SECTION 4

WATER SUPPLY NEEDS ANALYSIS

4.1 INTRODUCTION

This section looks at the various needs related to water supply in North Reading. Future water demands are developed based upon existing water supply and usage. Furthermore, issues with the current water system are identified. Defining water needs in North Reading provides the basis for determining viable alternatives.

4.2 WATER NEEDS ASSESSMENT METHODOLOGY

The major component to determining water supply needs in North Reading is identifying future water demands. To determine future water needs, first a future population was estimated for a the twenty year planning period of this study. Historical water demand trends were applied this future population to confidently estimate a future water demand.

Population and future water demand projections are based on the 2014 Waster Master Plan completed by Wright-Pierce, Annual Statistical Reports, and input from the Town. This was applied to historical water demands.

In addition to determining future water needs, the Town seeks also to reduce system complexity, simplify and reduce operations and maintenance, and reduce stress on the Ipswich River Basin.

4.3 PROJECTED WATER DEMAND

Projected water demands for North Reading are determined based on future population projections and historical water demands.

4.3.1 Population Projections

As part of the 2014 Master Plan, population projections developed by a variety of planning organizations were used as a basis for making water demand projections. Data was obtained from the US Census Bureau, MISER and the Metropolitan Area Planning Council (MAPC). The projections provided by these agencies relied on the 2000 US Census Bureau estimates as a starting point for making their future projections.

The U.S. Census Bureau developed population data the years 2000 and 2010. MAPC developed projections in 10 year intervals for the years 2020 and 2030. MAPC also developed a projection for the year 2035. In general, the estimates developed by the agencies assume a linear growth rate ranging from 0.1% to 3.0%.

MAPC projections indicated that the population of North Reading would be 14,848 residents in the year 2030, which would be a decrease from the reported 2010 US Census Population of 14,892 residents. Note that the projection made by MAPC is based on a projected 2010 population of 14,418 which under-estimates the actual census data by 474 persons. Despite this discrepancy, the 2014 Water System Master Plan recommended that growth percentages determined by MAPC be used as a basis for determining an accurate 2013 population. MAPC estimated growth between 2010 and 2013 at 0.03%. This growth rate was applied to the US Census Bureau's 2010 population of 14,892, resulting in a 2013 population of 14,896.

Discussions with the North Reading Community Planning Department have indicated that there is a strong desire in Town to encourage growth in Town. While the desire for growth does not necessarily drive a need for water, the population projection for future use should take the potential growth into account. To establish potential growth for a twenty year planning period, a review of the Town's undeveloped and under developed lots was conducted. This analysis concluded that there are approximately 368 undeveloped residential lots based on GIS data provided by the town.

A residential lot was considered underdeveloped if the lot size was at least double the minimum lot size for the zoning designation for the lot. For example, if a lot was zoned for residential use over 80,000 square feet, then lots with an area greater than 160,000 square feet were considered under developed since the lot could be split for subdivision. The analysis estimated that there are approximately 559 lots that are underdeveloped.

Assuming a household density of 2.71 people per house as established by the 2010 U.S. Census Bureau's Demographic Profile for North Reading, the 927 undeveloped and under developed lots represents a potential population increase of 2,512 people over the next twenty years. This growth is significantly higher than the growth estimated by the MAPC study. Therefore, to improve the Town's ability to provide drinking water for its entire population, any buildout scenario should include these 2,512 people.

Based on the information presented above and the evaluation of the data available, the Town's growth over the planning period of this report could be significant. The population projections discussed above will be used as a basis for developing residential water use forecasts, with the population projected to increase from 14,896 in 2013 to 17,408 during build out.

4.3.2 Water Demand Trends

There is generally a close relationship between a community's population and total water consumption. Residential water consumption is directly linked to population growth in a community.

Historical water usage in North Reading was evaluated to determine past water usage trends and characteristics. An analysis of water use in North Reading from 2002 through 2014 was made and used to forecast future demands. Historical water use data was obtained from the Town's Annual Statistical Reports (ASRs) which is submitted each year to the MassDEP.

The table below shows Average Day Demands (ADD) and Maximum Day Demands (MDD) in North Reading through 2002 and 2014. ADD is defined as the total water used over a year divided by 365 days. The ADD is useful in estimating total water demand (Safe Yield or Permitted Withdrawal). MDD is defined as the maximum day of water use that occurs over a given year and typically occurs during a prolonged high usage period. MDD is considered the single most critical water-use component used to evaluate a system as treatment, pumping and transmission capacity must be adequate to provide the MDD. The ratio of the maximum to average-day demand (MDD/ADD), or the peaking factor, provides an indication of the degree of fluctuation of demands throughout the year. Table 4-1 shows the total raw water pumped from Town sources and total purchased from Andover.

