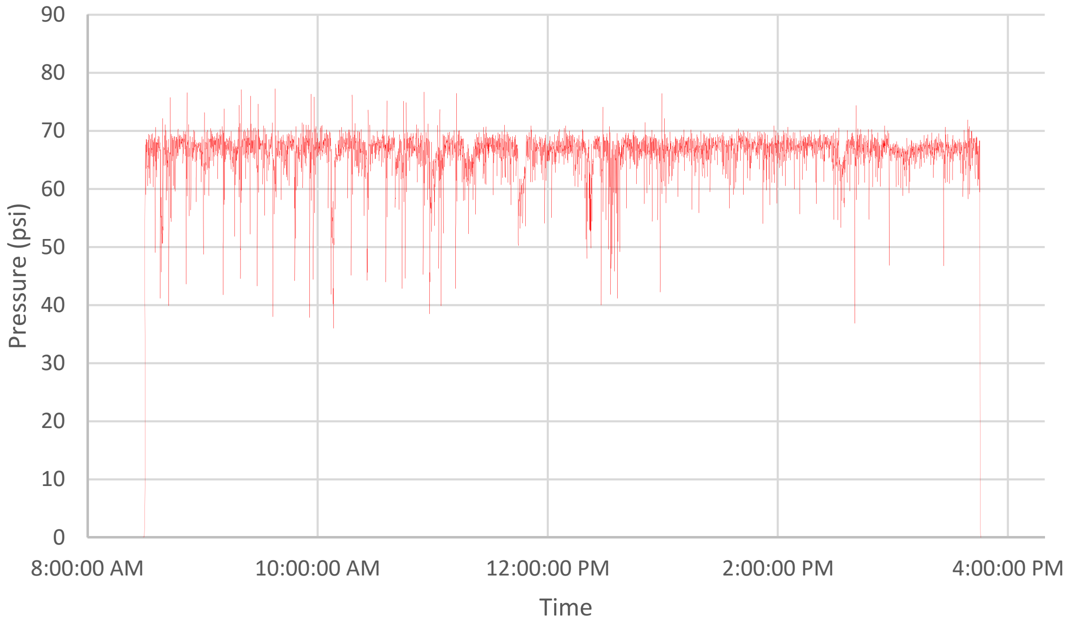
TABLE 6 DG FIRE FLOW TEST RESULTS Middlebury, VERMONT September 25, 2018				
Test No.	**Test Location**	**Static Pressure (psi)**	**Flow (gpm)**	**Residual Pressure (psi)**
1	Morningside Street	135	1630	111
2	Industrial Avenue	125	1530	98
3	Munger Street	72	-[2]	-[2]
4	Mead Lane	107	1030	58
5	Meadow Glen Drive	122	1330	80
6	Wilson Road	108	1595	98
7	Golf Course Road	87	875	50
8	Adirondack View	104	1410	89
9	Cedar Court	120	1595	113
10	Harrow Way	123	1670	112
11	Lucius Shaw Way	138	1635	124
12	Shannon Street	124	1495	103
13	Airport Road	97	1370	72

Notes:

1. The listed results were recorded during field testing performed on July 25, 2018 by DG with the assistance of the Middlebury Water Department.
2. Residual pressure during test 3 on Munger Street was observed to be negative and flow at pitot gauge was too low to register. The test procedure was discontinued and the data from this field test was not used in calibration of the model.

FIGURE 2
PRESSURE RECORDER DATA – MUNGER STREET
JULY 25, 2018

FIGURE 3
PRESSURE RECORDER DATA – GRANDVIEW STREET
JULY 25, 2018



Water Model Calibration

To calibrate the water model to field testing conditions, the base model conditions were revised to match actual system conditions during the testing, including system demand, tank levels, and pump on/off status.

Locations of hydrants utilized for flow tests and pressure monitoring were represented in the computer model by a junction or "node" at the hydrant's approximate physical location. Elevations were assigned based on DG field survey data for the respective hydrants.

For each flow test simulation, the measured flow was assigned to the representative junction(s) and the resulting pressure at the residual junction was compared to the actual residual pressure recording during a particular field test. If the model residual pressures did not agree to within 10% of the field results, pipeline C-values in selected areas were increased or decreased to reduce the difference in the model results compared to the field data. These steps were repeated for each field test. The process was iterative and required numerous fire flow re-simulations, as model modifications for a single data set potentially changed previous model results.

Comparison of Results

The results of the model calibration are summarized in Table 7. As shown, static pressures for the model agree very closely with the pressures measured on July 25, 2018. The accuracy of residual hydraulic gradeline for the model compared to field results varies, with a difference of less than 5% (less than 1% in most cases).

Model results were also compared to pressures recorded by the three pressure recorders installed by DG during the field testing. Included as Figures 2 through 4 and presented previously, the data shows that during normal/non-fire flow conditions, the computer model indicates results that closely match the field data.

As recommended by the American Water Works Association (AWWA), calibration results are considered acceptable if the calculated hydraulic gradelines in the model are within 5-10 feet of the field results (except for test no. 13). Based on this criterion, the Hyde Park water system model is calibrated to the data obtained on June 26, 2018 and as shown the model results are all within acceptable limits.

