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KENT COUNTY WATER AUTHORITY
WEST WARWICK, RHODE ISLAND

2014 TANK STUDY
UPDATE REPORT

KCWA
Kent County Water Authority

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1.0 Introduction

1.1 Purpose and Scope

In 2007, C&E Engineering Partners, Inc. (C&E) completed a study of the Kent County Water Authority's (KCWA) storage facilities. This study was completed by utilizing the KCWA's computerized hydraulic model that was updated in 2006 to evaluate the entire supply and distribution system for the existing and twenty (20) year planning periods to determine the ability of water system infrastructure components to effectively meet those demands. At the request of the KCWA, C&E performed an update to the computer model recently in 2014 whereby new and replaced infrastructure components, changes in operation, changes in system demands, etc., were included in the computer model. This updated computer model was then utilized to update the KCWA's 2007 study of the system storage facilities.

This updated tank study consisted of a detailed hydraulic study and evaluation of the entire KCWA service area including approximately 471 miles of water main, 27,700 services and all water producing, storage and wholesale distribution facilities. This updated storage facilities evaluation considered system demands for both the existing and twenty (20) year projected planning periods and an evaluation of the ability of water system infrastructure components to effectively meet these demands. Consideration in this updated tank study was given to supply capability, storage capacity, storage location, transmission and distribution capacity, pressure and flow limitations and the ability of the water system to effectively meet distribution system demands including fire flow for the planning period.

This updated storage facility evaluation was premised upon an identified concern related to the operations of the KCWA water storage facilities and their ability to provide adequate supply during all demand conditions, both present and future, and to effectively turnover an adequate volume of water on a daily basis. Water turnover of a storage tank is critical to ensure that water quality in a particular tank is not compromised as stagnant conditions are considered a potential threat to overall water quality. As part of this updated tank study, C&E evaluated the water storage facilities and made recommendations for water storage facility improvements to increase tank turnover rates and eliminate stagnant conditions. There are five (5) active storage facilities and three (3) inactive storage facilities for a total of eight (8) water storage facilities in the KCWA water system that are identified as follows.

1. Read School House Road Tank
2. Tiogue Tank (inactive/offline)
3. Frenchtown Road Tank
4. Technology Park Tank
5. Carr Pond Road Tank
6. West Street Tank (inactive/offline)
7. Setian Lane Tank
8. Wakefield Street Tank (inactive/offline)

The tank study completed in 2007 has indicated that the West Street and Wakefield Street Tanks remain in a "locked up" condition throughout all demand scenarios. An additional hydraulic evaluation of the Wakefield Street Tank was conducted in November 2013 as result of water quality issues associated with poor turnover of the tank. The Wakefield Street Tank evaluation considered the impact of completed and proposed water system infrastructure improvements on the turnover rates of the tank. The November 2013 evaluation also indicated that the Wakefield Street Tank continuously remains in a locked up condition throughout all demand scenarios. As a result of multiple evaluations concluding that the West Street and Wakefield Street Tanks continuously remain in locked up conditions, these tanks were taken offline from the water system and were not considered or evaluated in this updated tank study. Also, the previous 2007 tank study included two (2) underground storage reservoirs known as the Fiskeville Tanks. The 2007 storage facilities evaluation concluded that these reservoirs were maintained in a continued "locked up" condition and had become obsolete as the KCWA water system had grown and expanded over the years. It was recommended that the Fiskeville Tanks be permanently removed from service. Therefore, this updated tank study did not evaluate the Fiskeville Tanks as they have permanently been removed from service and are no longer part of the KCWA water system. Since the completion of the 2007 study, the Tiogue Tank was taken offline and the area surrounding this tank which was re-serviced from the High Service South Pressure Gradient through a pressure reducing valve (PRV) station in an effort to increase pressures in this area. As such, the Tiogue Tank was not considered or evaluated in this updated tank study.

Also since the completion of the 2007 study, a new 1.5 million gallon storage facility was constructed and placed into service in the Read School House Road Pressure Gradient. The old Read School House Road Tank was taken out of service and the pressure zone was increased from 430 feet to 500 feet and is now referred to as the High Service North Pressure Gradient. These changes have also been reflected in this 2014 tank study update.

This updated evaluation also reviewed areas of the distribution system where substandard pressures occurred when supply and transmission pump stations were offline in an attempt to provided potential solutions for these conditions. When the system supply sources and pump stations are offline, the storage facilities must be capable of meeting system demands. This evaluation determined the viability and effectiveness of the KCWA's existing storage facilities and also provided recommendations for either upgrading existing facilities or new facilities that may be necessary to meet future demands and to ensure a high level of water quality and supply reliability.

The 2014 updated hydraulic model was utilized to perform simulations to evaluate the existing water system and identify deficiencies. Further analysis was completed with build out scenarios for the 20 year planning period. Various hydraulic simulations were also performed under the build out analysis and system deficiencies were identified. Standards were developed for various demand scenarios to determine the effectiveness of the existing storage tanks, supply facilities and transmission capabilities to meet system demands. These standards were also utilized to identify additional storage and related transmission facility needs to meet the current and future demands throughout the system.

The standards utilized to identify deficiencies were based upon general standard water works practice including Ten States Design Standards, American Water Works Association (AWWA) Standards, Rhode Island Department of Health (RIDOH) Regulations, prudent engineering judgment and the most recent KCWA Regulations. System deficiencies were identified with recommendations for system improvements for both the short (immediate) and long term (20 year) planning horizons.

2.0 Storage Facility Evaluation Technical Memorandums

2.1 General

As previously indicated, this project included utilizing the KCWA's computerized hydraulic model updated in 2006 to evaluate the system storage facilities to determine the viability and effectiveness of the existing storage facilities and to provide recommendations for either a facility upgrade or new facilities that may be necessary to meet future demands to ensure a high level of water quality and supply reliability. The evaluation of the KCWA's storage facilities was completed once again recently utilizing the KCWA's computerized hydraulic model that was updated in 2014. The results and conclusions of this most recent evaluation are included herein.

The completed 2007 storage facility evaluation included the preparation of five (5) Technical Memorandums. Each of these Technical Memorandums included a specific task evaluation related to the storage facility evaluation. A description of the scope for each of the Technical Memorandums and the findings and conclusions of the 2007 storage facility evaluation follow along with the findings and conclusions of the 2014 updated storage facility evaluation for each Technical Memorandum.

2.2 Technical Memorandum No. 1

Technical Memorandum No. 1 of the 2007 tank study is entitled *Data Collection, Review and Existing Water System Analysis* and was prepared in August 2006.

2.2.1 Purpose and Scope

The purpose of Technical Memorandum No. 1 was to present information that was gathered to provide the basis and foundation for the evaluation and analysis of the system storage facilities, and ultimately, for the development of recommendations and conclusions. The policies and goals of the KCWA and the anticipated future growth within the service territory that would impact water demands were critical factors of this task. This task included a review of the KCWA's Strategic Plan and Goals, the Water Supply System Management Plan, the Hydraulic Model Study and updates, the latest Capital Improvement Program, the Wakefield Tank

Hydraulic Evaluation, various task orders associated with water supply availability in the High Service South Gradient and Comprehensive Community Plans of the Cities and Towns serviced by the KCWA.

The local City and Town Comprehensive Community Plans were reviewed to determine planned or projected population changes and significant economic development in each community serviced by the KCWA water system. A review of the existing model studies was also conducted to ensure that the conclusions and recommendations of those studies were still valid. The Capital Improvement Program was reviewed to quantify the infrastructure projects that had been completed, were currently in progress or are to be undertaken in the future. All of the aforementioned data was reviewed to ensure that current and planned infrastructure improvements continue to meet the strategic supply, storage and transmission goals of the KCWA. Finally, KCWA staff was consulted on current system operations and identified system problems and deficiencies.

2.2.2 2007 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were presented in Technical Memorandum No. 1 and were based upon the data review completed for the 2007 storage facility evaluation.

- Overall population growth within the customer service territory from 2000 through the year 2020 is projected to increase by 7.8% (4,667 persons). This population growth included service population changes of -0.7% for Warwick, +4.6% for West Warwick, +12.2% for Coventry, +28.8% for West Greenwich and +13.2% for East Greenwich. Projections for Cranston, North Kingstown or Scituate were not completed as these communities comprise a relatively insignificant customer base and the KCWA has no plans to increase its service territory within these communities. These population projections represent changes in customer services based on existing service territory and may not reflect total change in population within the particular community. For example, the City of Warwick is served by both the KCWA water system and the Warwick water system. Therefore, growth in the City of Warwick does not automatically constitute growth in the portion served by the KCWA system.

- It was determined that the system average day demand was 11.0 million gallons per day (MGD), the maximum day demand was 21.1 MGD and the peak hour demand was 25.3 MGD.
- It was concluded that without supply augmentation in the High Service South Gradient, approvals of new developments would increase the deficit of water to meet maximum day demands. Approval of new developments would further exacerbate the supply deficit and increase the risk of the water system not being able to meet overall consumer demands which may result in service interruptions or the inability to maintain critical levels in the storage tanks for adequate pressure and fire protection.
- The identified deficiencies and problematic areas within the water system were both specific (i.e. known areas of low pressure and flow) and general (i.e. elimination of dead ends, loop water mains and increase flushing). Specific areas of concern, which were primarily related to low pressure, were identified within each community and were then considered in subsequent portions of the storage tank evaluation.

2.2.3 2014 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were determined based upon the information gathered and the data review completed for the 2014 updated storage facility evaluation.

- Overall population growth within the customer service territory from 2015 through the year 2035 is projected to increase by 3.3% (2,941 persons). This population growth included service population changes of -5.2% for Warwick, -1.5% for West Warwick, +9.2% for Coventry, +32.9% for West Greenwich, +7.5% for East Greenwich, +3.1% for Cranston, 0.0% for North Kingstown and +3.6% for Scituate. The service area in North Kingstown does not include any residential customers and the KCWA has no plans to increase its service territory within this community. These population projections represent changes in customer services based on the existing service territory and may not reflect total change in population within the particular community.
- It was determined that the new system average day demand was 7.99 MGD, resulting in a revised maximum day demand of 15.46 MGD and a peak hour demand of 18.80 MGD. When comparing the system demands utilized in the 2007 storage facility evaluation, the

average day demand has decreased by 27.4% (3.01 MGD), the maximum day demand has decreased by 26.7% (5.64 MGD) and the peak hour demand has decreased by 25.7% (6.50 MGD).

- Due to the decrease in system demands, the supply deficit in the High Service South Gradient no longer exists. The decrease of the system demand in the High Service South Gradient is a result of industrial water users paring back their facility operations or completely moving facility operations out of the KCWA service territory. Based on projected system growth it is now unlikely that the potential for new developments in the High Service South Gradient will result in the previously projected demand issues with the water supply in this area. The High Service South Gradient now has the ability to meet overall consumer demands and to maintain critical levels in the storage tanks for adequate pressure and fire protection for the 20 year demand period.
- The Low Service Gradient has experienced the decline in water usage and/or loss of two (2) of the largest commercial major users that were identified in the 2007 tank study. The water usage of Clariant has decreased by 93.4% or 122.73 million gallons of water per year and ON Semiconductor is no longer identified as a major water user in this tank study update.
- Deficiencies and problematic areas within the water system still remain however, these issues have been declining. This decline can be attributed to infrastructure projects completed since the 2007 tank study to address water system deficiencies and water system service issues in problematic areas. The KCWA is continuously performing infrastructure replacement projects to address areas of concern within the water system. The remaining specific areas of concern are primarily related to low pressure and were considered in subsequent portions of this storage tank evaluation.

2.3 Technical Memorandum No. 2A

Technical Memorandum No. 2A of the 2007 tank study is entitled *Development of Water System Evaluation Criteria* and was prepared in September 2006.

2.3.1 Purpose and Scope

The tasks of Technical Memorandum No. 2A consisted of developing and reviewing the criteria by which existing and proposed water storage facilities were evaluated and sized which included the development of criteria that could be utilized to evaluate the water supply and distribution system and the design of any proposed improvements.

The following documents were utilized as standard design guidelines for hydraulic considerations in the planning and construction of storage tanks. The criteria in these documents were also utilized to assess the existing storage facilities to plan for future growth.

- AWWA Manual M31 – *Distribution System Requirements for Fire Protection*
- AWWA Manual M32 – *Distribution Network Analysis for Water Utilities*
- AWWA Manual M42 – *Steel Water Storage Tanks*
- Ten States Standards – *Recommended Guide for the Design of Waterworks Facilities*

The standard guidelines included in the above mentioned documents ensure that the water system maintains adequate volumes of water storage for meeting domestic demands, fire flow and emergency storage as well as ensuring adequate hydraulics of the water system (i.e. adequate pressures and flow).

An overview of the various types of storage facilities (i.e. ground storage reservoir, standpipe, elevated storage) was also completed for this task which also included a description and cataloging of the existing system water storage facilities.

2.3.2 2007 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were presented in Technical Memorandum No. 2A and were based upon the standard guidelines reviewed for hydraulic considerations in the planning and construction of storage tanks.

- It was determined that the volume of effective storage is the volume that provides a minimum pressure of 20 pounds per square inch (psi) in the distribution system.

- It was determined that the volume of equalization storage is the volume that will provide a minimum pressure of 35 psi in the distribution system up to the tank overflow.
- It has been concluded that the measure by which the adequacy of total equalization storage is premised upon achieving 25% of the system average day demand.
- In order to determine a reliable and reasonable equalization storage volume, the hydraulic model will be utilized to examine the system under an extended period simulation.
- It was concluded that the fire flow volume is the volume that provides a minimum of 20 psi residual pressure up to the bottom of the equalization storage.
- Each of the storage components were identified for each tank facility in the system along with a total of each storage component by pressure zone.

2.3.3 2014 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were determined based upon the standard guidelines reviewed for hydraulic considerations in the planning and construction of storage tanks for the 2014 updated storage facility evaluation.

- The volume of effective storage continues to be the volume that provides a minimum pressure of 20 psi in the distribution system.
- The volume of equalization storage remains as the volume that provides a minimum pressure of 35 psi in the distribution system up to the tank overflow elevation.
- The measure by which the adequacy of total equalization storage is premised continues to be premised upon achieving 25% of the system average day demand.
- The hydraulic model was utilized to determine a reliable and reasonable equalization storage volume which included examining the water system under an extended period simulation.
- The fire flow volume remains the volume that provides a minimum of 20 psi residual pressure up to the bottom of the equalization storage.
- Each of the various storage components of each storage facility were identified along with a total of each storage component by pressure zone. The 1.5 million gallon Read School House Road Tank has been replaced by a new 1.5 million gallon tank and the pressure zone in this area has been increased from 430 feet to 500 feet, which is the

overflow of the new tank. This new tank has been incorporated into the hydraulic model so that the various storage components could be evaluated.

- The Tiogue Tank has been replaced by a PRV station that services an isolated area from the High Service South Gradient in an effort to increase pressures in this area.

2.4 Technical Memorandum No. 2B

Technical Memorandum No. 2B of the 2007 tank study is entitled *Existing Water Storage Facilities* and was prepared in March 2007.

2.4.1 Purpose and Scope

The tasks of Technical Memorandum No. 2B included verifying the elevation set points for the base and overflow elevations of the KCWA's existing storage tanks. The following are the specific efforts that were necessary to complete this task.

- Verification of the base and overflow elevations of the existing storage facilities by a registered professional surveyor in the State of Rhode Island.
- Set bounds at each of the tank sites to identify and benchmark a site elevation as needed at each tank site.
- Establish horizontal and vertical controls for the bounds (RISPC – NAD83)(NAVD 88).
- Locate tanks and take measurements necessary for height determination at base and overflow elevations.
- Install benchmark bounds at each tank site where granite bound property markers do not exist.

2.4.2 2007 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were presented in Technical Memorandum No. 2B and were based upon the verification of the elevation set points for the base and overflow elevations of the KCWA's existing storage tanks.

- Surveys to determine the base and overflow elevations of the Read School House Road and Tiogue Tanks were not performed as these tanks were slated to be removed from service. The Read School House Road Tank is scheduled to be replaced with a tank of higher elevation and the Tiogue Tank will be taken out of service. The area surrounding the Tiogue Tank will be re-serviced from the High Service South Gradient.

- The West Street Tank is offline due to the fact that it continuously remains in a locked up condition.
- As a result of the field surveys conducted for the existing storage facilities in the KCWA water system, the following base and overflow elevations were determined:

STORAGE TANK FACILITY	BASE (GROUND) ELEVATION (FEET)	OVERFLOW ELEVATION (FEET)
Technology Park Tank	350.14	500.69
Carr Pond Tank	418.84	500.10
Frenchtown Road Tank	284.40	334.03
Setian Lane Tank	315.55	334.60
Wakefield Street Tank	265.45	333.70
West Street Tank (Offline)	281.07	331.50
Fiskeville Tank 1	338.83	334.60
Fiskeville Tank 2	338.97	334.60

2.4.3 2014 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were determined based upon the verification completed for the 2014 tank study of the base and overflow elevations of the KCWA's existing storage tanks.