TABLE 4-1
HISTORICAL WATER DEMAND*

Year	Total Production (Town Sources) (MG/year)	Total Purchased (MG/year)	ADD (MGD)	MDD (MGD)	Ratio of MDD/ADD
2002	207.8	302.6	1.40	2.38	1.70
2003	242.5	263.9	1.39	2.39	1.72
2004	194.5	293.5	1.34	2.07	1.55
2005	211.7	360.2	1.57	2.56	1.63
2006	203.5	321.6	1.44	2.27	1.58
2007	164.9	359.9	1.43	2.27	1.58
2008	187.2	332.9	1.42	2.36	1.66
2009	171.8	315.2	1.33	2.17	1.62
2010	181.7	322.9	1.38	2.47	1.79
2011	198.7	342.3	1.48	2.38	1.61
2012	212.6	313.0	1.44	2.26	1.57
2013	186.8	319.4	1.39	2.15	1.55
2014	169.8	346.9	1.41	2.23	1.58
Average 2008-2014	186.9	327.5	1.41	2.29	1.63

* Data as reported in the 2002 – 2014 Massachusetts DEP Annual Reports.

Based on this analysis, it was determined that data between 2008 and 2014 is the best representation of North Reading, and data from this six year period was used for projection purposes. Water conservation efforts and system O&M improvements have led to more stable and sustainable water use practices and less unaccounted-for water. As shown in Table 4-1, the average ADD between 2008 and 2014 was approximately 1.41 MGD.

4.3.3 Projected Residential Water Demand

To best account for future growth in the water demand projection, it is important to analyze residential and non-residential flow trends independently.

Analysis of water usage trends on a "gallons per service" and "gallons per capita" basis is another important tool used to evaluate past trends and project future demands. Per the Water Management Act (WMA) guidelines, communities are encouraged to meet specific residential per capita thresholds through water conservation efforts.

The Town reports per service water usage annually. Table 4-2 presents historical use figures for each customer category from 2002 through 2014. These numbers are based on metered finished water usage as reported in the Town's ASRs.

TABLE 4-2
HISTORICAL WATER USAGE BY CUSTOMER CATEGORY (MGD)

Year	Residential	Commercial	Institutional/Industrial Other*	Total
2002	1.07	0.12	0.08	1.28
2003	1.00	0.11	0.11	1.22
2004	0.84	0.06	0.11	1.01
2005	0.90	0.06	0.10	1.07
2006	0.83	0.09	0.12	1.04
2007	0.93	0.07	0.11	1.11
2008	0.91	0.04	0.12	1.07
2009	0.86	0.08	0.14	1.07
2010	0.94	0.07	0.11	1.12
2011	1.07	0.06	0.08	1.21
2012	1.03	0.07	0.05	1.15
2013	0.89	0.05	0.01	1.00
2014	1.02	0.09	0.07	1.18
Average 2008-2014	0.96	.07	.08	1.11

*Reported differently from year to year in ASRs, other can include municipal, industrial, recreational

Residential flows are often presented in term of use per person, or Gallons per Capita Day (gpcd). As shown in Table 4-3 the average residential water demand between 2008 and 2014 was 0.96 MGD. Assuming a residential population of 14,896, of which 621 people are well users, the average residential water demand can be represented as approximately 67 gpcd.

Table 4-3 (below) shows per capita water usage per system total and residential total as reported in the Town's ASRs.

TABLE 4-3
PER CAPITA WATER USAGE

Year	Gallons per Capita per Day-Residential Only
2002	79.6
2003	70.8
2004	62.4
2005	67.0
2006	61.2
2007	67.6
2008	65.2
2009	61.0
2010	65.0
2011	74.0
2012	69.2
2013	59.1
2014	70.0
Average	**67.1**

The residential per capita usage is an important trend used by the WMA for water supply permitting, as well as for projecting future water supply needs. While the Town does not fall under the WMA, the WMA's recommended per capita use of 65 gpcd has been accepted by the industry and many entities, such as the MWRA, use this value.

The Town's residential per capita usage ranged from 61 gpcd to 75 gpcd between 2008 and 2014 as reported in the Town's ASR, and based on the ADD discussed above the per capita demand is approximately 67 gpcd. Through conservation efforts, pricing controls and other methods the town expects to be at or below the 65 gpcd standard, with a long term goal of eventually lowering water use to less than 55 gpcd. North Reading believes that it can manage demand to the levels that are seen in surrounding communities whose water use are nearing 50 gpcd.

For the purposes of this study a per capita demand of 65 gpcd is used. A reduction in current use to 65 gpcd within the study time frame is attainable; however, reaching per capita flow below 60 gpcd will require a community wide collaboration which will likely extend beyond the study time frame.

When a 65 gpcd demand is used with the projected population of 17,408, the resulting projected ADD is 1.13 MGD. It should be noted that by using the projected population as the served population in the calculation, it is assumed that all current well users will be added to the water distribution system. This is consistent with the buildout scenario and the Town's goals.

