C&E Engineering Partners, Inc.
342 Park Avenue
Woonsocket, RI, 02895
Ph: (401) 762-1711
Fax: (401) 235-9088

Kent County Water Authority
Distribution Storage Tank Hydraulic Evaluation

Technical Memorandum No. 5A
Storage Facility Analysis – Future Demand Conditions
May 2007 (Revised July & August 2007)

1.0 Purpose and Scope

This project relates to utilizing the updated computerized hydraulic model of the Kent County Water Authority (Authority) water system to complete a detailed hydraulic study and evaluation of the entire supply and distribution system in regards to distribution storage for the next twenty (20) year planning period. This evaluation is intended to consider system demand for both the existing and the projected planning period and an evaluation of the ability of the water system infrastructure distribution storage components to effectively meet these demands.

The project has been divided into various sub tasks and each of which will be further detailed in a specific technical memorandum. The purpose of this technical memorandum is to evaluate the existing water storage facilities within the distribution system including their ability to meet future projected consumer demands for the planning period, provide adequate system pressure, provide fire flow reserve, etc. The criteria previously presented in Technical Memorandum No. 2A along with the future consumer demands developed in Technical Memorandums 1 and 3 will be utilized to evaluate facilities. The following are the specific efforts associated with this task.

1. The water system shall be evaluated using the existing hydraulic model to determine its capability to deliver water for the future projected consumer demands under average and peak demand (maximum day) conditions as well as fire flow conditions. The following model scenarios will be evaluated.

   - Average Day Demand
   - Peak Hour Demands (during Maximum Day)
   - Maximum Day Demand Plus Fire Flow

   Storage and supply capacities will also be reviewed to ensure that they meet operational and regulatory requirements. Other critical factors will be identification of potential surplus water supply capacity and potential for future growth.

2. Perform hydraulic model simulations for both steady state and extended period for the water system with critical attention for each of the varied pressure zones in the system. Based on the aforementioned model scenarios, specific water system improvements for the future-planning horizon shall be identified. Any recommended improvements will also be included in various modeling scenarios to demonstrate their effectiveness in meeting deficiencies and to assist in sizing of components.

3. An operational assessment of the seven (the Fiskeville Tanks have been removed for purposes of this evaluation, refer to Technical Memorandum 4A) existing storage tanks in order to determine their effectiveness in meeting the various future system demands shall be conducted. Such determination would include specific analysis of each tank including fill and draw rates, system influences on tank operation including pump station set points and operation, etc.

    a. An assessment will be provided for potential solutions and alternatives for cycling those tanks, which are problematic. This may include retrofitting tanks with mixing systems, operation modifications such as off-hour pumping systems, control valve sequencing or reconfiguration of underground infrastructure. This would all be performed in consideration of the critical nature of these tanks in providing fire protection in the general area of the tanks.

    b. A discussion will be provided on the overall effect on system operation for the removal of "locked up" or low turn over tanks and what affect they may have on fire flow capacity in the surrounding areas.

    c. For each existing storage tank, a determination shall be performed for the volumes of fire flow storage, emergency storage, equalization storage, as well as active and dead storage by service zone. These volumes shall be compared to the standards that were previously developed as part of this study and appropriate recommendations shall be made.

2.0 Future Projected (2025) Water Demands

Analysis of the various storage components was performed for each of the pressure zones that incorporate the water system. For purpose of this analysis, it was required to analyze the various pressure zones collectively when they are directly interconnected (i.e. by pressure reducing valve) or when the sources are dedicated to providing supply to a particular number of pressure zones (Hope Road Gradient). For example, when analyzing the Low Service Pressure Gradient (334'), it was necessary to include those consumer demands that comprised the Low Pressure Reduced Gradient and the Hope Road Gradient. It should also be noted that the Oaklawn Pressure Gradient (232') was not included in the tank capacity analysis as this Gradient is supplied directly through a wholesale interconnection with Providence Water and the service area contains no storage facilities nor is it interconnected to any portion of the Authority's distribution system.

The analysis comprised the two primary gradients identified as the Low Service Pressure Gradient (334') and the High Service Pressure Gradient (500'), which is to be combined with the Read School House Road Gradient (500'). The new Read School House Road storage tank with overflow elevation of 500 feet will be placed in operational service in 2008. This will allow the interconnection of the existing High Service Pressure Gradient (500 feet) and the Read School House Gradient (500 feet) via new water transmission mains. For purpose of this analysis, it is assumed that the two independent pressure zones will be combined. The following is a summary of future (2025) demands for each of these gradients.

LOW SERVICE GRADIENT (334') FUTURE (20 YEAR) CONSUMER DEMANDS

PRESSURE ZONE	AVERAGE DAY DEMAND (MGD)	MAXIMUM DAY DEMAND (MGD)	PEAK HOUR DEMAND (MGD)
Low Service (334') Gradient	6.357	12.055	13.950
Low Service Reduced (334') Gradient	2.246	4.474	5.187
Hope Road (510') Gradient	0.007	0.014	0.016
TOTALS	**8.61 MGD**	**16.54 MGD**	**19.15 MGD**

HIGH SERVICE GRADIENT (500') FUTURE (20 YEAR) CONSUMER DEMANDS

PRESSURE ZONE	AVERAGE DAY DEMAND (MGD)	MAXIMUM DAY DEMAND (MGD)	PEAK HOUR DEMAND (MGD)
High Service (500') Gradient*	3.668	6.951	9.031
High Service (500') Reduced Gradient	0.679	1.331	1.636
TOTALS	**4.35 MGD**	**8.28 MGD**	**10.67 MGD**

* Includes consumer demands from the Read School House Road Gradient and former Tiogue Tank Gradient.

The following water system improvements to both the water system infrastructure and operations were previously identified in Technical Memorandum 4A. These improvements are either in the construction or design phase and were incorporated into this evaluation. The computerized hydraulic model was also updated to incorporate these improvements.

- The existing Tiogue Tank Pressure (350') Gradient is serviced and will become a permanent part of the High Service Pressure (500') Gradient. A PRV station is installed on the new water main to supply the Tiogue service area. The existing Tiogue Tank and booster pump station are removed from service.

- The Bald Hill Booster Pump Station is upgraded in capacity to 10.0 MGD. This includes installation of significant water main infrastructure such that the pump station will have the ability to pump directly to the High Service Pressure Gradient. The breakdown of the pumping capacity is as follows: 2.0 MGD to High Service Pressure Gradient and 8.0 MGD to Low Service Pressure Gradient. High Service Pumps are on level control with Carr Pond Tank and Low Service pumps are on level control with Frenchtown Road Tank.

- The new Read School House Road Tank is in service and the pressure zone increased from a hydraulic grade of 430 feet to 500 feet. This includes activation of the 3.0 MGD High Service Pumps at Clinton Avenue Pump Station that are designed to supply this pressure zone.

- The existing Knotty Oak Pump Station that currently supplies the Read School House Road Pressure Gradient is removed from service (replaced by pumps at Clinton Avenue Pump Station).

- East Greenwich and Spring Lake Well are redeveloped and returned to original supply capacity.

- Installation of a new interconnection to Providence Water in vicinity to Wakefield Street with the ability to pump up to 6 MGD into the Low Service Pressure Gradient and 2 MGD into the High Service Pressure Gradient. *This emergency interconnection was not active during any of the simulations performed for this evaluation.*

- Installation of new water main infrastructure along Harding Street, Main Street, Pleasant Street, etc. in West Warwick which will serve in combination with the emergency interconnection to increase flow capacity from the emergency interconnection to the remainder of the system.

Following are additional future water system improvements for both the water system infrastructure and operations. These additional future improvements are in the design phase and were incorporated into this evaluation. The computerized hydraulic model was also updated to incorporate these additional future improvements.

- Removal of the Fiskeville Tanks from the Low Service Pressure Gradient.

- The West Street and Wakefield Street Tanks will require design improvements such that they can be more effectively utilized (i.e. not in "locked up" condition).

- Installation of new water main infrastructure for the interconnection of the existing High Service Pressure Gradient and the new Read School House Road Gradient. This interconnection would include the installation of new water main infrastructure along Read School House Road, Flat River Road, Reservoir Road, Nooseneck Hill Road and Mishnock Road in Coventry.

- Construction of a new water treatment plant at the location of the Mishnock well field with a design capacity of 2.9 MGD. This also includes construction of a new distribution water storage tank (with overflow of 334 feet) with the ability to supply both the Low and High Service Pressure Gradients. A new booster pump station will be required to supply the High Service Gradient.

3.0 Existing Water Storage Facility Assessment

3.1 General

The existing water supply and distribution system for the Authority as previously indicated has been divided into two (2) distinct pressure gradients for purposes of analysis, which include the Low Service and High Service Pressure Gradients. The criteria for evaluation was provided and discussed in Technical Memorandum 2A and is summarized below.

The Authority's water system currently functions in varied modes of operation for the each of the pressure gradients. The mode of operation in a particular pressure zone and the location of the tank in the pressure zone have a direct influence as to how each of the water storage tanks operates. The types of operating modes can generally be classified as follows.

Continuous Pumping

The Low Service Gradient operates primarily on a continuous mode of pumping whereby at any given time of the day or year there is at minimum one pump operating at the Clinton Avenue Pump Station. This is required to replenish the tank(s) in the distribution system and more importantly to maintain adequate pressures to customers at higher service elevations. Although the Low Service Pressure Gradient operates at a maximum overflow elevation of 334 feet (the overflow elevation of the storage tanks) the Clinton Avenue Pump Station will supply a pump head in vicinity to the station that varies from 350 – 380 feet depending upon system demand conditions.

This pump head is required to ensure that distant tanks (i.e. Setian Lane and Frenchtown Road) within the distribution system are supplied with adequate water volumes for refill. Also, areas of higher elevations (i.e. customer service elevations in range of 275 feet) rely on this pump head to maintain adequate pressure. In the event that all pumps at the Clinton Avenue Pump Station are turned off, the system pressures in proximity to the station will immediately be reduced to the Low Service system hydraulic grade, which is 334 feet or lower depending upon the water level in the storage tanks. This will likely result in an immediate drop of pressure to customers in proximity to the Clinton Avenue Pump Station of anywhere between 10 and 20 psi. This has an immediate and noticeable impact on service customers that maintain pressures between 20 – 30 psi with the Clinton Avenue Pump Station in operation and in the most severe demand conditions can result in service customers with pressures in the range of 0 – 10 psi.

The Authority is cognizant of these locations and is exploring alternatives to resolve these pressure problems at higher service elevations. The most obvious solution, if deemed feasible, is to re-service these areas from pressure gradients with higher hydraulic grades. Another inherent problem with continuous pumping is the effect on distribution system storage tanks. While tanks located away from the supply source are drained by customer demands and subsequently refilled from the supply source, those tanks located in proximity to the supply source can be adversely impacted. Due to the fact that the supply sources impart a hydraulic grade that is above the overflow elevation of tanks in close proximity, these tanks have a tendency to not drain while the supply source is in operation. This results in tanks that are essentially "locked up" with no ability to cycle on a routine basis. The West Street Tank and Fiskeville Reservoirs have historically been subject to this "locked up" condition.

The location of these identified "low pressure" areas is as follows. These include areas that have marginal pressure (20 psi and less) and areas that have pressures below the 35 psi regulatory (standard for all new development) standard of the Authority Regulations when the Clinton Avenue Pump Station is in operation. It should be noted that all the identified locations may not directly impact service customers as these locations could occur at high points along transmission mains with no customer services, areas around storage reservoirs and on the suction side of booster pump stations. These locations are also depicted on a system map in Enclosure No. 1.

LOCATIONS IN SYSTEM WITH PRESSURES BELOW 20 PSI

SERVICE PRESSURE ZONE	STREET	LOCATION/APPROXIMATE INTERSECTION	ELEVATION RANGE (FEET)	CALCULATED PRESSURE	CUSTOMER SERVICES (Y/N)
Low	Cowesett Road	Kulas Road to Fairgreen Drive	206 - 280	19 psi	Y
Low	South County Trail *	EG Medical Center to Pine Glen Drive	249 - 303	12 psi – 34 psi	Y
Low	Signal Ridge Way	Boulder Way to Division Street	270 - 290	18 psi – 27 psi	Y
Low	Lane A	Morningside Drive to Lane E	250 - 294	18 psi – 31 psi	Y
Low	Tiogue Avenue *	Jennifer Lane to Holloway Avenue	264 - 301	12 psi – 28 psi	Y
Low	Knotty Oak Road	Maple Street to Long Pond Road	273 - 302	14 psi – 34 psi	N
Low	Knotty Oak Road	White Rock Drive to Highwood Drive	279 - 315	9 psi – 24 psi	N
Low	Knotty Oak Road	Gervais Street to Oak Way	300	15 psi	N
Low	East Greenwich Avenue *	Juniper Drive to Setian Lane	259 - 295	16 psi – 32 psi	N

LOCATIONS IN SYSTEM WITH PRESSURES BELOW 35 PSI

SERVICE PRESSURE ZONE	STREET	LOCATION/APPROXIMATE INTERSECTION	ELEVATION RANGE (FEET)	CALCULATED PRESSURE	CUSTOMER SERVICES (Y/N)
Low	Cowesett Road	Church Street to Narragansett Avenue	235 - 260	28 psi – 34 psi	Y
Reduced Low	Windermere Way	Love Lane to Lantern Lane	180 - 205	27 psi – 34 psi	Y
Reduced Low	Love Lane*	Overhill Road to Cedar Street	204 - 205	27 psi – 29 psi	Y
Low	Major Potter Road*	Quaker Lane to Eagle Run	265	29 psi	N
Low	Division Street	Brooks Pharmacy Headquarters to Old Quaker Lane	243 - 275	24 psi	Y
Low	Mayflower Drive	Crest Ridge Drive to Bunker Hill Lane	170 - 201	29 psi – 34 psi	Y
Low	Frenchtown Road*	Cardinal Lane to High Hawk Road	266 - 276	29 psi	N
Low	Lynn Circle	Darl Court to Fernwood Drive	230 - 280	22 psi – 34 psi	Y
High	Carr Pond Road*	Carr Pond Tank to Deer Run Drive	410 - 430	28 psi – 33 psi	Y
Low	Greenbush Road	New London Turnpike to Bratt Lane	255 - 280	22 psi – 33 psi	N
Low	Arnold Road*	Larch Drive to Acorn Street	228 - 280	20 psi – 34 psi	Y
Low	Nooseneck Hill Road	Reservoir Road to Comfort Way	256 - 282	26 psi – 34 psi	Y
Low	Main Street (COV)	Battey Avenue to Sandy Bottom Road	234 - 255	34 psi	Y
Low	Laurel Avenue	Pilgrim Avenue to Princeton Avenue	228 - 267	28 psi – 34 psi	Y
Low	Hope Furnace Road	Howard Avenue to Colvintown Road	249 - 270	31 psi	Y
Low	North Road	White Lane to Blossom Lane	240 - 271	31 psi	Y
Low	Cranberry Drive	Mitchell Way to Kerri Court	240 - 276	29 psi	Y
Low	Blackrock Road*	Gervais Street to Country View Drive	250 - 270	28 psi	N
Low	Phenix Avenue	Harding Street to Garnet Street	245 - 273	26 psi – 33 psi	Y
Low	Fairview Avenue	Spencer Street to Marshall Circle	235 - 272	24 psi – 34 psi	Y
Low	New London Avenue	Factory Street to Iron Drive	231 - 261	27 psi – 33 psi	Y

Low	Macarthur Boulevard	Yates Avenue to Knight Street	245 - 273	25 psi – 30 psi	Y
Low	Beauchene Street	East Street to West Street	170 - 270	25 psi	Y
Low	River Run	Rosewood Court to Quail Court	249 - 260	29 psi – 32 psi	Y
Reduced High	Nooseneck Hill Road	Brant Trail to End of KCWA System	300 - 354	34 psi	Y
Low	Hornbeam Road	Mountain Laurel Drive to Hawthorne Road	250 - 260	33 psi	Y
Low	Hornbeam Road	Mountain Laurel Drive to Hawthorne Road	232 - 265	31 psi	Y
Low	Paddock Drive	Cowesett Road to Martingale Drive	230 - 243	33 psi	Y

* Denotes area of low pressure that consists of a transmission main, area near storage reservoir, suction side of booster pump station.

Call on Demand
The High Service Pressure Gradient operates in a call on demand mode whereby supply sources (booster pumps) are operated in response to water levels in the storage tanks. During periods when the supply sources are off line, the water level in the storage tank(s) provides adequate pressure to all areas within the service gradient. Upon a predetermined lowering of the water level in the tank(s), a signal is relayed to turn on the necessary number of supply sources (booster pumps at Setian Lane, Johnson Boulevard or West Warwick Industrial Park Station) and the Clinton Avenue High Service pumps. This mode of operation is advantageous in that it permits storage tanks to routinely cycle and maintain adequate system pressures when the supply sources are off line.

The High Service Pressure Gradient can operate in this mode due to the fact that the customer service elevations can be supplied with adequate flow and pressure by the water level in the tanks and does not rely on the pump head of the supply sources and booster pumps to increase the system head.

3.2 Storage Tank(s) Component Assessment

This section provides evaluation with regard to the various components of the total storage volume that comprises each of the distribution storage tanks. It was necessary during this evaluation to consider the existing overflow elevation in a particular service gradient and to determine that water elevation in the tank which equates to supplying a minimum pressure of 35 psi at a particular ground service elevation and a minimum pressure of 20 psi at a particular ground service elevation. This is necessary as the various volumes of components of storage in the tank relate to providing a minimum pressure in the service gradient.

This process is relatively straightforward within the pressure gradients that operate on a "call on demand" mode of operation which include the Read School House Road and High Service Pressure Gradients. These gradients can maintain adequate pressure throughout the service area when the supply sources are off and the water level in the storage tanks are required to maintain the system hydraulic grade. The Low Service Gradient which predominately operates on a "continuous pumping" basis differs in that the Clinton Avenue Pump Station must be operated on a continuous basis to ensure adequate pressure at higher customer service elevations in vicinity to the station.

For purposes of this evaluation, it is assumed that a long-term goal of the Authority is to seek to eliminate through re-servicing, etc. those customer services at higher elevations such that the Clinton Avenue Pump Station would not require continuous operation simply for maintaining adequate pressure. It is likely however that given the critical nature of this facility for supplying water system supply that this station will be relied upon to provide a majority of the water supply to the system.

Multiple tanks in the same pressure zone should be placed roughly at equal distances from a source or sources of supply. If one tank is very close to the source while other tanks are at a greater distance, it may be difficult to effectively fill the remote tanks without "shutting off" or "locking up" the nearer tank(s). This is most common in water systems that have evolved and expanded over the years. As the water system expands, newer tanks are located at further points from the supply source and existing tanks are located between the supply source and new tanks. A tank that was on the "fringe of the system" years ago may now be close to the supply source relative to the new remote tanks within the growing service area.

This is indicative of what has occurred in the Authority's Low Service Gradient, the oldest portion of the distribution system, as it has slowly expanded to the south, east and west away from the primary supply source, the Clinton Avenue Pump Station in the north. In most cases, the use of control valves or booster pump stations can enable multiple tank systems with problematic tanks to be used effectively. Alternatively, to simplify system operations, it may be desirable in a particular instance to abandon a tank(s) in an undesirable location when it needs maintenance and, if required, replace it at a more suitable location within the distribution system. Each water system must consider and evaluate each storage facility on a case-by-case basis as there are no set criteria on which to base this decision as it usually considers many factors (i.e. age and size of tank, required maintenance and cost, need for additional storage at other locations, ability to cycle tank, complexity of operations, etc.).

3.2.1 Storage Tank(s) Assessment Criteria

The various components of storage were previously detailed in Technical Memorandum 2A and are briefly summarized below.

The water levels in a storage tank above which a minimum distribution system pressure of 35 psi can be maintained are comprised of two distinct components. These include the *operational* and *equalization storage* components. *Operational storage* is defined by the upper portion of the tank volume below the overflow and above the water level where the supply / booster pumps are set to turn on. This is the volume in the tanks that is set to routinely cycle on a daily basis.

Directly below the *operational storage* is the *equalization storage*, which is that volume of tank storage that meets the water system demands that are in excess of the pumping or supply capacity of the water system. This storage component is located below the *operational storage* and above the *emergency and fire storage*. The bottom of the *operational storage* volume is also defined by the water level in the tank at which 35 psi would be available at the highest service elevation. It is imperative that water levels in the tank do not drop below the *equalization storage* as this could result in pressures below 35 psi within areas of the distribution system and the volume of *emergency and fire storage* would be eroded. Typically, additional supply / booster pumps are called on to run when the water level in the tank reaches the top of the *equalization storage*. The water volume dedicated to *equalization storage* is also utilized during peak demand periods of the day that are in excess of the supply / pumping capacity.

Storage located below the *equalization storage* zone is referred to as *emergency and fire storage* and provides at minimum a pressure of 20 psi at the highest customer service elevation within the distribution system. The water volume that is dedicated to *emergency and fire storage* should always be available in the tank and is only utilized during emergency purposes as would occur during a fire.

Any water in the tank below the *emergency and fire storage* zone is considered ineffective or *dead storage*. Water in this zone cannot effectively supply the distribution system with a minimum pressure of 20 psi.

The *effective storage* in a storage tank is that water volume below the *operational storage* zone and above the *dead storage* zone. Theoretically, this volume of water is always available to the water system to meet peak hour, fire and emergency needs. Therefore, the total *nominal storage* volume of a tank does not provide a true indication of the available *effective storage* volume that would be readily available for use in the water system under all demand scenarios.

Refer to Figure 1 for a graphical presentation of the various water storage components of a tank.

3.2.2 Service Gradient – Customer Service Elevations

As previously indicated it was necessary to determine customer service elevations within each of the pressure zones such that a minimum pressure of 35 psi can be maintained at the highest customer service elevation. This 35-psi requirement is also in accord with the Authority's Regulations, which require that all new customer water services conform to this minimum pressure requirement. As previously indicated all locations currently serviced by the Low Service Pressure Gradient do not meet this minimum requirement. Additionally, in an attempt to maintain pressures, the Authority is required to maintain operation of the Clinton Avenue Pump Station at all times in order that the pump head provide additional pressure to service these areas with low pressures. The Authority has a long-term goal to eliminate these previously identified "low-pressure" areas.

As the Low Service Pressure Gradient is set to operate at a hydraulic grade line of 334 feet, which is the existing overflow elevation of the system storage tanks, the maximum service elevation in the system was premised on this overflow elevation. All customer services above the maximum elevation to achieve 35 psi should further be examined for alternative methods of supply or means to increase pressure.

Low Service Pressure Gradient
The Low Service Pressure Gradient is controlled by the overflow elevation in four water storage tanks (West Street, Wakefield Street, Setian Lane and Frenchtown Road storage tanks), which are at approximately 334 feet (survey has determined that the majority of these storage tanks are within one foot of this elevation). C&E conducted a review of the historical tank chart records for the Low Service Gradient that indicates that the Authority is capable of maintaining the water level in the tanks within the top ten feet of the overflow. This includes the period of peak hour system demand.

The water level set points for control of the operation of booster pumps and supply sources are maintained within a span of five feet within the control tanks (i.e. Frenchtown Road and Setian Lane tanks). Therefore, for purposes of defining the range and volumes of *operational storage* within the Low Service Gradient tanks, the top five feet in each of the storage tanks was utilized.

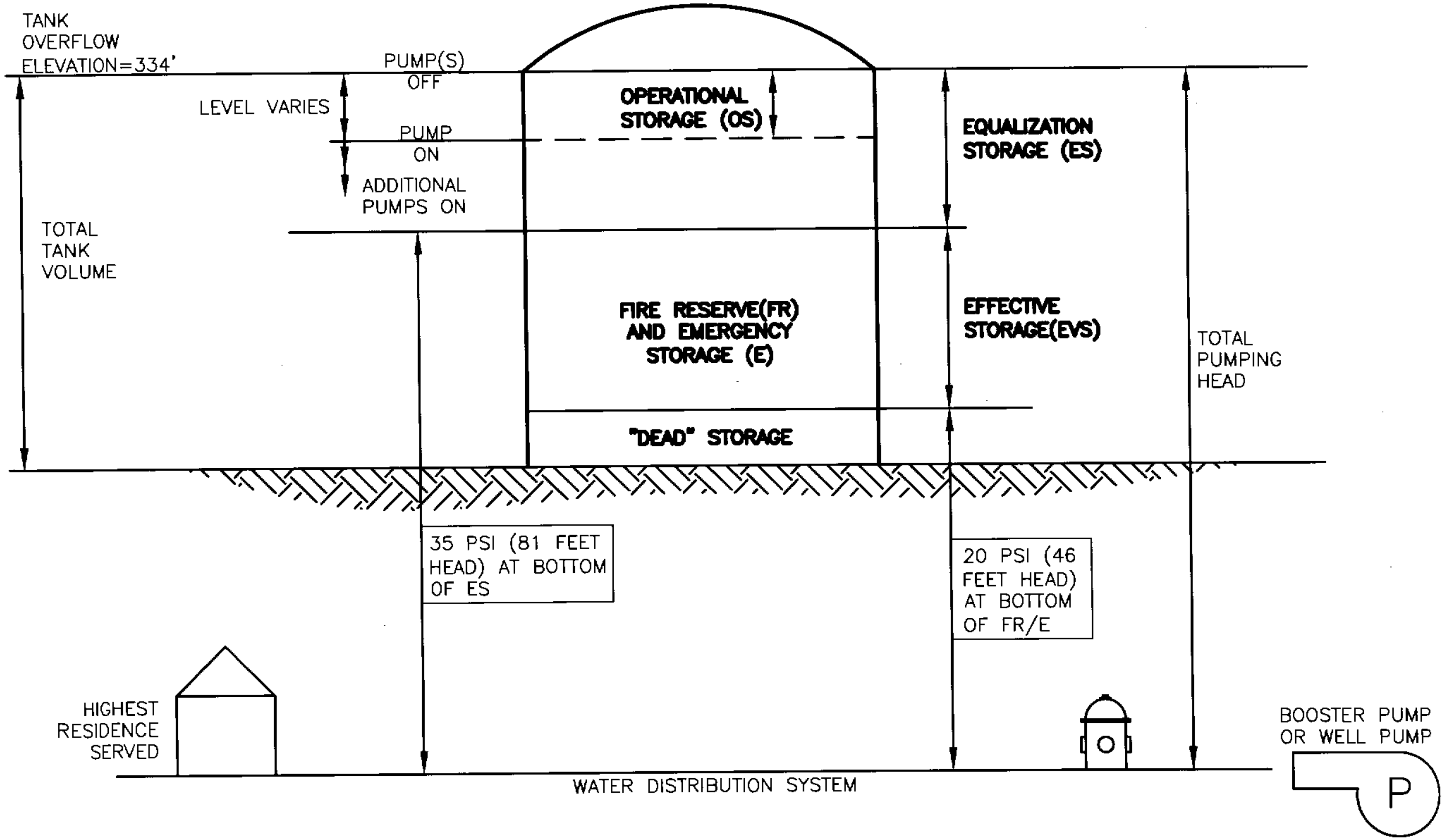
The range for *equalization storage* was defined to be the water volume below the *operational storage* (5 feet down in the tank) to a water level within the tank that the historic tank charts indicate that the system is capable of maintaining. As previously indicated, historic tank charts indicate that the Low Service Gradient tanks are maintained at minimum within the top ten feet from the overflow elevation.

Based on this ten-foot potential drawdown for *operational* and *equalization storage* a maximum ground elevation within the service territory that can be provided with a minimum pressure of 35 psi (i.e. bottom of *equalization storage*) was calculated as follows.

334 feet (overflow) – 10 feet (bottom of *operational* and *equalization storage*) = 324 feet (water level)

35 psi (minimum pressure) X 2.31 feet/psi = 80 feet (35 psi converted to feet of water)

FIGURE 1



TYPICAL LOW SERVICE GRADIENT TANK–
WATER STORAGE COMPONENTS
N.T.S.

324 feet (tank level) – 80 feet (feet of water for 35 psi) = 244 feet (ground elevation)

This corresponds to a water elevation in the storage tanks of 324 feet at which a minimum pressure of 35 psi would be maintained at a ground elevation of 244 feet. Similarly, the water elevation that corresponds to servicing a ground elevation of 244 feet while maintaining a minimum pressure of 20 psi (i.e. bottom of *effective storage* and *fire/emergency reserve storage*) equates to a water level of 290 feet in the tanks. All water in any Low Service Gradient tank below a water elevation of 290 feet is therefore considered *dead storage,* as it cannot provide a minimum pressure of 20 psi at a ground elevation of 244 feet. Also, if a tank has a bottom elevation above 290 feet then there is no *dead storage* in the tank, as all the water in the tank can be considered available to supply a minimum pressure of 20 psi at a ground elevation of 244 feet.

With these elevations established, each of the various components of storage volume was calculated for each storage tank in the Low Service Pressure Gradient. These elevations in each of the Low Service storage tanks are depicted graphically on Figures 2 through 5 and the related storage volume component is listed in Table 1.

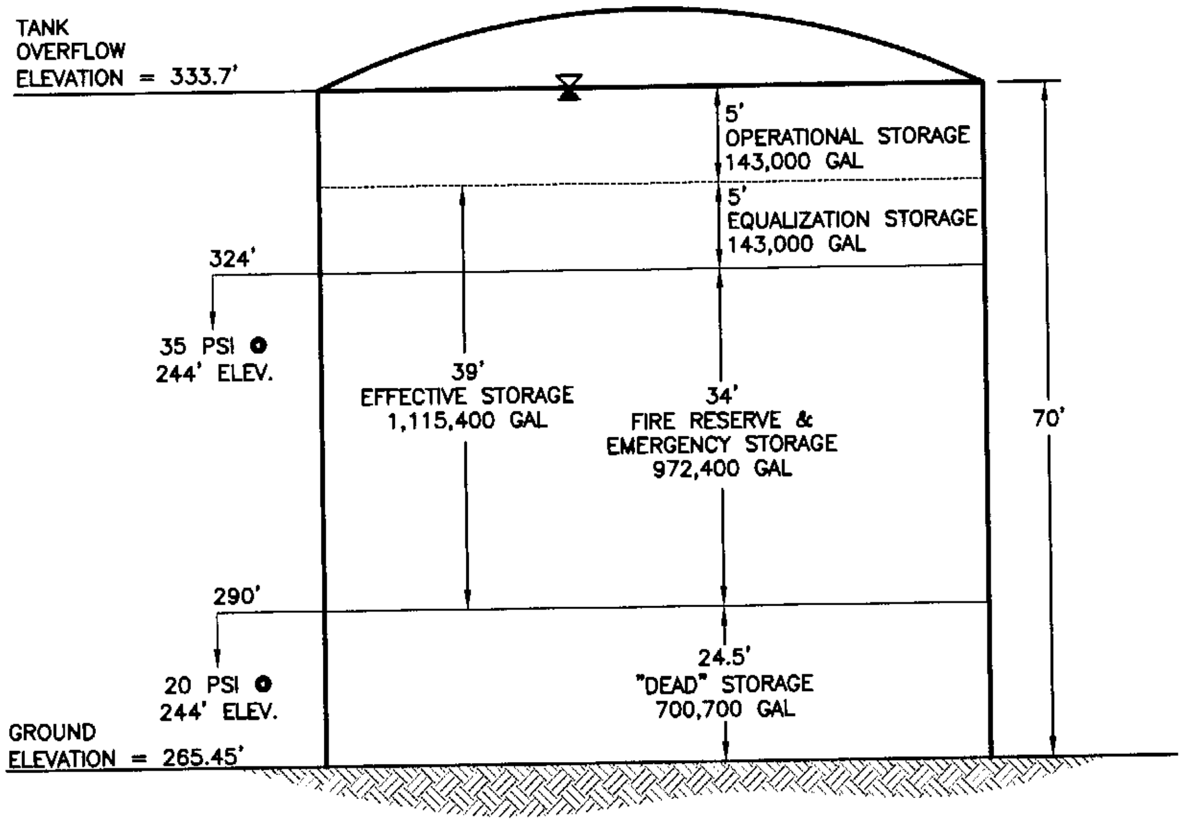
TABLE 1
LOW SERVICE GRADIENT (334') FUTURE (20 YEAR) STORAGE VOLUMES

FACILITY	EFFECTIVE STORAGE (MG)	OPERATIONAL STORAGE (MG)	EQUALIZATION STORAGE (MG)	FIRE RESERVE & EMERGENCY STORAGE (MG)	"DEAD" STORAGE (MG)
Wakefield Street Tank	1.115	0.143	0.143	0.972	0.701
Frenchtown Road Tank	1.170	0.150	0.150	1.020	0.165
Setian Lane Tank	2.250	0.750	0.750	1.500	0
West Street Tank	0.760	0.080	0.080	0.680	0.180
TOTALS	**5.295**	**1.123**	**1.123**	**4.172**	**1.046**

The total nominal storage capacity of all storage tanks in the Low Service Pressure Gradient is equal to 7,500,000 gallons. (Note: Fiskeville Tanks have been removed from the storage volume table.)

For the immediate future, it is considered necessary to maintain continuous operation of the Clinton Avenue Pump Station to provide adequate pressures above a ground service elevation of 244 feet until such time that these elevations can be evaluated and potentially re-serviced by alternate means. Various alternatives to perform this will be evaluated in the pending Capital Improvement Plan (CIP). This results in "locking up" the West Street storage tank (consideration will be given to utilizing the West Street Tank through off peak pumping) as model simulations and observed field conditions confirm that the hydraulic grade at these tanks never drops below 334 feet when Clinton Avenue Pump Station is in operation. It was not considered practical in this evaluation to perform model simulations without Clinton Avenue Pump Station in operation as this would result in extreme low pressures within the distribution system (possible negative pressures under certain demand scenarios) and result in difficulty in performing and interpreting model results.

LOW SERVICE GRADIENT (334')



TOTAL VOLUME = 2,000,000 GALLONS; 28,600 GAL/FT
HEIGHT = 70 FEET
DIAMETER = 70 FEET
MATERIAL = CONCRETE
CONSTRUCTED = 1990

WAKEFIELD STREET TANK

N.T.S.

FIGURE 2

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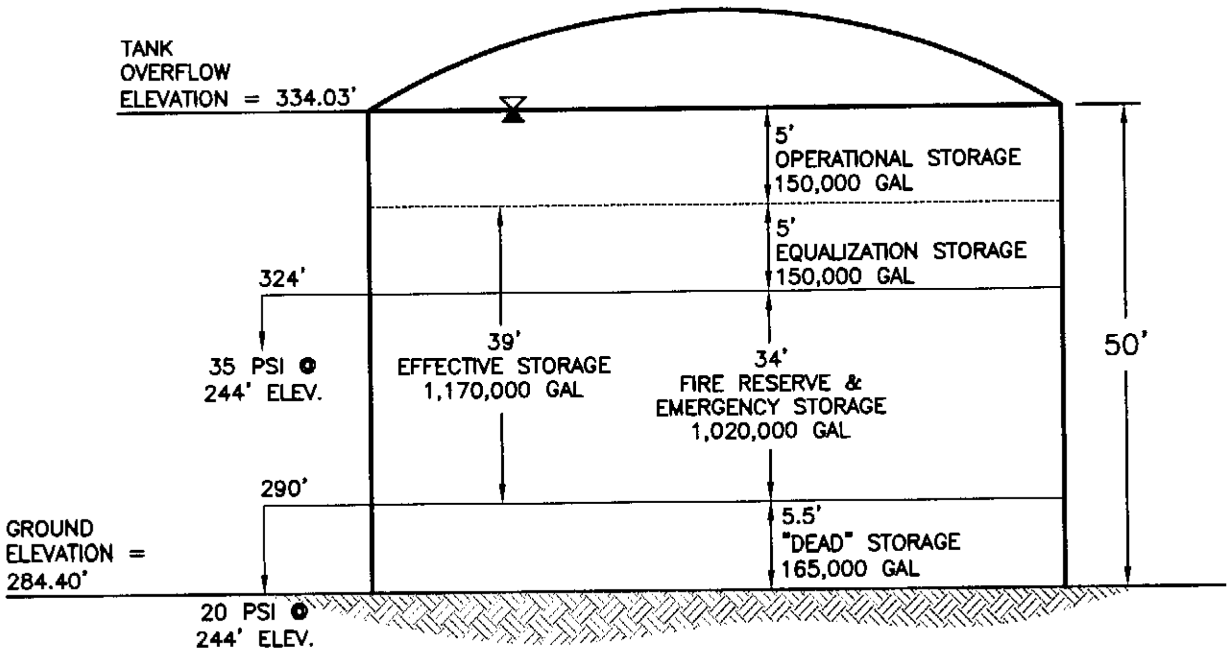
LOW SERVICE GRADIENT (334')



TOTAL VOLUME = 1,500,000 GALLONS; 30,000 GAL/FT
HEIGHT = 50 FEET
DIAMETER = 73 FEET
MATERIAL = CONCRETE
CONSTRUCTED = 1977

FRENCHTOWN ROAD TANK
N.T.S.

FIGURE 3

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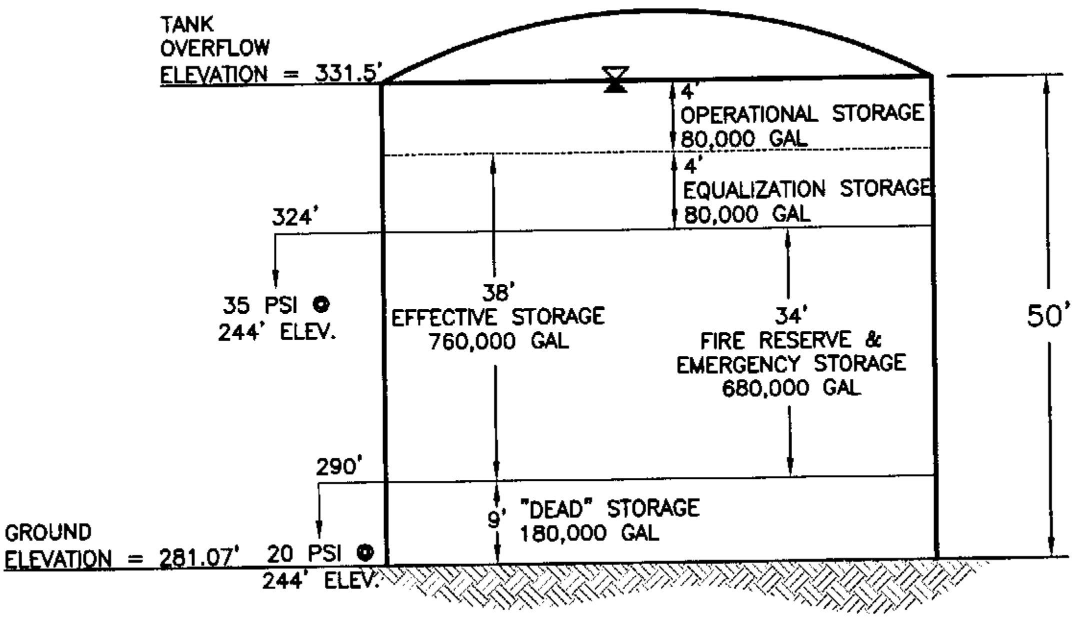
LOW SERVICE GRADIENT (334')



TOTAL VOLUME = 1,000,000 GALLONS; 20,000 GAL/FT
HEIGHT = 50 FEET
DIAMETER = 58 FEET
MATERIAL = STEEL
CONSTRUCTED = 1956

WEST STREET TANK
N.T.S.

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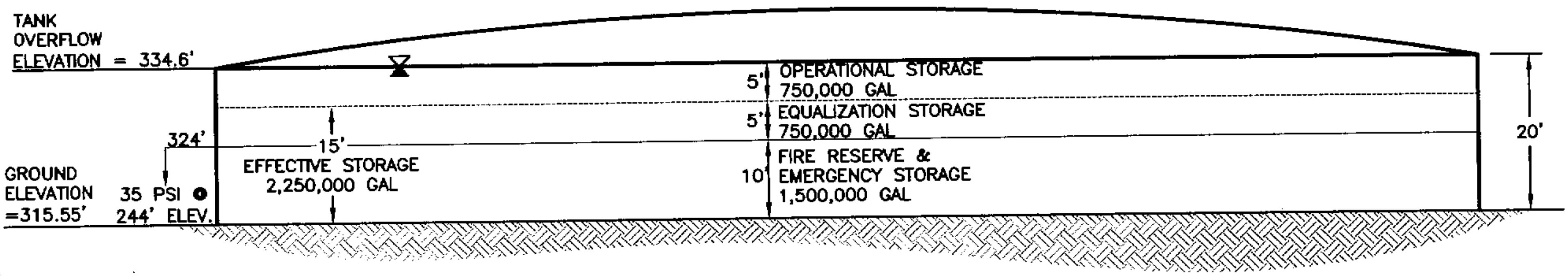
FIGURE 4

LOW SERVICE GRADIENT (334')



TOTAL VOLUME = 3,000,000 GALLONS; 150,000 GAL/FT
HEIGHT = 20 FEET
DIAMETER = 160 FEET
MATERIAL = STEEL
CONSTRUCTED = 1968

CROMPTON (SETIAN LANE) TANK
N.T.S.

NOTE: NO "DEAD" STORAGE AS ABLE TO ACHIEVE A MINIMUM 20 PSI @ HIGHEST SERVICE ELEVATION OF 244 FEET

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FIGURE 5

High Service Pressure Gradient
The High Service Pressure Gradient is controlled by the overflow elevation in the Read School House Road, Technology Park and Carr Pond water storage tanks, which are at an elevation of 500 feet. C&E conducted a review of the historical tank chart records for these storage tanks, which indicates that the Authority is routinely capable of maintaining the water level in the tanks within the top fifteen feet of the overflow. This includes the period of peak hour system demand most notably during the summer months.

The water level set points for control of the operation of booster pump stations that supply this pressure zone are maintained within a span of five feet within each of the two tanks. Therefore, for purposes of defining the range and volumes of *operational storage* within the High Service Gradient tanks, the top five feet in each of the storage tanks was utilized.

The range for *equalization storage* was defined to be the water volume below the *operational storage* (5 feet down in the tank) to a water level within the tank that the historic tank charts indicate that the system is capable of maintaining. As previously indicated, historic tank charts indicate that the High Service Gradient tanks are maintained at minimum within the top fifteen feet from the overflow elevation.

Based on this fifteen-foot potential drawdown for *operational* and *equalization storage* a maximum ground elevation within the service territory that can be provided with a minimum pressure of 35 psi (i.e. bottom of *equalization storage*) was calculated as follows.

500 feet (overflow) – 15 feet (bottom of *operational* and *equalization storage*) = 485 feet (water level)

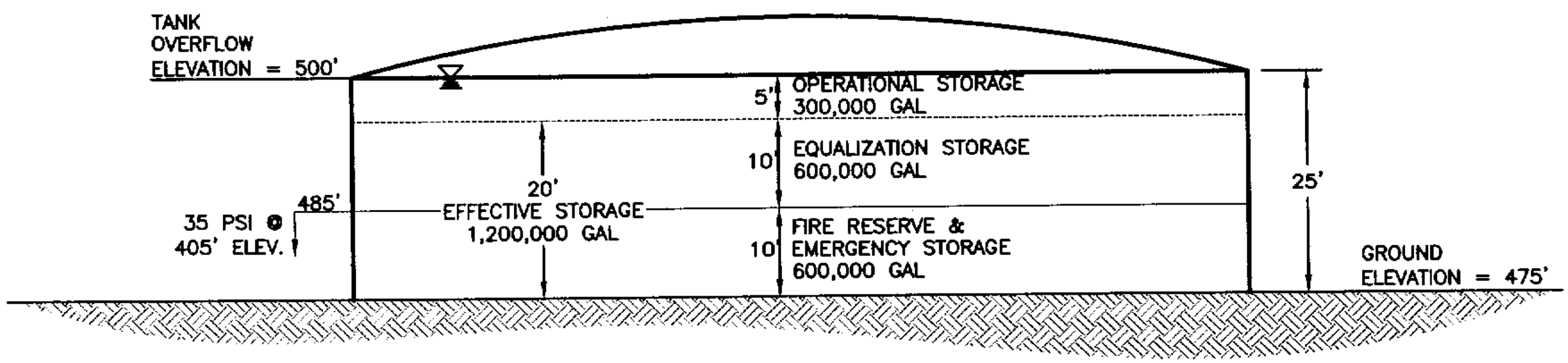
35 psi (minimum pressure) X 2.31 feet/psi = 80 feet (35 psi converted to feet of water)

485 feet (tank level) – 80 feet (feet of water for 35 psi) = 405 feet (ground elevation)

This corresponds to a water elevation in the storage tanks of 485 feet at which a minimum pressure of 35 psi would be maintained at a ground customer service elevation of 405 feet. Similarly, the water elevation that corresponds to servicing a ground customer service elevation of 405 feet while maintaining a minimum pressure of 20 psi (i.e. bottom of *effective storage* and *fire/emergency reserve storage*) equates to a water level of 451 feet in the tanks. All water in any High Service Gradient tank below a water elevation of 451 feet is therefore considered *dead storage,* as it cannot provide a minimum pressure of 20 psi at a ground customer service elevation of 405 feet. The Technology Park Tank has a bottom bowl elevation of 455 feet, which is above the 451-foot elevation, and therefore all water in this tank is considered to be *effective storage* and as a result there is no *dead storage*. The Carr Pond Tank that has a bottom tank elevation of 419 feet has a volume of associated *dead storage*. The Read School House Road Tank has a bottom elevation of 475 feet, which is above the 451-foot elevation, and therefore all water in this tank is considered to be effective storage and as a result there is no *dead storage*.

With these elevations established, each of the various components of storage volume was calculated for each storage tank in the High Service Pressure Gradient. These elevations in each of the High Service storage tanks are depicted graphically on Figures 6, 7 and 8 and the related storage volume component is listed in Table 4.

READ SCHOOL HOUSE ROAD GRADIENT (500')



TOTAL VOLUME = 1,500,000 GALLONS; 60,000 GAL/FT
HEIGHT = 25 FEET
DIAMETER = 105 FEET
MATERIAL = CONCRETE
CONSTRUCTED = 2007/2008

READ SCHOOL HOUSE ROAD TANK

N.T.S.

NOTES:

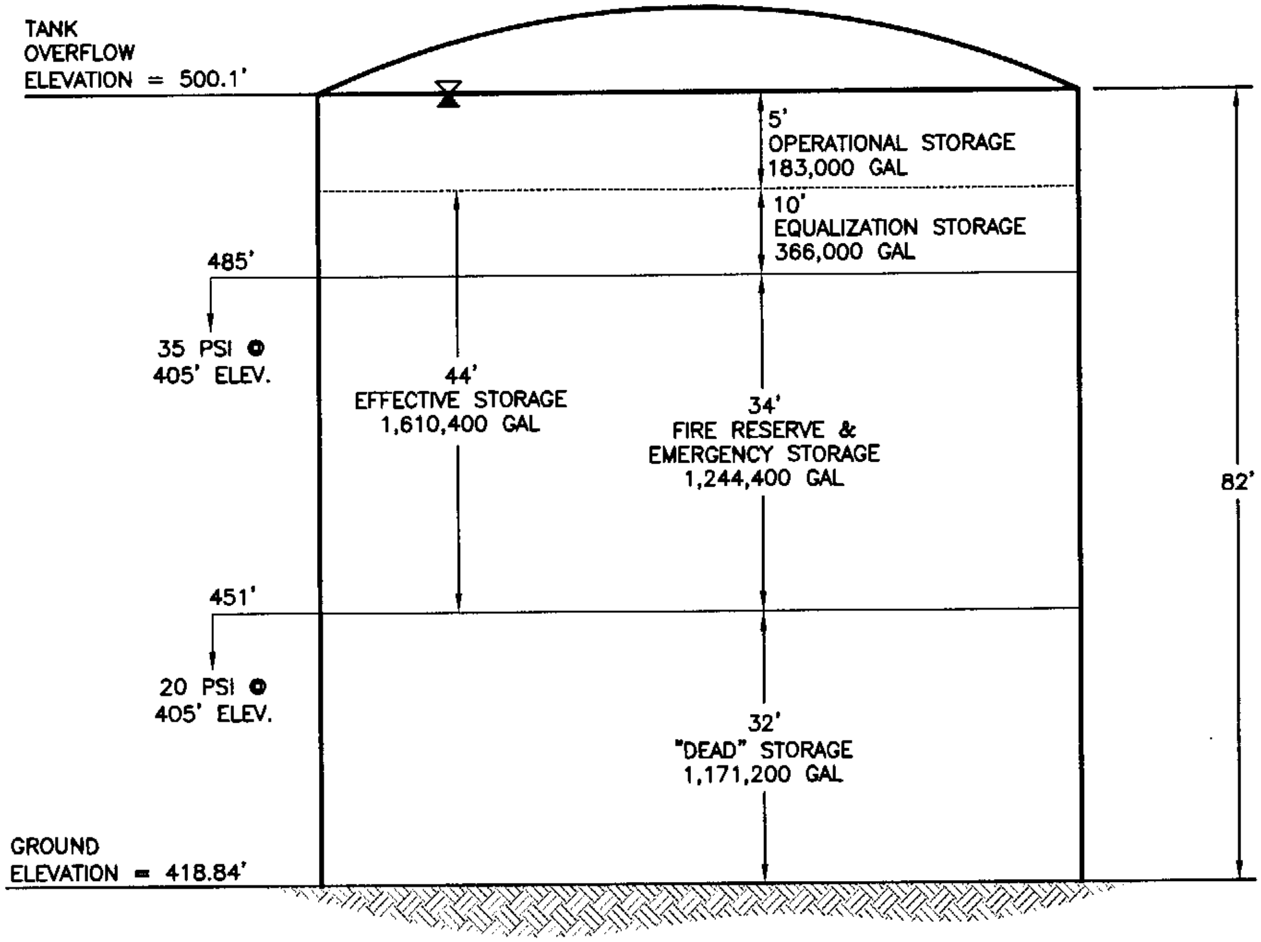
1. TANK ANTICIPATED TO BE PLACED IN SERVICE IN 2008

2. NO "DEAD" STORAGE AS ABLE TO ACHIEVE A MINIMUM OF 20 PSI @ HIGHEST SERVICE ELEVATION OF 410 FEET

Civil & Environmental Engineering Partners, Inc.
342 Park Avenue, Woonsocket, RI 02895

FIGURE 6

HIGH SERVICE GRADIENT (500')



TOTAL VOLUME = 3,000,000 GALLONS; 36,600 GAL/FT
HEIGHT = 82 FEET
DIAMETER = 80 FEET
MATERIAL = CONCRETE
CONSTRUCTED = SEPTEMBER 2001

CARR POND ROAD TANK
N.T.S.

FIGURE 7

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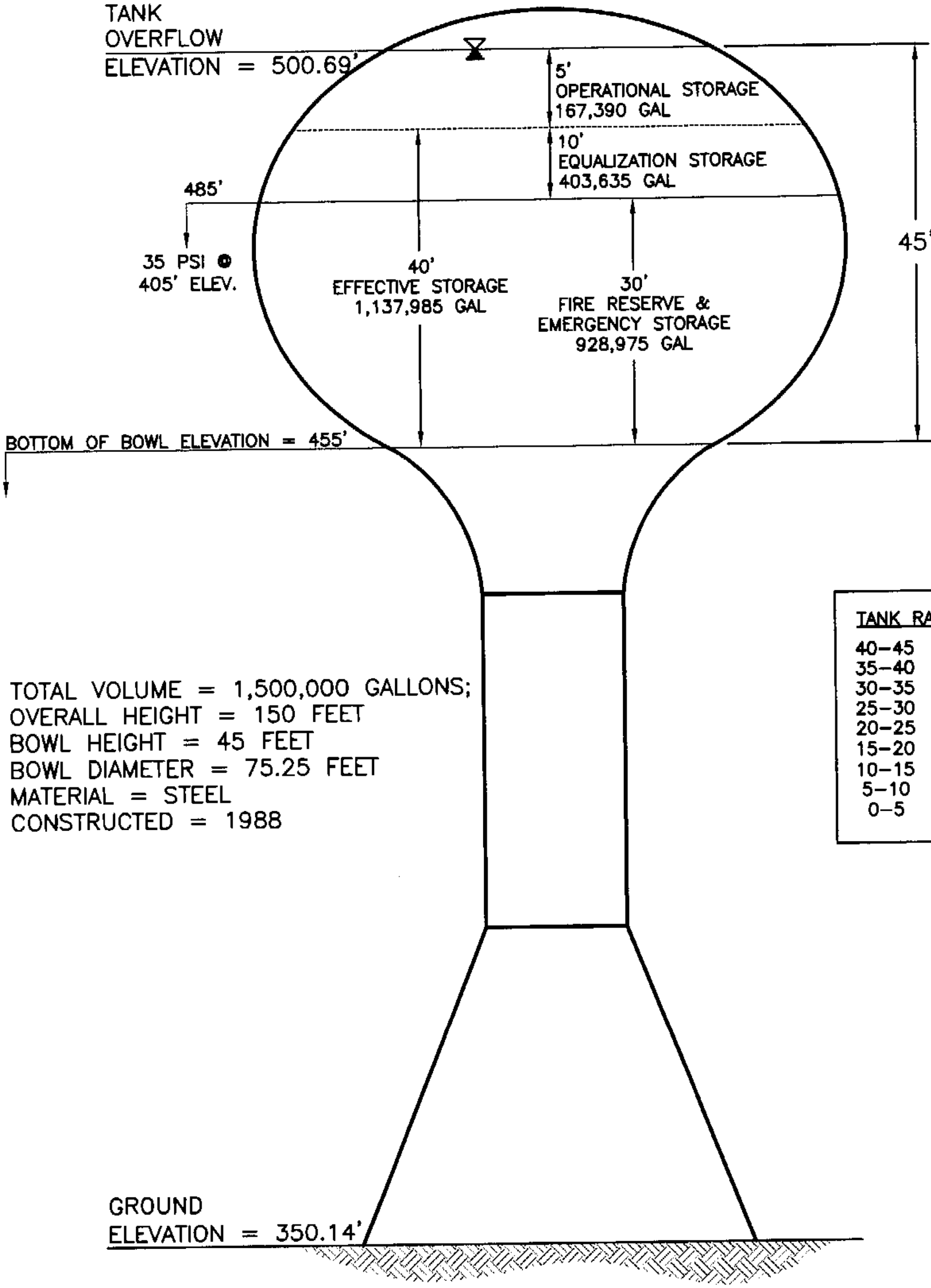
HIGH SERVICE GRADIENT (500')



TOTAL VOLUME = 1,500,000 GALLONS;
OVERALL HEIGHT = 150 FEET
BOWL HEIGHT = 45 FEET
BOWL DIAMETER = 75.25 FEET
MATERIAL = STEEL
CONSTRUCTED = 1988

TANK RANGE	GAL/FT
40–45	33,478
35–40	38,925
30–35	41,802
25–30	42,408
20–25	40,745
15–20	36,375
10–15	29,864
5–10	21,035
0–5	15,410

TECHNOLOGY PARK ELEVATED TANK
N.T.S.

NOTE: NO "DEAD" STORAGE AS ABLE TO ACHIEVE A MINIMUM OF 20 PSI @ HIGHEST SERVICE ELEVATION OF 405 FEET

FIGURE 8

Civil & Environmental Engineering Partners, Inc.
342 Park Avenue, Woonsocket, RI 02895

TABLE 4
HIGH SERVICE GRADIENT (500') FUTURE (20 YEAR) STORAGE VOLUMES

FACILITY	EFFECTIVE STORAGE (MG)	OPERATIONAL STORAGE (MG)	EQUALIZATION STORAGE (MG)	FIRE RESERVE & EMERGENCY STORAGE (MG)	"DEAD" STORAGE (MG)
Read School House Road Tank	1.200	0.300	0.600	0.600	0
Carr Pond Road Tank	1.610	0.183	0.366	1.244	1.171
Technology Park Tank	1.138	0.167	0.404	0.929	0
TOTALS	**3.948**	**0.650**	**1.370**	**2.773**	**1.171**

The total nominal storage capacity of all storage tanks in the High Service Pressure Gradient is equal to 6,000,000 gallons. (Note: Read School House Road Pressure Gradient and High Service Pressure Gradient have been interconnected.)

3.3 Existing Storage Tank(s) Volume Assessment

The following includes an analysis of each of the primary pressure gradients in the water distribution system with regard to the various aforementioned components of storage as related to consumer water system demands, fire flow requirements and emergency storage requirements. As previously indicated, there are no specific formulas on which to definitively size and evaluate storage tanks as each system is unique with regard to its demand consumption, supply production and fire flow and emergency requirements. There are however general water works standards and practice, typically referred to regulatory based sizing criteria, which can be utilized to evaluate the storage facilities including various components of storage (i.e. operational, equalization, fire, emergency, etc.). This evaluation would be further supported through extended period simulations of hydraulic modeling. The results from the modeling evaluation would lend support to the regulatory-based sizing criteria. Significant difference or variation between the two methods would need to be further examined.

3.3.1 Evaluation Criteria

The following criteria that was previously discussed in Technical Memorandum No. 2A shall be utilized to assess the various storage tank components. The criteria and definition of the various storage components are briefly summarized below.

Effective Storage volume is equal to the total nominal volume less the volume of *operational* and *dead storage.* It is this volume in the tank that is always available to meet peak consumer demands or during fire and emergency conditions. The *operational storage* is that volume in the tank that is routinely cycled on a daily basis. The area of *dead storage* is defined as the water elevation in the tank below which a satisfactory pressure (i.e. 20 psi) cannot be supplied for purposes of emergency or fire flow storage. Only the volume of *effective storage* will be used to determine the actual available, or design, storage volume. Again, it is noted that there exist isolated areas within the service territory within particular pressure zones that do not meet this 20-psi criteria. These must be examined on an individual basis.

The *equalization storage* is that volume of tank storage, which lies below the *operational storage* volume that meets water system demands that are in excess of the pumping or supply capacity of the water system. The bottom of the *equalization storage* volume is also defined by the water level in the tank at which 35 psi would be available at the highest serviceable ground customer service elevation. These customer serviceable ground elevations were previously defined for each pressure service zone. The water volume dedicated to *equalization storage* is utilized during peak demand periods of the day.

The measure of the adequacy of *equalization storage* will be evaluated on the premise of achieving 25 percent of the system average day demand. This is a general water works guideline and will provide an indication of the overall ability of the water system to meet anticipated peak demands that are in excess of the supply capability of the water system. As the water system is segregated into two distinct pressure zones, the assessment of the volume of the tanks will include the aggregate storage capacity of all tanks in a particular pressure zone.

This will however only provide a general interpretation of the adequacy of the storage tank volumes. The modeling evaluations, most notably extended period simulations, will provide a more definitive indication as to how each of the individual tanks operates with regard to meeting varied system demand conditions. It is critical for example that during modeling evaluations that no one storage tank (exclusive of fire flow conditions) remains in a constant locked up condition, drains or fills at excessive rates with respect to other tanks and that there is no erosion of the storage volume below the level of established *equalization storage.*

Storage located below the *equalization storage* zone is referred to as *emergency and fire storage* and must provide a minimum pressure of 20 psi throughout the water distribution system. The Authority's distribution system including each of the two primary pressure zones consists of a variety of mixed uses including suburban and urban residential, commercial and office and varied intensity industrial development. The residential and commercial development will in general require fire flows in the range of 1,000 – 1,500 gpm. High intensity use areas and industrial facilities may require fire flows up to (and at times in excess of) 3,500 gpm.

For purposes of this evaluation, each storage tank was evaluated for its ability to supply a required fire flow of 3,500 gpm for a duration of 3 hours as required by NFPA (National Fire Protection Association) for a fire flow requirement of this rate. This fire flow rate equates to a total fire flow volume of 630,000 gallons, which would necessarily need to be available in a storage tank. This is considered a conservative approach for the evaluation in that during an actual fire flow event the water system will have the ability to supply the required fire flow from multiple tanks, as they are available in the pressure gradient, and from redundant supply sources.

As always, it is recommended that fire flows for specific developments or facilities be evaluated on an individual basis. This is due to the fact that there may be adequate reserve for fire flow in a particular tank however the infrastructure (water mains, hydrants, etc.) may be limited in their ability to transmit this flow rate from the tank to the point of required fire flow.

The volume of water, if any, in excess of the required fire flow is considered to be *emergency storage.* Below this water level, storage is ineffective or considered to be *dead storage* that cannot effectively supply the distribution system with an adequate pressure of 20 psi.

The following tables provide an indication of the ratio of the total tank equalization storage to future average day demand and an assessment of the available fire flow capacity on a tank-by-tank basis for each of the two major pressure zones.

LOW SERVICE (334') GRADIENT

EQUALIZATION STORAGE ASSESSMENT – FUTURE 20 YEAR DEMANDS

DEMAND SCENARIO	FUTURE SYSTEM DEMAND (GAL)	TOTAL EQUALIZATION VOLUME (GAL)	% STORAGE OF AVERAGE DAY DEMAND
Average Day	8,610,000	1,123,000	13%

The total of the *equalization storage* volume in all the Low Service tanks provides 13% of the future average day demand, which is below the water works 25% guideline. It is also critical to evaluate these storage tanks under an extended period modeling scenario. It should also be noted that the Low Service Gradient is operated under a continuous pumping mode. The continual operation of the Clinton Avenue Pump Station and its ability to effectively meet a large portion of the overall system demand may in part serve to reduce the reliance on the tanks in meeting peak consumer demands. This is represented in the historic tank charts, which indicate that overall the Low Service storage tanks are not excessively taxed or drained during periods of peak demands.

FIRE & EMERGENCY STORAGE ASSESSMENT

STORAGE TANK	TOTAL FIRE & EMERGENCY STORAGE (GAL)	REQUIRED FIRE STORAGE IN TANK (GAL)	AVAILABLE EMERGENCY STORAGE IN TANK (GAL)
Wakefield Street Tank	972,000	630,000	342,000
Frenchtown Road Tank	1,020,000	630,000	390,000
West Street Tank	680,000	630,000	50,000
Setian Lane Tank	1,500,000	630,000	870,000
TOTALS	**4,172,000**		**1,652,000**

All of the Low Service Gradient storage tanks provide a fire flow volume of 630,000 gallons, which is equivalent to a 3,500 gpm fire flow rate for a three hour duration. Additionally, all the storage tanks, provide a varied source of emergency volume that cumulatively equals 1,652,000 gallons. This emergency storage volume is approximately 19% of the Low Service average day demand. The storage volumes associated with the fire and emergency reserve are considered to be adequate and will be further assessed during the modeling portion of the evaluation.

HIGH SERVICE (500') GRADIENT

EQUALIZATION STORAGE ASSESSMENT – FUTURE 20 YEAR DEMANDS

DEMAND SCENARIO	FUTURE SYSTEM DEMAND (GAL)	TOTAL EQUALIZATION VOLUME (GAL)	% STORAGE OF AVERAGE DAY DEMAND
Average Day	4,350,000	1,370,000	31%

The total of the *equalization storage* in the High Service tanks provides 31% of the average day demand, which is above the water works 25% guideline. It is also important to evaluate these storage tanks under an extended period modeling scenario to ensure proper operation. Additionally, the Authority has in the past effectively maintained water levels in these storage tanks within the range for equalization storage volumes under peak demand scenarios.

FIRE & EMERGENCY STORAGE ASSESSMENT

STORAGE TANK	TOTAL FIRE & EMERGENCY STORAGE (GAL)	REQUIRED FIRE STORAGE IN TANK (GAL)	AVAILABLE EMERGENCY STORAGE IN TANK (GAL)
Read School House Road Tank	600,000	630,000	0
Carr Pond Road Tank	1,244,400	630,000	614,400
Technology Park Tank	929,000	630,000	299,000
TOTALS	**2,773,400**		**913,400**

The Read School House Road Tank provides a fire flow storage volume of 600,000 gallons, which is near equivalent to a 3,500 gpm fire flow rate at a three hour duration. Based on this fire flow rate, there is no emergency storage provided in this tank. This storage tank is of adequate capacity to provide for the various components of storage for this pressure gradient. Each of the remaining High Service Gradient storage tanks can provide a fire flow volume of 630,000 gallons, which is equivalent to a 3,500 gpm fire flow rate at a three hour duration. Additionally, each of these tanks provide a varied source of emergency volume that cumulatively equals 913,400 gallons. This emergency storage is approximately 21% of the High Service average day demand. The storage volumes associated with the fire and emergency reserve are considered to be adequate and will be further assessed during the modeling portion of the evaluation.

4.0 Extended Period Simulations Without Fire Flow – Future Demands

Extended period simulations (EPS) were completed for a 96 hour (4 day) period during which future (2025) average day and maximum day demands were utilized with the diurnal flow curves that were previously developed for each of the various pressure zones. The supply sources (wells and interconnections) and booster pump stations were set on level control with the corresponding tank that currently controls operation of these facilities. For the EPS, one pump at Clinton Avenue was in continuous operation while second and third pumps were set on operational control with Frenchtown Road Tank. The intent of these EPS evaluations was to determine the adequacy of the distribution system storage tanks during an EPS of average day and maximum day demand conditions to determine how the storage tanks operate.

The critical indicators that were examined for each storage facility were the rate of fill and draw, time of recovery, extent of drawdown in the tank (i.e. not eroding fire and emergency storage volume), ability to cycle and overall effectiveness in meeting system demands. A time step graph for each of the storage tanks is provided as Attachment No. 1 (EPS Average Day) and No. 2 (EPS Maximum Day). A description of the tank(s) effectiveness in meeting these demands is also provided. Additionally, due to the fact that the Clinton Avenue facility is critical with regard to supply and pressure for the Low Service Gradient, time step graphs of the operation of these pumps are also provided in the Attachments. For purposes of this analysis, it is assumed that adequate backup is provided at each interconnection or booster pump station in the form of redundant pumps at the facility. It should be noted that this simulation did not include evaluation of fire flows, which were performed in subsequent EPS evaluations.

4.1 Extended Period Simulation (96 Hour) – Future Average Day Demand

An extended period simulation (EPS) was completed for a 96 hour (4 day period) during which future (2025) average day demands were utilized with the diurnal flow curves that were previously developed for each of the various pressure zones. The intent of this EPS was to determine the adequacy of the distribution system storage tanks during an EPS of average day demand conditions to determine how the storage tanks operate.

4.1.1 High Service Pressure (500') Gradient Evaluation

This pressure gradient contains three storage tanks, the Read School House Road Tank, Technology Park Tank and Carr Pond Tank that are all at an overflow elevation of 500 feet. Reference the time step graph for these tanks in Attachment No. 1. For this simulation the 3.0 MGD pump(s) at the Clinton Avenue Pump Station (level control with Read School House Road Tank), Quaker Lane Booster Pump Station (level control with Carr Pond Tank), West Warwick Business Park Pump Station (level control with Technology Park Tank) and Johnson Boulevard Booster Pump Station (level control with Technology Park and Carr Pond Tanks) were on during this simulation. The Setian Lane Booster Pump Station was off during this simulation.

Read School House Road Tank
The EPS for this pressure gradient depicts the Read School House Road Tank fluctuating within a range of approximately 3.5 feet from its overflow elevation of 500 feet. This cycle range is coincident with the set points for the 3.0 MGD pump(s) at the Clinton Avenue Pump Station, which are designed to supply this tank. Over the span of the EPS, the tank cycles within its set point range on average of one to two times daily which is within the prescribed "operational" storage range (i.e. 10 feet) for this facility. The EPS demonstrates that this tank is of sufficient capacity to meet future average day demands.

Carr Pond Tank
The EPS for this pressure gradient depicts the Carr Pond Tank as fluctuating within a range of approximately 2 feet (from 492.7 to 494.7 feet) below its overflow elevation of 500 feet. This cycle range is coincident

with the set points for the Quaker Lane Booster Pump Station and Johnson Boulevard Pump Station. Over the span of the EPS, the tank cycles within its set point range on average of four times daily and within the prescribed "operational" storage range (i.e. 10 feet) for this facility. The cycle range of the tank is such that it never refills to the pump off elevation of 499 feet, however it does fill sufficiently to avoid depletion below an acceptable low water point in the tank on subsequent drawdowns. The EPS demonstrates that this tank is of sufficient capacity to meet future average day demands.

Technology Park Tank
The EPS for this pressure gradient depicts the Technology Park Tank as fluctuating within a range of approximately 3.5 feet (from 495.1 to 498.6 feet) below its overflow elevation of 500 feet. This cycle range is coincident with the set points for the Johnson Boulevard and West Warwick Business Park Booster Pump Stations. Over the span of the EPS, the tank cycles within its set point range on average of one time daily and is within the prescribed "operational" storage range (i.e. 10 feet) for this facility. Depletion in the tank is within an acceptable low water point on subsequent drawdowns. The EPS demonstrates that this tank is of sufficient capacity to meet future average day demands.

4.1.2 Low Service Pressure (334') Gradient Evaluation

This pressure gradient contains four storage tanks, Frenchtown Road, Setian Lane, Wakefield Street and West Street and all are at an overflow elevation of 334 feet. Reference the time step graphs for these tanks in Attachment No. 1. For this simulation the Clinton Avenue Pump Station (level control with Frenchtown Road Tank), Quaker Lane Pump Station (level control with Setian Lane Tank) and East Greenwich Well (level control with Frenchtown Road Tank) were on during this simulation. The Spring Lake Well was off during this simulation.

Frenchtown Road Tank
The EPS for this pressure gradient depicts the Frenchtown Road Tank as fluctuating within a range of approximately 5 feet (from 329 to 334 feet) below its overflow elevation of 334 feet. This cycle range is coincident with the set points for the Clinton Avenue Pump Station and East Greenwich Well. Over the span of the EPS, the tank cycles within its set point range on average of two to three times daily and within the prescribed "operational" storage range (i.e. 10 feet) for this facility. The cycle range of the tank is such that it refills to 334 feet, which is above the pump off elevation of 333 feet, and depletion in the tank is within an acceptable low water point in the tank on subsequent drawdowns. The EPS demonstrates that this tank is of sufficient capacity to meet future average day demands.

Setian Lane Tank
The EPS for this pressure gradient depicts the Setian Lane Tank as fluctuating within a range of approximately 1.5 feet (from 332.5 to 334 feet) below its overflow elevation of 334 feet. This cycle range is coincident with the set points for Quaker Lane Pump Station. This tank is also provided with significant refill volume from the Clinton Avenue Pump Station, which is on level control with Frenchtown Road Tank. Over the span of the EPS, the tank cycles within its set point range on average of one to two times daily and within the prescribed "operational" storage range (i.e. 5 feet) for this facility. The cycle range of the tank is such that it refills to 334 feet, which is above the pump off elevation of 333 feet, and depletion in the tank is within an acceptable low water point in the tank on subsequent drawdowns. The EPS demonstrates that this tank is of sufficient capacity to meet future average day demands.

Wakefield Street Tank
The EPS for this pressure gradient depicts the Wakefield Street Tank as being in a "locked up" condition throughout the EPS. Several factors can be attributed to this condition. The operation of the Clinton Avenue Pump Station, which during this simulation has at minimum one pump operating at all times, creates a system hydraulic grade in proximity to this tank that is above the overflow elevation of 334 feet. Additionally, the new distribution water mains from Main Street to Wakefield Street (i.e. Harding, Phenix,

Harris, Potter, etc.) along with the new transmission mains in West Warwick on Main, Ames and across the Pawtuxet River allow for increased flow capacity to this storage tank. Previously, the older cast iron mains allowed for greater friction losses and decreased flow capacity, which permitted this tank to cycle. It is likely that this tank will continue to operate in a near "locked up" mode during off peak demand periods (i.e. non summer periods) due to the new water infrastructure and the influence of the pump head from the Clinton Avenue Pump Station.

In order to promote cycling of this tank, it is recommended that options be examined during the update of the CIP (Capital Improvement Plan) that would include isolating this tank to the west on Wakefield Street with a valving station. It is intended that this create a condition whereby the tank would be supplied from the east on Wakefield Street and at a lower system hydraulic grade that would promote tank cycling. In addition, the valving station should include a provision to open and allow flow to the west along Wakefield Street in the event the hydraulic grade drops below the overflow elevation in the tank (i.e. under a fire flow condition). Recent model simulations for the proposed emergency interconnection with Providence Water off of Wakefield Street have also shown that the Wakefield Street Tank will remain in a "locked up" condition during operation.

West Street Tank
The EPS for this pressure gradient depicts the West Street Tank as being in a "locked up" condition throughout the EPS. The primary factor related to this condition is the influence of the pump head from the Clinton Avenue Pump Station and the corresponding increase in the system hydraulic grade in proximity to this tank that is above the tank overflow elevation of 334 feet (survey revealed actual overflow at an elevation of 331.5 feet). Normal system operations require that the Clinton Avenue Pump Station run at minimum one pump on a continuous basis in order to meet system demand and maintain adequate distribution system pressure at areas of higher customer service elevation. It should be noted that the slightly lower overflow elevation does not affect the "locked up" condition of this tank as the hydraulic grade is consistently above the 334-foot gradient.

System operations over the past several years have included isolating this tank from the system due to this tendency to remain in a "locked up" condition under all demand scenarios. It has been reported by system operations personnel that the hydraulic grade at the tank never drops below the overflow elevation of this tank. Given that the probability of shutting down the Clinton Avenue Pump Station for any length of time during any given 24 hour period is not likely for the immediate future due to its critical nature to the system as a whole, other options need to be considered for this tank. It is also considered that this tank provides a measure of fire reserve storage for the general surrounding area in which it is located. Further, this tank was recently rehabilitated which included interior and exterior coating replacement and structural repair.

It is therefore recommended to maintain this tank in service for purposes of reserve storage for fire protection. In order to avoid conditions of stagnant water and poor tank turnover, a booster pump system could be installed at the tank to periodically pump water back into the distribution system. In this manner, it would be likely to turn off Clinton Avenue Pump Station for a period of time (i.e. 1 – 2 hours) during the early morning hours when the pump station at the tank is in operation. The pump station would be sized to replicate the pump head conditions produced by Clinton Avenue Pump Station in order that the customers at higher service elevations would still maintain adequate pressure. The control for operation of this station would need to be coordinated through the Authority's SCADA system.

Once the long-term goal of re-servicing customers at higher elevations is achieved and if the pumps at Clinton Avenue can be periodically turned off, this tank will fluctuate on a routine basis.

4.2 Extended Period Simulation (96 Hour) – Future Maximum Day Demand

An extended period simulation (EPS) was completed for a 96 hour (4 day period) during which future (2025) maximum day demands were utilized with the diurnal flow curves that were previously developed for each of the various pressure zones. The intent of this EPS was to determine the adequacy of the distribution system storage tanks during an EPS of maximum day demand conditions and under a scenario when the tanks would most likely be strained.

4.2.1 High Service Pressure (500') Gradient Evaluation

This pressure gradient contains three storage tanks, the Read School House Road Tank, Technology Park Tank and Carr Pond Tank that are all at an overflow elevation of 500 feet. Reference the time step graph for these tanks in Attachment No. 2. For this simulation the 3.0 MGD pump(s) at the Clinton Avenue Pump Station (level control with Read School House Road Tank), Quaker Lane Booster Pump Station (level control with Carr Pond Tank), West Warwick Business Park Pump Station (level control with Technology Park Tank) and Johnson Boulevard Booster Pump Station (level control with Technology Park and Carr Pond Tanks) were on during this simulation. The Setian Lane Booster Pump Station was off during this simulation.

Read School House Road Tank
The EPS for this pressure gradient depicts the Read School House Road Tank fluctuating within a range of approximately 3 feet (from 496.5 to 499.5 feet) from its overflow elevation of 500 feet. Reference the time step graph for this tank in Attachment No. 2. This cycle range is coincident with the set points for the 3.0 MGD pump(s) at the Clinton Avenue Pump Station, which are designed to supply this tank. Over the span of the EPS, the tank cycles within its set point range on average of three to four times daily which is within the prescribed "operational" storage range for this facility. The EPS demonstrates that this tank is of sufficient capacity to meet the future maximum day demands.

Carr Pond Tank
The EPS for this pressure gradient depicts the Carr Pond Tank as fluctuating within a range of approximately 3.5 feet (from 492.5 to 496 feet) below its overflow elevation of 500 feet. This cycle range is coincident with the set points for the Quaker Lane Booster Pump Station and Johnson Boulevard Pump Station. Over the span of the EPS, the tank cycles within its set point range on average of two to three times daily and within the prescribed "operational" storage range (i.e. 10 feet) for this facility. The cycle range of the tank is such that it never refills to the pump off elevation of 499 feet, however it does fill sufficiently to avoid depletion below an acceptable low water point in the tank on subsequent drawdowns. The EPS demonstrates that this tank is of sufficient capacity to meet the future maximum day demands.

Technology Park Tank
The EPS for this pressure gradient depicts the Technology Park Tank as fluctuating within a range of approximately 5.3 feet (from 494.5 to 499.8 feet) below its overflow elevation of 500 feet. This cycle range is coincident with the set points for the Johnson Boulevard and West Warwick Business Park Booster Pump Stations. Over the span of the EPS, the tank cycles within its set point range on average of two times daily and is within the prescribed "operational" storage range (i.e. 10 feet) for this facility. The cycle range of the tank is such that it refills above the pump off elevation of 499 feet and depletion in the tank is within an acceptable low water point in the tank on subsequent drawdowns. The EPS demonstrates that this tank is of sufficient capacity to meet the future maximum day demands.