- The field surveys completed for the 2007 tank study for verification of tank overflow and base elevations were reviewed to determine if any changes had occurred since 2007. The Read School House Road Tank has been replaced with a new 1.5 million gallon tank with a higher overflow elevation and the old tank has been taken out of service. The elevations of the new Read School House Road Tank were obtained from information and plans provided by KCWA personnel. The Tiogue Tank has been taken out of service and the area around this tank has been re-serviced through a PRV station from the High Service South Gradient.

- The West Street Tank continues to remain offline due to poor turnover of the tank. The Wakefield Street Tank has also been taken offline due to water quality issues in the area surrounding this tank associated with poor turnover of the tank.
- The Fiskeville Tanks have been permanently removed from service and are no longer a part of the KCWA's system due to the fact that these tanks were continuously maintained in a locked up condition. The infrastructure in this area is now serviced from the High Service North Gradient.
- As a result of a review of the tank field studies conducted for the previous 2007 tank study and plans provided by the KCWA, the following storage facility base and overflow elevations were determined and were utilized in the hydraulic model for the 2014 updated tank study:

STORAGE TANK FACILITY	BASE (GROUND) ELEVATION (FEET)	OVERFLOW ELEVATION (FEET)
Technology Park Tank	350	500
Carr Pond Tank	418	500
Frenchtown Road Tank	284	334
Setian Lane Tank	314	334
Read School House Road Tank	475	500

2.5 Technical Memorandum No. 3A

Technical Memorandum No. 3A of the 2007 tank study is entitled *Existing and Future System Demands* and was prepared in December 2006 and finalized in January 2007.

2.5.1 Purpose and Scope

In this Technical Memorandum, the consumer water demands for the current and future planning periods were established for average day, maximum day and peak hour demand conditions and were utilized in the computer hydraulic modeling scenarios. The current and future demands included in the hydraulic model database were tabulated by community and pressure gradient. The population projections completed in Technical Memorandum No. 1 were utilized to calculate the current and future water system demands.

An additional task of Technical Memorandum No. 3A included the development of system wide diurnal flow curves. The diurnal flow curves predict the variation in water use throughout the water system at certain times of the day and are utilized for extended period simulation (EPS) model evaluations. These diurnal flow curves are critical to model EPS's because they allow the model to gauge and predict how the water system responds to periods of increased demand, especially during peak demand periods.

2.5.2 2007 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were presented in Technical Memorandum No. 3A and were based upon the calculations of current and future water system demands and the development of system diurnal flow curves.

- The current and future population projections for the various communities within the KCWA's service territory that were previously developed in Technical Memorandum No. 1 were utilized to develop and allocate future water demands. The following table represents the KCWA service population up to the year 2020 based upon year 2000 census data and population projections prepared by Rhode Island Statewide Planning (RISWP).

COMMUNITY	2000 SERVICE POPULATION	2020 SERVICE POPULATION	CHANGE (VALUE) AND %
Warwick	8,578	8,521	(-57) -0.7%
West Warwick	18,083	18,906	(+823) +4.6%
Coventry	19,941	22,382	(+2,441) +12.2%
West Greenwich	824	1,062	(+238) +28.8%
East Greenwich	9,262	10,484	(+1,222) +13.2%
Cranston	2,005	2,005	(0) 0.0%
North Kingstown	28	28	(0) 0.0%
Scituate	1,170	1,170	(0) 0.0%
TOTALS	**59,891**	**64,558**	**(+4,667) +7.8%**

Based upon the service populations presented above, it was concluded that the KCWA service population would increase by 7.8% or 4,667 people in the 20 year planning period.

- The following table indicates the current year (2006) water system demands for each of the various demand scenarios.

COMMUNITY	AVERAGE DAY DEMAND (MGD)	MAXIMUM DAY DEMAND (MGD)	PEAK HOUR DEMAND (MGD)
Warwick	1.866	3.594	4.153
West Warwick	2.916	5.751	6.804
Coventry	2.735	5.232	6.152
West Greenwich	1.064	1.765	2.361
East Greenwich	1.990	3.990	4.880
Cranston	0.303	0.592	0.686
Scituate	0.096	0.195	0.222
TOTALS	**11.00**	**21.10**	**25.30**

The demands presented above were utilized in the hydraulic model for the model year (2006) simulations.

- The water system demands for the future 20 year (2026) planning period were predicated on the previously calculated population projections, planned development in the service area and an additional 10% factor for growth to account for unplanned growth and potential in fill development. The future demand estimates also included all High Service South Gradient developments that were previously approved and all planned development projects known to the KCWA that had yet to be approved. The calculations of the future system demands were based upon the anticipated increase in the service population of each community. Following is a table that depicts the future 20 year (2026) planning period demands.

COMMUNITY	AVERAGE DAY DEMAND (MGD)	MAXIMUM DAY DEMAND (MGD)	PEAK HOUR DEMAND (MGD)
Warwick	2.052	3.954	4.569
West Warwick	3.342	6.590	7.798
Coventry	3.346	6.399	7.523
West Greenwich	1.165	1.983	2.672
East Greenwich	2.451	4.916	6.012
Cranston	0.333	0.651	0.755
Scituate	0.105	0.215	0.245
TOTALS	**12.80**	**24.70**	**29.60**

The demands presented above were utilized in the hydraulic model for the future 20 year (2026) planning period simulations. It has been concluded that the total system demand for the 20 year planning period (2026) will increase by approximately 20%.

- As previously mentioned, system wide diurnal flow curves were developed as part of this task. These flow curves were developed from hourly water production and tank level data that was representative of the maximum day water use patterns of the pressure zones in the KCWA system. A review of water production and tank level records concluded that the maximum day water demands occurred on July 2, 2002. This date is representative of a time period of maximum water use and when the system had been most stressed therefore, the system wide diurnal flow curves are based upon the records reviewed from July 2, 2002. The diurnal flow curves for the various pressure gradients of the water system are provided in Appendix A.

2.5.3 2014 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were determined based upon a review of the 2007 tank study current (2012 baseline model year) and future water system demands and diurnal flow curves that were completed for the 2014 updated storage facility evaluation.

- The current and future population projections for the various communities within the KCWA's service territory were based upon year 2010 census data and population projections prepared by the KCWA and RISWP. The following table represents the KCWA service population up to the year 2035.

COMMUNITY	2015 SERVICE POPULATION	2035 SERVICE POPULATION	CHANGE (VALUE) AND %
Warwick	15,116	14,330	(-786) -5.2%
West Warwick	28,483	28,058	(-425) -1.5%
Coventry	27,294	29,805	(+2,511) +9.2%
West Greenwich	1,862	2,475	(+613) +32.9%
East Greenwich	12,118	13,027	(+909) +7.5%
Cranston	2,243	2,313	(+70) +3.1%
North Kingstown	0	0	(0) 0.0%
Scituate	1,363	1,412	(+49) +3.6%
TOTALS	**88,479**	**91,420**	**(+2,941) +3.3%**

Based upon the service populations presented above, it was concluded that the KCWA service population would increase by 3.3% or 2,941 people in the 20 year planning period. This increase in population in the 20 year planning period will occur at a slower rate than the increase of 7.8% calculated for the 20 year planning period in the 2007 tank study. It should be noted that the service area in North Kingstown does not include any residential services and the KCWA does not have any plans in place to expand their service territory in this area.

- The following table indicates the current year (2014) water system demands for each of the various demand scenarios.

COMMUNITY	AVERAGE DAY DEMAND (MGD)	MAXIMUM DAY DEMAND (MGD)	PEAK HOUR DEMAND (MGD)
Warwick	1.797	3.504	4.258
West Warwick	2.122	4.209	5.153
Coventry	1.842	3.618	4.412
West Greenwich	0.386	0.528	0.566
East Greenwich	1.591	3.097	3.786
Cranston	0.150	0.297	0.364
Scituate	0.106	0.210	0.257
TOTALS	**7.99**	**15.46**	**18.80**

The demands presented above were utilized in the hydraulic model for the current year (2014) simulations and take into consideration the reduction in demands in the new baseline model year (2012). Based upon the above calculated current year demands, it was concluded that the average day demand is 27.4% lower, the maximum day demand is

26.7% lower and the peak hour demand is 25.7% lower than the current year demands calculated for the 2007 tank study.

- The water system demands for the future 20 year (2034) planning period were predicated on the KCWA and RISWP population projections, planned development in the service area and an additional 10% factor for growth to account for unplanned growth and potential in fill development. The future demand estimates also included all developments approved by the KCWA that have been constructed and all those developments that have been approved by the KCWA that have yet to be constructed. The calculations of the future system demands were based upon the anticipated increase of the service population in each community. Following is a table that depicts the future 20 year (2034) planning period demands.

COMMUNITY	AVERAGE DAY DEMAND (MGD)	MAXIMUM DAY DEMAND (MGD)	PEAK HOUR DEMAND (MGD)
Warwick	1.883	3.672	4.462
West Warwick	2.302	4.567	5.591
Coventry	2.196	4.313	5.259
West Greenwich	0.552	0.755	0.809
East Greenwich	1.869	3.639	4.449
Cranston	0.170	0.336	0.412
Scituate	0.120	0.239	0.292
TOTALS	**9.09**	**17.52**	**21.27**

The demands presented above were utilized in the hydraulic model for the future 20 year (2034) planning period simulations. It has been predicted that the total system demand for the 20 year planning period (2034) will increase by approximately 13% over the demands presented in the 2014 model update but will be significantly less than those projected in the 2006 model evaluation. Based upon the above calculated 20 year planning period demands, it was concluded that the average day demand is 29.0% lower, the maximum day demand is 29.1% lower and the peak hour demand is 28.1% lower than the 20 year planning period demands calculated for the 2007 tank study.

- The system wide diurnal flow curves from the 2007 tank study were updated as part of this task. These flow curves were developed from hourly water production and tank level data that was representative of the maximum day water use patterns of the pressure zones in the KCWA system. A review of water production and tank level records concluded that the maximum day water demands occurred on July 17, 2012. This date is representative of a time period of maximum water use and when the system had been most stressed under the new 2014 model demand scenarios therefore, the updated system wide diurnal flow curves are based upon the records reviewed from July 17, 2012. The updated diurnal flow curves for the various pressure gradients of the water system are provided in Appendix B.

2.6 Technical Memorandum No. 3B

Technical Memorandum No. 3B of the 2007 tank study is entitled *Existing and Future Water System Capabilities* and was prepared in March 2007.

2.6.1 Purpose and Scope

The tasks of Technical Memorandum No. 3B included establishing the various steady state and extended period hydraulic model simulations that were necessary to determine fill and draw rates of the existing water storage facilities under the current and future 20 year planning period demand conditions. These model simulations were also utilized to evaluate and size any additional storage facilities that may be required in the water system and to identify specific water system improvements. Any additional storage facilities or planned water system improvements were then included in various modeling scenarios to demonstrate their effectiveness in meeting deficiencies and to assist in sizing of components.

2.6.2 2007 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were established after a review of the evaluation criteria that were previously developed in Technical Memorandum No. 2A which were utilized to determine the hydraulic model simulations necessary to identify areas of the KCWA's water system that may need additional storage capacity.

- It was determined that four (4) steady state simulations would be conducted for the current year (2006) demands and also for the future 20 year (2026) demands for a total of eight (8) steady state simulations. The steady state simulations included the following.

Steady state simulations 2006 and 2026 demands:

- Average Day
- Maximum Day
- Peak Hour
- Maximum Day Plus Fire Flow

These steady state simulations helped to identify isolated areas of the distribution system that experience low pressures on a routine basis. The steady state model simulations also identified areas of deficient storage, tanks that do not cycle, tanks that are undersized and tanks that may be problematic due to their location in the system.

The Average Day simulations were utilized to determine the effective and total storage volumes of the storage tanks. The effective storage is defined as the minimum acceptable hydraulic grade line (HGL) for the tank. The total storage volume is defined as the nominal capacity of the tank.

The Maximum Day and Peak Hour simulations were utilized to determine the equalization storage volume of the tanks. Equalization storage is defined as the volume in the tank which meets the water system demands that are in excess of the pumping capacity of the water system.

The Maximum Day Plus Fire Flow and Peak Hour simulations were utilized to determine the emergency and fire storage volumes of the tanks. The emergency and fire storage is typically used for emergency purposes that would occur during a fire flow event, pipeline failures or equipment failures. Below this water level is the ineffective storage that cannot effectively supply the distribution system with adequate pressure of 20 psi or greater.

- It was concluded that one (1) extended period simulation for the current year (2006) demands and one (1) extended period simulation for the future 20 year (2026) demands for a total of two (2) EPS's would be conducted. The EPS's included the following.

  Extended period simulations 2006 and 2026 demands:

- Maximum Day at 96 hour time period

The Maximum Day EPS's were utilized to evaluate various water storage alternatives as well as to size water mains associated with these storage facilities. It was critical to examine the Fiskeville Reservoirs, West Street Tank and Wakefield Street Tank to evaluate options to optimize the use of these storage facilities because they do no float on the system due to their proximity to the Clinton Avenue Pump Station.

The EPS was critical when examining the volumes and fill/draw rates that would occur in a particular tank during maximum day demand conditions. Examination of the fill/draw rates aided in determining the equalization storage of a tank. Examining the fill/draw rates of the various storage tanks also provided a determination as to which tanks were the most critical in meeting peak demands.

The EPS also aided in determining the total storage capacity and final tank sizing and location. The final tank size and location is a function of various factors that included the volumes of equalization storage and emergency storage, fire flow requirements, fill and draw cycles of the existing tank and hydraulics of the water system.

- When evaluating the 20 year planning period (2026) demands, future water system infrastructure improvements were considered to determine the effectiveness of the tanks in the water system conditions that would occur in 20 years. The water system infrastructure improvements were contained in the KCWA's Capital Improvement Plan and Infrastructure Replacement Program and were scheduled to be in place during the 20 year planning period.

2.6.3 2014 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were established after a review of the hydraulic model simulations that were previously developed in the 2007 tank study which were utilized to identify areas of the KCWA's water system that may need additional storage capacity.

- It was determined that two (2) steady state simulations would be conducted for the current year (2014) demands (2012 baseline model year demands) and four (4) steady state simulations would be conducted for the future 20 year (2034) demands for a total of six (6) steady state simulations. The steady state simulations included the following.

  Steady state simulations 2014 demands:

  - Average Day
  - Maximum Day

  Steady state simulations 2034 demands:

  - Average Day
  - Maximum Day
  - Average Day with Future System Improvements
  - Maximum Day with Future System improvements

These steady state simulations helped to identify isolated areas of the distribution system that experience low pressures on a routine basis. The steady state model simulations also identified areas of deficient storage, tanks that do not cycle, tanks that are undersized and tanks that may be problematic due to their location in the system. After reviewing the steady state model simulations conducted in the 2007 tank study, it was determined that the Average Day and Maximum Day model simulations identified above for both the current year and 20 year demands were sufficient to identify storage facility deficiencies.

It was concluded that Maximum Day Plus Fire Flow and Peak Hour simulations would not be conducted as part of this tank study update. Both the current and future planning period consumer demands utilized in this updated tank study are approximately 30% lower than the consumer demands utilized in the 2007 tank study for all demand conditions (i.e. average day, maximum day, peak hour) so it was therefore determined that tank cycling was the only issue that needed to be evaluated for this updated tank study. Because of the reasons mentioned above, it was determined that conducting Average Day and Maximum Day steady state simulations would be sufficient for this evaluation and fire flows were irrelevant to this storage tank evaluation. Should fire flow analysis be required for non-operational consideration (i.e. litigation or concerns for the general public), past fire flow analysis with much higher demands or without system improvements can be utilized to address these issues.

- It was concluded that one (1) extended period simulation for the current year (2014) demands and two (2) extended period simulations for the future 20 year (2034) demands for a total of three (3) EPS's would be conducted. The EPS's included the following.

  Extended period simulations 2014 demands:

  - Maximum Day at 48 hour time period

  Extended period simulations 2034 demands:

  - Maximum Day at 48 hour time period
  - Maximum Day at 48 hour time period with Future System Improvements

  The EPS's aided in determining the volumes and the fill/draw rates that would occur in a particular tank during the current year and future 20 year demand periods. Due to the fact that the current and future planning period demands utilized for the updated tank study were approximately 30% lower that the consumer demands utilized in the 2007 tank study, it was determined that the cycling of the storage facilities was the only issue that needed to be evaluated as part of this updated tank study. It was concluded that the Maximum Day extended period simulations referenced above are sufficient for this storage facility evaluation and because of the decrease in consumer demand, fire flow model simulations were not relevant to this storage facility evaluation.