4.3.4 Projected Non-Residential Water Demand

Non-residential water demand does not necessarily correlate with population growth, or residential water demand. Table 4-4 shows the combined commercial, institutional, and industrial water use between 2002 and 2014. As shown in Table 4-4 non-residential use has been on the decline since 2009.

TABLE 4-4
NON-RESIDENTIAL WATER DEMAND (MGD)

Year	Total
2002	0.21
2003	0.22
2004	0.17
2005	0.16
2006	0.22
2007	0.18
2008	0.16
2009	0.21

2010	0.18
2011	0.13
2012	0.12
2013	0.10
2014	0.16

A continued decrease in non-residential water use is not sustainable. Based on discussion with the Town's Community Planning Department they have identified several causes of the commercial decline in Town. One of the most prevalent causes of limited growth and increased abandonment of commercial lots is the lack of municipal infrastructure. The Town has plans to renew growth in commercial areas such as the Route 28 corridor. Rebuilding the commercial and industrial consumer base will be a lengthy process and cannot be accurately captured at this time. To strike a balance between the current downward trend and the planned growth, the non-residential water demand was assumed to be 80% of the maximum demand experienced over the last twelve years (0.22 MGD in 2003 and 2006). This results in a non-residential demand of approximately 0.18 MGD or 65 MG per year. This demand has been observed as recently as 2010 and represents an increase of approximately 1.46 MG per year over the next 20 years.

Similar to residential flow projections, an evaluation of undeveloped and underdeveloped lots was conducted. It was determined that approximately four percent of the lots zoned for nonresidential use in North Reading were undeveloped or underdeveloped. Therefore, a four percent increase in nonresidential flow was estimated. When these additional lots are accounted for, the total projected non-residential flow is 0.19 MGD. This future flow requirement is modest and consistent with the Town's growth initiatives.

4.3.5 Maximum Daily Demand

The Maximum Daily Demand (MDD) is the highest daily demand that occurs in the water system over the course of a calendar year. While evaluation of the ADD is important, the system experiences demand both lower and higher than the ADD from day to day. It is important to evaluate the impact higher demand has on the water system; therefore the MDD is often used for planning and design of water infrastructure.

The MDD often correlates to the ADD for a given system. Therefore the MDD is often represented as a ratio or peaking factor to the ADD. To determine the appropriate MDD peaking factor for the North Reading system, the relationship of ADD and MDD was analyzed for the last six years. The MDD/ADD ratio for North Reading ranged from 1.53 to 1.79 with an average of 1.6 between 2008 and 2014, as shown in Table 4-2 (historical water demand table). There was not an apparent upward or downward trend with the ratio; therefore, the average value experienced over the period (1.6) will be used for projections.

4.3.6 Future Requirements

Future water demand requirements are based on a number of factors including:

- Per capita water use
- Residential and non-residential average day demand
- Municipal water use
- Unaccounted for water use
- Residential and non-residential maximum day demand
- Peak hourly demand

This section presents a summary of calculating these factors as well as a total projected flow.

4.3.6.1 Per Capita Water Use

As described previously, the residential per capita usage is an important trend used by the WMA for water supply permitting, as well as for projecting future water supply needs. While the Town does not currently fall under the WMA, the WMA's recommended per capita use of 65 gpcd has been accepted by the industry and many entities, such as the MWRA. This value will be used to determine future water requirements.

Futhermore, North Reading hopes to follow the lead of a few surrounding communities whose water use are nearing 50 gpcd. Future water requirements based on this residential water use will also be shown.

4.3.6.2 Residential and Non-residential Average Day Demand

As discussed in Sections 4.4.3 and 4.4.4 above, the projected residential and non-residential ADDs are 1.13 and 0.19 MGD, respectively. These values are based on a projected population of 17,408 people. This population was determined by a potential growth of 2,512 people from the 2013 base population of 14,896. This also assumes all current well users will transition to public water supply.

4.3.6.3 Municipal Water Use

Confidentially estimated municipal water use (CEMU) is also an important factor to consider. As shown in Table 4-5 below, the CEMU estimated by North Reading in 2013 was 45.4 million gallons, or 0.12 MGD. These numbers were reported in their 2013 ASR. Values have ranged from 0.05 to 0.12 between 2008 and 2014, thus 0.12 MGD will be used as a representative estimate of municipal water use moving forward. Table 4-5 shows a breakdown of municipal water use.

TABLE 4-5
CONFIDENTLY ESTIMATED MUNICIPAL USE MG/YEAR

Year	2013
Fire Protection and Training	2
Hydrant/Water Main Flushing, Main Construction	1.43
Flow testing	0.05
Bleeders/blow offs	3.86
Tank overflow and drainage	0
Sewer and Stormwater system flushing	0
Street Cleaning	0.05
Source Meter Calibration Adjustments	37.6
Major water main breaks	0.38
Total	**45.4**

4.3.6.4 Unaccounted for Water Use

All water systems include a percentage of water that is produced but not accounted for through meters; defined as the unaccounted-for water (UAW) which must be accounted for in projections. In the past, a range of 15 to 20 percent for UAW has been the accepted industry standard. Massachusetts, under the Water Management Act, has established a performance standard for UAW of 10 percent. Many organizations and permitting agencies, including the MWRA and Water Resources Commission (IBTA), have adopted this guideline. Therefore, North Reading should work towards this.