TABLE 7
COMPARISON OF FIELD DATA TO THE CALIBRATED WATER MODEL DURING THE FLOW TESTING
Middlebury, VT
September 25, 2018

Fire Flow No.	Location	Hydraulic Gradeline at Residual Hydrant (ft)				Field vs. Model % Difference	
		Field Static	Model Static	Field Residual	Model Residual	Static	Residual
1	Morningside Street	670.8	668.1	615.4	617.8	0.4%	0.4%
2	Industrial Avenue	665.9	666.5	603.5	604.9	0.1%	0.2%
3	Munger Street	664.5	665.8	-[1]	-[1]	0.2%	-[1]
4	Mead Lane	741.0	740.1	627.8	619.1	0.1%	1.4%
5	Meadow Glen Drive	672.9	672.5	575.9	577.2	0.1%	0.2%
6	Wilson Road	672.8	678.1	649.7	649.7	0.8%	0.0%
7	Golf Course Road	669.2	668.2	583.8	584.4	0.1%	0.1%
8	Adirondack View	667.8	668.2	633.2	629.5	0.1%	0.6%
9	Cedar Court	668.9	668.9	652.7	651.3	0.0%	0.2%
10	Harrow Way	670.3	671.6	644.9	641.2	0.2%	0.6%
11	Lucius Shaw Way	665.2	667.7	632.8	633.7	0.4%	0.1%
12	Shannon Street	668.6	668.3	620.1	617.7	0.0%	0.4%
13	Airport Road	713.3	719.6	655.6	653.7	0.9%	0.2%

Notes:

1. Residual pressure during test 2 on Munger Street was observed to be negative and flow at pitot gauge was too low to register. The test procedure was discontinued and the data from this field test was not used in calibration of the model.

Front of reservoir with parking areas.

Repairs on reservoir wall.

Repaired area on reservoir wall.

Side view of reservoir.

Roof of reservoir.

View of reservoir roof.

Access hatches for the reservoir showing vents.

Interior view of reservoir.

Access hatches and landing at the rear of the reservoir.

Reservoir wall showing handrail.

Tank vent is shown with wire screen guard.

Font view of reservoir showing temporary access ladder.

Rear view of reservoir showing handrail.

Well house front view.

Water treatment area for Well 2.

Chemical storage area for treatment area in Well House 2.

Diaphragm metering chemical pump.

Pressure relief valve installed in treatment area.

50-gallon fluoride storage tank.

Propane tanks for backup power generation

Phase changer for cold weather propane use.

Gas piping for propane fuel delivery system.

Pipe and well room at Well House 2.

Treatment area inside well and pipe room for chlorine injection.

LMI chemical pump for chlorine injection.

Chlorine 50-gallon storage tank.

Blow-off assembly installed adjacent to the chemical injection area with 4" Cla-Val pressure reducing valve.

Chlorine storage area in pump room.

10” Magnetoflow Primo magnetic flow meter.

Check valve.

View of piping out of well pump. Threaded rods are installed for extra needed thrust protection.

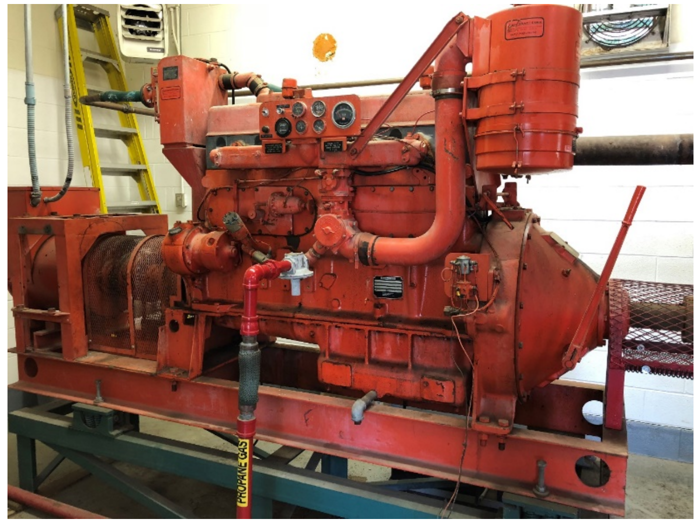
Wear on the fittings and pipe caused by the flexing of the threaded retainer rods.

Actuated flow control valve.

Air relief valve.

Well Pump 2.

Connection between Well Pump 2 and the backup motor.



Backup motor for powering Well Pump 2.

Electronic control towers for Well house 2.

Front of Pump Hose 2 building showing doors to the fluoride injection room and pump room.

Exterior piping for Pump House 2.

Cracking visible on the exterior of the building.

Front view of Well House 3 showing chemical room addition being constructed.

Well House 2 piping, showing the top of the submerged well in the foreground.

Close-up view of the cap on the submerged well.

Backflow preventer valve is shown as part of the blow-off assembly.

Blow-off assembly.

New piping installed in the new chemical treatment room.

New Rosemount magnetic flow meter installed in the new treatment room.

Front view of Pump House 4.

Water treatment room.

50-gallon fluoride tank.

LMI fluoride feed pump.

50-gallon hypochlorite tank with pump.

LMI hypochlorite feed pump

Pipe room overview.

Submerged well with piping.