  If it is determined that in the future, removing certain tanks from service due to poor cycling is necessary these should be modeled in a site specific basis. This will insure that any operational changes included in removing the specific tank for service can be modeled as well.

- When evaluating the 20 year planning period (2034) demands, future planned water system infrastructure improvements were considered to determine the effectiveness of the tanks in the water system conditions that would occur in 20 years. The water system infrastructure improvements were contained in the KCWA's Capital Improvement Plan and Infrastructure Replacement Program and were scheduled to be in place during the 20 year planning period. For this updated tank study, the Maximum Day extended period simulations for the 20 year planning period were conducted with both the current water system infrastructure conditions and the future planned water system infrastructure improvements.

2.7 Technical Memorandum 4A

Technical Memorandum No. 4A of the 2007 tank study is entitled *Existing Storage Facility Analysis* and was prepared in April 2007 and revised in June and July 2007.

2.7.1 Purpose and Scope

The tasks of Technical Memorandum No. 4A consisted of evaluating the existing water storage facilities within the distribution system including their ability to meet system demands, provide adequate system pressures and provide fire flow reserve that was based upon previously developed criteria. Hydraulic model simulations were performed for both steady state and extended period to determine the capability of the water system under current planning year average day and maximum day demand conditions as well as fire flow conditions while simultaneously reviewing storage and supply capacities to ensure that they meet operational and regulatory requirements. Each of the five (5) storage facilities within the water system were also evaluated to assess their effectiveness in meeting existing system demands.

2.7.2 2007 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were provided in Technical Memorandum No. 4A and were based upon the hydraulic model simulations conducted for this task.

- It was concluded that there are certain locations within the KCWA water system that have marginal pressures (less than 20 psi). These locations of low pressures may not directly impact customer services as some occur at high points along transmission mains with no services, areas around storage reservoirs, on the suction side of booster pump stations and on the upstream side of PRV stations.
- It was concluded that the operation of the Clinton Avenue Pump Station on a continuous basis created difficulties with several of the storage tanks in the Low Pressure Gradient. These difficulties related to the inability of these storage tanks to turnover and routinely

remain in a locked up condition due to the pump head of the Clinton Avenue Pump Station which was above the overflow of the tanks. However, it was recognized that there is an inherent need to operate the Clinton Avenue Pump Station continuously due to the necessity to maintain adequate pressures at higher elevations, to provide upwards of 70% of the water supply to the water system, to replenish distant water storage tanks in the Low Service Gradient and to provide supply to the booster pump stations and PRV stations that supply other pressure gradients which rely on the Low Service Gradient as the primary source of supply.

- It was recommended that the Fiskeville Reservoirs, located in the Low Service Gradient, be permanently removed from service due to the fact the model simulations indicated that these storage facilities remained in a continued locked up condition due to their proximity to the Clinton Avenue Pump Station. Due to these storage facilities being located at the extreme northern end of the water system and the inherent problems associated with maintaining sanitary conditions for below grade structures, it was not considered practical to maintain these facilities in operational service. Additionally, these storage facilities predated the construction of the Clinton Avenue Pump Station and became obsolete over the years as the water system and customer service area grew and expanded. It was recommended that the general service area surrounding the Fiskeville Reservoirs be re-serviced from the High Service Gradient to alleviate any low pressures in this portion of the water system.
- The hydraulic model simulation results concluded that the West Street and Wakefield Street Tanks were constantly maintained in a locked up condition due to their proximities to the Clinton Avenue Pump Station.

The West Street Tank was not considered significant to daily water system operations due to its locked up condition. This tank was considered significant in terms of fire and emergency storage due to its location in the water system in proximity to densely populated urban areas and mill complexes. It was recommended that a booster pump station be installed at the West Street Tank to promote tank cycling and turnover.

The Wakefield Street Tank was considered beneficial in supplying daily peak system demands and fire and emergency storage. The addition of new pipeline infrastructure associated with the Providence Water Emergency Interconnection has caused this tank to remain in a locked up condition on a frequent basis. These new pipelines have increased the flow of water from the Clinton Avenue Pump Station to the general area of the tank causing the pump head to influence the tank. It was recommended that a valve station to isolate the Wakefield Street Tank be installed to promote tank cycling and turnover.

- A review of the available historical tank charts concluded that the KCWA was able to maintain an adequate water level in each storage tank within the ranges necessary for maintaining adequate consumer system pressures and fire flow pressures in each pressure zone.
- The extended period model simulations indicated that the water system's storage tanks operated within a range defined for operational and equalization storage based on previously developed criteria. It was concluded that for all demand scenarios there were no instances in which the dedicated volume for fire protection or emergency storage was depleted.
- It was concluded that each of the system's water storage tanks, excluding the Fiskeville Reservoirs, had adequate fire reserve such that a 20 psi minimum residual pressure was maintained for a fire flow rate of 3,500 gpm for a duration of three (3) hours.
- It has been concluded that the model simulations indicate that all of the KCWA's storage facilities (with the exception of the West Street and Wakefield Street Tanks) routinely drain and refill under the current year (2006) demand conditions.
- It was concluded that the KCWA relies on the wholesale connection with Providence Water at the Clinton Avenue Pump Station to provide a majority (upwards of 70%) of water supply to the system. Disruption of the wholesale connection would severely hamper the supply capability of the water system. However, it was concluded that alternate sources of supply were available to the KCWA including well facilities (East Greenwich, Coventry/Spring Lake and Mishnock) and the Quaker Lane Pump Station (wholesale supply from Warwick Water). These supply sources would collectively have the ability to meet average day system demands.

It was therefore concluded that the KCWA had emergency supply source capability, which would have a greater value on a day-to-day basis than a distinct volume of water in the tanks in the case of an emergency as the tanks would be readily depleted in an emergency. It was also concluded that the KCWA had a greater benefit in redundant supply sources than any available emergency storage in the tanks.

2.7.3 2014 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were determined based upon a review and comparison of the hydraulic model simulations conducted for the 2007 tank study and updated hydraulic model simulations conducted for this 2014 tank study update. The primary focus of this assessment is to determine how the reduction in system demands effects distribution system storage operation in regards to turnover rates, water age and water quality.

- It was concluded that there continue to be locations within the KCWA water system that have marginal pressures of less than 20 psi. It is recommended that the KCWA should continue to monitor the areas of low pressures and should also continue to implement water system infrastructure improvements to eliminate the dead ends and the older and smaller diameter water mains within the water system which would improve flow to some of the areas with low pressures.
- Since completion of the 2007 tank study, variable frequency drives (VFD's) were installed on two (2) of the Low Service Gradient pumps at the Clinton Avenue Pump Station in an effort to alleviate some of the water system conditions that occur due to the pump head of the Clinton Avenue Pump Station. The model evaluations completed for this tank study update included the use of the VFD's at the Clinton Avenue Pump Station and have concluded that the installation of the VFD's has alleviated some of the problems in the water system associated with the pump head of the Clinton Avenue Pump Station. Though these improvements improved operational pressures in the northern portion of the Low Service area they did not result in hydraulic conditions that would allow tanks previously removed from service to be returned to proper operation. The results of the average day and maximum day steady state hydraulic model simulations for the current year (2014) planning period are included in Appendix C. The results of the maximum

day extended period simulations for the current year (2014) planning period are included in Appendix D.

- The 2007 tank study recommended that the Fiskeville Reservoirs be permanently removed from service due to the fact that model simulations indicated that these storage facilities remained in a continuous locked up condition due to their proximity to the Clinton Avenue Pump Station. Since the completion of the 2007 tank study, the Fiskeville Reservoirs have been permanently removed from service and are no longer a part of the KCWA water system. Therefore, these reservoirs were not considered or included in any model simulations conducted for this updated tank study as they are no longer represented in the hydraulic model of the KCWA water system.
- Several modeling studies conducted since the completion of the 2007 tank study have indicated that the West Street and Wakefield Street Tanks are maintained in a constant locked up condition. A hydraulic evaluation of the Wakefield Street Tank completed in November 2013 as a result of water quality issues associated with poor turnover of the tank considered the impact of completed and proposed water system infrastructure improvements on the turnover rates of the tank. The November 2013 evaluation indicated that the Wakefield Street Tank continuously remained in a locked up condition throughout all demand scenarios.
- The model update included verifying and adjusting some of the water system facility elevations but despite these elevation adjustments there continue to be some areas with lower than desired pressures.
- The operational data for the maximum day demand, which occurred in 2012, were reviewed. The review of these tank charts concludes that the KCWA continues to have the ability to maintain an adequate water level in each storage tank within the ranges necessary for maintaining adequate consumer system pressures and fire flow pressures in each pressure zone.
- The extended period simulation performed for the current year (2014) planning period concludes that the water system's storage tanks continue to operate within a range defined for operational and equalization storage based on previously developed criteria. In conclusion, for all demand scenarios there were no instances in which the dedicated volume for emergency storage was depleted. The extended period simulation results

indicate that all of the storage tanks within the KCWA water system cycle and turnover at decreased rates than they did in the 2007 tank study due to the lower consumer demands utilized for this updated tank study. This may result in future water quality issues that should be further assessed by the KCWA. These extended period simulation results are included in Appendix D.

- Fire flow model simulations were not conducted for this tank study update. The current year (2014) planning period demands utilized in this updated tank study are approximately 30% lower than the current year (2006) planning period demands utilized in the 2007 tank study. Based upon the lower consumer demands utilized in this 2014 tank study update, it was concluded that each of the system's water storage tanks have adequate fire reserve such that a 20 psi minimum residual pressure could be maintained within the water distribution system for a fire flow rate of 3,500 gpm for a duration of three (3) hours. This is based on the fact that reduced customer demands could only improve the ability to keep tanks full and provide fire flow. If these parameters could be maintained with the higher consumer demands utilized in the 2007 tank study, then the lower consumer demands of the 2014 tank study update would only improve the adequacy of the fire reserve of the system's water storage tanks.
- The model simulations conducted as a part of this 2014 tank study update have concluded that the KCWA continues to rely on the wholesale connection with Providence Water at the Clinton Avenue Pump Station to provide a majority of water supply to the system. The KCWA continues to rely on the well facilities, the Quaker Lane Pump Station and the Providence Water Emergency Interconnection as alternate sources of supply. The East Greenwich Well is currently undergoing redevelopment as this well is a critical supply source to the southern portion of the water system due to hydraulics of the water system. The Coventry/Spring Lake Well is offline due to issues with water quality but the Mishnock Water Treatment Plant has recently been constructed to address water quality issues and the Mishnock Well Field has been brought back online providing an alternate water supply to the system. The Quaker Lane Pump Station has recently been upgraded and also serves as an alternate supply to the water system. Also, the Providence Water Emergency Interconnection could temporarily back up the Clinton Avenue Pump Station during non-peak demands.

Due to the lower consumer demands of the updated model/tank study compared to the higher consumer demands of the 2007 model/tank study and the numerous alternate water supplies of the KCWA system, it is concluded that the KCWA continues to have emergency supply source capability and that the KCWA has a greater benefit in redundant supply sources than any available emergency storage in the tanks.

The model update and revised tank study also identified issues with tank cycling. With the reduction in demands, several tanks are filling and draining at a much lower rate than previously. Specifically, the Carr Pond Road Tank had a water age of 68 days in the updated model as opposed to 12 days in the 2007 tank study. This increase in water age can lead to water quality concerns and issues with compliance with the Disinfection By-Product Rule. Such issues should be further evaluated on a tank by tank basis to determine if there is the potential to remove some of the tanks with poor cycling from service.

2.8 Technical Memorandum No. 4B

Technical Memorandum No. 4B of the 2007 tank study is entitled *Available Fire Flow Analysis* and was prepared in June 2007 and revised in July 2007.

2.8.1 Purpose and Scope

The tasks of Technical Memorandum No. 4B included an analysis of the entire water distribution system under the current year planning period maximum day conditions. This analysis was performed utilizing the hydraulic model in order to determine the available fire flow rates throughout the water system. An evaluation was also performed to determine the fire flow rate that would be available for each of the various water main segments in the model.

The criteria that were utilized to determine the available fire flow rates included specifying a minimum fire flow of 500 gpm and a maximum fire flow of 3,500 gpm. For the purposes of this analysis, these fire flow rates correspond to the upper and lower ranges in the hydraulic model and are considered typical for a service territory such as the KCWA's which consists of a mixed use of urban, suburban, commercial and industrial uses. All of the fire flow rates were based upon a minimum residual pressure of 20 psi at the fire flow location and a minimum system pressure of 0 psi. Note, the zero pressure is not an operating pressure for the system but rather a model setting necessary to determine the available fire flow at a specific location. Any fire flow determination analysis at a pressure below 20 psi would be considered deficient in accordance with regulatory standards. The minimum system pressure was established at 0 psi due to the fact that there are locations within the water system that routinely experience pressures below 20 psi during normal demand conditions.

2.8.2 2007 Tank Study Conclusions and Recommendations

The following conclusions and recommendations were provided in Technical Memorandum No. 4B and were based upon the analysis of the water distribution system conducted for this task.

- The available fire flow calculations were performed under a maximum day demand condition. It was concluded that fire flow rates would vary under other demand conditions (i.e. average day and peak hour).
- The fire flow calculations were performed individually at each location. It was concluded that the fire flows are representative of the available capacity in the water main at a particular location. The model results indicated that the fire flow was not directly available from a single hydrant assembly or hose connection. It was also concluded that these fire flow rates are exclusive in that each represents an available fire flow rate at a specific location. In other words, the individual results calculated for each location could not be combined to represent total available fire flow.
- The calculation of the fire flow results was premised upon maintaining a residual pressure of 20 psi at the fire flow location and a minimum system wide residual pressure of 0 psi (see Section 2.8.1 regarding the 0 psi pressure setting). The fire flow results are typically calculated within a minimum system wide residual pressure of 20 psi. Due to the fact that the KCWA has areas in their water system with static pressures that are less than 20 psi, it was recommended that the boundary condition for system wide residual pressure be set at 0 psi (see Section 2.8.1 regarding the 0 psi pressure setting).

- The residual pressure at the fire flow locations was not driven down to 20 psi in certain instances due to another location in the water system having a calculated pressure of 0 psi. It was concluded that if areas of substandard pressures were corrected, then the available fire flow at the flow location would be calculated at a higher rate.
- The hydraulic model results did not imply that a particular water main had fire hydrants or was used for fire fighting purposes. Based upon the model results it was concluded that smaller diameter service mains (i.e. 1-inch, 2-inches) would not likely have hydrants but the model calculated fire flow results for these water mains. It was recommended that when reviewing the model results for a particular location, information such as the location and number of hydrants also needed to be considered.

2.8.3 2014 Tank Study Conclusions and Recommendations

As indicated previously in this report, extensive additional fire flow model simulations were not conducted for this 2014 tank study update. The 2007 tank study, followed by the study of the Wakefield Street Tank in 2013, showed that the distribution system is capable of meeting the water system's fire fighting requirements with the exception of a few isolated areas that, due to elevation or undersized mains, are fire flow deficient. The current year (2014) planning period consumer demands that were utilized in this updated tank study are approximately 30% lower than the current year (2006) planning period consumer demands that were utilized in the 2007 tank study and it was determined that the cycling of the tanks was the only issue that needed to be evaluated. Based upon these facts, it was concluded that fire flow model simulations were not necessary for this updated tank study as the system fire flows were not relevant to this evaluation. It was also concluded that the results of the fire flow model simulations would be more favorable with the lower consumer demands utilized in this tank study.

2.9 Technical Memorandum No. 5A and No. 5B

Technical Memorandum No. 5A of the 2007 tank study is entitled *Storage Facility Analysis – Future Demand Conditions* and was prepared in May 2007 and revised in July 2007 and August 2007. Technical Memorandum No. 5B of the 2007 tank study is entitled *Available Fire Flow Analysis of Future Conditions* and was prepared in April 2007 and revised in December 2007.

Technical Memorandum 5A and 5B of the 2007 Storage Tank Evaluation related to assessing the existing KCWA water storage tanks in their ability to meet both existing demands (2006) and future projected demands throughout the 20-year planning horizon (2026). In addition, in 2013 the Wakefield Street Tank and the area around it was extensively evaluated using the hydraulic model to determine if removing this tank from service would have any effect on meeting fire flow demands. Both these assessments showed that the distribution storage tanks adequately meet the required fire flows for both current and projected demands. The 2013 Wakefield Street Tank study also indicated that this tank could be removed from service and fire flows in this area of the system would continue to be more than adequately met. The 2013 Wakefield Tank study included the integration of the infrastructure improvements in this area of the system. Therefore, with the lower demands of the 2014 update the conclusions of the 2013 study remain valid.