In 2006, the MassDEP developed and implemented a standard methodology for calculating UAW by water systems. The formula gives communities credit for various categories of non-metered uses such as water used for flushing and fire flow testing, treatment plant process water, mains and service leakage, inaccuracies in meters, etc.

Sources of unaccounted-for water use reported by North Reading between 2002 and 2011 include:

- Lost water from water main leaks.
- Losses due to under and over registering water service and master meters.
- Fire protection.

Table 4-6 presents the estimates of UAW as reported by North Reading in the ASRs between 2002 and 2014. The data shows that the Town's UAW decreasing after 2008 but increasing in

2014. Though the data shows the UAW over the state standard of 10 percent, demand projections for the future will use a 10 percent UAW use as the town works towards that goal.

TABLE 4-6
UNACCOUNTED FOR WATER USE

Year	Total (MG/Yr)	% of Total Production
2002	44.4	8.7
2003	59.8	11.8
2004	59.8	12.2
2005	97	17
2006	85.7	16.3
2007	68	13.6
2008	76.1	15.0
2009	63.1	13.3
2010	64.5	13.2
2011	66.6	12.7
2012	70.0	13.7
2013	84.9	17.2
2014	63.3	12.2

4.3.6.5 Residential and Non-residential Maximum Day Demand

As discussed previously, the MDD/ADD ratio, or peaking factor, North Reading averaged 1.6 in 2008. This value was applied to the total ADD to come up with a project MDD. The projected residential and non-residential ADDs are 1.13 and 0.19 MGD, respectively. These values, in addition to CEMU and UAW, total 1.6 MGD. Thus the projected maximum day demand for a 65 gpcd scenario is 2.56 MGD.

4.3.6.6 Peak Hourly Demand

The peak hourly demand (PHD) is the highest demand that occurs in the water system during a single hour. The peak-hour demand is satisfied from the supply and storage in the system. Water supply systems should be designed to handle the peak hourly demand or maximum day demand plus fire flows, whichever is greater. Thus PHD is important demand component and is used for evaluation and sizing of:

- Water storage facilities
- Booster pumps in service areas without storage
- Transmission and distribution water mains

For the purposes of calculating future peak hour demands, we recommend using a factor of two times the maximum day rate as this is typical for a community of North Reading's size.

The peak hour demand is a rate that occurs typically twice a day and will vary from day to day and season to season. For analysis of the distribution system and storage facilities, the peak hour demand during maximum-day will be used as presented in Table 4-7.

TABLE 4-7
PROJECTED PHD WATER DEMANDS IN MGD

Year	Buildout
ADD	1.6
MDD	2.58
PHD Factor	2
Max Day PHD	**5.15**

4.3.6.7 Projected Flow Summary

A summary of the factors used to determine future MDD requirements is presented in Table 4-8. While future water needs will be based on a 65 gpcd, a scenario of 50 gpcd is also shown for comparison.

TABLE 4-8
PROJECTED WATER DEMANDS (MGD)

	65 GPCD	50 GPCD
Residential ADD	1.13	0.87
Non-Residential ADD	0.19	0.19
CEMU	0.12	0.12
UAW	0.16	0.13
Total ADD	**1.60**	**1.31**
Total MDD	**2.58**	**2.11**

In summary, a future water demand of 2.58 MGD is expected.

4.4 PERMITTED WATER SUPPLY

As stated in the Water Supply Systems section, the Town is permitted for an average daily withdrawal rate of 0.96 MGD from their local water supplies. The Town is also permitted to purchase 1.5 MGD from the town of Andover.

4.4.1 Local Sources

The Town is permitted to withdraw 0.96 MGD from its local sources. Though the treatment plants are designed for a total capacity of 1.8 MGD, they have recently only been able to produce a maximum of 0.68 MGD, or 71 percent of their permitted capacity. Table 4-9 shows the designed treatment capacity of Town-owned sources and the current capacities as reported in the ASR. It is important to note that these current capacities are maximum single day pumped volumes, while the average annual flows pumped are lower.

TABLE 4-9
ANNUAL TOWN SUPPLY WITHDRAWAL AMOUNTS (MGD)

Source	Treatment Design Capacity	2014 Maximum Single Day Pumped*	2014 Average Flows
Lakeside	0.9	0.346	0.27
Railroad Bed	0.5	0.267	0.20
Central Street	0.4	0.113	0.07
Total	**1.8**	**0.726**	**0.54**

* Current Capacity based on operator records and/or ASR pumping data. Peak withdrawals did not occur on the same days.