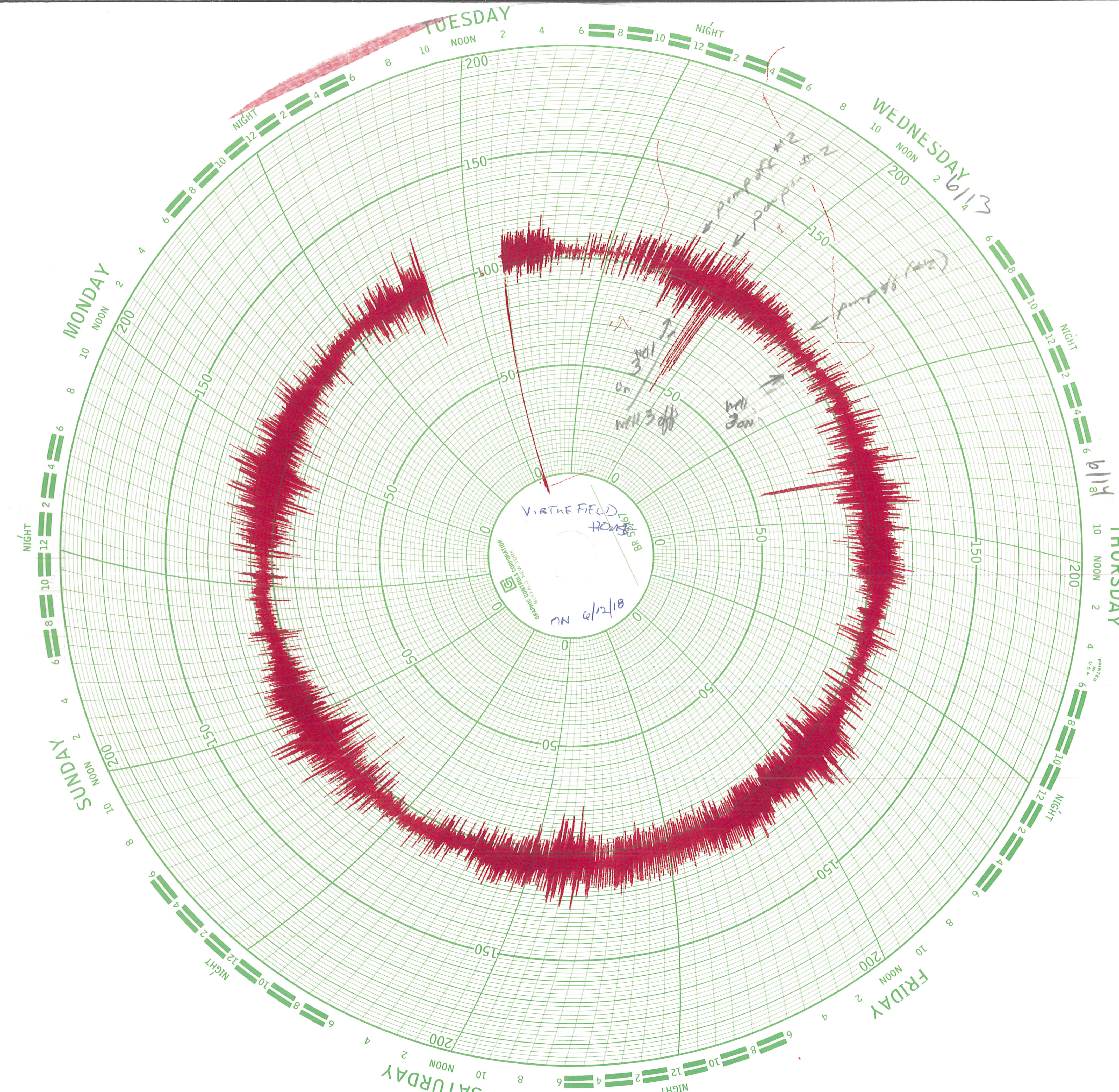
Air relief valve.

8-inch gate valve with backflow preventer.

Pump control valve (left) and blow-off assembly (right).

Sensus propeller meter.

Sensus meter installed.



TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY
MONDAY
NIGHT
NOON
6/13
6/14
Well 3 off
Well 3 on
ON 6/12/18

Sanitary Survey

WSID: VT0005004 MIDDLEBURY WATER DEPT

User ID: Select...

Site Visit Info

Site Visit Date 9/29/2017 **System Notification Date** 11/20/2017

Comments

Category Evaluation Summary

Source	No Deficiencies	**Water System Management**	No Deficiencies
Treatment	Significant	**Operator Compliance**	No Deficiencies
Distribution System	No Deficiencies	**Security**	Significant
Finished Water	Significant	**Financial**	No Deficiencies
Pump	No Deficiencies	**Other**	No Deficiencies
Monitoring Reporting	Minor		

Parties Present

Name	Role
SMART, PATRICK (DWGWPD)	Primary Surveyor
GLEN, WILLIAM	Select...
WERNER, DANIEL R (MIDDLEBURY TOWN)	Select...

Deficiencies

Deficiency

T650

Category Code Treatment **Severity Code** Significant

Determination Date 2/23/2015 **Facility ID** TP001

Resolved Date

Comments:

System is required to continuously monitor disinfection residuals due to population over 3300. Currently system is theoretically calculating the residuals. System does not have fw taps. Still a deficiency during 2017 survey - Water System forced to re-bid work for installing continuous analyzers during spring of 2018. -PCS

Associated Site Visits

Site Visit Date	Site Visit Reason Code
2/23/2015	SNSV

Deficiency

D726

Category Code Distribution **Severity Code** Recommended

Determination Date 7/31/2012 **Facility ID** DS001

Resolved Date 2/23/2015

Comments:

Associated Site Visits

Site Visit Date	Site Visit Reason Code
7/31/2012	SNSV

Deficiency

F705 - Required Storage Facility Inadequate

Category Code Finished Water Storage **Severity Code** Significant

Determination Date 9/29/2017 **Facility ID** ST001

Resolved Date

Comments:

concrete roof is in need of repair or replacement, rebar exposed on portions of damaged roof.

Associated Site Visits

Site Visit Date	Site Visit Reason Code
9/29/2017	SNSV

Deficiency

M002 - Inadequate Security Measures

Category Code Management & Operation
Severity Code Significant
Determination Date 9/29/2017
Facility ID ST001
Resolved Date

Comments:

Unrestricted access to ST001, water system reported that site was a 'party spot' - unauthorized uses of storage tank roof incldue campfires, skateboard park.