A water storage tank's ability to meet an area's fire flow requirements is dependent upon two factors which are the volume held in storage (i.e. size of the tank) and the ability of these tanks to be filled (or remain at a high level) during high demand periods (is the tank undersized so it excessively drains during peak demand). This was not a concern during the 2007 study when the demands were 30% greater therefore they are not a concern in 2014. In addition, due to the fact the projected demand in the projected 20-year planning period 2034 is also less than the demands in 2007, these fire flow requirements should continue to be met.

3.0 Conclusions and Recommendations

3.1 General

This 2014 updated study of the KCWA storage facilities consisted of a hydraulic evaluation of the entire water distribution system while considering system demands for both the current (2014) and 20 year (2034) planning periods and the ability of the water system infrastructure components to effectively meet these demands. The current year planning period utilized the 2012 baseline model year demands. Following are the conclusions and recommendations of the 2014 storage facility evaluation.

- Based upon a review of the Comprehensive Community Plans of the various Cities and Towns serviced by the KCWA, RISWP data, 2010 US Census data and information provided by KCWA staff, it was concluded that the overall population growth within the customer service territory from 2015 through the year 2035 is projected to increase by 3.3% (2,941 persons). As previously indicated, this population growth included service population changes of -5.2% for Warwick, -1.5% for West Warwick, +9.2% for Coventry, +32.9% for West Greenwich, +7.5% for East Greenwich, +3.1% for Cranston, 0.0% for North Kingstown and +3.6% for Scituate. The service area in North Kingstown does not include any residential customers and the KCWA has no plans to increase its service territory within this community. These population projections represent changes in customer services based on the existing service territory and may not reflect total change in population within the particular community. It was also concluded that the new system average day demand was 7.99 MGD, resulting in a revised maximum day demand of 15.46 MGD and a peak hour demand of 18.80 MGD. When comparing these demands to the system demands utilized in the 2007 storage facility evaluation, the average day demand has decreased by 27.4% (3.01 MGD), the maximum day demand has decreased by 26.7% (5.64 MGD) and the peak hour demand has decreased by 25.7% (6.50 MGD). The decrease in consumer demands can also be attributed to the loss of large commercial users such as ON Semiconductor and the reduction of water utilized by several commercial users such as Clariant. These commercial demands are not expected to be replaced in the water system by new commercial businesses in the near and distant future.

- As a result of a review of the tank operational conditions, the storage tanks are being operated in a manner consistent with the operational conditions in 2007 at lower rates of turnover. The only exception to this is that the Wakefield Street Tank is no longer in service and this was removed in 2013 only after extensive additional hydraulic evaluations indicated that water service would not be affected. The critical parameters for the water storage tanks are as follows.

STORAGE TANK FACILITY	BASE (GROUND) ELEVATION (FEET)	OVERFLOW ELEVATION (FEET)
Technology Park Tank	350	500
Carr Pond Tank	418	500
Frenchtown Road Tank	284	334
Setian Lane Tank	314	334
Read School House Road Tank	475	500

- It was concluded that the KCWA service population would increase by 3.3% or 2,941 people in the 20 year planning period. This increase in population in the 20 year planning period will occur at a slower rate than the increase of 7.8% calculated for the 20 year planning period in the 2007 tank study. It has also been concluded that the total system demand for the 20 year planning period (2034) will increase by approximately 13% over the current demands presented in the 2014 model update but will be significantly less than those projected in the 2006 model evaluation. Based upon the above calculated 20 year planning period demands, it was concluded that the average day demand is 29.0% lower, the maximum day demand is 29.1% lower and the peak hour demand is 28.1% lower than the 20 year planning period demands calculated for the 2007 tank study.

- The extended period simulation performed for the current year (2014) planning period concludes that all of the storage tanks within the KCWA water system cycle and turnover at decreased rates compared to the rates they cycled at in the 2007 tank study due to the lower consumer demands utilized for this updated tank study. Lower cycle or turnover rates for a water storage facility means that water in the storage tank is less often replaced with fresh water from the water system's sources of supply. The term Water Age is also applied to the numerical value that a tank requires to replace its entire volume with fresh water. For example, if a one million gallon tank cycles (i.e. takes in and withdraws 300,000 gallons per day) it cycles every 3.3 days and therefore the water in the tank has a Water Age of 3.3 days. It must be understood that water age is not a true representation of how long water remains in a storage tank. Some water tanks have mixing systems or separate fill and draw piping while others operate on a single pipe fill and draw system. All of these elements would affect the efficiency of mixing and therefore the actual age of the water in the storage facility. Water Age is more typically used on a qualitative basis when judging the cycling of a water tank to determine if the tank cycles or it is in a "locked up condition". A rule of thumb is that the higher the water age, the less the tanks adequately cycle with 5 to 7 days being a typical goal.

Below is the water age for the active tanks in the KCWA water system, comparing their operation in the 2006 Model and the 2014 Model update.

TANK	MIXING SYSTEM Y/N	2006 MODEL TANK TURNOVER (Water Age)	2014 MODEL TANK TURNOVER (Water Age)
Read School House Road Tank*	Y	7.14 days	7.14 days
Frenchtown Road Tank*	N	2.22 days	4.55 days
Technology Park Tank	N	4.50 days	9.38 days
Carr Pond Road Tank	N	12.61 days	68.31 days
Setian Lane Tank*	N	2.00 days	2.90 days

*Denotes control tank

In this table it can be noted that of the five active tanks, three have doubled their water age with the exception of the Carr Pond Road Tank which has increased the Water Age by a factor of five.

The above table also denotes which tanks are control tanks. Control tanks are tanks which operate other system components based on level. For example as the Frenchtown Road Tank level drops pumps can be turned on at the Clinton Avenue Pump Station to begin refilling the tank. The significance of whether a tank is a control tank or not is that as a control tank there is more flexibility on adjusting water age through adjusting control set points. Non-control tanks will fill, drain or remain locked up strictly from the hydraulics of the water system. That is not to say that extreme caution should be exercised when making changes to control tanks to ensure water system operation is not adversely effected.

3.2 Conclusions

Based upon the 2014 update of the 2007 Tank Study the system storage facilities continue to meet the needs of the water system as indicated in 2007. This has been made more evident with the dramatic drop off in system demand which is anticipated to remain below what was considered normal eight years ago. It is also very likely that future demand will remain far below previous projections therefore hydraulically the storage tanks, if properly maintained, will meet the needs of the system for many years to come.

Of concern is the fact that in the original tank study, it was determined that several of the KCWA's storage facilities were identified as having potential problems with cycling, leading to increased Water Age. In recent years Water Age has become more and more of a concern because it has been understood that water, stagnant in a water system, can result in water quality concerns. These include chlorine decay (and loss of disinfection protection), bio-film growth and issues with disinfection by-products. Chlorine decays with time and systems with excessive Water Age have been known to have issues in maintaining chlorine residual. Bio-growth in a distribution system is a direct result of reduction of disinfection protection and can result in Total Coliform Rule (TCR) violations and affects to water quality aesthetics. Lastly, the EPA has passed stringent regulations for the control of disinfection bi-products. These include Trihalomethanes (THM); Haloacetic acids (HAA) both suspected carcinogens. THM's and HAA's are formed when chlorine compounds in drinking water combine with naturally occurring organics. It is understood that the concentration of chlorine along with time in contact directly relate to the amount of THM's and HAA's produced. Therefore Water Age is becoming a key indicator in water systems with THM issues. The decreased system demand has adversely impacted tank cycling below a level that was somewhat concerning in the 2007 tank study and engineering standards subsequently increasing Water Age in these tanks, in some cases significantly.

3.3 Recommendations

Hydraulically, the existing water storage facilities in the KCWA water system will continue to meet the needs of the system for many years to come. Unfortunately, under the lower demand conditions, Water Age in the system related to these storage facilities is a concern and should be addressed. This can be done on either a tank by tank basis or on the water system as a whole. It is believed if this is not done, low chlorine residuals in the distribution system will likely continue until they are addressed in some manner. Potential solutions include removing additional tanks from active operation, possibly rotating different tanks as control tanks to improve cycling, changing control settings to improve cycling and use of other mechanical systems to address the effects of Water Age based water quality effects (i.e. improved mixing systems, remote distribution system disinfection and forced cycling through off-hour tank pumping). All of these possible improvements have the potential for improving water quality but also equally have the potential for other unexpected consequences. It is therefore recommended that each and every one of these proposed system changes be further evaluated using the updated hydraulic model.

Much of the same can be said for the potential of the system to be further affected by issues with disinfection by-products. Increasing system Water Age has been proven to have a direct correlation to the production of increased THM's in chlorinated water systems, especially those relying on surface water as a source of supply. As previously stated, Providence Water supplies approximately 70% of the KCWA's water and it is all chlorinated surface water. It is therefore recommended that any assessment to change the current configuration, operation or use of the water system's storage facilities should also take in to consideration the impacts on Disinfection By-Product Rule compliance.

Based on the evaluation of the remaining online tanks for the KCWA's water system the following facility specific recommendations are presented below.

1. Read School House Road Tank – The Read School House Road Tank is the newest tank in the water system and is equipped with a mixing system. The 2014 Model update shows that it has an approximately 7 day cycle rate which is close to the maximum recommended cycle rate or Water Age. If there are no water quality issues associated with this tank, no further evaluation is needed for this facility. If THM's are of concern in the area of this facility and it is determined that improving the cycling rate of this tank could potentially alleviate these concerns, measures could be taken to improve the Water Age in this water storage facility. This tank was constructed with an overflow of 500 feet with the idea that this pressure zone (High Service North) would eventually be connected to the High Service South pressure zone in the area of Technology Park. This connection would be very costly due to the permitting constraints in the routing. At this time it is unknown whether this connection will be needed in the next 20 years based upon the reduction in customer demands. This allows the High Service North pressure zone to be maintained as a separate pressure zone for the foreseeable future.

   Prior to the construction of this tank, the previous storage facility was at an overflow elevation of 430 feet which translated to low pressure problems in some service areas. To improve cycling in this tank, the normal operational level could be lowered to decrease the volume to be turned over in the tank. This new operational level would be somewhere between 430 feet and 500 feet allowing adequate pressures to be addressed while the usable volume of the tank is minimized thereby improving cycling time and reducing water age. These operational improvements will require extensive additional modeling to determine the elevation that will be required to ensure adequate domestic and fire flows will be maintained within this portion of the system.

2. Carr Pond Road Tank – The Carr Pond Road Tank had issues with tank cycling identified in the 2007 model update and the 2007 tank study. At that time, it was found that this tank had a water age of over 12 days, almost twice the recommended tank cycling rate.

In the 2014 update this turnover rate climbed to over 68 days. It is therefore recommended that the KCWA consider removing this tank from service similar to the Wakefield Street Tank which was removed from service in 2013. Though preliminary model runs conducted as part of this evaluation indicate that this tank could possibly be removed from service without negatively affecting domestic and fire flows in this portion of the system, more extensive modeling will be necessary to further evaluate all potential effects of removing this tank from the water system.

3. Technology Park Tank – The reduction of demands from the 2007 model update to the 2014 update resulted in the water age in this tank going from 4.5 days to 9.83 days. This is just over the recommended cycling rate of 7 days. This may increase in the future with further reductions in water demands with the planned closing of one of the largest users in the pressure zone, Amgen. If the cycling rate continues to decrease, it may be possible to reduce the operating level of this tank similar to the recommendations of the Read School House Road Tank (above). The new operating level would be somewhere below 500 feet, at an elevation still capable of providing adequate domestic and fire flows but reducing the volume in the tank needed to be turned over.

   The installation of a mixing system should also be considered to improve the tank turnover and overall water quality. It should be noted that if demands continue to decline in this pressure zone, the mixing system will only be marginally effective due to the volume of this tank (1.5 MG) and the water needed to service the customers in this pressure zone.

4. Frenchtown Road Tank – The Frenchtown Road Tank has a cycling rate within recommended standards (4.55 days). To improve water quality in this area of the system, it is recommended that a mixing system be installed to increase internal circulation.

5. Setian Lane Tank – Similar to the Frenchtown Road Tank, the Setian Lane Tank has a cycling rate within recommended standards (2.90 days). It is recommended that a mixing system be installed in this tank to improve internal mixing. The High Service South

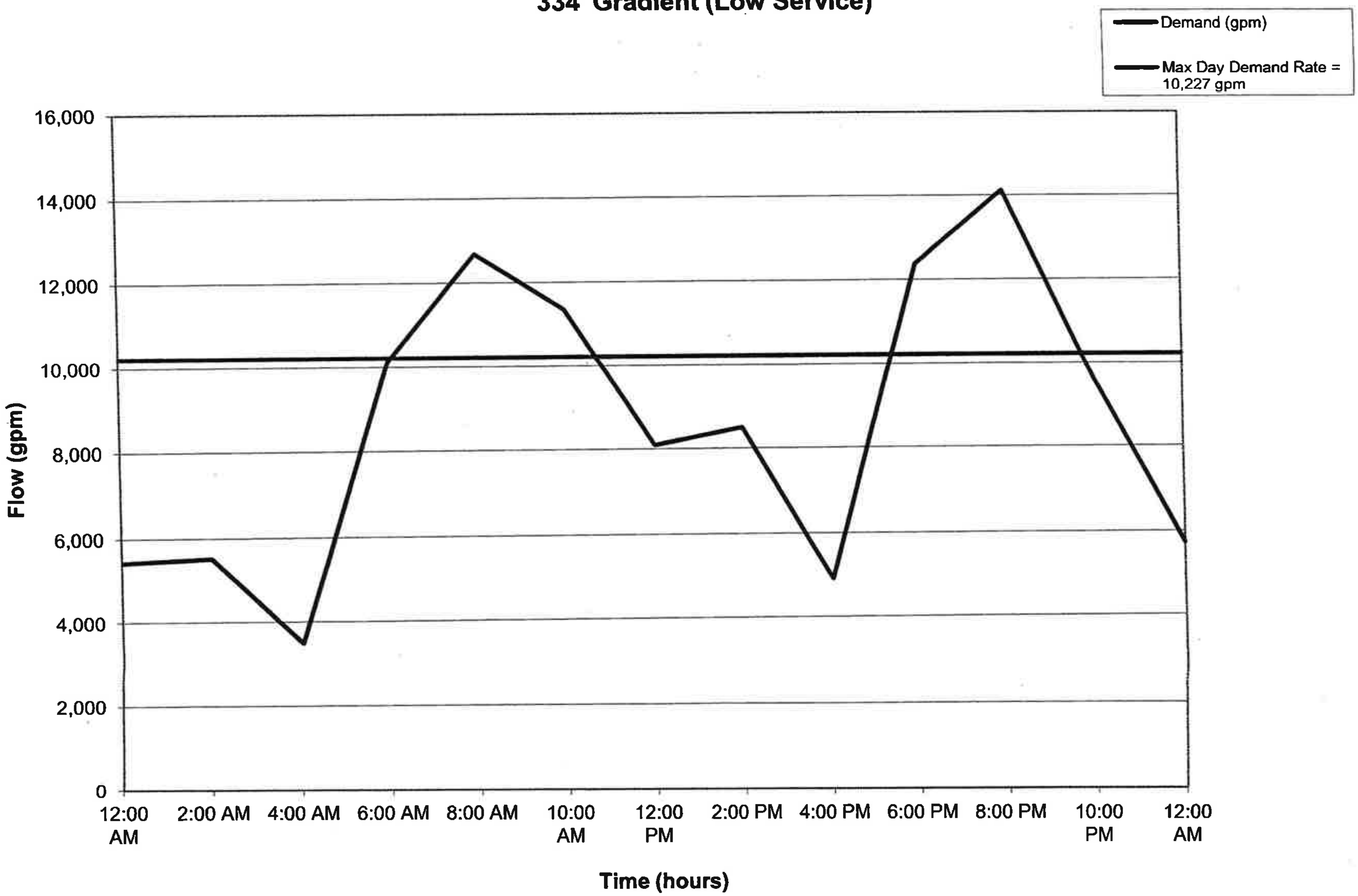
gradient withdraws flows from this tank via the Setian Lane Booster Pump Station. If demands continue to decline in this pressure zone, the cycling rate will continue to be adversely affected and due to the fact that this tank is a low profile tank, lowering the operating range to reduce the volume being cycled is not an option.

Lastly, in addition to the recommendations presented above, aside from removing certain tanks from service, it may be possible to install localized pumping systems at tanks with cycling problems to transfer water from storage tanks during non-peak hours to enhance tank turnover. Such pumps would have to be incorporated into the controls of the water system so that water could be withdrawn from a specific tank without an existing pump station attempting to refill the tank. This would require extensive modeling and assessment of the KCWA's SCADA system to determine operational changes necessary to make such a pumping system possible. If such a pumping system is determined to be viable, its installation should then be weighed against the pros and cons of the option of removing the subject tank from service permanently.