Operators report that Lakeside and West Village can only produce approximately 0.3 MGD or water quality is negatively impacted. North Reading's 2014 ASR reported that the Lakeside Treatment plant well sources pumped a total of 83.89 MG, or an average of 0.22 MGD. Their maximum single day pumped volume was 0.35 MG. Raw water from the Route 125 Well is also treated at the Lakeside Water Treatment plant. In 2014, the Route 125 well pumped a total of 17.553 MG or 0.05 MGD to the Lakeside Plant. This results in an average of approximately 0.27 MGD of raw water being treated at the Lakeside plant in 2014.

The 2014 ASR also reported that the Railroad bed wells pumped 71.94 MG or 0.20 MGD on average, with a maximum single day pumped volume at 0.27 MG.

The Water Master Plan reported that the town is only able to pump 0.07 to 0.08 MGD out from the Central Street Wells. The well points have become clogged and some of the screens may have failed. In 2014, the Central street wells pumped at total of 11.368 MG or 0.07 MGD (pumps running only 165 days of the year). The maximum single day pumped volume was 0.113 MG.

The average amount of water pumped by the Town's sources was about 0.54 MGD. These amounts to 30 percent of what the plants were designed to treat and 56 percent of the Town's permitted withdrawal.

Assuming a MDD of 2.58 MGD and 1.5 MGD purchased from Andover, under specific conditions, a deficit of between 0.51 and 0.4 MGD can be anticipated. However, it is important to note that utilizing the Town's sources to their full permitted withdrawal of 0.96 MGD leaves a deficit of about 0.12 MGD. Therefore, North Reading cannot meet their future MDD without an increase in permitted supply.

A discussion of water quality in relation to limited capacity is presented later in this section. (section 4.7.2).

4.4.2 Interconnections

As stated in the Water Supply Systems section the Town supplements demands above the available capacity from the Town of Andover through an IBTA permit and Inter-Municipal Agreement (IMA). The agreement stipulates a maximum daily withdrawal of 1.5 MGD. The 2013 ASR reports that North Reading purchased 319.42 MG from Andover, or an average of 0.88 MGD. As shown in Table 4-1 (Section 4.3.2), the average water purchased between 2008 and 2014 is 327.5 MG, or 0.89 MGD. This is lower than the IBTA capacity for the North Reading/Andover connection, but relates to changes in water use throughout the year. Under cold weather conditions water use is typically lower.

The availability of water from Andover will depend on future supply and demand conditions for the Town of Andover. As Andover grows and water demands increase, they may not have available supply or even reduce the water available to North Reading. In the past Andover has reduced supplies to the Town as Andover's customers are a priority over the needs of out-of-town customers like North Reading. For example, Andover imposes voluntary and mandatory conservation measures on its customers dependent on the drought stage. The Town of North Reading is Andover's largest user and Andover can enforce conservation measures on North Reading and its stressed water system. This further emphasizes how North Reading is dependent on Andover for a reliable water source especially during periods of shortage of water.

4.5 WATER NEEDS ANALYSIS

Based on comparison of future needs and existing conditions it is clear that North Reading needs to be able to supply additional water to its residents. Table 4-10 outlines the deficit.

TABLE 4-10
WATER NEEDS SUMMARY (MGD)

Current withdrawal Capacities	0.54-0.701
Andover Interconnection	1.5
Future MDD	2.58
Deficit	**0.57-0.379**

As shown above, there is water supply deficit of between 0.379 and 0.54 MGD. North Reading's current water system will not meet future demands without changes. Alternatives to meet these needs will be discussed in Section 5.

In addition to the water supply deficit described, the North Reading water system has a number of needs. The Town seeks to:

- Reduce water system complexity
- Keep capital, operations, and maintenance costs manageable
- Mitigate stress on the Ipswich River Basin
- Provide a long-term and sustainable solution

The treatment systems have numerous issues in addition to limited capacity and water quality as described in Section 3. Because the Town's wells and treatment system cannot produce as much water as permitted, Wright-Pierce conducted an optimization study for the Town's two water treatment facilities; the West Village WTP and Lakeside Boulevard WTP. Data was gathered concerning:

- Equipment models, capacities, sizes
- Raw and finished water quality
- Pumping records
- Operations records
- Current issues and challenges with operation of the facility

In addition to data collection, Wright-Pierce observed operational practices and inspected equipment. The findings of the Optimization Study are presented below.

4.5.1 Water Operation and Maintenance Needs

The North Reading water system requires operation and maintenance of many system components. The Town must maintain multiple wells, two treatment plants, storage tanks, water mains and fire hydrants. Maintenance of wells is particularly difficult. For example, as stated in the Water Supply Systems section, the Railroad Bed well primary motor has failed consistently every three years. The physical state of the WTP buildings and associated equipment is generally in fair to poor condition. The buildings require some minor structural and architectural upgrades such as concrete repair, roof repair and recoating of most surfaces. Plumbing and HVAC upgrades may be warranted as this equipment is reaching the end of its useful life. The filter vessels are in good condition, but the valves and ancillary equipment (air compressors, blowers) should be rehabilitated or replaced. Most of the chemical feed pumps and the backwash pump at the West Village WTP should be replaced over the next couple of years. Addressing the issues with the physical condition of the equipment will require significant capital investment

The Route 125 well and structure needs to replaced. The Central Street wellfield requires yearly maintenance yet the capacity from the wellfield continues to decline. It is suspected that many of the wellpoint screens have failed while others have clogged which would not be unexpected for a system of this age. As a result, only 9 of the original 15 wells are currently in-service.