Associated Site Visits

Site Visit Date	Site Visit Reason Code
9/29/2017	SNSV

Deficiency

F700 - Inadequate Storage Volume

Category Code Finished Water Storage
Severity Code Minor
Determination Date 9/29/2017
Facility ID ST001
Resolved Date

Comments:

Existing storage tank size does not provide for ADD and fire flows. system asked to provide proposed plan and schedule to provide additional storage.

Associated Site Visits

Site Visit Date	Site Visit Reason Code
9/29/2017	SNSV

Deficiency

R578 - Test Equipment Unavailable/Inadequate or Inadequate Testing Reagent

Category Code M&R
Severity Code Minor
Determination Date 9/29/2017
Facility ID WL003
Resolved Date

Comments:

Need smooth-nosed sample taps on for collecting source samples at each treatment facility.

Associated Site Visits

Site Visit Date	Site Visit Reason Code
9/29/2017	SNSV

Deficiency

R578 - Test Equipment Unavailable/Inadequate or Inadequate Testing Reagent

Category Code M&R
Severity Code Minor
Determination Date 9/29/2017
Facility ID WL004
Resolved Date

Comments:

Need smooth-nosed sample taps on for collecting source samples at each treatment facility.

Associated Site Visits

Site Visit Date	Site Visit Reason Code
9/29/2017	SNSV

Deficiency

D225 - Inadequate Cross-Connection Controls (Storage Bypass)

Category Code	Finished Water Storage	**Severity Code**	Recommended
Determination Date	9/29/2017	**Facility ID**	ST001
Resolved Date			

Comments:

ST001 overflows into 'Old Reservoir' - an uncovered reservoir formerly associated with the system. Water System actively manages water level in Old Reservoir to maintain air gap from ST001 Overflow. Recommend that the system consider installing install passive drainage at old reservoir to eliminate need to actively monitor water level and to remove the attractive nuisance.

Associated Site Visits

Site Visit Date	Site Visit Reason Code
9/29/2017	SNSV

Deficiency

M177 - Operation and Maintenance (O&M) Manual Needed

Category Code	Management & Operation	**Severity Code**	Recommended
Determination Date	9/29/2017	**Facility ID**	
Resolved Date			

Comments:

water system is working on O&M Manual Update (Voluntariarly) - reminded system that all updates are subject to Division review and approval, requested to receive update by 12/31/18.

Associated Site Visits

Site Visit Date	Site Visit Reason Code
9/29/2017	SNSV

System Info

System Name	MIDDLEBURY WATER DEPT		
System Type	Community	**Owner Type**	Local
Active Status	Active	**Operating Category**	3
Activity Date	9/20/1989	**Activity Reason**	Select...
Activity Comments			
Memo Text			

Connections

Connection Type	Meter Type	Number	Meter Size	Remove
Residential	Metered	2,200	0.000	☐

Service Areas

Service Area Type	Primary (Select One)	Remove
Day Care Center	☐	☐
Hotel/Motel	☐	☐
Highway Rest Area	☐	☐
Institution	☐	☐
Medical Facility	☐	☐
Mobile Home Park	☐	☐
Other Area	☐	☐
Other Non-Transient Area	☐	☐
Other Transient Area	☐	☐
Recreation Area	☐	☐
Condominiums	☐	☐
Residential Area	☑	☐
Restaurant		

	☐	☐
Industrial (State)	☐	☐
Agricultural (State)	☐	☐
Nursing Home (State)	☐	☐
School	☐	☐
Summer Camp	☐	☐
Service Station	☐	☐

System Flow Rates

Name	Rate	Unit	Remove
Average Daily Production (Depreciated)	1,200,000.000	GPD	☐
Max Daily Production	2,400.000	GPM	☐
Total Design Capacity (Depreciated)	1,728,000.000	GPD	☐

System Indicators

Name	Indicator	Date	Remove
Required to Chlorinate	Yes		☐
Continuously Chlorinating	Yes		☐
Select...	Yes		☐

Population Served

Start Month	Start Day	End Month	End Day	Begin Date	End Date	Population Type	Count
1	1	12	31	12/11/2009		Residential	5,806

Facility Flows

Supplying Facility		Receiving Facility	Remove Flow
TP001	►	DS001	☐
TP002	►	DS001	☐
TP002	►	SS003	☐
TP002	►	SS004	☐
WL002	►	TP001	☐
WL003	►	TP002	☐
WL004	►	TP002	☐
DS001	►	ST001	☐
ST001	►	DS001	☐

Wells

Well Details

Name WELL #1

Local Name

Facility ID WL001 | **Well ID** 0

Well Type Gravel Well | **Water Type** Groundwater

Activity Inactive | **Activity Date** 1/1/1956

Activity Reason Select... | **Availability** Emergency

Activity Comment Emergency well

Constructed Date 1/1/1956 | **Physical Mod Date**

Pump Type Submersible | **Pump Description**

TNC SWAP Status Select... **TNC SWAP Date**

Well Cap **Source Treatment** No Treatment

Direction

Well Comments physically disconnected from system

Casing Details

Casing ID	Casing Type	Casing Diameter (IN)	Casing Depth	Depth Units
CASE1	STEEL	12	0.0	FT

Screen Details

Screen ID	Screen Type	Screen Top (FT)	Screen Bottom (FT)	Lithology Type	Aquifer Type
SCREEN 1		0.0	0.0		Select...