4.2.2 Low Service Pressure (334') Gradient Evaluation

This pressure gradient contains four storage tanks, Frenchtown Road, Setian Lane, Wakefield Street and West Street and all are at an overflow elevation of 334 feet. Reference the time step graphs for these tanks in

Attachment No. 2. For this simulation the Clinton Avenue Pump Station (level control with Frenchtown Road Tank), Quaker Lane Pump Station (level control with Setian Lane Tank) and East Greenwich Well (level control with Frenchtown Road Tank) were on during this simulation. The Spring Lake Well was off during this simulation.

Frenchtown Road Tank
The EPS for this pressure gradient depicts the Frenchtown Road Tank as fluctuating within a range of approximately 9 feet (from 323 to 332 feet) below its overflow elevation of 334 feet. This cycle range is coincident with the set points for the Clinton Avenue Pump Station and East Greenwich Well. Over the span of the EPS, the tank cycles within its set point range on average of two times daily and within the prescribed "operational" storage range (i.e. 10 feet) for this facility. The cycle range of the tank is such that it never refills to the pump off elevation of 333 feet, however depletion in the tank is within an acceptable low water point in the tank on subsequent drawdowns. The EPS demonstrates that this tank is of sufficient capacity to meet the future maximum day demands.

Setian Lane Tank
The EPS for this pressure gradient depicts the Setian Lane Tank as fluctuating within a range of approximately 4.2 feet (from 329 to 333.2 feet) below its overflow elevation of 334 feet. This cycle range is coincident with the set points for Quaker Lane Pump Station. This tank is also provided with significant refill volume from the Clinton Avenue Pump Station, which is on level control with Frenchtown Road Tank. Over the span of the EPS, the tank cycles within its set point range on average of two times daily and within the prescribed "operational" storage range (i.e. 5 feet) for this facility. The cycle range of the tank is such that it fills to just above the pump off elevation of 333 feet and depletion in the tank is within an acceptable low water point in the tank on subsequent drawdowns. The EPS demonstrates that this tank is of sufficient capacity to meet the future maximum day demands.

Wakefield Street Tank
The EPS for this pressure gradient depicts the Wakefield Street Tank as fluctuating within a range of approximately 0.5 feet (from 333.5 to 334 feet) below its overflow elevation of 334 feet and remains in a near "locked up" condition throughout the EPS. As with the EPS Average Day, several factors are attributed to this condition. The operation of the Clinton Avenue Pump Station, which during this simulation has at minimum two pumps operating at all times, creates a system hydraulic grade in proximity to this tank that is above the overflow elevation of 334 feet. Additionally, the new distribution water mains in West Warwick from Main Street to Wakefield Street (i.e. Harding, Phenix, Harris, Potter, etc.) along with the new transmission mains on Main, Ames and across the Pawtuxet River allow for increased flow capacity to this storage tank. Previously, the older cast iron mains in these areas allowed for greater friction losses and decreased flow capacity, which permitted this tank to cycle.

As previously indicated, it is recommended that consideration be given to isolating this tank to the west on Wakefield Street with a valving station.

West Street Tank
The EPS for this pressure gradient depicts the West Street Tank as fluctuating within a range of approximately 0.5 feet (from 333.5 to 334 feet) below its overflow elevation of 334 feet and remains in a "locked up" condition throughout the EPS. Similar to the EPS Average Day, the primary factor related to this condition is the influence of the Clinton Avenue Pump Station and the corresponding increase in the system hydraulic grade in proximity to this tank that is above the tank overflow elevation of 334 feet (survey revealed actual overflow at an elevation of 331.5 feet). As previously indicated, the slightly lower overflow elevation does not affect the "locked up" condition of this tank as the hydraulic grade is consistently above the 334-foot gradient.

5.0 Extended Period Simulations With Fire Flow – Future Demands

Extended period simulations (EPS) were completed for a 24 hour (1 day) period during which future (2025) average day and maximum day demands were utilized with the diurnal flow curves that were previously developed for each of the various pressure zones. This also included simulating a 2,000 gpm fire flow at two (2) specific junction nodes in proximity to each of the distribution system storage tanks. This fire flow rate was applied for a two-hour duration beginning at 12:00 PM and ending at 2:00 PM under each EPS. The 2,000 gpm fire flow rate was selected as a conservative fire flow requirement in that the majority of locations within the service territory are not anticipated to require fire flows in excess of this rate.

The primary intent was to determine to what extent the water system and storage tanks were impacted by these fire flows. Of critical nature was the extent of drawdowns in tanks during the fire flow period and the recovery period following the two-hour fire flow duration. The evaluation was also critical in that it examined tanks that typically do not cycle (i.e. West Street and Wakefield Street) during normal system operations.

The fire flow analysis was not performed at all the junction nodes simultaneously as this was considered an unlikely event of occurrence.

The critical indicators that were examined for each storage facility were the rate of fill and draw, time of recovery, extent of drawdown in the tank and overall effectiveness in meeting fire flow demands. A time step graph for each of the storage tanks is provided as Attachment No. 3 (EPS Average Day with Fire Flow) and No. 4 (EPS Maximum Day with Fire Flow). A description of the tank(s) effectiveness in meeting these fire flow demands is also provided.

The supply sources (wells and interconnections) and booster pump stations were set on level control with the corresponding tank that currently controls operation of these facilities. For the EPS, one pump at Clinton Avenue was placed in continuous operation while a second and third pump were set on operational control with Frenchtown Road Tank.

5.1 Average Day - Extended Period Simulations With Fire Flow
5.1.1 High Service Gradient

The High Service Gradient contains three (3) storage tanks. A total of six (6) junction nodes were evaluated within this pressure zone as follows.

Read School House Road Tank:

J-7154 – located on Flat River Road along a 12" AC water main, elevation of 254 feet. The EPS model results indicate that at the start of the fire flow the tank is draining. The fire flow has the effect of dropping the tank level a total of approximately 2 feet during the two-hour period. At the end of the fire flow period the tank recovers to a complete refill in approximately 2 hours. The Carr Pond Tank is refilling at the start of the fire flow and continues to fill approximately 0.3 feet during the two-hour period. This tank then goes into its normal draining cycle two hours after the fire flow has ended. The Technology Park Tank is draining during the start of the fire flow and continues to drain slightly approximately 0.1 feet during the two-hour period. This tank begins to refill at the end of the fire flow. These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

J-7258 – located on Hunters Crossing Drive along a 16" DI water main, elevation of 343 feet. The EPS model results indicate that at the start of the fire flow the tank is draining. The fire flow has the effect of dropping the tank level a total of approximately 2 feet during the two-hour period. At the end of the fire flow period the tank recovers to a complete refill in approximately 2 hours. The Carr Pond Tank is refilling at the start of the fire flow and continues to fill approximately 0.3 feet during the two-hour period. This tank then goes into its normal draining cycle two hours after the fire flow has ended. The Technology Park Tank is draining during the start of the fire flow and continues to drain slightly approximately 0.1 feet during the two-hour period. This tank begins to refill at the end of the fire flow. These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

Carr Pond Road Tank:

J-4117 – located on Middle Road along a 16" DI water main, elevation of 300 feet. The EPS model results indicate that at the start of the fire flow the tank is in refill mode. The fire flow has the effect of dropping the tank level a total of approximately 5 feet during the two-hour period. At the end of the fire flow period the tank begins to recover and stabilizes at an elevation of approximately 492.5 feet (7.5 feet below overflow). The Technology Park Tank is draining during the start of the fire flow and continues to drain approximately 1 foot during the two-hour period. This tank begins to refill at the end of the fire flow. The Read School House Road Tank is draining during the start of the fire flow and continues to drain approximately 0.5 feet during the two-hour period. This tank continues to drain for an additional 8 hours to an elevation of approximately 496.6 feet (3.4 feet below overflow) and then begins to refill. These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

J-4056 – located on Frenchtown Road along a 12" DI water main, elevation of 246 feet. The EPS model results indicate that at the start of the fire flow the tank is in refill mode. The fire flow has the effect of dropping the tank level a total of approximately 5 feet during the two-hour period. At the end of the fire flow period the tank begins to recover and stabilizes at an elevation of approximately 492.5 feet (7.5 feet below overflow). The Technology Park Tank is draining during the start of the fire flow and continues to drain approximately 1 foot during the two-hour period. This tank continues to drain for an additional 8 hours to an elevation of approximately 495 feet (5 feet below overflow) and then begins to refill. The Read School House Road Tank is draining at the start of the fire flow and continues to drain approximately 0.5 feet during the two-hour period. This tank drains for an additional 8 hours to an elevation of 496.5 feet (3.5 feet below overflow) and then begins to refill. These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

Technology Park Tank:

J-8145 – located on Hopkins Hill Road along a 12" DI water main, elevation of 316 feet. The EPS model results indicate that at the start of the fire flow the tank is filling. The fire flow has the effect of dropping the tank level a total of approximately 4 feet during the two-hour period. At the end of the fire flow period the tank begins to recover and stabilizes at an elevation of approximately 496 feet (4 feet below overflow). The Read School House Road Tank is draining at the start of the fire flow and continues to drain approximately 1 foot during the two-hour period. This tank drains for an additional 4 hours to an elevation of 496.5 feet and then begins to refill. The Carr Pond Tank is refilling at the start of the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal refill rate. These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

J-951 – located on Lonsdale Street along a 12" AC water main, elevation of 298 feet. The EPS model results indicate that at the start of the fire flow the tank is filling. The fire flow has the effect of dropping the tank level a total of approximately 2 feet during the two-hour period. At the end of the fire flow period the tank begins to refill to an elevation of approximately 496.3 feet (3.7 feet below overflow).

The Read School House Road Tank is draining at the start of the fire flow and continues to drain slightly approximately 0.1 feet during the 2 hour period. This tank drains for an additional 8 hours to an elevation of 496.7 feet and then begins to refill. The Carr Pond Tank is refilling at the start of the fire flow and then drains approximately 3 feet during the two-hour fire flow period. This tank then begins to refill at the end of the fire flow and stabilizes at an elevation of 494 feet (6 feet below overflow). These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

5.1.3 Low Service Gradient

The Low Service Gradient includes four (4) storage tanks. A total of eight (8) junctions nodes were evaluated including two (2) junction nodes in proximity to each storage tank.

Wakefield Street Tank:

J-727 – located on River Farms Drive along a 12" PVC water main, elevation of 190 feet. The model results indicate that the Wakefield Street Tank is "locked up" during the 24-hour span of the EPS. The only tanks that are apparently affected by the fire flow are Setian Lane and Frenchtown Road. Setian Lane is refilling at the start of the fire flow and then drops approximately 0.3 feet to elevation 333.4 feet during the two-hour fire flow period. At the end of the fire flow, the tank continues to refill and stabilize at elevation 334 feet. The Frenchtown Road Tank is filling at the start of the fire flow but immediately drops 2 feet during the course of the 2-hour fire flow period. At the end of the fire flow the tank begins to refill 2 hours after the fire flow to an elevation of 332.5 feet. The West Street Tank remains "locked up" throughout the span of the fire flow EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

J-769 – located on Main Street along a 20" DI water main, elevation of 92 feet. The model results indicate that the Wakefield Street Tank is "locked up" during the 24-hour span of the EPS. The only tanks that are apparently affected by the fire flow are Setian Lane and Frenchtown Road. Setian Lane is refilling at the start of the fire flow and then drops approximately 0.1 feet to elevation 333.6 feet during the two-hour fire flow period. At the end of the fire flow, the tank continues to drain another 0.1 feet for an hour after the fire flow has ended and then begins to refill and stabilize at elevation 334 feet. The Frenchtown Road Tank is filling at the start of the fire flow but immediately drops 2 feet during the course of the 2-hour fire flow period. At the end of the fire flow the tank continues to fluctuate within a range of 2 feet throughout the EPS. The West Street Tank remains "locked up" throughout the span of the fire flow EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

Frenchtown Road Tank:

J-4091 – located on Frenchtown Road along a 20" AC water main, elevation of 247 feet. The model results indicate that the Frenchtown Road Tank is draining at the start of the fire flow and then drops a total of 4 feet from 330.5 to 326.5 feet during the span of the fire flow. The tank continues to drain 0.1 feet over the next 1-hour period after the fire flow and then begins to recover to an elevation of 333.5 feet. The Setian Lane Tank is refilling at the start of the fire flow scenario. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal refill rate. Both tanks operate at sufficient levels throughout the EPS. The West Street Tank and Wakefield Street Tank are "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

J-4175 – located on South County Trail along a 12" AC water main, elevation of 109 feet. The model results indicate that the Frenchtown Road Tank is draining at the start of the fire flow and then drops a total of 2 feet from 328.5 to 326.5 feet during the span of the fire flow. The tank recovers at the end of the fire flow to elevation 333.5 feet. The Setian Lane Tank is refilling at the start of the fire flow scenario. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal refill rate and continues to refill to its overflow elevation. Both tanks operate at sufficient levels throughout the EPS. The West Street Tank and Wakefield Street Tank are "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

Setian Lane Tank:

J-390 – located on Cowesett Road along a 12" AC water main, elevation of 205 feet. The model results indicate that the Setian Lane Tank is refilling at the start of the fire flow and then drops a total of 0.5 feet from approximately 333.5 to 333 feet during the span of the fire flow. The tank recovers at the end of the fire flow period to its overflow elevation of 334 feet and continues to cycle within a normal range throughout the EPS. The Frenchtown Road Tank is draining during the course of the fire flow and at the start of the fire flow drops 1.5 feet from 330.5 to 329 feet. At the end of the fire flow it begins to refill to cycle within a normal range throughout the EPS. Both tanks operate at sufficient levels throughout the EPS. The West Street Tank and Wakefield Street Tank are "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

J-2005 – located on Centerville Road along a 12" AC water main, elevation of 100 feet. The model results indicate that the Setian Lane Tank is refilling at the start of the fire flow and then drops a total of approximately 0.5 feet from 333.5 to 333 feet during the span of the fire flow. The tank recovers at the end of the fire flow period to its overflow elevation of 334 feet and then stabilizes and continues to cycle within a normal range throughout the EPS. The Frenchtown Road Tank is draining during the course of the fire flow and at the start of the fire flow drops 1.5 feet from 330.5 to 329 feet. At the end of the fire flow it begins to refill to cycle within a normal range throughout the EPS. Both tanks operate at sufficient levels throughout the EPS. The West Street Tank and Wakefield Street Tank are "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

West Street Tank:

J-626 – located on West Street along a 16" AC water main, elevation of 245 feet. This tank is "locked up" during the span of the EPS and does not provide fire flow to this junction node. Upon reviewing the model results, it would appear that the Setian Lane and Frenchtown Road tanks are affected by this fire flow. Setian Lane is slightly filling at the start of the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal fill rate and continues to cycle within a normal range throughout the EPS. The Frenchtown Road Tank is refilling during the course of the fire flow scenario however at the start of the fire flow it starts to drop and during the course of the 2 hour period drops a total of 1.5 feet from 331 to 329.5 feet. At the end of the fire flow the tank begins to refill to an elevation of 331.5 feet 4 hours after the end of the fire flow and cycles within a normal range throughout the EPS. Both tanks operate at sufficient levels throughout the EPS. The Wakefield Street Tank is "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

J-7879 – located on Fairview Avenue along a 16" AC water main, elevation of 255 feet. This tank is "locked up" during the span of the EPS and does not provide fire flow to this junction node. Upon reviewing the model results, it would appear that the Setian Lane and Frenchtown Road tanks are affected by this fire flow. Setian Lane is slightly filling at the start of the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal fill rate and continues to cycle within a normal range throughout the EPS. The Frenchtown Road Tank is refilling during the course of the fire flow scenario however at the start of the fire flow it starts to drop and during the course of the 2 hour period drops a total of 1.5 feet from 331 to 329.5 feet. At the end of the fire flow the tank begins to refill to an elevation of 331.5 feet 4 hours after the end of the fire flow and cycles within a normal range throughout the EPS. Both tanks operate at sufficient levels throughout the EPS. The Wakefield Street Tank is "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

5.2 Maximum Day - Extended Period Simulations With Fire Flow

5.2.1 High Service Gradient

The High Service Gradient contains three (3) storage tanks. A total of six (6) junction nodes were evaluated within this pressure zone as follows.

Read School House Road Tank:

J-7154 – located on Flat River Road along a 12" AC water main, elevation of 254 feet. The EPS model results indicate that at the start of the fire flow the tank is draining and drops a total of 2.5 feet from 499 to 496.5 feet during the course of the fire flow. At the end of the fire flow the tank continues to drain 0.5 feet to an elevation of 496 feet during a 1 hour period and then begins to refill to an elevation of 499 feet (1 foot below overflow). The tank then resumes its normal cycle. The Carr Pond Tank is refilling at the start of the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal fill rate and continues to cycle within a normal range throughout the EPS. The Technology Park Tank is draining during the course of the fire flow and at the start of the fire flow drops 0.5 feet from 496 to 495.5 feet. At the end of the fire flow it slowly begins to refill and recovers to an elevation of 495.7 feet 2 hours after the fire flow has ended. These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude during a maximum day demand scenario including if it begins at the low end of the normal pump cycle elevation.

J-7258 – located on Hunters Crossing Drive along a 16" DI water main, elevation of 343 feet. The EPS model results indicate that at the start of the fire flow the tank is draining and drops a total of 2.5 feet from 499 to 496.5 feet during the course of the fire flow. At the end of the fire flow the tank continues to drain approximately 0.3 feet during a 1 hour period and then begins to refill to an elevation of 499 feet (1 foot below overflow). The tank then resumes its normal cycle. The Carr Pond Tank is refilling at the start of the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal fill rate. The Technology Park Tank is draining during the course of the fire flow and at the start of the fire flow drops approximately 0.5 feet from 496 to 495.5 feet. At the end of the fire flow it begins to refill and recovers to an elevation of 495.7 feet 2 hours after the fire flow has ended. These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude during a maximum day demand scenario including if it begins at the low end of the normal pump cycle elevation.

Carr Pond Road Tank:

J-4117 – located on Middle Road along a 16" DI water main, elevation of 300 feet. The EPS model results indicate that at the start of the fire flow the tank is in refill mode. The fire flow has the effect of dropping the tank level a total of approximately 5 feet during the two-hour period. At the end of the fire flow the tank begins to recover and stabilizes at an elevation of approximately 491 feet (9 feet below overflow). The Technology Park Tank is draining during the start of the fire flow and continues to drain approximately 0.5 feet during the two-hour period. This tank continues to drain for an additional hour to an elevation of approximately 495 feet (5 feet below overflow) and then begins to refill. The Read School House Road Tank is draining at the start of the fire flow. The fire flow has the effect of increasing the rate that the tank is draining. At the end of the fire flow the tank resumes its normal rate of draining and begins to recover to an elevation of 499 feet (1 foot below overflow). These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

J-4056 – located on Frenchtown Road along a 12" DI water main, elevation of 246 feet. The EPS model results indicate that at the start of the fire flow the tank is draining. The fire flow has the effect of dropping the tank level a total of approximately 5 feet during the two-hour period. At the end of the fire flow the tank begins to recover and stabilizes at an elevation of approximately 491 feet (9 feet below overflow). The Technology Park Tank is draining during the start of the fire flow and continues to drain approximately 0.5 feet during the two-hour period. This tank continues to drain for an additional hour to an elevation of approximately 495 feet (5 feet below overflow) and then begins to refill. The Read School House Road Tank is draining at the start of the fire flow. The fire flow has the effect of increasing the rate that the tank is draining. At the end of the fire flow the tank resumes its normal rate of draining and begins to recover to an elevation of 499 feet (1 foot below overflow). These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

Technology Park Tank:

J-8145 – located on Hopkins Hill Road along a 12" DI water main, elevation of 316 feet. The EPS model results indicate that at the start of the fire flow the tank is refilling and then drops a total of 4 feet from approximately 496 to 492 feet during the span of the fire flow. At the end of the fire flow the tank begins to recover and stabilizes at an elevation of approximately 494.5 feet (5.5 feet below overflow). The Read School House Road Tank is draining at the start of the fire flow. The fire flow has the effect of increasing the rate that the tank is draining. At the end of the fire flow the tank resumes its normal rate of draining and begins to recover to an elevation of 499 feet (1 foot below overflow). The Carr Pond Tank is refilling at the start of the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal fill rate and continues to cycle within a normal range throughout the EPS. These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

J-951 – located on Lonsdale Street along a 12" AC water main, elevation of 298 feet. The EPS model results indicate that at the start of the fire flow the tank is refilling and then drops a total of 2 feet from approximately 496 to 494 feet during the span of the fire flow. At the end of the fire flow the tank begins to recover and stabilizes at elevation 496.4 feet (3.6 feet below overflow). The Read School House Road Tank is draining at the start of the fire flow. The fire flow has the effect of increasing the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal fill rate and continues to cycle within a normal range throughout the EPS. The Carr Pond Tank is refilling at the start of the fire flow and then continues to drain approximately 2 feet during the two-hour fire flow period. This tank then begins to refill and stabilizes over the next 4 hours at elevation 493.5 feet (6.5 feet below overflow). These tanks have adequate fire reserve capacity to accommodate a fire flow rate of this magnitude including if it were to begin at the low end of the normal pump cycle elevation.

5.2.2 Low Service Gradient

The Low Service Gradient includes four (4) storage tanks. A total of eight (8) junctions nodes were evaluated including two (2) junction nodes in proximity to each storage tank.

Wakefield Street Tank:

J-727 – located on River Farms Drive along a 12" PVC water main, elevation of 190 feet. The model results indicate that the Wakefield Street Tank is "locked up" during the 24-hour span of the EPS. The only tanks that are apparently affected by the fire flow are Setian Lane and Frenchtown Road. Setian

Lane is refilling at the start of the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal fill rate and begins to recover and stabilizes at an elevation of 331 feet (3 feet below overflow). The Frenchtown Road Tank is filling during the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal refill rate. The West Street Tank remains "locked up" throughout the span of the fire flow EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

J-769 – located on Main Street along a 20" DI water main, elevation of 92 feet. The model results indicate that the Wakefield Street Tank is "locked up" during the 24-hour span of the EPS. The only tanks that are apparently affected by the fire flow are Setian Lane and Frenchtown Road. Setian Lane is refilling at the start of the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal fill rate and stabilizes at an elevation of 331 feet (3 feet below overflow). The Frenchtown Road Tank is filling during the fire flow. The effect of the fire flow is to decrease the rate of refill during the two-hour period. At the end of the fire flow the tank resumes its normal refill rate. The West Street Tank remains "locked up" throughout the span of the fire flow EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

Frenchtown Road Tank:

J-4091 – located on Frenchtown Road along a 20" AC water main, elevation of 247 feet. The model results indicate that the Frenchtown Road Tank is refilling at the start of the fire flow and then drops a total of 6 feet from 325 to 319 feet during the span of the fire flow. The tank recovers over the next 2-hour period after the fire flow to elevation 326 feet and continues to cycle within a normal range throughout the EPS. The Setian Lane Tank is refilling during the course of the fire flow scenario although at a decreased rate during the 2-hour fire flow period. Both tanks operate at sufficient levels throughout the EPS. The West Street Tank and Wakefield Street Tank are "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

J-4175 – located on South County Trail along a 12" AC water main, elevation of 109 feet. The model results indicate that the Frenchtown Road Tank is refilling at the start of the fire flow and then drops a total of 5 feet from 325 to 320 feet during the span of the fire flow. The tank recovers over the next 2-hour period after the fire flow to elevation 326 feet and then stabilizes and continues to refill throughout the EPS. The Setian Lane Tank is refilling during the course of the fire flow scenario although at a decreased rate during the 2-hour fire flow period. Both tanks operate at sufficient levels throughout the EPS. The West Street Tank and Wakefield Street Tank are "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

Setian Lane Tank:

J-390 – located on Cowesett Road along a 12" AC water main, elevation of 205 feet. The model results indicate that the Setian Lane Tank is refilling at the start of the fire flow and then drops a total of approximately 0.5 feet from 329.8 to 329.3 feet during the span of the fire flow. The tank recovers over the next 2-hour period after the fire flow to elevation 330.5 feet and continues to cycle within a normal range throughout the EPS. The Frenchtown Road Tank is refilling during the course of the fire flow scenario although at a decreased rate during the 2-hour fire flow period. At the end of the fire flow it continues to refill to an elevation of 330 feet and cycles within a normal range throughout the EPS. Both tanks operate at sufficient levels throughout the EPS. The West Street Tank and Wakefield Street Tank are "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

J-2005 – located on Centerville Road along a 12" AC water main, elevation of 100 feet. The model results indicate that the Setian Lane Tank is slowly refilling at the start of the fire flow and then drops a total of 0.4 feet from 329.8 to 329.4 feet during the span of the fire flow. The tank recovers over the next 2-hour period after the fire flow to elevation 331 feet and continues to cycle within a normal range throughout the EPS. The Frenchtown Road Tank is refilling during the course of the fire flow scenario although at a decreased rate during the 2-hour fire flow period. At the end of the fire flow it continues to refill to elevation 329.5 feet and cycles within a normal range throughout the EPS. Both tanks operate at sufficient levels throughout the EPS. The West Street Tank and Wakefield Street Tank are "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

West Street Tank:

J-626 – located on West Street along a 16" AC water main, elevation of 245 feet. This tank is "locked up" during the span of the EPS and does not provide fire flow to this junction node. Upon reviewing the model results, it would appear that the Setian Lane and Frenchtown Road tanks are affected by this fire flow. Setian Lane is slightly filling at the start of the fire flow and continues to fill at a decreased rate during the 2-hour fire flow period. At the end of the fire flow the tank continues to refill to an elevation of 331 feet and continues to cycle within a normal range throughout the EPS. The Frenchtown Road Tank is refilling during the course of the fire flow scenario although at a decreased rate during the 2-hour fire flow period. At the end of the fire flow it continues to refill to an elevation of 330.5 feet and cycles within a normal range throughout the EPS. Both tanks operate at sufficient levels throughout the EPS. The Wakefield Street Tank is "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

J-7879 – located on Fairview Avenue along a 16" AC water main, elevation of 255 feet. This tank is "locked up" during the span of the EPS and does not provide fire flow to this junction node. Upon reviewing the model results, it would appear that the Setian Lane and Frenchtown Road tanks are affected by this fire flow. Setian Lane is slightly filling at the start of the fire flow and continues to fill at a decreased rate during the 2-hour fire flow period. At the end of the fire flow the tank continues to refill to an elevation of 331 feet and continues to cycle within a normal range throughout the EPS. The Frenchtown Road Tank is refilling during the course of the fire flow scenario although at a decreased rate during the 2-hour fire flow period. At the end of the fire flow it continues to refill to an elevation of 330.5 feet and cycles within a normal range throughout the EPS. Both tanks operate at sufficient levels throughout the EPS. The Wakefield Street Tank is "locked up" throughout the span of the EPS. The Low Service tanks possess adequate fire reserve capacity to accommodate a fire flow rate of this magnitude.

6.0 Summary, Conclusions and Recommendations

6.1 Summary

- Projected consumer demands for the project-planning period (2025) of the Authority's service territory have been categorized for each of the major pressure zones as depicted in the following tables.

LOW SERVICE GRADIENT (334') FUTURE (20 YEAR) CONSUMER DEMANDS

PRESSURE ZONE	AVERAGE DAY DEMAND (MGD)	MAXIMUM DAY DEMAND (MGD)	PEAK HOUR DEMAND (MGD)
Low Service (334') Gradient	6.357	12.055	13.950
Low Service Reduced (334') Gradient	2.246	4.474	5.187
Hope Road (510') Gradient	0.007	0.014	0.016
TOTALS	**8.61 MGD**	**16.54 MGD**	**19.15 MGD**

HIGH SERVICE GRADIENT (500') FUTURE (20 YEAR) CONSUMER DEMANDS

PRESSURE ZONE	AVERAGE DAY DEMAND (MGD)	MAXIMUM DAY DEMAND (MGD)	PEAK HOUR DEMAND (MGD)
High Service (500') Gradient*	3.668	6.951	9.031
High Service (500') Reduced Gradient	0.679	1.331	1.636
TOTALS	**4.35 MGD**	**8.28 MGD**	**10.67 MGD**

* Includes consumer demands from the Read School House Road Gradient and former Tiogue Tank Gradient.

- For purposes of this storage capacity evaluation, the Oaklawn Pressure Gradient (232') was not considered as this Gradient is supplied directly through a wholesale interconnection with Providence Water. Further there are no water storage facilities in this portion of the system. This area of the Authority's service system is supplied directly from the Providence Water system and relies on the storage facilities in the Providence System to supply peak, fire and emergency demands.

  The Authority should give consideration to providing a backup or emergency connection from the existing Low Service Gradient portion of the water system to service this area in the event of an emergency on the Providence Water system. This would require the addition of a PRV station in order to reduce the hydraulic grade from 334 feet. Additionally, the Authority could also consider investigating options to service this portion of the distribution system on a full time basis either in part or in whole from the existing Low Service Gradient.

- The storage tank facilities in each of the major pressure zones were evaluated with regard to various components of storage and volume totals were developed for components for each tank facility. The storage volume component assessment was based on maintaining a water elevation in each storage tank that would supply a minimum pressure of 35 psi (Authority Standard for new service connections) at the highest customer service elevation and a minimum pressure of 20 psi (AWWA and NFPA standard) for fire flow and emergency storage. This was also premised on maintaining adequate storage volumes in the storage tank facilities that would ensure sufficient capacity to meet normal daily (operational storage) and peak system demands (equalization storage). The maximum customer serviceable elevations were determined as follows.

MAXIMUM CUSTOMER SERVICEABLE ELEVATION BY PRESSURE GRADIENT

PRESSURE ZONE	35 PSI SERVICE ELEVATION	TANK(S) OVERFLOW ELEVATION
Low Service (334') Gradient[1]	244 feet	334 feet
High Service (500') Gradient[2]	405 feet	500 feet

[1] Includes Low Service Reduced Gradient and Hope Road Gradient
[2] Includes Read School House Road Gradient, High Service Reduced Gradient and Tiogue Tank Service area

There currently exist customer services within these pressure gradients, which are above these elevations and experience pressures below 35 psi. These locations predate the requirements of the current Authority regulations, which now require that for new services at the point of connection a minimum of 35 psi must be available under an average day condition and that a minimum of 20 psi be available under any system flow condition. The Authority's long-term goal is to seek to increase the pressures at these locations either through re-servicing or other means.

It is also noted that there are locations in the distribution system that have low pressures which are not supplying customer services and generally do not require correction. These could occur at high points along transmission mains with no customer services, areas around storage reservoirs, suction side of booster pump stations and the downstream side of PRV stations. These locations are identified in the following table and are graphically depicted on a system map in Enclosure No. 1.

LOCATIONS IN SYSTEM WITH PRESSURES BELOW 20 PSI

SERVICE PRESSURE ZONE	STREET	LOCATION/APPROXIMATE INTERSECTION	ELEVATION RANGE (FEET)	CALCULATED PRESSURE	CUSTOMER SERVICES (Y/N)	SITE
Low	Cowesett Road	Kulas Road to Fairgreen Drive	206 - 280	19 psi	Y	1
Low	South County Trail *	EG Medical Center to Pine Glen Drive	249 - 303	12 psi – 34 psi	Y	2

Low	Signal Ridge Way	Boulder Way to Division Street	270 - 290	18 psi – 27 psi	Y	3
Low	Lane A	Morningside Drive to Lane E	250 - 294	18 psi – 31 psi	Y	4
Low	Tiogue Avenue *	Jennifer Lane to Holloway Avenue	264 - 301	12 psi – 28 psi	Y	5
Low	Knotty Oak Road	Maple Street to Long Pond Road	273 - 302	14 psi – 34 psi	N	6
Low	Knotty Oak Road	White Rock Drive to Highwood Drive	279 - 315	9 psi – 24 psi	N	7
Low	Knotty Oak Road	Gervais Street to Oak Way	300	15 psi	N	8
Low	East Greenwich Avenue *	Juniper Drive to Setian Lane	259 - 295	16 psi – 32 psi	N	9

LOCATIONS IN SYSTEM WITH PRESSURES BELOW 35 PSI

SERVICE PRESSURE ZONE	STREET	LOCATION/APPROXIMATE INTERSECTION	ELEVATION RANGE (FEET)	CALCULATED PRESSURE	CUSTOMER SERVICES (Y/N)	SITE
Low	Cowesett Road	Church Street to Narragansett Avenue	235 - 260	28 psi – 34 psi	Y	10
Reduced Low	Windermere Way	Love Lane to Lantern Lane	180 - 205	27 psi – 34 psi	Y	11
Reduced Low	Love Lane*	Overhill Road to Cedar Street	204 - 205	27 psi – 29 psi	Y	12
Low	Major Potter Road*	Quaker Lane to Eagle Run	265	29 psi	N	13
Low	Division Street	Brooks Pharmacy Headquarters to Old Quaker Lane	243 - 275	24 psi	Y	14
Reduced Low	Mayflower Drive	Crest Ridge Drive to Bunker Hill Lane	170 - 201	29 psi – 34 psi	Y	15
Low	Frenchtown Road*	Cardinal Lane to High Hawk Road	266 - 276	29 psi	N	16
Low	Lynn Circle	Darl Court to Fernwood Drive	230 - 280	22 psi – 34 psi	Y	17
High	Carr Pond Road*	Carr Pond Tank to Deer Run Drive	410 - 430	28 psi – 33 psi	Y	18
Low	Greenbush Road	New London Turnpike to Bratt Lane	255 - 280	22 psi – 33 psi	N	19
Low	Arnold Road*	Larch Drive to Acorn Street	228 - 280	20 psi – 34 psi	Y	20
Low	Nooseneck Hill Road	Reservoir Road to Comfort Way	256 - 282	26 psi – 34 psi	Y	21
Low	Main Street (COV)	Battey Avenue to Sandy Bottom Road	234 - 255	34 psi	Y	22

Low	Laurel Avenue	Pilgrim Avenue to Princeton Avenue	228 - 267	28 psi – 34 psi	Y	23
Low	Hope Furnace Road	Howard Avenue to Colvintown Road	249 - 270	31 psi	Y	24
Low	North Road	White Lane to Blossom Lane	240 - 271	31 psi	Y	25
Low	Cranberry Drive	Mitchell Way to Kerri Court	240 - 276	29 psi	Y	26
Low	Blackrock Road*	Gervais Street to Country View Drive	250 - 270	28 psi	N	27
Low	Phenix Avenue	Harding Street to Garnet Street	245 - 273	26 psi – 33 psi	Y	28
Low	Fairview Avenue	Spencer Street to Marshall Circle	235 - 272	24 psi – 34 psi	Y	29
Low	New London Avenue	Factory Street to Iron Drive	231 - 261	27 psi – 33 psi	Y	30
Low	Macarthur Boulevard	Yates Avenue to Knight Street	245 - 273	25 psi – 30 psi	Y	31
Low	Beauchene Street	East Street to West Street	170	25 psi	Y	32
Low	River Run	Rosewood Court to Quail Court	249 - 260	29 psi – 32 psi	Y	33
Reduced High	Nooseneck Hill Road	Brant Trail to End of KCWA System	300 - 354	34 psi	Y	34
Low	Hornbeam Road	Mountain Laurel Drive to Hawthorne Road	250 - 260	33 psi	Y	35
Low	Hornbeam Road	Mountain Laurel Drive to Hawthorne Road	232 - 265	31 psi	Y	36
Low	Paddock Drive	Cowesett Road to Martingale Drive	230 - 243	33 psi	Y	37

* Denotes area of low pressure that consists of a transmission main, area near storage reservoir, or the suction side of a booster pump station.

- The operation of the Clinton Avenue Pump Station on a near continual basis creates operational difficulties with several storage tank facilities in the Low Service Pressure Gradient as previously identified in Technical Memorandum 4A (TM 4A). This predominately relates to the inability of these storage facilities to "turn over" which results in the routine condition of being "locked up" due to the pump head from the pump station that is above the overflow elevation of these tanks.

  It is also recognized that there is an inherent need to operate Clinton Avenue Pump Station which is primarily due to the necessity to maintain adequate pressures at higher customer service elevations; to provide upwards of 70% of water supply to the entire distribution system; the need to replenish distant water storage tanks in the Low Service Gradient; and to provide supply to booster pump stations and PRV stations that supply the High Service Gradient that rely on the Low Service Gradient as the primary source of supply. It is also a long term goal of the Authority to attempt to periodically shut down the Clinton Avenue Pump Station, as may be practical in the early morning hours, in order that the facility would operate in response to water tank levels during low demand periods. This will require correction of low-pressure areas that rely on the pump head from the station for adequate pressure.

- It was recommended in TM 4A that the Fiskeville Reservoirs in the Low Service Pressure Gradient be permanently removed from service as these storage facilities are maintained in a continued "locked up" condition due to their proximity (less than 1 mile) to the Clinton Avenue Pump Station. In addition, due to their location at the extreme northern end of the 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.

  These reservoir facilities predate the construction of the Clinton Avenue Pump Station and have become "obsolete" over the years as the distribution system and customer service base has grown and expanded. It is likely that the customer service area surrounding these reservoirs will be re-serviced from the High Service Pressure Gradient, which will assist in alleviating low pressures in this portion of the distribution system.

- TM 4A also identified the West Street and Wakefield Street Tanks as being routinely maintained in a "locked up" condition due to their proximity to the Clinton Avenue Pump Station. The following is a summary of each of these facilities and recommended course of action.

  - The West Street Tank was constructed in 1956 and was completely rehabilitated in 2002. As this facility remains in a constant "locked up" condition, it is not considered significant to the daily operation of the water system. It is however considered significant in terms of available fire and emergency storage due largely to its location within the distribution system that includes proximity to densely populated urban areas and mill complexes.

  - The Wakefield Street Tank was constructed in 1990 and is in overall good condition. This tank is beneficial in supplying daily peak system demands and fire and emergency storage. With the addition of new pipeline infrastructure associated with the Providence Water emergency connection, it is anticipated that this tank will remain in a "locked up" condition on a frequent basis. The new pipelines will increase the flow of water from Clinton Avenue Pump Station to the general area around this tank and while in operation the pump head from the Clinton Avenue will influence the tank.

  Due to the importance of these tank facilities, it is recommended that alternatives be considered to maintaining these facilities in operation while promoting tank cycling or turnover. Potential alternative methods include booster pump stations (West Street Tank) and valve stations to isolate the tank (Wakefield Street Tank). These alternative methods are to be further evaluated in the CIP.

- Based on these established customer service elevations, the volumes for the various storage components for each of the storage tanks were calculated. The various components of storage are summarized for each pressure zone as follows. Note that the Fiskeville Reservoirs are considered removed from service and are not included in the table.

SYSTEM STORAGE TANKS – TOTAL COMPONENT VOLUMES

PRESSURE GRADIENT	EFFECTIVE STORAGE (MG)	OPERATIONAL STORAGE (MG)	EQUALIZATION STORAGE (MG)	FIRE RESERVE & EMERGENCY STORAGE (MG)	"DEAD" STORAGE (MG)
Low Service (334') Gradient[1]	5.295	1.123	1.123	4.172	1.046
High Service (500') Gradient[2]	3.948	0.650	1.370	2.773	1.171

[1] Includes Low Service Reduced Gradient and Hope Road Gradient
[2] Includes Read School House Road Gradient, High Service Reduced Gradient and Tiogue Tank Service area

- Historical tank charts indicate that the Authority is capable of maintaining a water level in each of the distribution storage tanks within the ranges as indicated for maintaining an adequate consumer system pressure of 35 psi and a fire flow pressure of 20 psi for the serviceable elevations in each pressure zone. Reference Figures 2 – 8, which graphically portray the various components of storage for each tank facility.

- The measure of the adequacy of the equalization storage component (i.e. volume in tank dedicated to meeting peak demands that are in excess of the supply capacity) was premised on maintaining 25 percent of the projected average day demand. This ratio is a general water works standard that also needs to be combined with additional evaluation such as extended period hydraulic modeling and review of tank charts to ensure that the storage tanks fill and drain at acceptable rates and maintain adequate water elevations under all demand conditions.

  In other words, having a ratio of 25 percent water volume of average day demand in equalization storage does not in of itself ensure that a particular storage facility is of sufficient size, capacity or location in the distribution system. Similarly, not having a ratio of 25 percent water volume of average day demand in equalization storage does not necessarily indicate that a particular tank is insufficient in size, capacity or location in the distribution system.

- An assessment of the equalization storage volumes from each of the storage facilities in the major pressure zones was performed. The Low Service Gradient tanks' total equalization volume (without the Fiskeville Reservoirs) provides a ratio of 13 percent of the average day demand while the High Service Gradient tanks provide 31 percent. In terms of the water works standard, the High Service Gradient has in excess of the ratio of 25 percent storage capacity of equalization storage while the Low Service Gradient in terms of this standard is considered deficient in that the storage tanks supply a ratio of 13 of the recommended 25 percent standard.

- Extended period model simulations for projected average and maximum day (with peak hour demand) indicate that all of the distribution system storage tanks operate within a range that has been defined for operational and equalization storage capacity. Equalization storage is primarily drawn upon when the demands exceed the supply capacity of the water system. For all scenarios there were no instances under which the dedicated volume for fire and emergency storage protection was depleted.

It is concluded that the Low Service Gradient storage tanks, while only providing a ratio of 13 percent of the recommended 25 percent volume of average day demand in equalization storage, are not adversely affected in this regard. This is primarily the result of the near continuous operation of the Clinton Avenue Pump Station, which provides sufficient water supply capacity during peak demand conditions such that storage facilities are not over taxed.

- Each of the system's storage tanks (excluding the Fiskeville Reservoirs) are determined to have adequate water volume for fire reserve at an elevation such that a 20 psi minimum is maintained for a fire flow rate of 3,500 gpm for a duration of three hours which equates to a total volume of 630,000 gallons.

- Although there is no standard or regulation that indicates that water storage facilities should "turn over" the water volume on a periodic basis, it is generally recognized within the water works industry that this should occur at regular intervals to promote "good" water quality. This practice, which is improved by internal tank mixing, will assist in maintaining water quality and avoid potential water quality issues such as chlorine decay, adverse color, odor, and taste. At a minimum, it is recommended that each storage tank turn over its volume on a weekly basis during low demand periods (i.e. winter months).

The frequency of turn over for a particular storage facility will be primarily dependant upon seasonal factors and is such that during periods of increased demand will result in a greater drawdown in the storage facility(s) to meet these peak demand periods. During periods of low or average demand the volume and frequency of water that is entering and leaving a storage facility is diminished and turn over rates are increased. Other factors such as stratification, common inlet / outlet, "dead" zones, poor circulation and low demand periods all contribute to poor efficiency in tank turn over.

Model simulations indicate that each of the storage facilities in the Authority's system (with exception of West Street and Wakefield Street tanks) routinely drain and refill at a rate such that the total nominal volume of the tank during a low demand period (Average Day) is turned over in a 1 to 2 week period. For example, the Setian Lane Reservoir fills and drains at a rate during low demand periods such that an excess of 3 million gallons enters and exits the tank in a period of 6 days and 3 days under a maximum day demand period. The West Street and Wakefield Street tanks, which are routinely locked up, do not turn over on a routine basis and as previously indicated require an investigation into alternatives to cycle these tanks.

STORAGE FACILITY "TURN-OVER" RATES

FACILITY	CAPACITY (MG)	AVERAGE DAY VOLUME CHANGE (GAL)	# OF DAYS TO "TURN-OVER" AVERAGE DAY	MAXIMUM DAY VOLUME CHANGE (GAL)	# OF DAYS TO "TURN-OVER" MAXIMUM DAY
Technology Park Tank	1.5	165,000	9	333,000	5
Carr Pond Tank	3.0	219,600	14	219,600	14
Read School House Road Tank	1.5	150,000	10	522,000	3
Wakefield Street Tank*	-	-	-	-	-

Frenchtown Road Tank	1.5	267,000	6	414,000	4
West Street Tank*	-	-	-	-	-
Setian Lane Tank	3.0	480,000	6	1,080,000	3

*Tank is in a "locked up" condition during average day and maximum day demand scenarios.

- The combination of all storage facilities in the distribution system provides a total emergency storage volume of 2.57 MGD, which is approximately 20% of the overall average day system demand of 12.96 MGD. This is premised on maintaining a fire flow volume of 630,000 gallons within each of the storage facilities and does not include any "dead" storage, which would not be available to the system at a minimum of 20 psi.

  The volume of emergency storage that any water system would maintain is typically a function of the perceived "emergency". A general rule is that a water system without an adequate redundant source of supply should maintain a minimum of one-day volume of average day demand as emergency storage. Water systems with adequate backup or redundant sources of supply often maintain considerably less volume for emergency storage. The premise is that during an emergency such as loss of the main supply source it is more advantageous to maintain additional supply sources that can be used for an indefinite period of time rather than a discrete storage volume, which would be readily consumed.

  The Authority relies upon its primary interconnection with Providence Water at the Clinton Avenue Pump Station to supply the majority (upwards of 70 percent) of water supply to the system. Disruption of this supply interconnection would severely hamper the overall supply capability to the water system. There are however alternate existing sources of supply available to the Authority, which could be relied upon to provide water supply to the system in an emergency situation with the assumption that water use restrictions would be put into place. These sources include well facilities (East Greenwich, Spring Lake and Mishnock) and the Quaker Lane Pump Station (wholesale supply from Warwick Water) and which collectively have the ability to meet system average day demand.

  It is therefore considered that the Authority has emergency supply source capability, which has a greater value on a day-to-day basis for emergency use rather than a separate and defined volume of water in storage tanks, which would be readily depleted in an emergency. It is therefore considered that the Authority has a greater benefit in redundant supply sources than any available emergency storage in the tanks and that the 20 percent volume of emergency storage to average day demand is sufficient.

6.2 Conclusions

This evaluation has determined that the existing water storage facilities provide adequate volumes to meet projected future consumer demands including average day, maximum day, maximum day peak hour and fire flows. This is premised on the ability of each of the storage tanks to collectively meet varying consumer demands while maintaining sufficient capacity for the various defined components of storage (i.e. equalization storage, operational storage, etc.). Further, hydraulic model analysis of the storage facilities demonstrates that the individual tanks are able to operate within their operational and equalization storage ranges such that no erosion of fire reserve and emergency storage occurs. The hydraulic model simulations also indicate that the water system transmission and distribution mains can effectively transfer flows to and from the storage facilities and the supply sources that supply these facilities throughout the distribution system. Note, this does not suggest that all locations within the distribution system maintain adequate flows and pressures.

As previously indicated, areas in the distribution system with high customer service elevations and areas with older and small diameter pipe sections routinely experience pressure and flow problems. These localized areas throughout the water distribution system are primarily located within the Low Service Gradient where older and/or undersized water mains cannot adequately convey sufficient fire flow rates. These locations have been identified graphically on a system wide map in TM 4B. Additionally, localized areas of high customer service elevations will continue to experience pressure problems (i.e. below 35 psi) until these locations are further evaluated and re-serviced. These locations were previously identified by geographic area in tables and graphically on a system wide map in Enclosure 1.

A significant number of these identified low-pressure areas are not deemed to be problematic. These include areas immediately surrounding ground storage tanks, on the suction side of booster pump stations, along transmission mains and on the downstream side of PRV stations. Generally, these areas should contain no new customer services and those that exist will be evaluated for re-servicing.

The projected future average day system demands are projected to increase from the current 10.61 MGD to 12.96 MGD or 22 percent. The Low Service Pressure Gradient portion of the system is projected to increase from 7.27 MGD to 8.61 MGD or 18 percent. The High Service Pressure Gradient portion of the system is projected to increase from 3.34 MGD to 4.35 MGD or 30 percent. Without the addition of additional storage facilities, this projected increase in consumer demand will reduce the ratio of equalization storage to average day demand on a system-wide basis. The Low Service Pressure Gradient is primarily impacted as the ratio is decreased from 15 to 13 percent and which considers that the Fiskeville Reservoirs are permanently removed from service. The High Service Pressure Gradient, through the benefit of combination with the Read School House Road Gradient, actually increases the overall ratio from 26 to 31 percent of equalization storage to projected average day demand.

Even though the Low Service Pressure Gradient storage facilities do not maintain the standard 25 percent ratio of equalization storage to average day demand, the hydraulic model simulations have indicated that the storage facilities are able to sufficiently meet future projected demands. The storage facilities have sufficient volume of operational and equalization storage such that no erosion of fire and emergency reserve capacity occurs. The model simulations also support that the storage facilities within the High Service Pressure Gradient in addition to providing an adequate volume based on general water works standards are capable of meeting all future system demands without erosion of fire and emergency reserve capacity.

It is noted that two of the storage tanks in the Low Service Gradient, West Street and Wakefield Street, currently and will continue to have problems related to turn over, as they are maintained in a locked up condition. This is due to the need to maintain the Clinton Avenue Pump Station in near continuous operation for overall system supply purposes and the need to maintain pressures at higher elevations through pump head. These tanks will require further assessment such that they can be circulated on a routine basis. This may include pumping back into the system during off peak demand periods or selective isolation within the distribution system such that the influence of Clinton Avenue Pump Station on these tanks is diminished. Further consideration for options to circulate these tanks will be performed in the Authority's updated CIP.

6.3 Recommendations

High Service Pressure Gradient

The redefined High Service Pressure Gradient, which includes the combined High Service Pressure Gradient and the Read School House Road Pressure Gradient, has been determined to have adequate storage capacity including operational, equalization, fire and emergency storage components to meet future consumer demands. Further, the configuration of the existing tanks (i.e. overflow elevation, nominal capacity, height, diameter and volume per foot) is such that each storage facility is effective in functioning within the

Gradient. The storage tanks drain and fill in combination during normal and peak demand periods and operate such that no one tank drains excessively or remains in a "locked up" condition.

This was evidenced through steady state and extended period hydraulic model analysis for projected average and maximum day demands as well as fire flow conditions. In addition, the High Service Pressure Gradient also maintains a ratio of equalization storage to average day demand of 31 percent, which is above the recommended water works guideline of 25 percent. On this basis, it is not recommended that additional storage capacity be provided in the High Service Pressure Gradient at this time. It is recommended that each of the three storage facilities in the High Service Pressure Gradient be routinely monitored to ensure that daily operation and fluctuation in the tanks (including periods of peak demands) are consistent with the levels for the various storage components as described herein.

Low Service Pressure Gradient

The Low Service Pressure Gradient has been determined to have adequate storage including operational, equalization, fire and emergency storage components to meet future consumer demands. It is noted that the determination for adequacy of the storage tank volumes was premised upon the operation mode of the Clinton Avenue Pump Station, which runs in a near continuous mode of operation. The operational mode of this pump station facility, which is largely operated in response to consumer system demands (i.e. increased number of pumps are placed on line during heavy demands periods and when storage tanks are draining), serves to maintain the water level in the storage tanks during increased consumer demand periods. As such, the storage tanks are not heavily relied upon to supply water demands during periods of peak consumer demand and there is no corresponding rapid depletion in water levels in the storage tanks.

As previously indicated the mode of operation of this pump station creates difficulties with normal operation of several storage tanks in the Low Service Pressure Gradient that are in close proximity to this pump station. This primarily included the Fiskeville, West Street and Wakefield Street storage facilities. TM 4A advised that the Fiskeville Reservoirs be removed from operational service due to the fact that they remain in a continuous "locked up" condition during all times when the Clinton Avenue Pump Station is in operation. In addition, the West Street and Wakefield Street tanks remain in a continued "locked up" condition due to the pump head from the pump station, which is greater than the overflow elevation of these tanks. It was advised that alternatives be investigated to promote cycling of these particular tank facilities, which could include off peak pumping into the distribution system and isolation valve stations. These tanks also afford a certain level of fire storage protection in the general area in which they are located and are considered critical in that regard.

The configuration of the remaining Low Service Pressure Gradient tanks which includes the Setian Lane reservoir and Frenchtown Road tank have been determined to have adequate storage volumes including operational, equalization, fire and emergency storage components to meet future consumer demands. Further, the configuration of these tanks (i.e. overflow elevation, nominal capacity, height, diameter and volume per foot) is such that each is effective in operating within the Gradient. These two facilities drain and fill in close combination during normal and peak demand periods and are such that no one tank drains excessively or remains in a "locked up" condition.

The operational effectiveness of the Low Service Pressure Gradient storage tanks was evidenced through steady state and extended period hydraulic model analysis for projected average and maximum day demands as well as fire flow. Further, the Low Service Pressure Gradient maintains a ratio of equalization storage to average day demand of 13 percent, which is below the recommenced water works guideline of 25 percent. An approach, which involves increasing the total storage volume in this Gradient to achieve the 25 percent ratio, could be considered a reasonable course of action however other factors also need to be considered.

The existing storage tanks in this Gradient have a demonstrated ability to effectively meet future peak demands. This in large part is due to the continuous operation of the Clinton Avenue Pump Station, which also creates difficulty with cycling of several of the closer storage tanks (West Street and Wakefield Street). Adding additional storage capacity must be performed in combination with assessment of the location and affect of the Clinton Avenue pump station on any new tank facility. Any new storage facility must contribute to overall system operations, must fill and drain at rates conducive to cycling, provide benefit to a specific portion of the system and not adversely affect the fill and drain rates of existing storage tanks in the Gradient.

Mishnock Well Field Expansion and Distribution Storage

The Authority has an ongoing capital improvement project, which includes development of groundwater sources at the existing Mishnock well fields for added source of supply. This project also includes the construction of a new water treatment plant (to treat the raw water from the well fields) and the addition of distribution system storage. The well fields are located in the southwestern portion of the distribution system opposite the primary sources of supply of the Clinton Avenue Pump Station to the north and Bald Hill Pump Station to the east. The water treatment plant is to be located in proximity to the well field and new transmission mains are to be installed to supply the distribution system storage tank which is to be located near the intersection of Mishnock and Hopkins Hill Road. These facilities are scheduled to be in service by 2010.

The new treatment facility for the Mishnock well fields will provide multiple benefits to the Authority's system. This includes reducing reliance on wholesale water purchase from Providence Water and Warwick Water (indirectly from Providence Water), providing a redundant source of supply during an emergency and providing an additional source of supply located in the southern and western portions of the distribution system.

The intent of the new treatment facility at the Mishnock well field is to optimize the withdrawal of groundwater resources in this area. The new distribution storage facility will also provide the ability to supply finished water to either the Low or High Service Pressure Gradients. This will be coupled with the installation of new transmission water mains from the well field and treatment plant along Nooseneck Hill and Mishnock Roads to the proposed location of the new storage facility at the approximate intersection of Mishnock and Hopkins Hill Road. Additional transmission water mains are to be installed to connect the storage tank to the Low and High Service Pressure Gradients.

In constructing the water treatment facility, it will be necessary to provide for clear well storage and/or distribution system storage in order to prevent the treatment plant filters from having to meet fluctuations in water demand. In addition, it may be required that a disinfectant (chlorine) contact time be provided with treatment plant storage and that a sufficient volume of backwash water for the filters be provided. Consideration should be given to evaluating the combination of clear well and distribution system volume storage at the treatment plant to meet these needs as well as supplying additional distribution system storage volume and fire flow protection.

The advantages of providing additional distribution storage associated with the Mishnock Well Field Treatment Plant project are as follows:

- Additional distribution system storage will provide for greater usable storage volume to the distribution system and the location in the system is such that routine cycling of the tank could be accomplished. Due to its location in the system, the effect of Clinton Avenue Pump Station is not likely to adversely affect this tank (i.e. "lock up" the tank).
- This new source coupled with storage will reduce the Authority's dependence on wholesale supply connections and provide for a redundant source of supply in the event of emergencies.

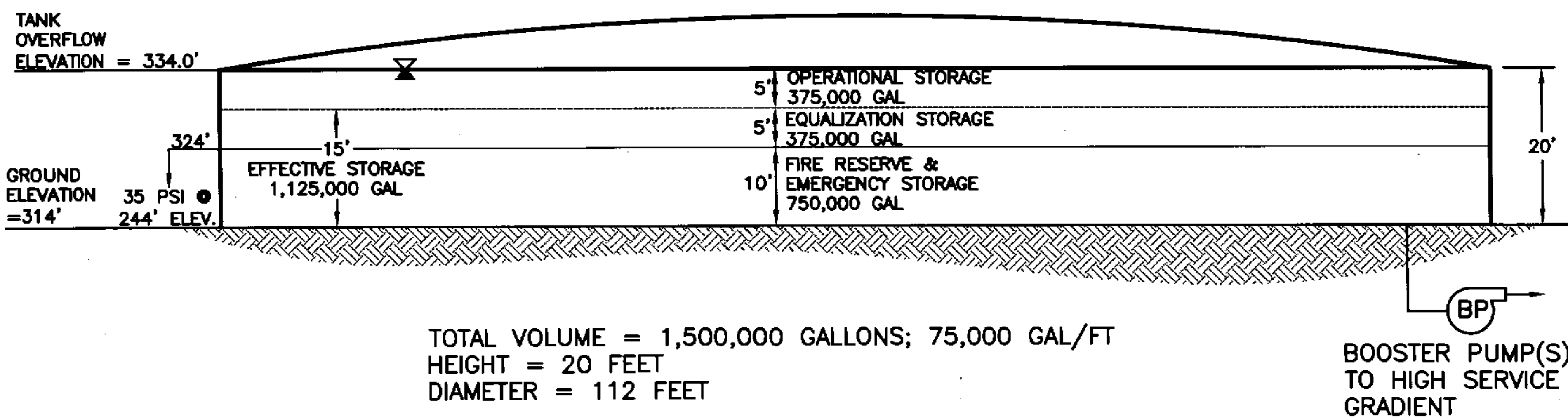
- The Authority owns or controls the land rights at these locations and would not require additional land procurement.
- The ground elevation at the site of the storage tank site is in the range of 300 feet and will permit the construction of a ground storage reservoir with overflow elevation equal to that of the Low Service Pressure Gradient at 334 feet.
- The construction of a ground storage reservoir is more economical than an equal size elevated storage tank.
- The proximity of the distribution storage tank is such that the water volume may be utilized for both the Low and High Service Pressure Gradients. Finished water can be supplied by gravity to the Low Service Pressure Gradient and pumped into the High Service Pressure Gradient.
- The addition of distribution system storage at this location in the Low Service Pressure Gradient will stabilize distribution system pressures across the Gradient and in localized areas during periods of peak consumer demand.
- This storage facility will assist in resolving the ongoing problem of marginal system pressures on the suction side of the Johnson Boulevard Booster Pump Station.
- This storage facility would be located within an area of the distribution system where future growth is most likely to occur.
- This storage facility will ease the demand pressure on the Frenchtown Road tank located to the south and east, which reportedly can be "stressed" in the summer months due to the increase in consumer irrigation demands.

The hydraulic model was updated to include the Mishnock project and included: new groundwater sources and treatment plant with total capacity of 2.5 MGD; supply pumps at the treatment plant rated at 1.25 MGD each; new 16 inch transmission main to connect the treatment plant to the distribution system storage tank; 1.5 MG storage reservoir at the intersection of Mishnock and Hopkins Hill Road; 20 inch transmission mains along Hopkins Hill Road to tie in the Low Service Pressure Gradient; 1.0 MG booster pump station at reservoir to the High Service Pressure Gradient.

The 1.5 MG storage reservoir was modeled to have an overflow elevation of 334 feet with a base ground elevation of 314 feet. The height is equal to 20 feet with a diameter of 112 feet and capacity of 75,000 gallons per foot. Figure 9 contains a schematic of the storage tank and corresponding components of storage (operational, equalization, fire reserve and emergency). These calculated volumes were premised upon customer service elevations that were previously established for the Low Service Pressure Gradient. These include a water elevation of 324 feet which equates to a maximum customer service elevation of 244 feet in order to achieve 35 psi at the point of connection to the system and a water elevation of 290 feet which equates to a minimum pressure of 20 psi for fire flow conditions at the maximum customer service elevation of 244 feet. Customer service elevations for the High Service Pressure Gradient were not considered critical in that water would be boosted from the tank into the Gradient. Dimensions for the reservoir would necessarily be confirmed during preliminary and final design stages of the project.

The following table includes a summary of the various storage components for each of the Low Service Gradient storage tanks with the new Mishnock reservoir.

LOW SERVICE GRADIENT (334')–GRAVITY
HIGH SERVICE GRADIENT (500')–PUMPED



TOTAL VOLUME = 1,500,000 GALLONS; 75,000 GAL/FT
HEIGHT = 20 FEET
DIAMETER = 112 FEET

1.5 MG MISHNOCK STORAGE RESERVOIR

N.T.S.

NOTE:

1. NO "DEAD" STORAGE AS ABLE TO ACHIEVE A MINIMUM 20 PSI HIGHEST SERVICE ELEVATION OF 244 FEET IN LOW SERVICE GRADIENT.

2. ENTIRE VOLUME OF RESERVOIR AVAILABLE FOR USE TO HIGH SERVICE PRESSURE GRADIENT THROUGH BOOSTER PUMP STATION.

FIGURE 9

Civil & Environmental Engineering Partners, Inc.
342 Park Avenue, Woonsocket, RI 02895

LOW SERVICE GRADIENT (334') FUTURE (20 YEAR) STORAGE VOLUMES WITH MISHNOCK RESERVOIR

FACILITY	EFFECTIVE STORAGE (MG)	OPERATIONAL STORAGE (MG)	EQUALIZATION STORAGE (MG)	FIRE RESERVE & EMERGENCY STORAGE (MG)	"DEAD" STORAGE (MG)
Wakefield Street Tank	1.115	0.143	0.143	0.972	0.701
Frenchtown Road Tank	1.170	0.150	0.150	1.020	0.165
Setian Lane Tank	2.250	0.750	0.750	1.500	0.0
West Street Tank	0.760	0.080	0.080	0.680	0.180
Mishnock Storage Reservoir	1.125	0.375	0.375	0.750	0.0
TOTALS	**6.420**	**1.498**	**1.498**	**4.922**	**1.046**

The total nominal storage capacity of all storage tanks in the Low Service Pressure Gradient is equal to 9,000,000 gallons. (Note: Fiskeville Tanks have been removed from the storage volume table.)

The following table provides an indication of the ratio of the total tank equalization storage to future average day demand

LOW SERVICE (334') GRADIENT

EQUALIZATION STORAGE ASSESSMENT – FUTURE 20 YEAR DEMANDS WITH MISHNOCK STORAGE RESERVOIR

DEMAND SCENARIO	FUTURE SYSTEM DEMAND (GAL)	TOTAL EQUALIZATION VOLUME (GAL)	% STORAGE OF AVERAGE DAY DEMAND
Average Day	8,610,000	1,498,000	17%

The total of the *equalization storage* volume in all the Low Service Pressure Gradient tanks provides 17% of the future average day demand, which is below the water works 25% guideline. This is however increased from the 13% provided by the existing storage tanks.

It was also critical to evaluate the new Mishnock reservoir under extended period modeling scenarios for future average and maximum day demand conditions.

Future Average Day Demand
The Mishnock reservoir was set on level control with the new pumps at the Mishnock treatment plant. Controls for the all other pump and booster stations remained unchanged from previous settings as described herein. A 72 hour (3 day) extended period model scenario was simulated utilizing average day demands and the system diurnal flow curve previously developed. The booster pump station that has the ability to pump directly from the Mishnock reservoir to the High Service Pressure Gradient was not active in this simulation. It was intended that the simulation attempt to identify the ability of the new storage facility to operate in conjunction with other storage facilities in the Low Service Pressure Gradient. The use of this booster pump station as a means to supply the High Service Pressure Gradient would require a review of operating procedures in conjunction with plans to utilize other booster pump stations.

The results (i.e. Low Service pump and tank graphs) of this simulation are provided in Attachment No. 6. The graphs indicate that the Mishnock reservoir fluctuates in a range from 329 to 334 feet. Additionally, the Mishnock pump cycles on a daily basis in response to the water level in the storage reservoir. Remaining tanks and pump stations function within a normal mode of operation. It will be necessary to review operation set points for other facilities and most notably for Clinton Avenue and Quaker Lane pump stations in order to increase the frequency of operation of the Mishnock wells and reduce reliance on wholesale water supply. The Authority intends to run the Mishnock pumps continuously to maximize well water use.

Future Maximum Day Demand with Peak hour
Similar to the average day extended period simulation, the Mishnock reservoir was set on level control with the new pumps at the Mishnock treatment plant and controls for all the other pump and booster stations remained unchanged from previous settings. A 72 hour (3 day) extended period model scenario was simulated utilizing maximum day demands and the system diurnal flow curve previously developed. Again, the booster pump station that has the ability to pump directly from the Mishnock reservoir to the High Service Pressure Gradient was not active in this simulation.

The results (i.e. Low Service pump and tank graphs) of this simulation are provided in Attachment No. 7. The graphs indicate that the Mishnock reservoir fluctuates in a range from 324 to approximately 328 feet. Additionally, one Mishnock pump is on continuously throughout the simulation in response to the water level in the storage reservoir.

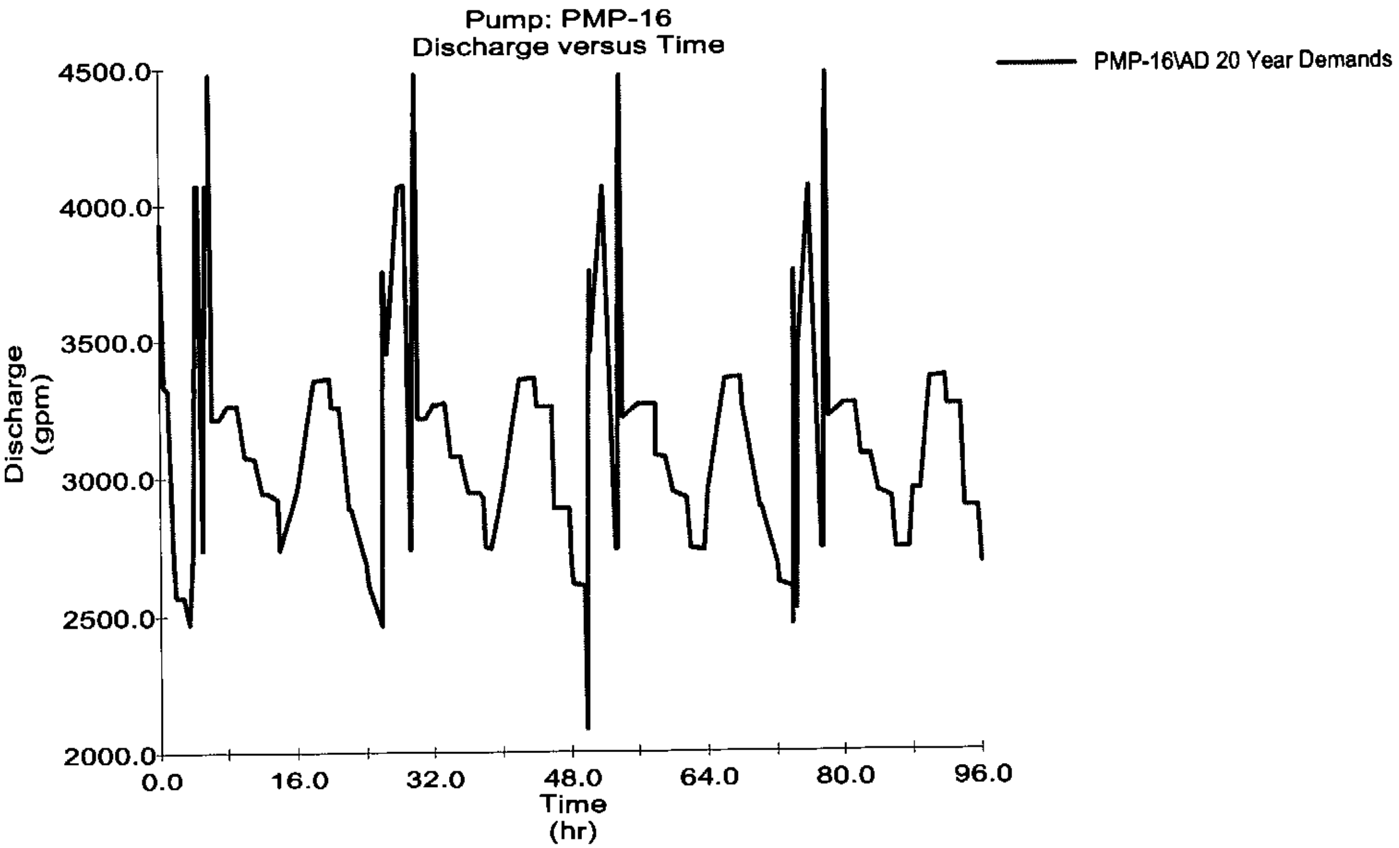
Remaining storage and pump facilities operate in normal mode of operation under extended maximum day demands. It is suggested that an additional pump could be utilized at the Mishnock well field to augment the storage level in the Mishnock reservoir. This second pump was not included in this simulation. It is also noted that the Wakefield Street and West Street storage tanks drain during this simulation. Also, it will be necessary to review operation set points for other facilities and most notably for Clinton Avenue and Quaker Lane pump stations in order to insure adequate supply capacity during the maximum day demand with peak hour demand periods.