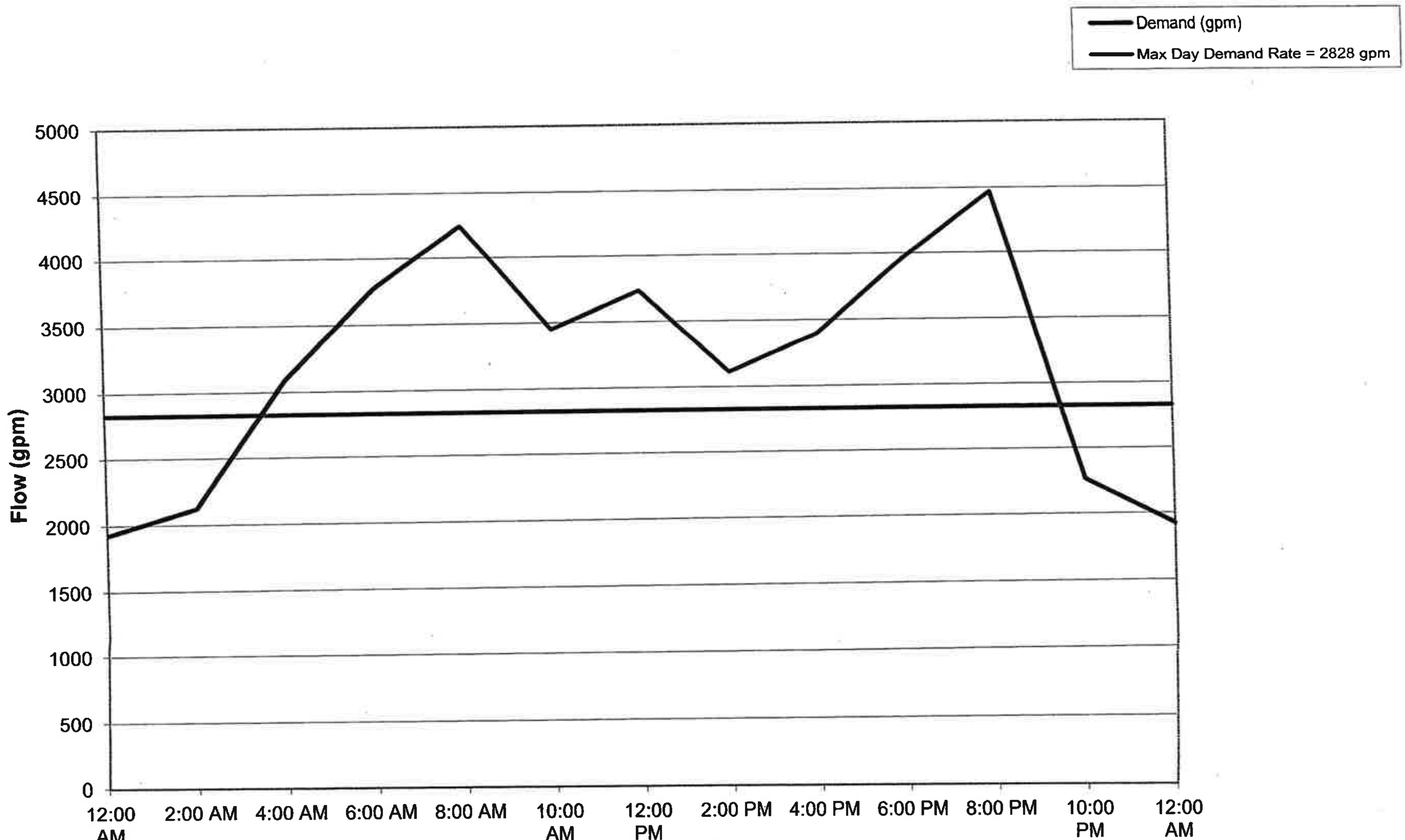
Appendix A

2007 Tank Study
Water System Diurnal Flow Curves

Maximum Day - Diurnal Flow Curve
334' Gradient (Low Service)

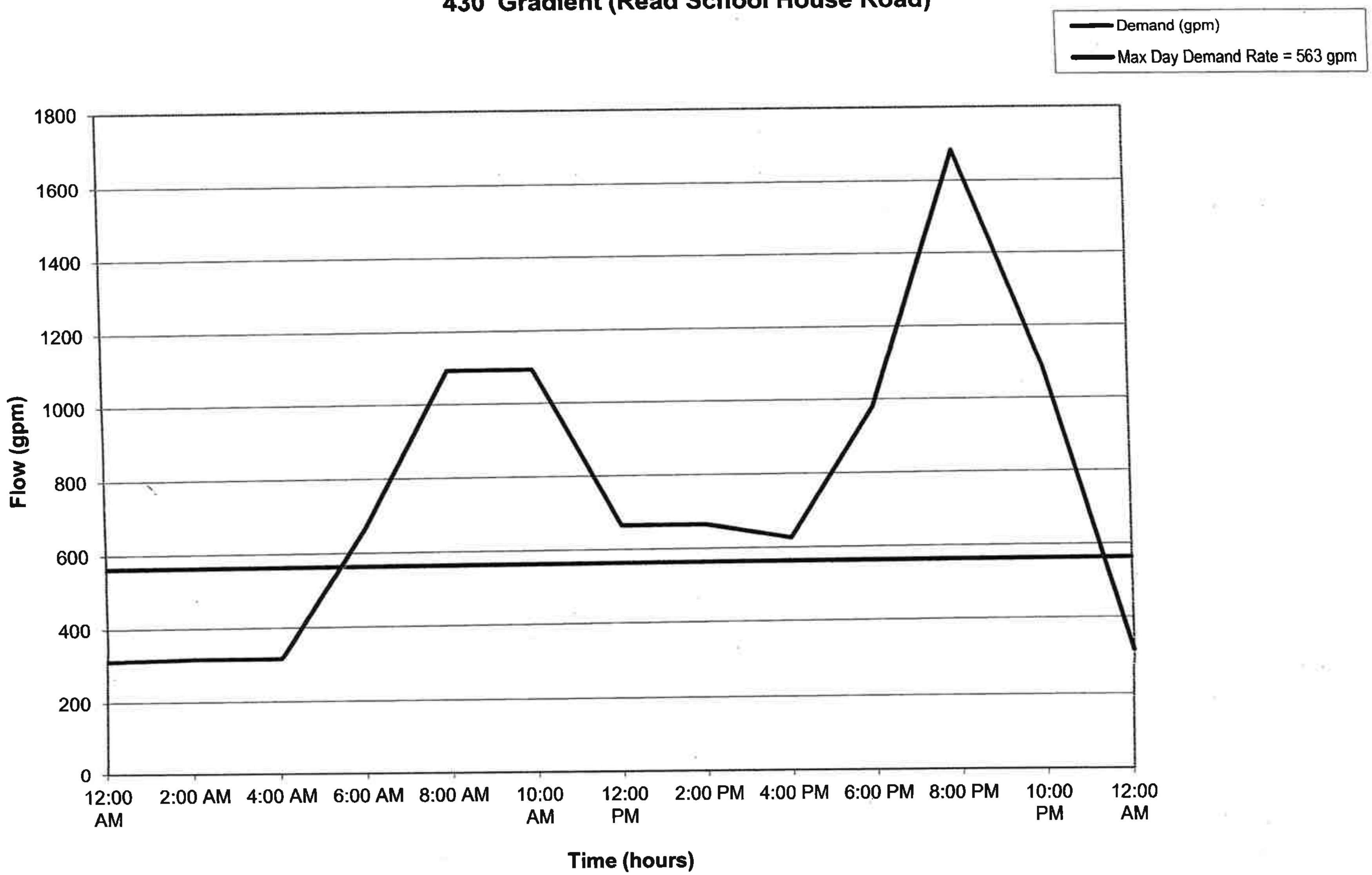


Maximum Day - Diurnal Flow Curve
500' Gradient (High Service)



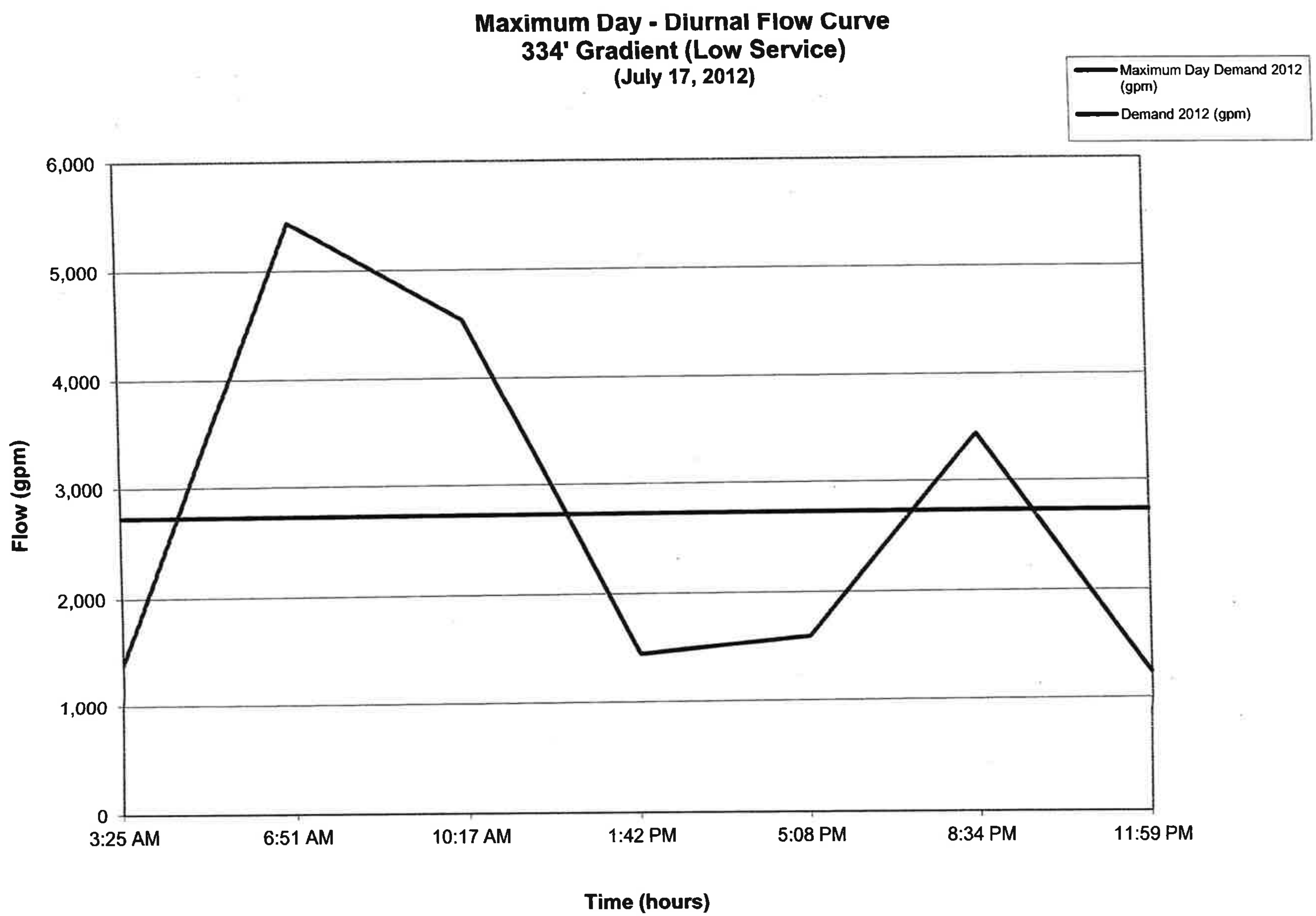
*Without Amgen Demand, Includes Tiogue Tank Gradient

Maximum Day - Diurnal Flow Curve
430' Gradient (Read School House Road)