Flows Rates

Flow Rate Name	Flow Rate Quantity	Flow Rate Unit	Remove

Measures

Measure Name	Measure Quantity	Measure Unit	Remove

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove
Emergency Power	NO		☐
GWUDISW Determination Done	YES	3/27/1996	☐
GWUDISW Exempt by Application	YES		☐
Source Protection Plan Update Date	YES	10/15/2014	☐

Well Details

Name WELL #2

Local Name PALMER SPRINGS

Facility ID WL002 **Well ID** 0

Well Type Gravel Well **Water Type** Groundwater

Activity Active **Activity Date** 1/1/1978

Activity Reason Select... **Availability** Permanent

Activity Comment

Constructed Date 1/1/1978 **Physical Mod Date**

Pump Type Vertical turbine **Pump Description**

TNC SWAP Status Select... **TNC SWAP Date**

Well Cap SANITARY CAP **Source Treatment** Treated

Direction

Well Comments Pump capacity changed due to installation of CT piping appurtenances increasing pump discharge head. Actual pumping rate is now at 1550 gpm per 12/09 survey.

Casing Details

Casing ID	Casing Type	Casing Diameter (IN)	Casing Depth	Depth Units
CASE1	STEEL	24	47.0	FT

Screen Details

Screen ID	Screen Type	Screen Top (FT)	Screen Bottom (FT)	Lithology Type	Aquifer Type
SCREEN 1		0.0	0.0		Select...

Flows Rates

Flow Rate Name	Flow Rate Quantity	Flow Rate Unit	Remove
Pump Capacity	1,550.000	GPM	☐

Measures

Measure Name	Measure Quantity	Measure Unit	Remove
Depth at Completion	47.000	FT	☐

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove

Emergency Power	YES		☐
GWUDISW Determination Done	YES	3/27/1996	☐
GWUDISW Exempt by Application	YES		☐
Source Protection Plan Original Date	YES	9/15/1999	☐
Source Protection Plan Update Date	YES	10/26/2017	☐

Well Details

Name	WELL #3		
Local Name	JOHNSON WELL #3		
Facility ID	WL003	**Well ID**	0
Well Type	Gravel Well	**Water Type**	Groundwater
Activity	Active	**Activity Date**	1/1/1985
Activity Reason	Select...	**Availability**	Permanent
Activity Comment			
Constructed Date	1/1/1985	**Physical Mod Date**	
Pump Type	Vertical turbine	**Pump Description**	
TNC SWAP Status	Select...	**TNC SWAP Date**	
Well Cap	SANITARY CAP	**Source Treatment**	Treated
Direction			
Well Comments			

Casing Details

Casing ID	Casing Type	Casing Diameter (IN)	Casing Depth	Depth Units
CASE1	STEEL	24	144.0	FT

Screen Details

Screen ID	Screen Type	Screen Top (FT)	Screen Bottom (FT)	Lithology Type	Aquifer Type
SCREEN 1		0.0	0.0		Select...

Flows Rates

Flow Rate Name	Flow Rate Quantity	Flow Rate Unit	Remove
Approved Design Capacity	400.000	GPM	☐

Measures

Measure Name	Measure Quantity	Measure Unit	Remove
Depth at Completion	144.000	FT	☐

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove
Emergency Power	NO		☐
GWUDISW Determination Done	YES	3/27/1996	☐
GWUDISW Exempt by Application	YES		☐
Source Protection Plan Original Date	YES	9/15/1999	☐
Source Protection Plan Update Date	YES	10/26/2017	☐

Well Details

Name	WELL #4		
Local Name	JOHNSON WELL #4		
Facility ID	WL004	**Well ID**	5086
Well Type	Gravel Well	**Water Type**	Groundwater
Activity	Active	**Activity Date**	1/1/1997
Activity Reason	Select...	**Availability**	Permanent
Activity Comment			
Constructed Date	1/1/1997	**Physical Mod Date**	

Pump Type Vertical turbine

Pump Description

TNC SWAP Status Select...

TNC SWAP Date

Well Cap SANITARY CAP

Source Treatment Treated

Direction

Well Comments 1997 pump test indicates yield of 800 gpm per old inventory, but operator says that it will not produce that much due to cavitations of pump. Rate of pumping is realistically 450 gpm

Casing Details

Casing ID	Casing Type	Casing Diameter (IN)	Casing Depth	Depth Units
CASE1	STEEL	14	147.0	FT

Screen Details

Screen ID	Screen Type	Screen Top (FT)	Screen Bottom (FT)	Lithology Type	Aquifer Type
SCREEN 1		0.0	0.0		Select...

Flows Rates

Flow Rate Name	Flow Rate Quantity	Flow Rate Unit	Remove
Drillers Yield	800.000	GPM	☐
Pump Capacity	450.000	GPM	☐

Measures

Measure Name	Measure Quantity	Measure Unit	Remove
Depth at Completion	187.000	FT	☐
Static Water Level	28.000	FT	☐

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove
Emergency Power	NO		☐
GWUDISW Determination Done	YES	8/11/1998	☐
GWUDISW Exempt by Application	YES		☐
Source Protection Plan Original Date	YES	9/15/1999	☐
Source Protection Plan Update Date	YES	10/26/2017	☐

Treatment Plants

Treatment Details

Name TREATMENT PLANT PALMER SPRINGS

Local Name

Facility ID TP001

Water Type Groundwater

Activity Active

Activity Date 1/1/1956

Activity Reason Select...

Availability Permanent

Activity Comment

Constructed Date

Physical Mod Date

Pump Type Positive displacement

Pump Description

Contact Time (min) 23

Filter Type Select...