ATTACHMENT NO. 1

EXTENDED PERIOD SIMULATION
AVERAGE DAY DEMAND
STORAGE TANK GRAPHS

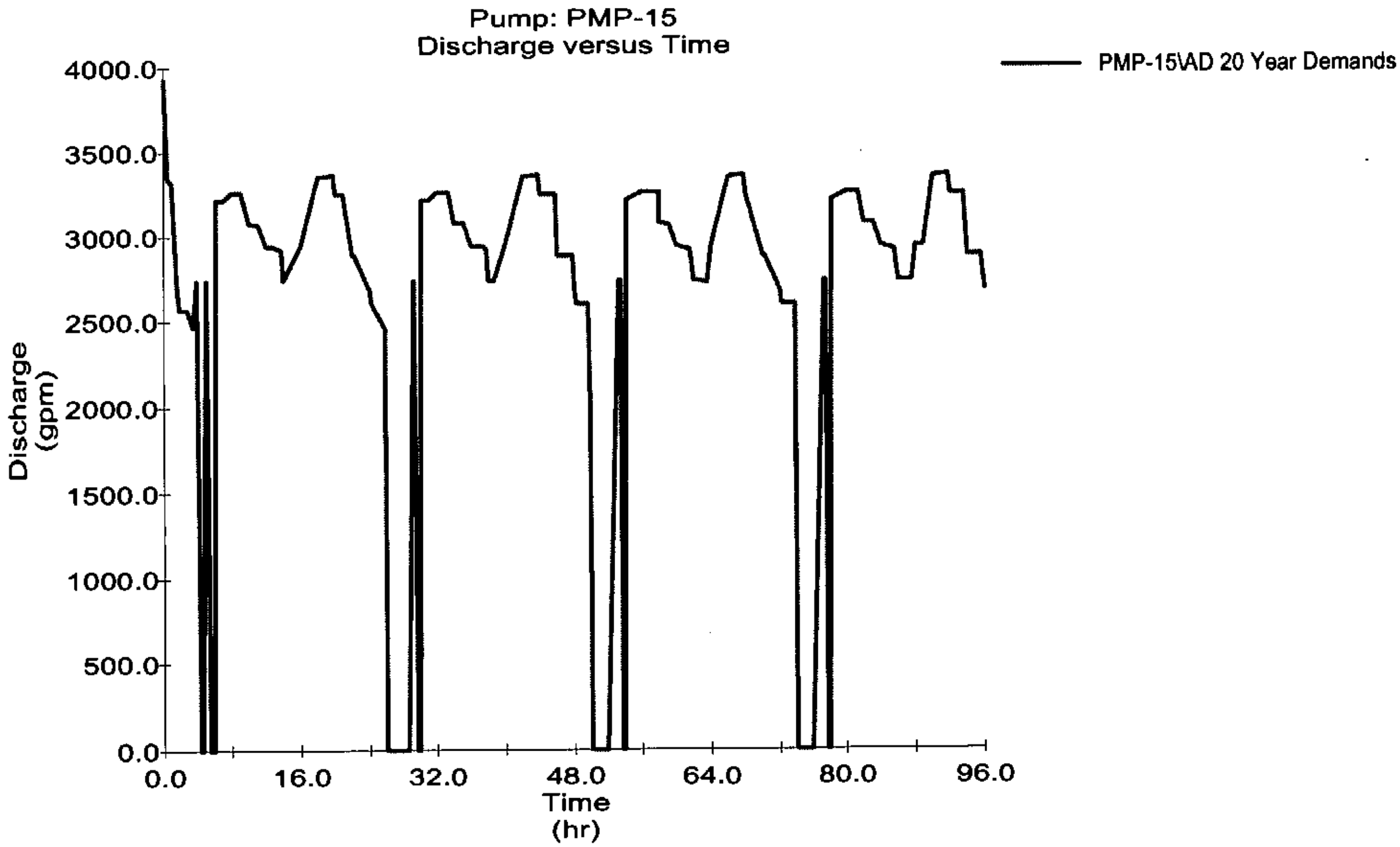
Graph

Clinton Avenue Pump #1



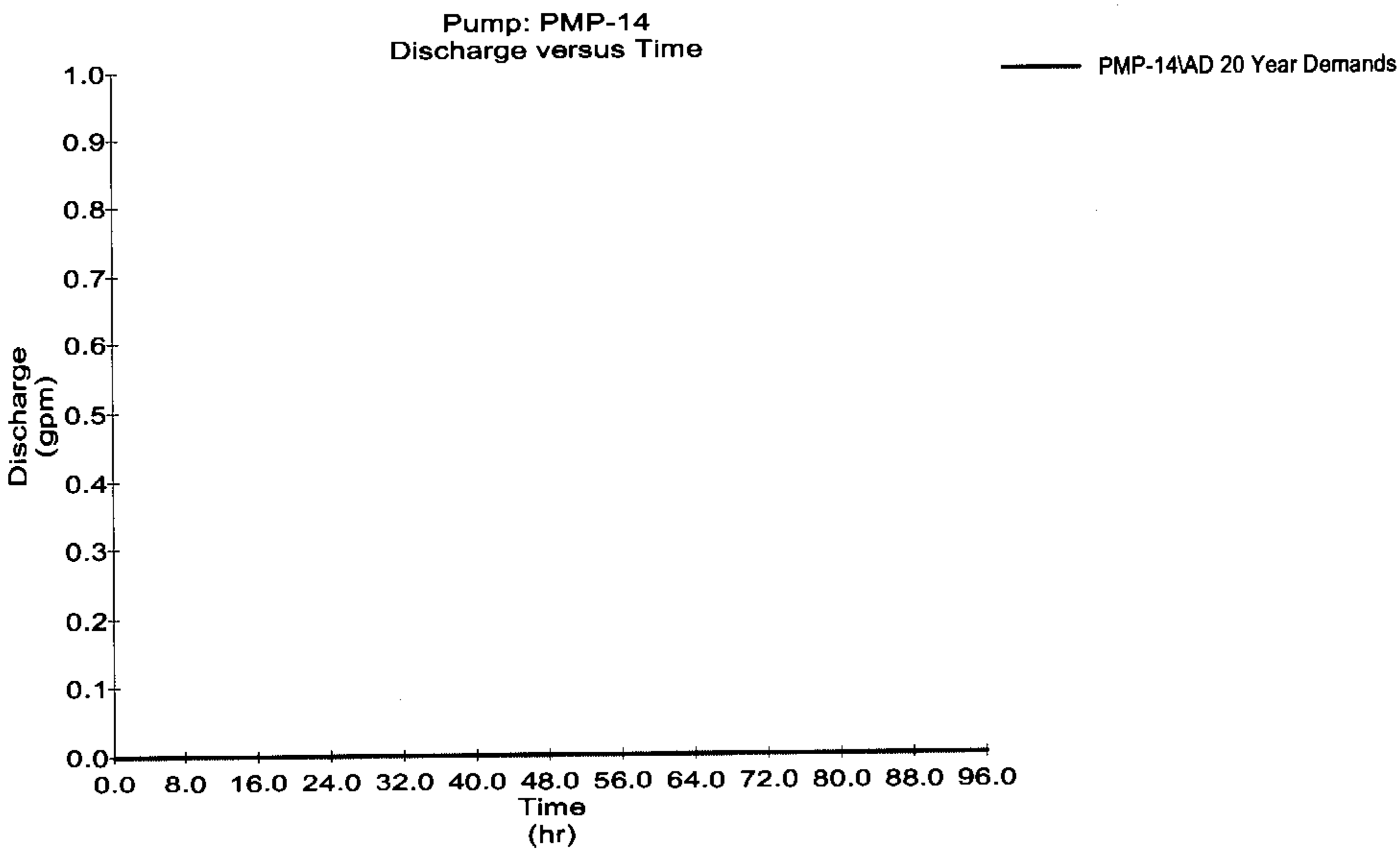
Graph

Clinton Avenue Pump #2



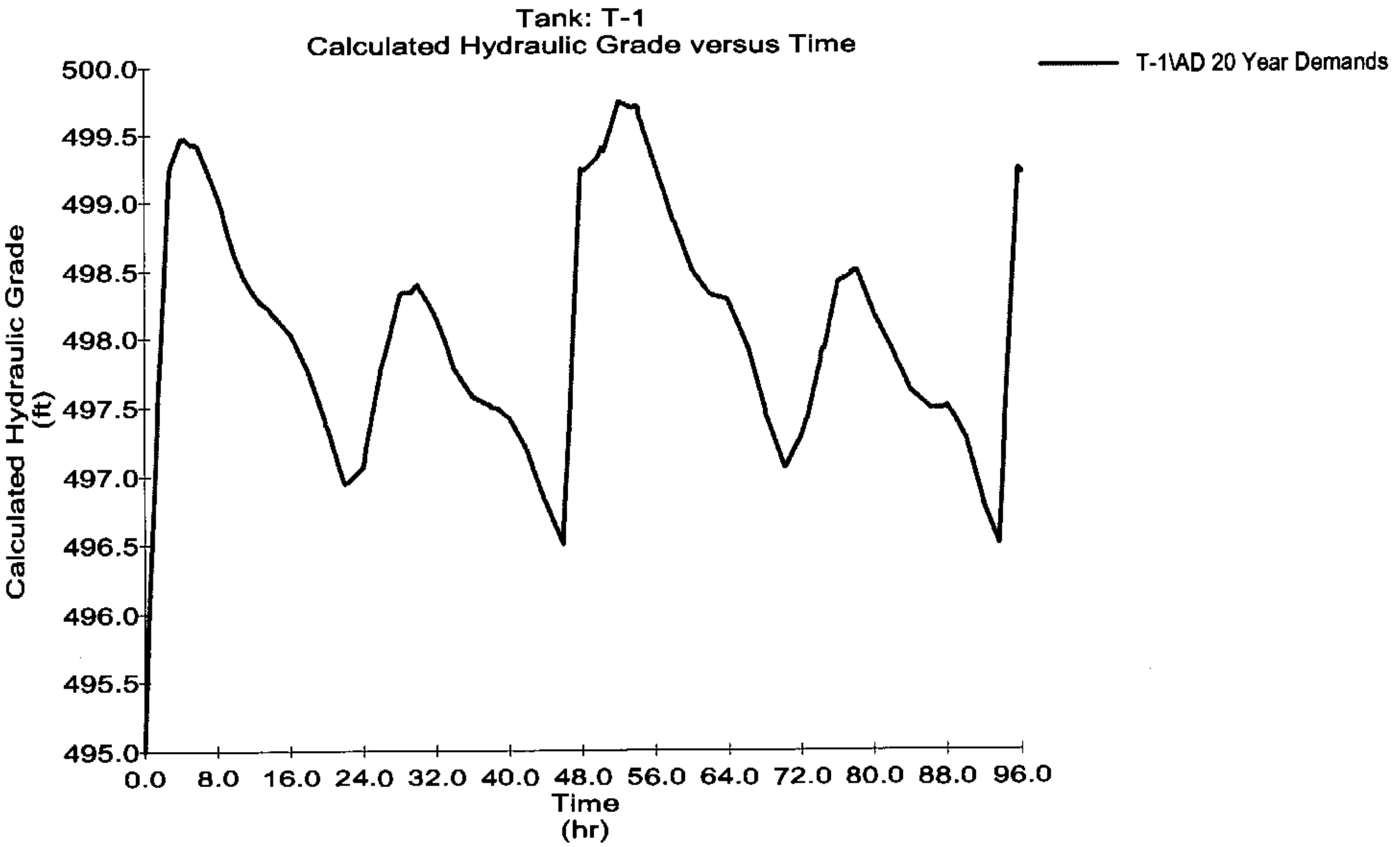
Graph

Clinton Avenue Pump #3



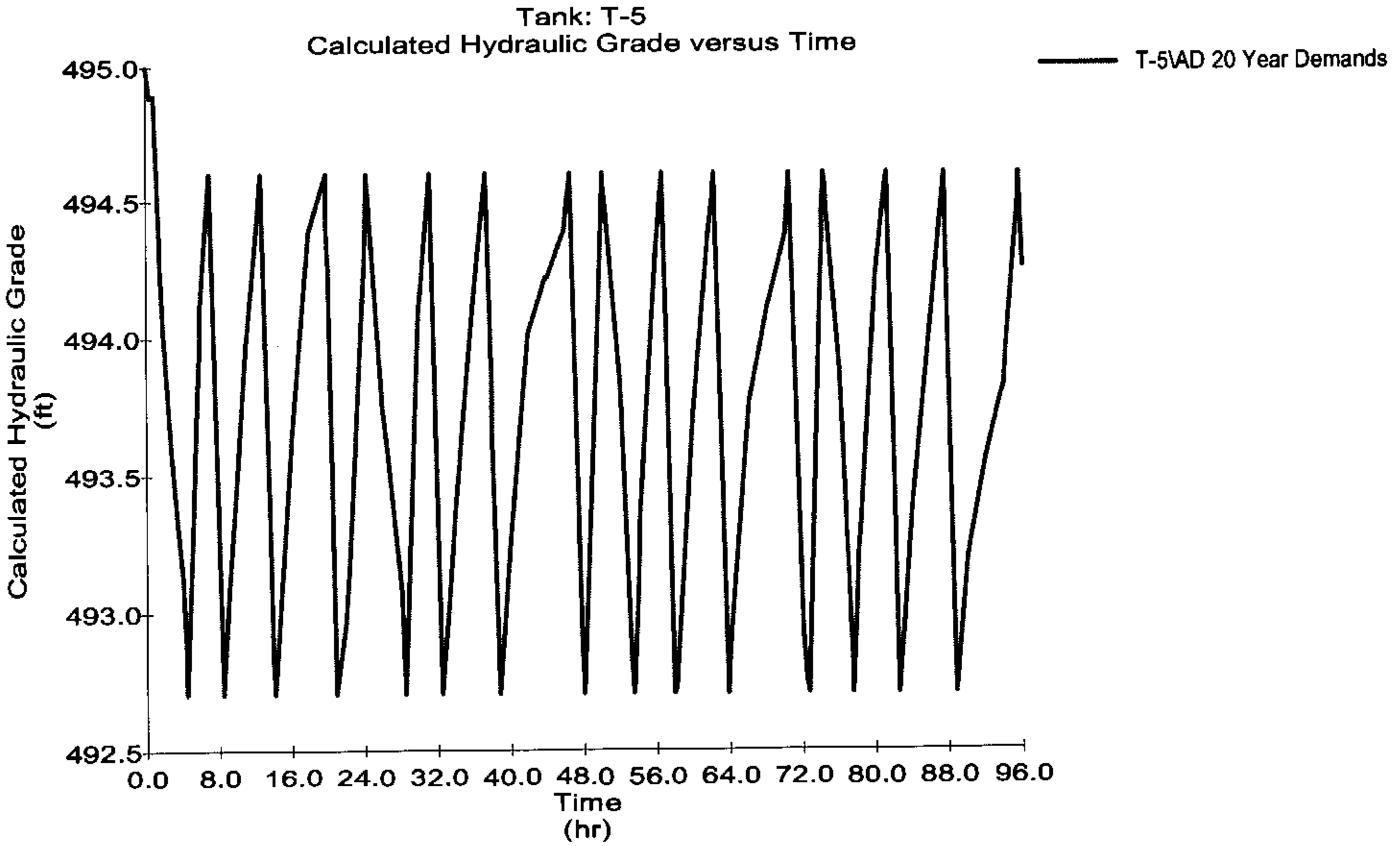
Graph

Read School House Road Tank



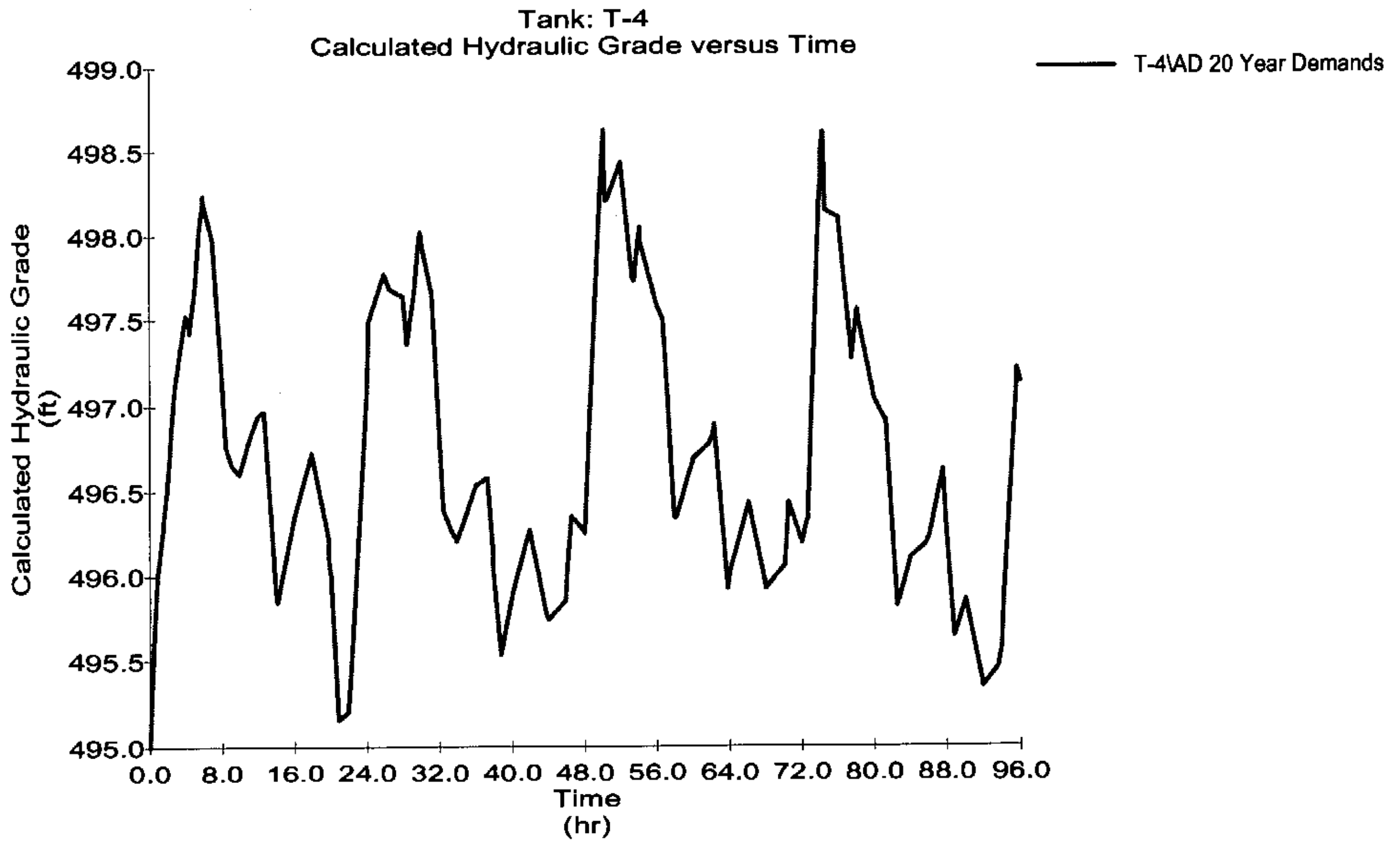
Graph

Carrs Pond Road Tank



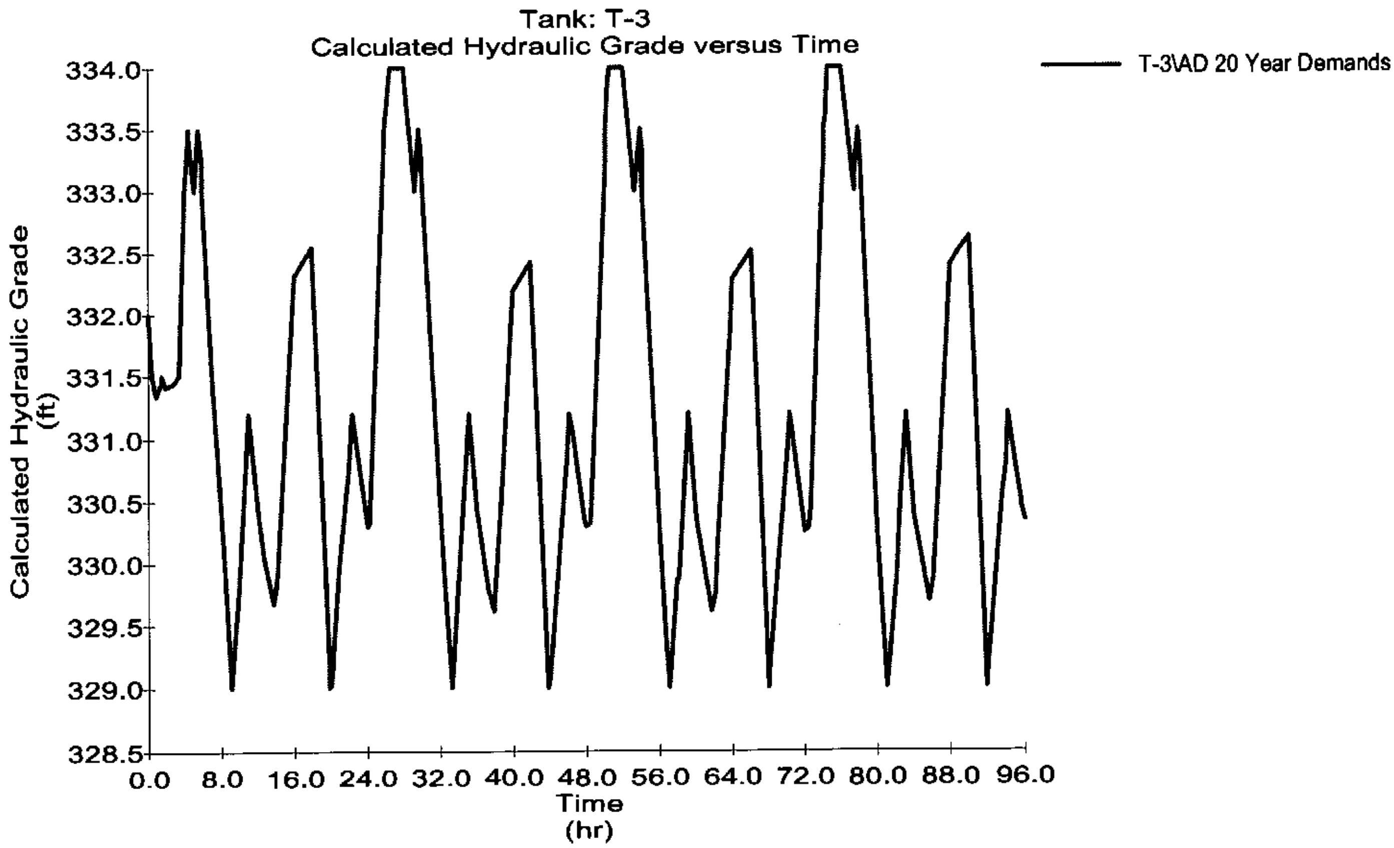
Graph

Technology Park Tank



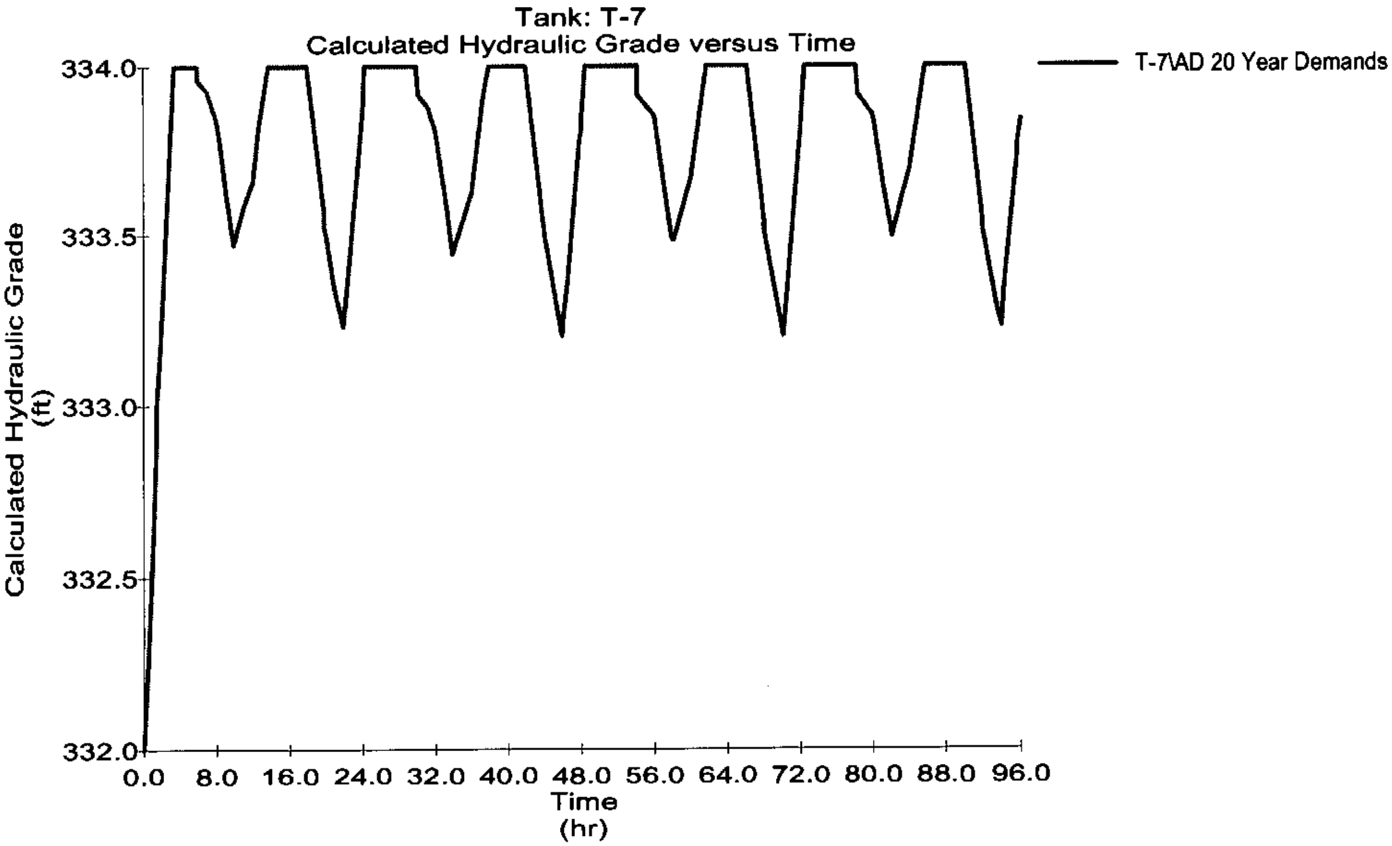
Graph

Frenchtown Road Tank



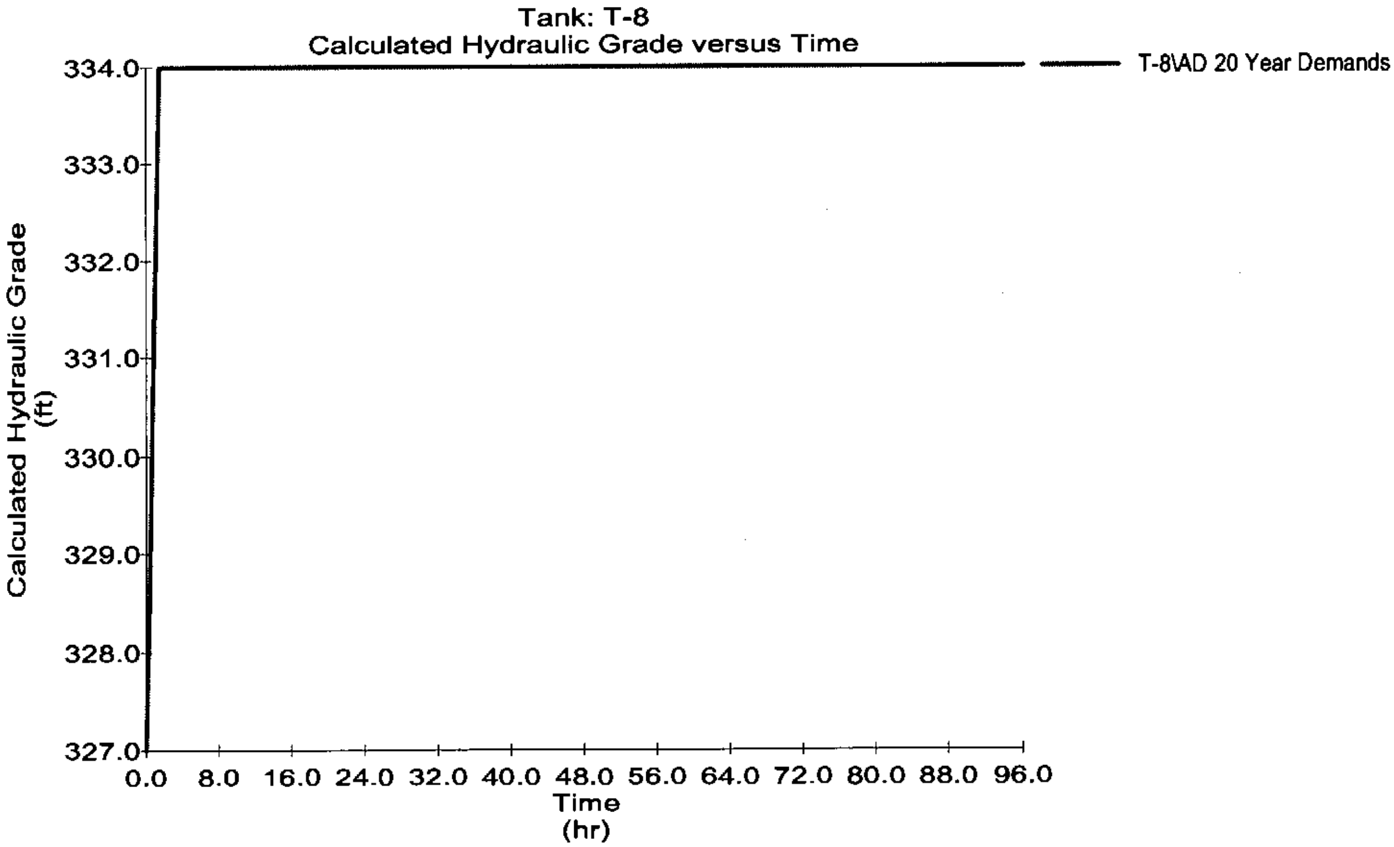
Graph

Setian Lane Tank



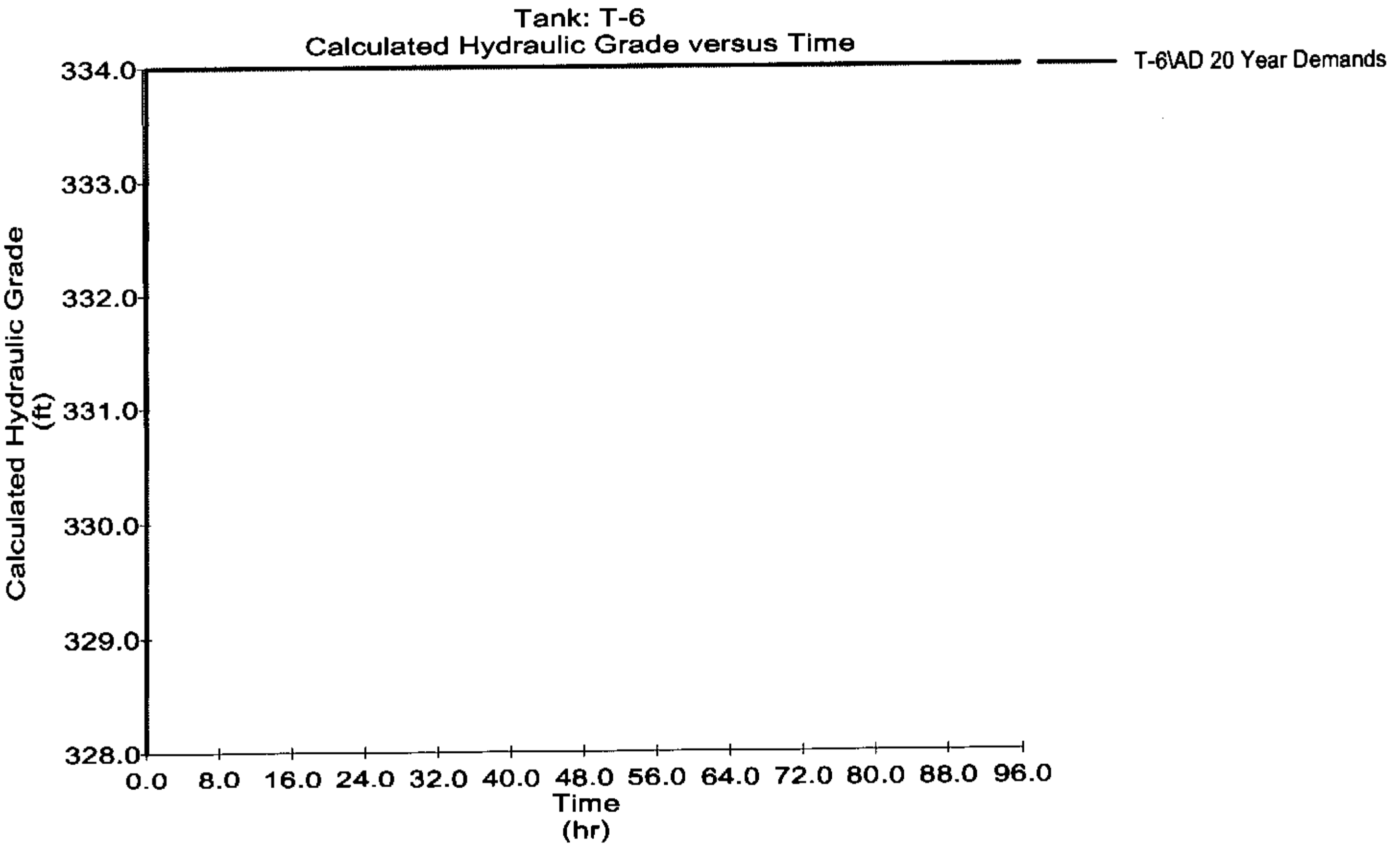
Graph

Wakefield Street Tank



Graph

West Street Tank

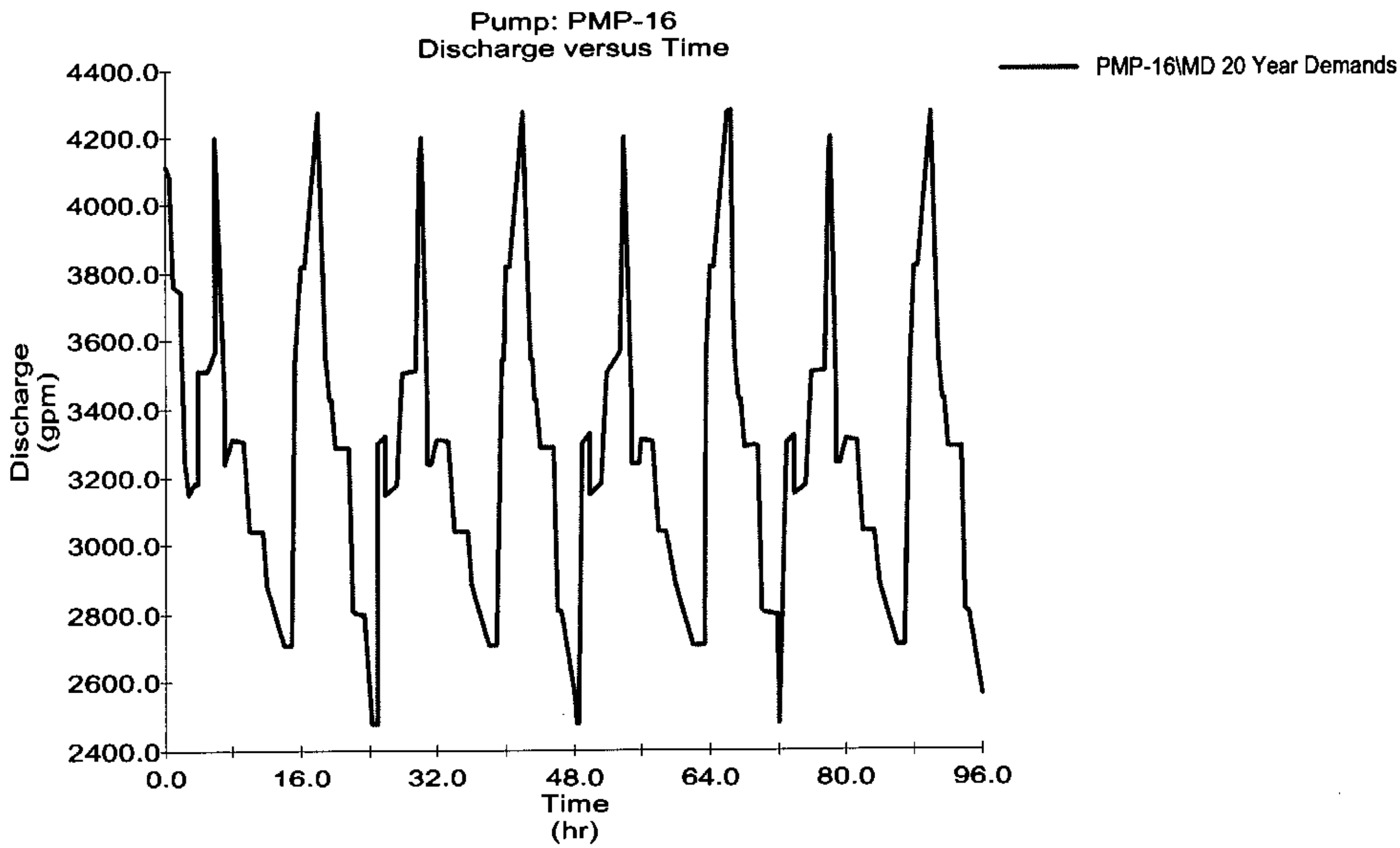


ATTACHMENT NO. 2

EXTENDED PERIOD SIMULATION
MAXIMUM DAY DEMAND
STORAGE TANK GRAPHS

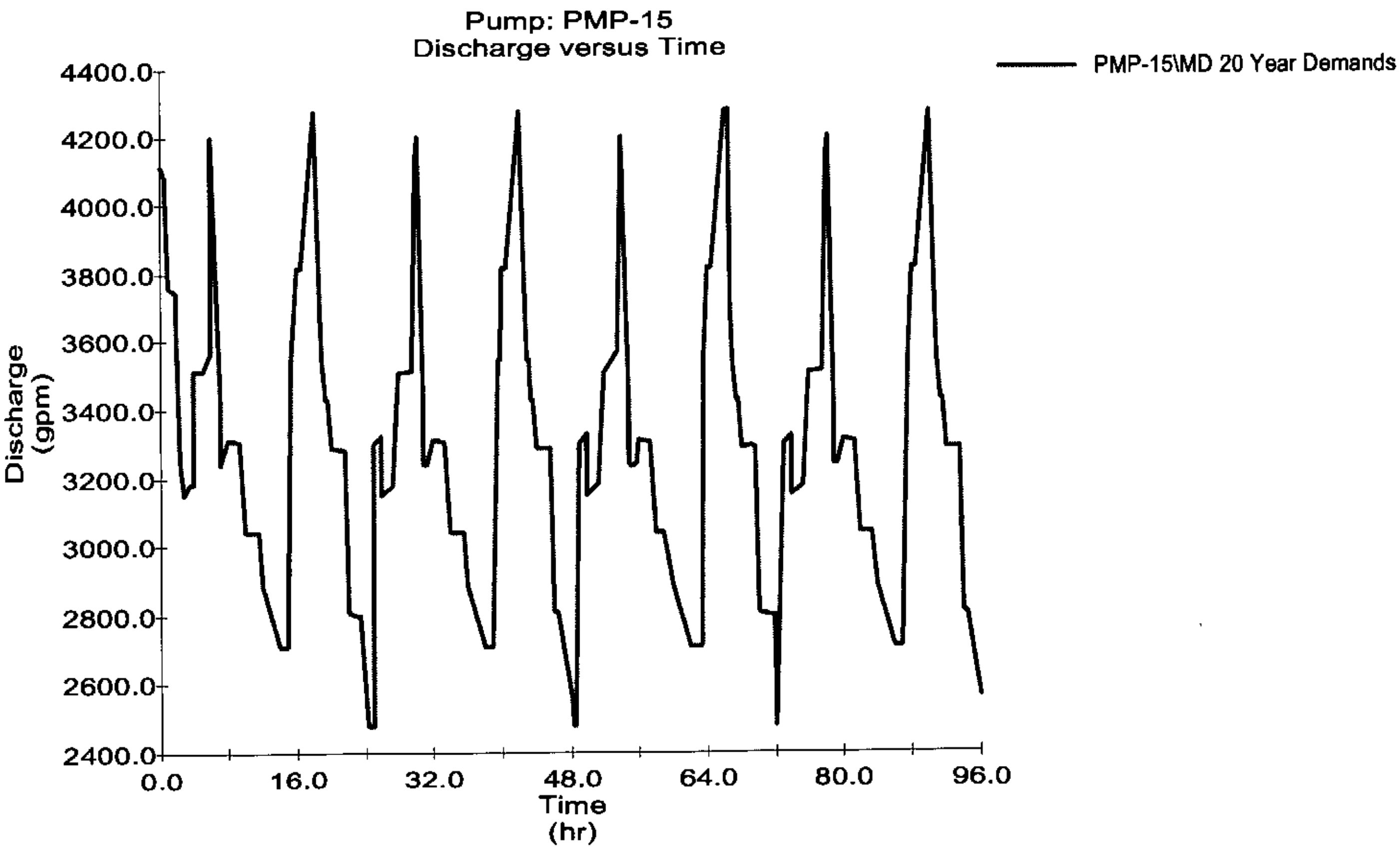
Graph

Clinton Avenue Pump #1



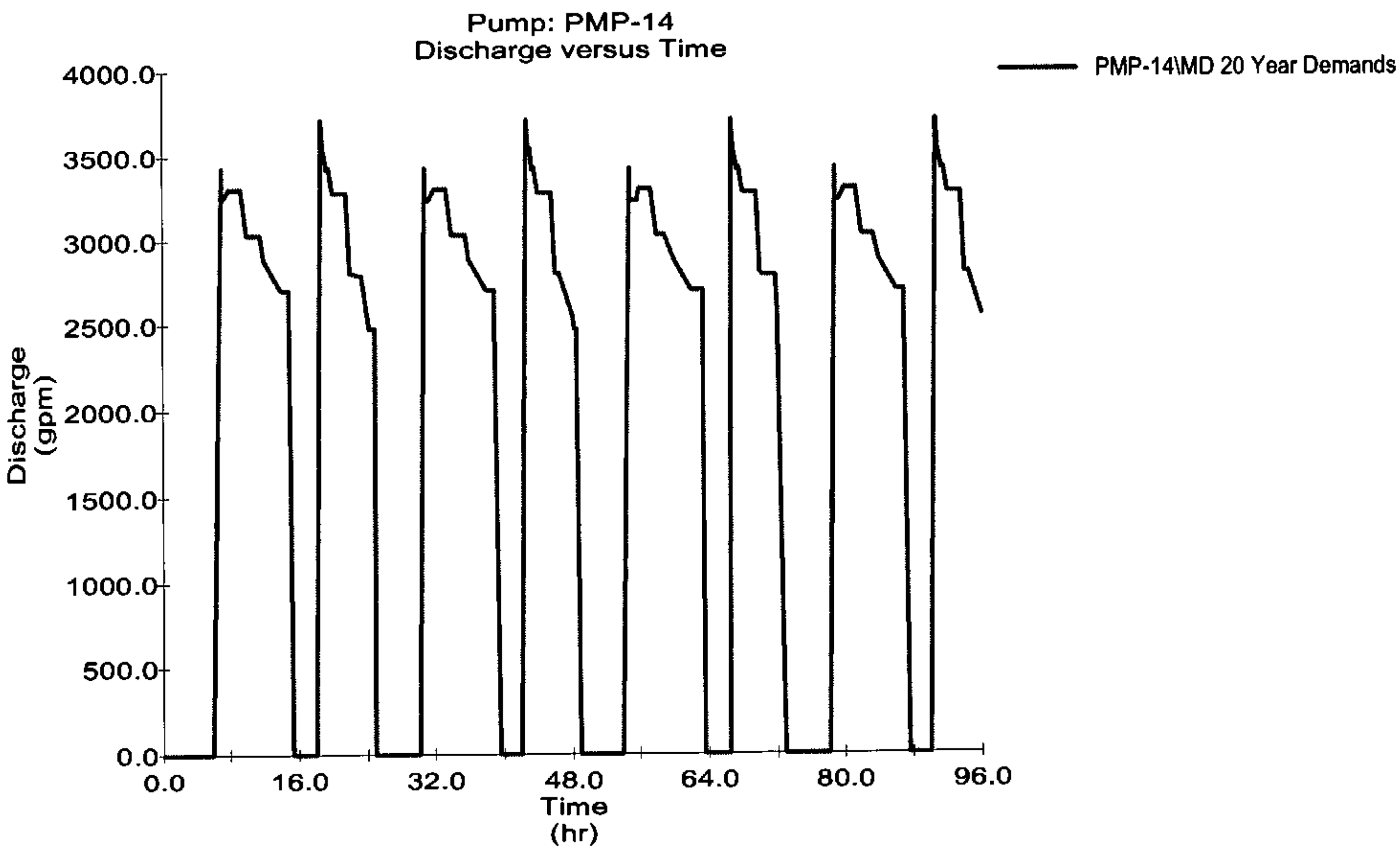
Graph

Clinton Avenue Pump #2



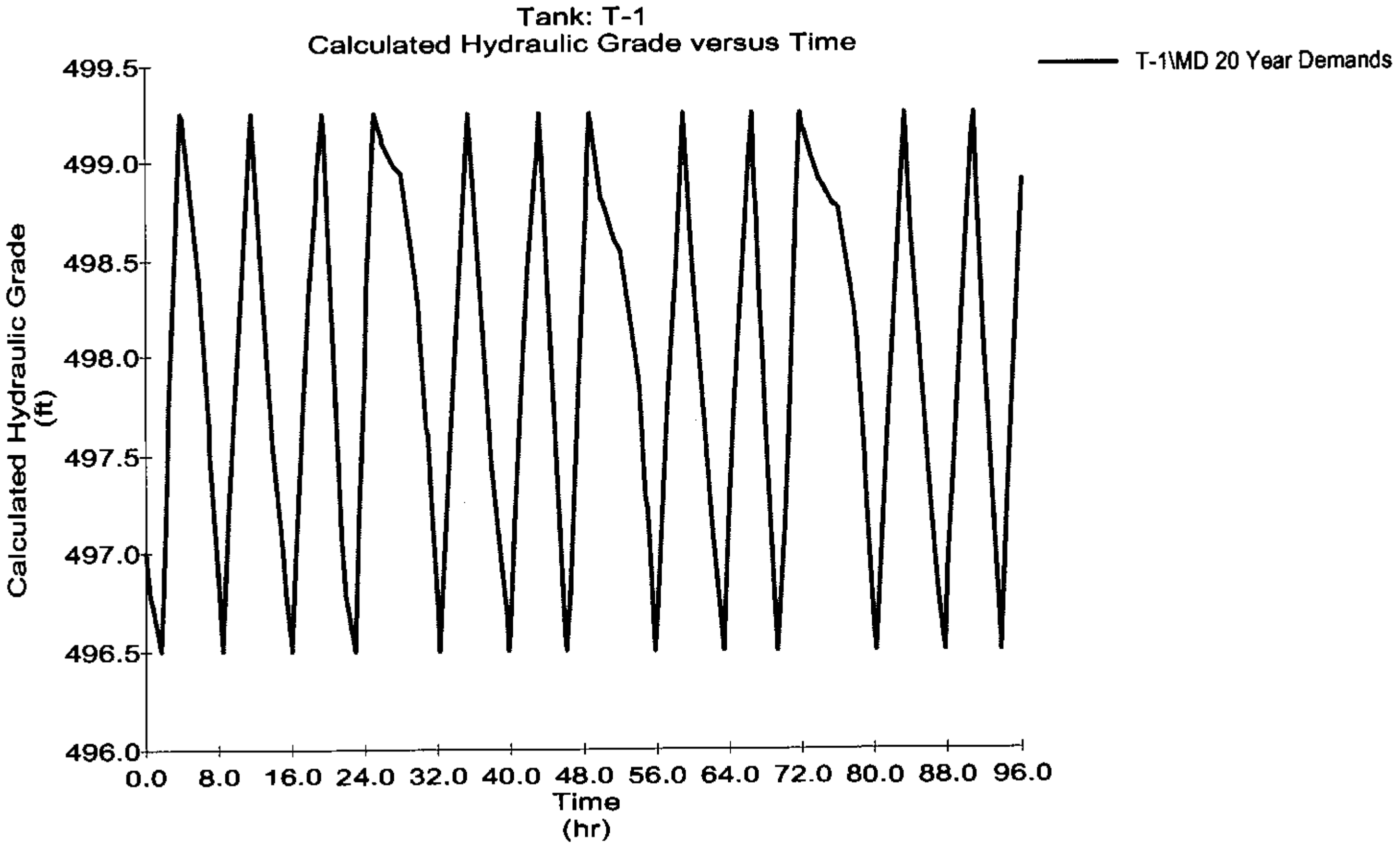
Graph

Clinton Avenue Pump #3



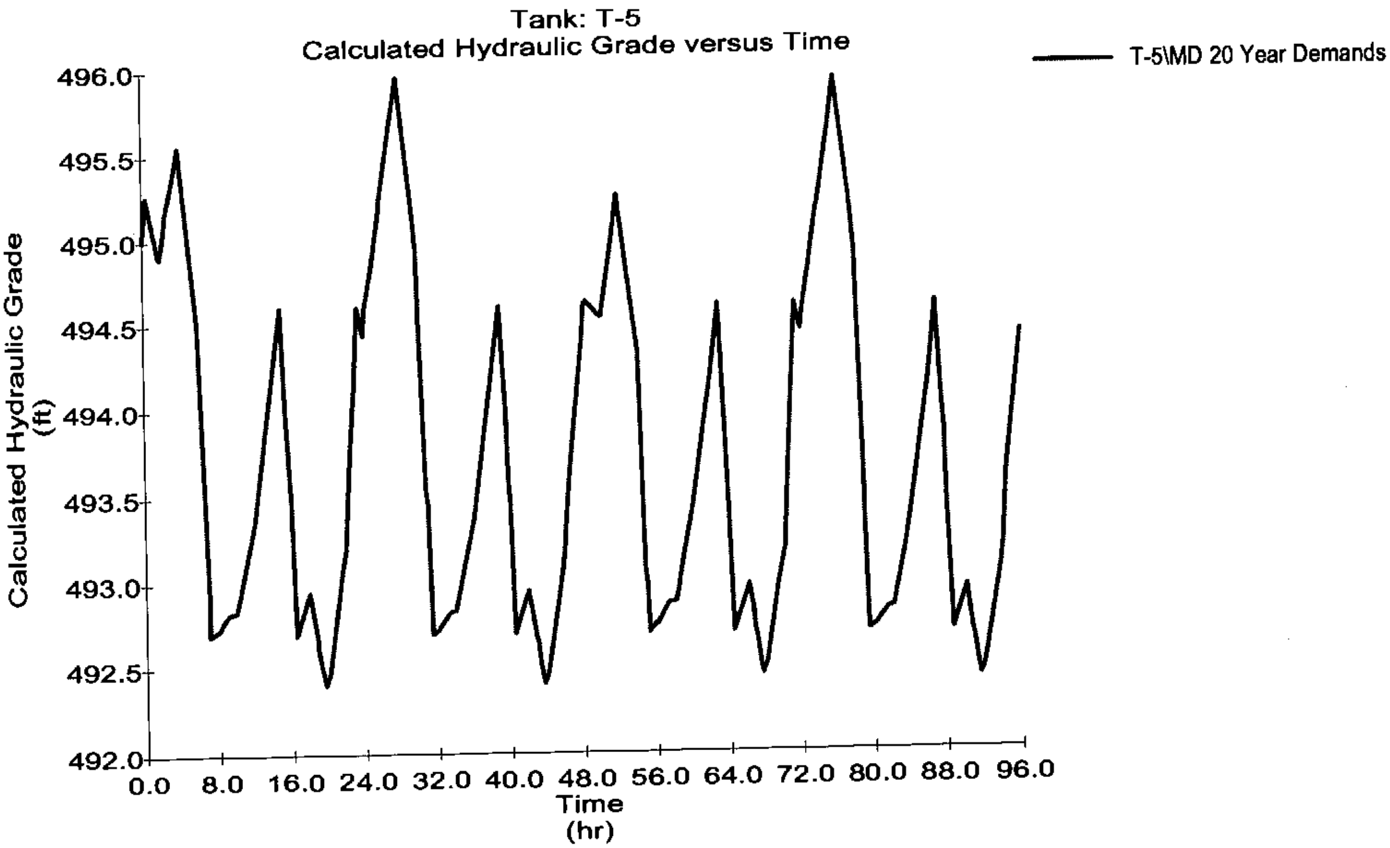
Graph

Read School House Road Tank



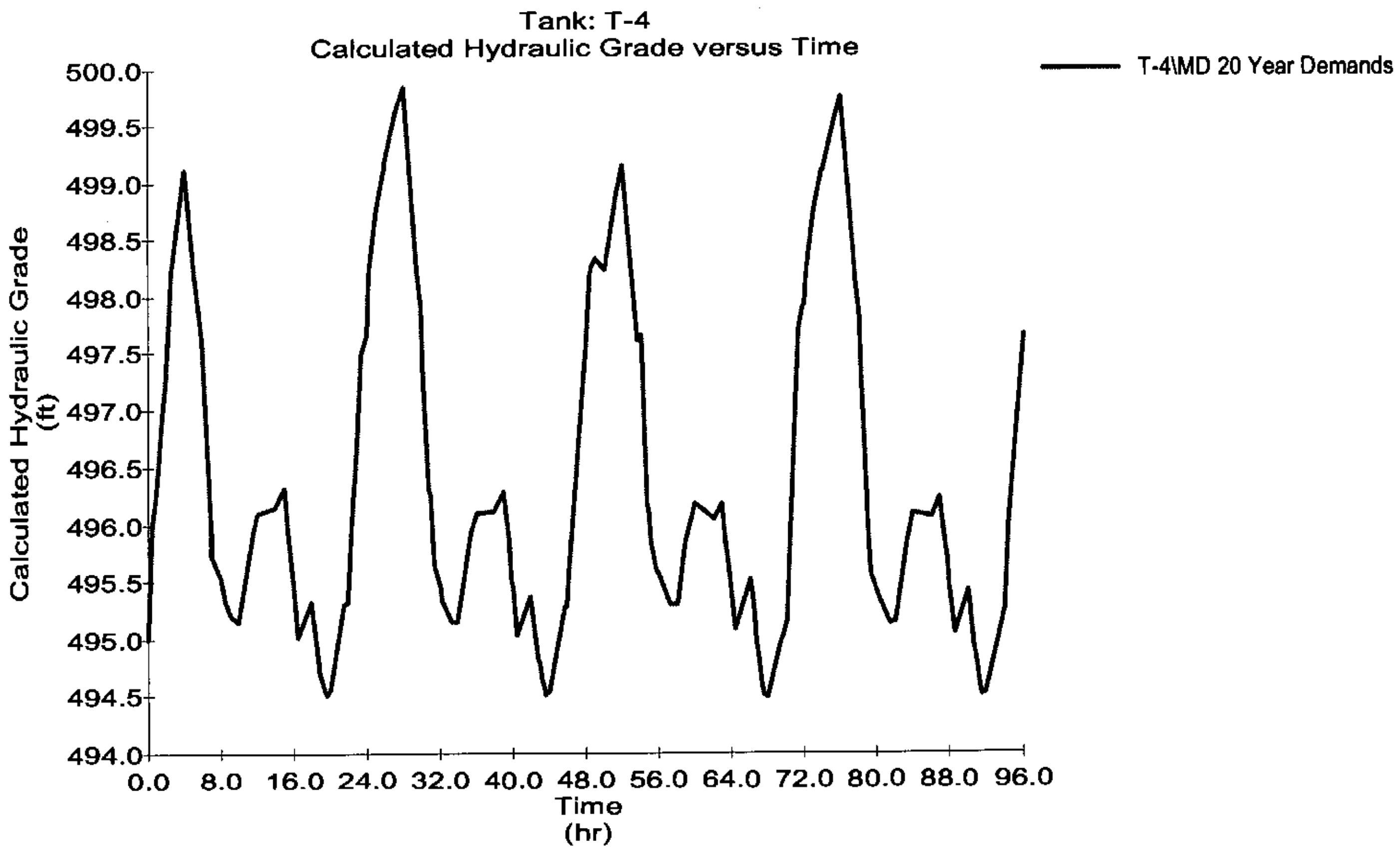
Graph

Carrs Pond Road Tank



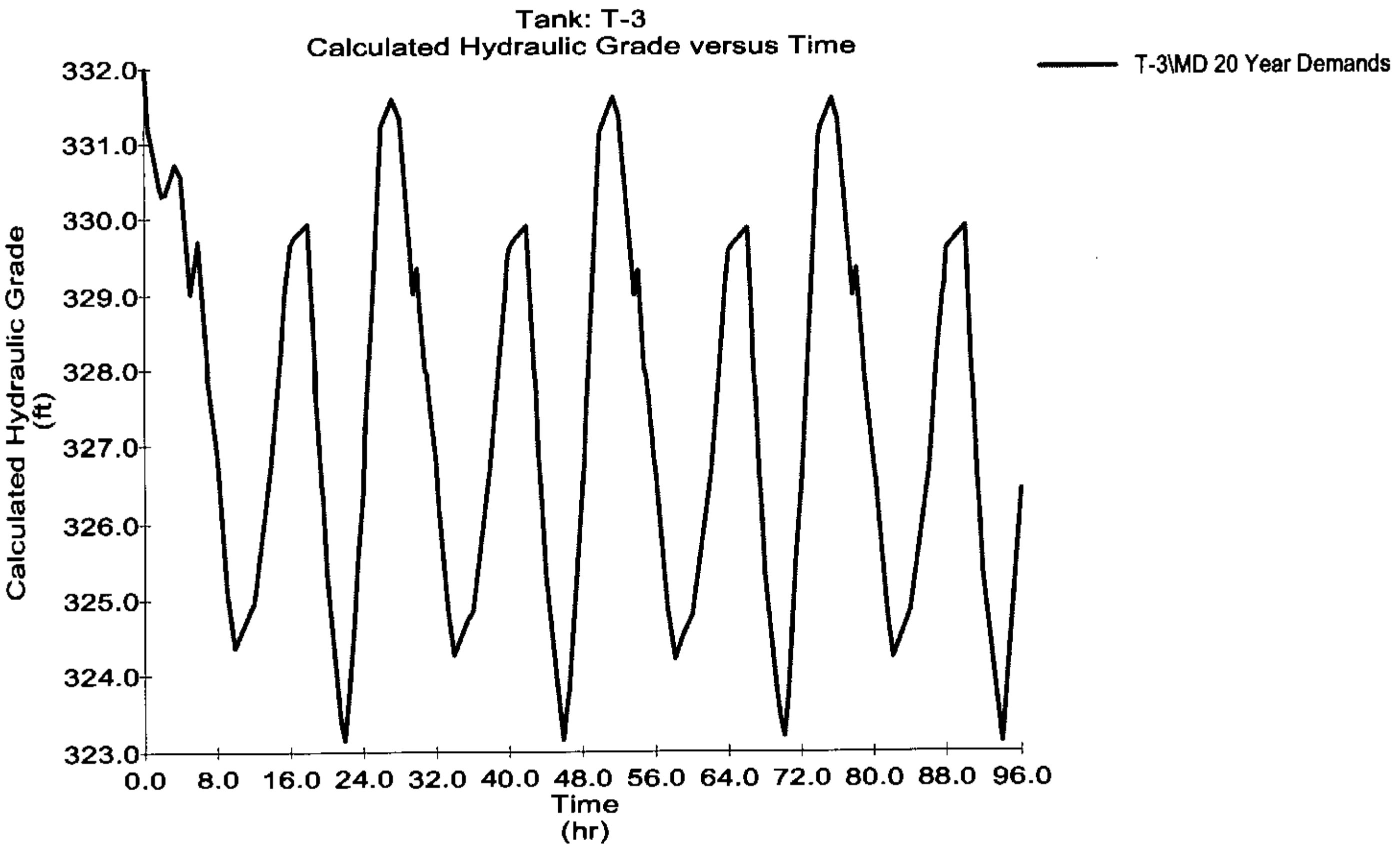
Graph

Technology Park Tank



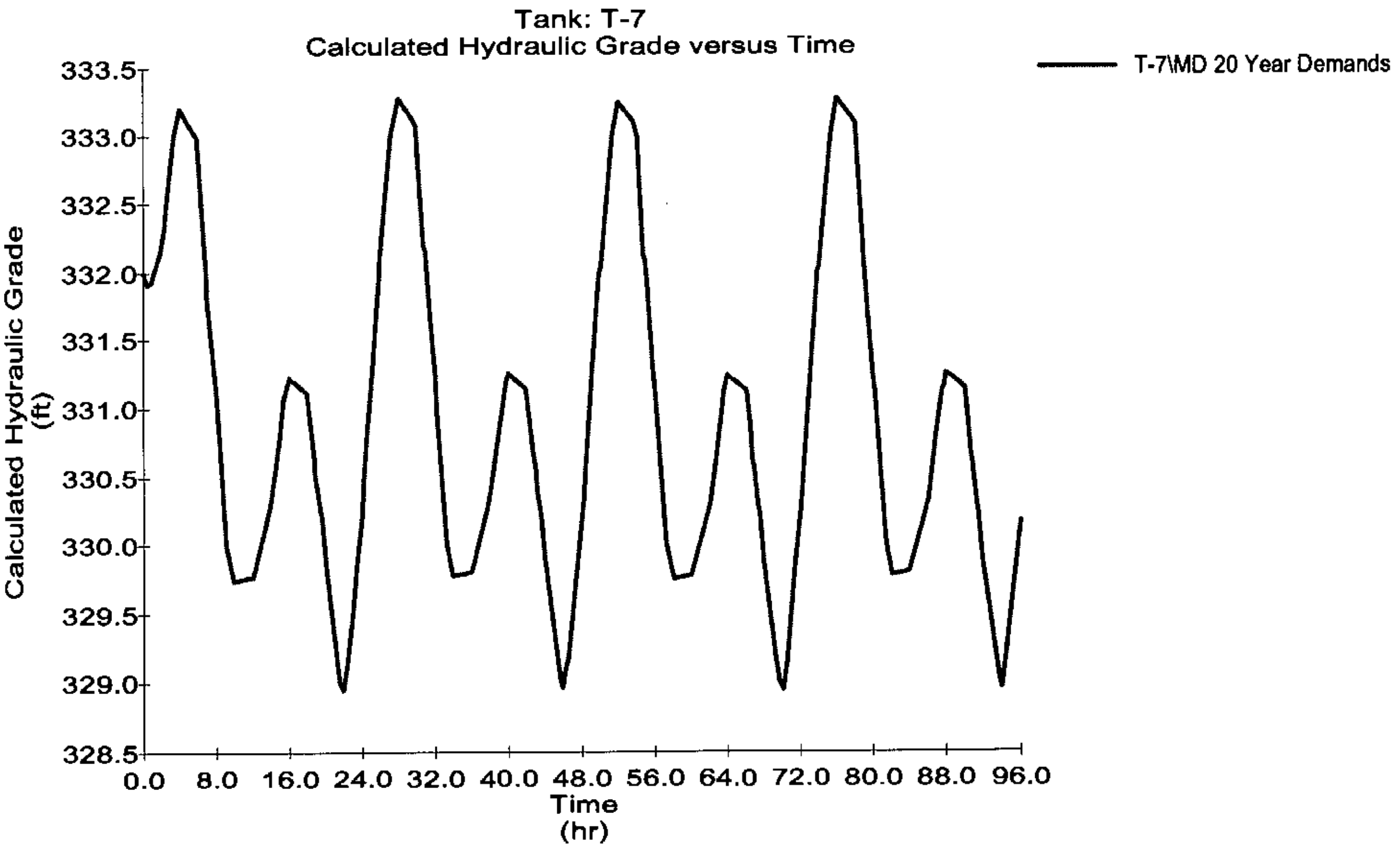
Graph

Frenchtown Road Tank



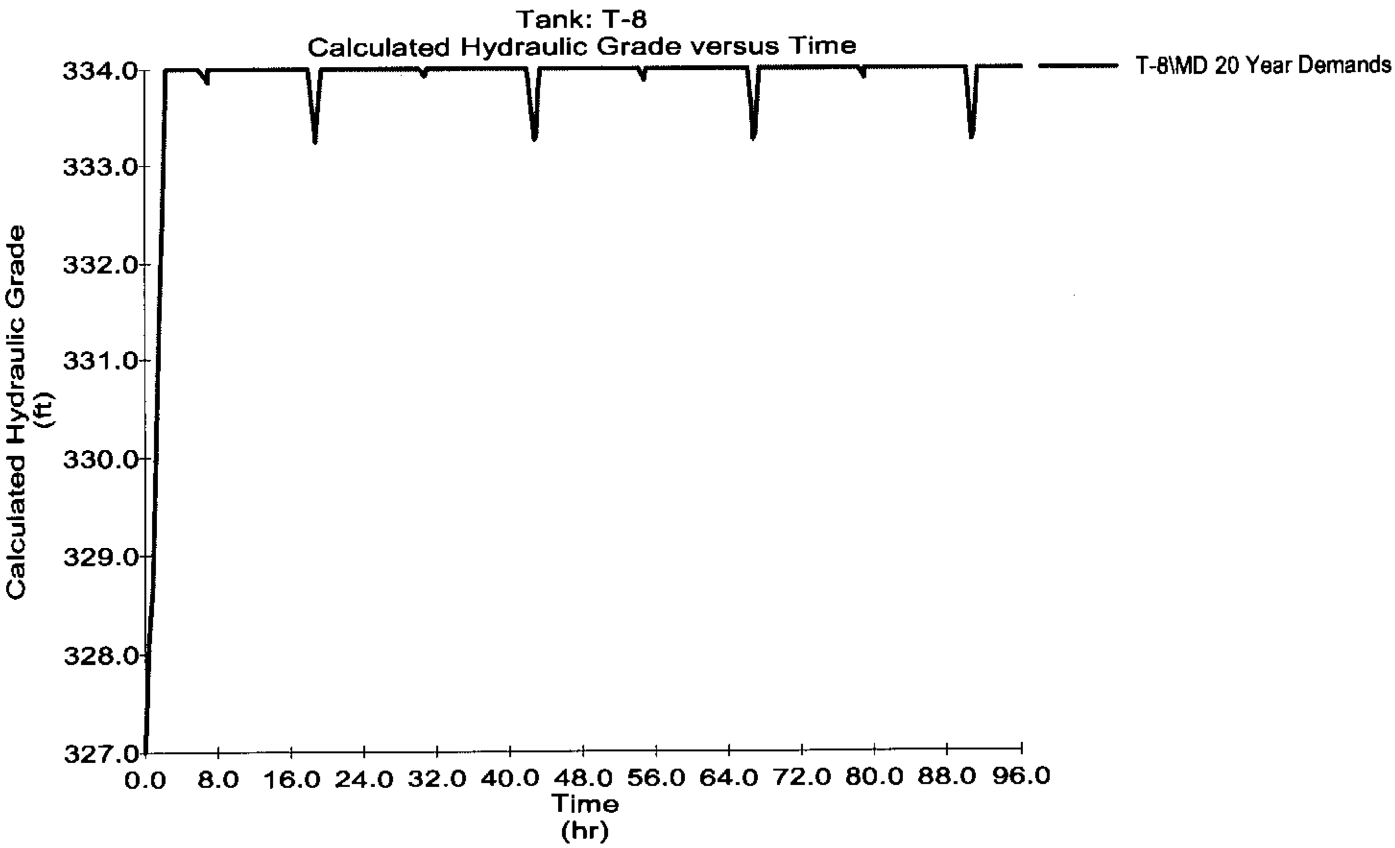
Graph

Setian Lane Tank



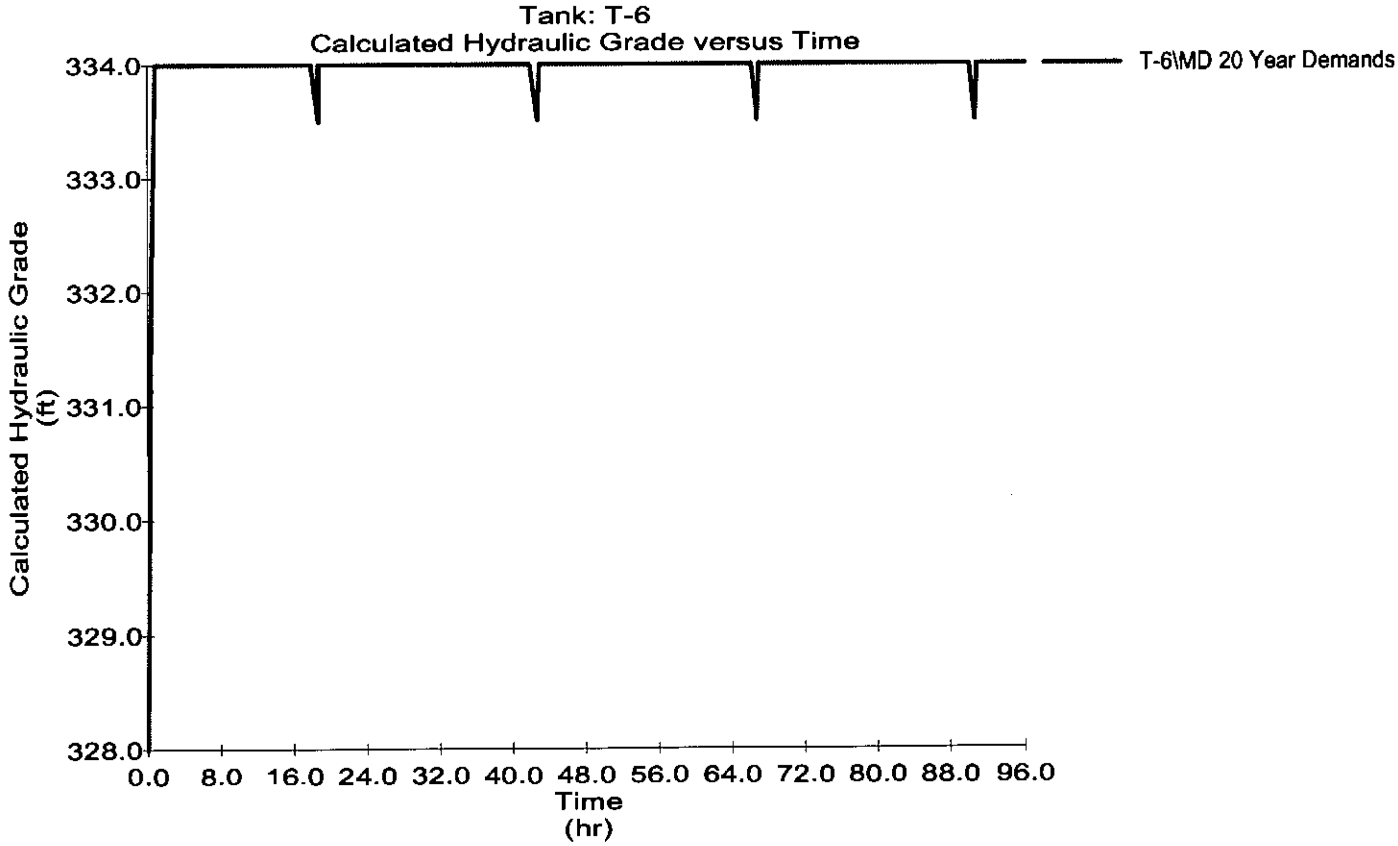
Graph

Wakefield Street Tank



Graph

West Street Tank

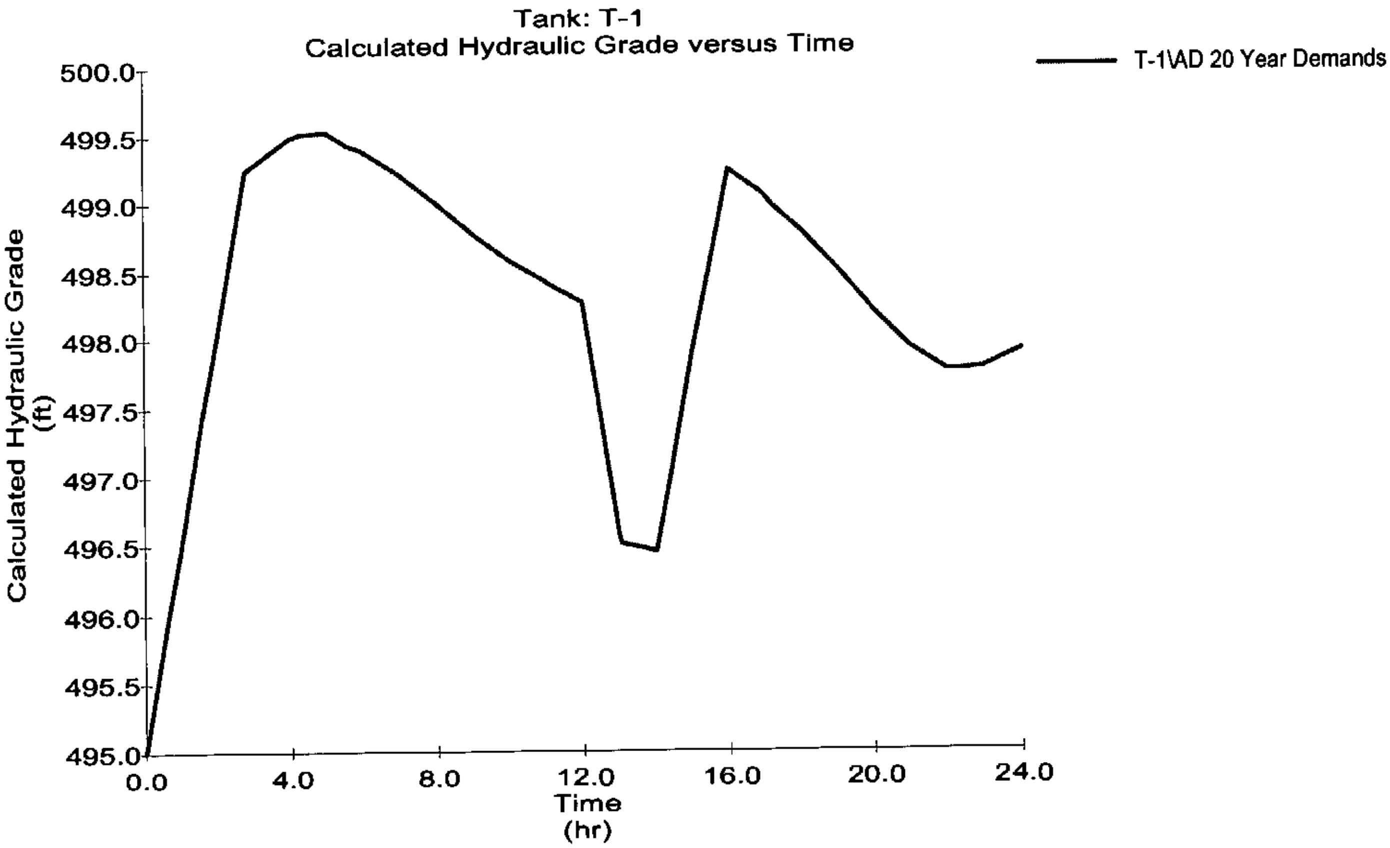


ATTACHMENT NO. 3

EXTENDED PERIOD SIMULATION
AVERAGE DAY DEMAND WITH FIRE FLOW
STORAGE TANK GRAPHS

Graph

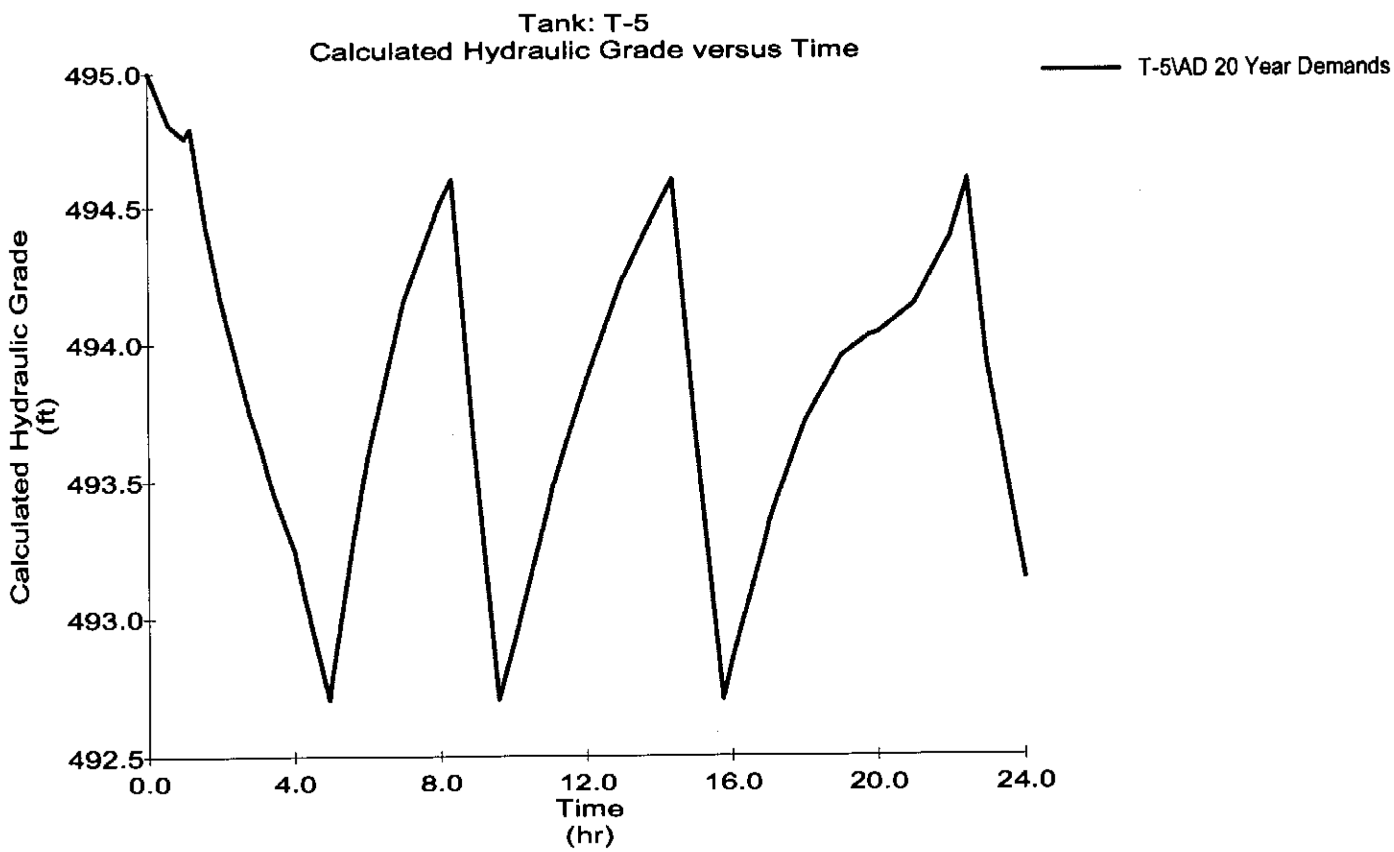
Read School House Road Tank



- 2000 gpm fire flow at node J-7154
- Flat River Rd.
- 16" DI main
- Elevation = 254 ft
- Average Day demand