Like the Route 125 Well building, the Central Street wellfield building is in need of rehabilitation. The electrical systems are original and outdated. The entire station and wellfield at the Central Street facility is in need of a complete overhaul and replacement if the source is to remain in service. The wellpoints would need to be replaced with a more efficient tubular well design and individual well pumps. The station, to meet current regulations, would need to be designed above the floodplain to conform to code and include modern safety, instrumentation and electrical systems.

The Lakeside treatment plant controls and instrumentation is outdated. Neither treatment plant communicates with the main SCADA system. The Master Plan estimated that the building and systems of the West Village treatment plant would need to be overhauled in the year 2019.

Backwash Waste Management

The solids created during the treatment process are sent to onsite lagoons. Annual solids production was estimated for each WTP during the Optimization Study.

At the West Village WTP, the average solids production was estimated to be 37,300 gallons of 2% solids. The lagoons at the West Village WTP have an estimated available solids storage volume of 43,000 gallons per lagoon. With two lagoons, the operation should allow for alternating between the two with the solids removed every other year from a lagoon after a freeze-thaw cycle.

At the Lakeside WTP, the average solids production was estimated to be 41,500 gallons of 2% solids. The lagoons at the Lakeside WTP have an estimated available solids storage volume of around 16,000 gallons per lagoon. This is equivalent to only four months of solids production. Thus, there is insufficient storage capacity for the amount of solids being generated. The solids should be removed from both lagoons every six months. This analysis demonstrates operational challenges and needs associated with the treatment process.

4.5.2 Water Quality, Capacity, and Treatment Needs

The Optimization Study examined well performance by comparing the original design of the wells to the current performance. Each well's performance was assessed based on its production and specific capacity. In addition to well performance, the impact of raw water quality was evaluated. Central Street well was not assessed during this study because it pumps directly into the distribution system without filtration.

Each well or wellfield is granted a maximum withdrawal capacity from MassDEP through the WMA Permit process. Allowable pumping rates are presented in Table 4-11:

TABLE 4-11
WELL PERMITTED CAPACITY

Well Source	Permitted Capacity
Railroad Bed	0.40 MGD[a]
Lakeside	0.90 MGD
Route 125	0.19 MGD

[a] Permit allows for up to 0.50 MGD withdrawal over a 24 hour period, not to exceed 0.40 MGD average daily withdrawal over a full month.

A review of recent well usage was completed and the range of flows recorded from 2012 to 2014 is presented in Table 4-12.

TABLE 4-12
WELL PUMPING RATES

Well Source		2012 [a]	2103 [a]	2014 [b]
Railroad Bed	Average	0.34 MGD	0.26 MGD	0.22 MGD
	Maximum	0.50 MGD	0.33 MGD	0.27 MGD
Lakeside #3 & #4	Average	0.16 MGD	0.17 MGD	0.17 MGD
	Maximum	0.373 MGD	0.33 MGD	0.31 MGD
Route 125	Average	0.11 MGD	0.08 MGD	0.07 MGD
	Maximum	0.161 MGD	0.111 MGD	0.13 MGD

[a] From Annual Statistical Reports.
[b] From operator logs through August 2014.

All of the well supplies are providing significantly less than their permitted capacities. The Railroad Bed Wells and the Route 125 Well are also showing a slight to moderate decline in production over the past three years.

Railroad Bed Well #1 contributes very little to the overall production of the wellfield and has essentially become a pumping chamber. It has also been reported that the submersible well pump and motor has to be replaced every couple years. The pump and the well screen are likely becoming encrusted with oxidized iron that is pulled into the well through the vacuum eductor system which draws water from Wells #2 and #3.

4.5.2.1 Well Cleaning

Cleaning improves specific capacity but does not restore the wells to original capacity and the wells have steadily declined in production. Generally, the physical condition of the wells is examined after each cleaning and comments on its condition are included in a Well Cleaning Report. Table 4-13 presents the pre-cleaning and post-cleaning specific capacities for the wells over the past few years.

TABLE 4-13
WELL SPECIFIC CAPACITY

Stage	**Specific Capacity (gal/ft)**					
	Railroad Bed			**Lakeside**		
	Well 1	Well 2	Well 3	Well 3	Well 4	Route 125
Original	17	26	26.9	10.4	32	N/A
2012 – Pre-Cleaning				N/A	6.11	10.47
2012 – Post-Cleaning				N/A -	13	11.3
2013 – Pre-Cleaning	0.86	5.4	3.2			
2013 – Post-Cleaning	2.5	12.8	12.5			

N/A = Not Available

In order to restore the capacity of the Town's local sources extensive upgrades are required. Further discussion on the recommended upgrades will be presented in Section 5.