Contact Time Comments CT is provided using CT Pipe. See WSID file back flap for piping detail. 40,000 gallon credited volume/1700=23.5 minutes. 6/23.5=0.25 ppm min. free Cl2 residual to provide for 4-long inactivation of viruses. Use minimum of 0.3 ppm

Direction Text

Treatment Units

Unit Name GENERIC UNIT

Unit Type Generic Unit

Treatment Code	Remove
D423 - DISINFECTION - HYPOCHLORINATION, PRE	☐
Z380 - OTHER - FLUORIDATION	☐

Measures

Measure Name	Measure Quantity	Measure Unit	Remove
Cl concentration for 4-log disinfection	0.300	Select...	☐

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove
Emergency Power	YES		☐
Approved/Permitted	YES		☐

Treatment Details

Name TREATMENT PLANT WELLS 3 AND 4

Local Name

Facility ID TP002 **Water Type** Groundwater

Activity Active **Activity Date** 1/1/1978

Activity Reason Select... **Availability** Permanent

Activity Comment This facility has two locations, each well, with chemical injected into well feed line. There is a shared contact line for each treatment location.

Constructed Date **Physical Mod Date**

Pump Type Positive displacement **Pump Description**

Contact Time (min) 20 **Filter Type** Select...

Contact Time Comments CT is provided using CT Pipe. See WSID file back flap for piping detail. 23,000 gallon credited volume/1150=20 minutes. 6/20=0.3 min. free Cl2 residual to provide for 4-long inactivation of viruses

Direction Text

Treatment Units

Unit Name GENERIC UNIT **Unit Type** Generic Unit

Treatment Code	Remove
D423 - DISINFECTION - HYPOCHLORINATION, PRE	☐
Z380 - OTHER - FLUORIDATION	☐

Measures

Measure Name	Measure Quantity	Measure Unit	Remove
Cl concentration for 4-log disinfection	0.300	Select...	☐

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove
Emergency Power	NO		☐
Approved/Permitted	YES		☐

Storage

Storage Details

Name NEW CHIPMAN HILL RESERVOIR

Local Name

Facility ID ST001 **Water Type** Groundwater

Storage Type Ground

Construction Material Concrete **Coating Type** Unlined

Activity Active **Activity Date** 1/1/1956

Activity Reason Select... **Availability** Permanent

Activity Comment Floats on the system

Constructed Date 1/1/1956 **Physical Mod Date**

Pump Type Select... **Pump Description**

Direction

Storage Comments

Flow Rates

Flow Rate Name	Flow Rate Quantity	Flow Rate Unit	Remove
Approved Design Capacity	1,500,000.000	GAL	☐
Effective Volume	1,500,000.000	GAL	☐

Measures

Measure Name	Measure Quantity	Measure Unit	Remove

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove
Covered Indicator	YES		☐
Pressurized Indicator	NO		☐
Altitude Valve Indicator	NO		☐
Emergency Power	NO		☐
Approved/Permitted	YES		☐

Other Facilities

Other Facility Details

Name DISTRIBUTION SYSTEM

Local Name

Facility Type Distribution System

Facility ID DS001 **Water Type** Groundwater

Activity Active **Activity Date** 1/1/1910

Activity Reason Select... **Availability** Permanent

Activity Comment all connections served by source pumps and gravity storage that floats on the system

Constructed Date **Physical Mod Date**

Pump Type Select... **Pump Description**

Directions

Flow Rates

Flow Rate Name	Flow Rate Quantity	Flow Rate Unit	Remove

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove
Emergency Power	NO		☐
Approved/Permitted	YES		☐
AC Pipe	YES		☐
PB Pipe	NO		☐

Other Facility Details

Name WELL 3 SAMPLING POST TREATMENT

Local Name

Facility Type Sampling Station

Facility ID SS003 **Water Type** Select...

Activity Active **Activity Date** 12/21/2009

Activity Reason Select... **Availability** Permanent

Activity Comment

Constructed Date **Physical Mod Date**

Pump Type Select... **Pump Description**

Directions

Flow Rates

Flow Rate Name	Flow Rate Quantity	Flow Rate Unit	Remove

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove

Other Facility Details

Name	WELL 4 SAMPLING POST TREATMENT		
Local Name			
Facility Type	Sampling Station		
Facility ID	SS004	**Water Type**	Select...
Activity	Active	**Activity Date**	12/21/2009
Activity Reason	Select...	**Availability**	Permanent
Activity Comment			
Constructed Date		**Physical Mod Date**	
Pump Type	Select...	**Pump Description**	
Directions			

Flow Rates

Flow Rate Name	Flow Rate Quantity	Flow Rate Unit	Remove

Indicators

Indicator Name	Indicator Value	Indicator Date	Remove

ATTACHMENT 1
SCOPE OF SERVICES
WATER SYSTEM MODEL
MIDDLEBURY, VERMONT
December 5, 2017

I. GENERAL:

A. Dufresne Group (DG) will provide customary civil engineering and consulting services to prepare a computer model of the water system for the Town of Middlebury (CLIENT). A GIS based water system basemap will be prepared as part of the work. A calibration report will be prepared that describes the field testing and the methods used to calibrate the model to reflect actual field test results. DG will provide copies of the GIS database, the input data file, and on-site training in the use and maintenance of the model. These tasks and activities define this PROJECT. The scope of work includes the following items:

II. BASIC SERVICES:

A. DG will perform the following Basic Services:
   1. Attend a kick off meeting and discuss water system operation, water system data file structure, SCADA system (if any), project staff organization, goals and objectives.
   2. Review all record drawings related to the water system on file at the Town, scan the record drawings and provide a digital copy to the Town.
   3. Review existing information provided by the CLIENT including previous fire flow test data, tank level charts, certified pump curves or shop drawing information on well pumps and booster pumps, historical pressure data, source flow data, operational logs, SCADA information, customer complaint files, and characteristics of key system components.
   4. Meet with Town staff and discuss the operational aspects of the water system including the well sources of supply, pressure reducing stations or booster stations, and the distribution storage tank. Visit these facilities, record pertinent data, and photograph these facilities.