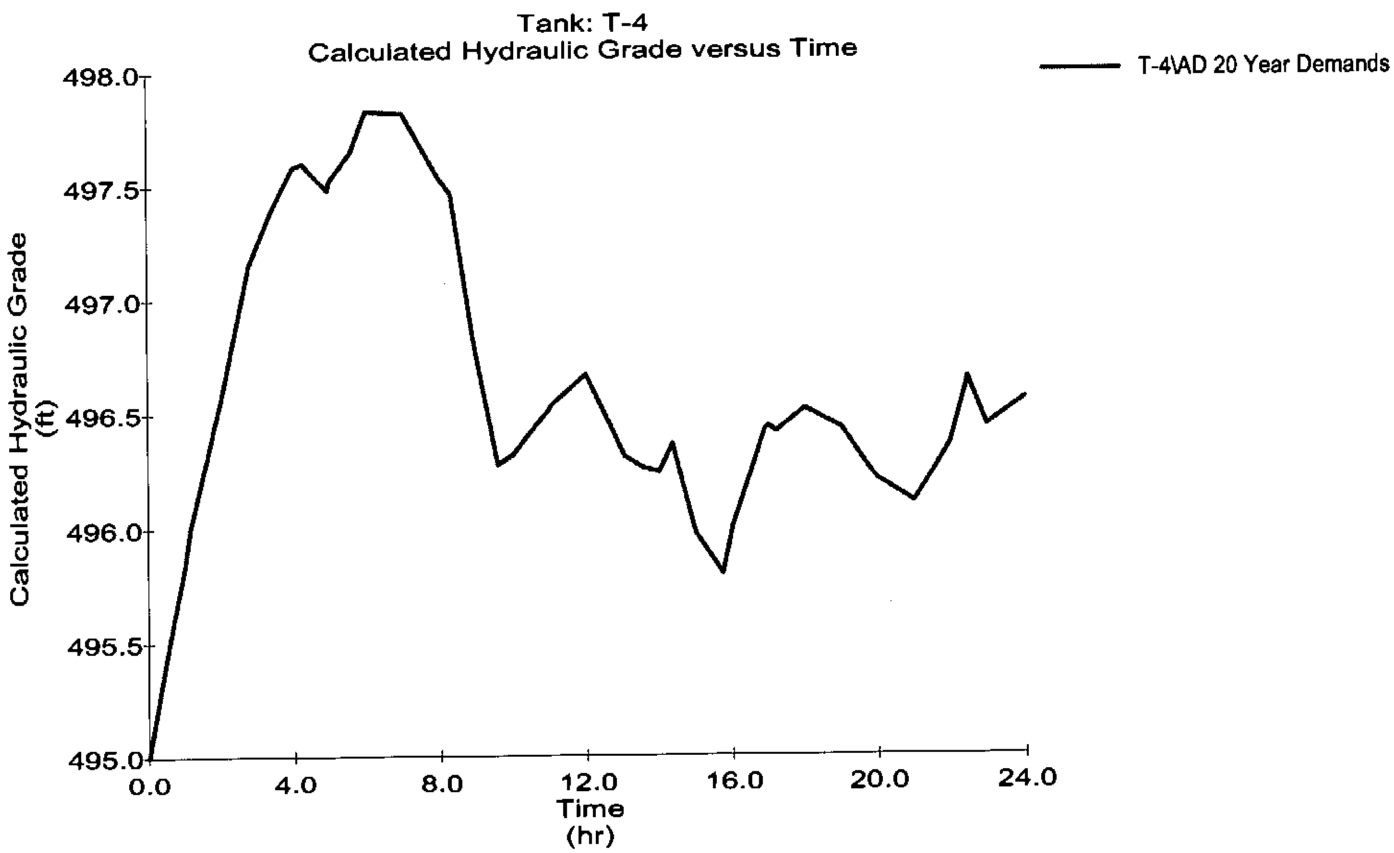
Graph

Carrs Pond Road Tank



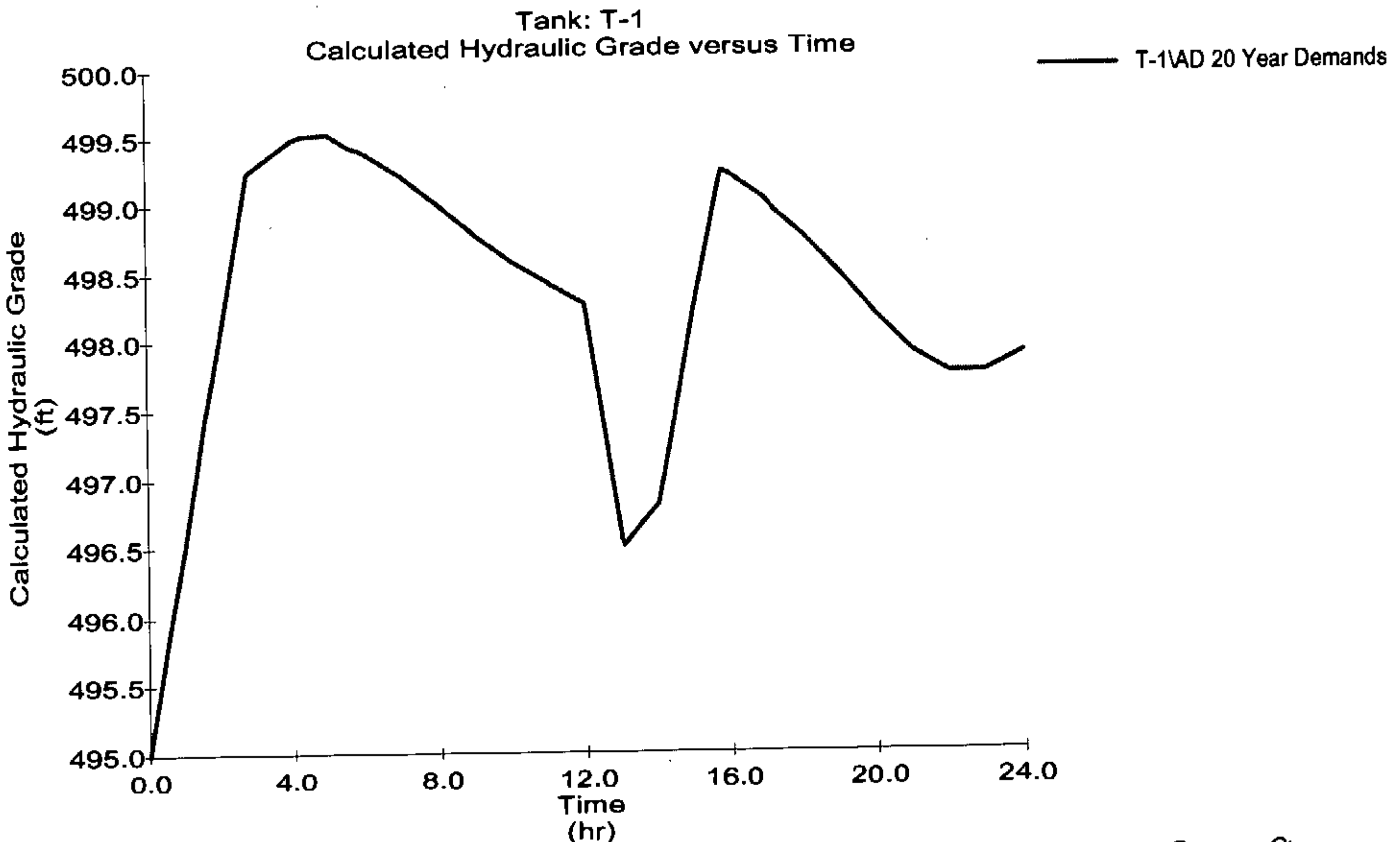
Graph

Technology Park Tank



Graph

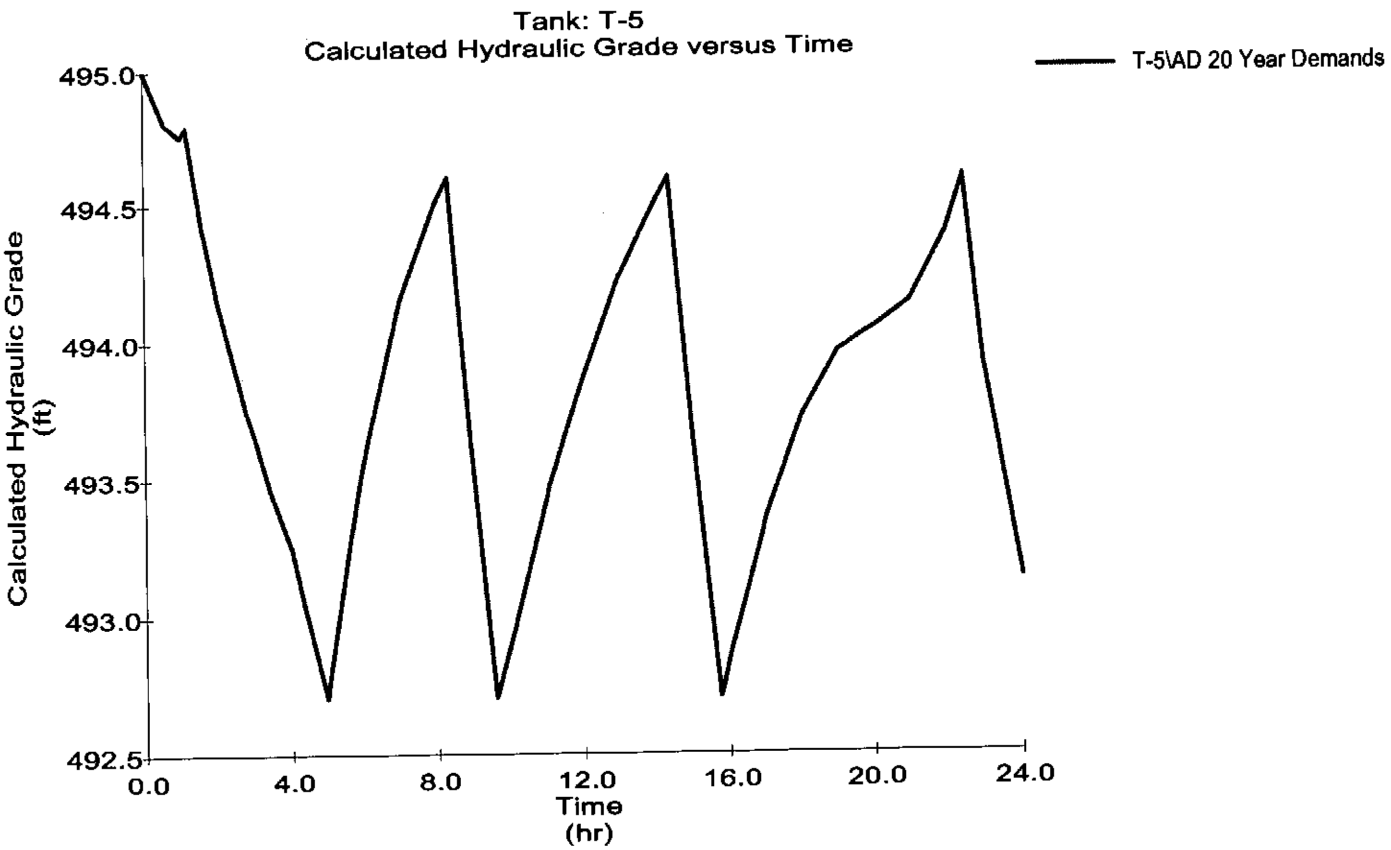
Read School House Road Tank



- 2000 gpm fire flow at node J-7258
- Hunters Crossing Dr.
- 16" DI main
- Elevation = 343 ft
- Average Day demand

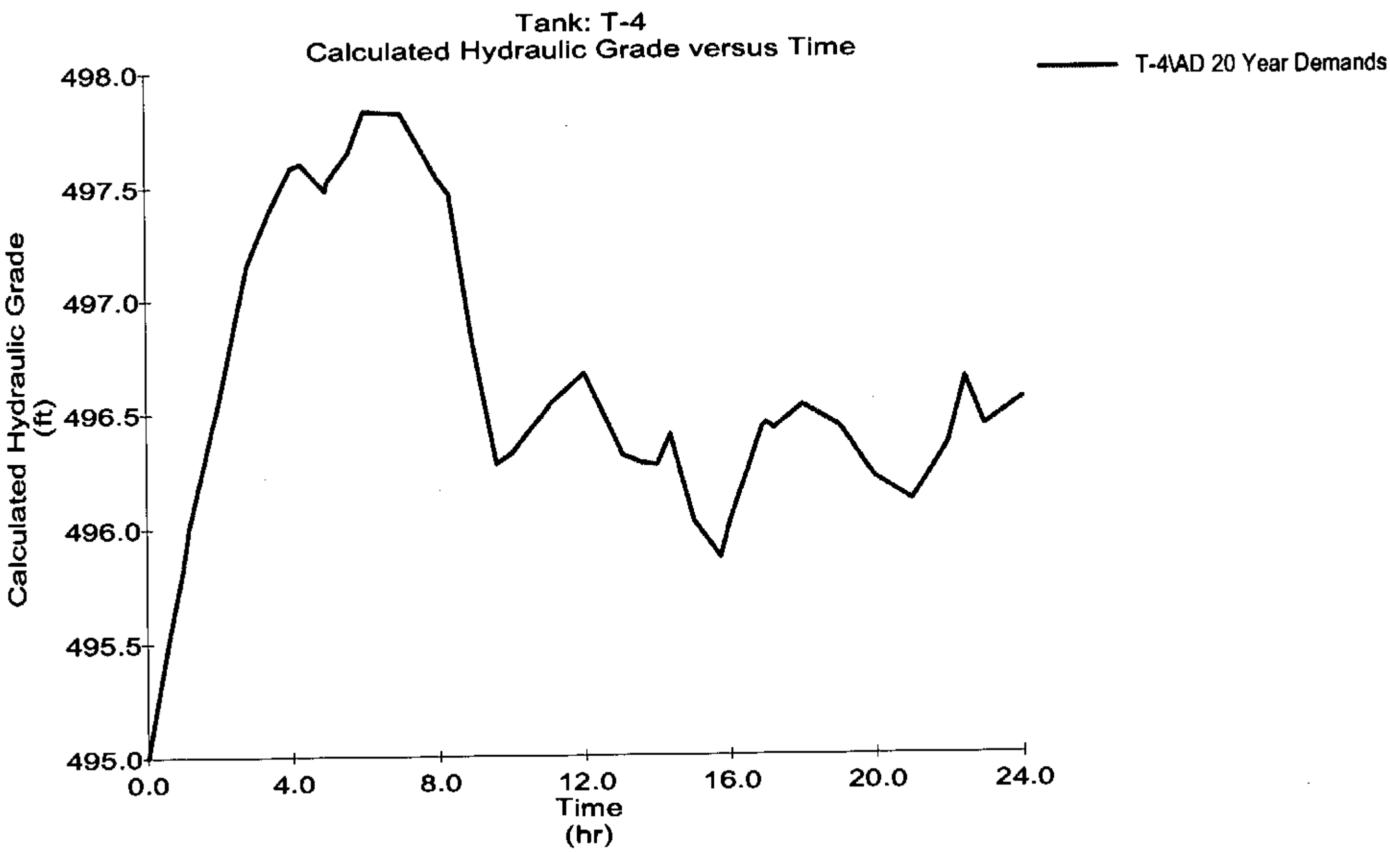
Graph

Carrs Pond Road Tank



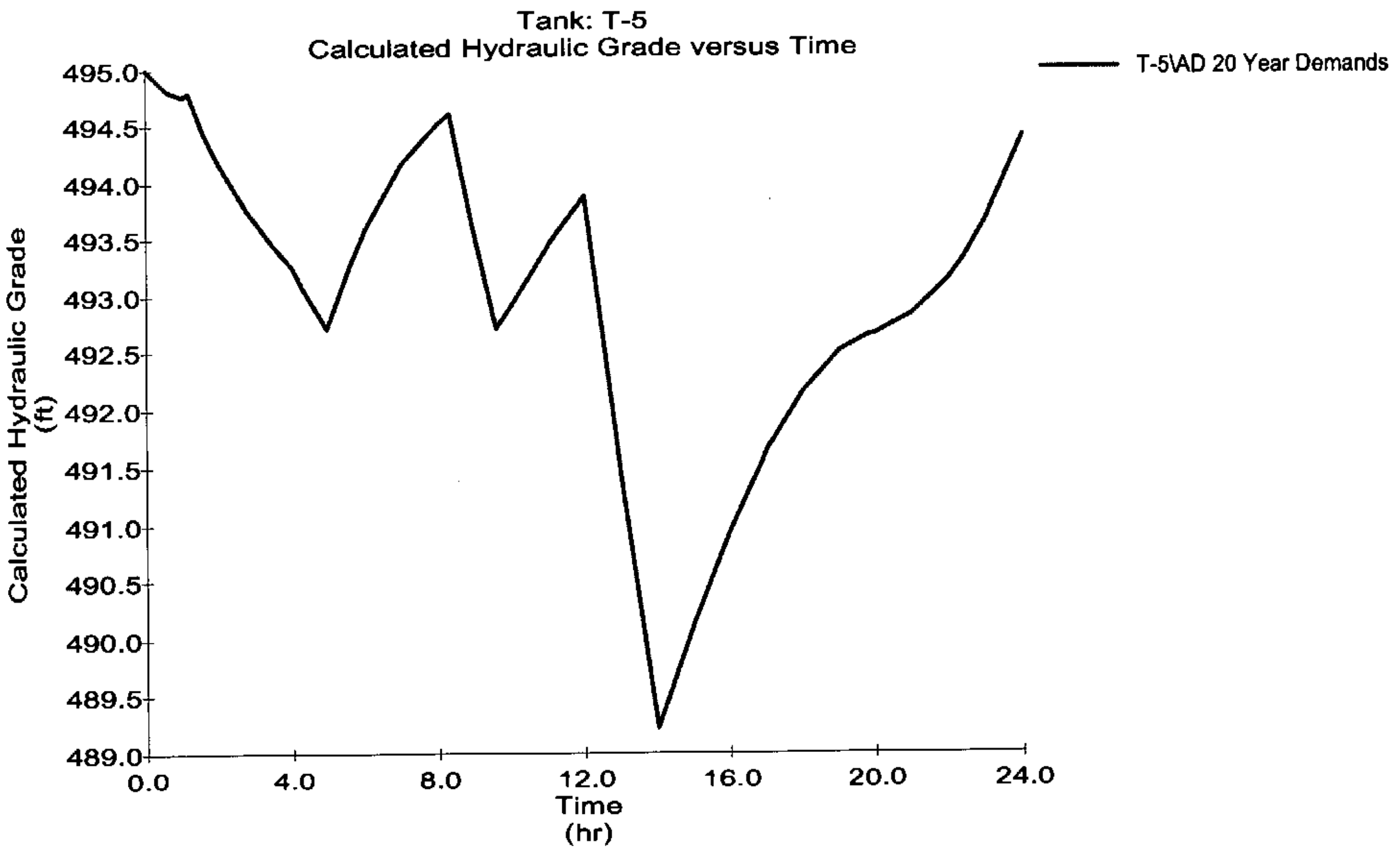
Graph

Technology Park Tank



Graph

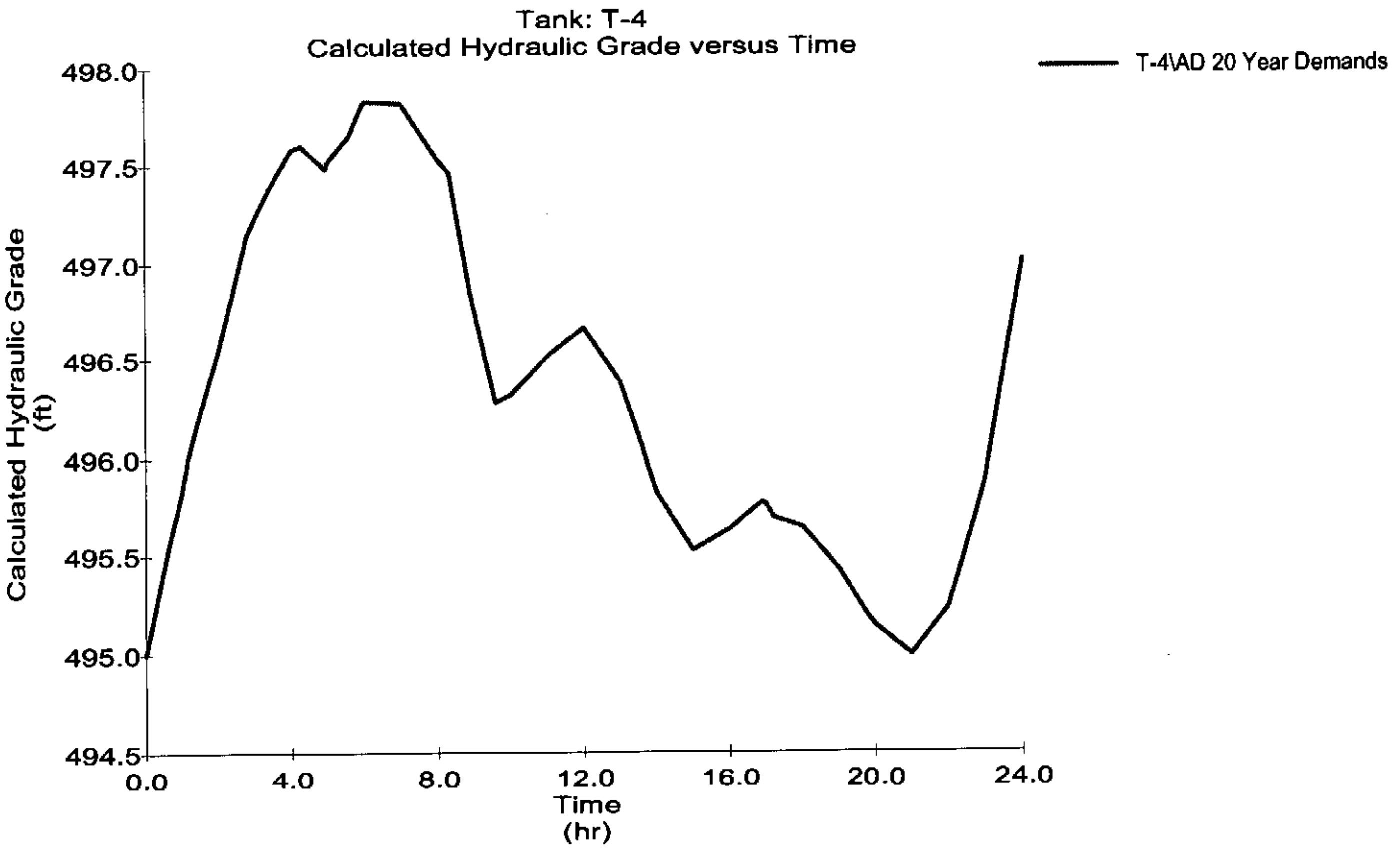
Carrs Pond Road Tank



- 2000 gpm fire flow at node J-4117
- Middle Rd.
- 16" DI main
- Elevation = 300 ft
- Average Day demand

Graph

Technology Park Tank



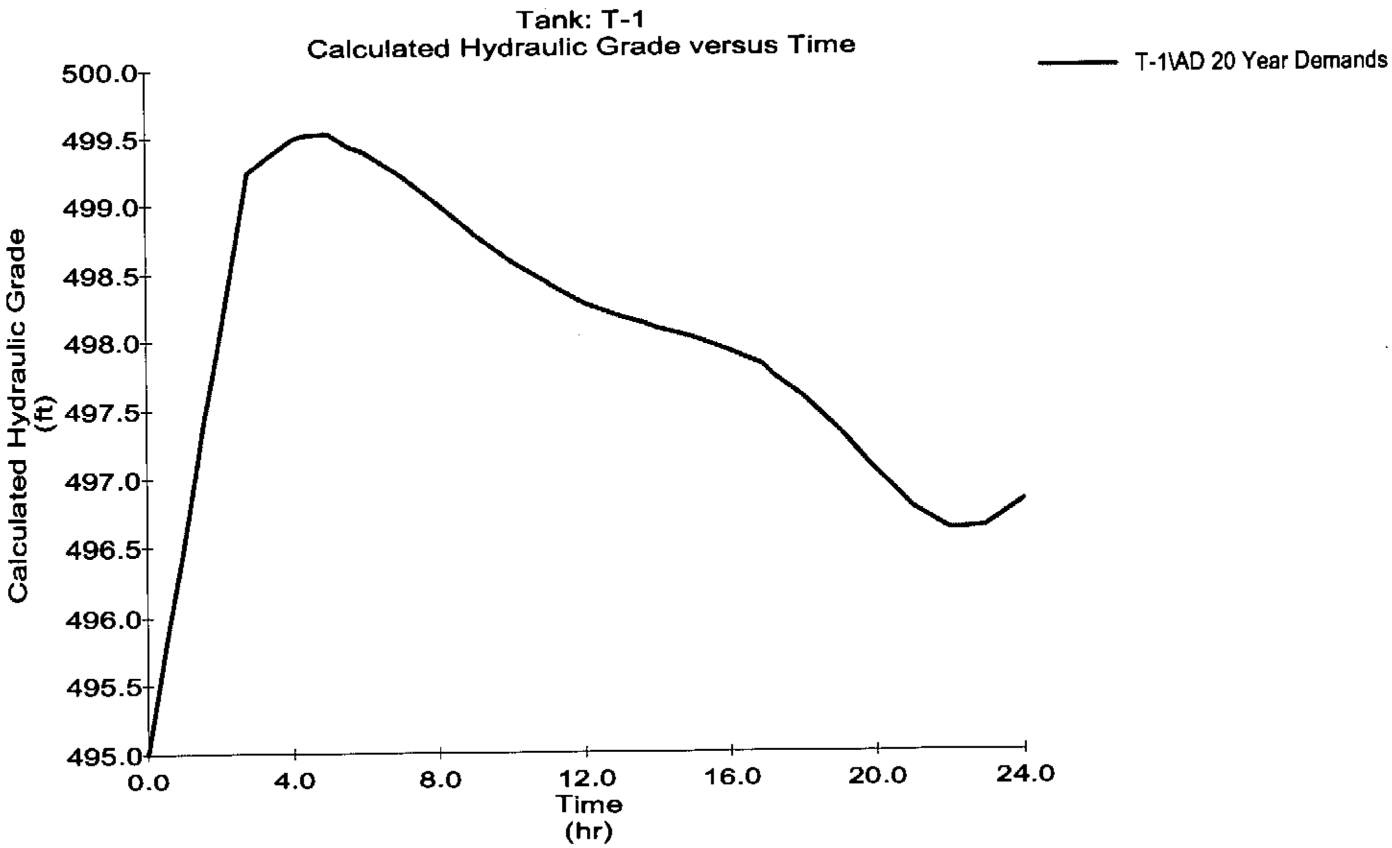
Title: KCWA Hydraulic Model
c:\...\kcwa hydraulic model.wcd
04/30/07 02:20:03 PM © Bentley Systems, Inc. Haestad Methods Solution Center Watertown, CT 06795 USA +1-203-755-1666

C&E Engineering

Project Engineer:
WaterCAD v7.0 [07.00.049.00]

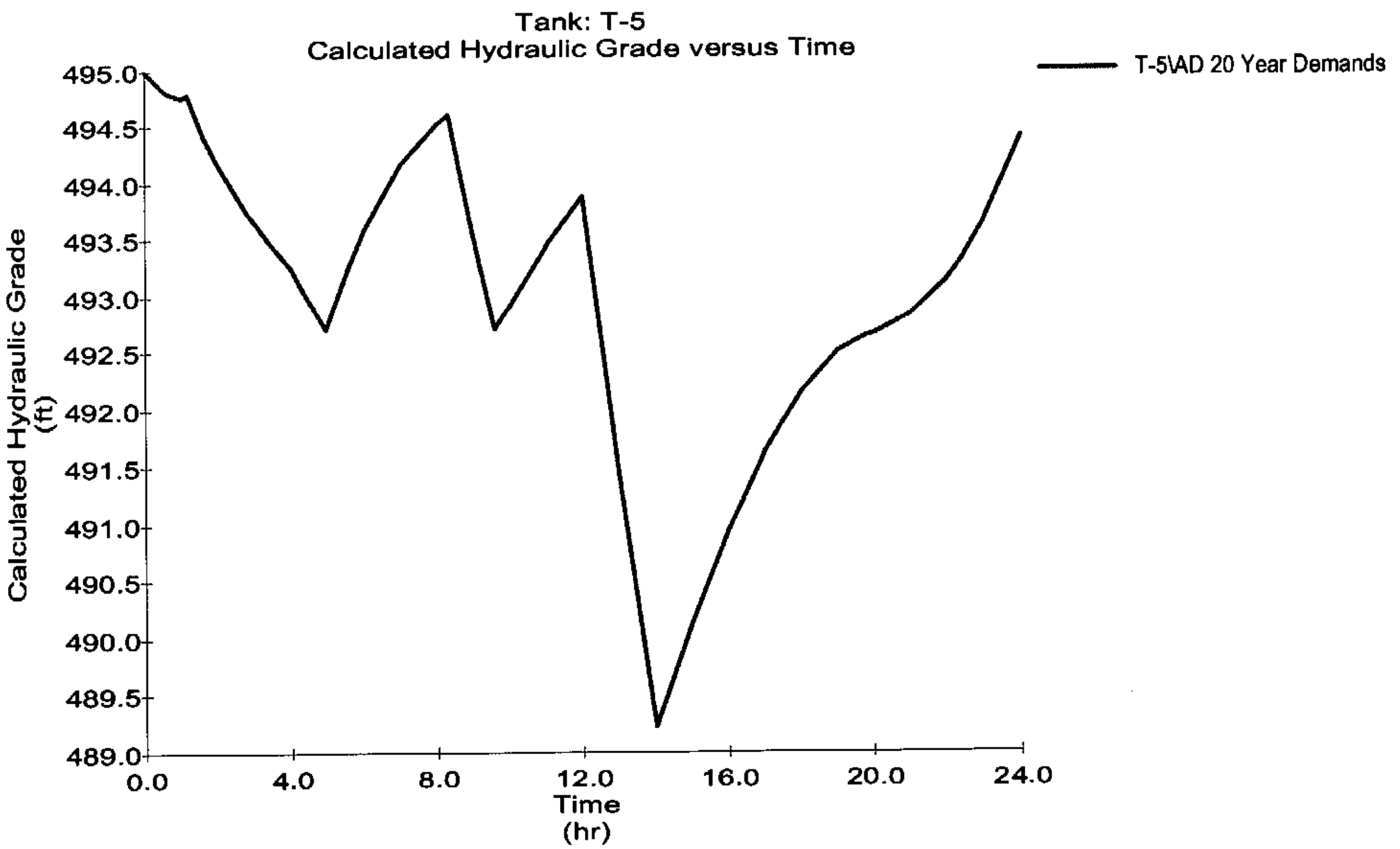
Graph

Read Schoolhouse Road Tank



Graph

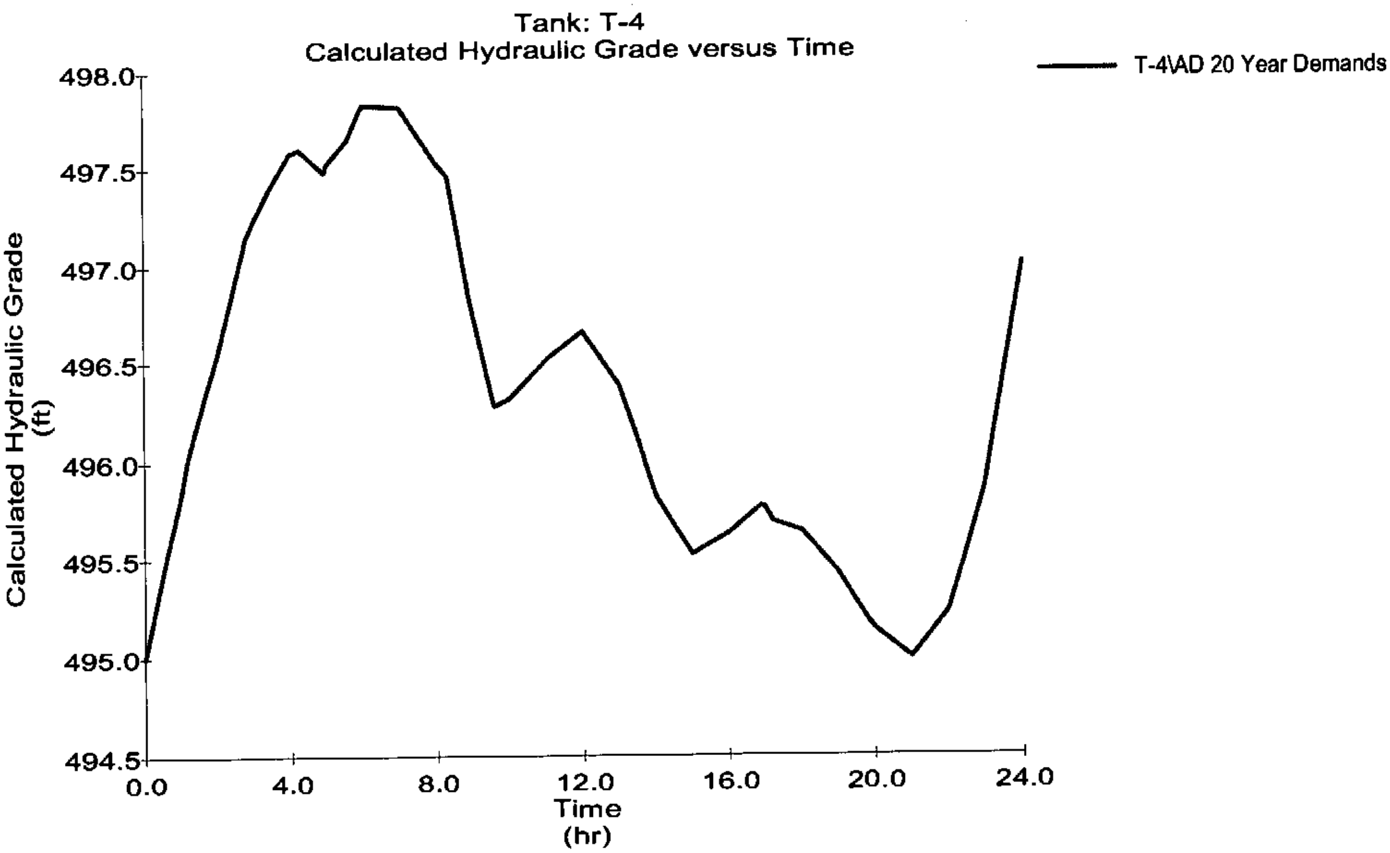
Carrs Pond Road Tank



- 2000 gpm fire flow at node J-4056
- Frenchtown Rd.
- 12" DI main
- Elevation = 246 ft
- Average Day demand

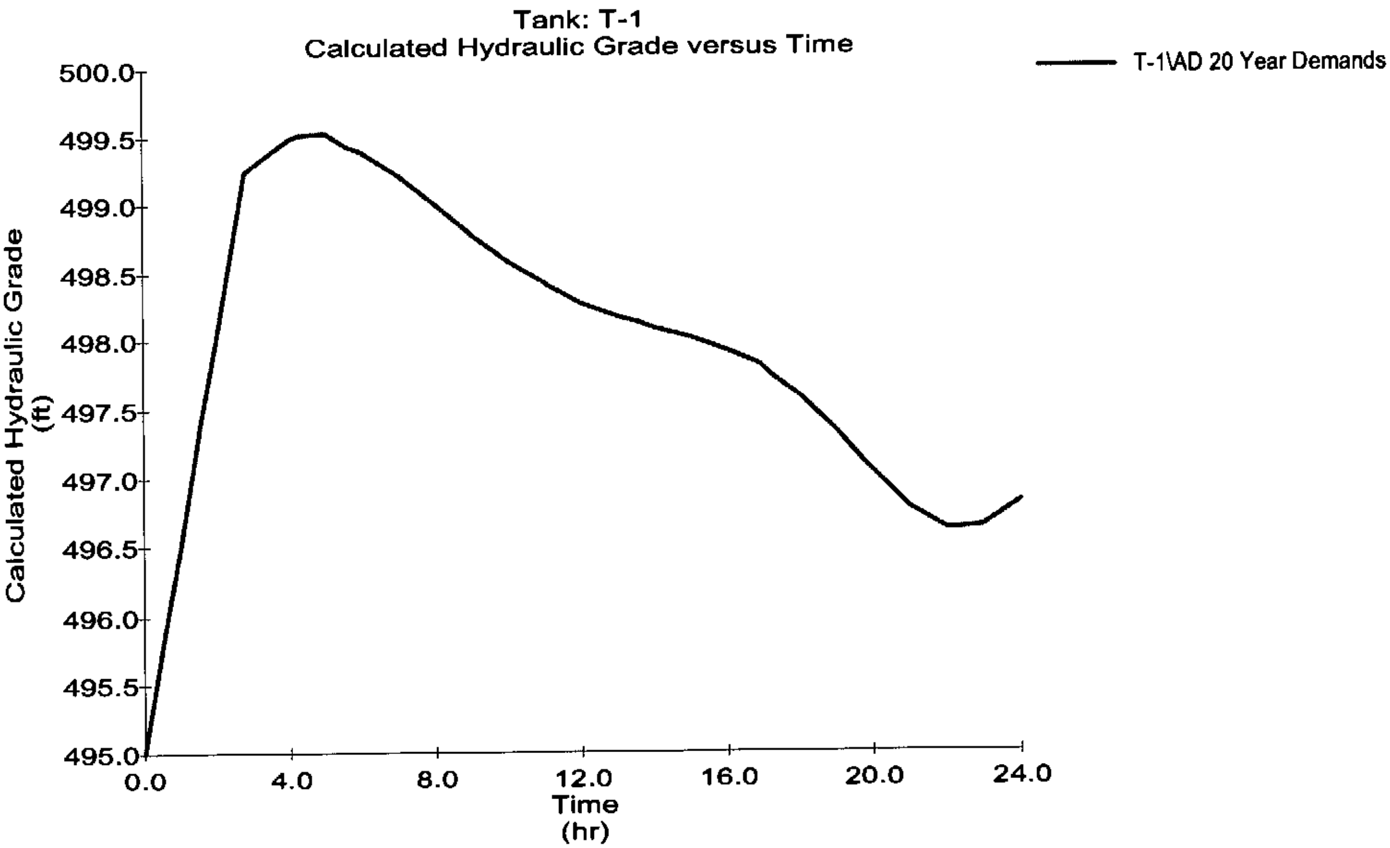
Graph

Technology Park Tank



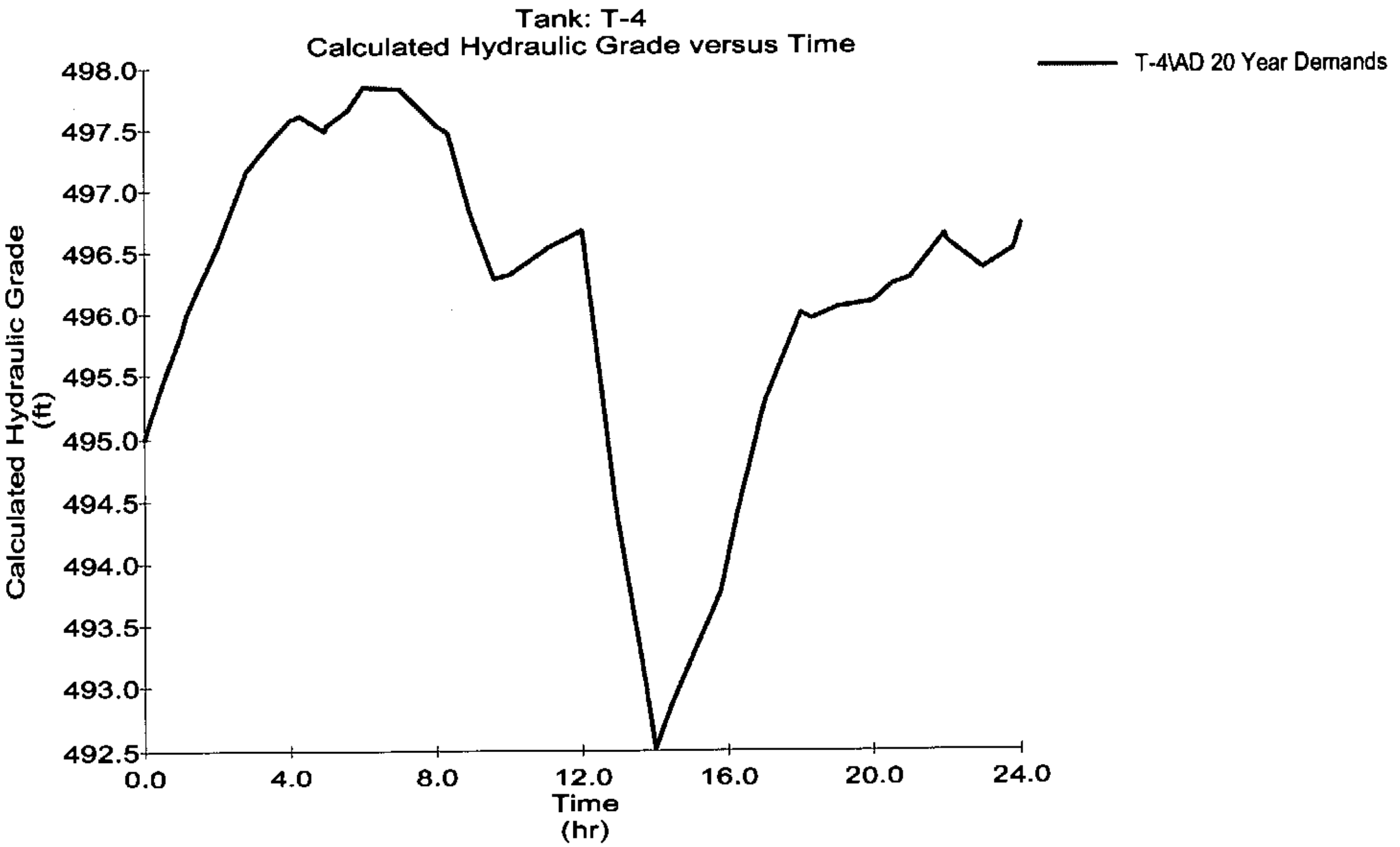
Graph

Read School House Road Tank



Graph

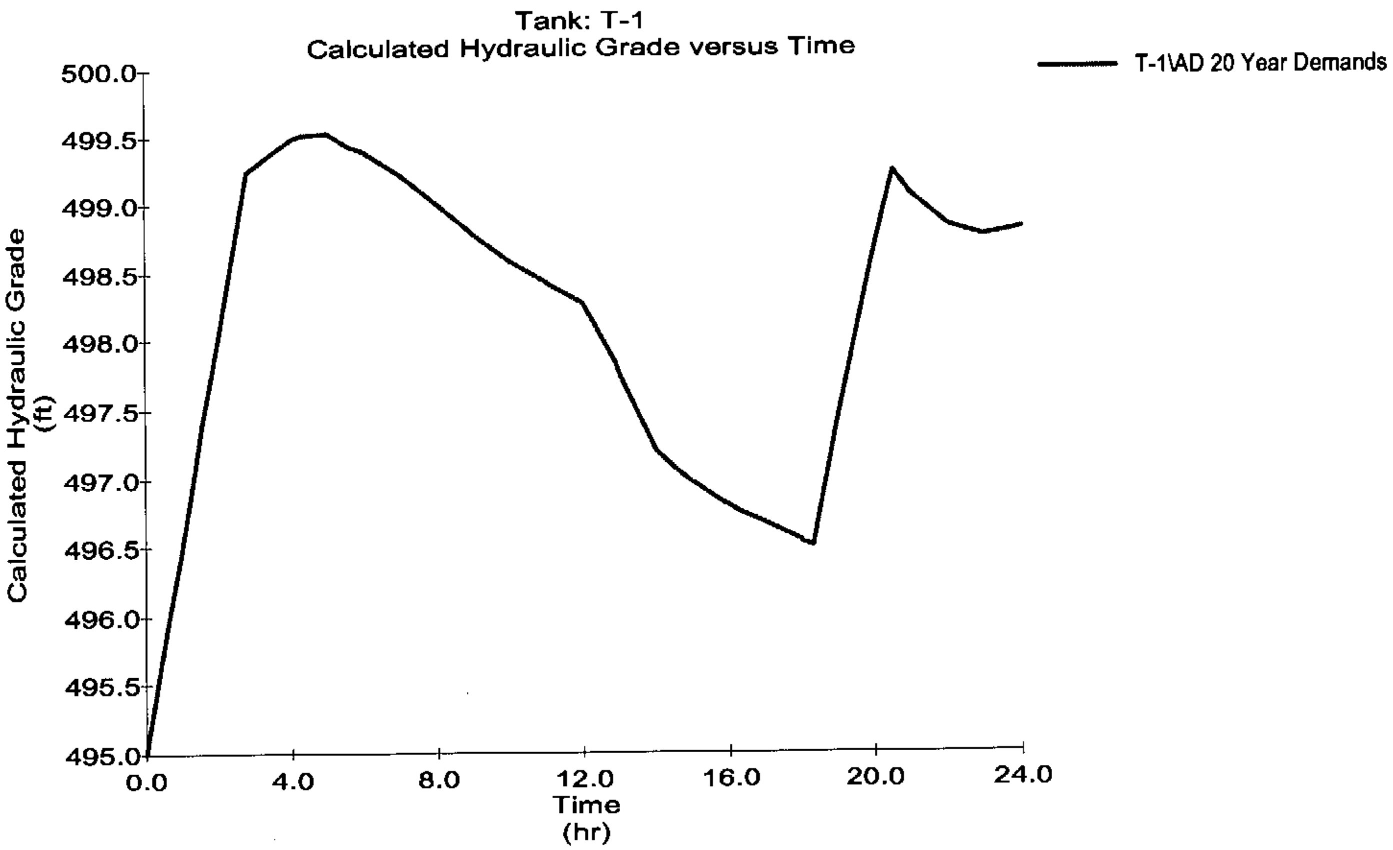
Technology Park Tank



- 2000 gpm fire flow at node J-8145
- Hopkins Hill Rd.
- 12" DI main
- Elevation = 316 ft
- Average Day demand

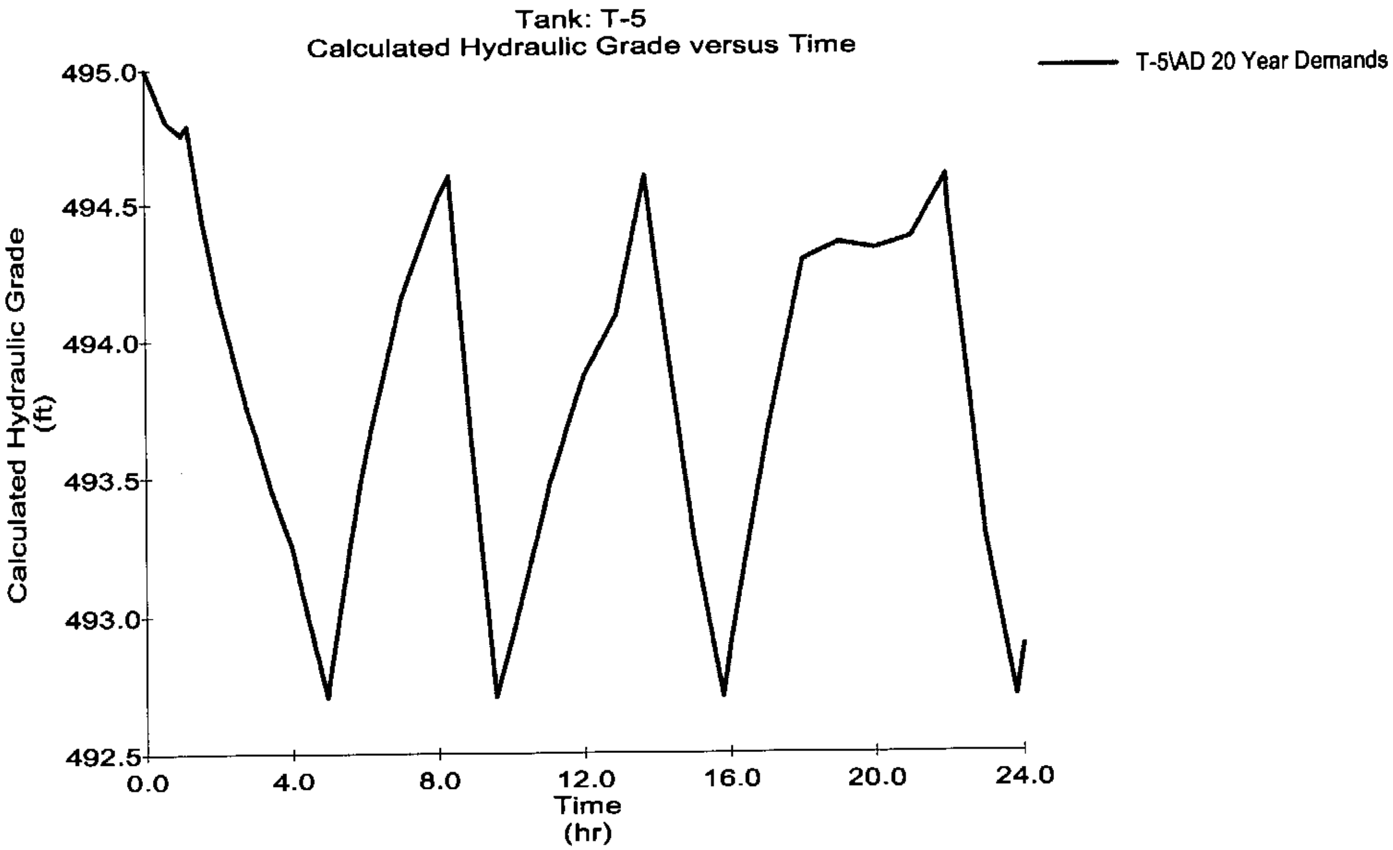
Graph

Read School House Road Tank



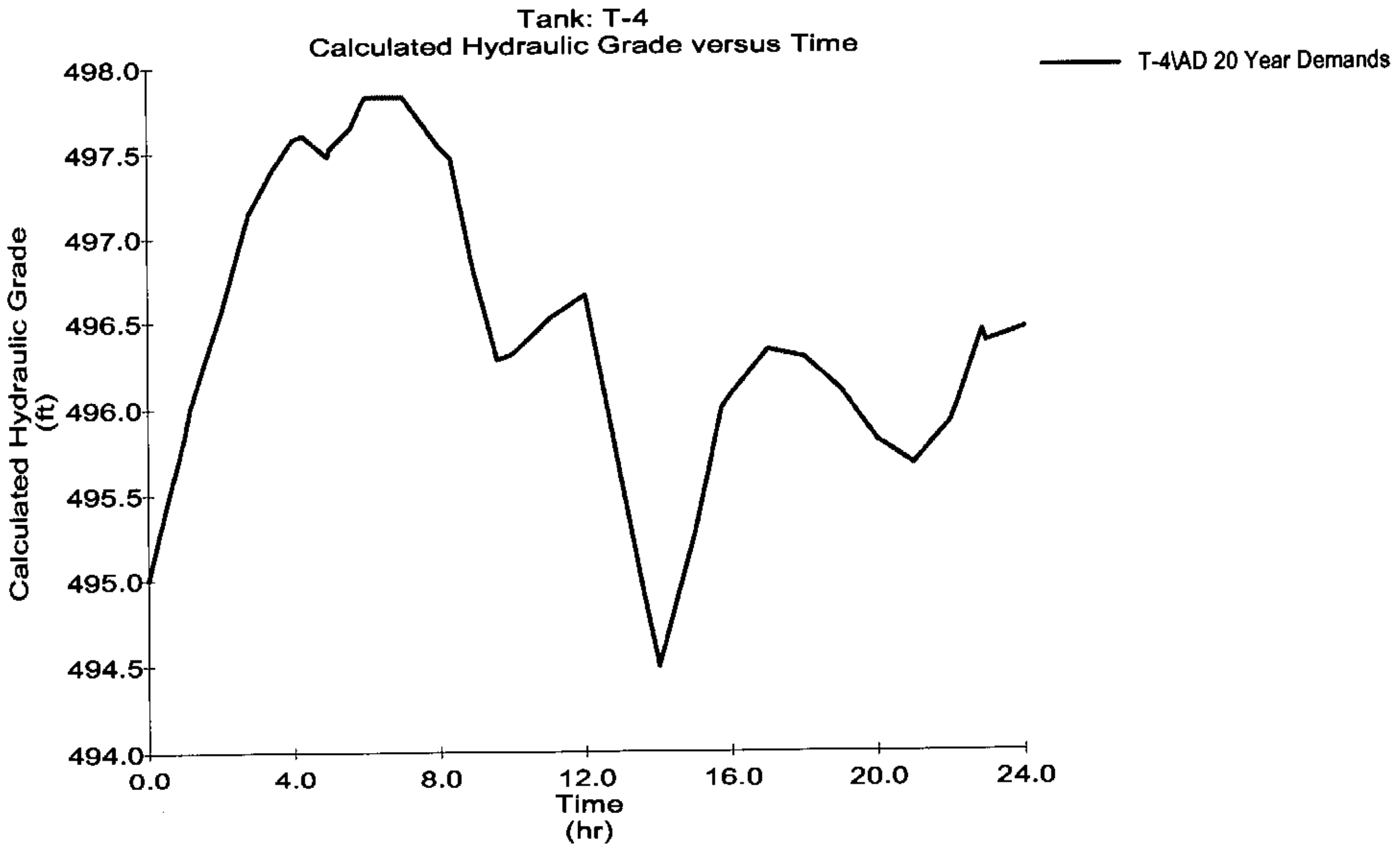
Graph

Carrs Pond Road Tank



Graph

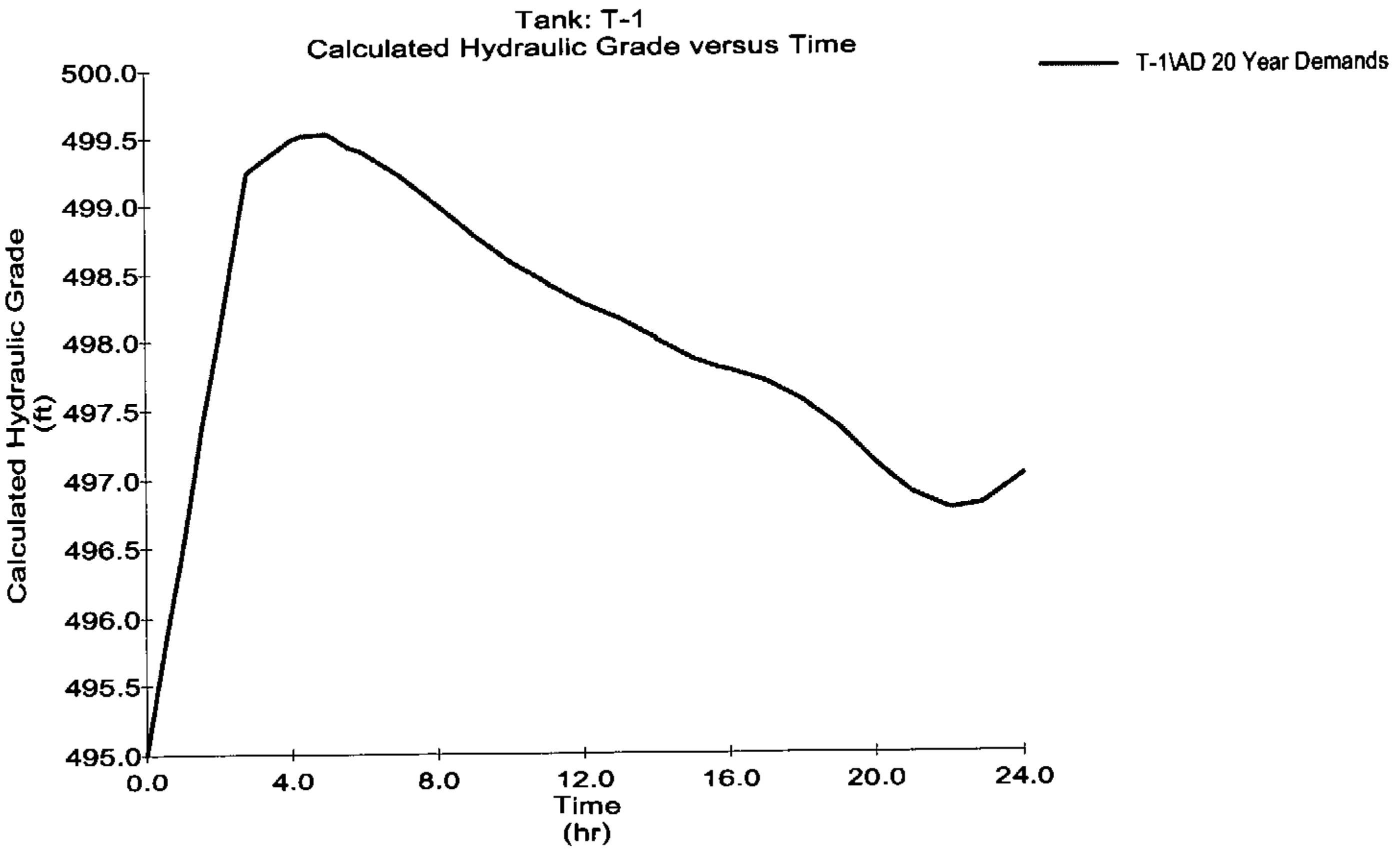
Technology Park Tank



- 2000 gpm fire flow at node J-951
- Lonsdale St.
- 12" AC main
- Elevation = 298 ft
- Average Day demand

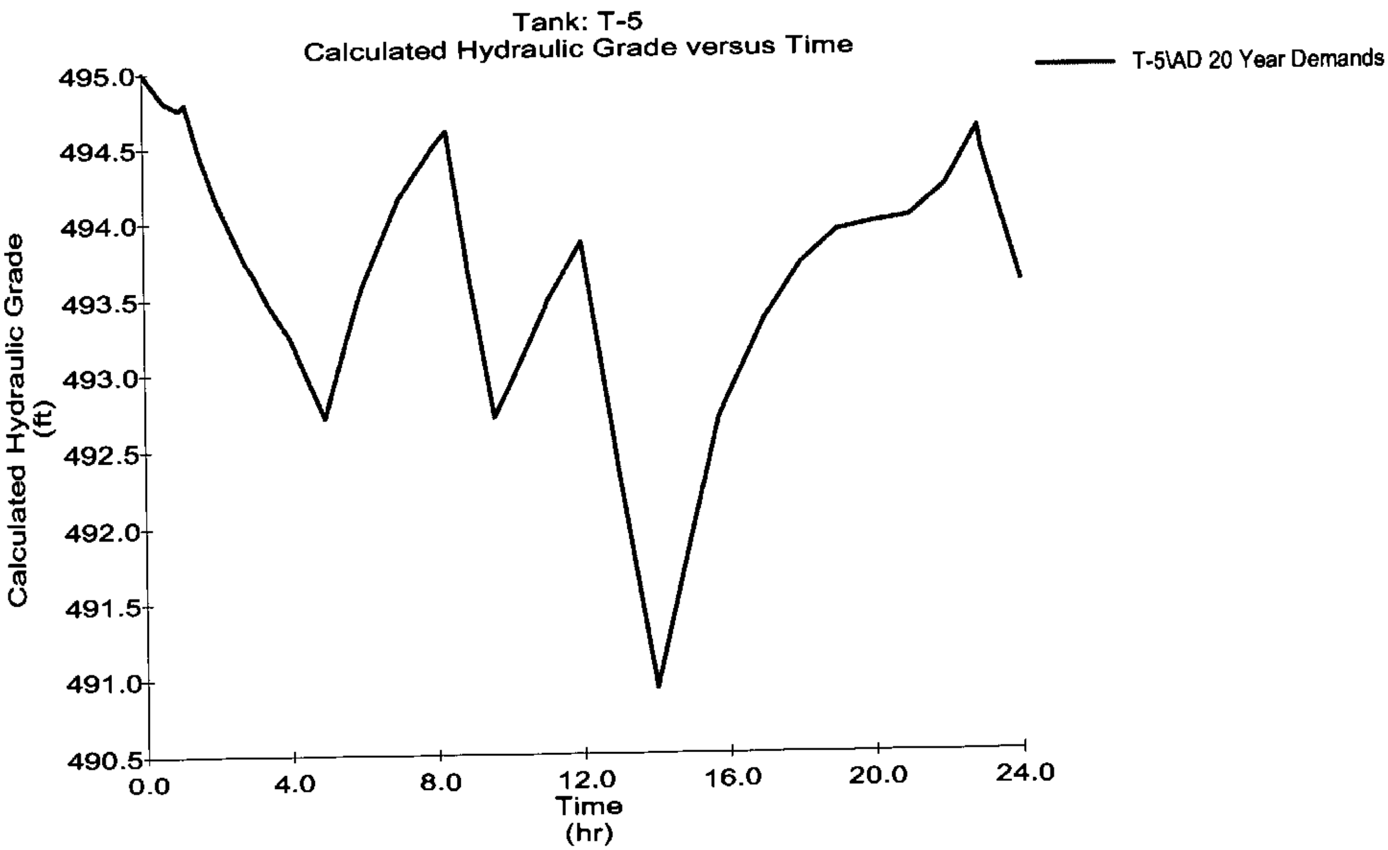
Graph

Read School House Road Tank



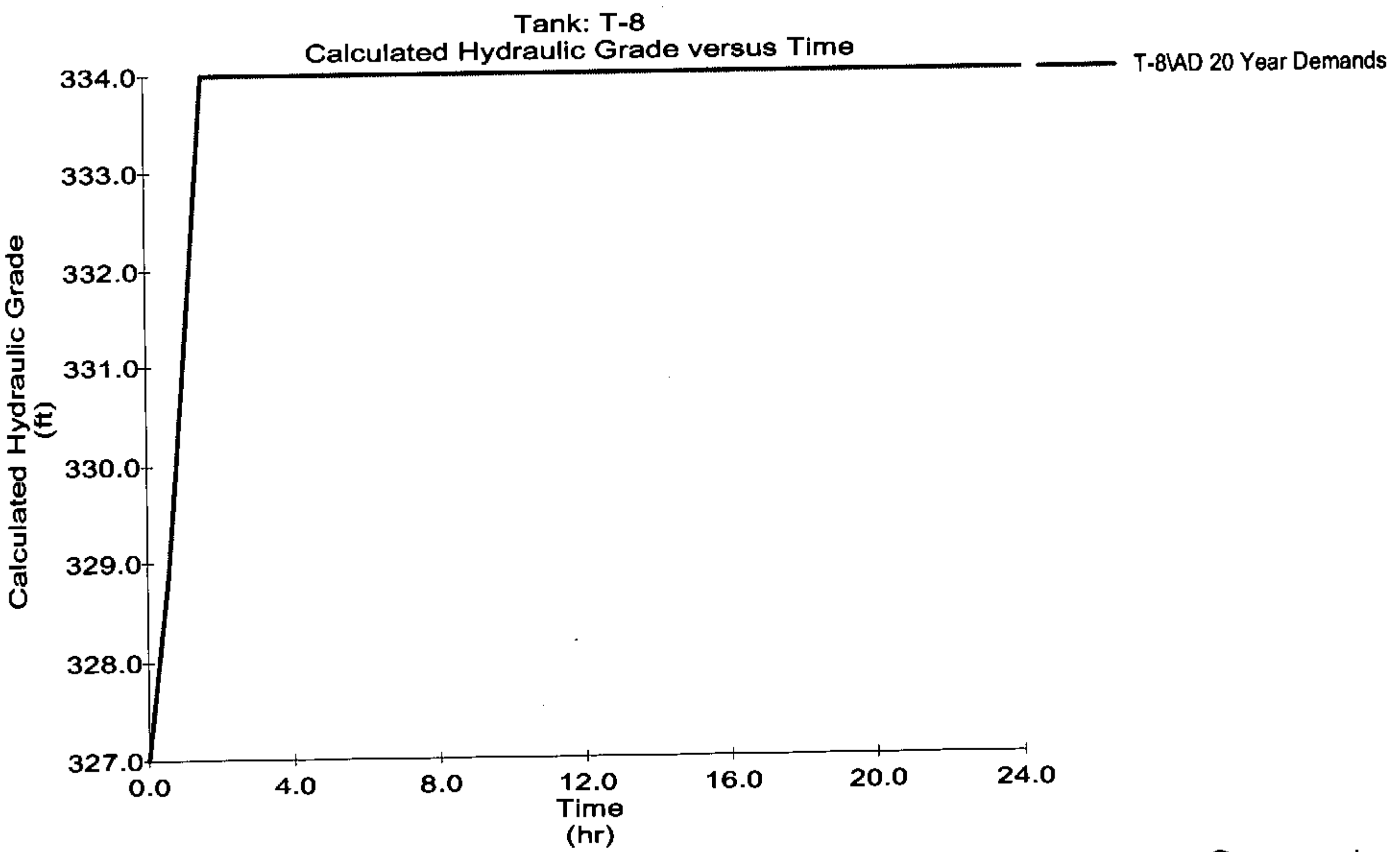
Graph

Carrs Pond Road Tank



Graph

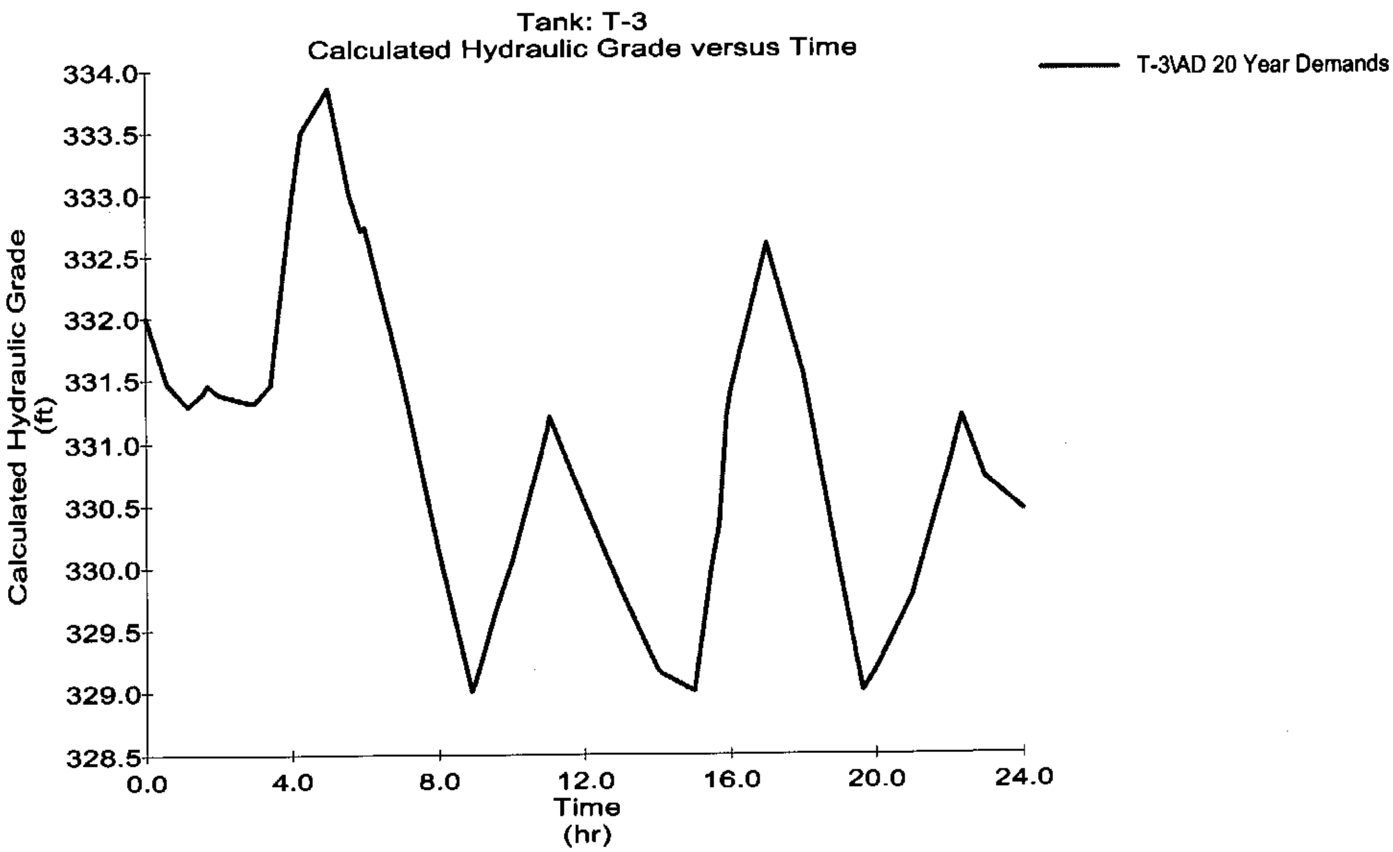
Wakefield Street Tank



- 2000 gpm fire flow at node J-727
- River Farms Dr.
- 12" PVC main
- Elevation = 190 ft
- Average Day demand

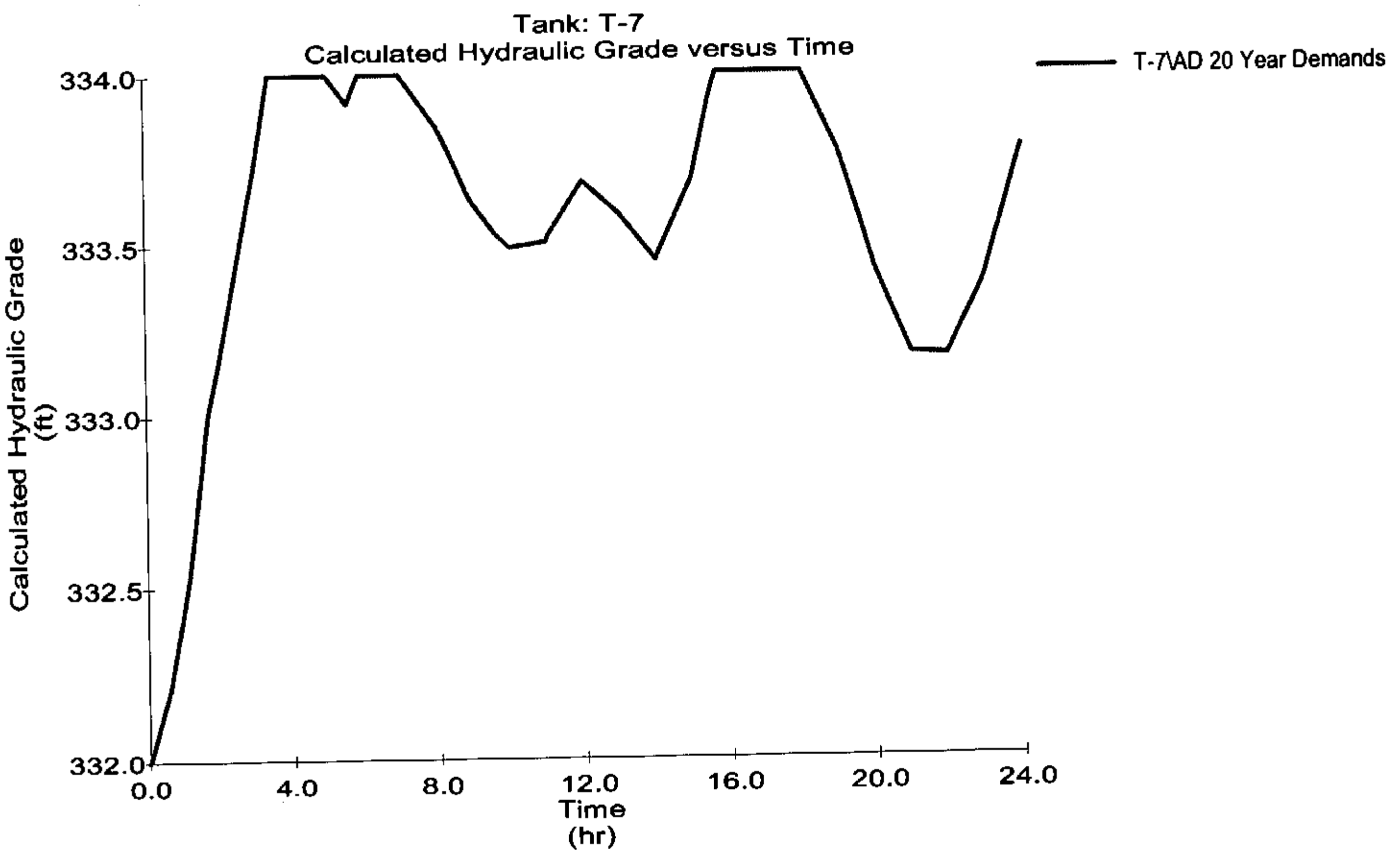
Graph

Frenchtown Road Tank



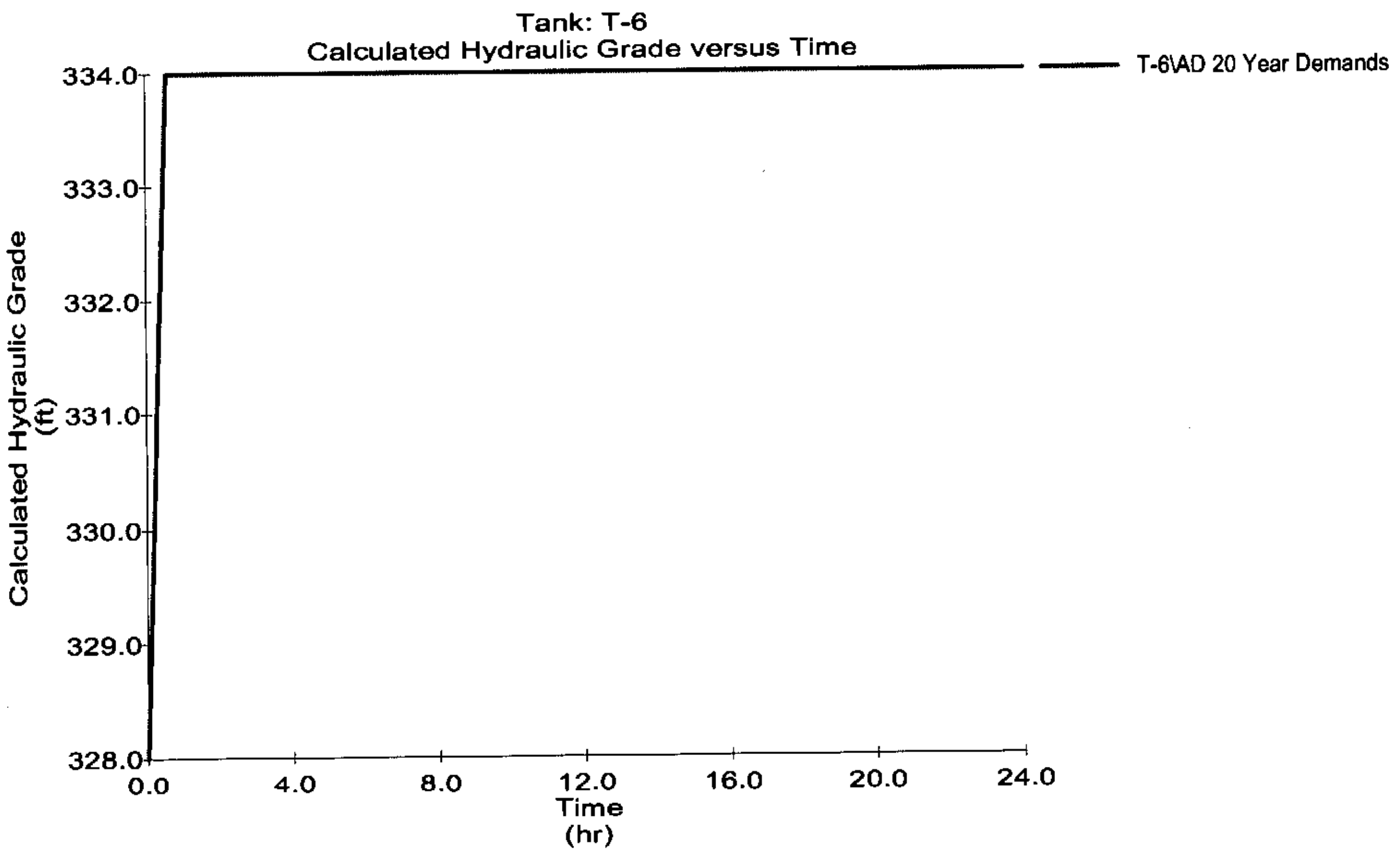
Graph

Setian Lane Tank



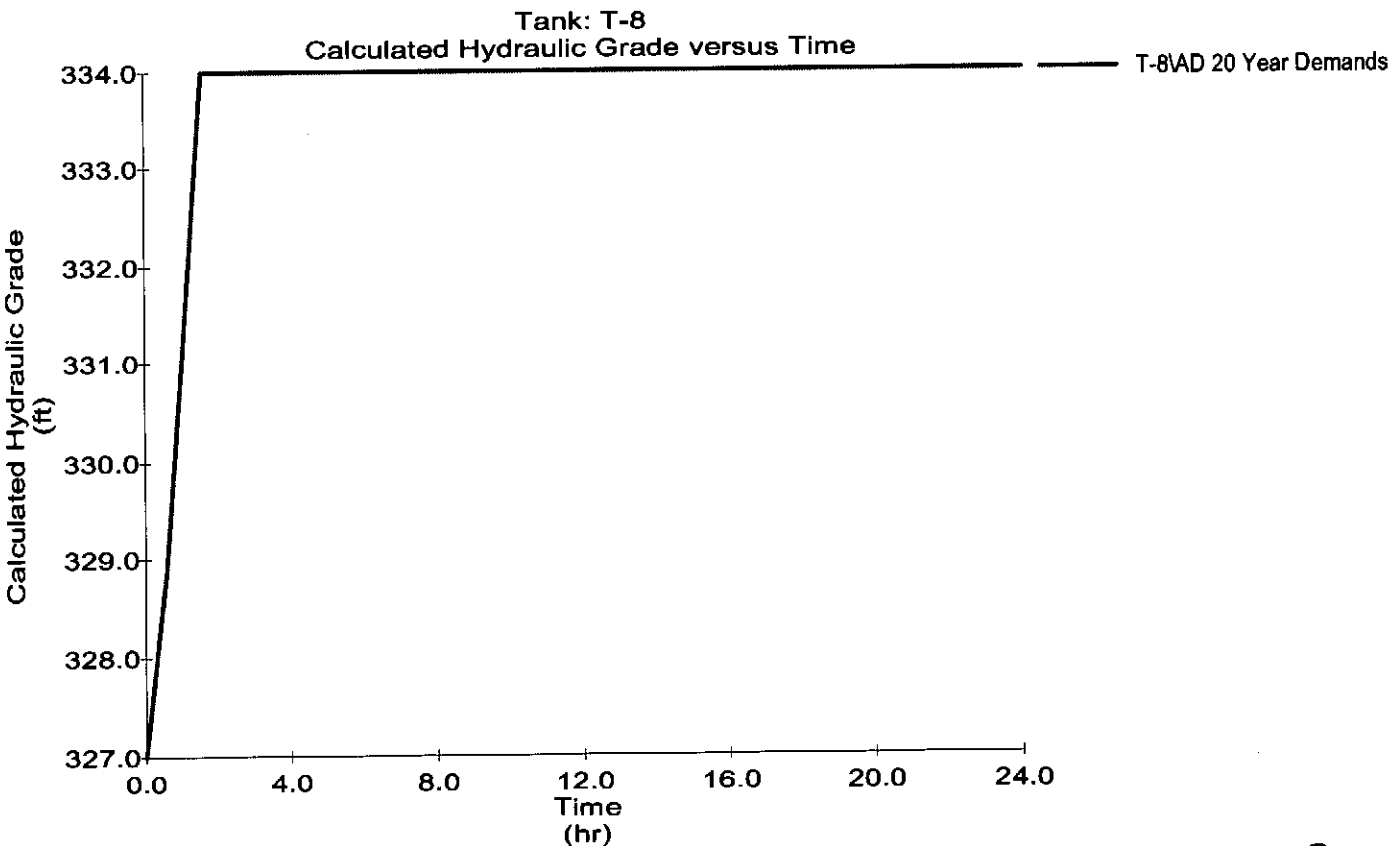
Graph

West Street Tank



Graph

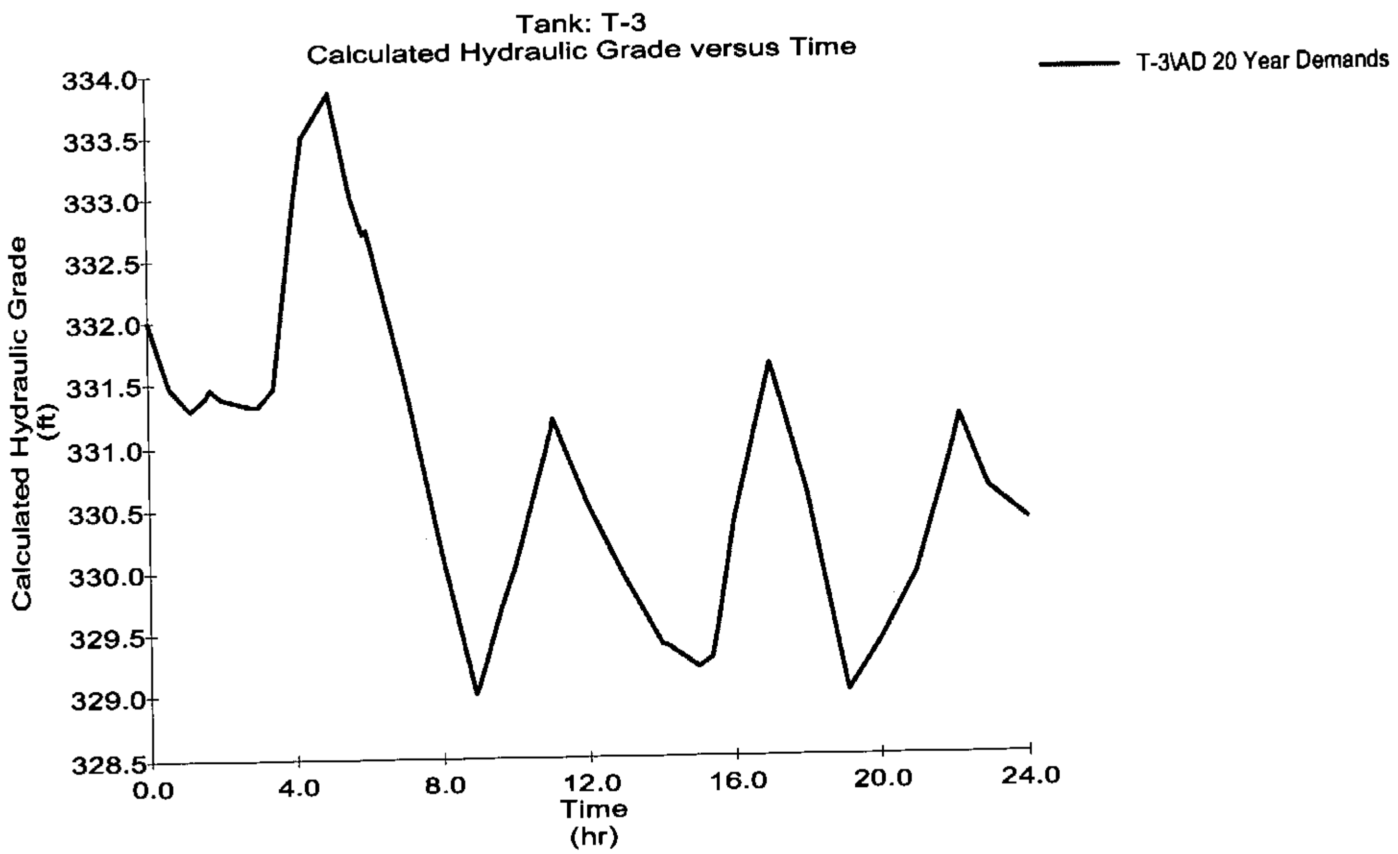
Wakefield Street Tank



- 2000 gpm fire flow at node J-769
- Main St.
- 20" DI main
- Elevation = 92 ft
- Average Day demand