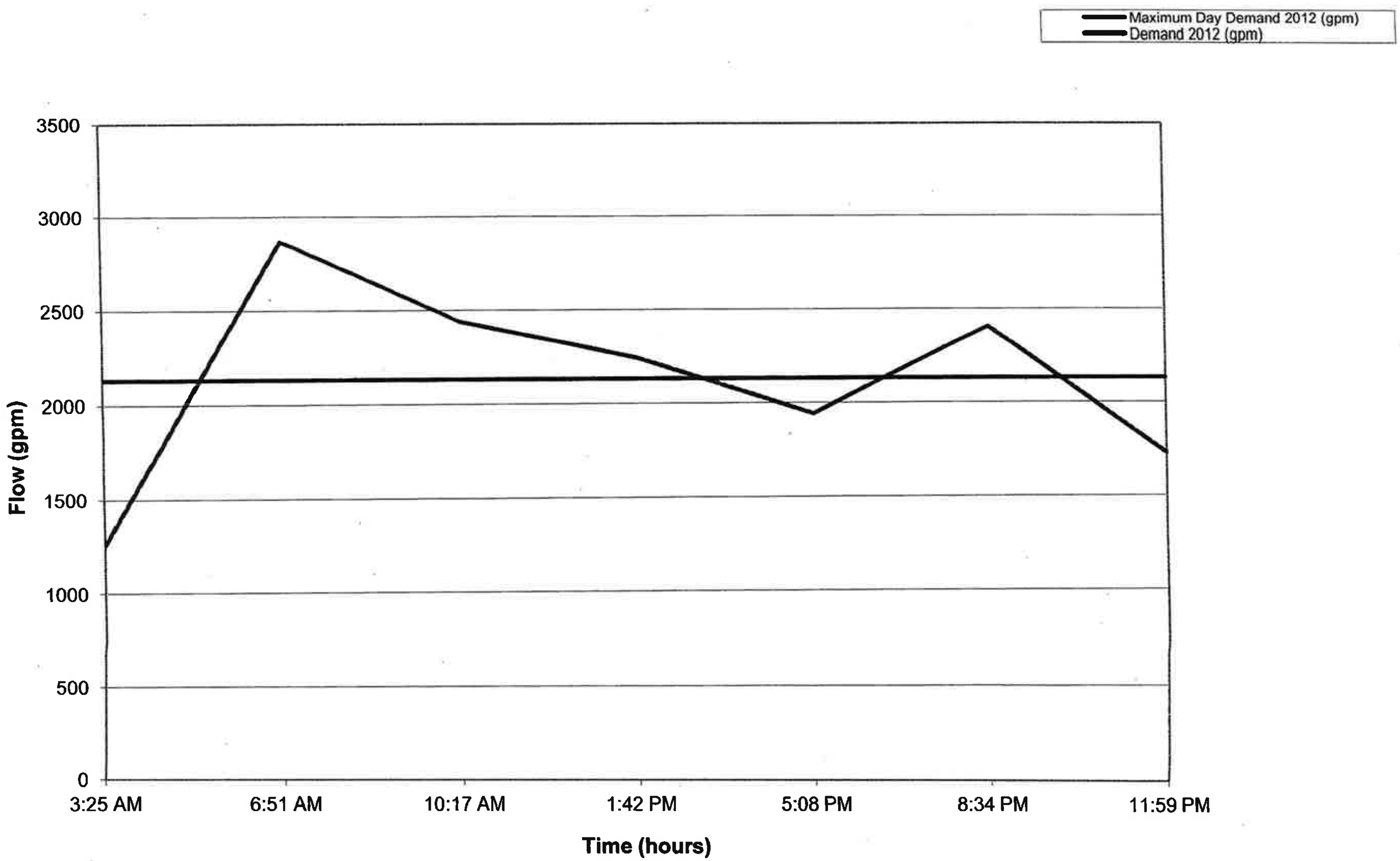


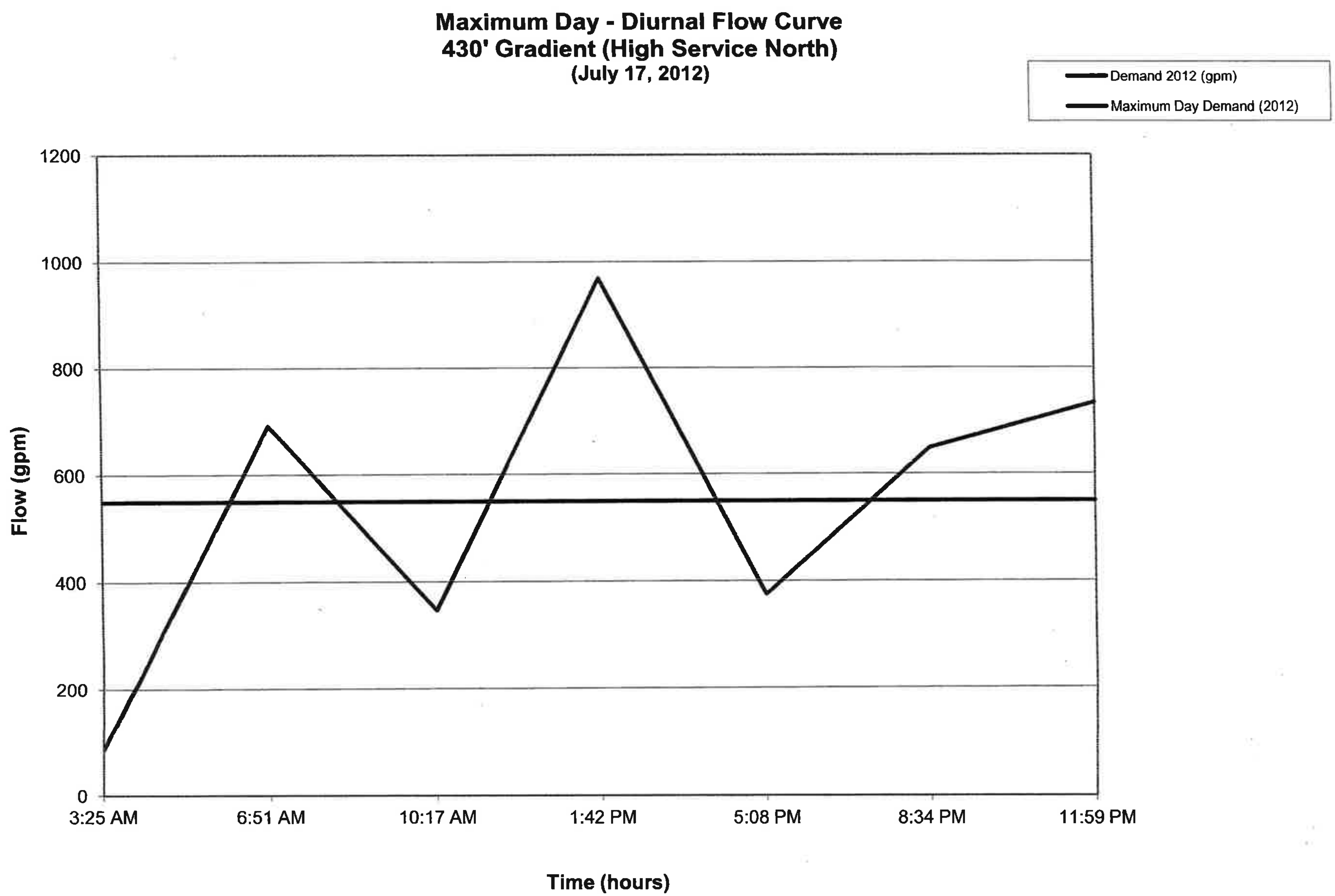
Appendix B

2014 Tank Study
Water System Diurnal Flow Curves


Maximum Day - Diurnal Flow Curve
334' Gradient (Low Service)
(July 17, 2012)
Maximum Day Demand 2012 (gpm)
Demand 2012 (gpm)
Flow (gpm)
6,000
5,000
4,000
3,000
2,000
1,000
0
3:25 AM
6:51 AM
10:17 AM
1:42 PM
5:08 PM
8:34 PM
11:59 PM
Time (hours)

Maximum Day - Diurnal Flow Curve
500' Gradient (High Service South)
(July 17, 2012)





Maximum Day - Diurnal Flow Curve
430' Gradient (High Service North)
(July 17, 2012)
Demand 2012 (gpm)
Maximum Day Demand (2012)
Flow (gpm)
1200
1000
800
600
400
200
0
3:25 AM
6:51 AM
10:17 AM
1:42 PM
5:08 PM
8:34 PM
11:59 PM
Time (hours)

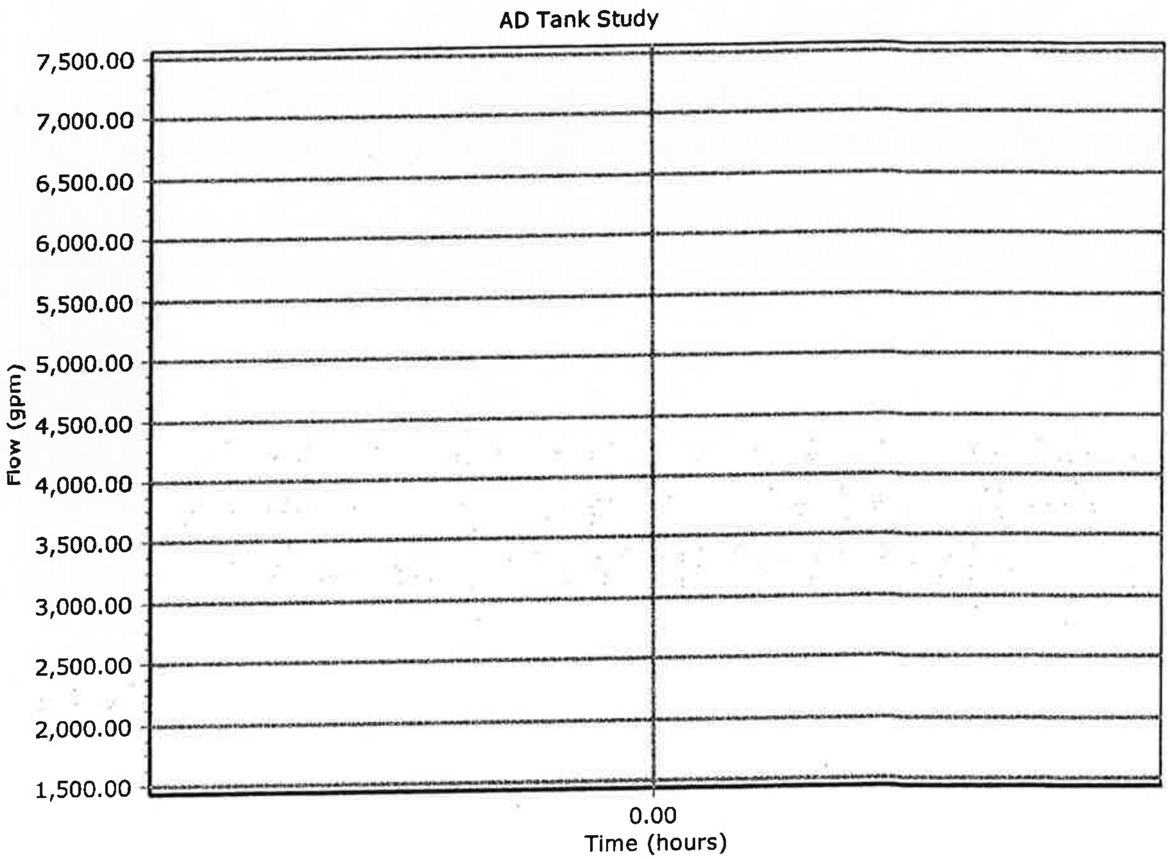
Appendix C

Current Year (2014) Planning Period
Steady State Simulations
Average Day and Maximum Day Demand

Active Scenario: AD Tank Study
Existing Infrastructure Conditions
Calculation Summary (10568: AD Tank Study)

Time (hours)	Balanced?	Trials	Relative Flow Change	Flow Supplied (gpm)
All Time Steps(0)	True	11	0.0002472	7,438.93
0.00	True	11	0.0002472	7,438.93

Flow Demanded (gpm)	Flow Stored (gpm)
5,552.13	1,886.93
5,552.13	1,886.93



Active Scenario: AD Tank Study
Existing Infrastructure Conditions
FlexTable: KCWA Tank Table

Current Time: 0.000 hours

Label	Diameter (ft)	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Net Inflow (gpm)	Description	Notes	Percent Full (%)
T-1	105.00	475.00	475.00	497.08	500.00	-269.59	Read School House Rd. Tank	COV	88.3
T-2	58.00	310.00	310.00	345.00	350.00	0.00	Tiogue Tank 0.771 MG - Off	COV	87.5
T-3	73.00	284.00	284.00	330.25	334.00	208.08	Frenchtown Rd. Tank 1.5 MG - LS	EG	92.5
T-4	75.25	350.00	450.00	497.50	500.00	-259.28	Technology Park Tank - HS	WG	95.0
T-5	80.00	418.00	418.00	495.82	500.00	859.96	Carr Pond Rd. Tank - HS	WG	94.9
T-6	58.00	284.00	284.00	328.00	334.00	0.00	West St. Tank 1 MG - Off	WW	88.0
T-7	160.00	314.00	314.00	327.00	334.00	1,347.74	Setian Ln. Tank - LS	WW	65.0
T-8	70.00	264.00	264.00	332.83	334.00	0.00	Wakefield St. Tank - Off	WW	98.3

Active Scenario: AD Tank Study
Existing Infrastructure Conditions
FlexTable: KCWA Pump Table

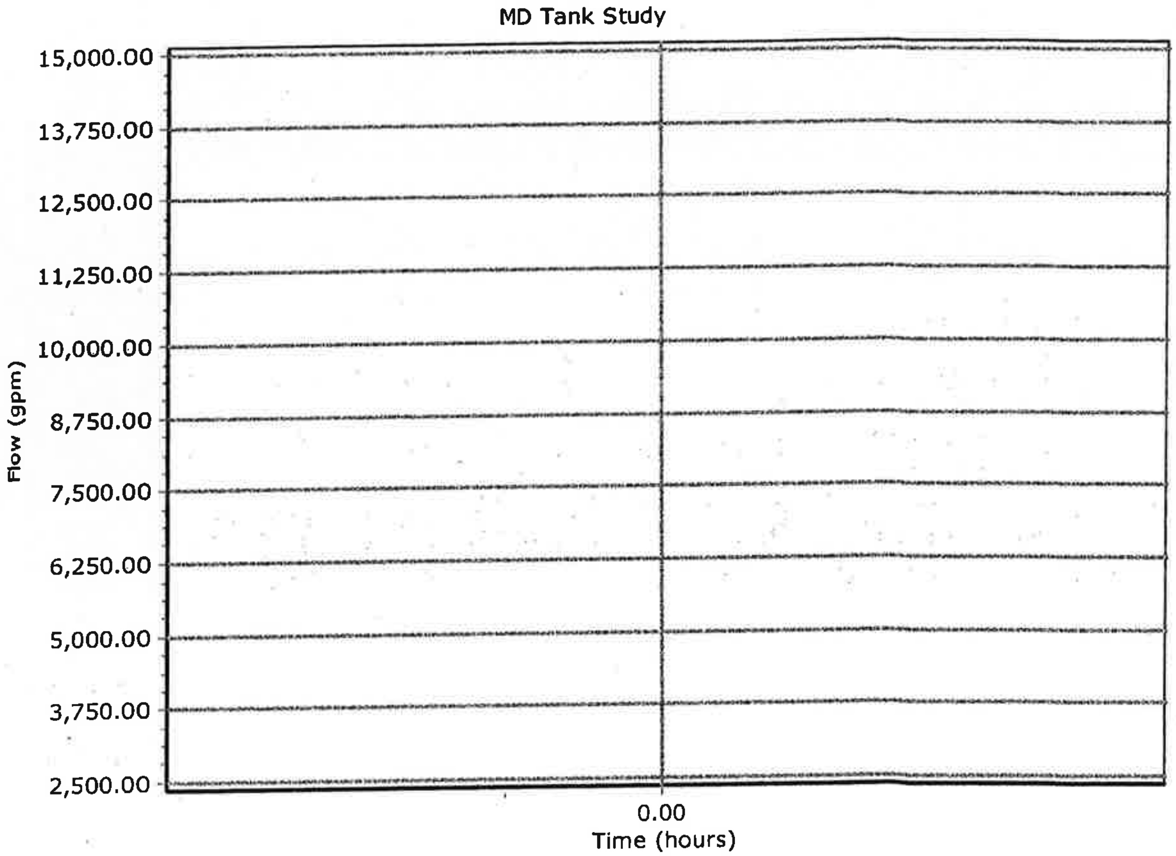
Current Time: 0.000 hours

Label	Elevation (ft)	Status (Calculated)	Hydraulic Grade (Suction) (ft)	Hydraulic Grade (Discharge) (ft)	Flow (Total) (gpm)	Pump Head (ft)	Pressure (Discharge) (psi)	Description	Notes
PMP-1	247.00	On	259.78	478.92	800.00	219.14	100.3	New Mishnock LS Pump	COV
PMP-2	247.00	Off	259.96	478.83	0.00	0.00	100.3	New Mishnock LS Pump	COV
PMP-4	229.80	Off	229.80	363.03	0.00	0.00	57.6	Coventry/Spring Lake Well	COV
PMP-5	15.00	On	15.44	333.64	1,144.59	318.20	137.9	EG Well	EG
PMP-9	250.00	Off	363.03	496.45	0.00	0.00	106.6	Pump 3 Johnson Blvd. PS	COV
PMP-10	250.00	Off	363.03	496.45	0.00	0.00	106.6	Pump 2 Johnson Blvd. PS	COV
PMP-11	250.00	Off	363.03	496.45	0.00	0.00	106.6	Pump 1 Johnson Blvd. PS	COV
PMP-13	182.00	Off	233.94	369.49	0.00	0.00	81.1	Pump 4 Clinton Ave. PS	SCIT
PMP-14	182.00	Off	233.94	369.49	0.00	0.00	81.1	Pump 3 Clinton Ave. PS	SCIT
PMP-15	182.00	On	233.78	369.84	1,570.74	136.06	81.3	Pump 2 Clinton Ave. PS	SCIT
PMP-16	182.00	On	233.78	369.84	1,570.74	136.06	81.3	Pump 1 Clinton Ave. PS	SCIT
PMP-17	130.00	On	227.63	349.53	2,186.69	121.90	95.0	Pump 1 Quaker Ln. PS	WAR
PMP-18	130.00	Off	231.16	333.79	0.00	0.00	88.2	Pump 2 Quaker Ln. PS	WAR
PMP-19	130.00	Off	231.16	333.79	0.00	0.00	88.2	Pump 3 Quaker Ln. PS	WAR
PMP-20	130.00	Off	231.16	333.79	0.00	0.00	88.2	Pump 4 Quaker Ln. PS	WAR
PMP-21	262.00	Off	326.98	501.18	0.00	0.00	103.5	Setian Ln. PS Pump 1	WW
PMP-22	262.00	On	325.98	506.29	799.46	180.31	105.7	Setian Ln. PS Pump 2	WW
PMP-24	238.00	Off	327.58	503.42	0.00	0.00	114.8	WW Business Park PS Pump 1	WW
PMP-25	238.00	On	321.44	504.73	867.26	183.29	115.4	WW Business Park PS Pump 2	WW
PMP-27	232.00	On	330.28	596.94	8.47	266.66	157.9	EG Medical Center Fire Pump	EG
PMP-30	182.00	Off	234.00	496.52	0.00	0.00	136.1	Clinton Ave. PS	SCIT (HS Pump)
PMP-31	182.00	Off	234.00	496.52	0.00	0.00	136.1	Clinton Ave. PS	SCIT (HS Pump)
PMP-33	182.00	Off	233.94	369.49	0.00	0.00	81.1	Pump 5 Clinton Ave. PS	SCIT
PMP-36	222.00	Off	222.00	363.92	0.00	0.00	61.4	Pump 1 Providence Water Interconnection PS	WW
PMP-37	222.00	Off	222.00	363.92	0.00	0.00	61.4	Pump 2 Providence Water Interconnection PS	WW (Prov. Interconnection)

Active Scenario: MD Tank Study
Existing Infrastructure Conditions
Calculation Summary (10570: MD Tank Study)

Time (hours)	Balanced?	Trials	Relative Flow Change	Flow Supplied (gpm)
All Time Steps(0)	True	7	0.0003497	13,536.21
0.00	True	7	0.0003497	13,536.21

Flow Demanded (gpm)	Flow Stored (gpm)
10,724.06	2,812.06
10,724.06	2,812.06



Active Scenario: MD Tank Study
Existing Infrastructure Conditions
FlexTable: KCWA Tank Table

Current Time: 0.000 hours

Label	Diameter (ft)	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Net Inflow (gpm)	Description	Notes	Percent Full (%)
T-1	105.00	475.00	475.00	498.20	500.00	1,515.71	Read School House Rd. Tank	COV	92.8
T-2	58.00	310.00	310.00	345.00	350.00	0.00	Tiogue Tank 0.771 MG - Off	COV	87.5
T-3	73.00	284.00	284.00	331.10	334.00	-149.89	Frenchtown Rd. Tank 1.5 MG - LS	EG	94.2
T-4	75.25	350.00	450.00	496.40	500.00	-865.15	Technology Park Tank - HS	WG	92.8
T-5	80.00	418.00	418.00	494.50	500.00	660.74	Carr Pond Rd. Tank - HS	WG	93.3
T-6	58.00	284.00	284.00	328.00	334.00	0.00	West St. Tank 1 MG - Off	WW	88.0
T-7	160.00	314.00	314.00	328.70	334.00	1,650.65	Setian Ln. Tank - LS	WW	73.5
T-8	70.00	264.00	264.00	327.00	334.00	0.00	Wakefield St. Tank - Off	WW	90.0