5. Review drawings and other information for any privately owned and maintained fire pumping systems for large customers which obtain water from the Town's distribution system.
6. Review sprinkler system flow and pressure requirements for large customers based on data provided by the CLIENT.
7. Discuss water main interconnection points within the distribution system and identify any areas where interconnections are in question.

B. Assess and Analyze Reported Water Distribution Surges:

1. Using calibrated digital data loggers and analog paper chart recorders complete two weeks of system pressure monitoring.
    a. Two of these monitoring stations will be located at or near water system interconnection points located between the Town of Middlebury and Middlebury College.
2. Review the monitoring data and note the existence of any hydraulic surges in the distribution system. Note the characteristics, date, duration, and time of these surges and comment on suspected causes. Screen the source facilities and comment on any potential surge effects due to operation of the well sources of supply. Provide written correspondence on these findings.
3. If the source of the surges is not identified, assist the CLIENT in developing a program to identify and resolve the pressure surges.

C. System Demand Analysis:

1. Review and analyze total system daily flow for the past three calendar years and determine average and maximum day demand for each of the three years. Develop estimates of peak hour demand based on similar communities. Plot the daily flow for each day of these three calendar years.
2. Review and analyze total system daily flow for the past ten years and develop a linear projection to project future estimated average day and maximum day demands for the next 20 years.
3. Summarize the existing and future (projected 20 years hence) average day, maximum day, and peak hour demand.
4. Using available water meter data provided by the CLIENT determine the ten largest water use customers.

5. Develop a system specific extended period simulation global demand factor curve by reviewing source of supply contribution and storage tank fluctuations.

D. System Storage Analysis:

1. Assess system storage needs based on emergency storage, peak hour fluctuation, and fire flow storage.
2. Discuss active and dead storage in the existing water storage tank.
3. Discuss the use of standby power or alternative drives to reduce total water storage requirements.
4. Based on engineering guidelines, identify any deficiencies in total water system storage and recommend the amount of additional storage necessary to comply with normal engineering practices.
5. Discuss the issue of disinfection byproducts, water age, and ice formation. Discuss the use of alternative mixers or aeration.

E. Basemap Preparation:

1. Using the existing water system basemap and record drawings, prepare a water system basemap showing water system attributes including source facilities, storage tanks, control vaults, pressure reducing valves, booster pumping stations, mainline valves, hydrants, and blow-offs and water main characteristics including diameter, material, minor losses, approximate installation date, location, interconnection details, and information source.
2. Receive any digital background GIS files from the CLIENT showing structures, roads, and ground elevation with contour intervals of at least 5 feet. The background for the basemap can be GIS layers, orthophotos, USGS, or other topographic mapping preferred by the CLIENT.
3. Ensure the basemap data will be interchangeable for viewing and plotting in either ArcGIS or AutoCAD software.

F. Using WaterGEMS®, prepare a water system computer model using water system information.

1. Use the water system basemap to set the general location of water mains and add other features and/or attribute files including:

a. Water main attributes as described above. All known distribution or transmission piping (including 2-inch diameter mains and above) will be included in the model input file. Any water line serving more than two customers as described by the CLIENT will be included in the model regardless of the diameter. Privately owned water mains or related water works facilities served by the Town of Middlebury will be identified as private and included in the model.
b. Customers located in high elevation areas. These customers will be represented as individual nodes for use in setting the system pressure requirements during fire flow suppression.
c. Groundwater source locations, pump curves, system head curve showing suction and discharge pressure relationships during various flow conditions.
d. Storage tank size, geometry, material, and construction date.
e. Any control structures such as altitude valves.
f. Any source control logic such as well operation based on tank level.

2. Meet with the Town of Middlebury Water Department Superintendent and review the basemap and input file for the model.
3. Update the basemap and input file for the model based on CLIENT input.

G. Model Calibration:

1. Calibrate the model using a steady state analysis and incorporate information obtained during the field tests.
2. In addition to field test locations and existing pressure monitoring stations (if any), establish three additional pressure calibration monitoring locations for use during fire flow testing and C-value testing. Under special services obtain horizontal location using Vermont State Plane coordinates and the elevation using NAVD88 vertical datum using sub-centimeter survey grade instruments. The calibrated pressure recorders will be provided and installed by DG to monitor and record system pressure during normal operation and during the field testing.

3. Obtain the most recent water system testing records from the Insurance Services Organization (ISO). Depending on the age of the data, this information may be used for preliminary calibration data and will be used to establish proposed fire flow locations and to establish the Needed Fire Flow (NFF) listed at these locations.
4. Verify that boundary conditions and operational parameters are accurately represented in the model using information obtained through the CLIENT or by field visits including:
    a. Observations of the operation of the well pumping stations to verify pump curves, flow, and pressure information. Calibrated pressure gauges will be used to obtain suction and discharge pressure.
    b. Observe the operation of any main line pressure reducing valves to verify pressure and hydraulic gradeline information. Calibrated gauges will be used to determine upstream and downstream pressures.
    c. Observe the operation of any main line booster pumping stations to verify pressure and hydraulic gradeline information. Calibrated gauges will be used to determine upstream and downstream pressures.
    d. Calibrate SCADA data for tank level to actual elevations
5. Documentation of attempts to calibrate shall be kept and incorporated into the model as notes, as well as in the final technical documents.
6. Prepare a calibration report which outlines how the water model was prepared, reviewed, and calibrated and provide color basemaps of the water system to include water mains colored by diameter.

H. Using of the Calibrated Model for analysis of alternative improvements:

1. Using the calibrated water system model, assist the CLIENT in identifying water system deficiencies and assessing potential system improvements to resolve these deficiencies. Identify existing water distribution infrastructure deficiencies as follows:
    a. Any areas in the water service area where customers have less than 35 psi during either existing or future average day demand conditions.
    b. Any areas in the water service area where customers have less than 20 psi during any of the “Needed Fire Flow” (NFF)

locations identified by the Insurance Service Organization (ISO) as listed in the latest ISO report or during peak hour demand.

   c. Any water transmission or distribution mains that are deficient based on headloss and velocity criteria as developed by the American Water Works Association (AWWA).