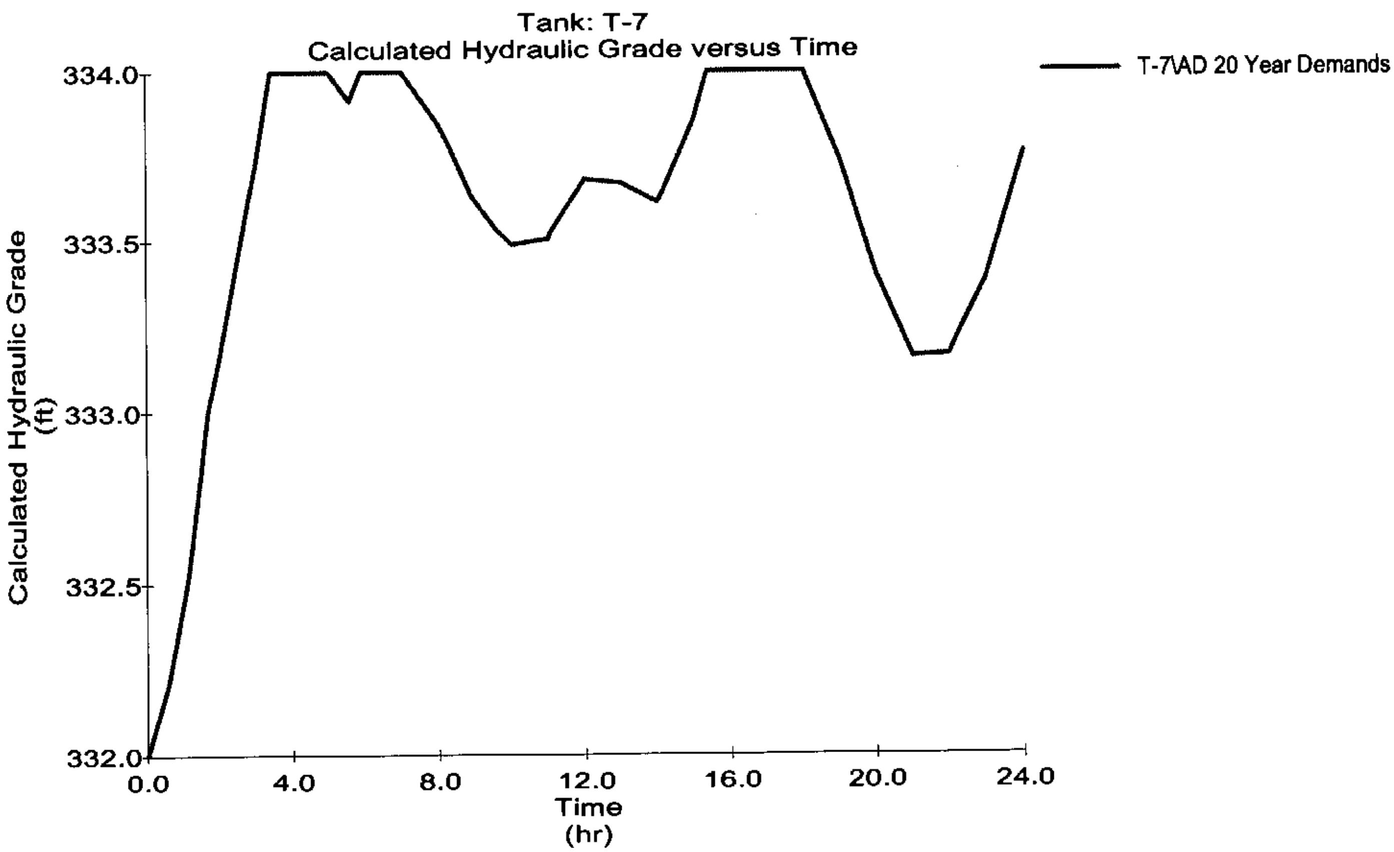
Graph

Frenchtown Road Tank



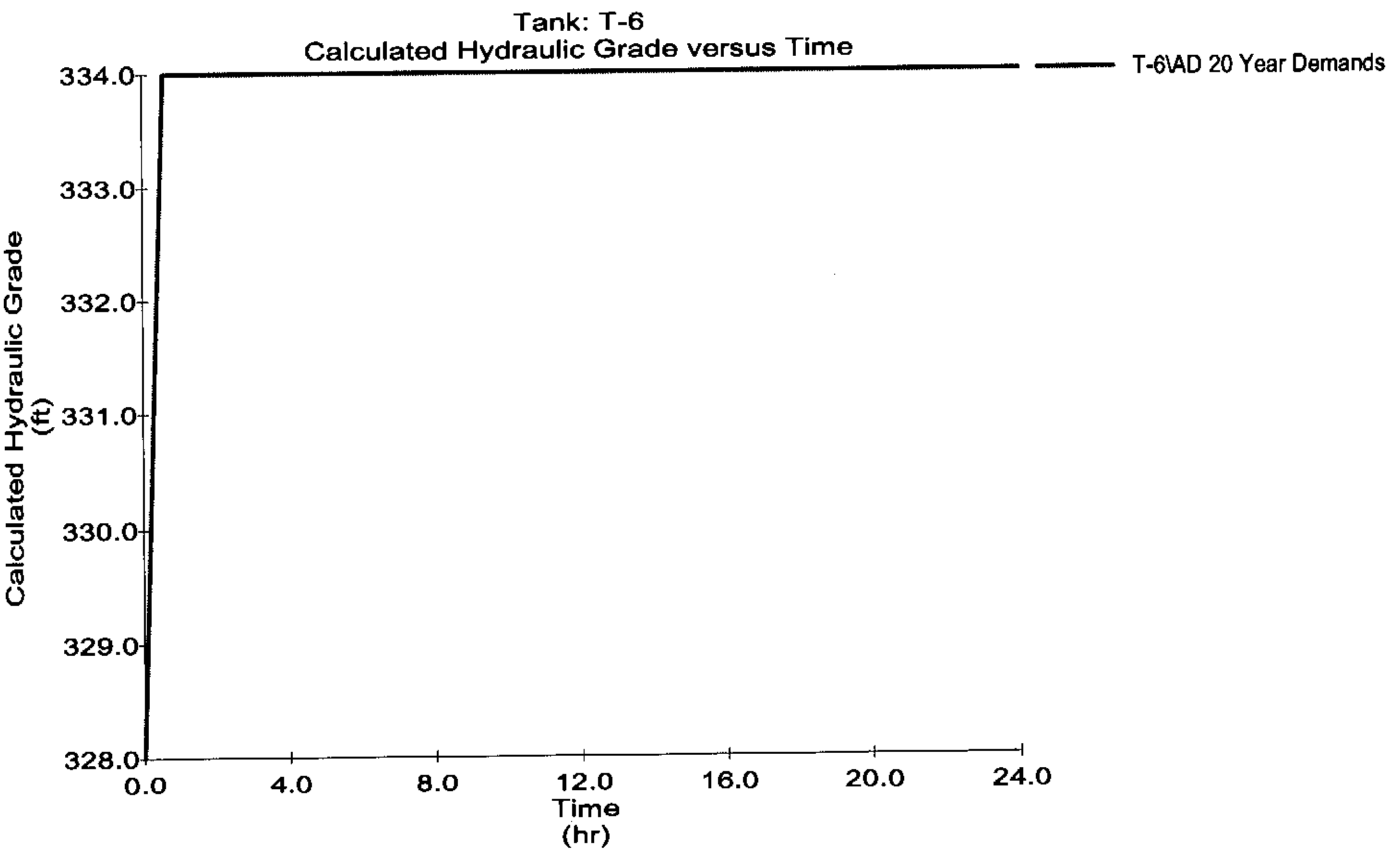
Graph

Setian Lane Tank



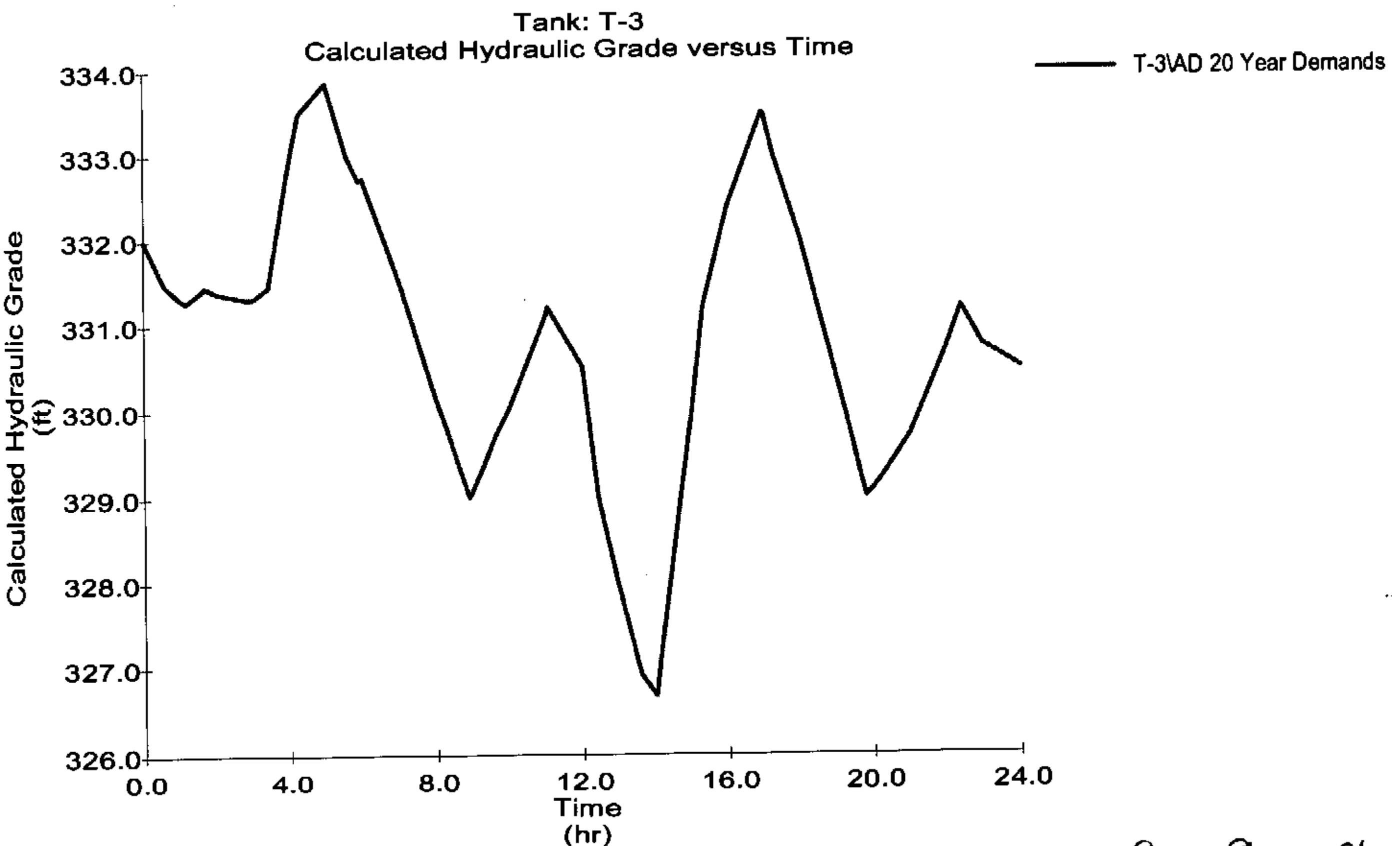
Graph

West Street Tank



Graph

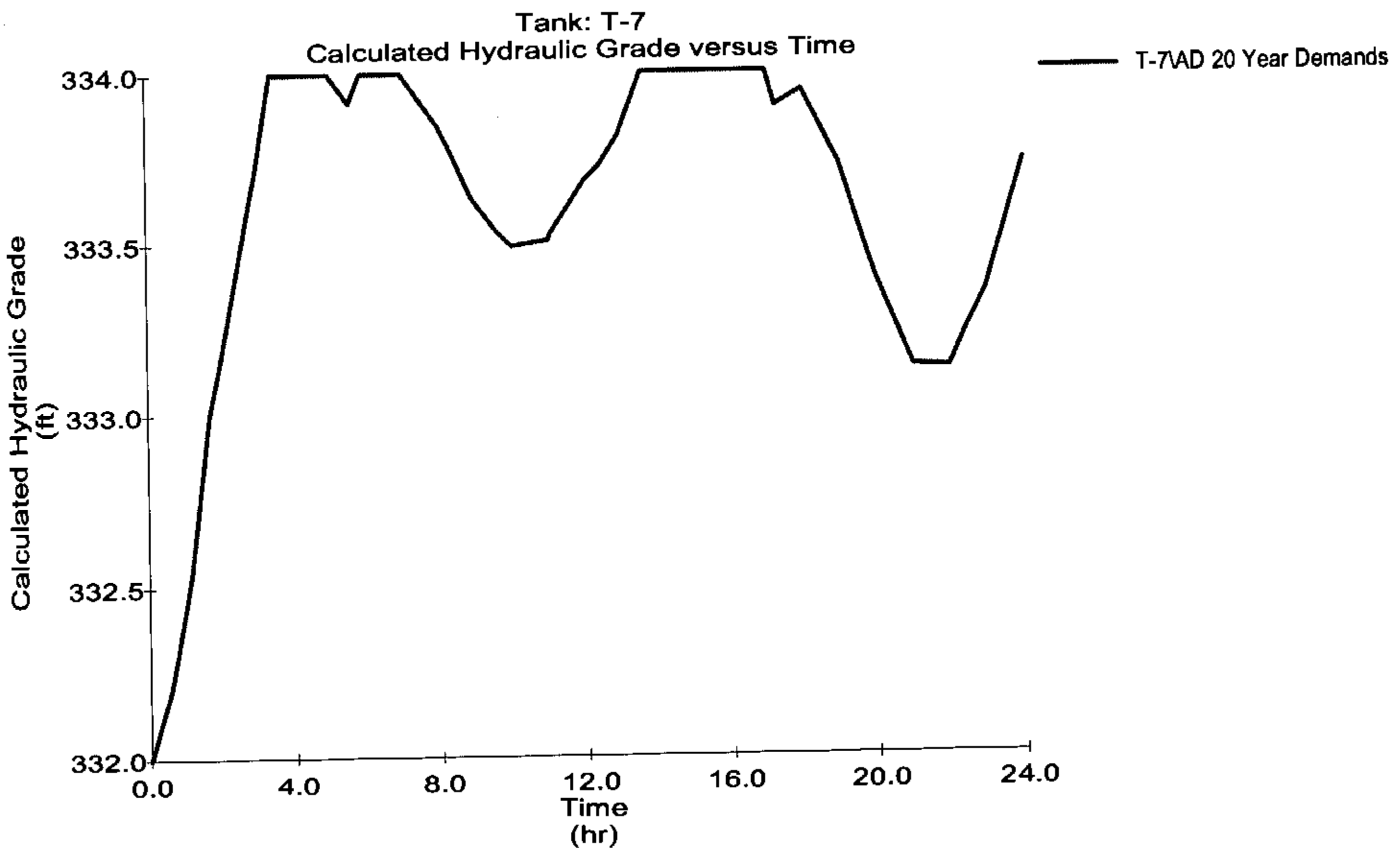
Frenchtown Road Tank



- 2000 gpm fire flow at node J-4091
- Frenchtown Rd.
- 20" AC main
- Elevation = 247 ft
- Average Day demand

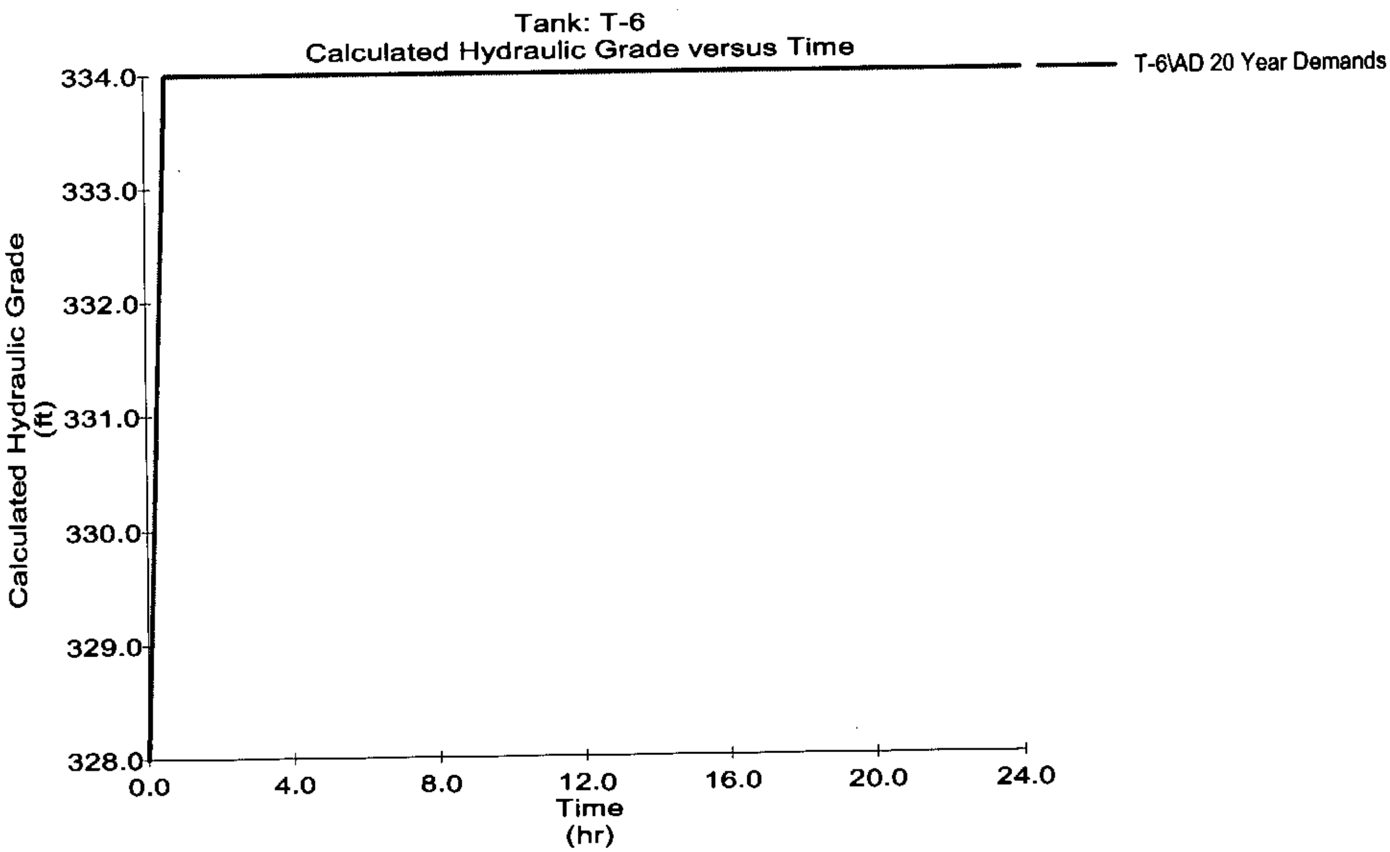
Graph

Setian Lane Tank



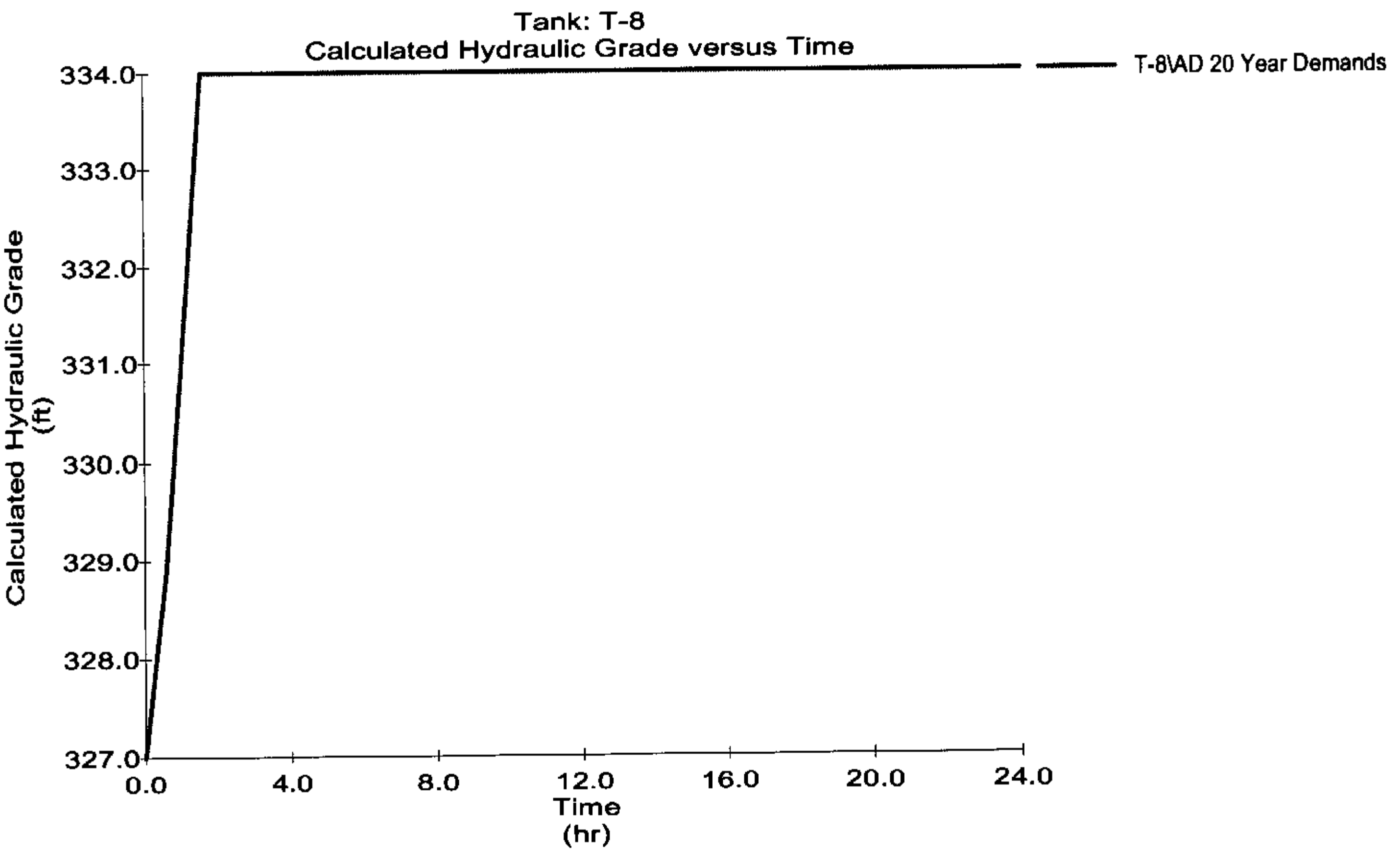
Graph

West Street Tank



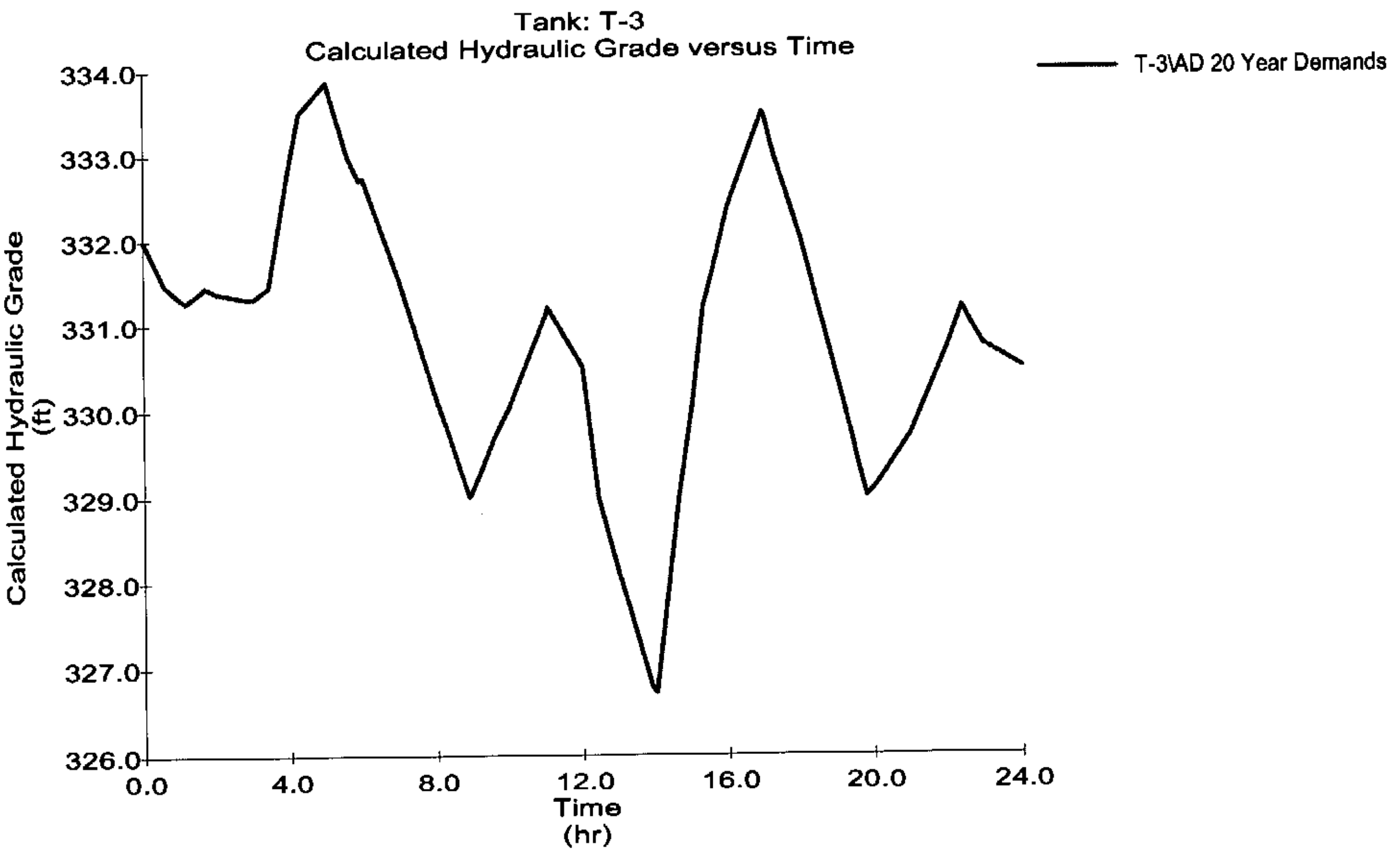
Graph

Wakefield Street Tank



Graph

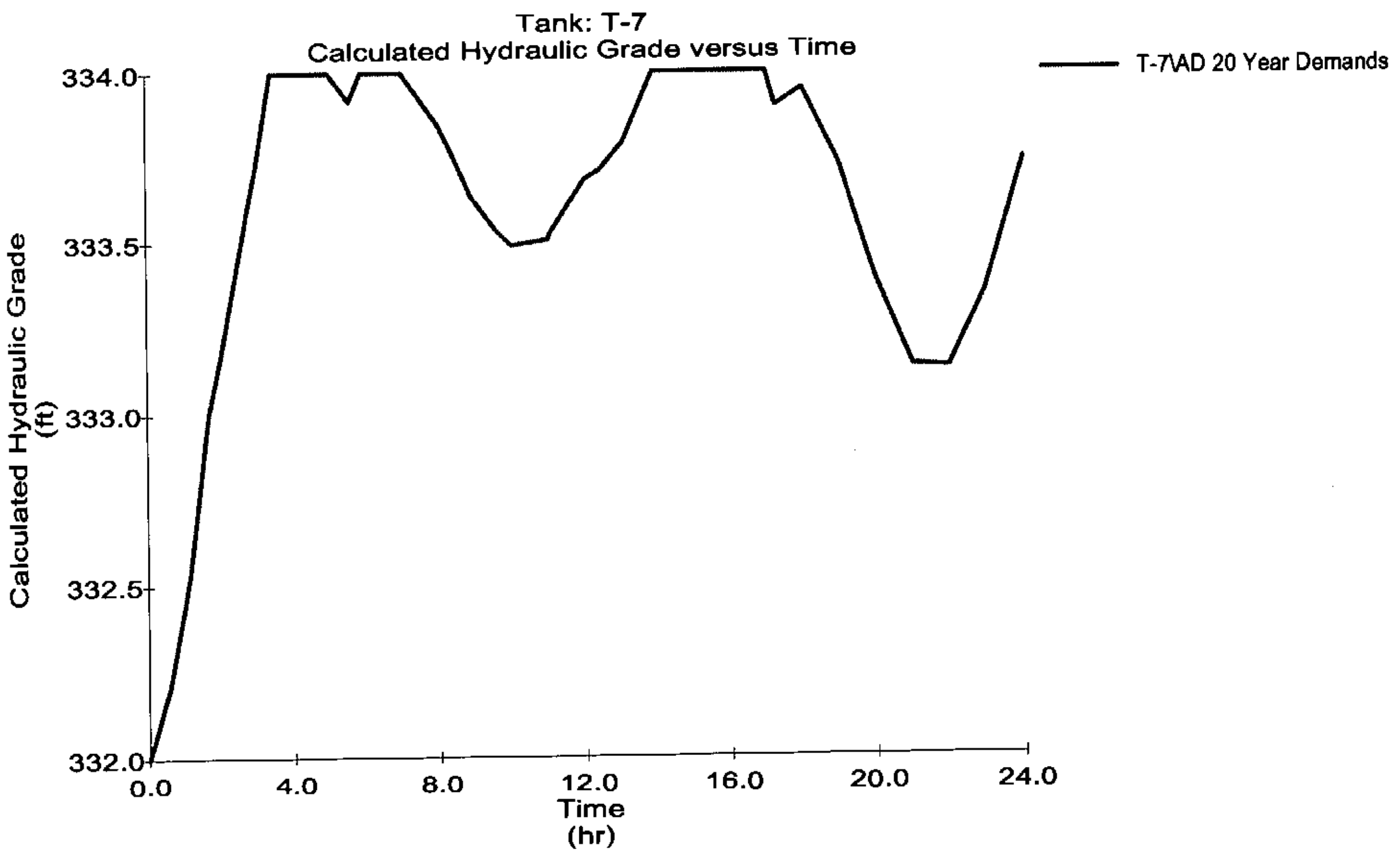
Frenchtown Road Tank



- 2000 gpm fire flow at node J-4175
- South County Tr.
- 12" AC main
- Elevation = 109 ft
- Average Day demand

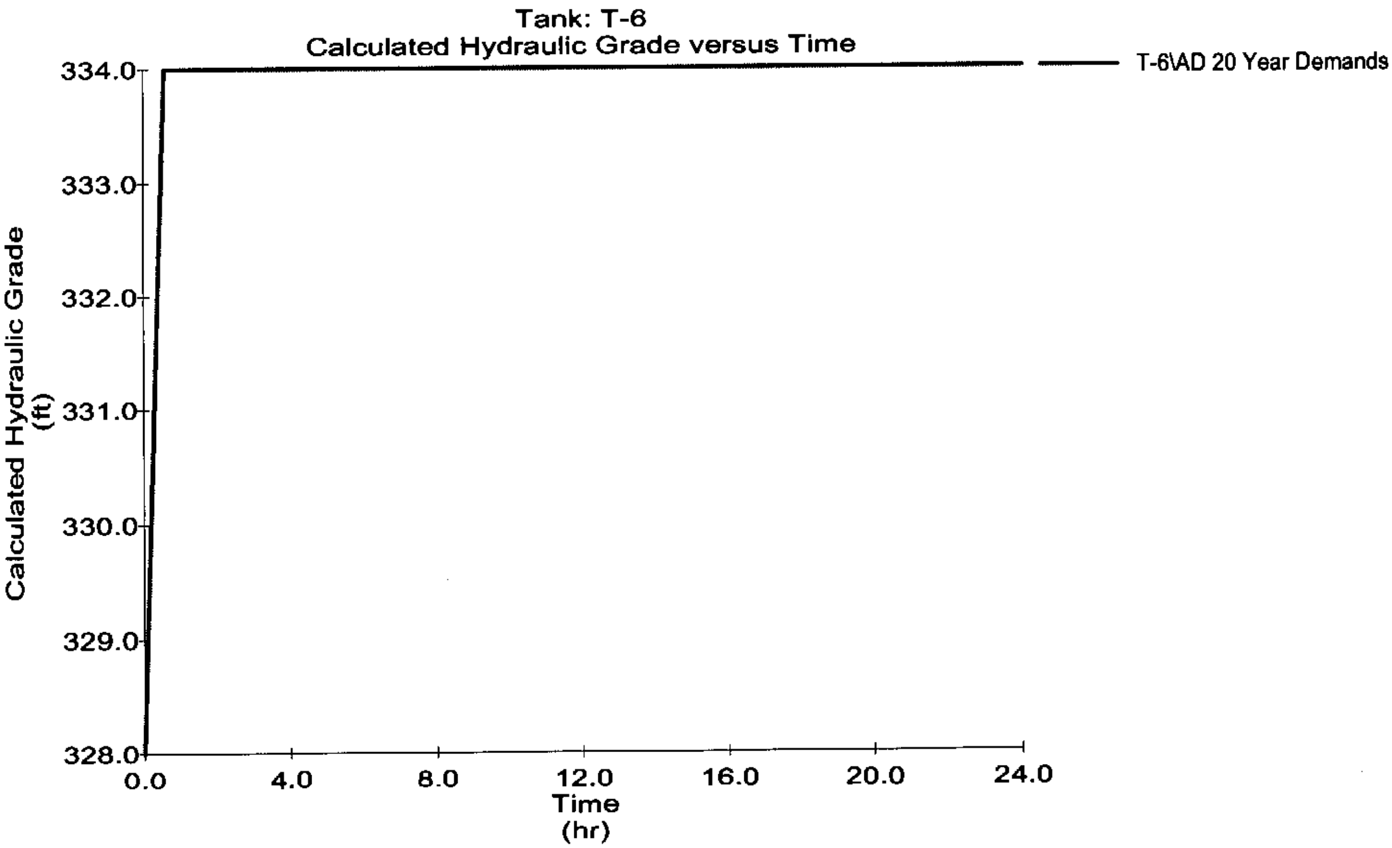
Graph

Setian Lane Tank



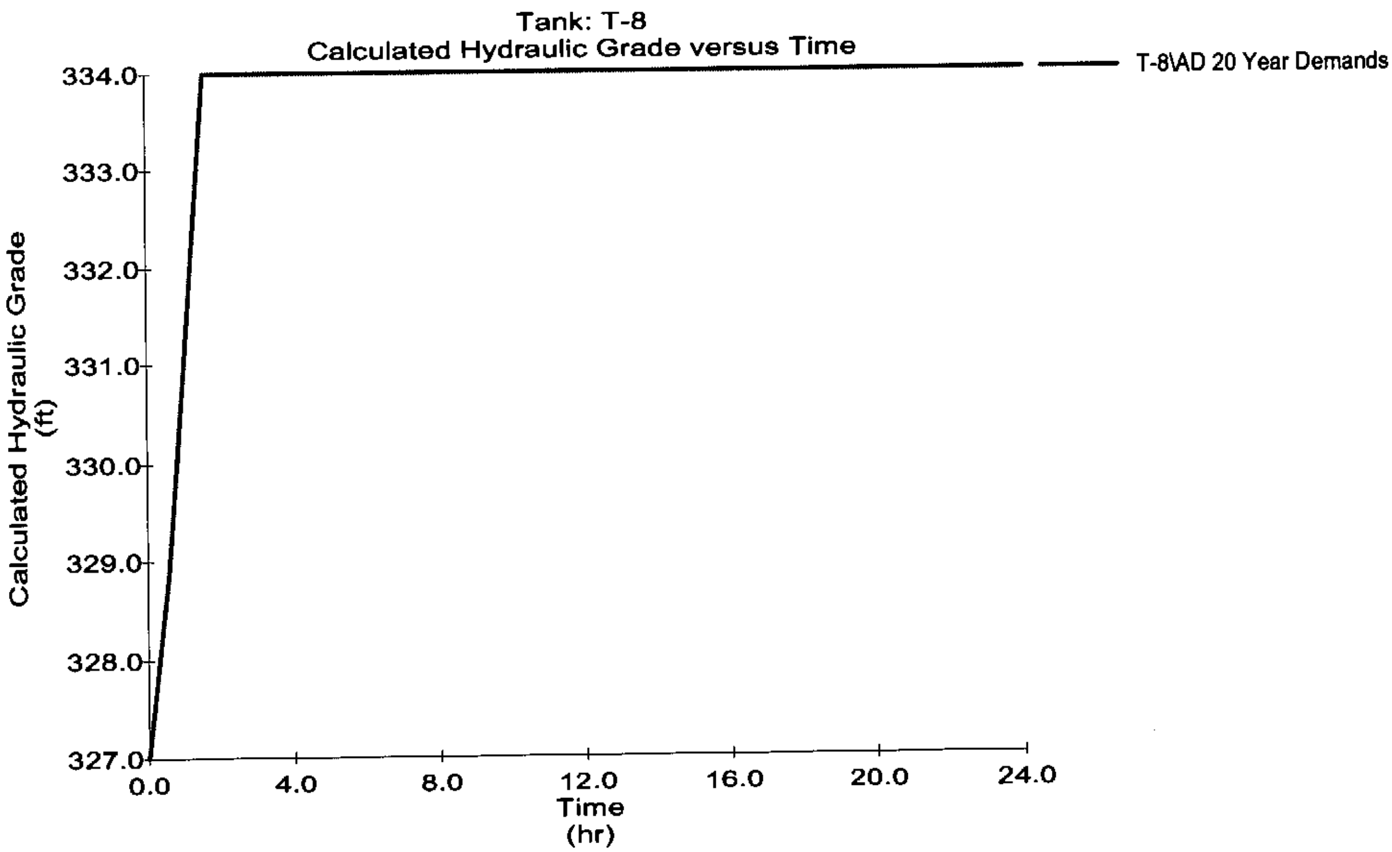
Graph

West Street Tank



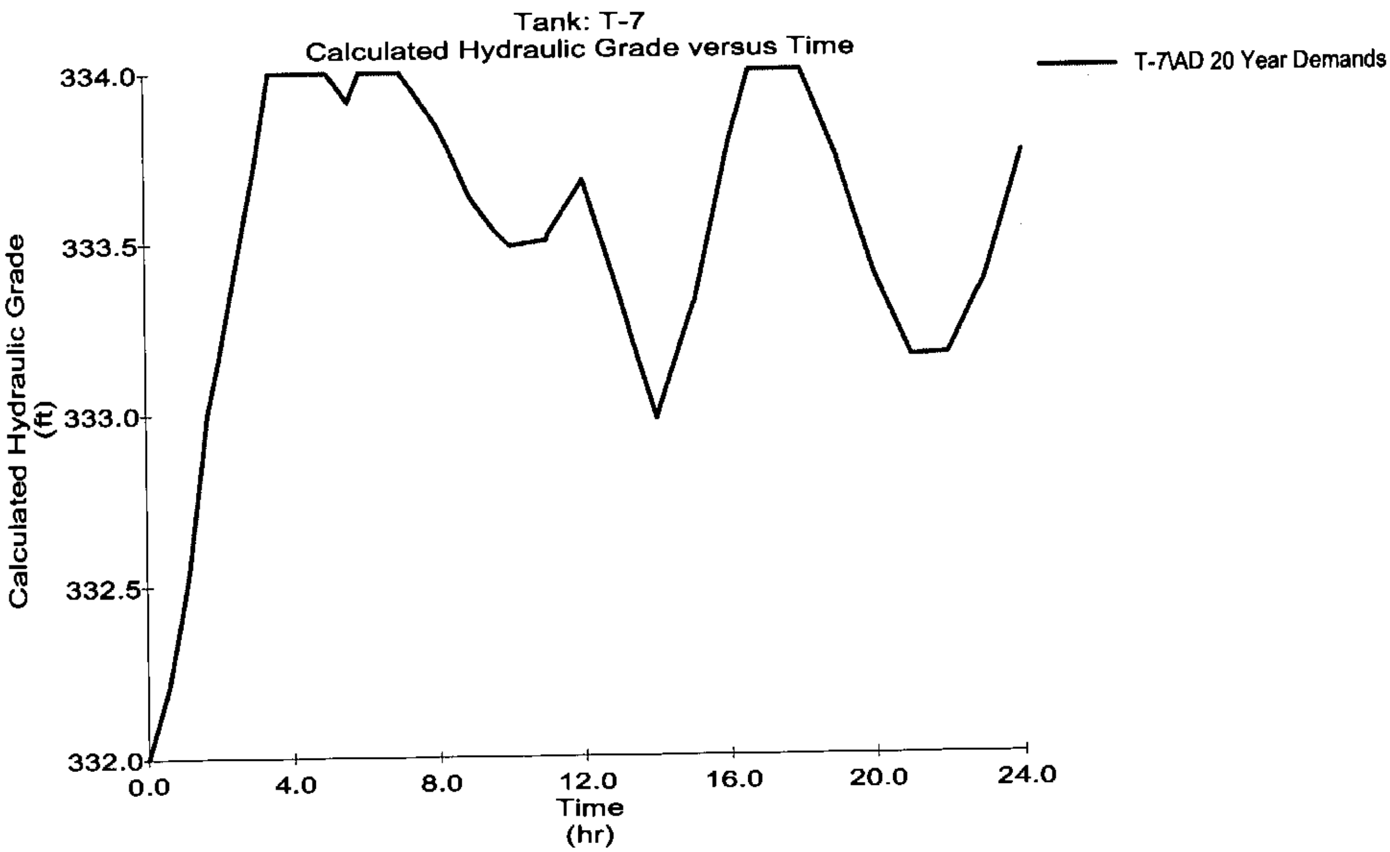
Graph

Wakefield Street Tank



Graph

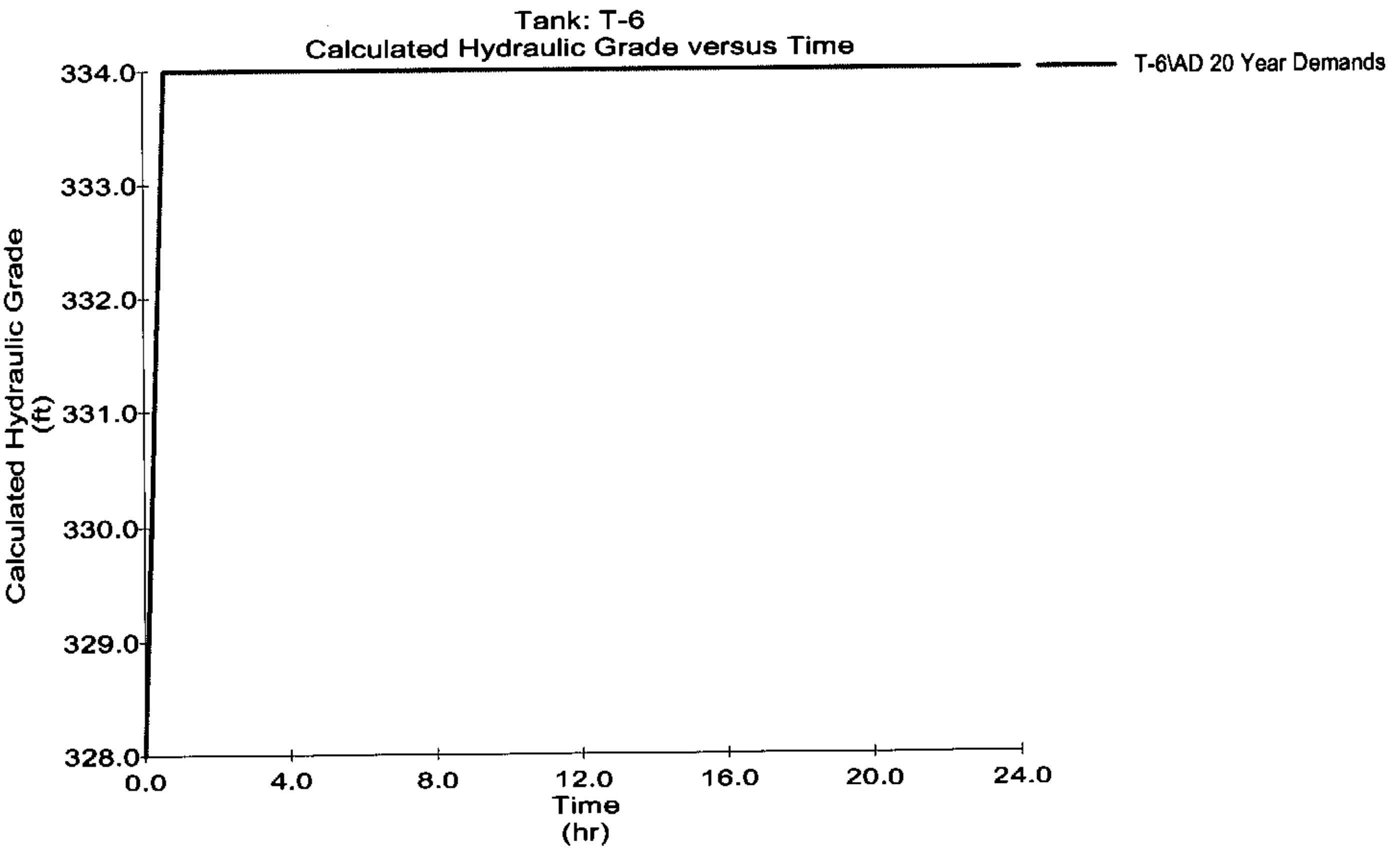
Setian Lane Tank



- 2000 gpm fire flow at node J-390
- Cowesett Rd.
- 12" AC main
- Elevation = 205 ft
- Average Day demand

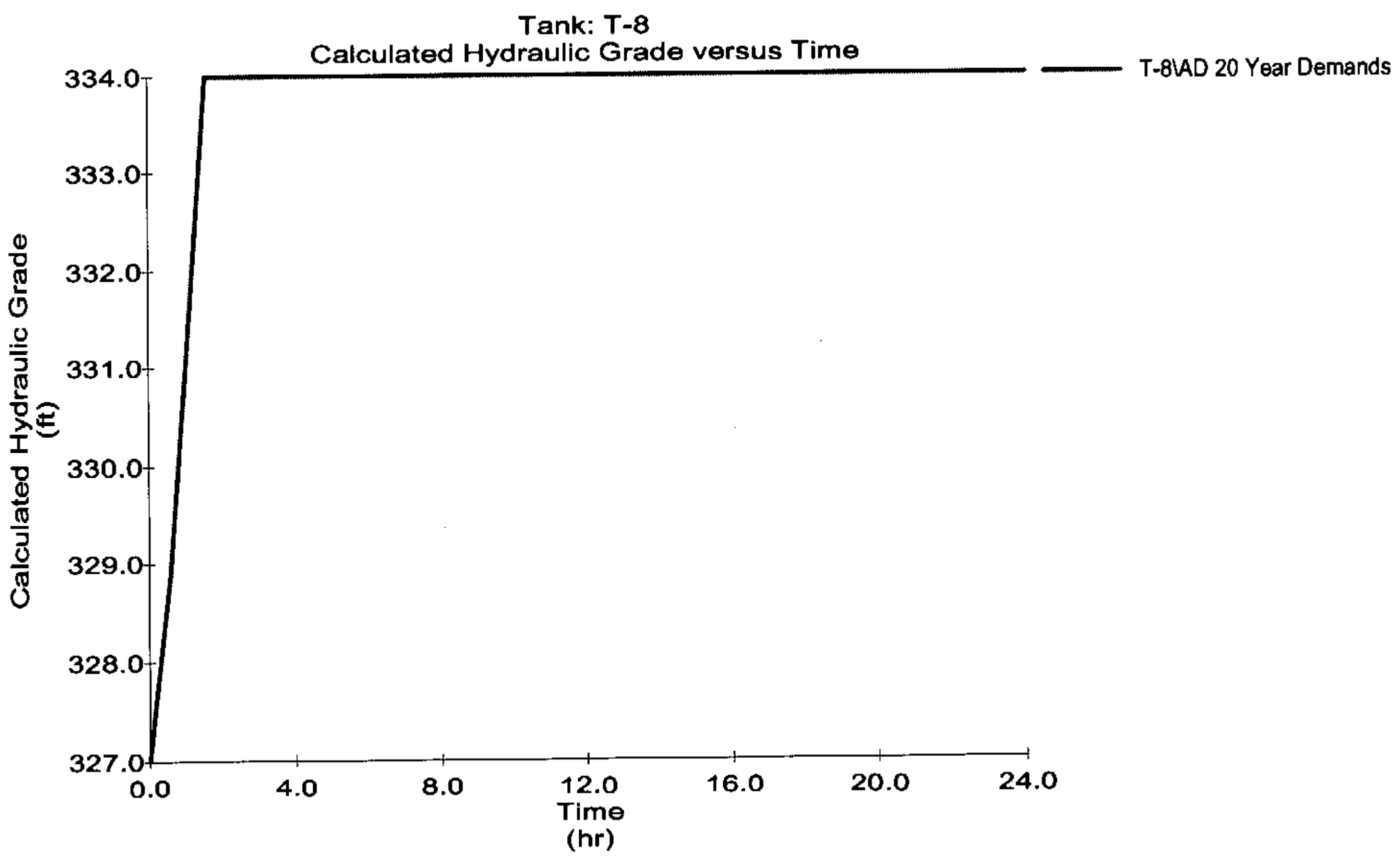
Graph

West Street Tank



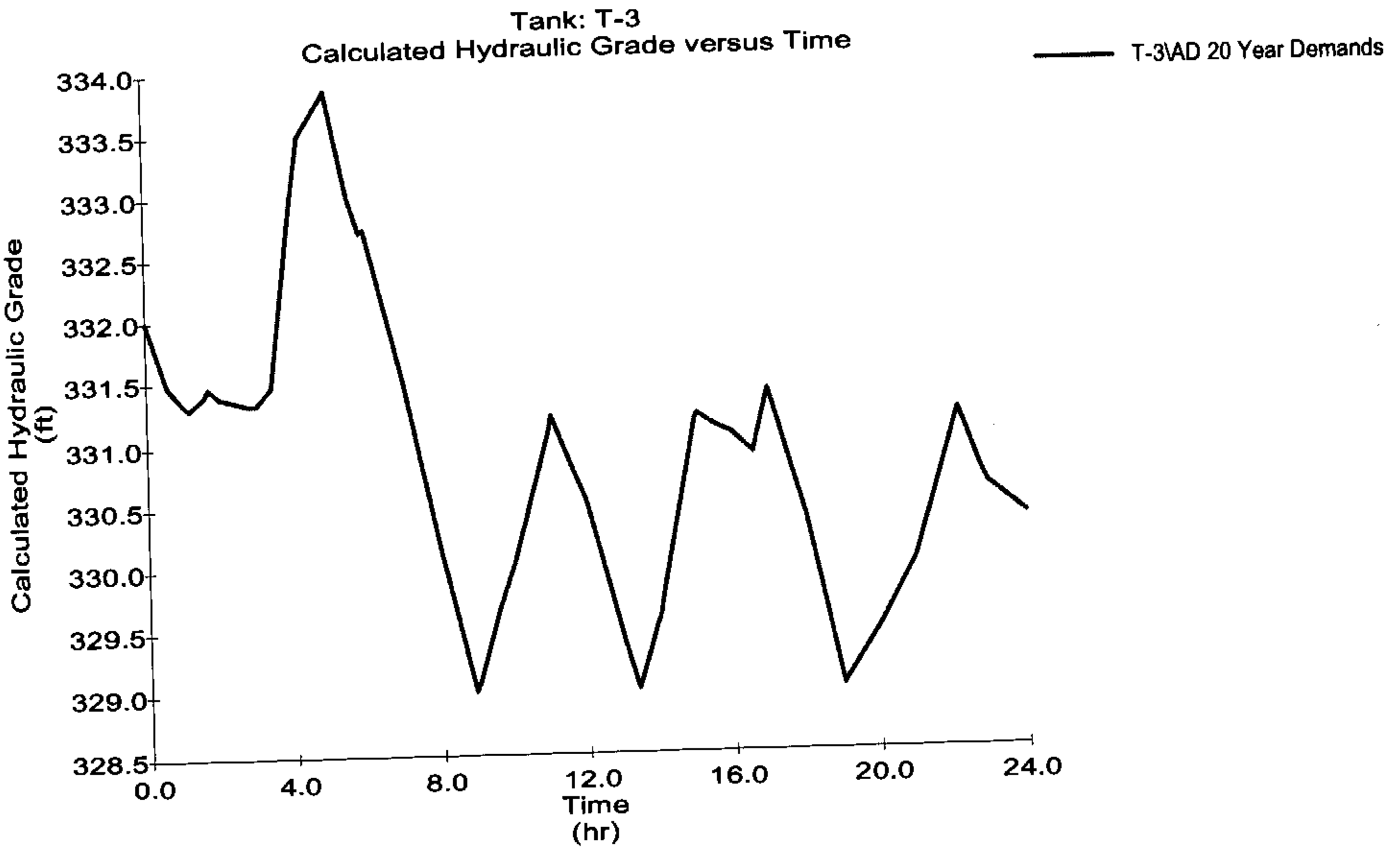
Graph

Wakefield Street Tank



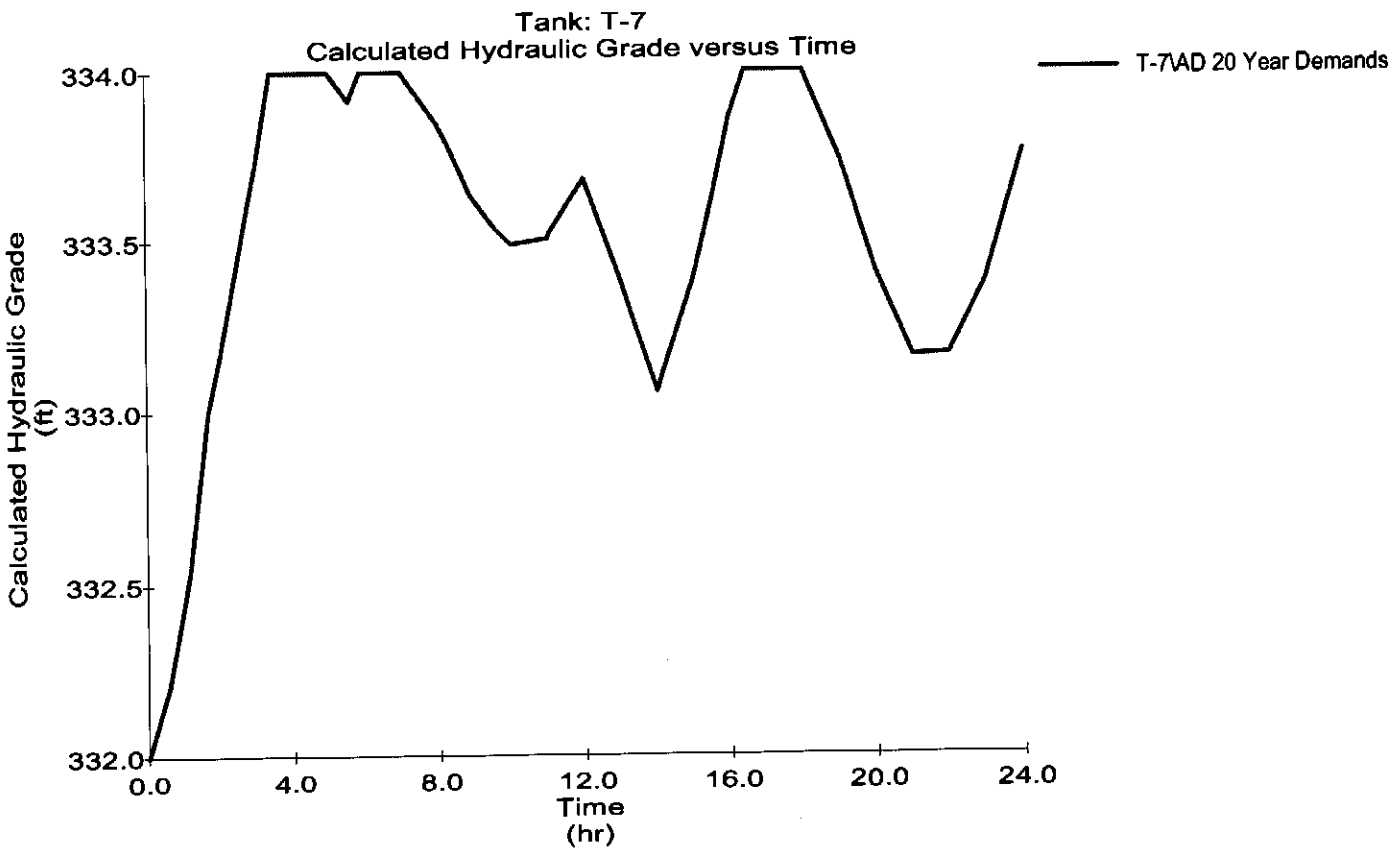
Graph

Frenchtown Road Tank



Graph

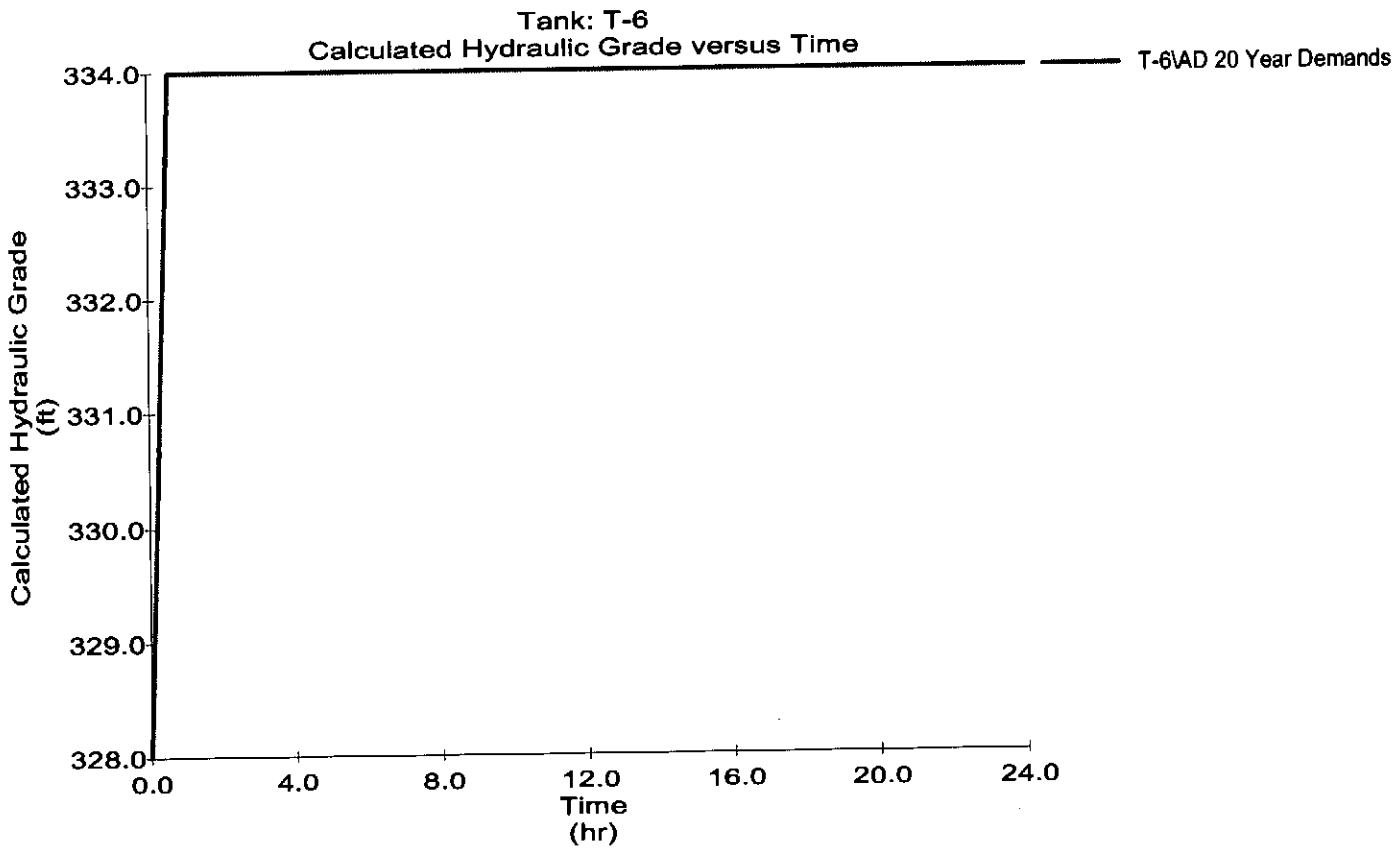
Setian Lane Tank



- 2000 gpm fire flow at node J-2005
- Centerville Rd.
- 12" AC main
- Elevation = 100 ft
- Average Day demand

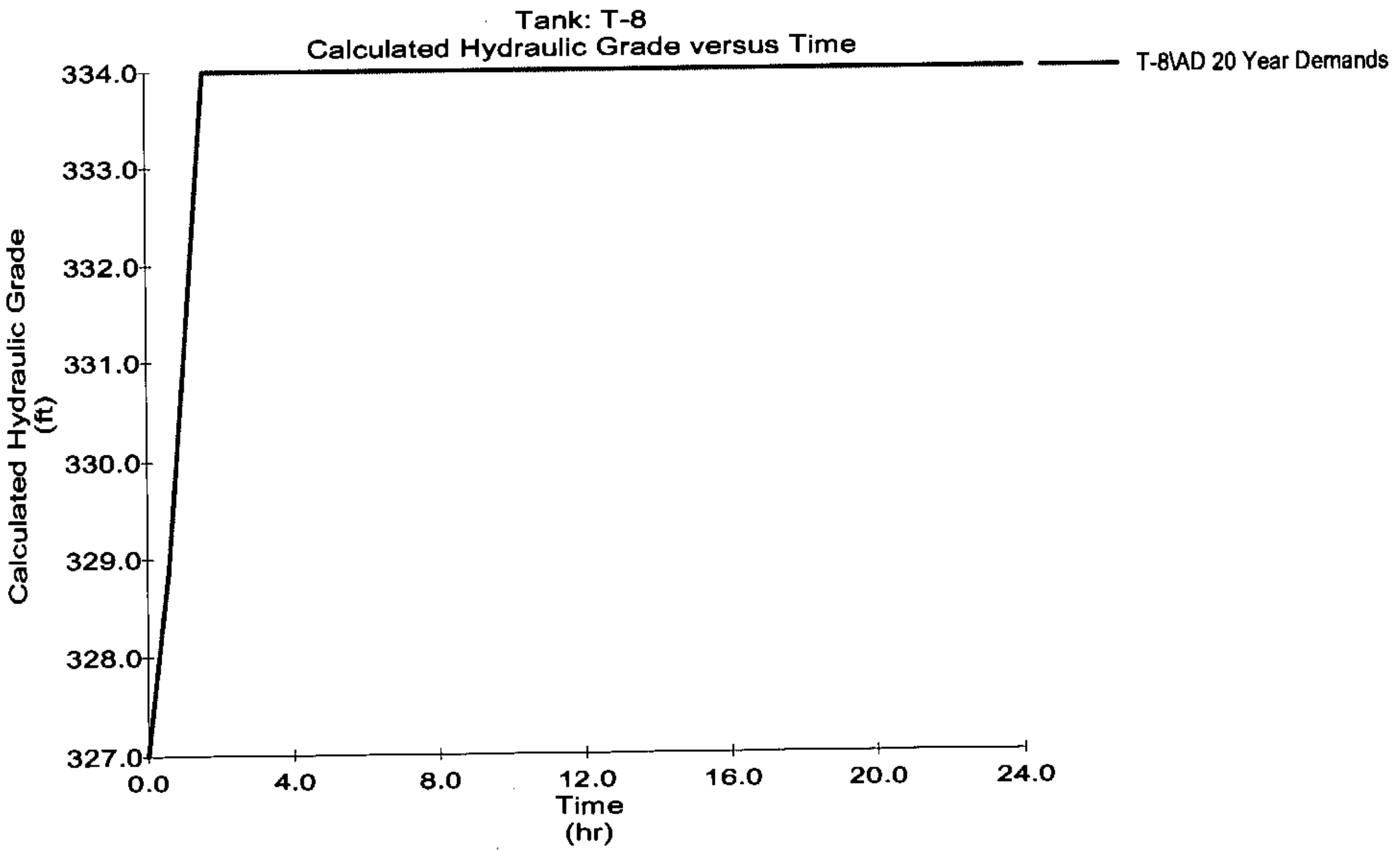
Graph

West Street Tank



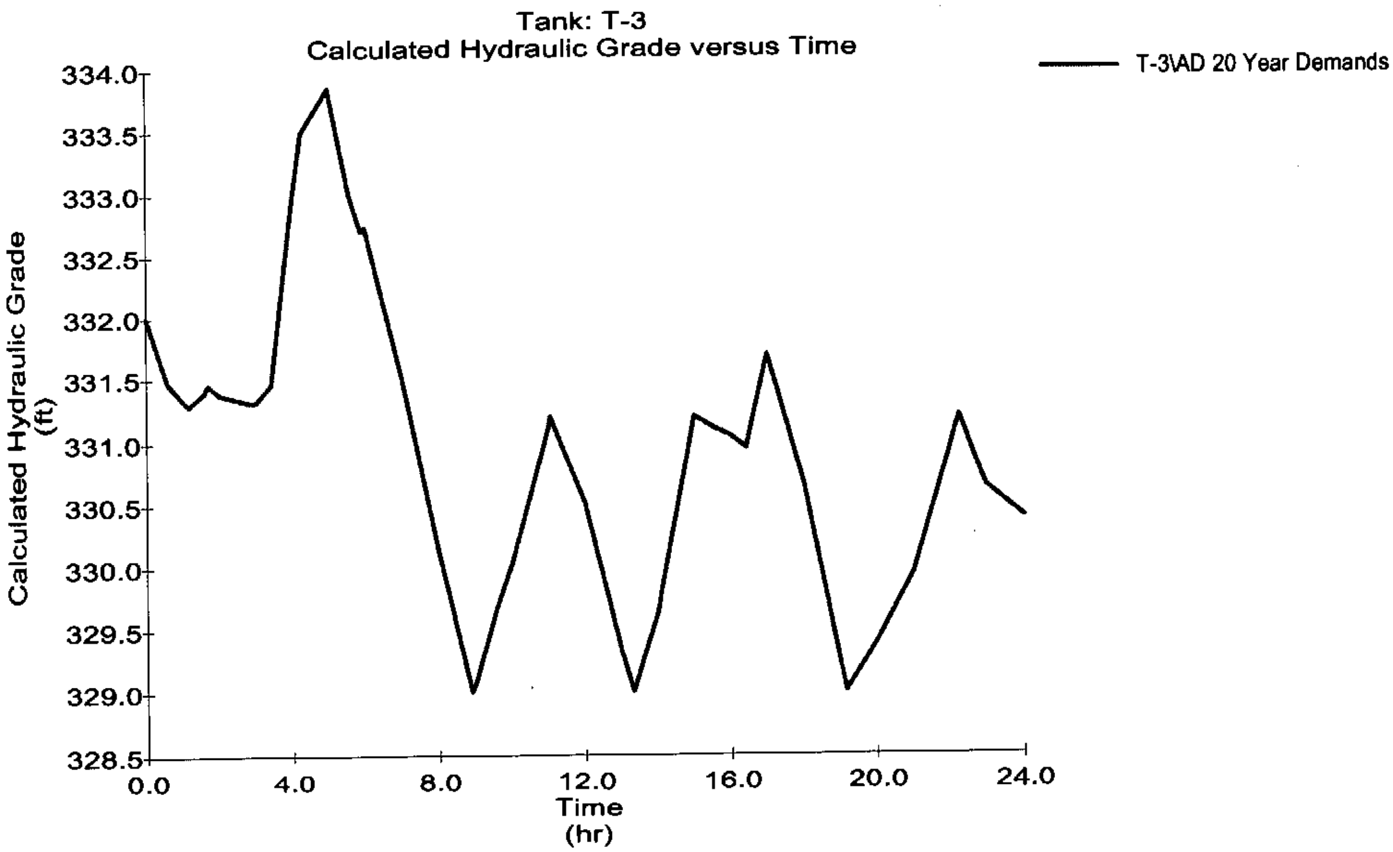
Graph

Wakefield Street Tank



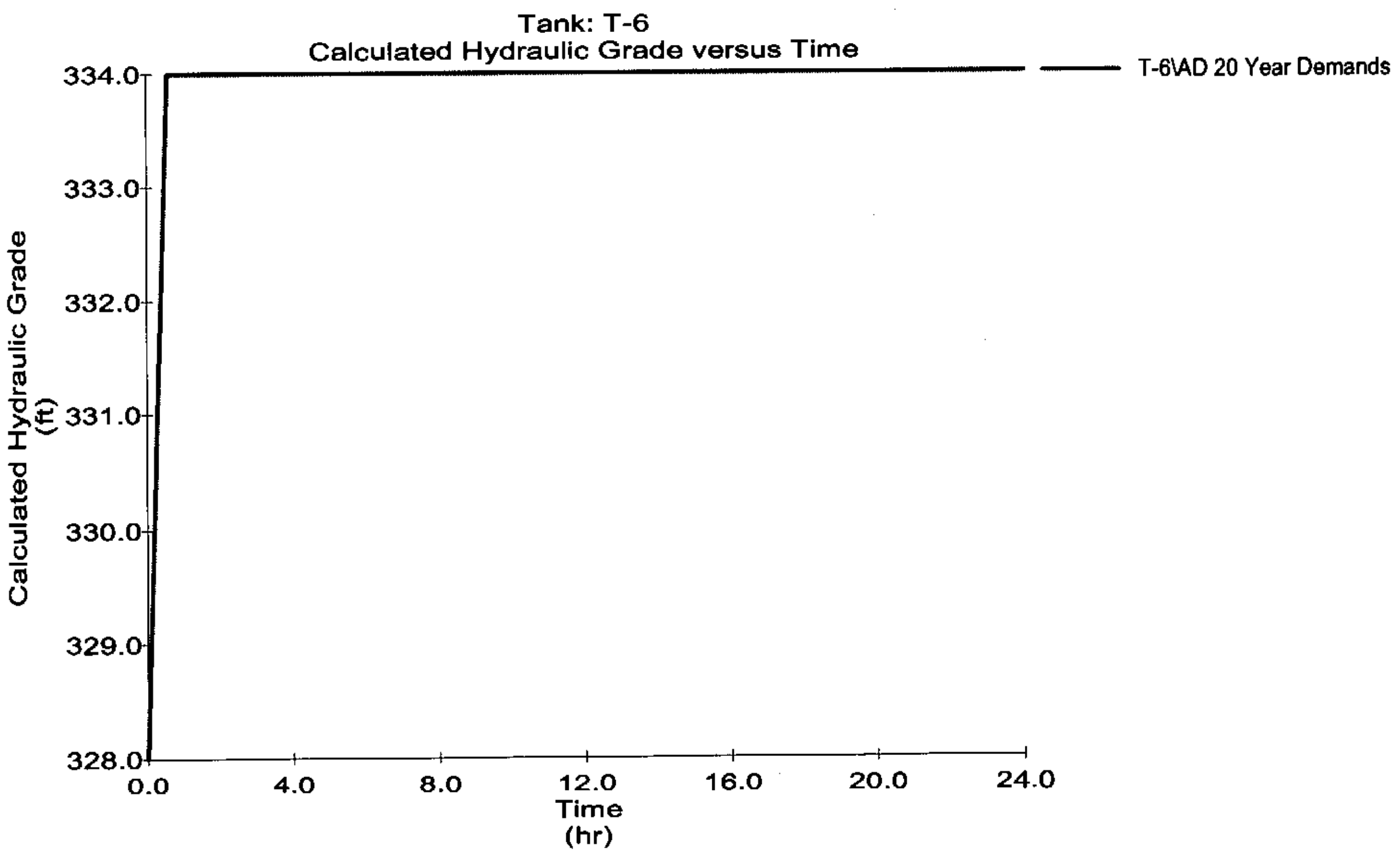
Graph

Frenchtown Road Tank



Graph

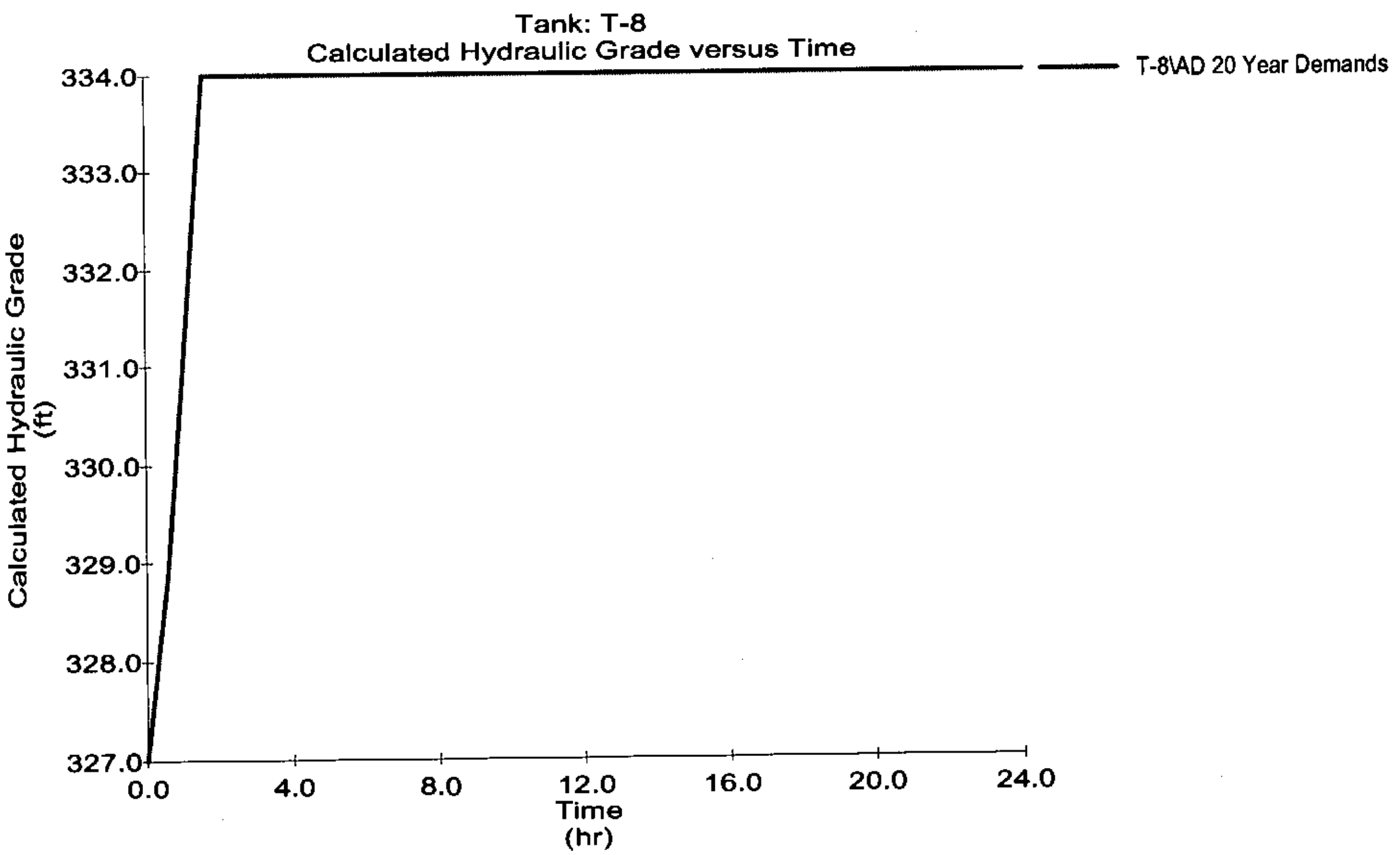
West Street Tank



- 2000 gpm fire flow at node J-626
- West St.
- 16" AC main
- Elevation = 245 ft
- Average Day demand