4.5.2.2 Well Water Quality

Well Water Quality is discussed in Section 3. In general, deteriorating water quality, primarily elevated levels of iron and manganese, is what prompted the construction of the WTPs. As noted, iron and manganese levels have since risen in these wells, making the water more difficult to treat. The more recent (2014) higher levels of iron and manganese will result in a greater quantity of solids in the wash water than were anticipated when the water sources were last assessed in 1993. This will impact the operations and storage capacity of the onsite lagoons.

Samples collected as parts of the optimization study were sent to the State Certified Laboratory (RI Analytical) were also analyzed for Total Organic Carbon (TOC). Although the treatment system is not designed specifically for the removal of this parameter, this was required to get a better understanding of the organics levels at each facility given the Trihalomethane (THM) concerns in the distribution system (chlorine and organics react to form THM's in the distribution system). The raw water at the West Village WTP contained 6.5 mg/L TOC and the finished water contained 4.2 mg/L TOC. The reduction in TOC is likely due to reactions with chlorine (forming THMs) and potassium permanganate (oxidation). The levels of THM's observed are fairly high and likely contributors to the distribution system THM concerns. The raw water at the Lakeside WTP contained approximately 2.5 mg/L TOC and the finished water contained 1.8 mg/L TOC. Similar to the West Village WTP, the reduction in TOC is likely due to reactions with chlorine and potassium permanganate. While the levels observed are much lower than the levels at the West Village WTP, they are elevated and also likely contributors to the distribution system THM concerns.

Filter Performance

Filter systems are designed using a number of parameters including hydraulic loading rates, headloss build-up or differential pressure across the filter media and removal capacity. The filter performance of the Town's WTPs was assessed on these parameters.

The hydraulic loading rate of a filter is a function of the flow rate applied to the surface area of the filter, most commonly expressed in gallons per minute per square foot (gpm/ft^2). Greensand media is typically designed for a loading rate of 3 gpm/ft^2, while Greensand-Plus media is commonly designed for loading rates as high as 4 – 6 gpm/ft^2. Table 4-14 presents the flow rates applied at each of the WTPs in 2014 January through October.

TABLE 4-14
2014 FLOW RATES

Month	West Village	Lakeside
	GPM	GPM
AVERAGE	153	180
MINIMUM	101	87
MAXIMUM	185	302

For the West Village WTP at an average flow rate of 153 gpm and two filters in operation, the filter loading rate is calculated to be 0.97 gpm/ft^2. During backwashing of one filter, the flow is directed through the other filter increasing the loading rate to 1.94 gpm/ft^2. The maximum flow rate of 185 gpm for 2014 corresponds to a maximum loading rate of 2.3 gpm/ft^2. This is well below the allowable loading rate of 4 gpm/ft^2 for Greensand-Plus media.

For the Lakeside WTP at the average flow rate of 180-gpm and two filters in operation (Filter #1 is off-line), the filter loading rate is calculated to be 0.79 gpm/ft^2. During backwashing of one filter, the flow is directed through the other filter increasing the loading rate to approximately 1.59 gpm/ft^2. The maximum flow rate of 302 gpm for 2014 corresponds to a maximum loading rate of 2.67 gpm/ft^2. This is slightly below the anticipated loading rate for Greensand media of 3 gpm/ft^2.

Headloss and Backwashing

The differential pressure (headloss) across the filters is an indication of the filter media becoming clogged requiring a backwash. The differential pressure is measured and recorded on a daily basis at both WTPs. The media suppliers recommend backwashing before a filter reaches 10 psi (277-inches of water).

It was found that on average, backwashing is occurring well before the maximum allowable differential pressure is achieved. Backwashes are conducted on a regular schedule based on time. Using a couple data points from the operator's logs, a potential headloss curve was developed for Filter 2 at the Lakeside WTP. The projected headloss curve suggests that the filters could be operated for 60+ hours before the maximum allowable headloss is reached. This could reduce the volume of backwash water that is used in half.

The flow rates recommended for effective backwashing are temperature dependent. The media suppliers recommend achieving 40% bed expansion for the most effective backwashing. Operators reported the water temperature to range between 40 – 45 °F. At these water temperatures, the recommended backwashing rate for 40% bed expansion is 10.21-10.87 gpm/ft^2, corresponding to a flow rate of 802-854 gpm for a 10-foot diameter filter and 1,156-1,230 gpm for a 12-foot diameter filter.

At the West Village WTP, the high rate backwash flow is controlled at approximately 950 gpm, which is higher than the recommended backwash rate. This higher backwash rate would result in greater bed expansion and possible media loss. A reduction in backwash rate should be considered for the West Village WTP.