Active Scenario: MD Tank Study
Existing Infrastructure Conditions
FlexTable: KCWA Pump Table

Current Time: 0.000 hours

Label	Elevation (ft)	Status (Calculated)	Hydraulic Grade (Suction) (ft)	Hydraulic Grade (Discharge) (ft)	Flow (Total) (gpm)	Pump Head (ft)	Pressure (Discharge) (psi)	Description	Notes
PMP-1	247.00	On	259.78	412.04	800.00	152.27	71.4	New Mishnock LS Pump	COV
PMP-2	247.00	Off	259.96	411.95	0.00	0.00	71.4	New Mishnock LS Pump	COV
PMP-4	229.80	Off	229.80	374.24	0.00	0.00	62.5	Coventry/Spring Lake Well	COV
PMP-5	15.00	On	15.44	332.44	1,148.81	317.00	137.3	EG Well	EG
PMP-9	250.00	Off	374.22	495.46	0.00	0.00	106.2	Pump 3 Johnson Blvd. PS	COV
PMP-10	250.00	Off	374.22	495.46	0.00	0.00	106.2	Pump 2 Johnson Blvd. PS	COV
PMP-11	250.00	Off	374.22	495.46	0.00	0.00	106.2	Pump 1 Johnson Blvd. PS	COV
PMP-13	182.00	Off	233.84	390.24	0.00	0.00	90.1	Pump 4 Clinton Ave. PS	SCIT
PMP-14	182.00	On	232.87	392.43	3,911.94	159.56	91.0	Pump 3 Clinton Ave. PS	SCIT
PMP-15	182.00	Off	233.85	390.24	0.00	0.00	90.1	Pump 2 Clinton Ave. PS	SCIT
PMP-16	182.00	On	233.74	390.48	1,291.95	156.74	90.2	Pump 1 Clinton Ave. PS	SCIT
PMP-17	130.00	On	226.27	355.70	2,066.12	129.43	97.6	Pump 1 Quaker Ln. PS	WAR
PMP-18	130.00	On	226.45	354.36	1,934.76	127.91	97.1	Pump 2 Quaker Ln. PS	WAR
PMP-19	130.00	Off	229.41	341.57	0.00	0.00	91.5	Pump 3 Quaker Ln. PS	WAR
PMP-20	130.00	Off	229.37	341.61	0.00	0.00	91.6	Pump 4 Quaker Ln. PS	WAR
PMP-21	262.00	On	327.63	503.88	818.73	176.25	104.7	Setian Ln. PS Pump 1	WW
PMP-22	262.00	Off	328.68	498.51	0.00	0.00	102.3	Setian Ln. PS Pump 2	WW
PMP-24	238.00	Off	329.74	501.08	0.00	0.00	113.8	WW Business Park PS Pump 1	WW
PMP-25	238.00	On	323.13	502.49	900.12	179.36	114.4	WW Business Park PS Pump 2	WW
PMP-27	232.00	On	331.30	597.96	16.87	266.65	158.3	EG Medical Center Fire Pump	EG
PMP-30	182.00	On	232.99	535.55	2,051.84	302.56	153.0	Clinton Ave. PS	SCIT (HS Pump)
PMP-31	182.00	Off	233.96	533.22	0.00	0.00	152.0	Clinton Ave. PS	SCIT (HS Pump)
PMP-33	182.00	Off	233.84	390.24	0.00	0.00	90.1	Pump 5 Clinton Ave. PS	SCIT
PMP-36	222.00	Off	222.00	376.57	0.00	0.00	66.9	Pump 1 Providence Water Interconnection PS	WW
PMP-37	222.00	Off	222.00	376.57	0.00	0.00	66.9	Pump 2 Providence Water Interconnection PS	WW (Prov. Interconnection)

Appendix D

Current Year (2014) Planning Period
Extended Period Simulation
Maximum Day Demand

Active Scenario: MD Tank Study
Existing Infrastructure Conditions
Calculation Summary (10570: MD Tank Study)

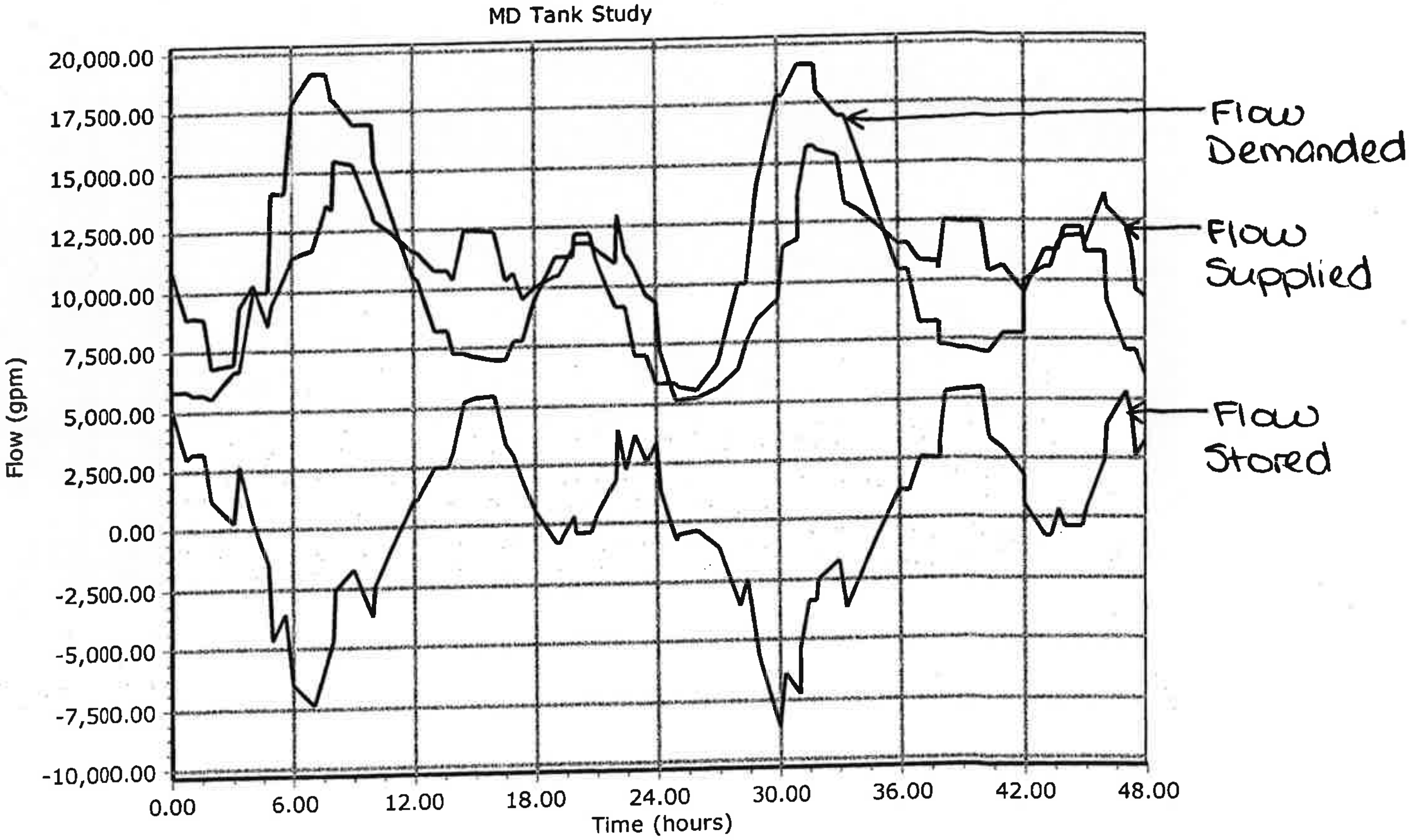
Time (hours)	Balanced?	Trials	Relative Flow Change	Flow Supplied (gpm)	Flow Demanded (gpm)	Flow Stored (gpm)
All Time Steps(90)	True	321	0.0009295	11,036.97	10,637.25	399.84
0.00	True	9	0.0000339	11,987.93	5,868.45	6,119.48
0.03	True	3	0.0008717	10,960.50	5,868.45	5,092.06
0.78	True	3	0.0004968	8,869.86	5,868.45	3,001.41
1.00	True	3	0.0001541	8,910.20	5,679.31	3,231.13
1.64	True	3	0.0002932	8,891.48	5,679.31	3,212.41
2.00	True	5	0.0000572	6,795.99	5,538.17	1,257.93
3.00	True	5	0.0000726	6,951.27	6,663.12	288.20
3.30	True	5	0.0003591	9,354.61	6,663.12	2,691.53
4.00	True	4	0.0003457	10,258.86	9,968.97	290.20
4.79	True	3	0.0005433	8,515.00	9,968.97	-1,453.67
5.00	True	4	0.0004433	9,446.74	14,118.82	-4,671.56
5.59	True	3	0.0004095	10,583.95	14,118.82	-3,534.35
6.00	True	5	0.0001735	11,401.35	17,879.68	-6,478.73
7.00	True	5	0.0002491	11,733.32	19,086.85	-7,352.88
7.72	True	4	0.0000812	13,609.71	19,086.85	-5,477.02
8.00	True	4	0.0000445	13,413.28	18,046.70	-4,633.49
8.05	True	3	0.0008943	15,478.08	18,046.70	-2,568.69
8.05	True	3	0.0004463	15,477.09	18,046.70	-2,569.68
9.00	True	3	0.0000994	15,284.38	17,009.41	-1,724.82
9.93	True	2	0.0004041	13,289.78	17,009.41	-3,719.42
10.00	True	3	0.0007650	12,938.74	15,407.04	-2,468.48
11.00	True	4	0.0003921	12,348.65	13,004.20	-655.21
12.00	True	4	0.0008778	11,567.13	10,414.78	1,152.10
12.19	True	3	0.0004089	11,563.68	10,414.78	1,148.65
13.00	True	4	0.0000934	10,778.91	8,246.82	2,532.15
13.68	True	3	0.0006567	10,740.03	8,246.82	2,493.27
14.00	True	3	0.0005039	10,393.79	7,266.21	3,127.92
14.49	True	3	0.0004763	12,474.73	7,266.21	5,208.86
15.00	True	3	0.0000219	12,447.82	7,106.05	5,341.84
15.02	True	3	0.0003612	12,448.43	7,106.05	5,342.46
16.00	True	3	0.0000261	12,399.12	6,987.53	5,411.67
16.55	True	2	0.0005653	10,329.48	6,987.53	3,342.03
17.00	True	3	0.0005093	10,598.12	7,720.14	2,878.07
17.43	True	4	0.0000638	9,497.35	7,720.14	1,777.30
18.00	True	4	0.0000245	9,976.69	9,419.71	556.89
19.00	True	4	0.0000314	10,477.98	11,269.42	-791.09
19.23	True	3	0.0007228	10,478.42	11,269.42	-790.66
19.87	True	3	0.0005348	11,587.53	11,269.42	318.46
20.00	True	3	0.0006021	11,822.46	12,217.41	-394.92
20.69	True	3	0.0004267	11,827.49	12,217.41	-389.90
21.00	True	4	0.0000260	11,557.34	11,206.30	350.89
22.00	True	4	0.0004245	10,951.75	9,102.74	1,848.92
22.09	True	3	0.0007028	13,036.15	9,102.74	3,933.33

Active Scenario: MD Tank Study
Existing Infrastructure Conditions
Calculation Summary (10570: MD Tank Study)

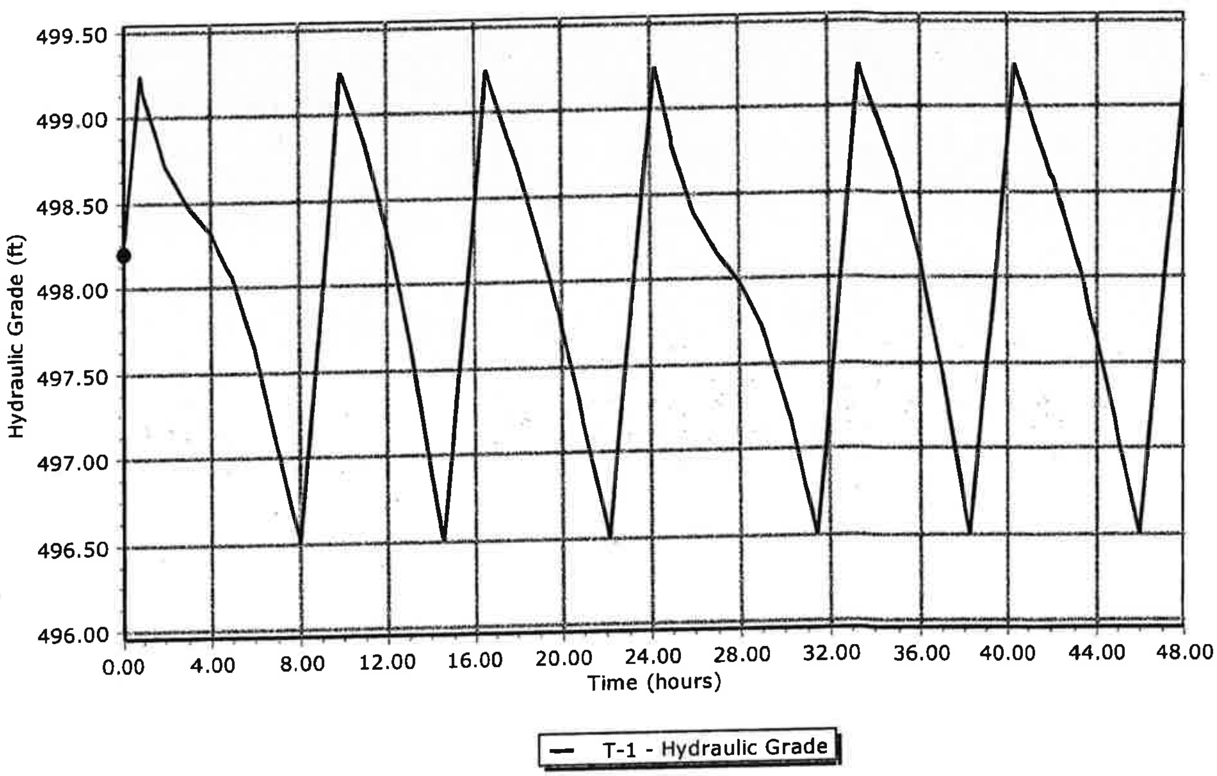
Time (hours)	Balanced?	Trials	Relative Flow Change	Flow Supplied (gpm)	Flow Demanded (gpm)	Flow Stored (gpm)
22.51	True	3	0.0004818	11,324.63	9,102.74	2,221.81
23.00	True	4	0.0003563	10,687.18	7,009.13	3,678.36
23.49	True	4	0.0000557	9,578.60	7,009.13	2,569.78
24.00	True	5	0.0003888	9,246.20	5,868.45	3,377.76
24.21	True	2	0.0007851	7,183.78	5,868.45	1,315.34
24.95	True	3	0.0003706	5,090.35	5,868.45	-778.10
25.00	True	3	0.0001875	5,132.05	5,679.31	-547.02
26.00	True	3	0.0001695	5,190.02	5,538.17	-348.04
27.00	True	4	0.0006211	5,560.58	6,663.12	-1,102.50
28.00	True	4	0.0002644	6,378.87	9,968.97	-3,589.80
28.43	True	4	0.0000364	7,518.88	9,968.97	-2,449.79
29.00	True	4	0.0002970	8,428.06	14,118.82	-5,690.24
30.00	True	5	0.0001139	9,244.92	17,879.68	-8,635.16
30.28	True	3	0.0009295	11,463.51	17,879.68	-6,416.56
31.00	True	5	0.0003438	11,775.38	19,086.85	-7,310.47
31.04	True	3	0.0007723	13,611.77	19,086.85	-5,474.25
31.47	True	3	0.0007166	15,712.19	19,086.85	-3,374.47
31.83	True	3	0.0005473	15,725.14	19,086.85	-3,361.59
32.00	True	3	0.0007996	15,507.44	18,046.70	-2,539.33
33.00	True	3	0.0001019	15,315.95	17,009.41	-1,693.25
33.40	True	2	0.0003206	13,304.13	17,009.41	-3,705.07
34.00	True	3	0.0006921	12,975.12	15,407.04	-2,432.11
35.00	True	5	0.0002922	12,386.84	13,004.20	-617.02
36.00	True	4	0.0007290	11,603.26	10,414.78	1,188.22
36.45	True	3	0.0003995	11,592.52	10,414.78	1,177.49
37.00	True	4	0.0000869	10,815.49	8,246.82	2,568.73
37.98	True	3	0.0006634	10,759.57	8,246.82	2,512.81
38.00	True	3	0.0004969	10,427.31	7,266.21	3,161.44
38.21	True	3	0.0004738	12,523.56	7,266.21	5,257.69
39.00	True	3	0.0000166	12,478.19	7,106.05	5,372.21
39.28	True	3	0.0004077	12,462.56	7,106.05	5,356.59
40.00	True	3	0.0000253	12,431.24	6,987.53	5,443.79
40.32	True	2	0.0005037	10,377.39	6,987.53	3,389.93
41.00	True	3	0.0005024	10,632.59	7,720.14	2,912.54
41.95	True	4	0.0001226	9,504.76	7,720.14	1,784.71
42.00	True	4	0.0000248	9,995.77	9,419.71	575.97
43.00	True	4	0.0000315	10,499.17	11,269.42	-769.90
43.30	True	3	0.0007144	10,500.26	11,269.42	-768.82
43.70	True	3	0.0005045	11,604.28	11,269.42	335.21
44.00	True	3	0.0005613	11,839.69	12,217.41	-377.69
44.80	True	3	0.0004239	11,846.15	12,217.41	-371.24
45.00	True	4	0.0000211	11,575.33	11,206.30	368.89
45.93	True	3	0.0007239	13,646.42	11,206.30	2,439.97
46.00	True	4	0.0003716	13,057.90	9,102.74	3,955.07