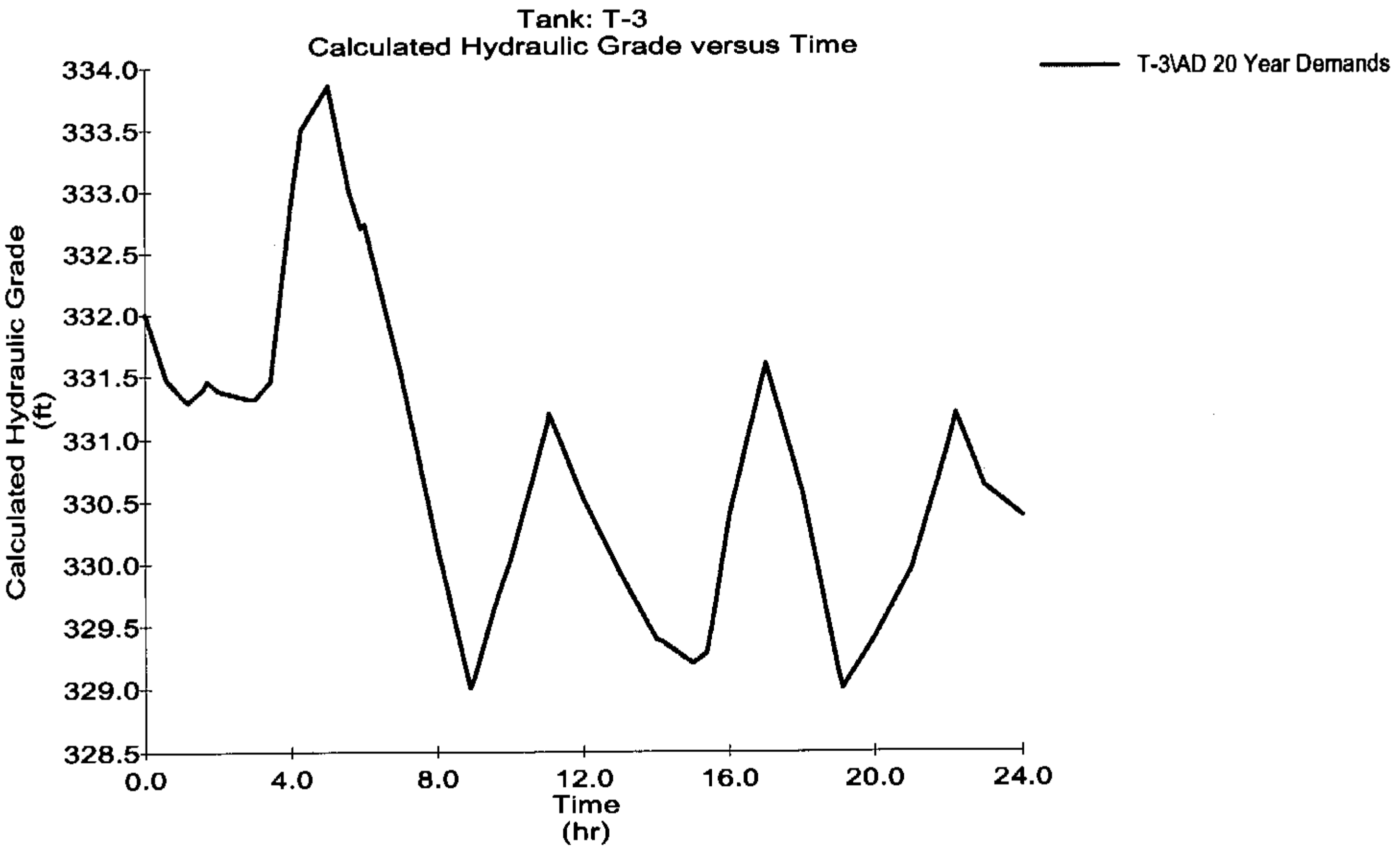
Graph

Wakefield Street Tank



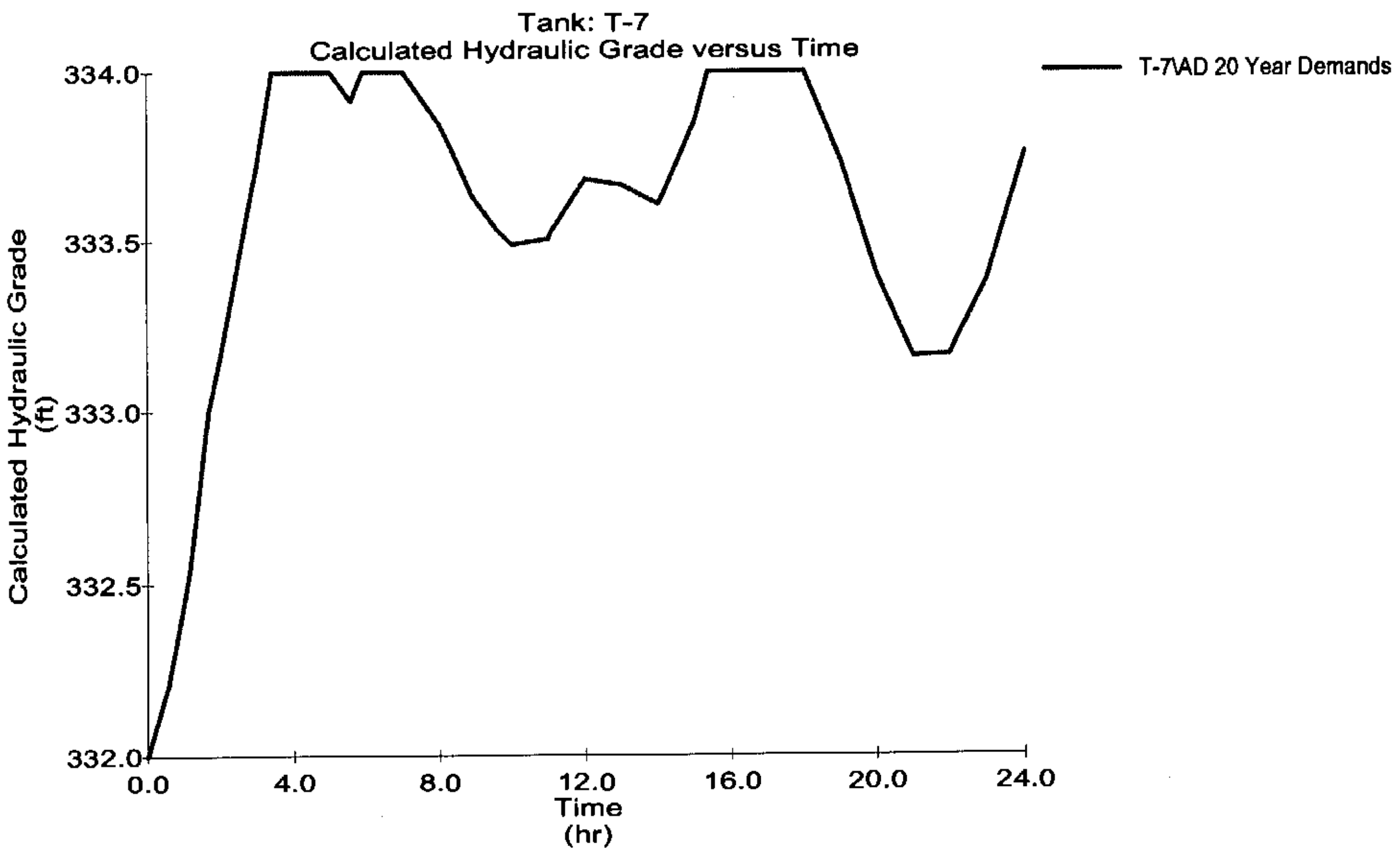
Graph

Frenchtown Road Tank



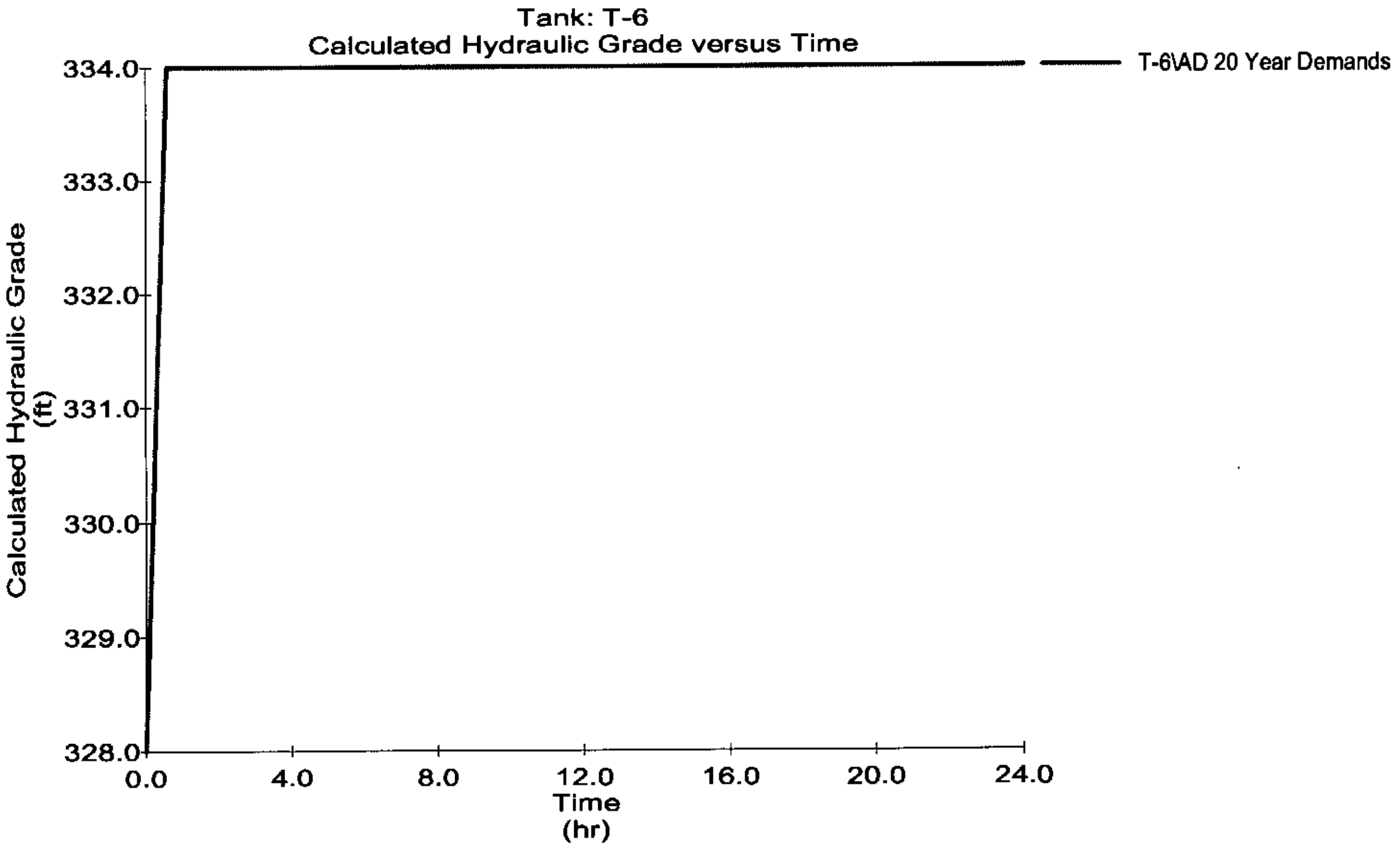
Graph

Setian Lane Tank



Graph

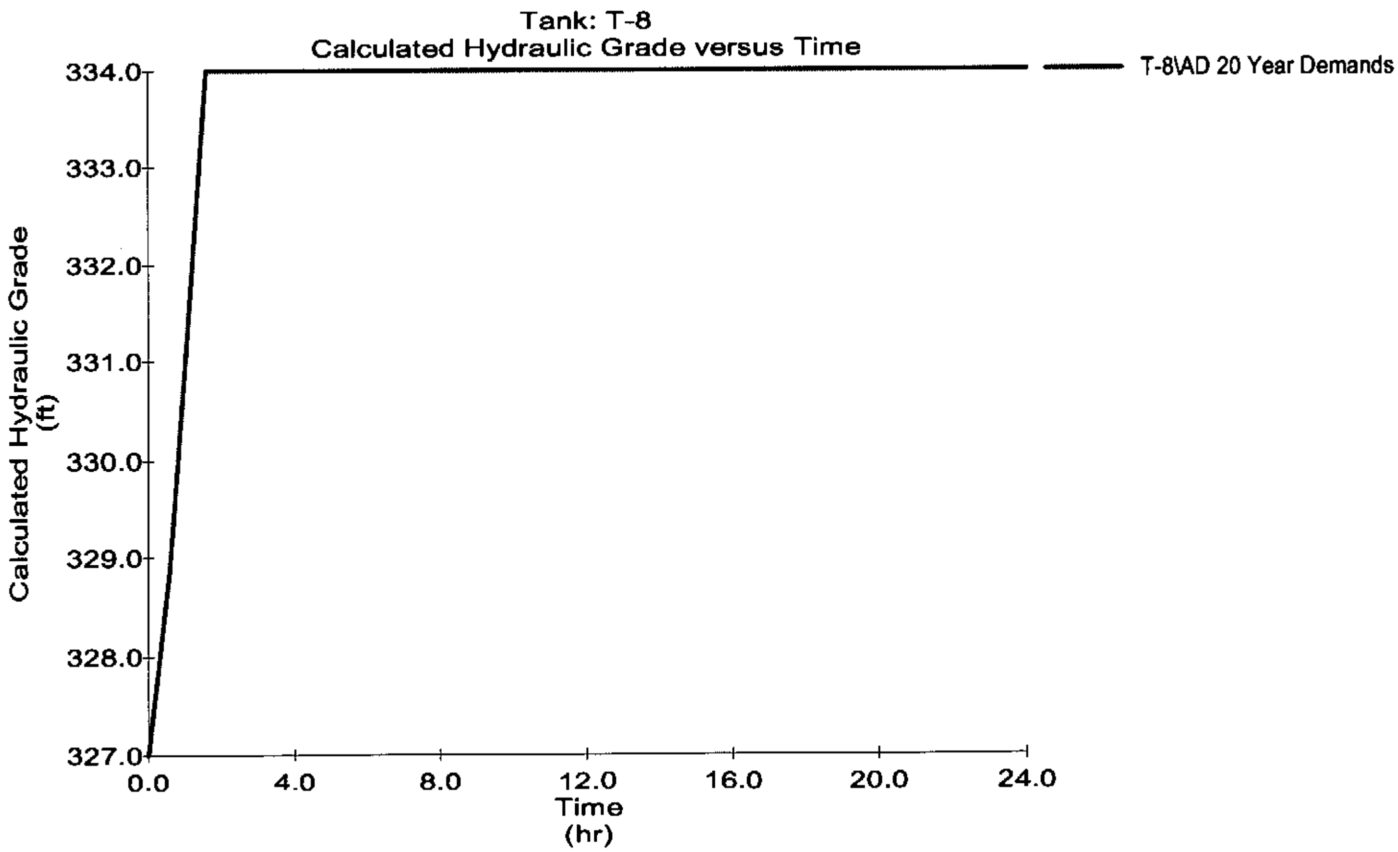
West Street Tank



- 2000 gpm fire flow at node J-7879
- Fairview Ave.
- 16" AC main
- Elevation = 255 ft
- Average Day demand

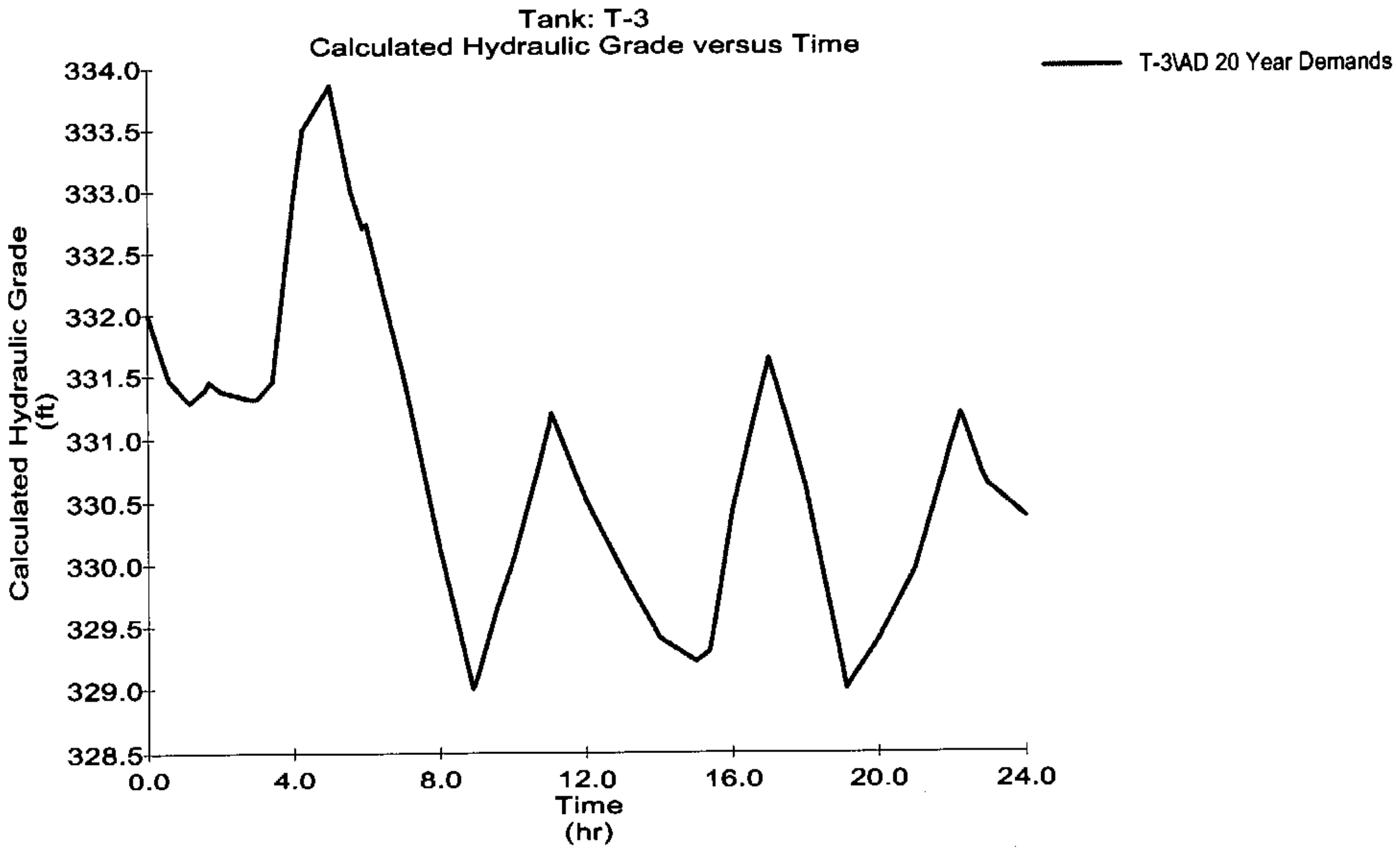
Graph

Wakefield Street Tank



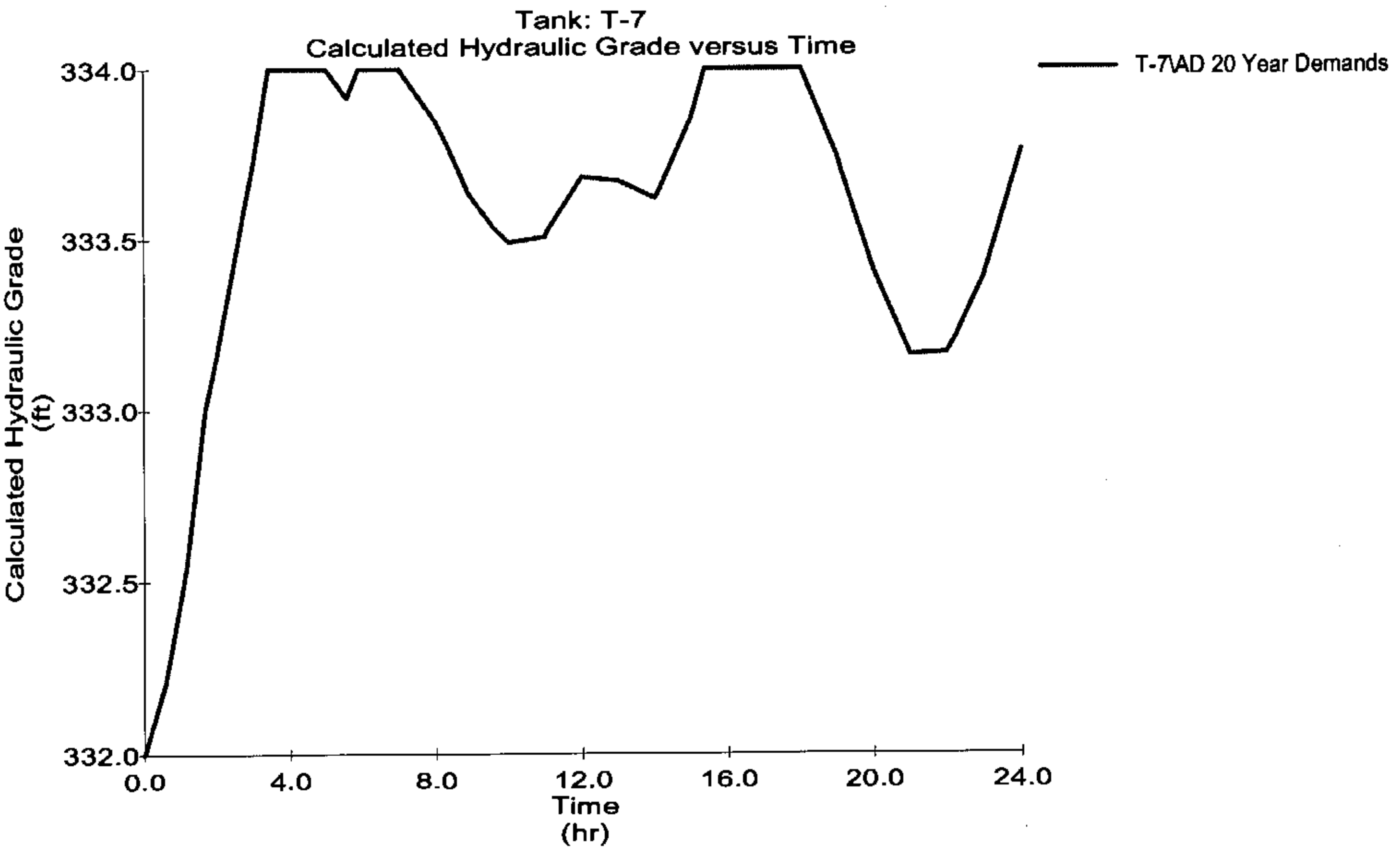
Graph

Frenchtown Road Tank



Graph

Frenchtown Road Tank

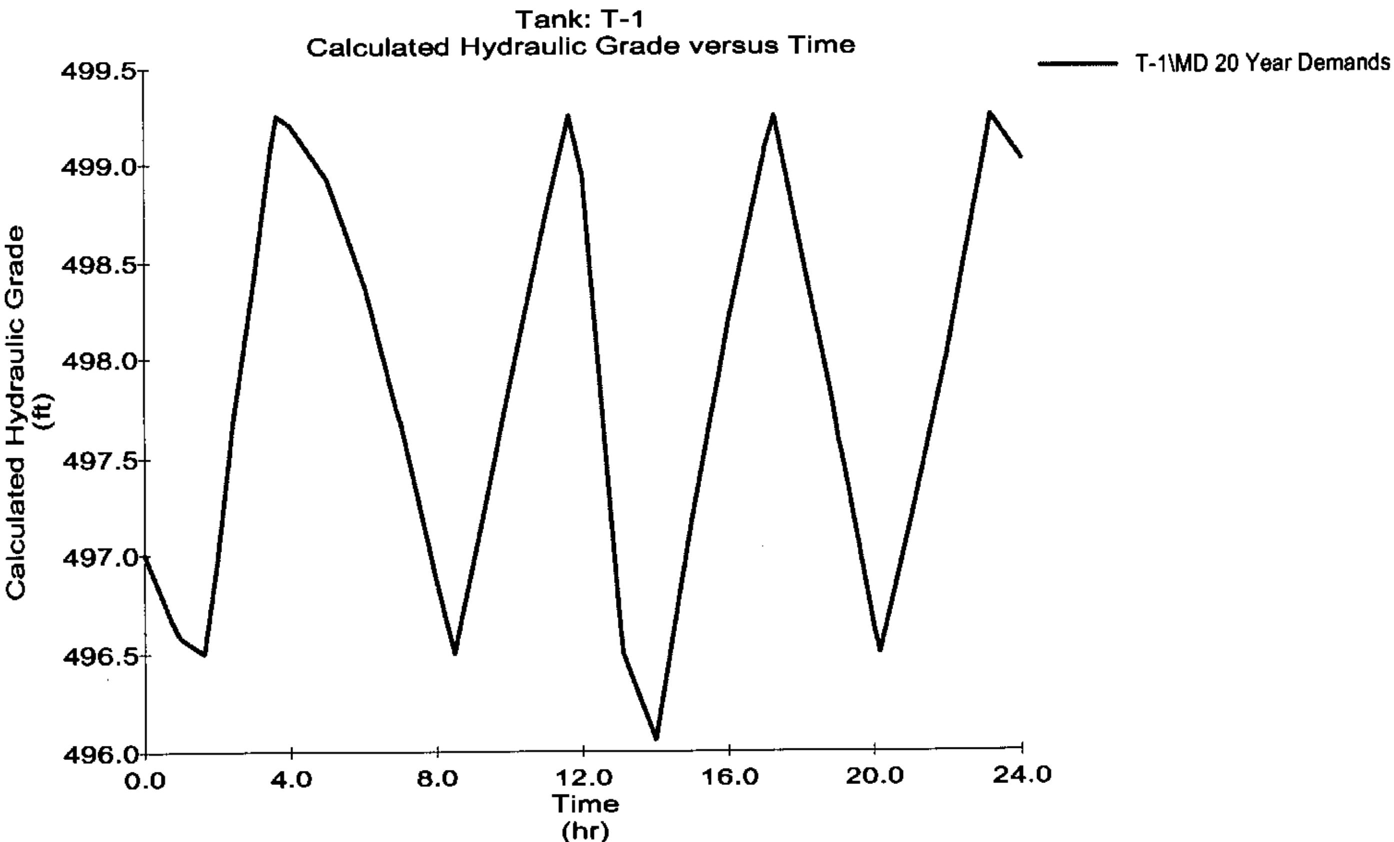


ATTACHMENT NO. 4

EXTENDED PERIOD SIMULATION
MAXIMUM DAY DEMAND WITH FIRE FLOW
STORAGE TANK GRAPHS

Graph

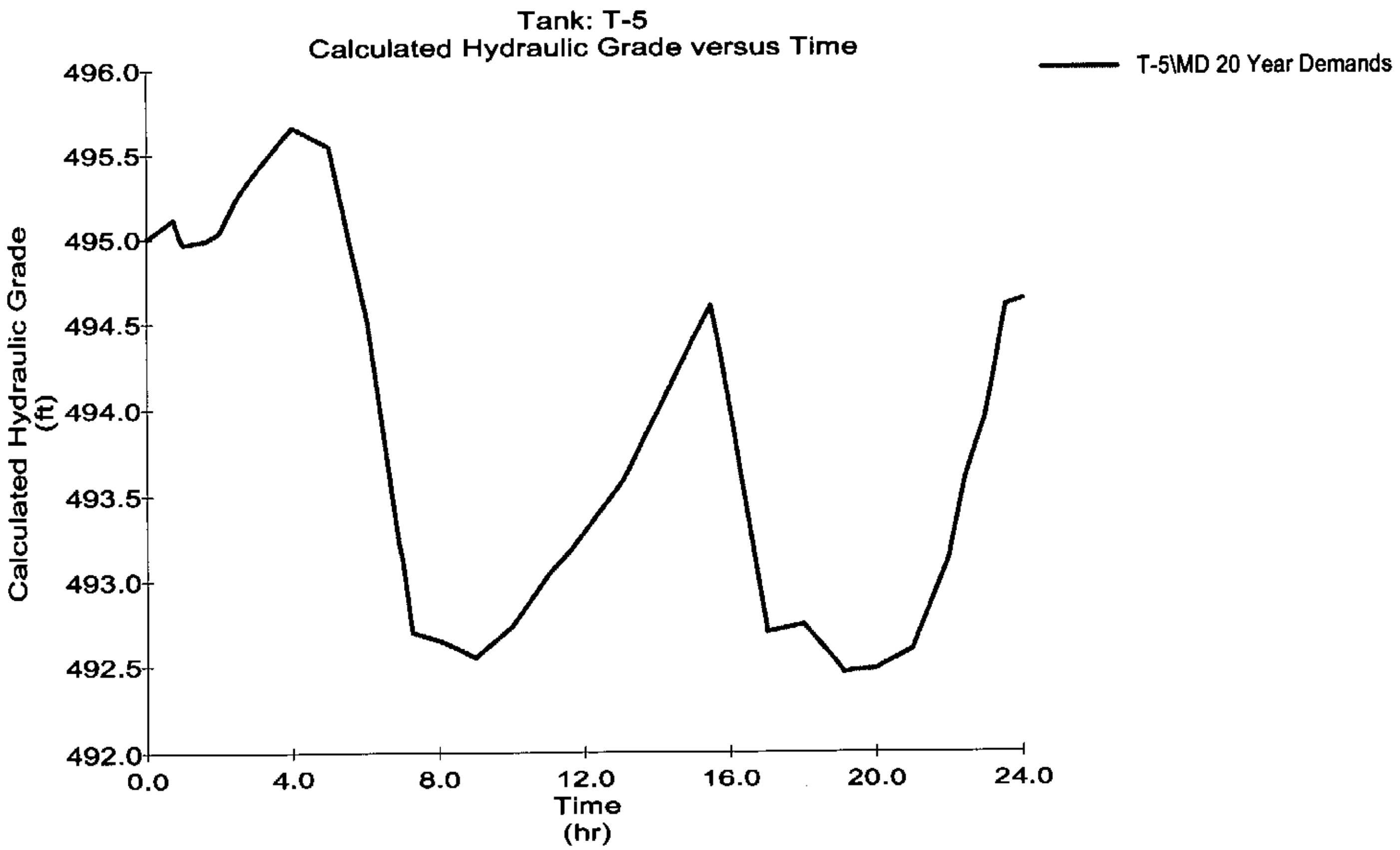
Read School House Road Tank



- 2000 gpm fire flow at node J-7154
- Flat River Rd.
- 16" DI main
- Elevation = 254 ft
- Maximum Day demand

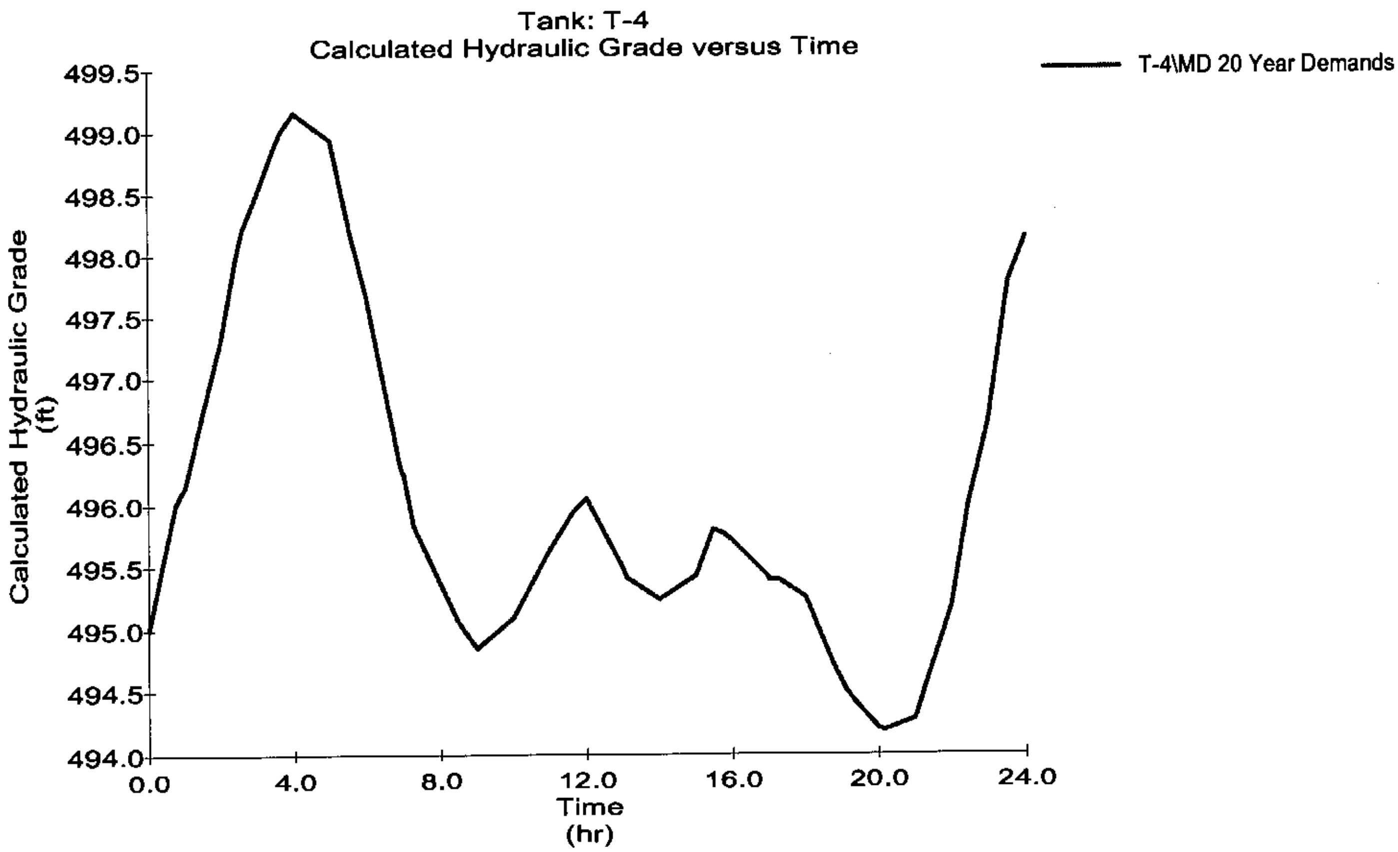
Graph

Carrs Pond Road Tank



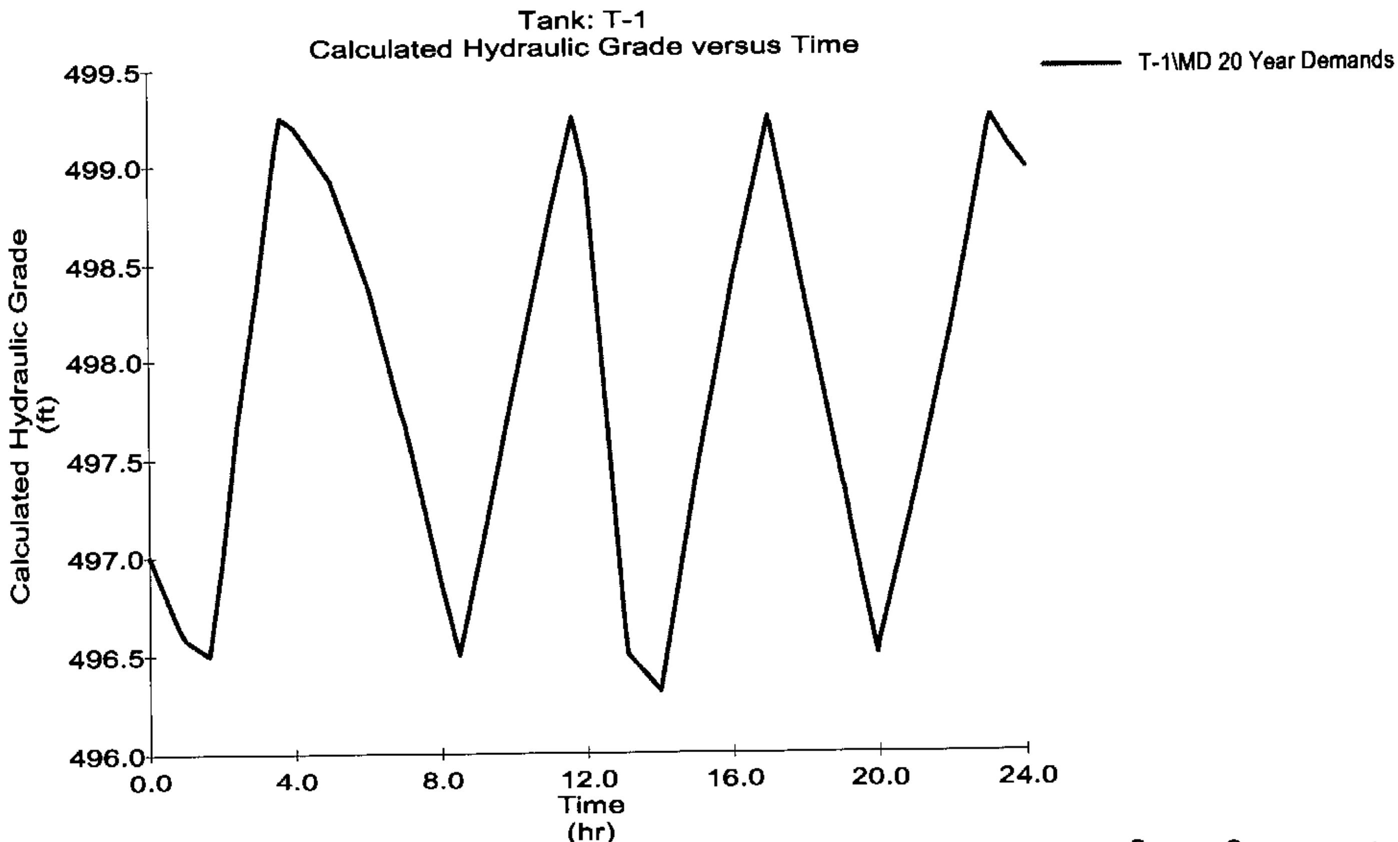
Graph

Technology Park Tank



Graph

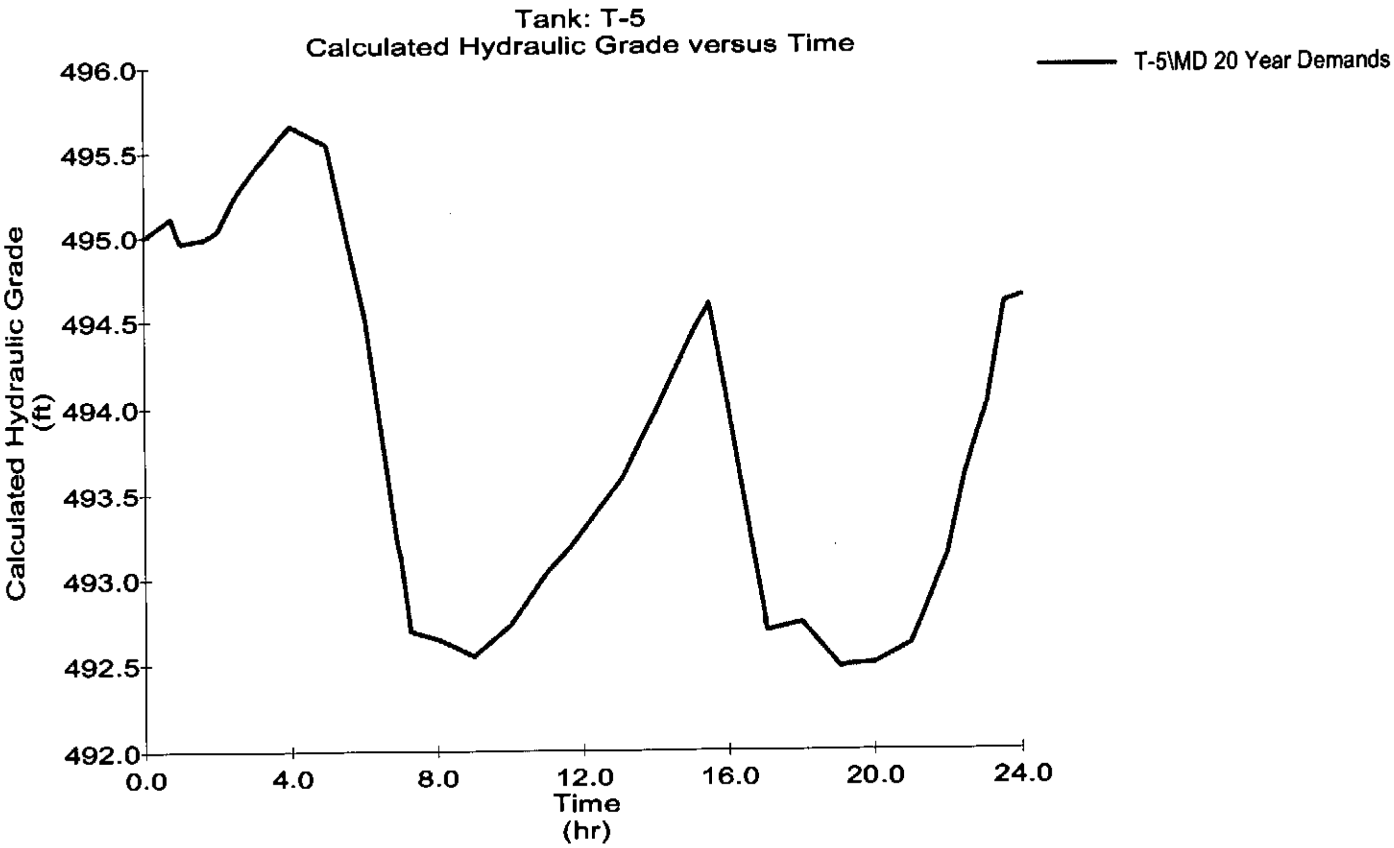
Read School House Road Tank



- 2000 gpm fire flow at node J-7258
- Hunters Crossing Dr.
- 16" DI main
- Elevation = 343 ft
- Maximum Day demand

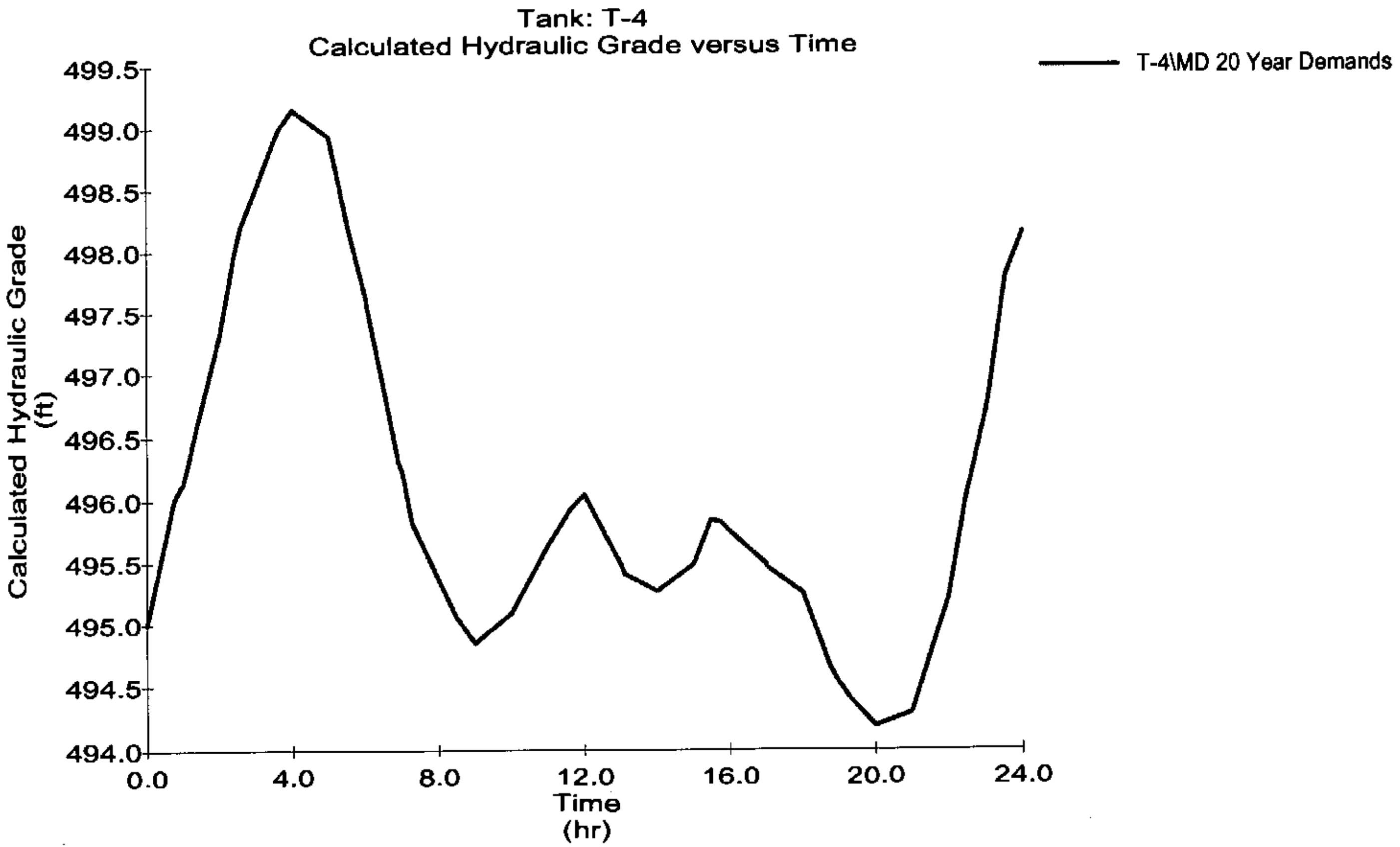
Graph

Carrs Pond Road Tank



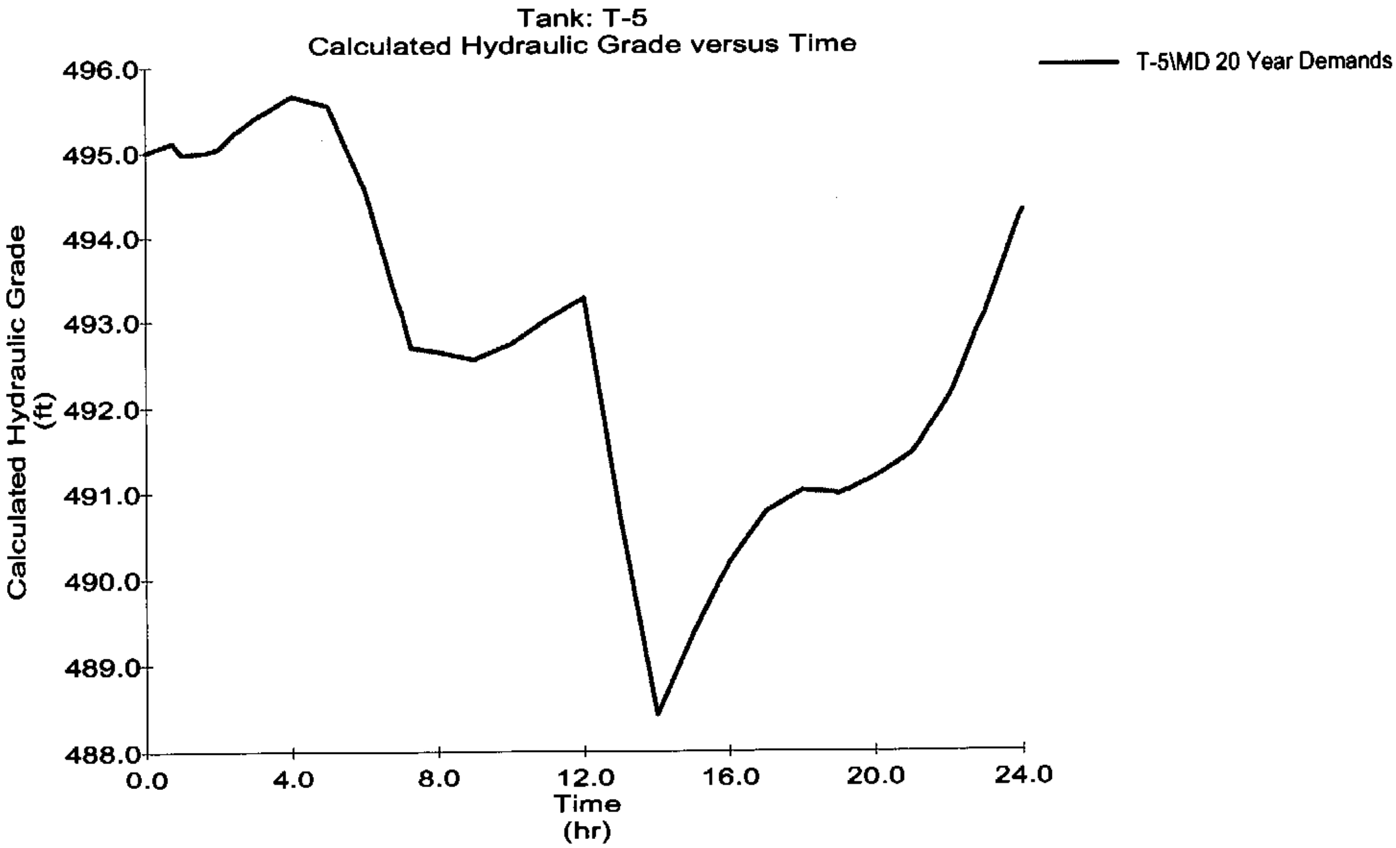
Graph

Technology Park Tank



Graph

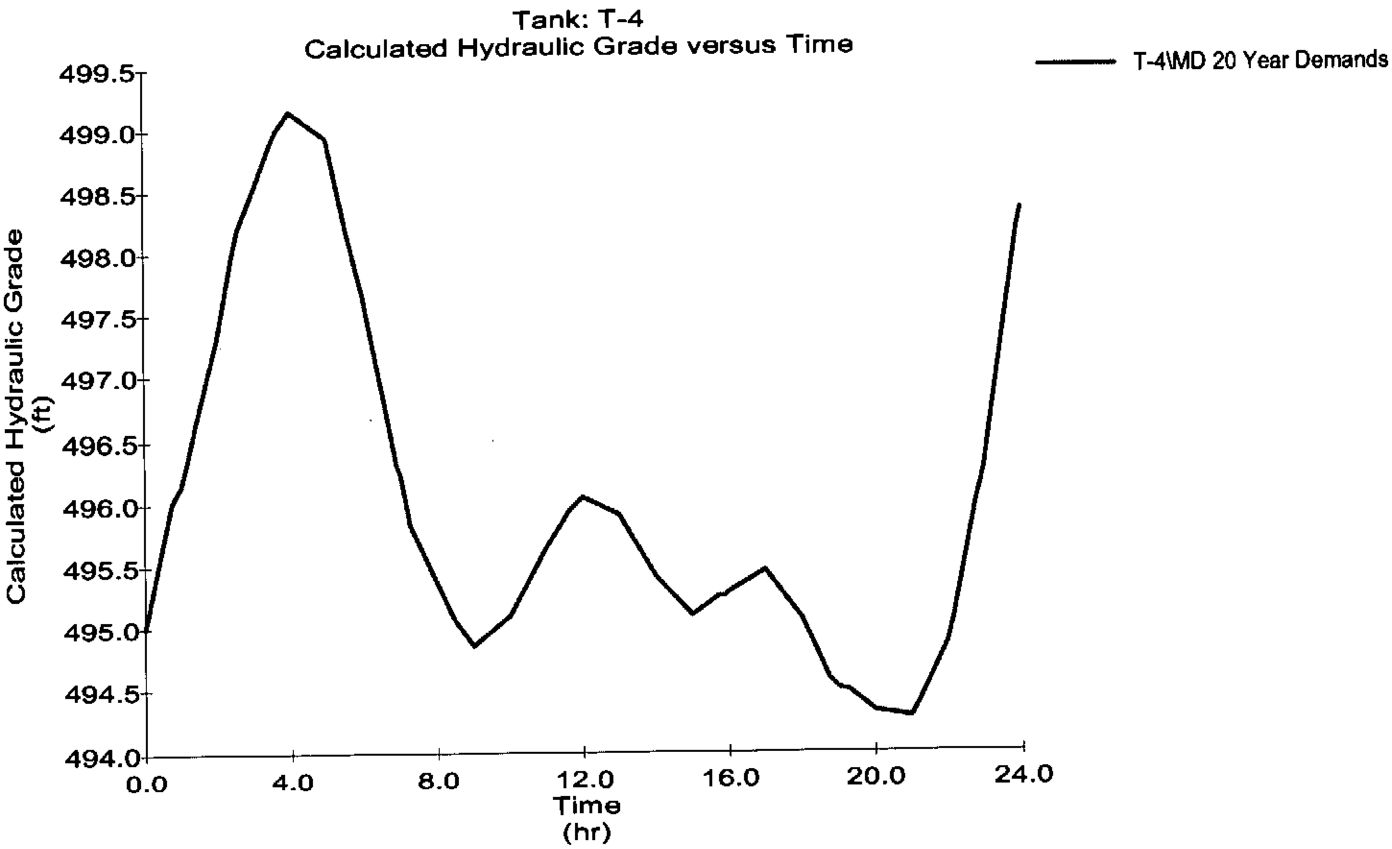
Carrs Pond Road Tank



- 2000 gpm fire flow at node J-4117
- Middle Rd.
- 16" DI main
- Elevation = 300 ft
- Maximum Day demand

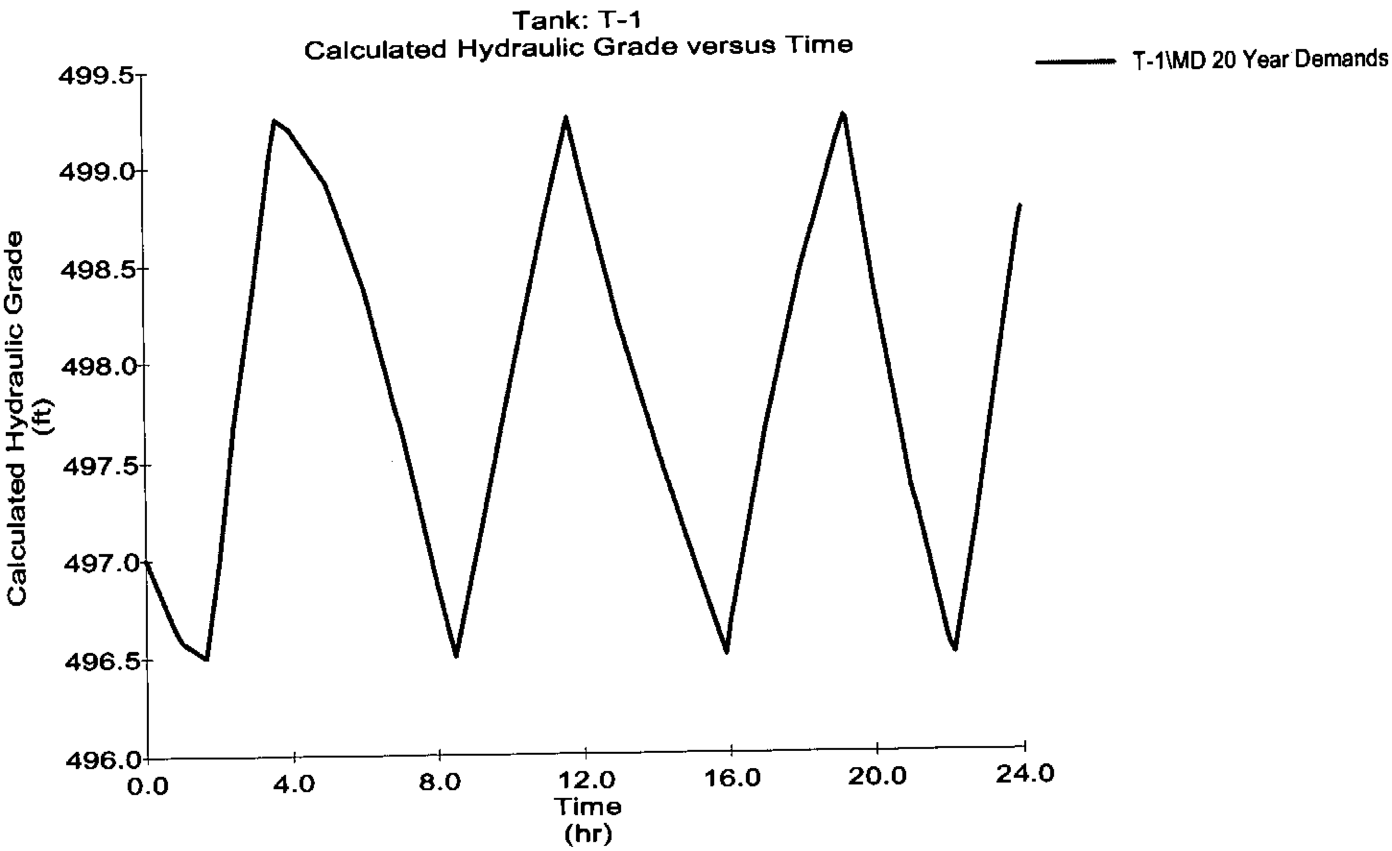
Graph

Technology Park Tank



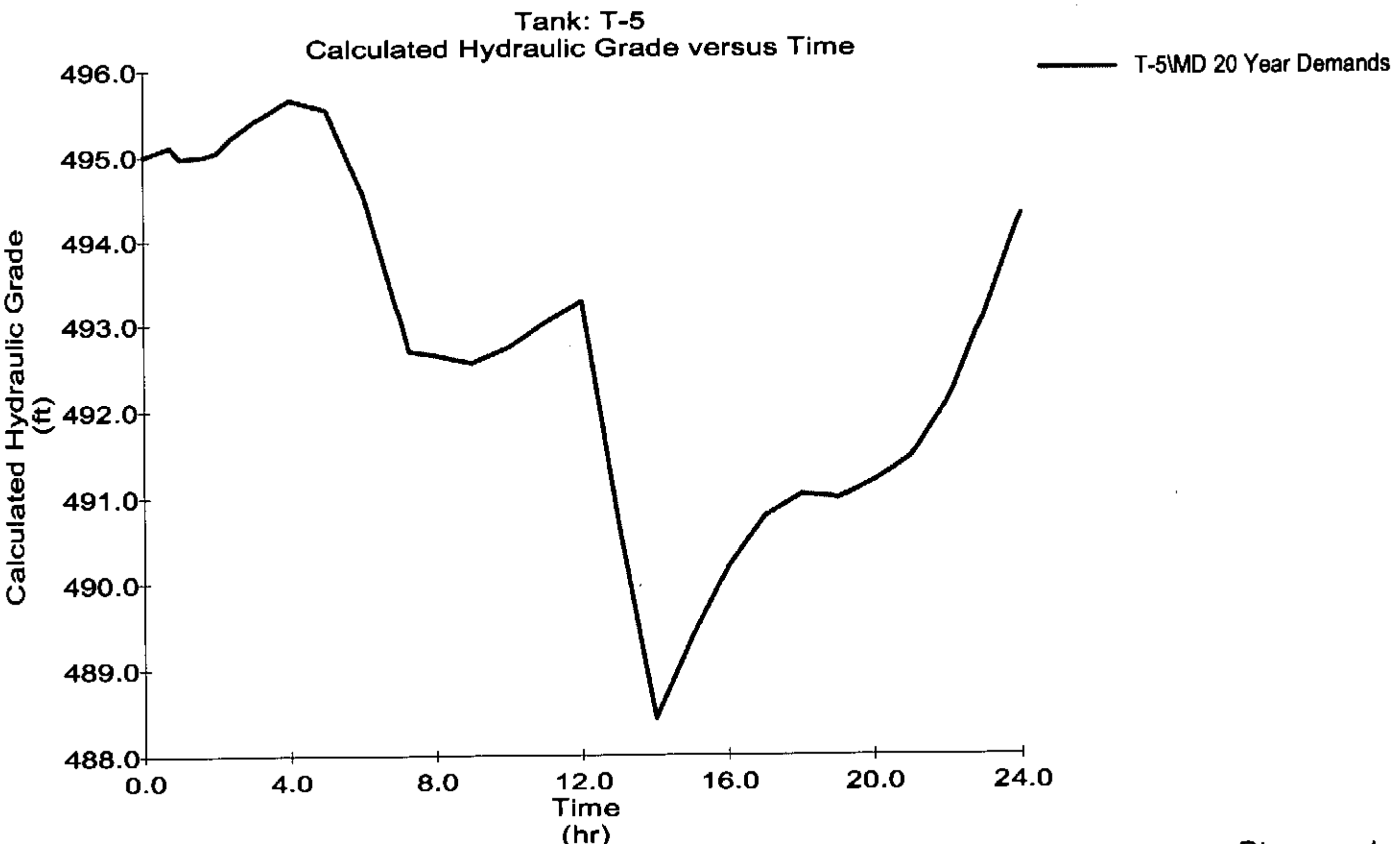
Graph

Read School House Road Tank



Graph

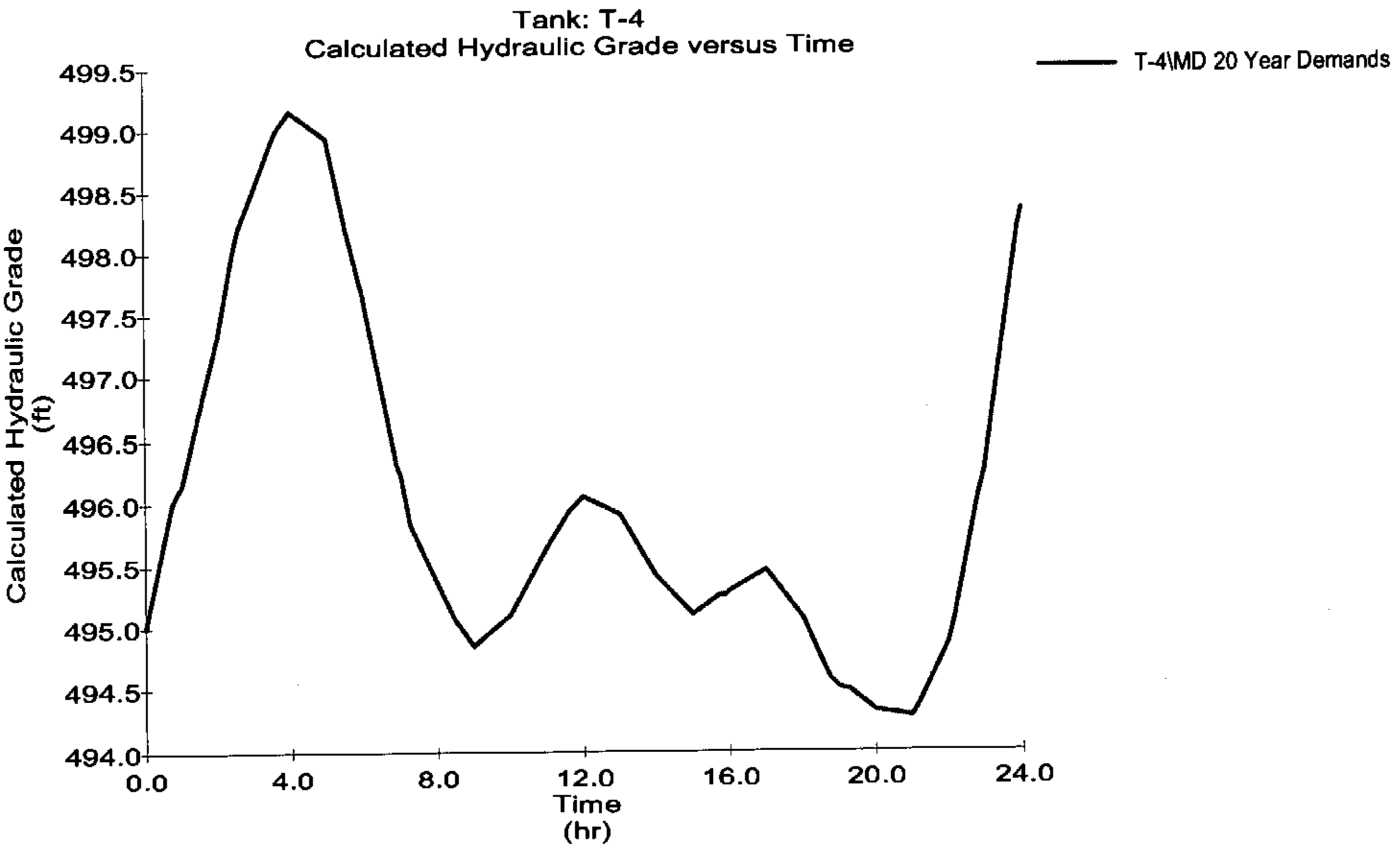
Carrs Pond Road Tank



- 2000 gpm fire flow at node J-4056
- Frenchtown Rd.
- 12" DI main
- Elevation = 246 ft
- Maximum Day demand

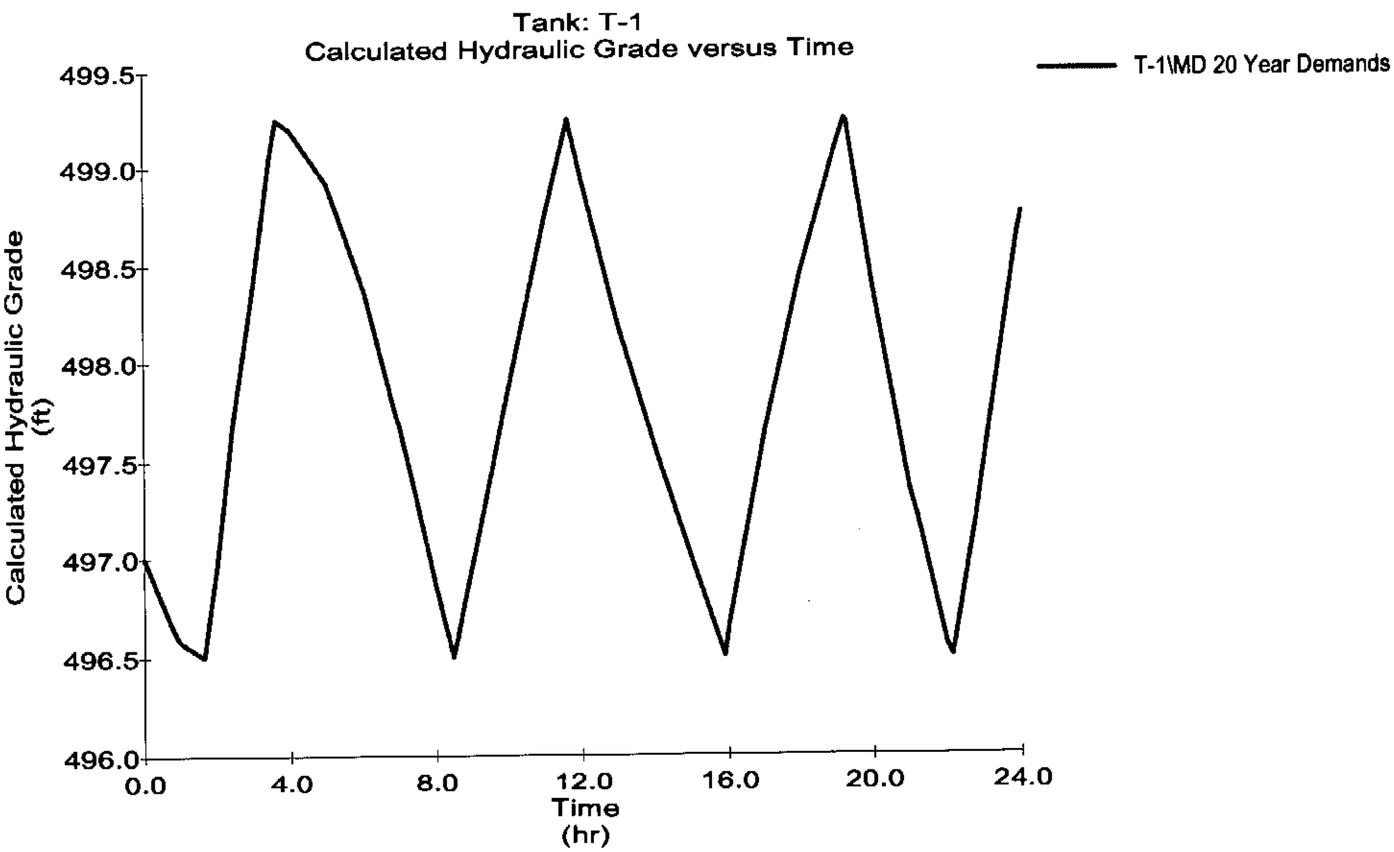
Graph

Technology Park Tank



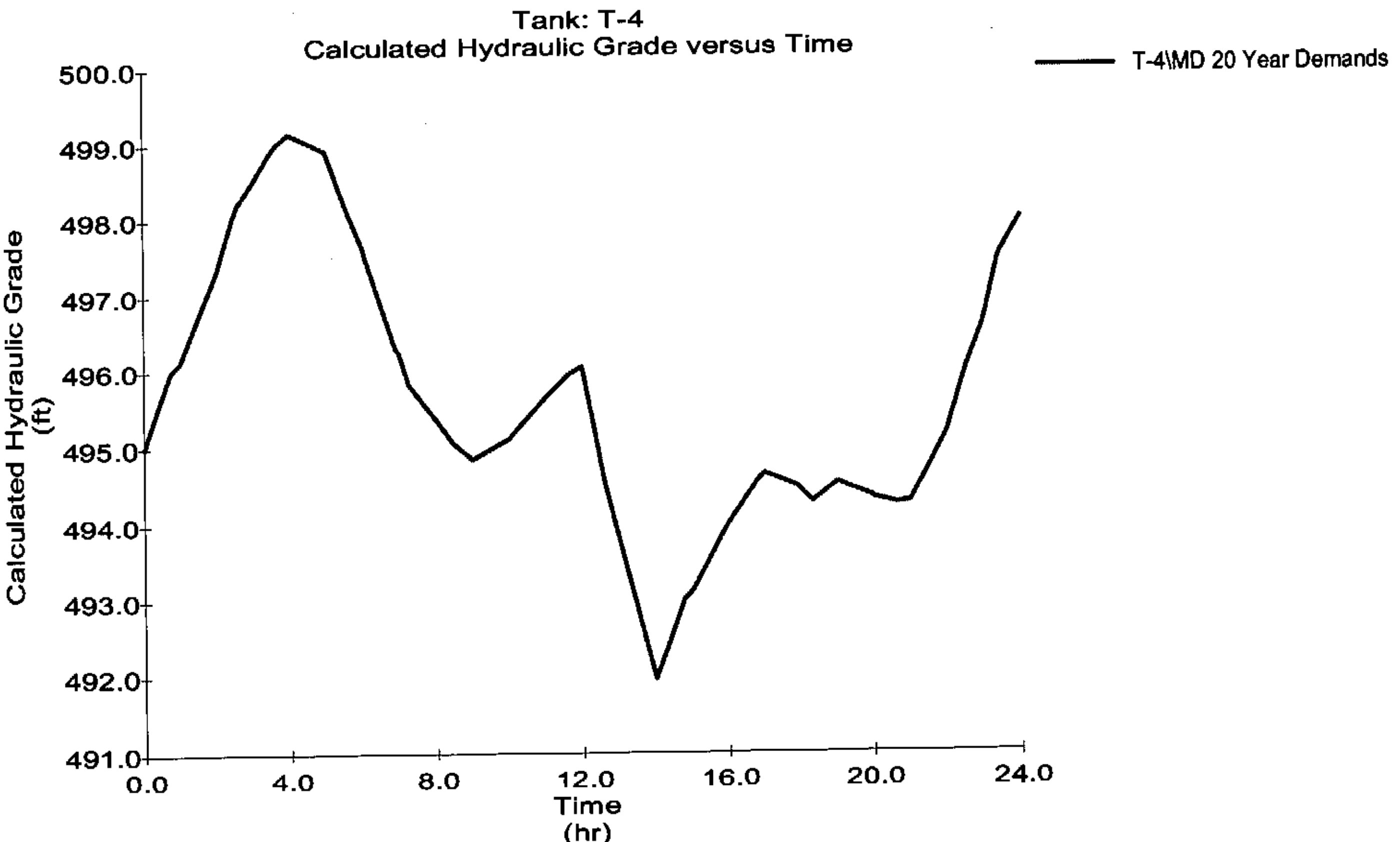
Graph

Read School House Road Tank



Graph

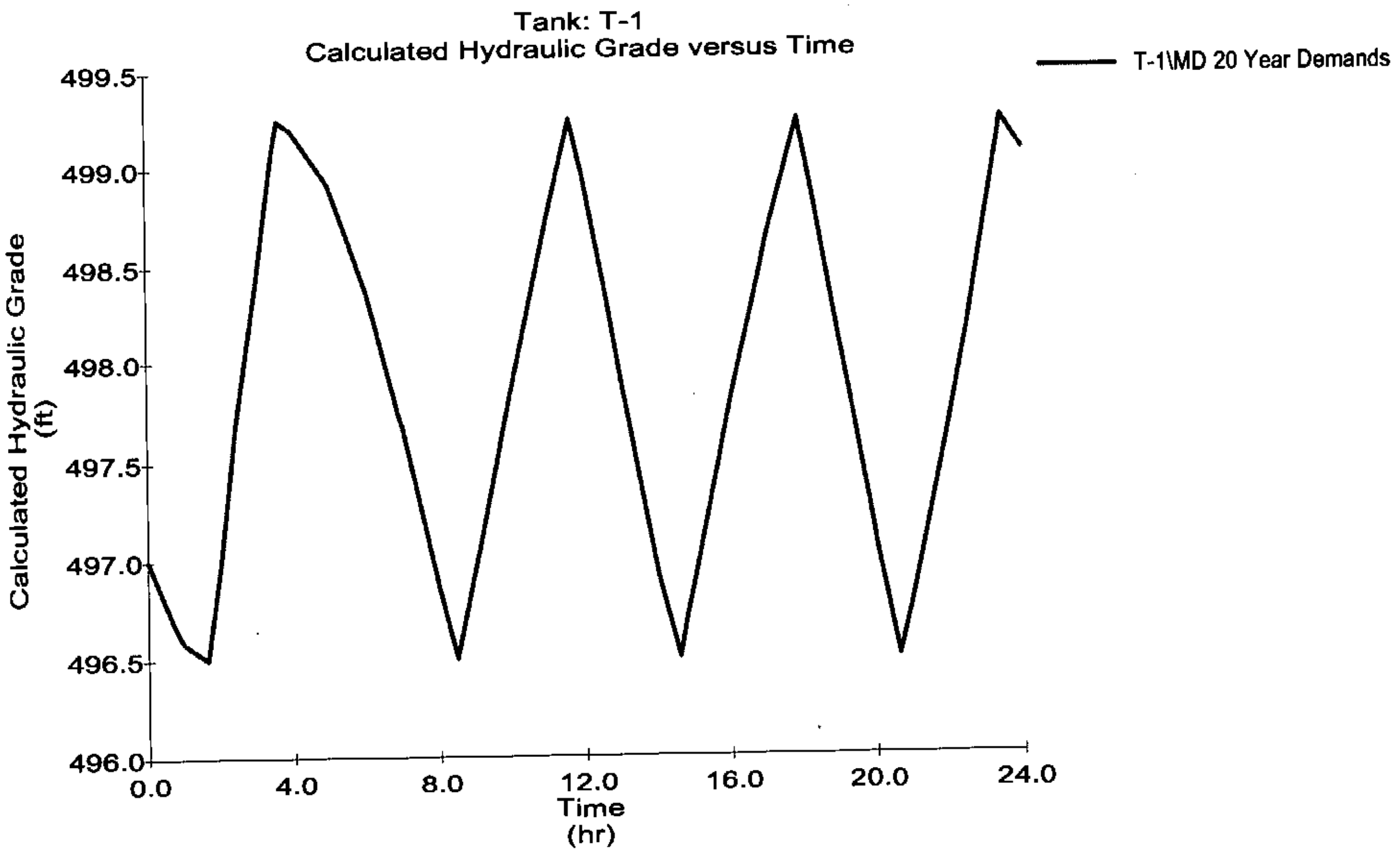
Technology Park Tank



- 2000 gpm fire flow at node J-8145
- Hopkins Hill Rd.
- 12" DI main
- Elevation = 316 ft
- Maximum Day demand