2. Prepare a water service area basemap showing areas within the Town of Middlebury that can be served based on the current water system gradeline such that customers have at least 35 psi at the first floor location. Identify areas that are subject to pressures less than 20 psi during ISO established Needed Fire Flows concurrent with future maximum day demand. Also show areas that are subject to pressures less than 20 psi during minimum fire flows of 500 gpm as provided under the Vermont Water Supply Rule concurrent with future maximum day demand.
3. Based upon modeling results, recommend existing infrastructure rehabilitation to resolve system deficiencies or add flexibility and reliability. Include consideration of water storage tanks if beneficial in stabilizing pressures at system extremities and contribution of fire flow. Assess the fill and draw rates for potential storage tanks using Extended Period Simulation analysis.
   a. One location for analysis of a potential future water storage tank will be on the property currently owned by A. Johnson located east of School House Hill Road
4. Discuss current planning and zoning trends and identify any areas planned for development likely to be above the current water service area or outside the limits of the existing water distribution system.
5. Evaluate the list of water main projects identified in the June 30, 2017 Water Main Replacement Planning Memo by simulating these projects as completed and noting any differences between the existing system (without these improvements) and if these improvements were completed. Analyze differences during fire flow transmission and peak demand. These potential projects currently defined include:

   a. 7,500 linear feet on US Route 7 – Cady Road
   b. 7,000 linear feet Exchange Street

c. A potential connecting loop from Happy Valley Road to Exchange Street as an alternative to improve peak hour pressures in the Painter Hills subdivision.
    i. Evaluate this potential loop as an alternative supply to the Exchange Street Industrial Park and its effect on the customers east of Happy Valley Road.
d. Court Square area
e. South Street from Main Street to Porter Field Road
f. 4,000 linear feet in the Gorham Subdivision
g. Foote Street
h. Woodland Park, Meadow Way and Swanage – Replace asbestos cement (AC) pipe
i. Cross Country Line from Palmer Springs to Colonial Drive
j. 2,600 linear feet on Sheep Farm Road from Waybridge Street to Sheep Farm Road
k. Colonial Drive
l. Washington Street Extension to Happy Valley Road
m. Washington Street

6. Evaluate opportunities for micro-electric generation in the water distribution system.
7. Develop a priority ranking system based on consideration of the following factors.
    a. Existing condition based on history of leakage
    b. Estimated Capital Cost
    c. System hydraulic benefits
    d. Local acceptance
    e. Compliance with local planning trends and infrastructure needs
8. Based upon modeling results, recommend a prioritized list of existing infrastructure rehabilitation to resolve system deficiencies or add flexibility and reliability. Estimate the construction cost and total capital cost for these improvements.

I. Provide the following deliverables as part of the project:

1. A data file on a thumb drive, which has all scanned mapping used in the PROJECT.
2. Agendas and memos for all meetings regarding the project.

3. A calibration report outlining the field test procedures, field test data, pressure monitoring charges, and the measures taken to calibrate the model.
4. A file with photos and equipment descriptions for the source, storage, and pumping facilities.
5. A copy of the input file.
6. A GIS database with the water system attributes. The database will be compatible with the CLIENT's MapInfo GIS Software. The database will include shape files (.shp) for use with CLIENT's MapInfo GIS Software.
7. A letter report on system surges.

III. SPECIAL SERVICES:

A. DG will provide the following special services for this PROJECT:

1. Meet with the CLIENT three times during the PROJECT (in addition to normal field visits) and discuss findings and receive input. Prepare agendas and written minutes of these proceedings. Distribute copies to those attending the meeting.
2. Using sub-centimeter survey grade equipment, complete topographic survey services and obtain the three dimensional location for major water works facilities including:
    a. Water source facilities
    b. Water storage facilities (floor and overflow elevations)
    c. Pressure monitoring locations
    d. Distribution system pressure reducing valve vaults
    e. Pressure booster stations
    f. High elevation customers
3. Using sub-centimeter survey grade equipment, complete topographic survey services and obtain the three dimensional location for the hydrants or pressure monitoring locations used during fire flow and C-Value testing.
4. Perform approximately ten fire flow tests and approximately two C-value tests. Locations of the various tests will be selected based on review of the existing model and existing information.
5. Assist with the preparation of funding applications including the State Revolving Loan Application for funding under the Drinking Water State Revolving Fund (DWSRF) program.

6. Meet with the CLIENT and the Infrastructure Committee two times during the PROJECT to review the results of the study and to review the next steps toward a bond vote. Prepare agendas and written minutes of these proceedings. Distribute copies to those attending the meeting.
7. After the CLIENT purchases a copy of WaterGEMS, provide 8 hours of on-site training in the use and maintenance of the water system hydraulic model including methods for the following:
    a. Data input for pipes, nodes, minor losses, tanks, pressure control valves, pumps and motors (constant rpm and variable speed), and sources of supply.
    b. Simulating a fire flow and analysis of system effects.
    c. Simulating an alternative system improvement; pipe, tank, booster pump station, and pressure reducing valve.
    d. Setting demand patterns for extended period simulations.
    e. Use of the extended period simulation for assessing tank fill rates and pressure fluctuations during the day.
8. Schedule and visit facilities of the 10 largest use customers and discuss water use characteristics including estimated peak instantaneous use. Attempt to obtain the data via phone or e-mail contact for any users that do not agree to a site visit.