Active Scenario: MD Tank Study
Existing Infrastructure Conditions
Calculation Summary (10570: MD Tank Study)

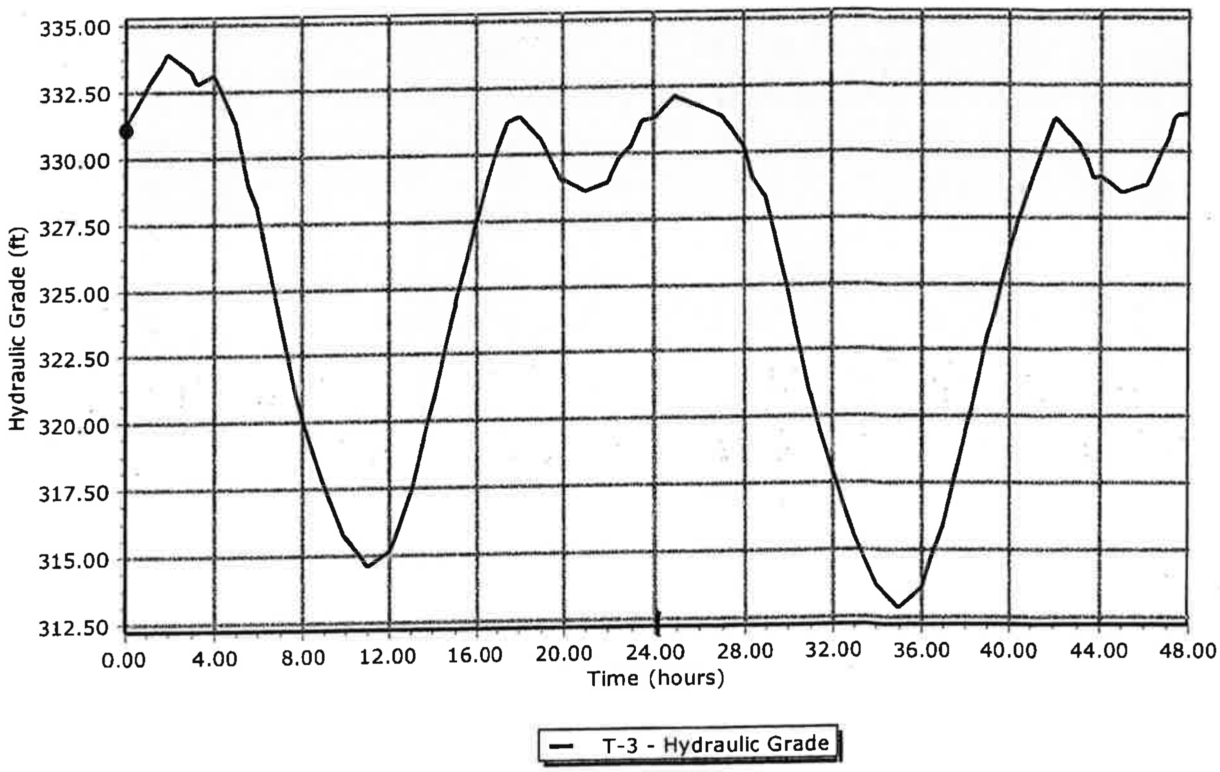
Time (hours)	Balanced?	Trials	Relative Flow Change	Flow Supplied (gpm)	Flow Demanded (gpm)	Flow Stored (gpm)
47.00	True	4	0.0000554	12,314.95	7,009.13	5,306.13
47.26	True	4	0.0000175	11,249.25	7,009.13	4,240.43
47.40	True	3	0.0003928	9,581.63	7,009.13	2,572.82
48.00	True	5	0.0003956	9,248.07	5,868.45	3,379.62

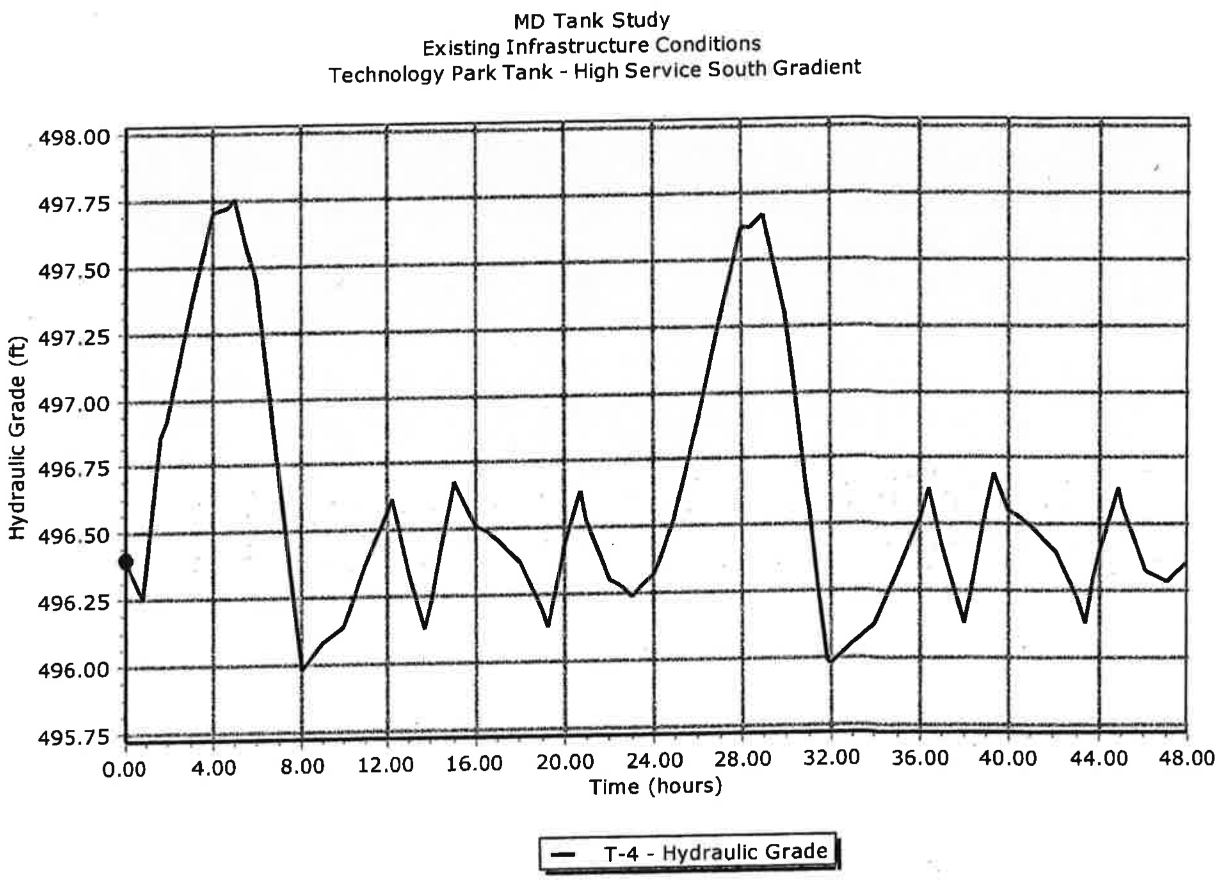


MD Tank Study
Existing Infrastructure Conditions
Read School House Road Tank - High Service North Gradient

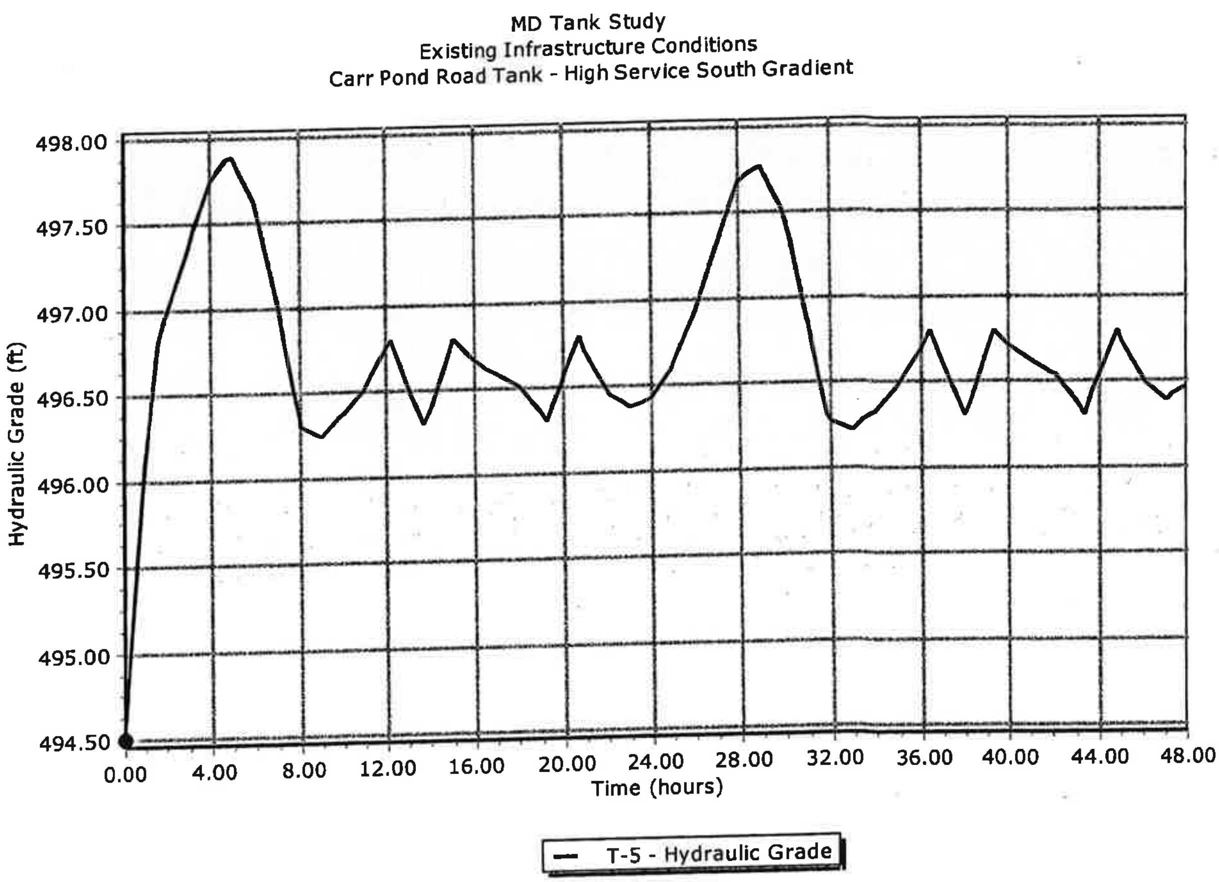


MD Tank Study
Existing Infrastructure Conditions
Frenchtown Road Tank - Low Service Gradient

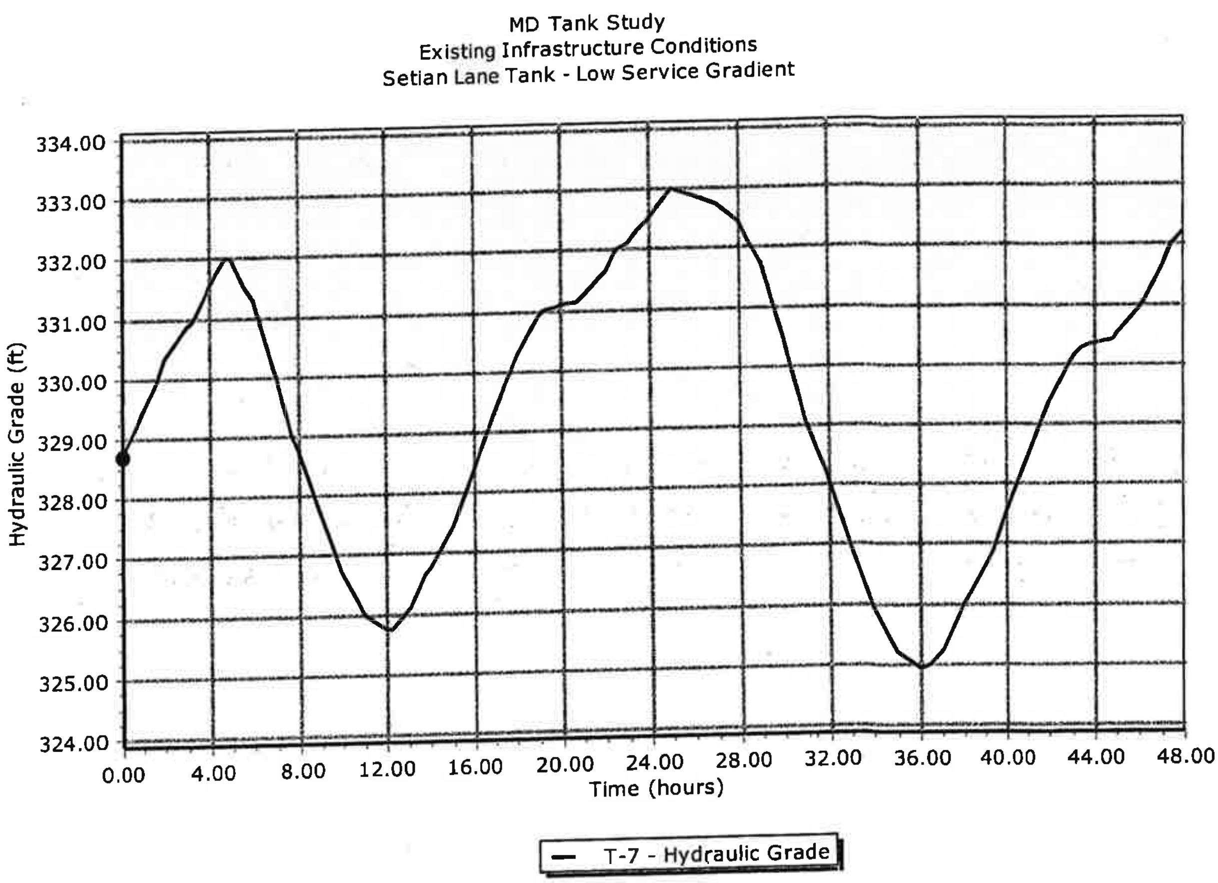




MD Tank Study
Existing Infrastructure Conditions
Technology Park Tank - High Service South Gradient
Hydraulic Grade (ft)
498.00
497.75
497.50
497.25
497.00
496.75
496.50
496.25
496.00
495.75
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
44.00
48.00
Time (hours)
T-4 - Hydraulic Grade



MD Tank Study
Existing Infrastructure Conditions
Carr Pond Road Tank - High Service South Gradient
Hydraulic Grade (ft)
498.00
497.50
497.00
496.50
496.00
495.50
495.00
494.50
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
44.00
48.00
Time (hours)
T-5 - Hydraulic Grade


MD Tank Study
Existing Infrastructure Conditions
Setian Lane Tank - Low Service Gradient
334.00
333.00
332.00
331.00
330.00
329.00
328.00
327.00
326.00
325.00
324.00
Hydraulic Grade (ft)
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
44.00
48.00
Time (hours)
T-7 - Hydraulic Grade