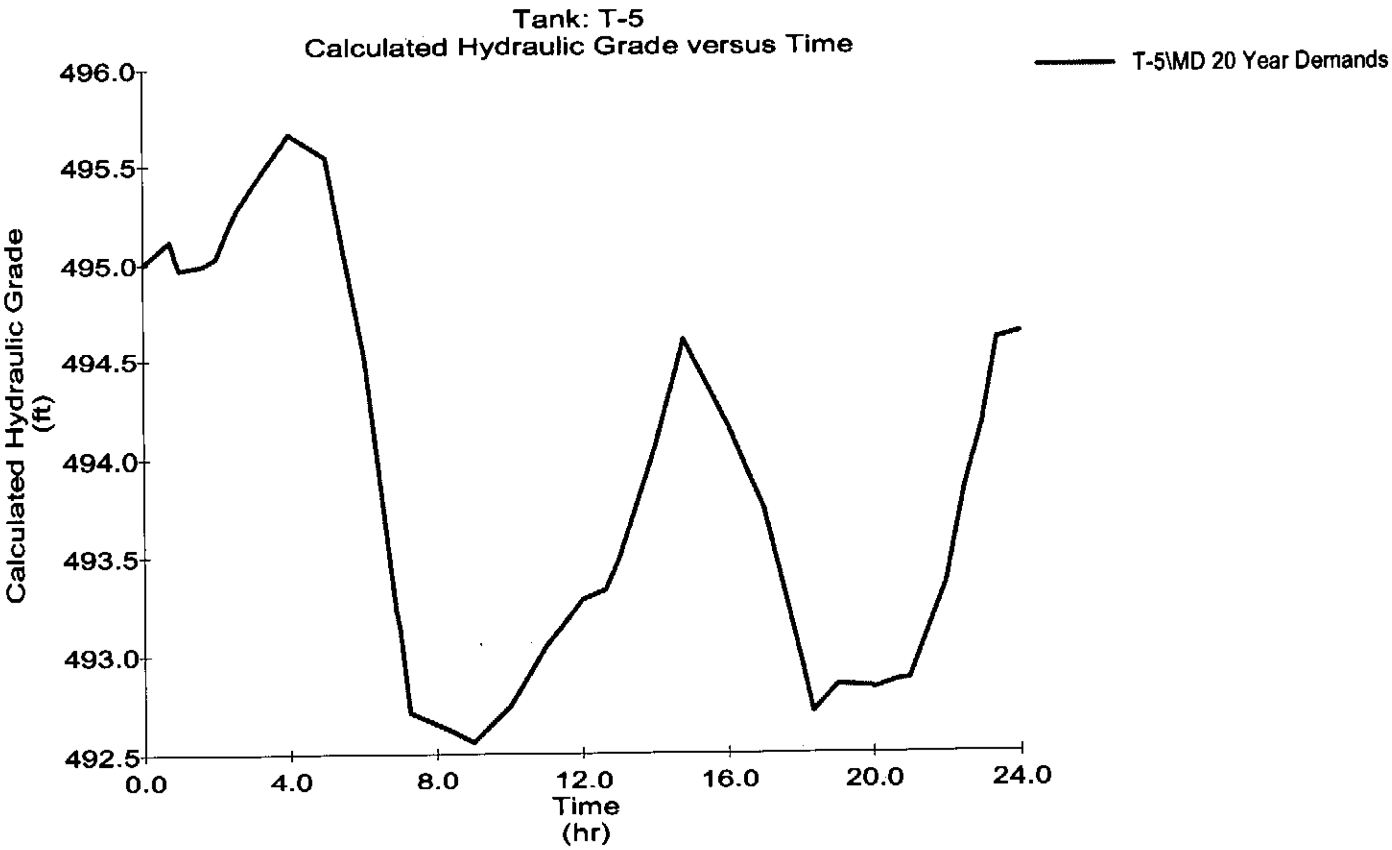
Graph

Read School House Road Tank



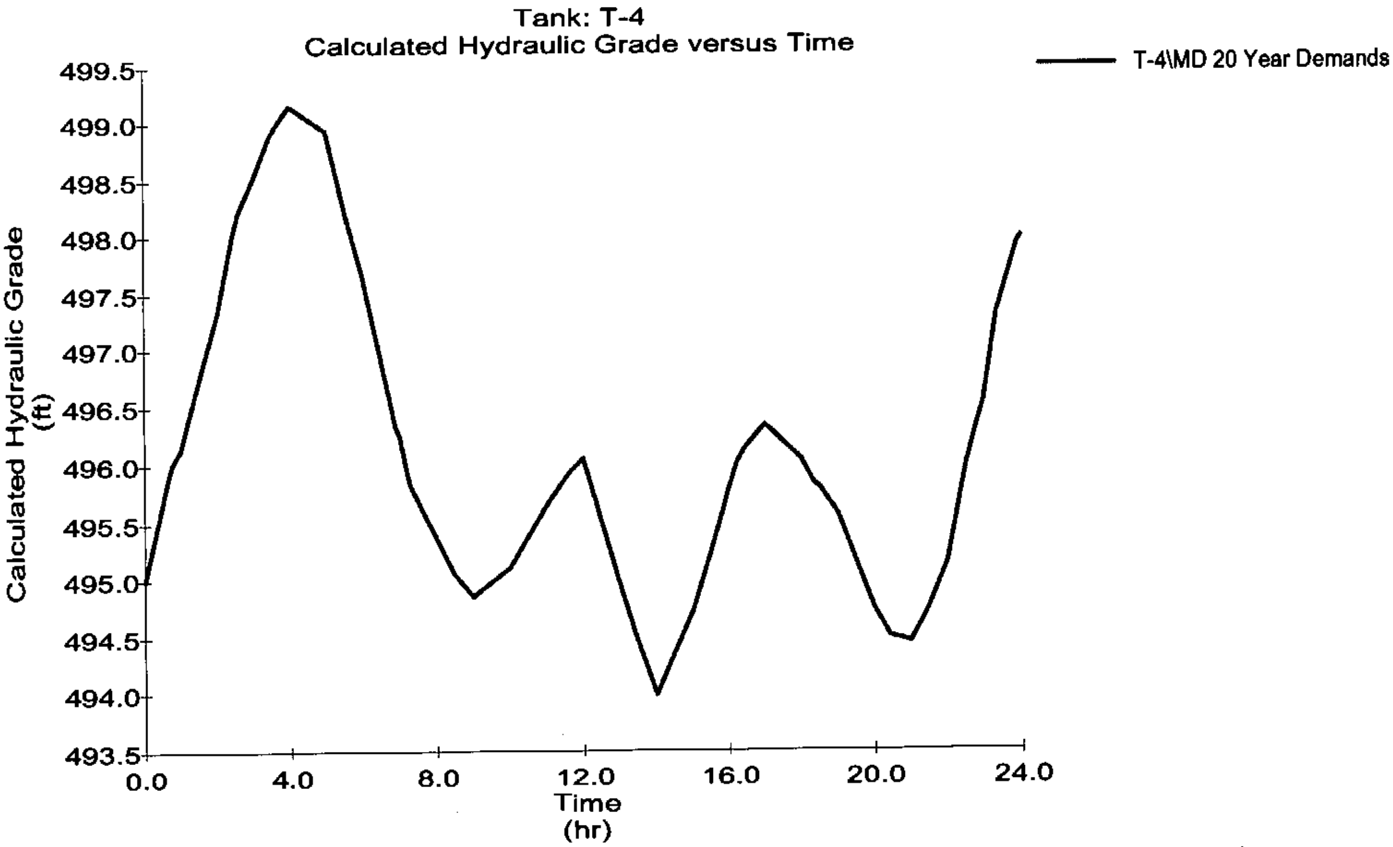
Graph

Carrs Pond Road Tank



Graph

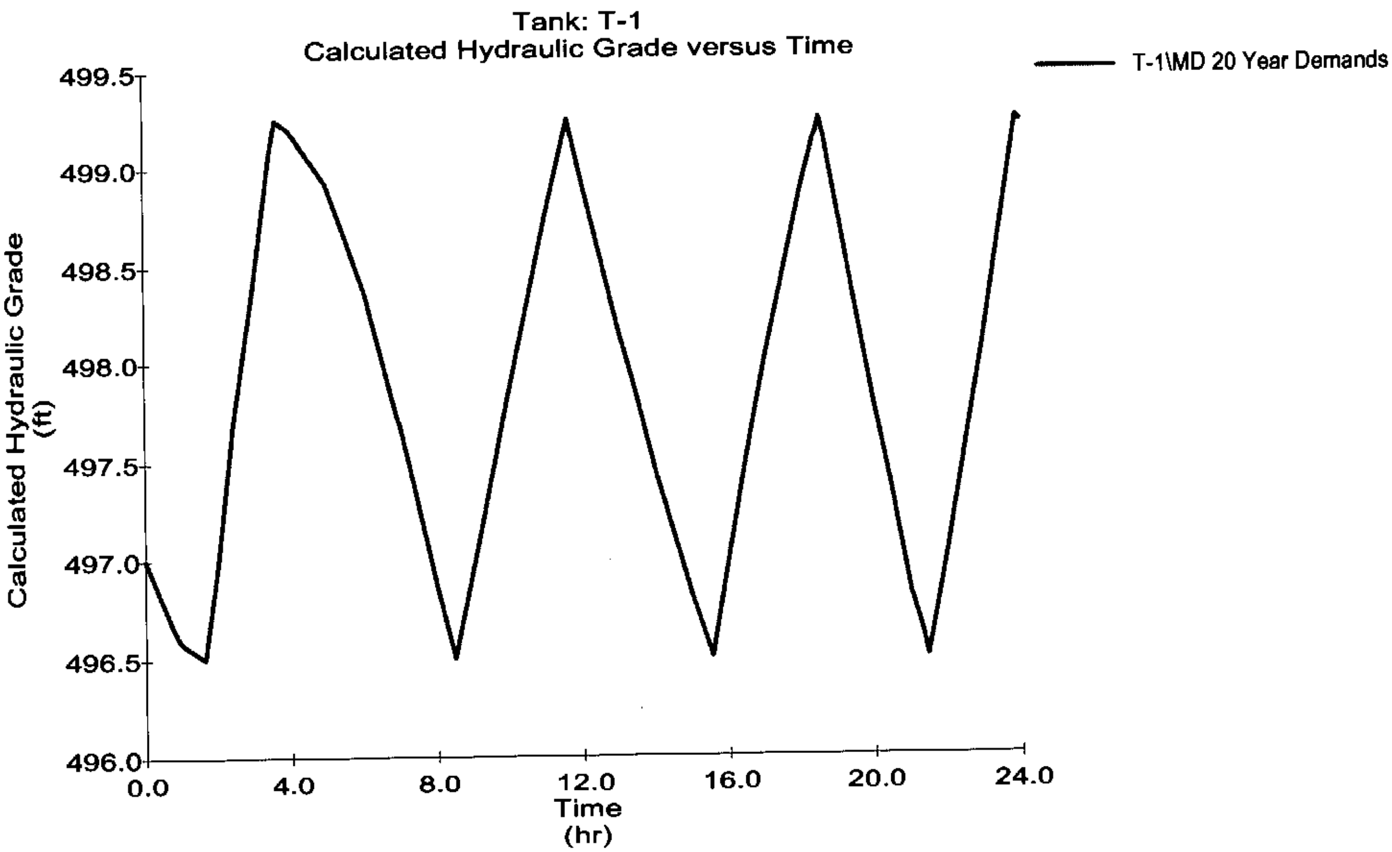
Technology Park Tank



- 2000 gpm fire flow at node J-951
- Lonsdale St.
- 12" AC main
- Elevation = 298 ft
- Maximum Day demand

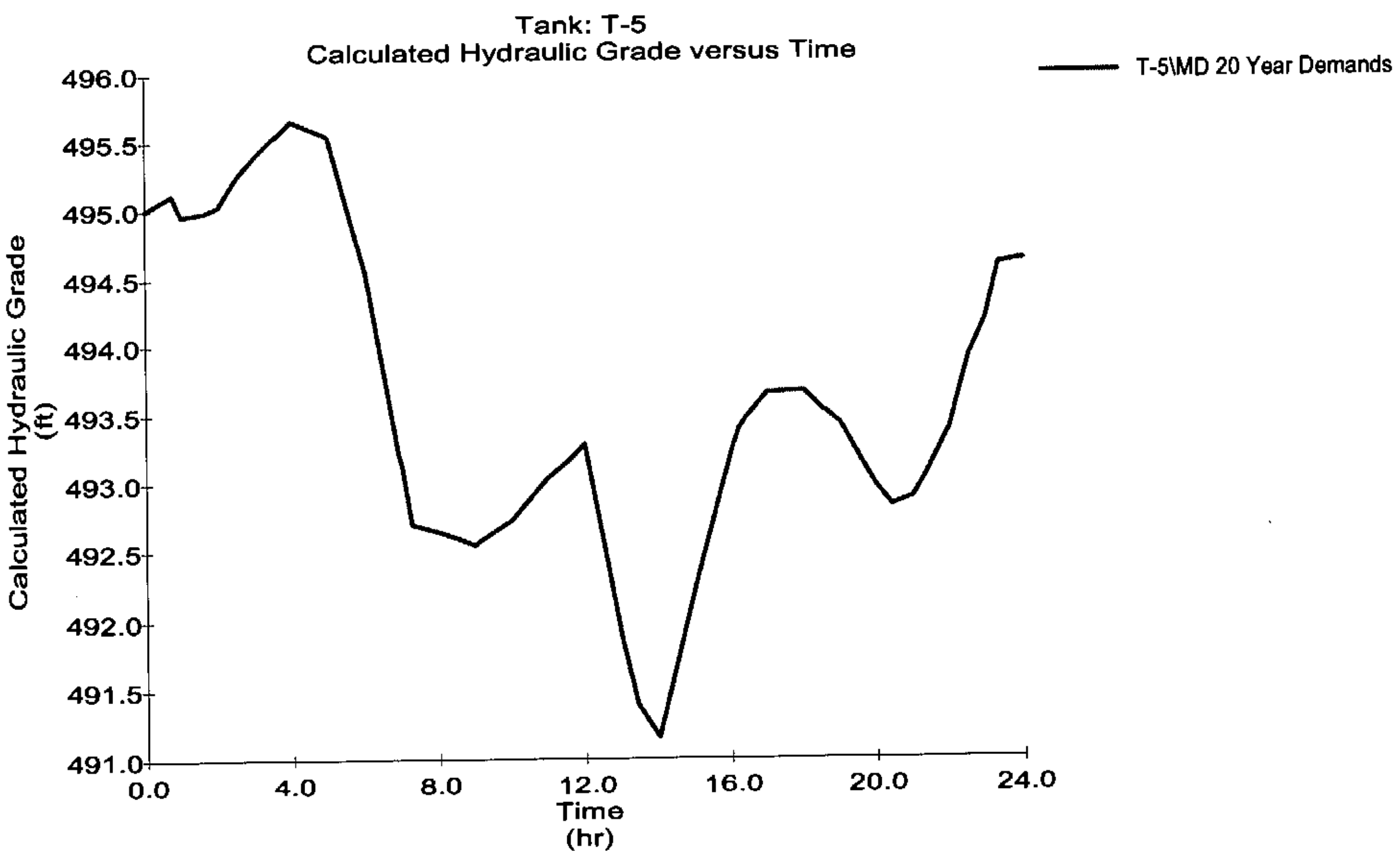
Graph

Read School House Road Tank



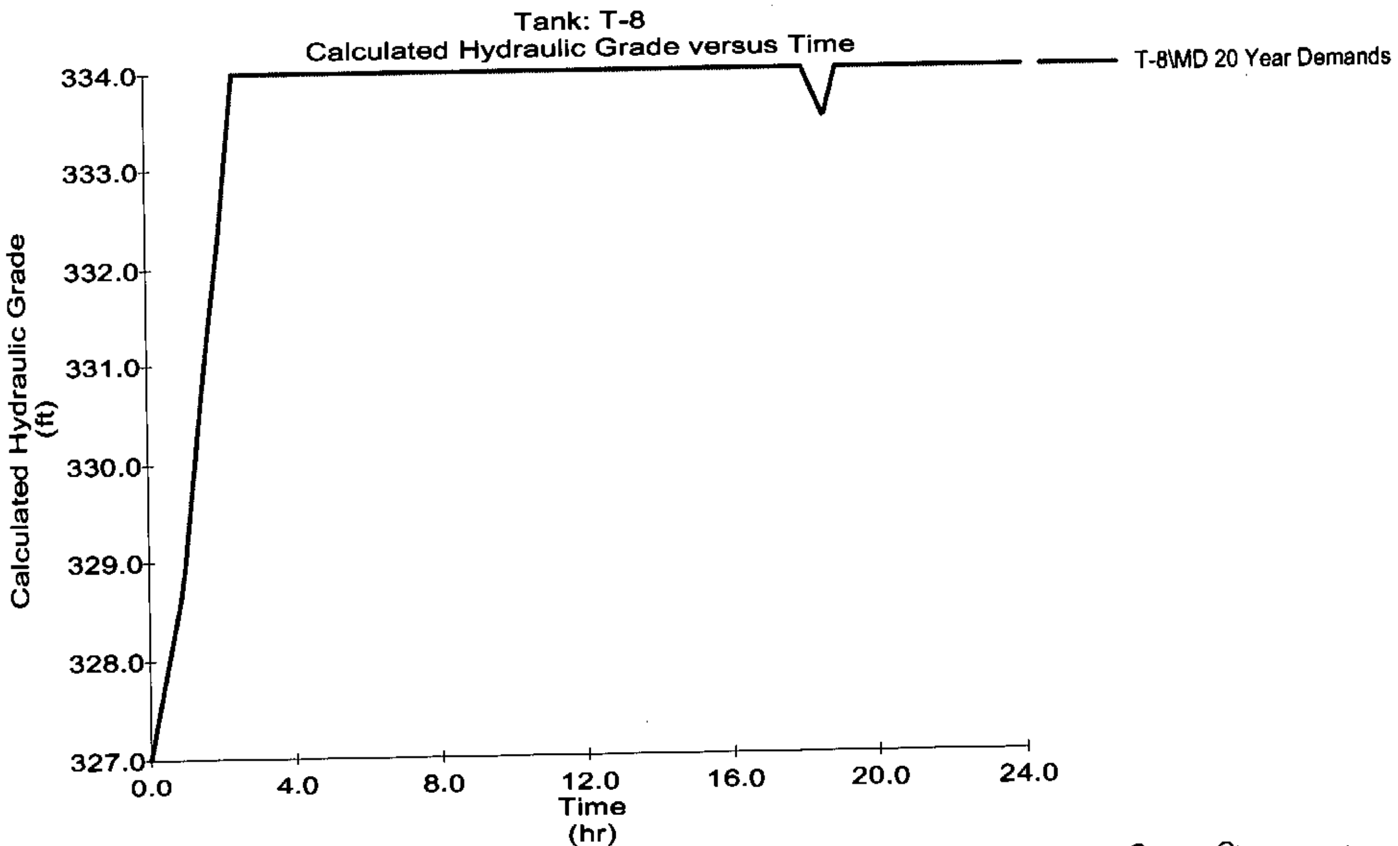
Graph

Carrs Pond Road Tank



Graph

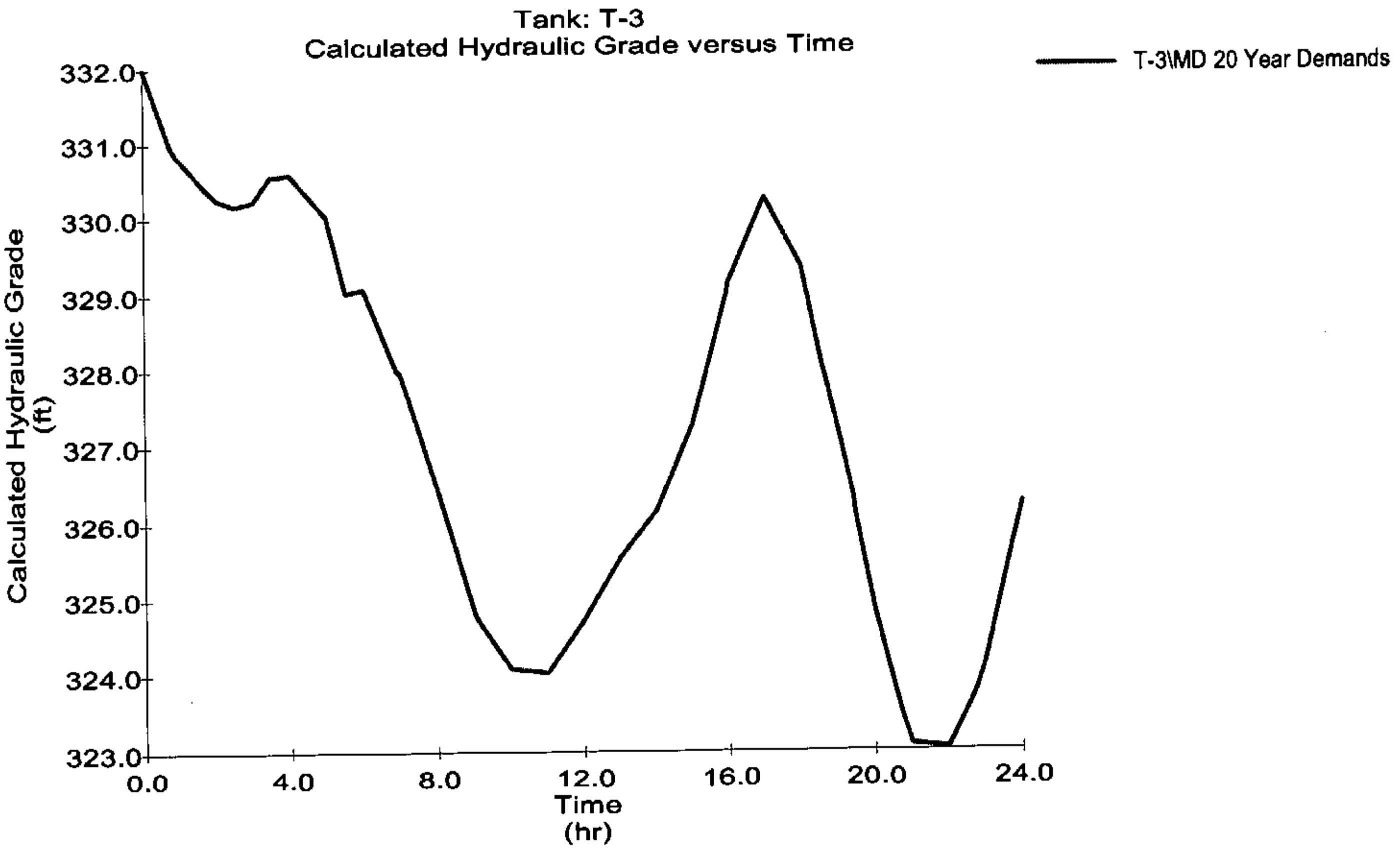
Wakefield Street Tank



- 2000 gpm fire flow at node J-727
- River Farms Dr.
- 12" PVC main
- Elevation: 190 ft
- Maximum Day demand

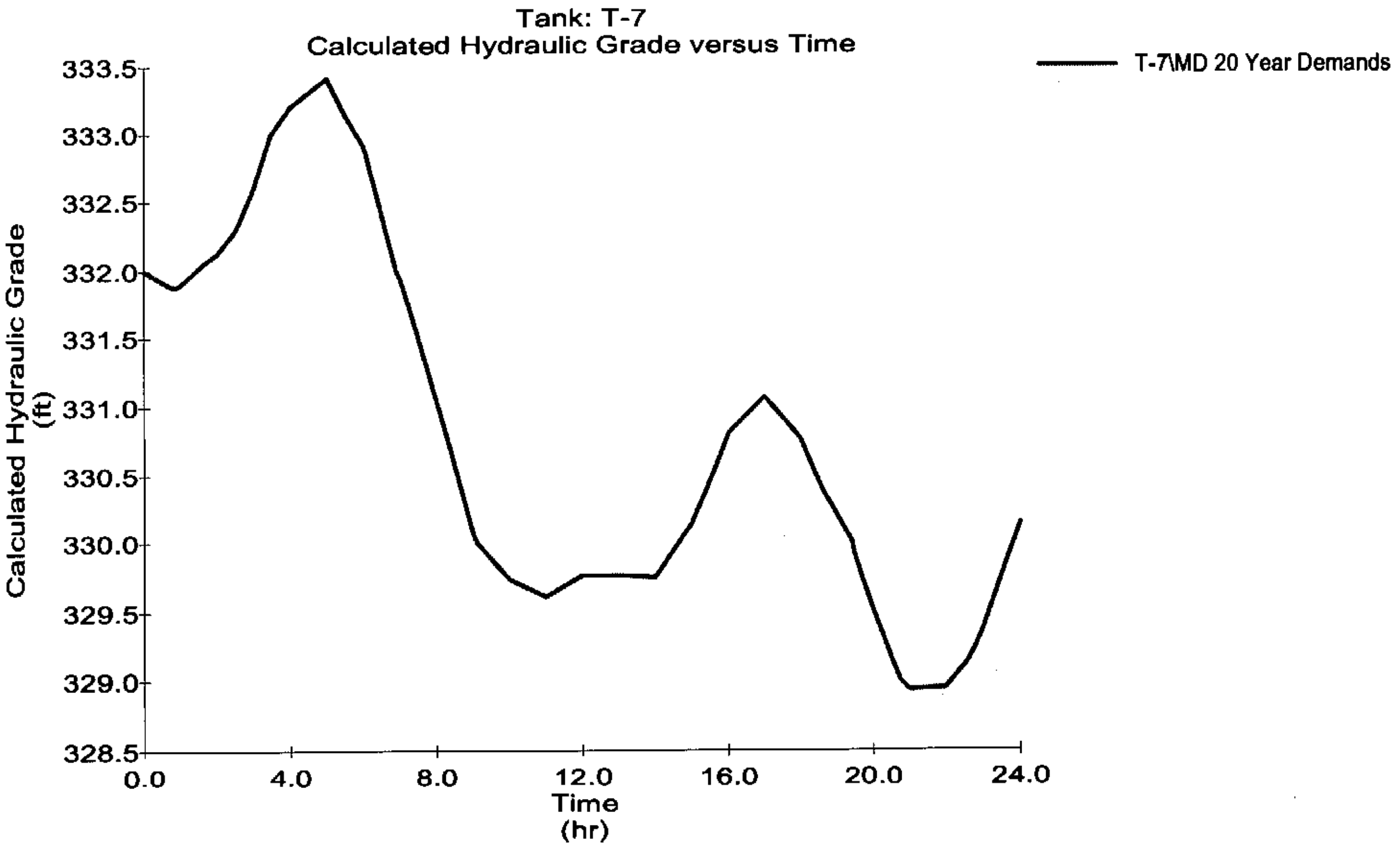
Graph

Frenchtown Road Tank



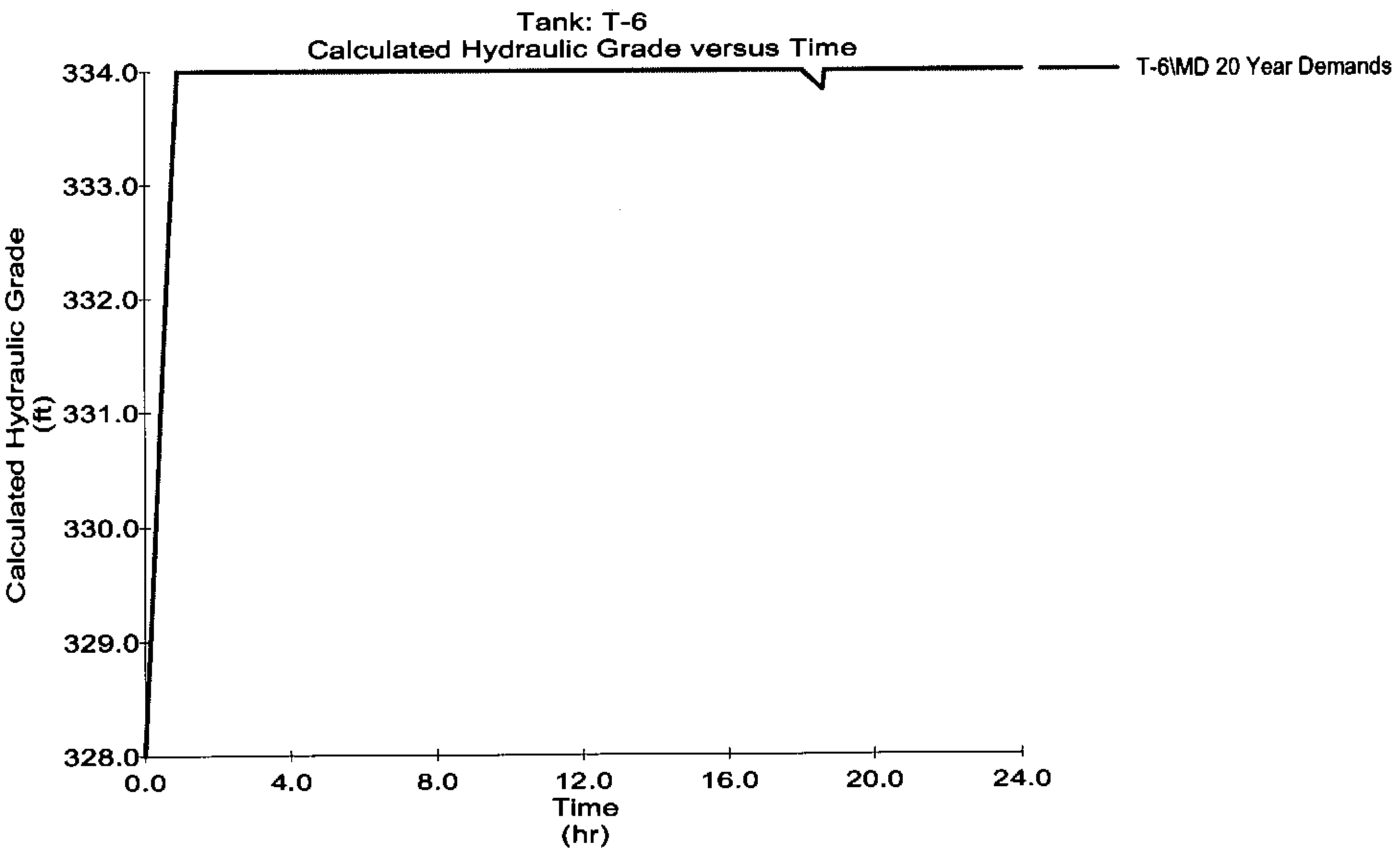
Graph

Setian Lane Tank



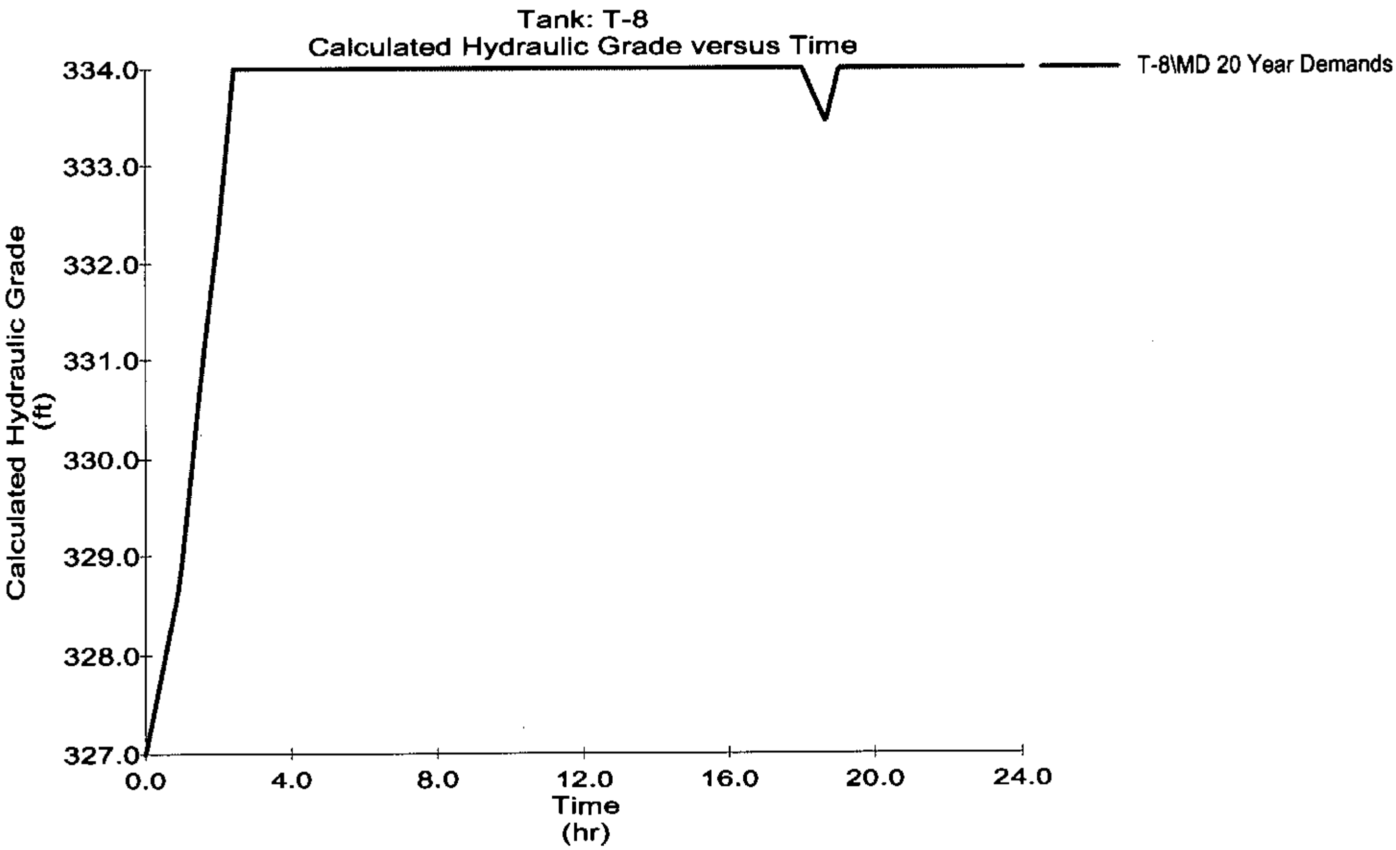
Graph

West Street Tank



Graph

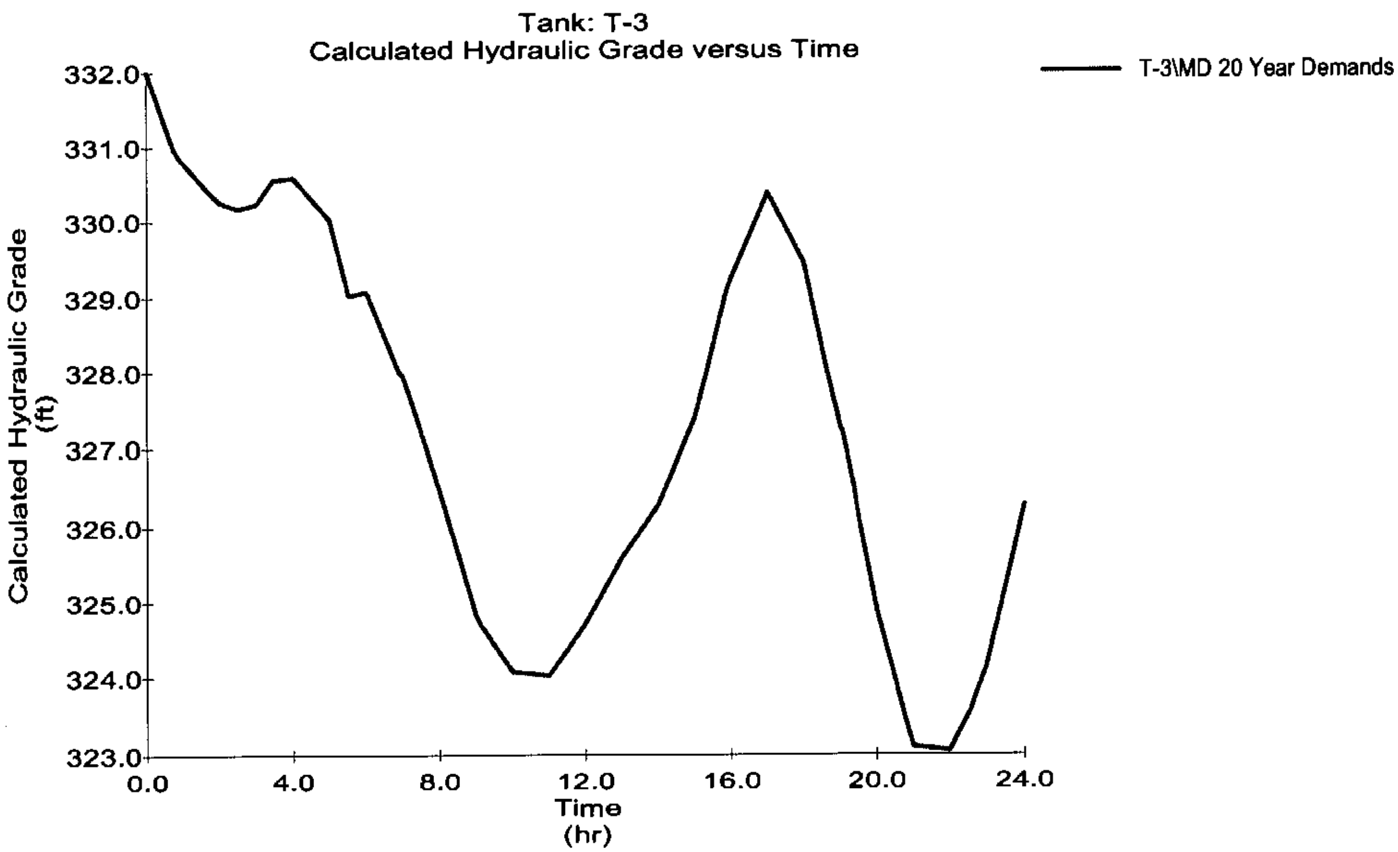
Wakefield Street Tank



- 2000 gpm fire flow at node J-769
- Main St.
- 20" DI main
- Elevation = 92 ft
- Maximum Day demand

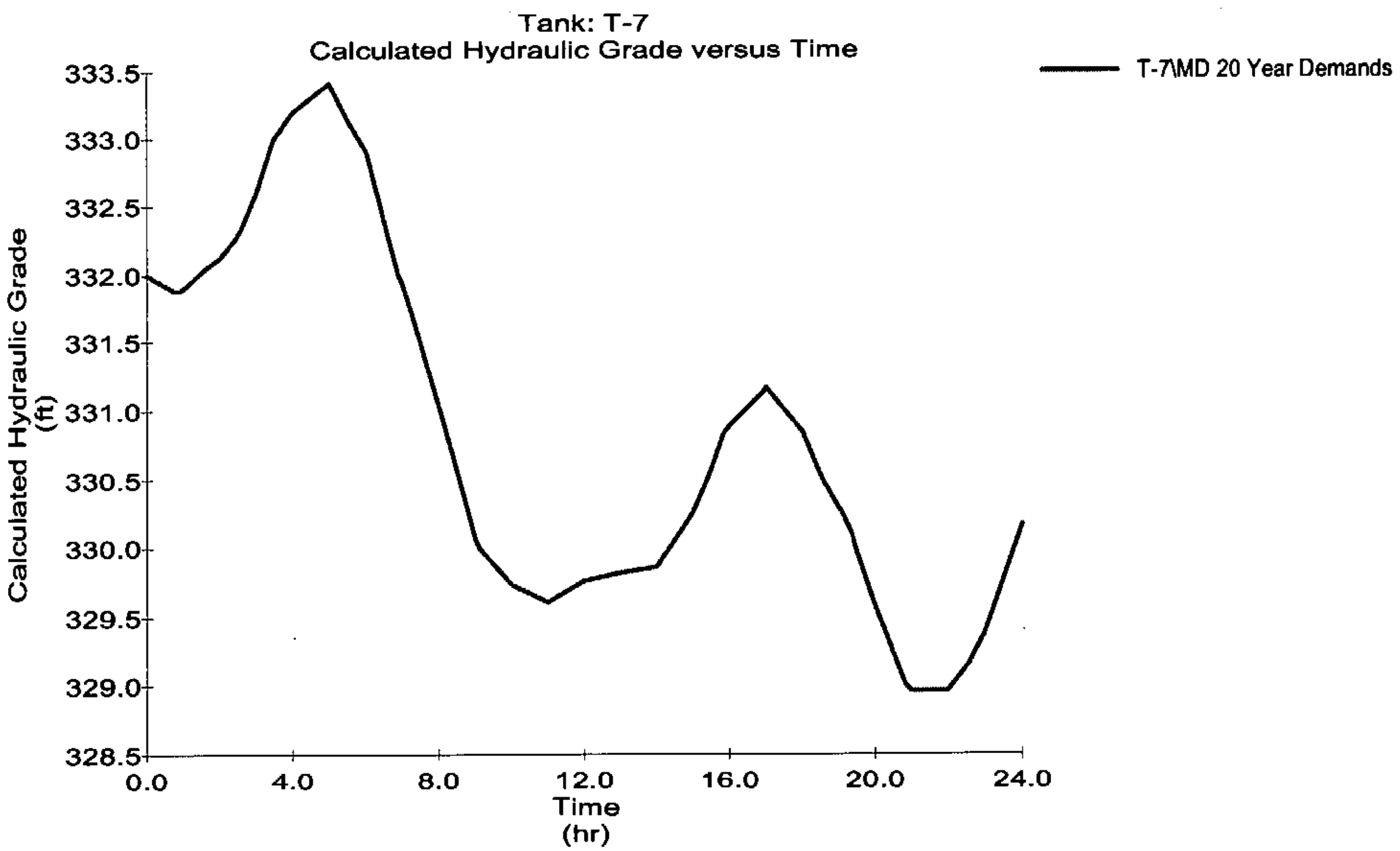
Graph

Frenchtown Road Tank



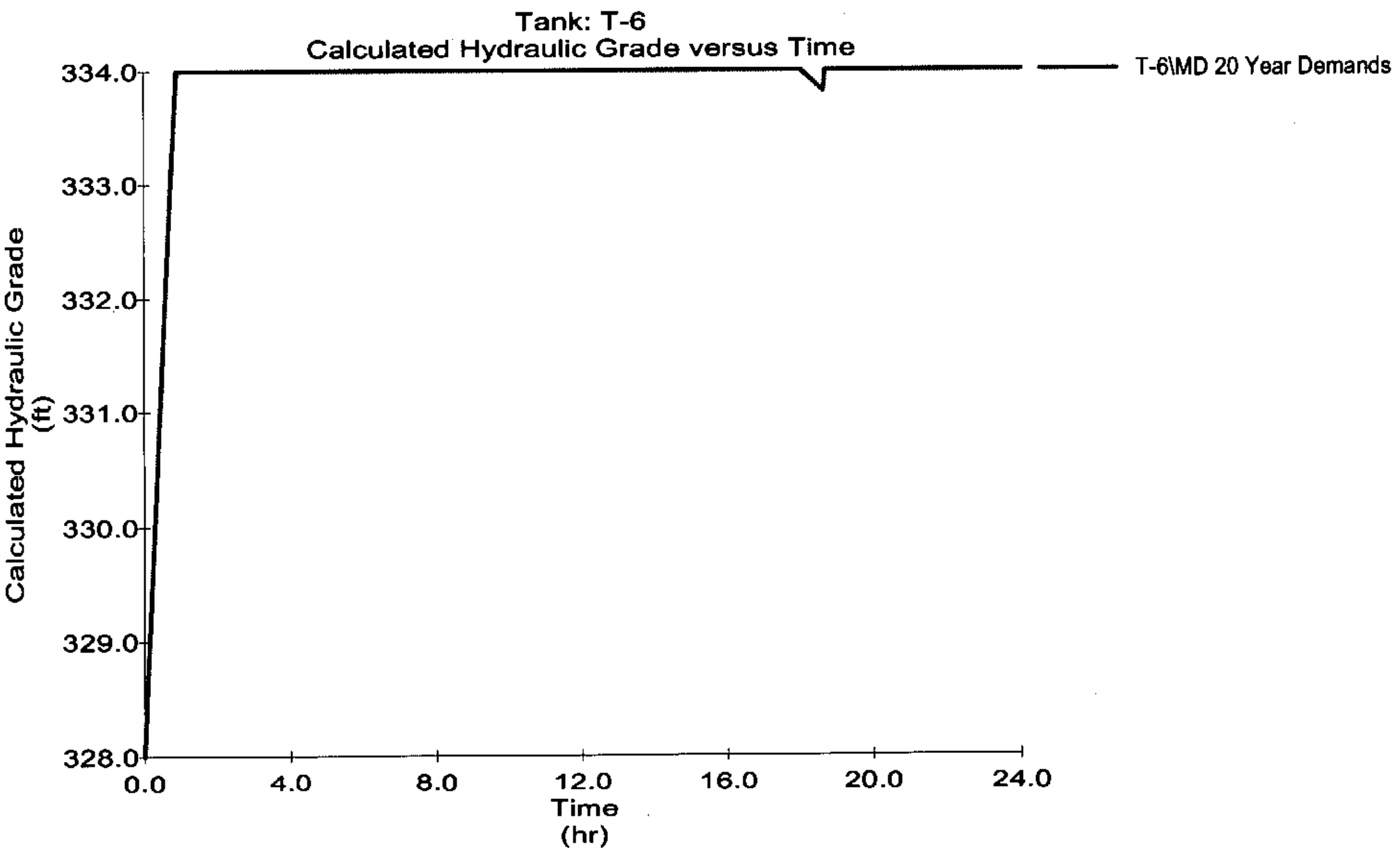
Graph

Setian Lane Tank



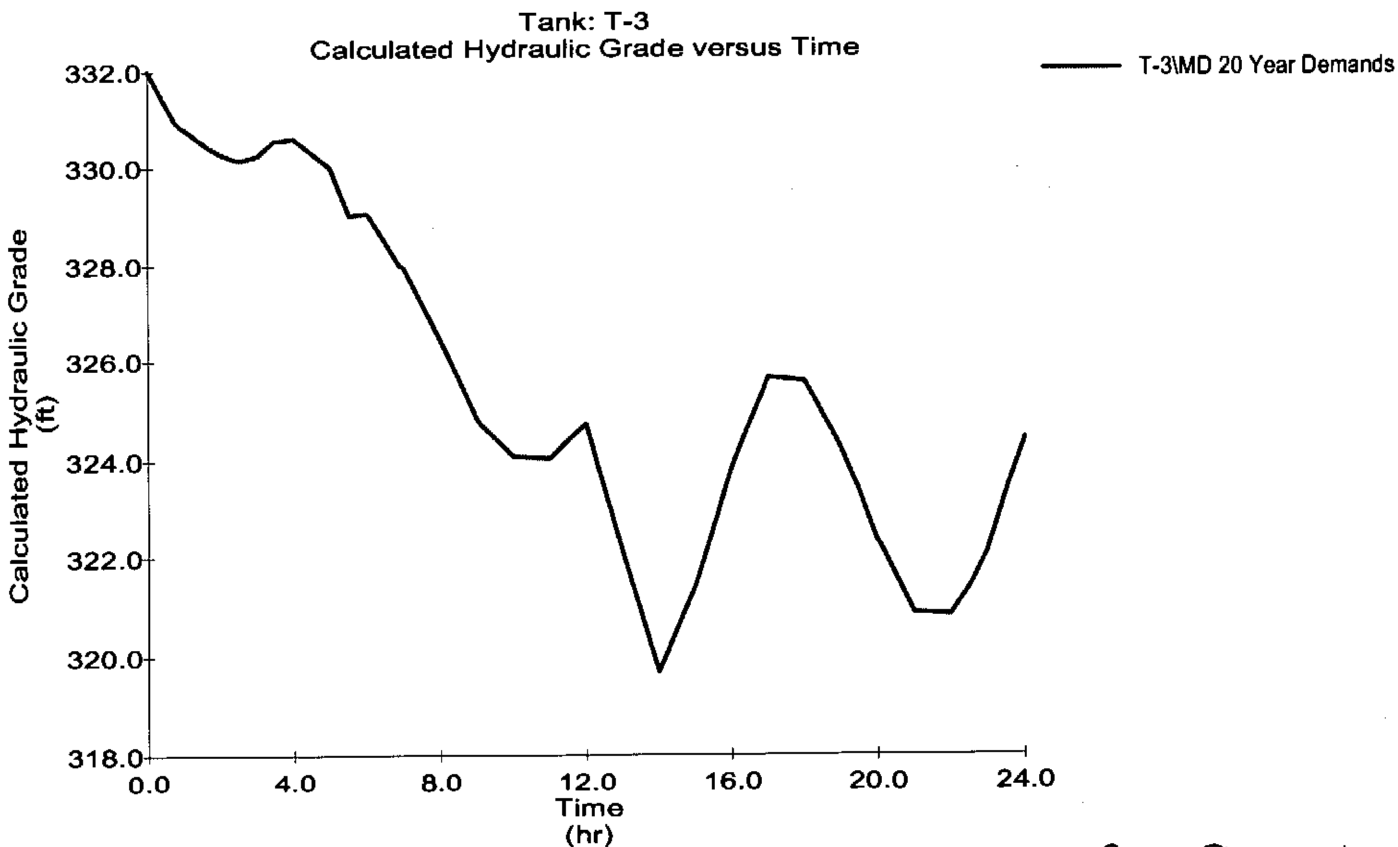
Graph

West Street Tank



Graph

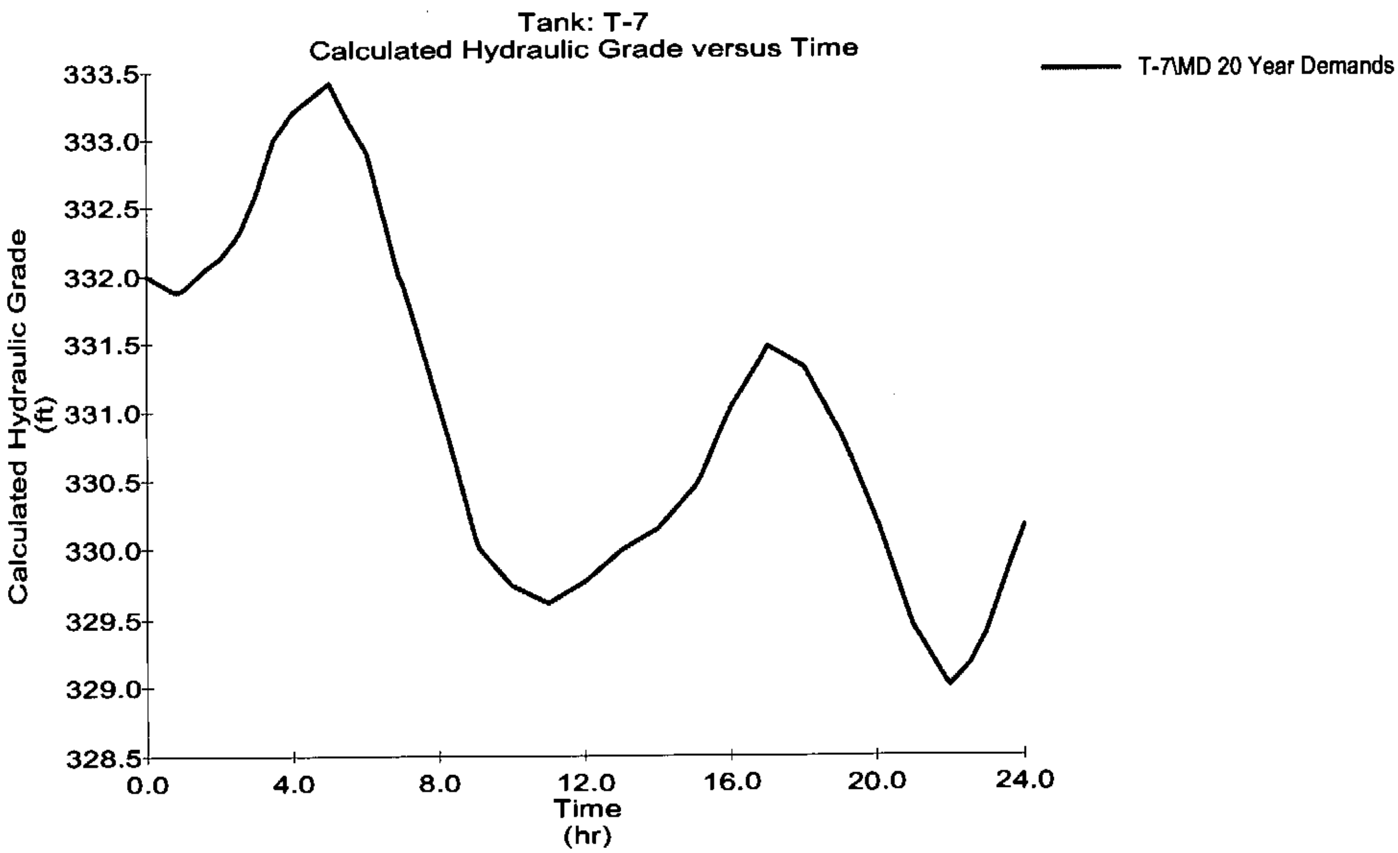
Frenchtown Road Tank



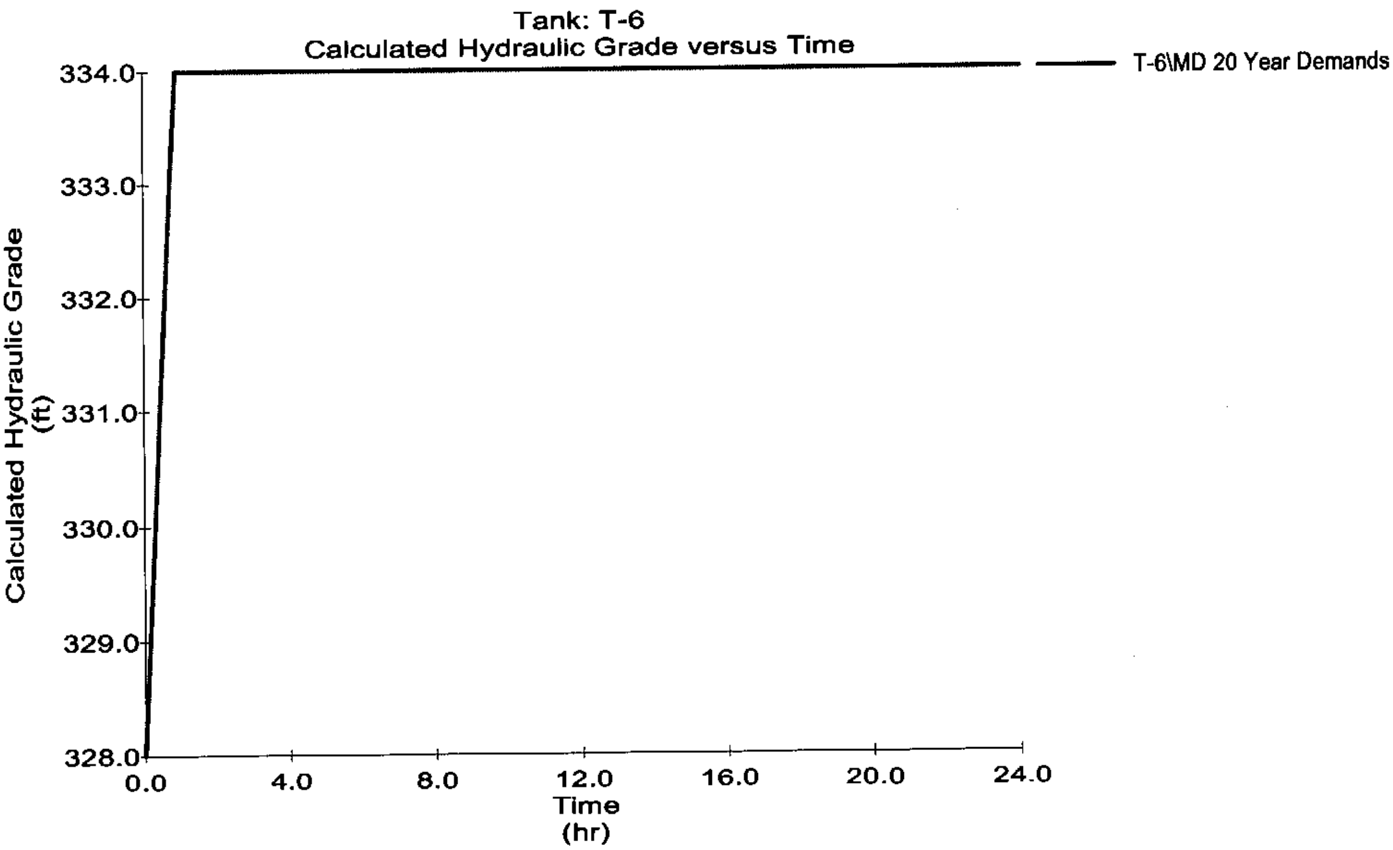
- 2000 gpm fire flow at node J-4091
- Frenchtown Rd.
- 20" AC main
- Elevation = 247 ft
- Maximum Day demand

Graph

Setian Lane Tank

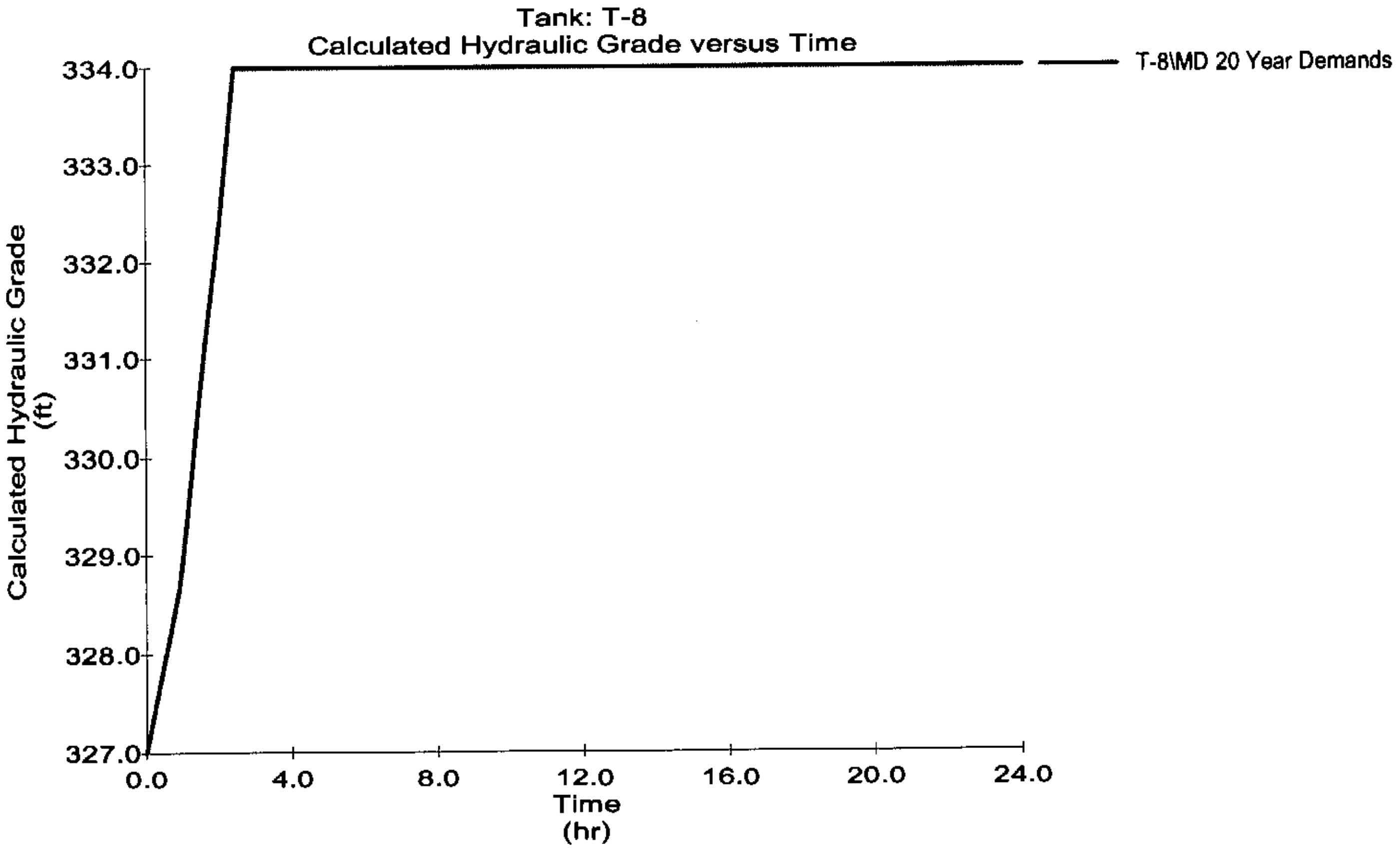


Graph
West Street Tank



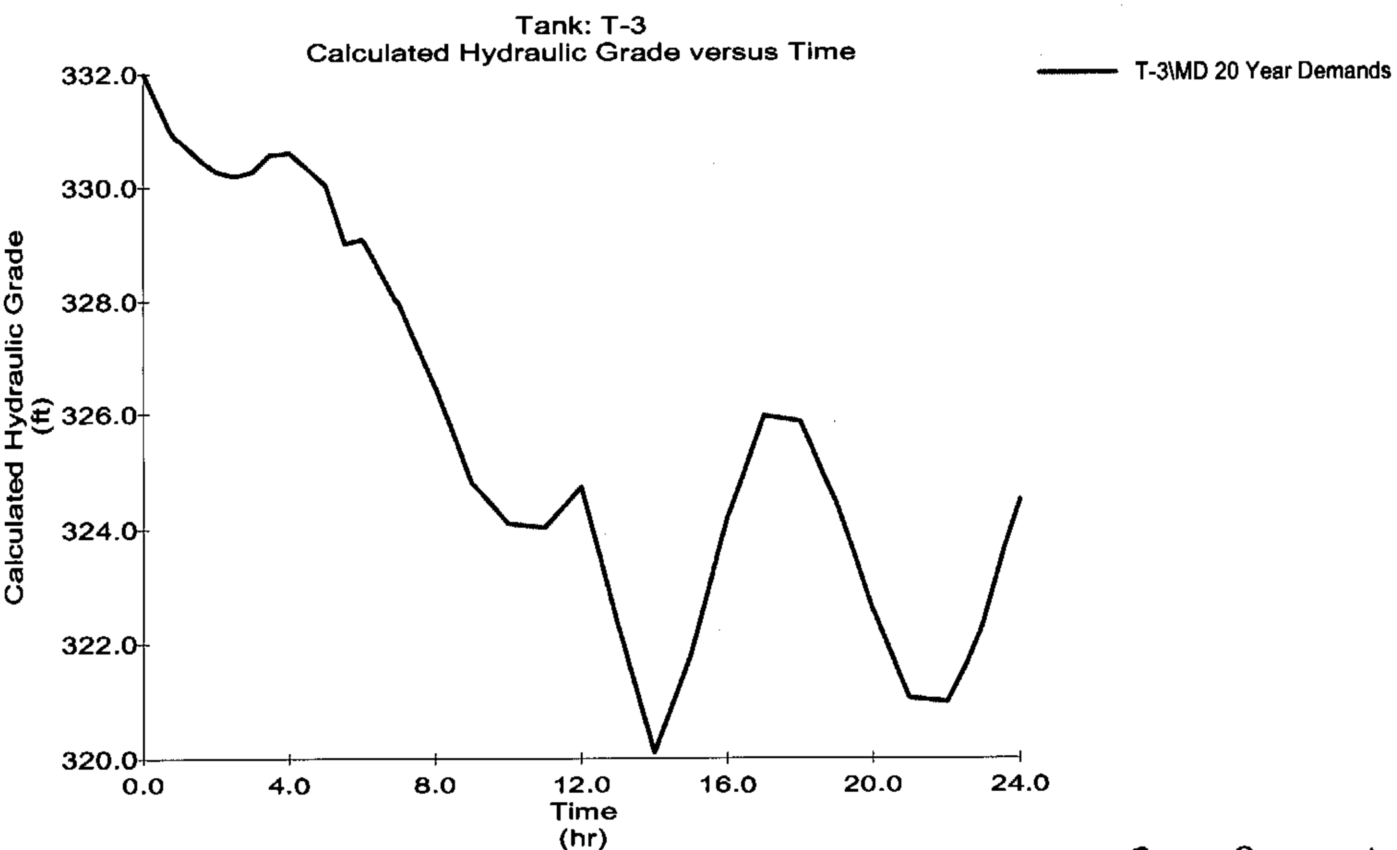
Graph

Wakefield Street Tank



Graph

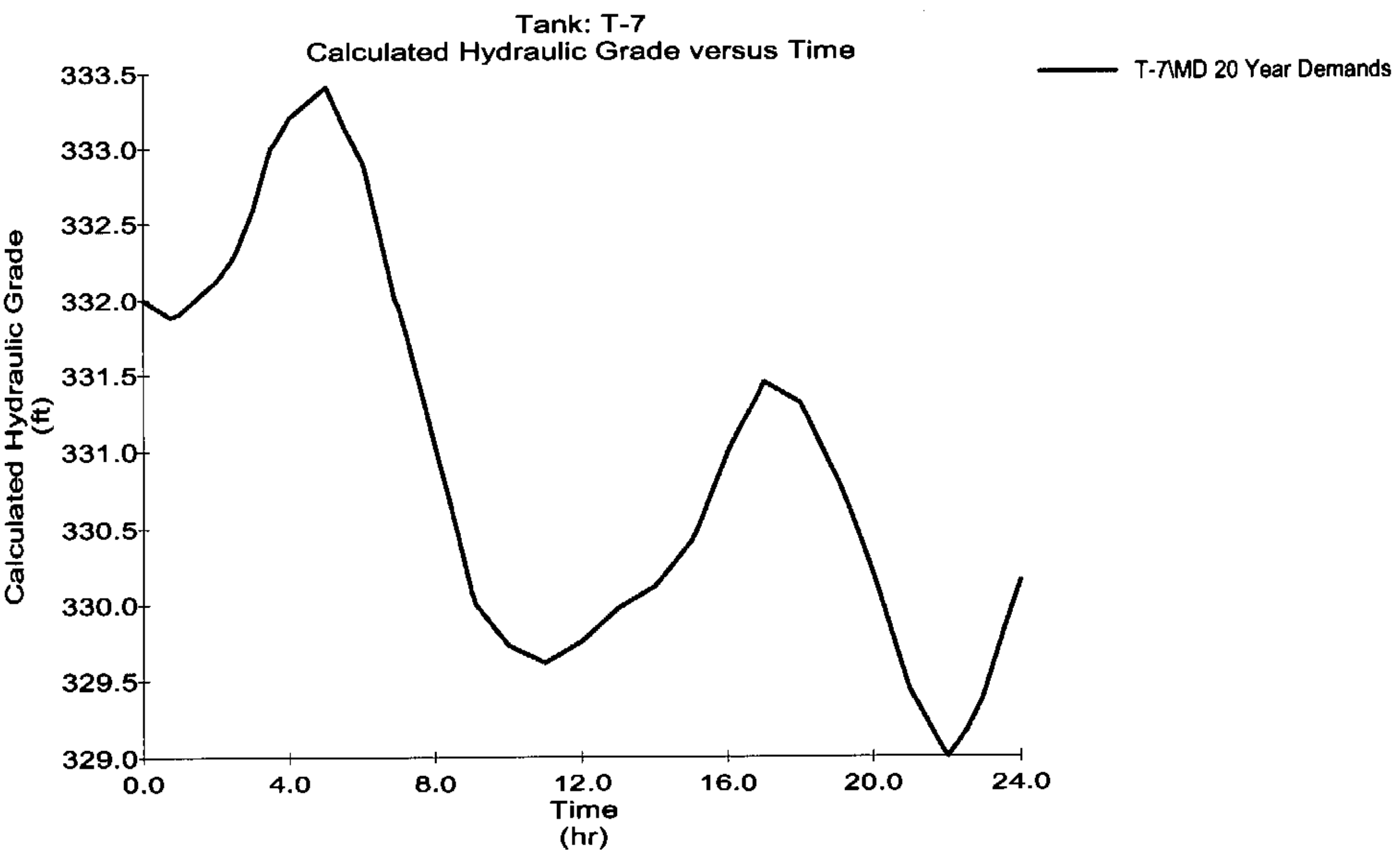
Frenchtown Road Tank



- 2000 gpm fire flow at node J-4175
- South County Tr.
- 12" AC main
- Elevation = 109 ft
- Maximum Day demand