At the Lakeside WTP, the high rate backwash flow is controlled at approximately 1,000 gpm, which is lower than the recommended backwash rate. This lower rate would result in a lower bed expansion, estimated to be between 30-35%. This may be the reason for the less than ideal clean bed headloss that has been observed for Filter #3.

4.5.3 Ipswich River Needs

The Ipswich River supplies water to more than 330,000 people in 13 communities, including North Reading. Every day between 25 and 30 million gallons are withdrawn for water supply, though the "volume withdrawn in the summer months can be more than twice this year round volume." The Ipswich River also supports a wide variety of plant and animal life, recreational activities including hiking and fishing, and fire safety for nearby golf courses, farms and industries.

4.5.3.1 Low Flow

Unfortunately, the Ipswich River has been named one of the 20 most stressed rivers in the country, as well as one of America's 10 most endangered rivers in 2003. According to North Reading's Water Conservation website, in the upper reaches of the river, between Reading and North Reading, the river frequently runs dry during the summer months, resulting in the loss of numerous fish and other species dependent on the river. They attribute low flow conditions to evapotranspiration, diminished aquifer recharge, and human factors including lawn watering, and increased summer month water demand.

In 1999 the USGS published a report titled *Assessment of Habitat, Fish Communities, and Streamflow Requirements for Habitat Protection, Ipswich River, Massachusetts, 1998-1999*. The report states that "as a result of withdrawals for public water supply, streamflows in the upper third of the basin frequently become very low or cease during the summer." The report was published as result of concerns from federal, state, and local agencies that "reduced streamflows in the basin are causing a loss of habitat that supports the biological integrity of the river". At the time of the study, only about 10 to 20 percent of water withdrawn from the basin was returned as wastewater and increased impervious area further contributed to decreased basin streamflow. The report also states that "one of the most flow-stressed reaches of the mainstem Ipswich River, as evidenced by fish kills and mussel die-offs in 1995, 1997, and 1999 is downstream of the Reading, North Reading, and Wilmington well fields between I-93 and the confluence of Martins Brook with the Ipswich River."

The Ipswich River Watershed Association stated that "conditions at Martin's Brook in North Reading...were so dry that the stream bed was now being used by ATV's. Martin's Brook is especially hard hit from water withdrawals from North Reading and Wilmington town wells. These wells collectively withdraw over 2 million gallons a day from the Martin's Brook aquifer, which normally would sustain the Brook's flow during dry periods."

Due to the link between the Ipswich River's flow and groundwater withdrawals within the basin, MassDEP has imposed withdrawal restrictions and conservation measures through Water Management Act (WMA) permit conditions to water supplies regulated under this program.

4.5.3.2 High Flow/Flooding

High flow conditions are also an issue. Development in the watershed area created an increase in impervious surfaces. North Reading reported that increases in impervious surfaces and the rerouting, therefore, "rainfall that once made its way into the ground to slowly recharge the aquifer is now collected and piped directly to the river and its tributaries. The result of this development is the higher "high" flows and the lower "low" flows." In both May of 2006 and April of 2007, flooding along the river, Martins Brook and other tributaries did extensive property damage to homes, businesses and the Town's roads, parks and other infrastructure. The

Ipswich River can quickly change from a high flow condition to a low flow condition. In April of 2007, the flow in the river was close to 700 cubic feet per second (cfs) in South Middleton, and the river was flooding its banks. By late July, the flow had decreased to about 4 cfs – a drop of more than 99 percent in three months." Therefore it is important that water supply alternatives do not create an increase in impervious surfaces (and potentially reduce impervious surface), and help to restore balance to the Ipswich River.

Summary

"The North Reading Water Department supports the efforts of the Ipswich River Watershed Association, the MassDEP, the Massachusetts Audubon Society, the Massachusetts Department of Conservation and Recreation, the Reading/North Reading Stream Team, the Martins Pond Association and other organizations, as well as the efforts of individuals in North Reading and across the watershed, to minimize the impacts the Town's water withdrawals have on this valuable water resource by promoting wise water use and minimizing water waste." Reducing water withdrawals would also support this effort. There is a need to reduce withdrawals on the river basin either through increased water conservation methods or alternative water sourcing. As stated in the ENF certificate, reducing water withdrawals from the stressed Ipswich River basin will benefit stream flow and habitat conditions. Ipswich Rivers are an important component of any water supply alternative to ensure future water needs, aquatic life and recreational activities will be supported.

4.6 WATER NEEDS ANALYSIS SUMMARY

This section showed that North Reading's maximum daily demand for build-out is 2.58 MGD. It was determined that the town's current supply sources cannot meet that demand, as the treatment systems are limited by permitted water withdrawal rates and decreased production from town owned sources. Improving the town's well productions by extensive upgrades and increased maintenance presents a challenge moving forward for the Town. The following section will examine alternatives that address these needs while reducing system complexity and stress on the Ipswich River Basin.