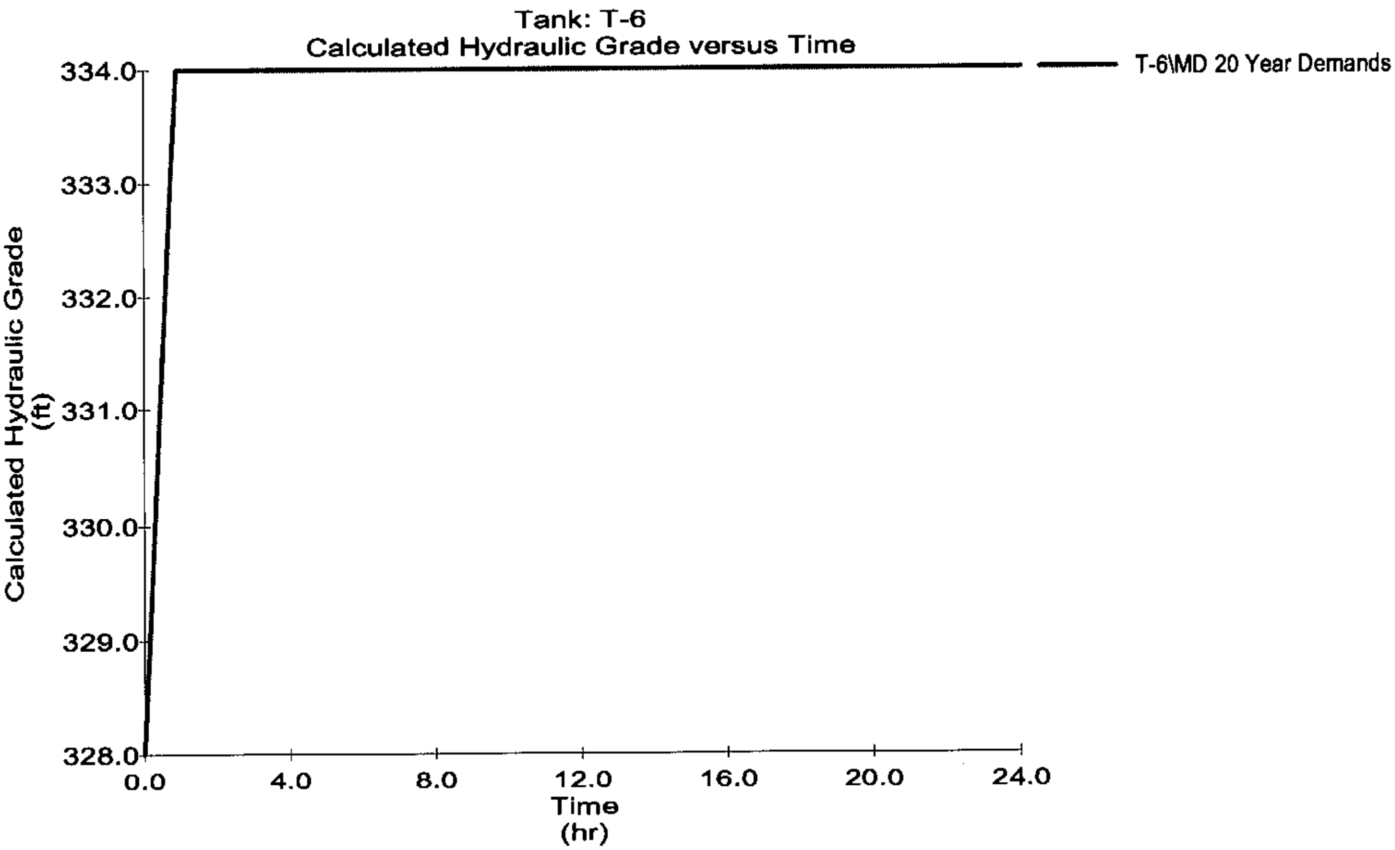
Graph

Setian Lane Tank



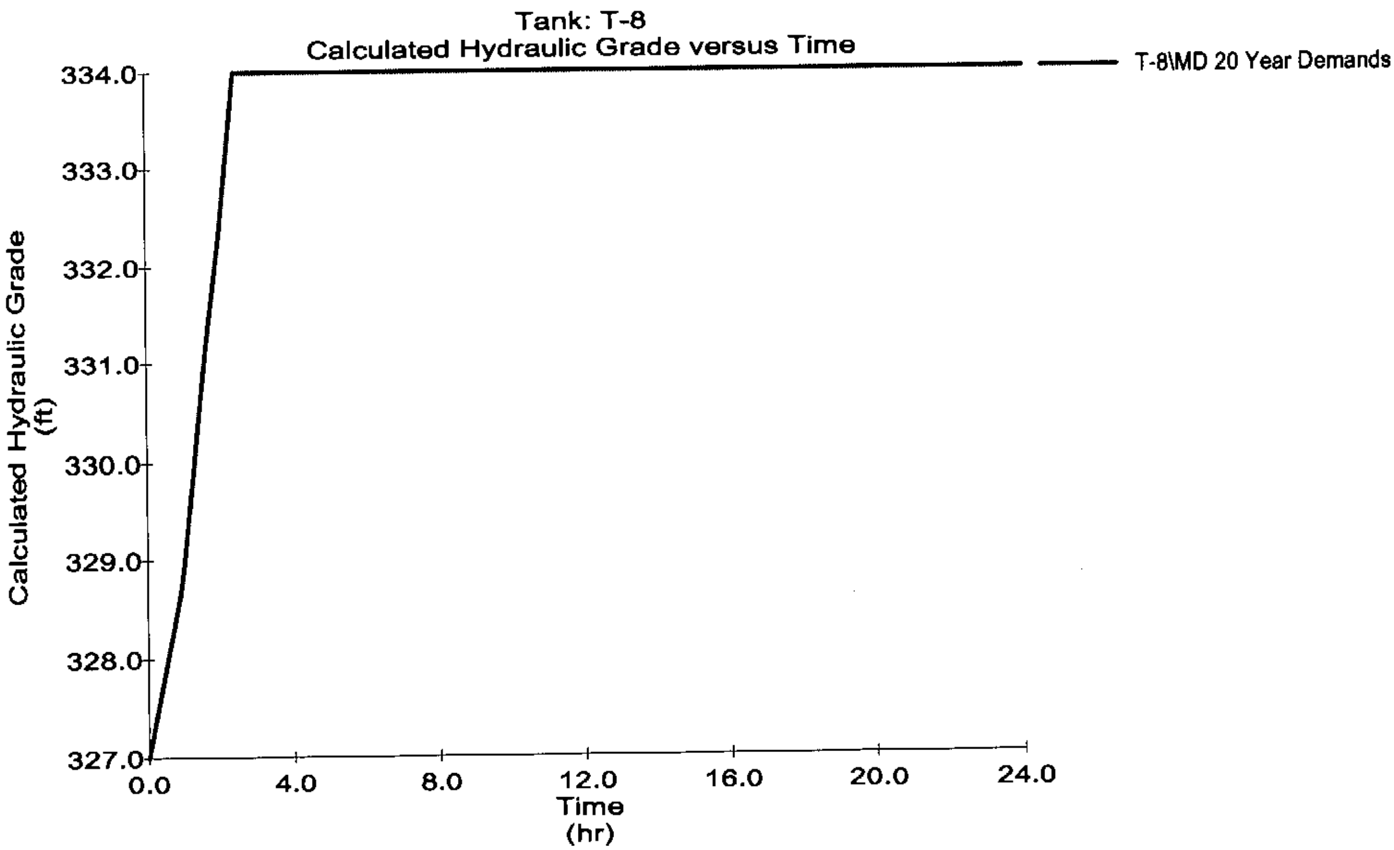
Graph

West Street Tank



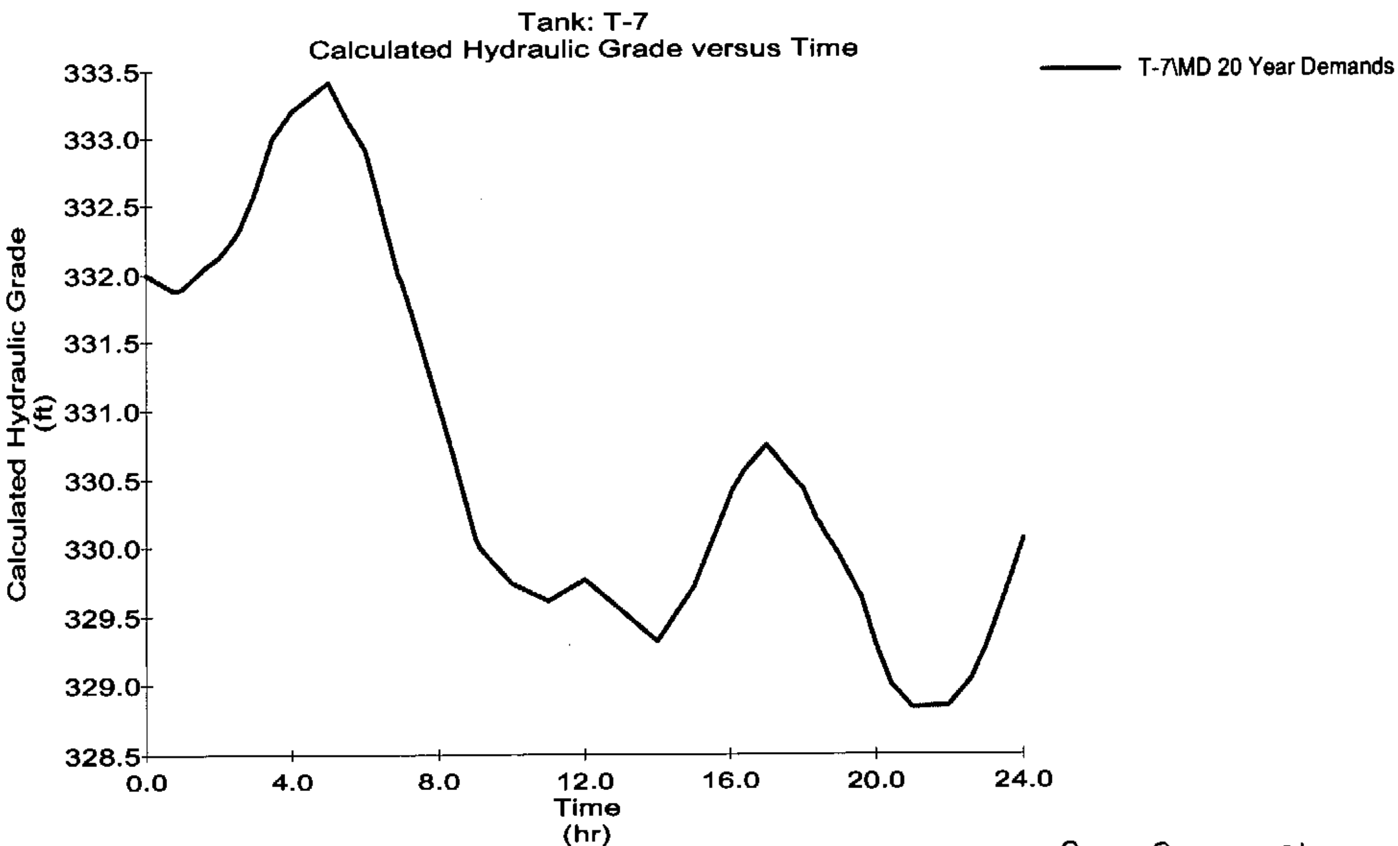
Graph

Wakefield Street Tank



Graph

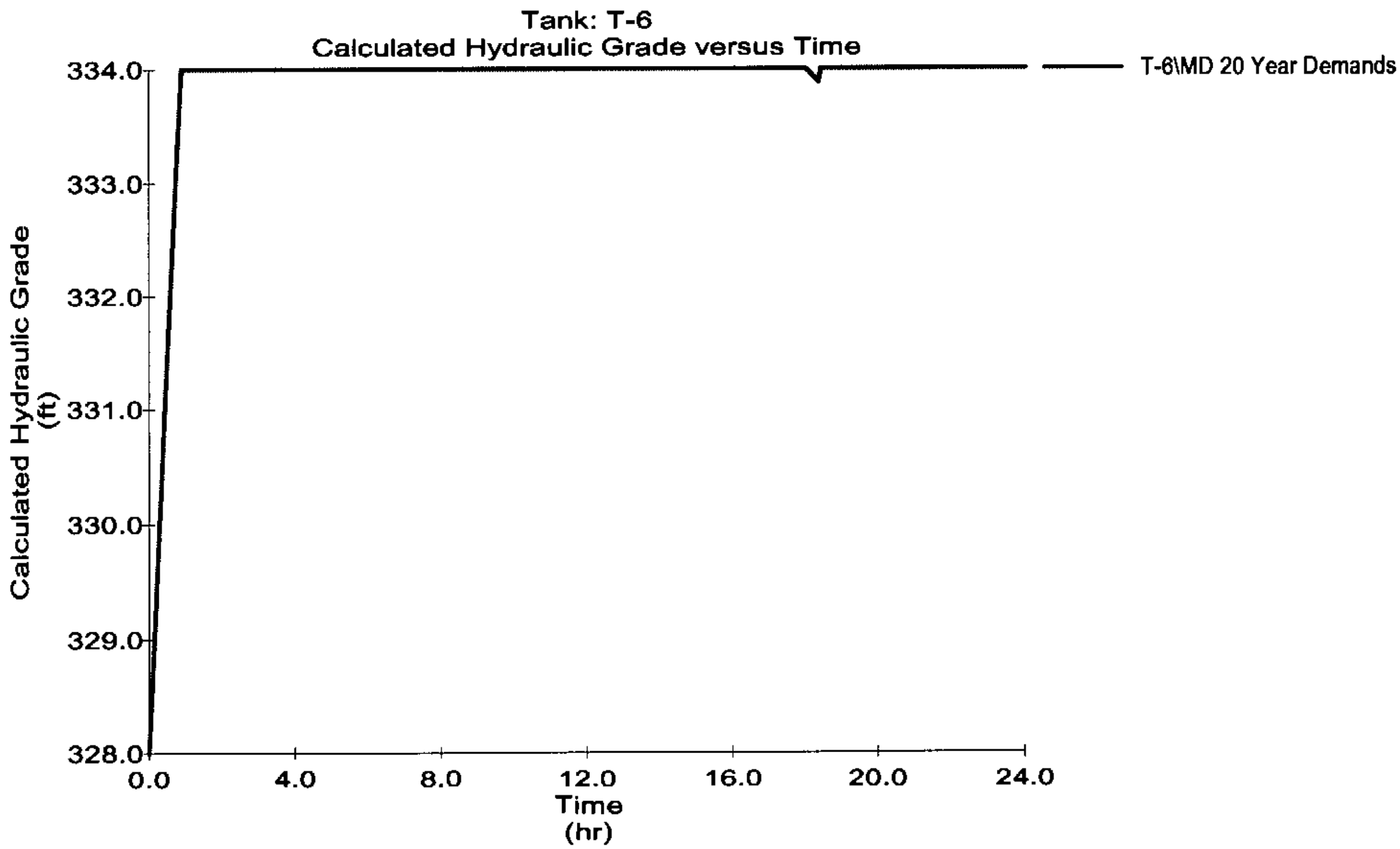
Setian Lane Tank



- 2000 gpm fire flow at node J-390
- Cowesett Rd.
- 12" AC main
- Elevation = 205 ft
- Maximum Day demand

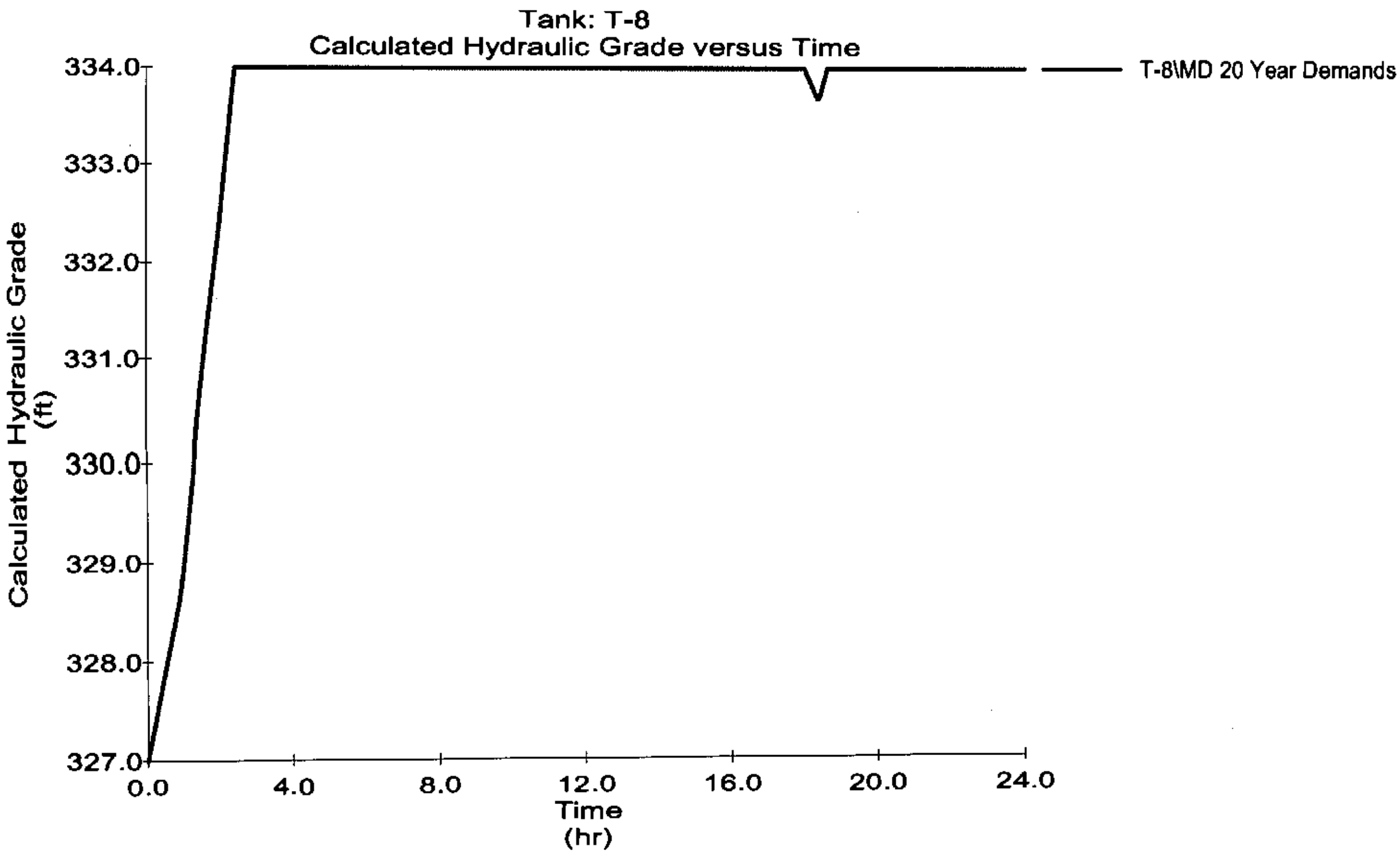
Graph

West Street Tank



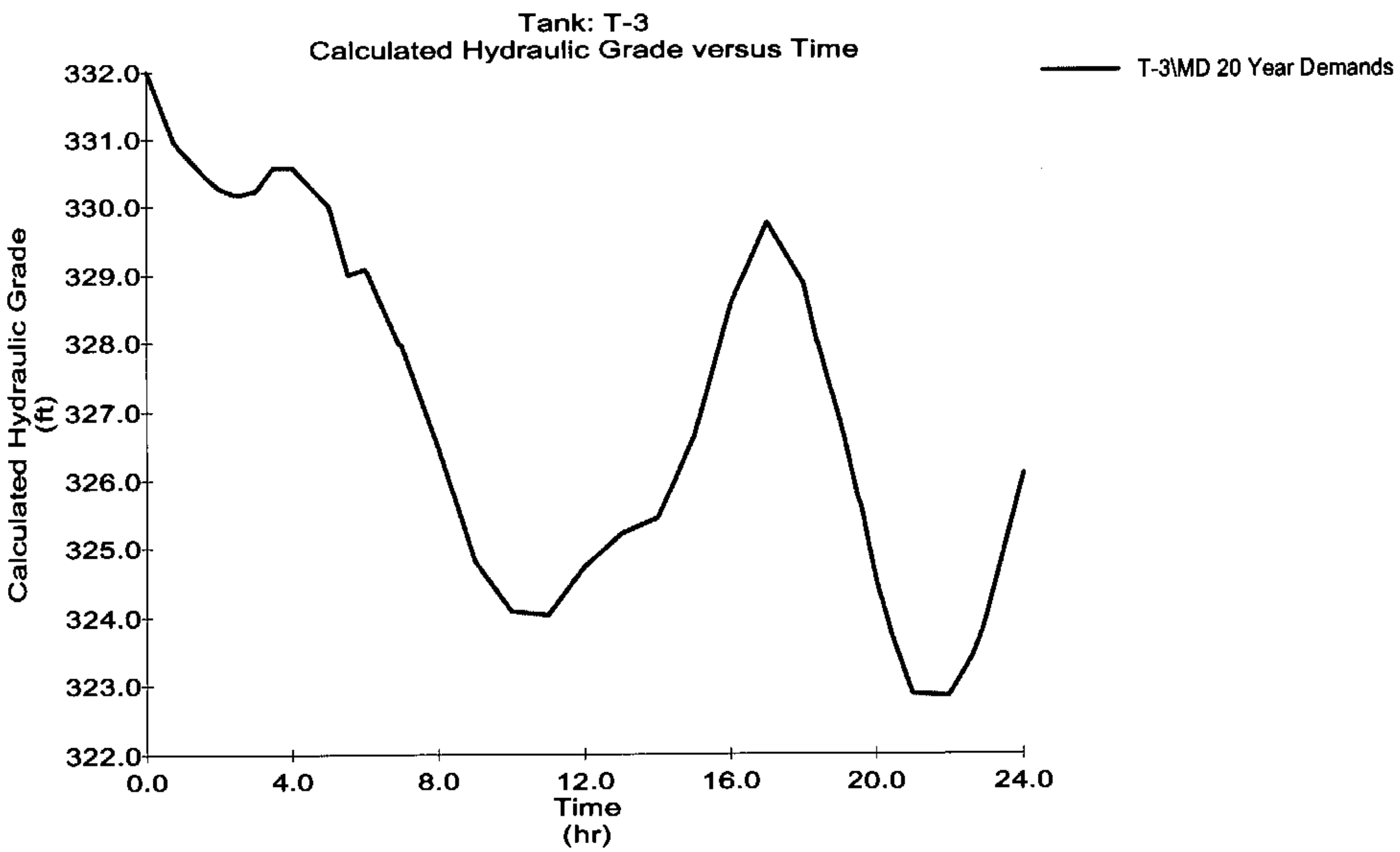
Graph

Wakefield Street Tank



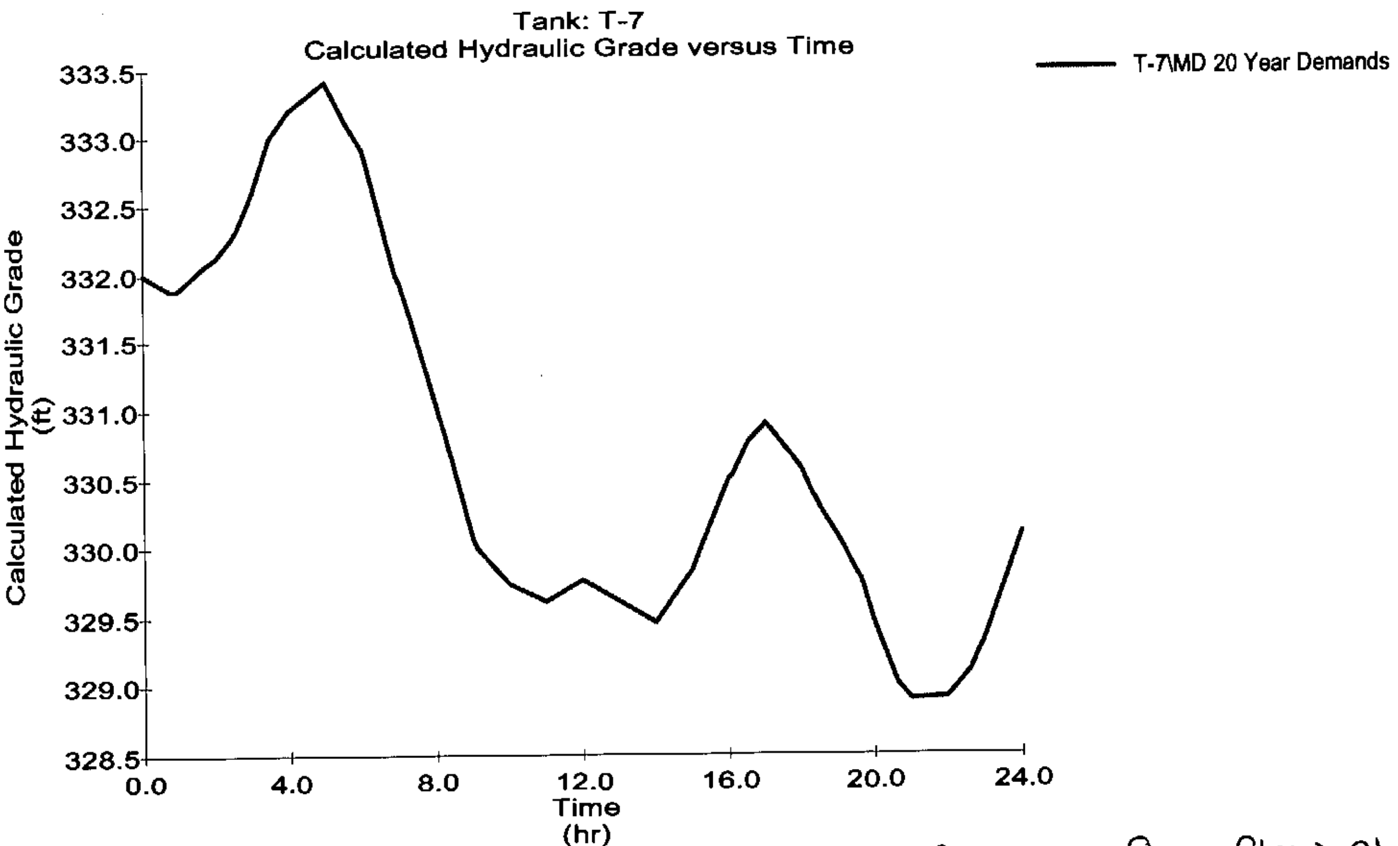
Graph

Frenchtown Road Tank



Graph

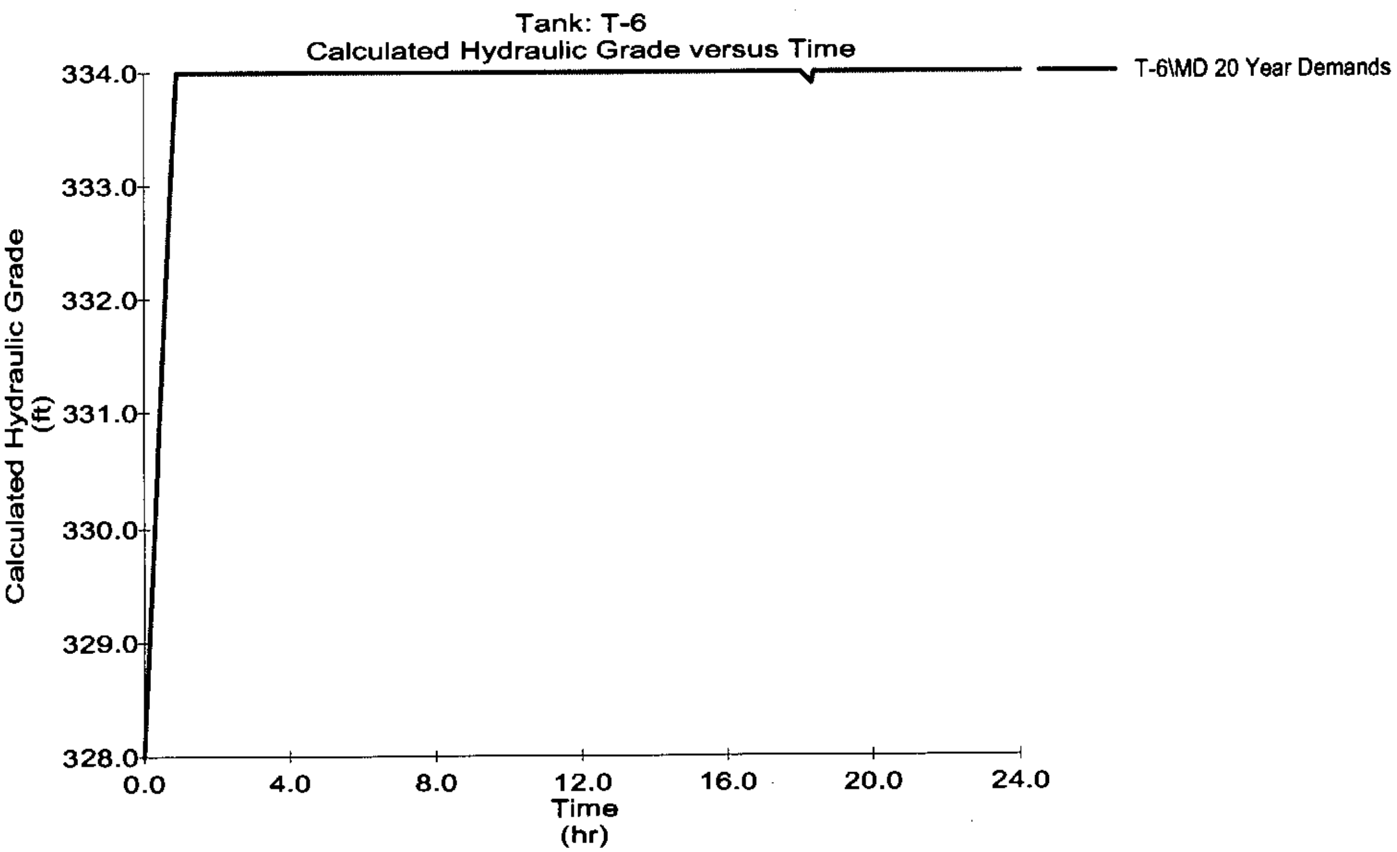
Setian Lane Tank



- 2000 gpm fire flow at node J-2005
- Centerville Rd.
- 12" AC main
- Elevation = 100 ft
- Maximum Day demand

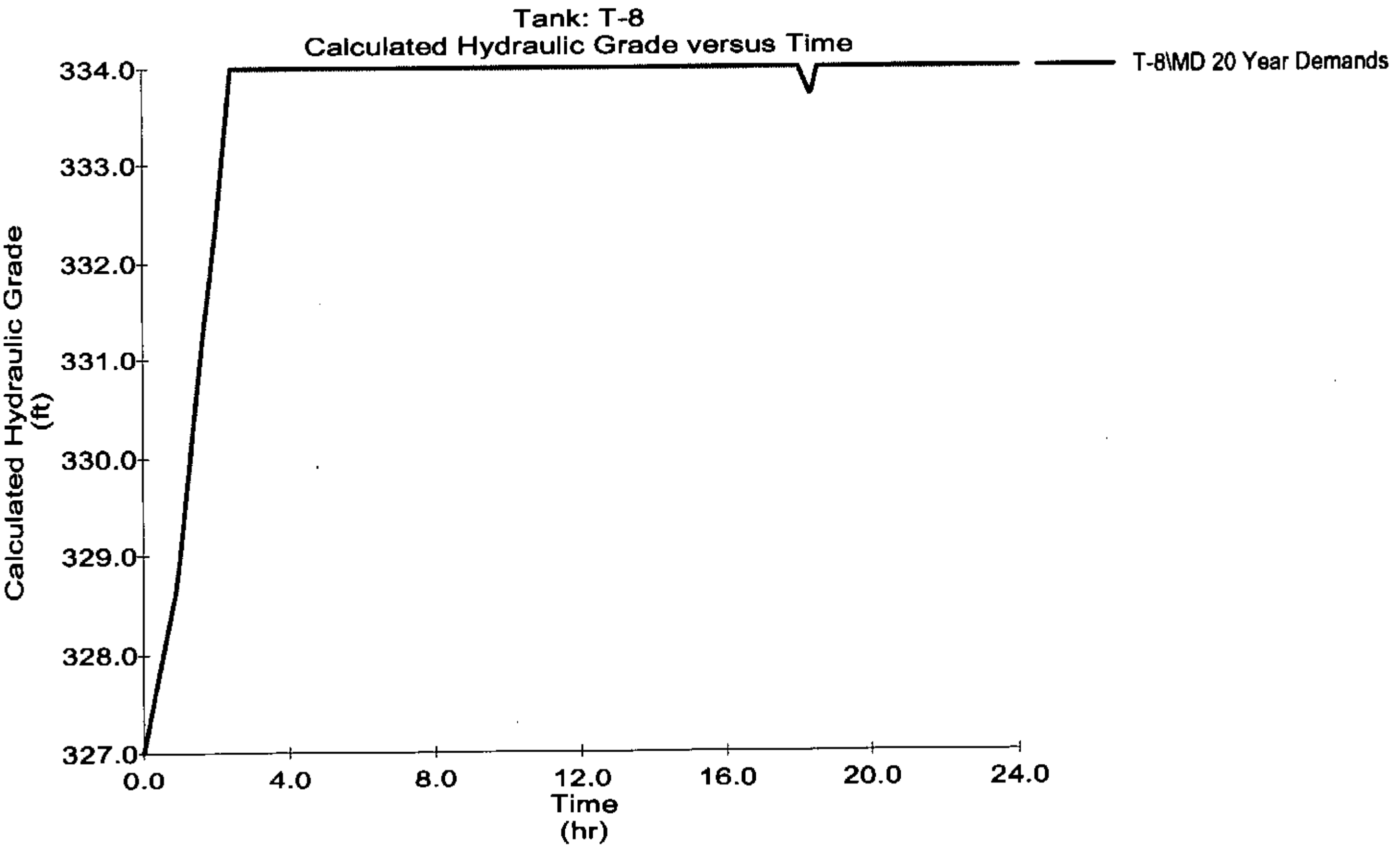
Graph

West Street Tank



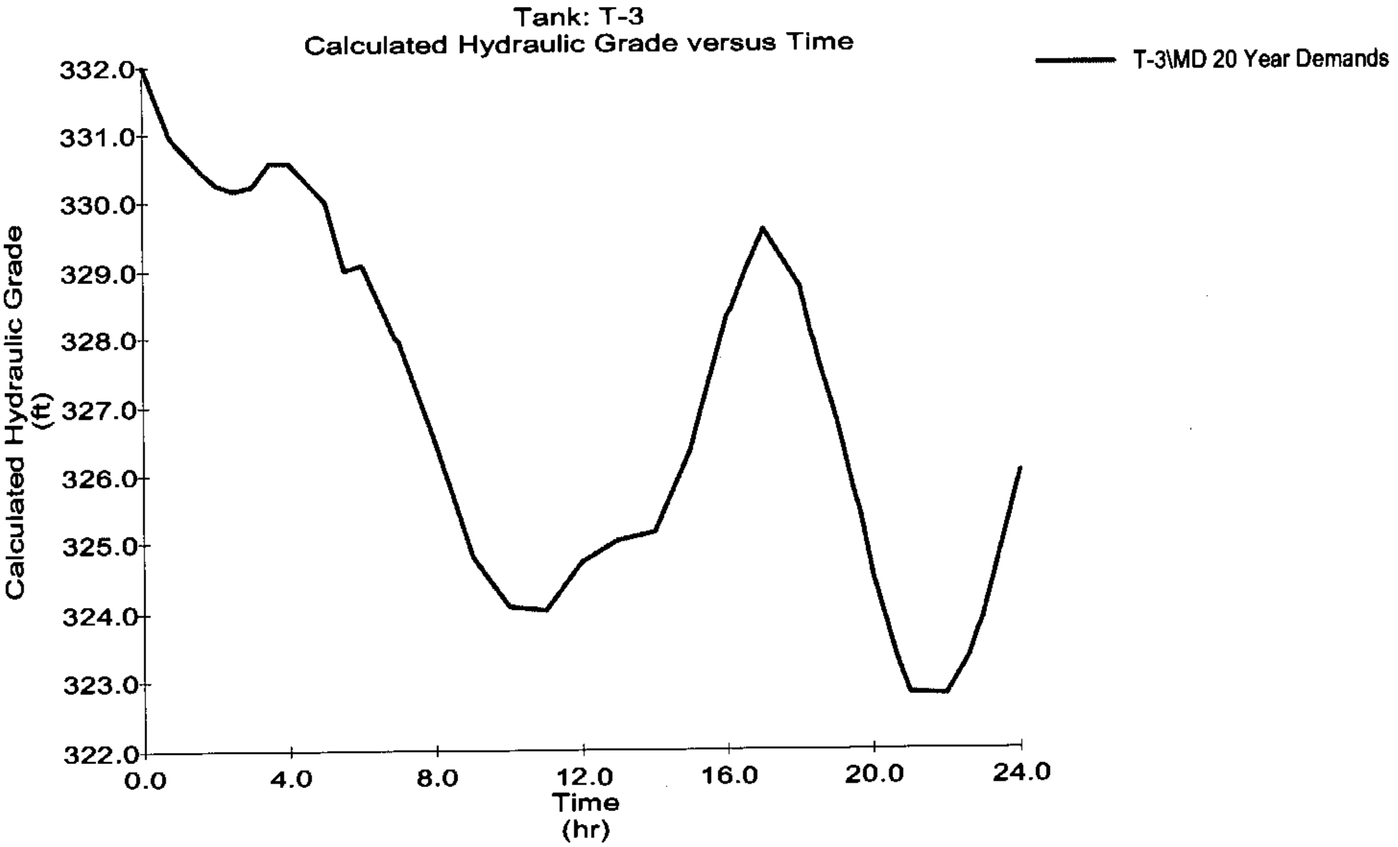
Graph

Wakefield Street Tank



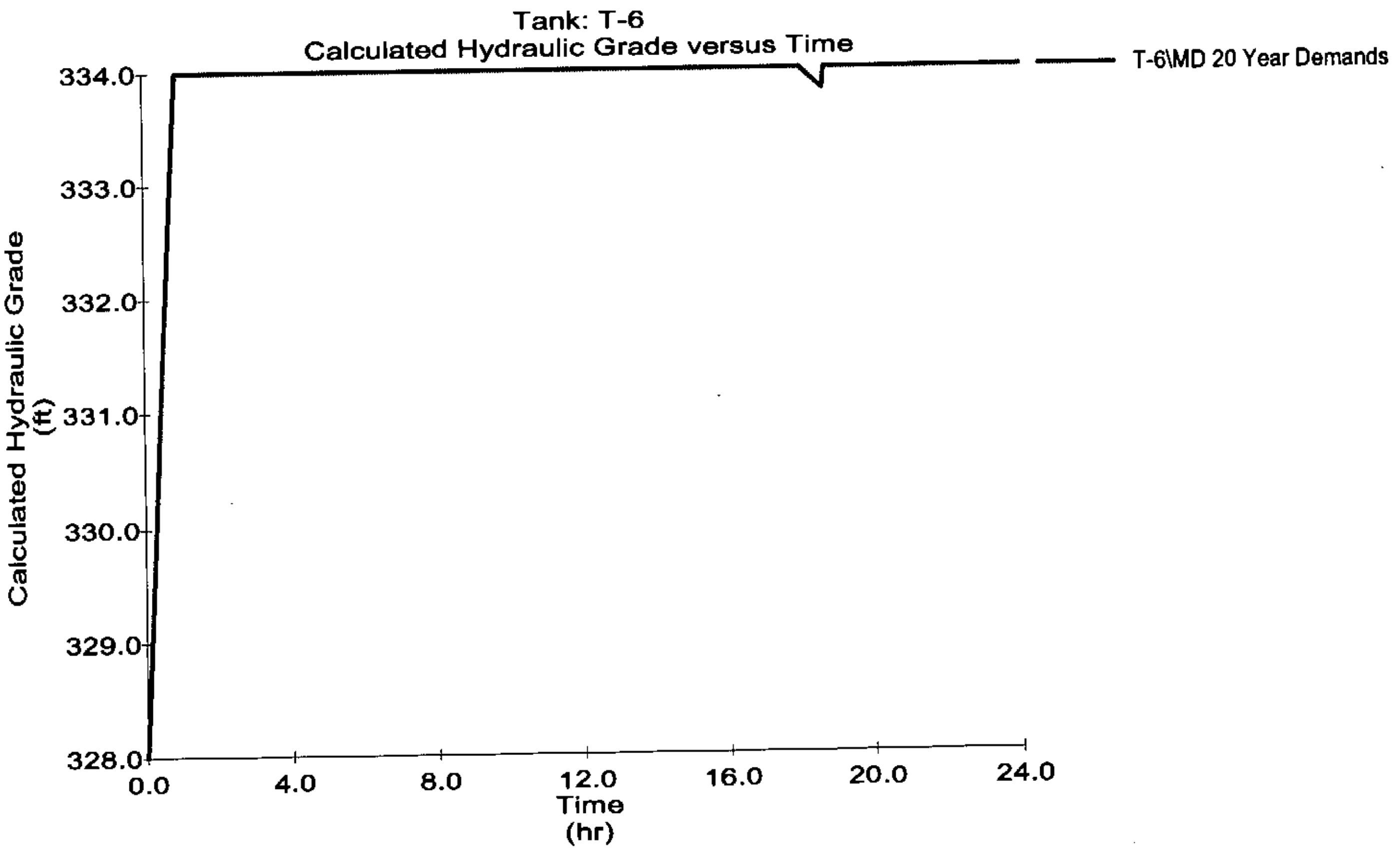
Graph

Frenchtown Road Tank



Graph

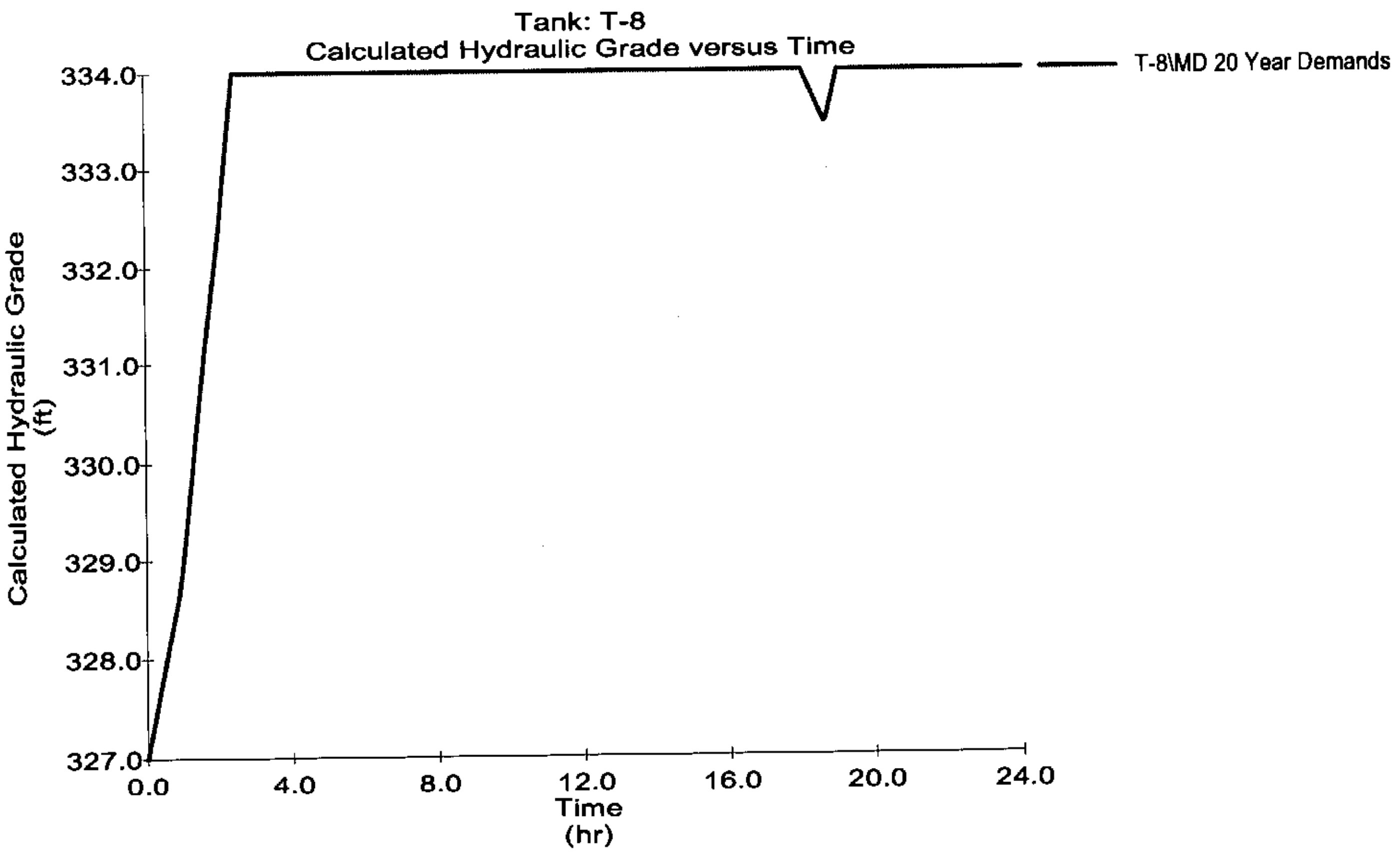
West Street Tank



- 2000 gpm fire flow at node J-626
- West St.
- 16" AC main
- Elevation = 245 ft
- Maximum Day demand

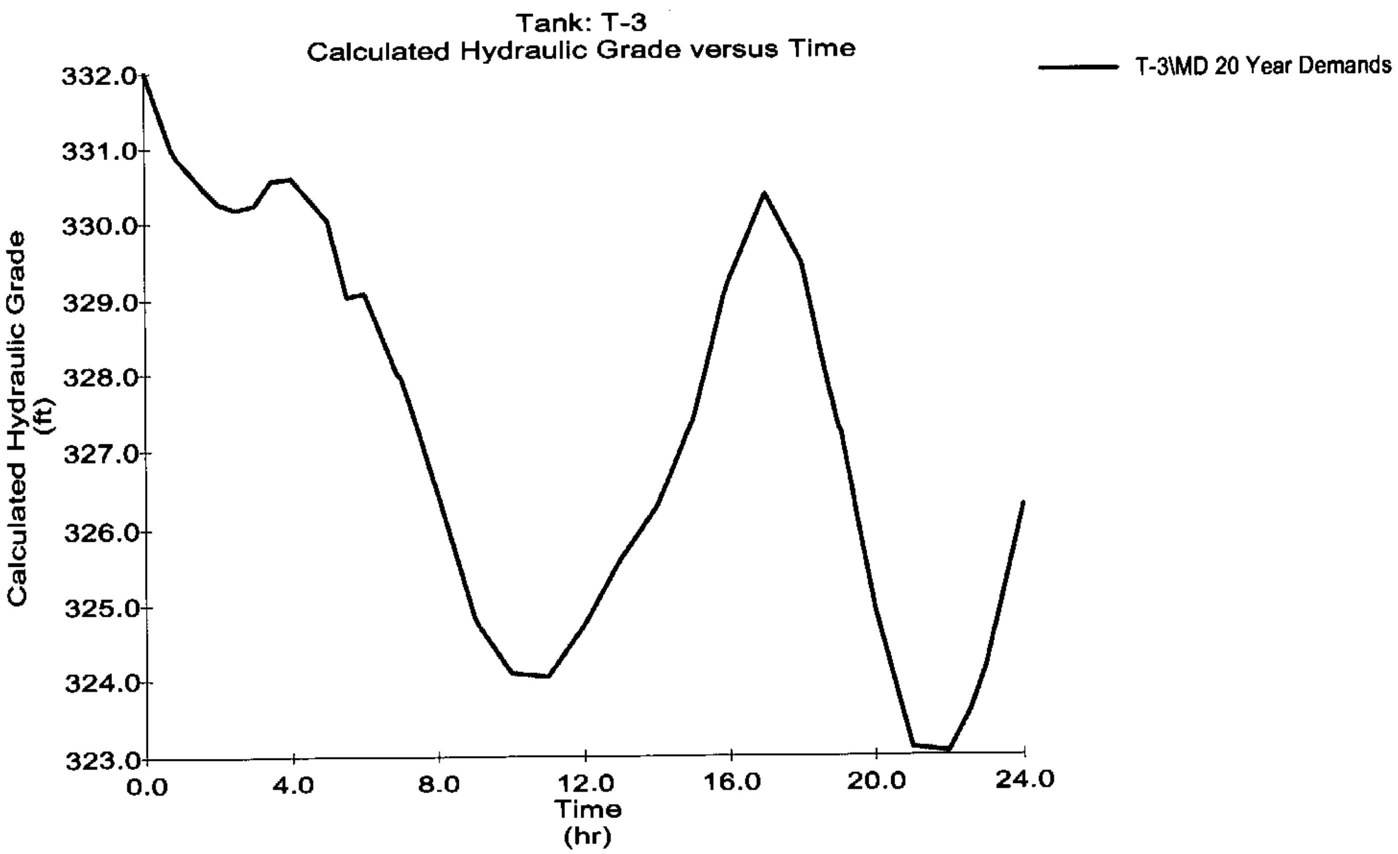
Graph

Wakefield Street Tank



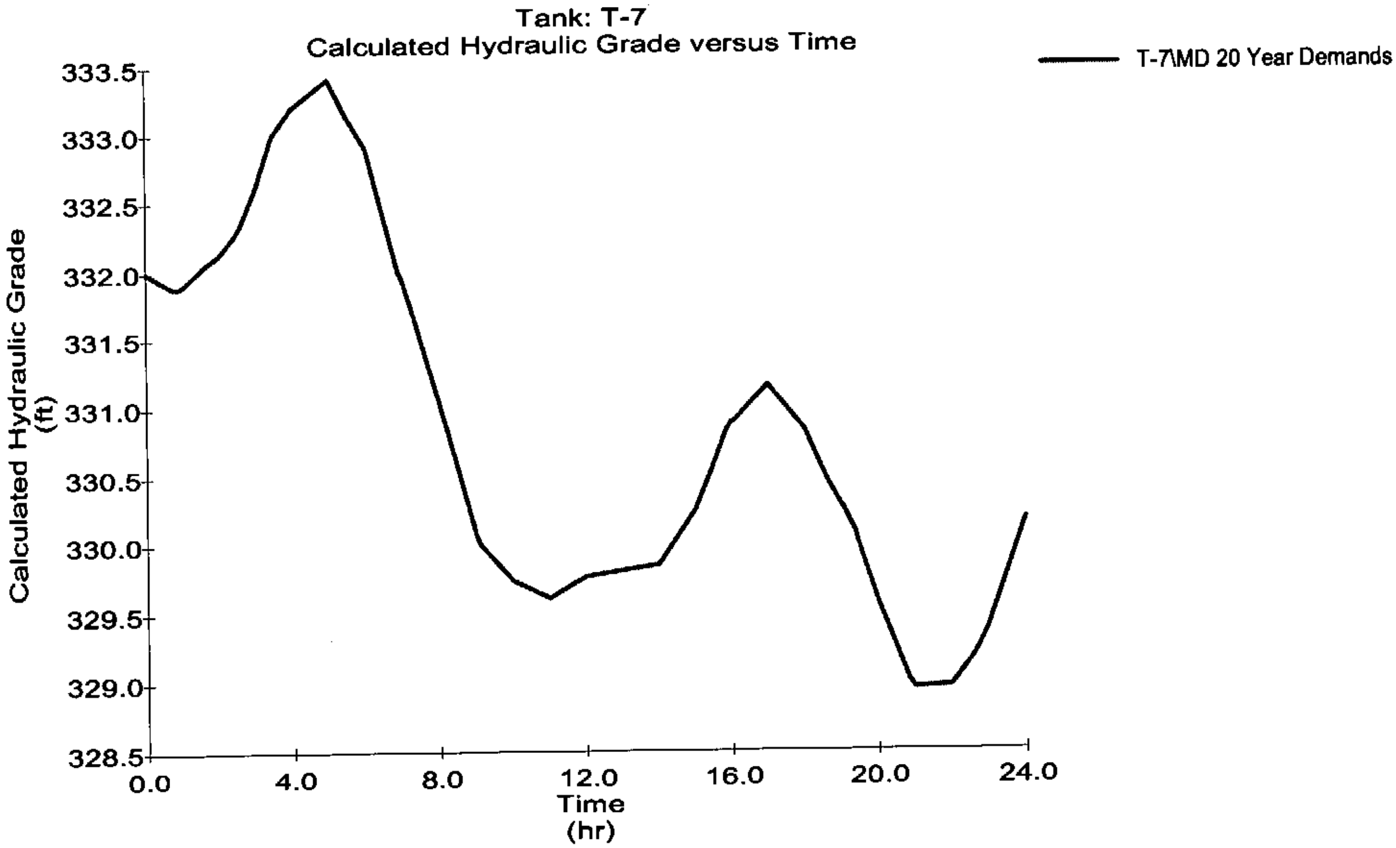
Graph

Frenchtown Road Tank



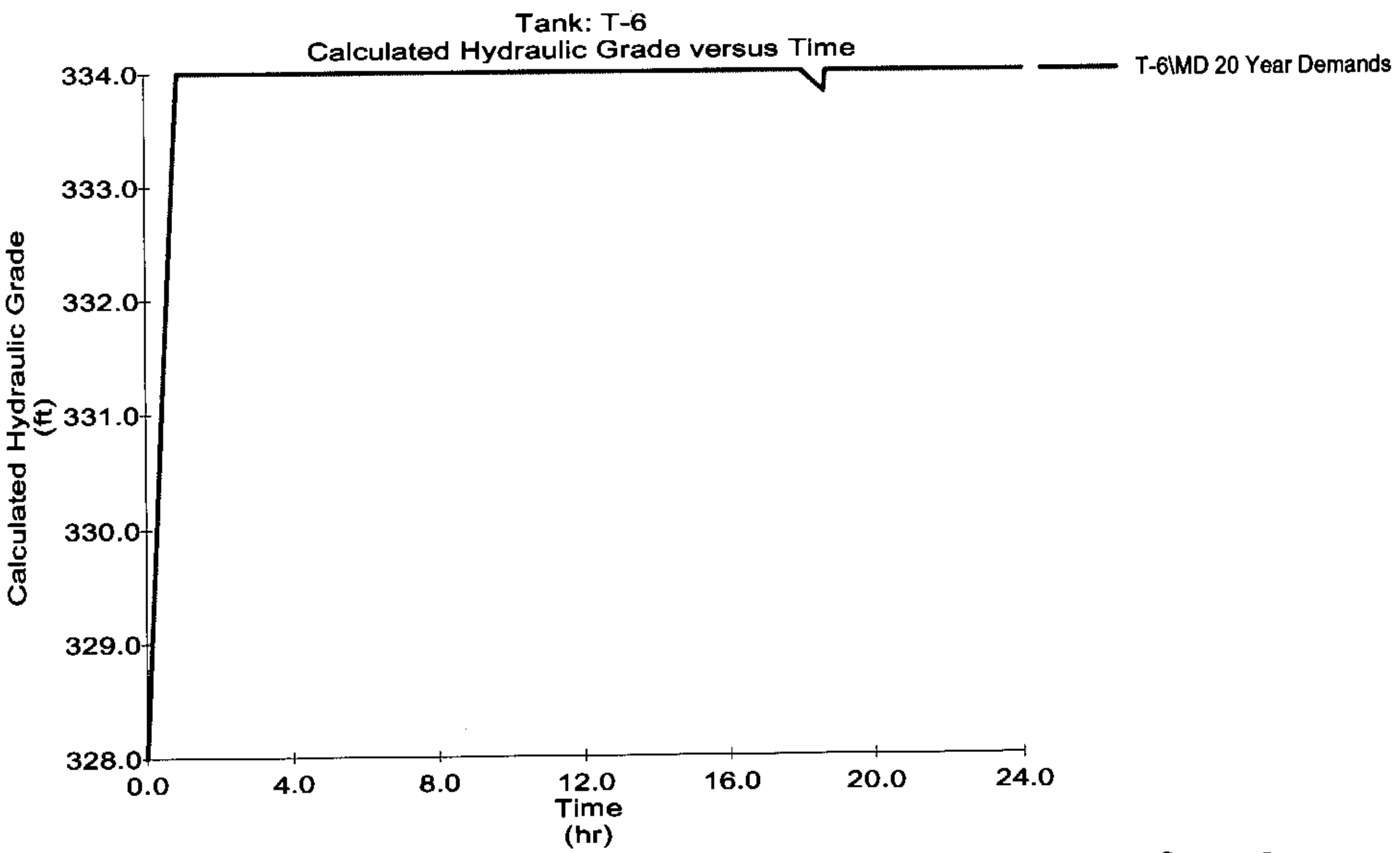
Graph

Setian Lane Tank



Graph

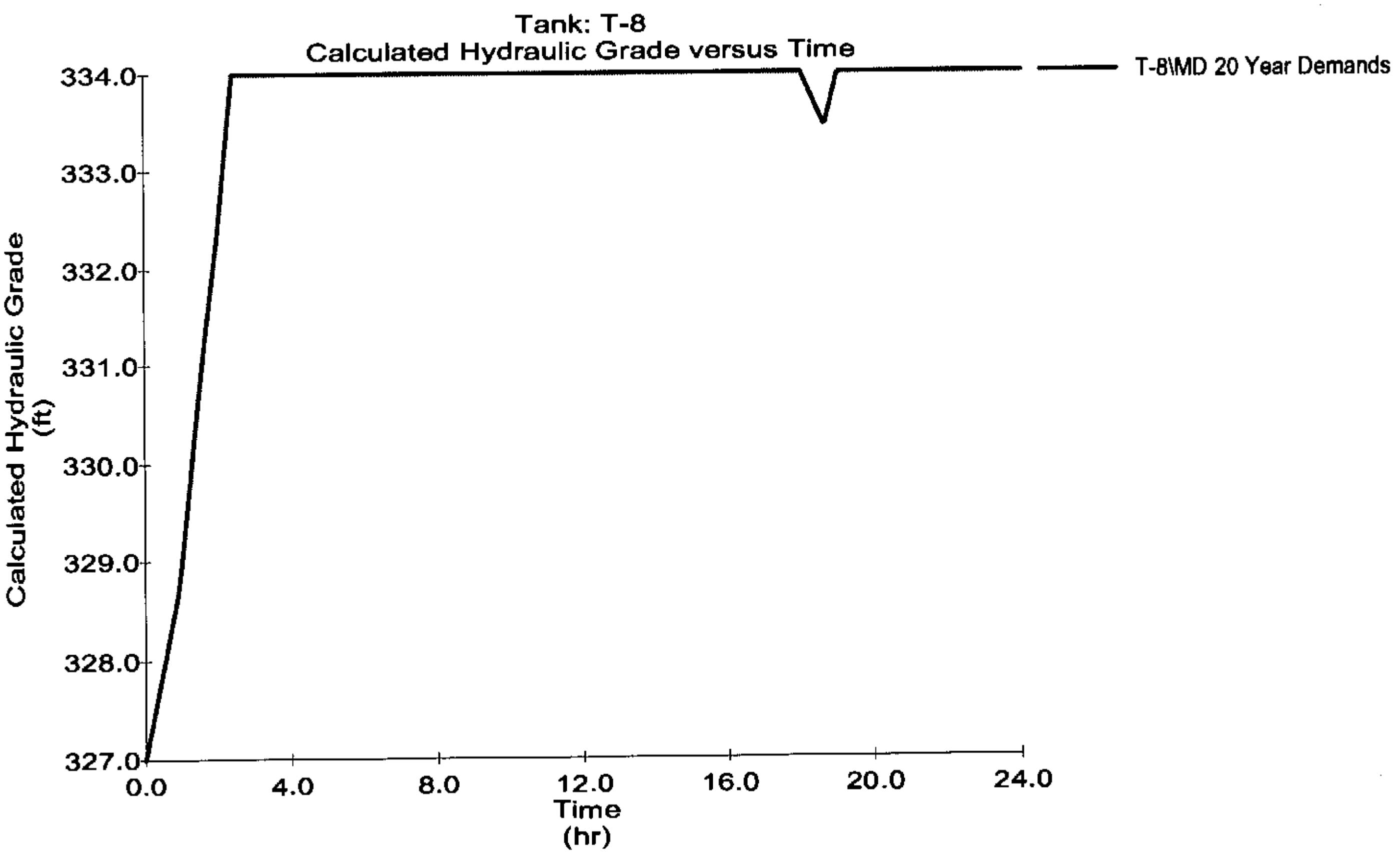
West Street Tank



- 2000 gpm fire flow at node J-7879
- Fairview Ave.
- 16" AC main
- Elevation = 255 ft
- Maximum Day demand

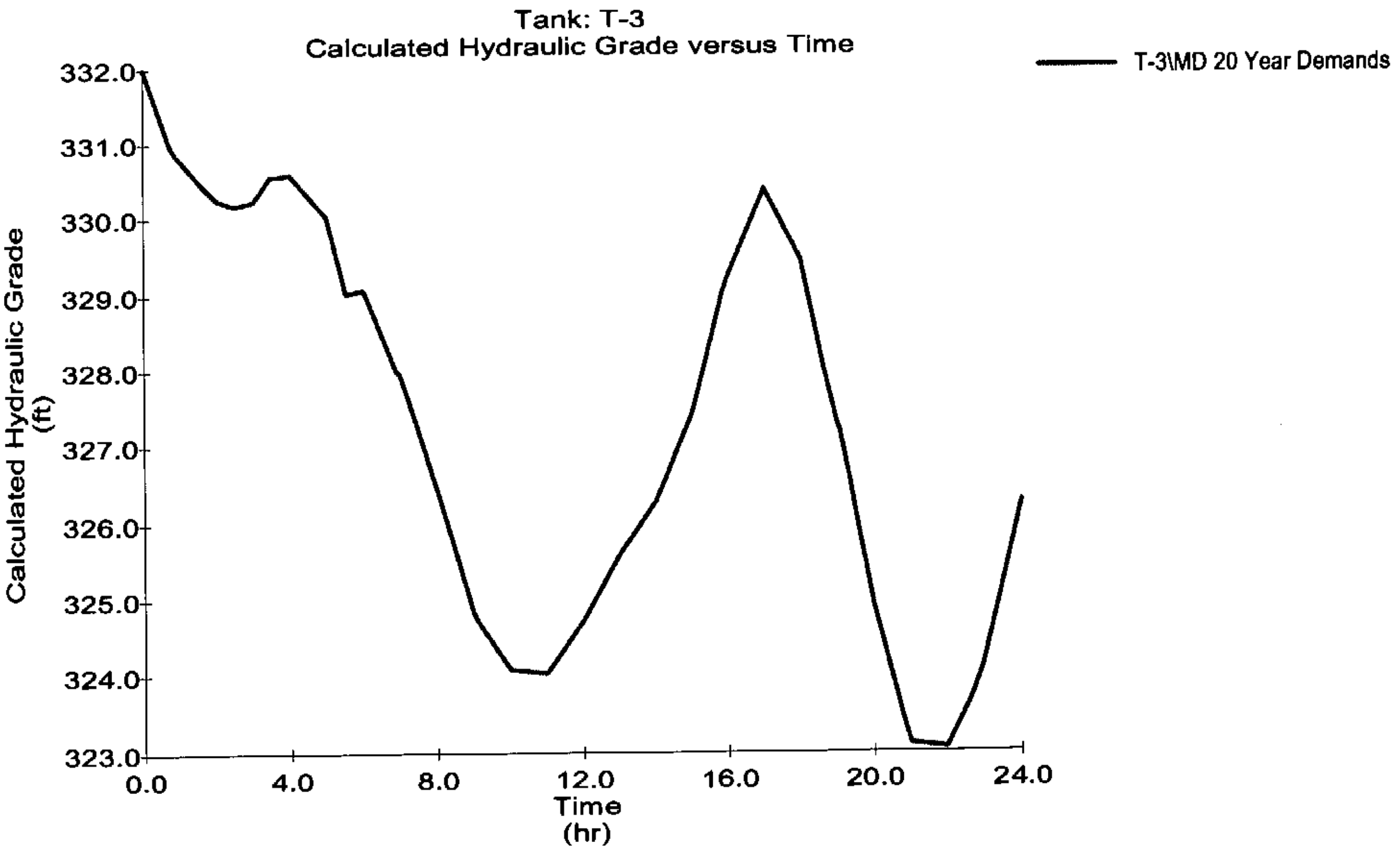
Graph

Wakefield Street Tank



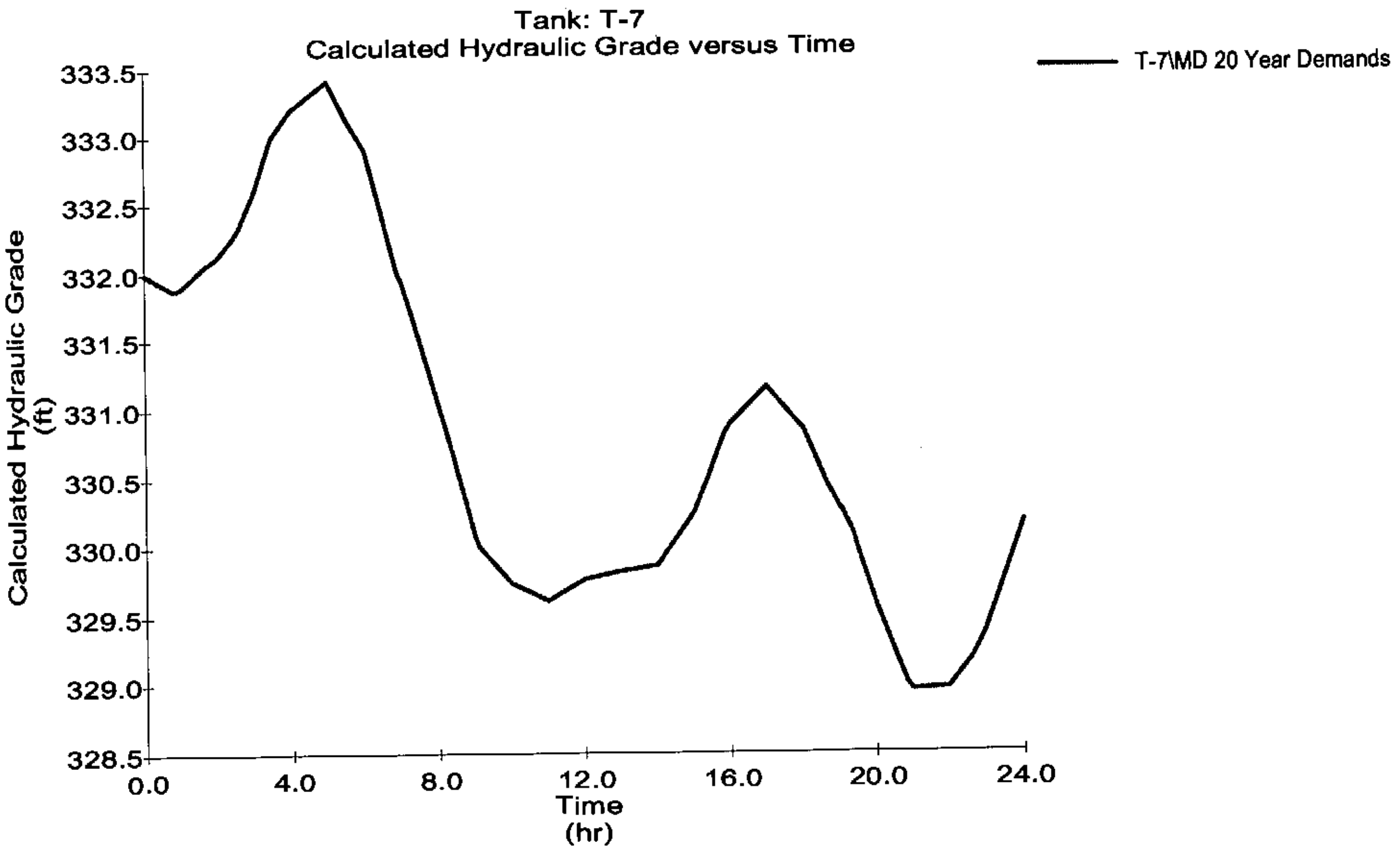
Graph

Frenchtown Road Tank



Graph

Setian Lane Tank

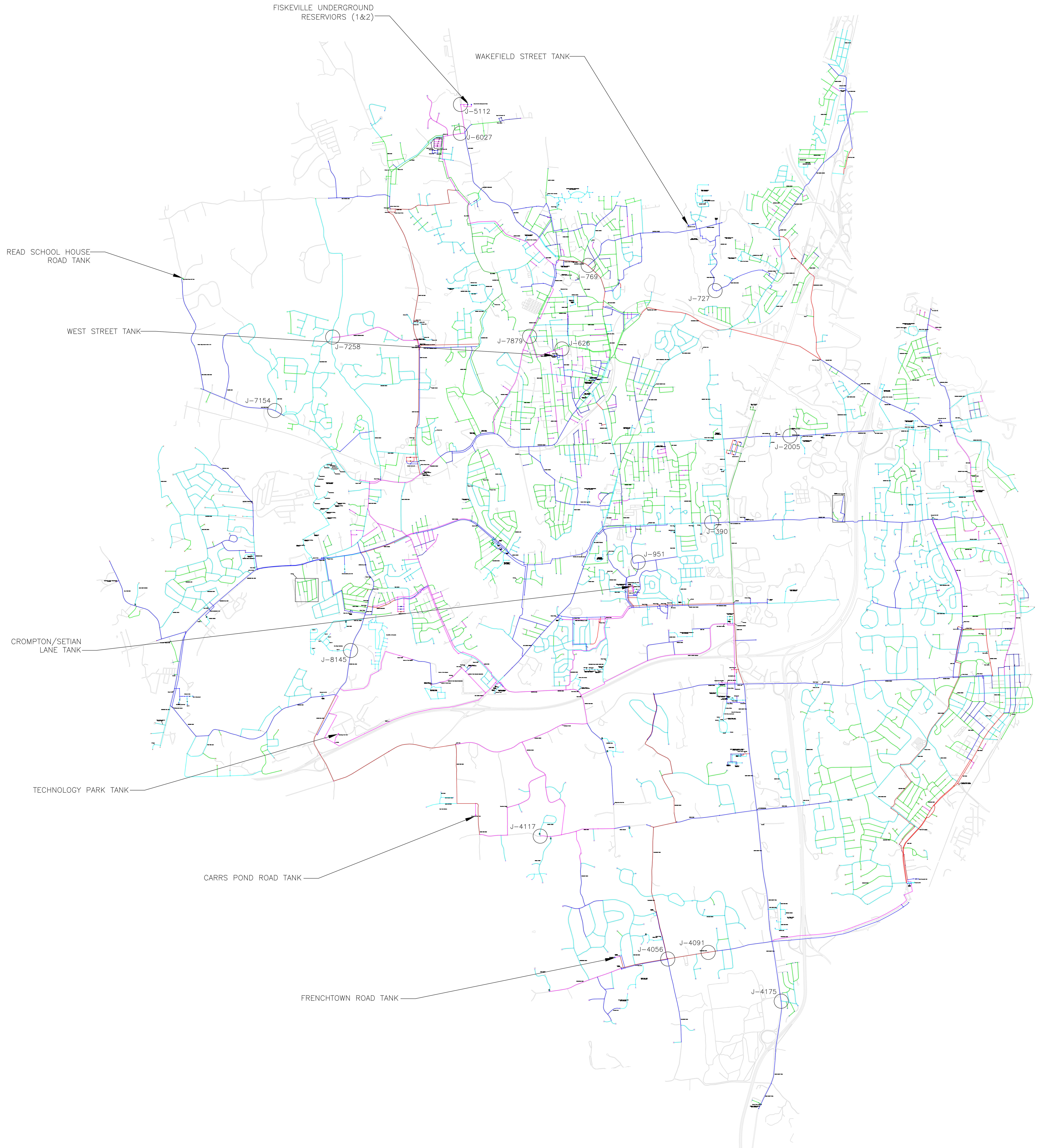


ATTACHMENT NO. 5

EXTENDED PERIOD SIMULATION
FIRE FLOW LOCATION SYSTEM MAP

KENT COUNTY WATER AUTHORITY
TANK STUDY

FIRE FLOW LOCATIONS



Color Coding Legend
Link: Diameter (in)

magenta	<= 2.0
dark blue	<= 4.0
green	<= 6.0
cyan	<= 8.0
red	<= 10.0
blue	<= 12.0
magenta	<= 16.0
dark red	<= 20.0
dark green	<= 24.0
black	<= 30.0

GRAPHIC SCALE
2200 0 1100 2200 4400 8800
(IN FEET)
1 inch = 2200ft.

KCWA WATER DISTRICT SYSTEM MAP
APRIL 2007 *J0612*

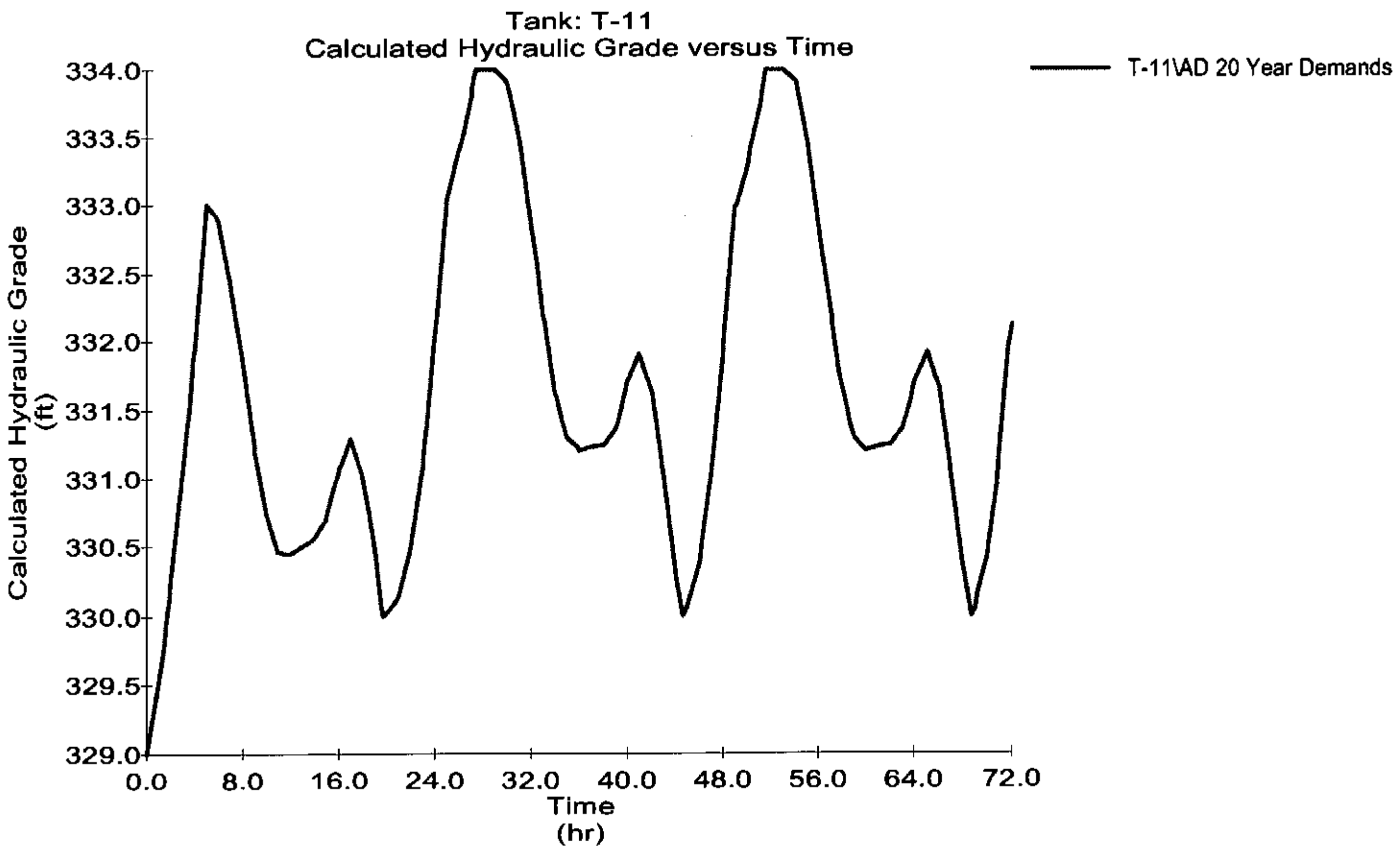
ATTACHMENT NO. 6

FUTURE AVERAGE DAY DEMAND
EXTENDED PERIOD SIMULATION WITH
MISHNOCK STORAGE RESERVOIR
LOW SERVICE PUMP AND STORAGE TANK GRAPHS

AD

Graph

Mishnock Storage Tank

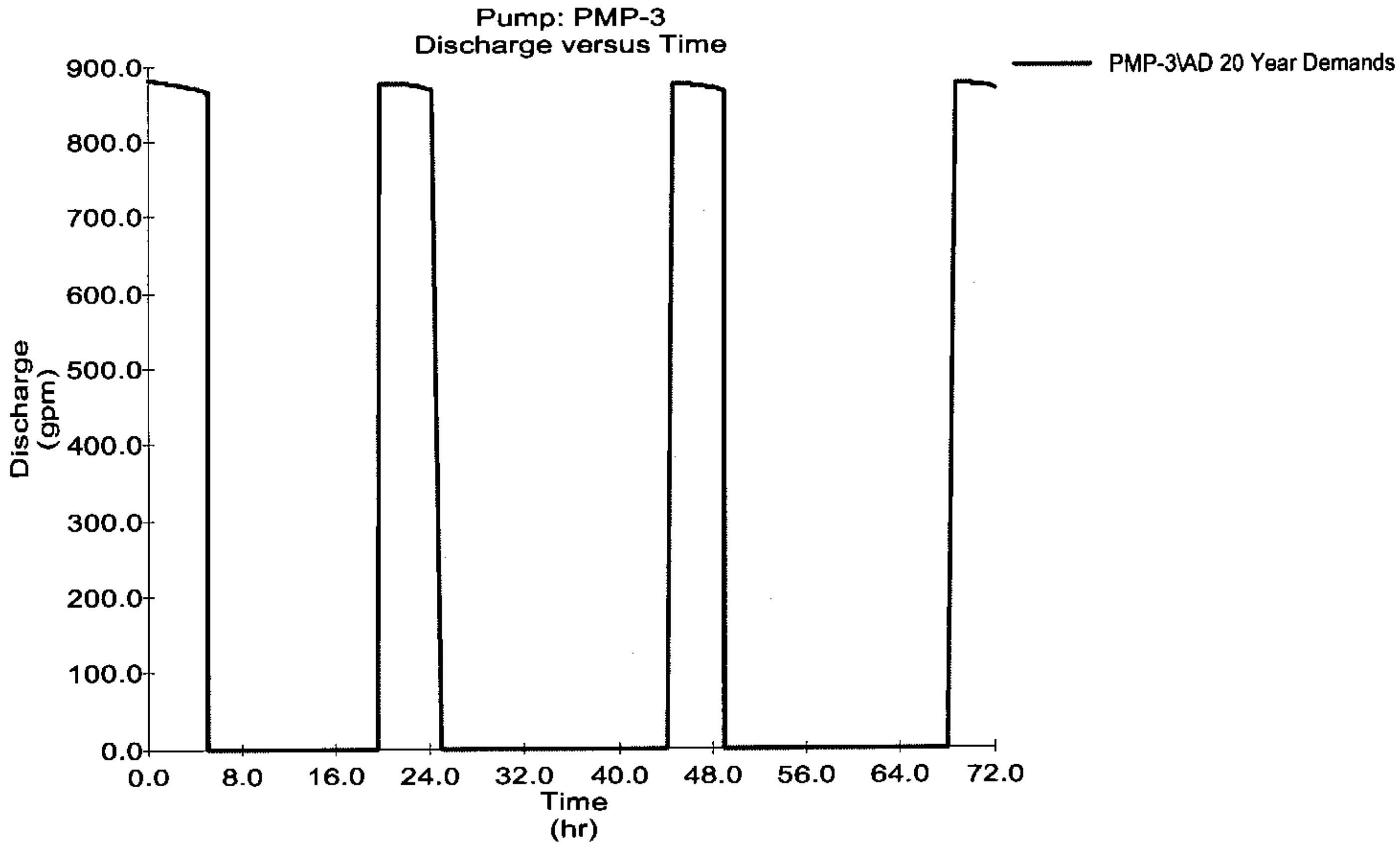


AD

Graph

Mishnock Well Pump

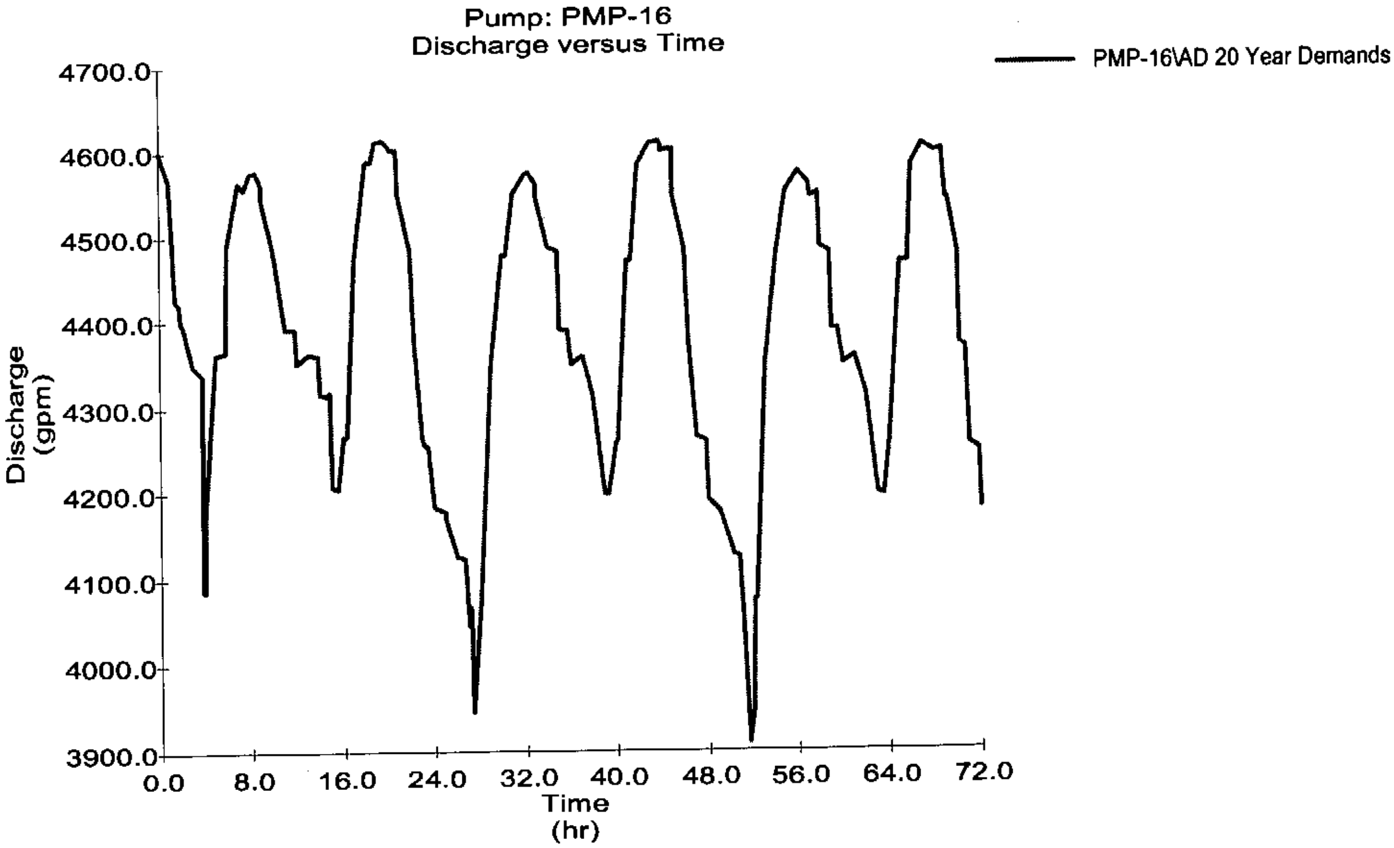
Level control w/ Mishnock



AD

Graph

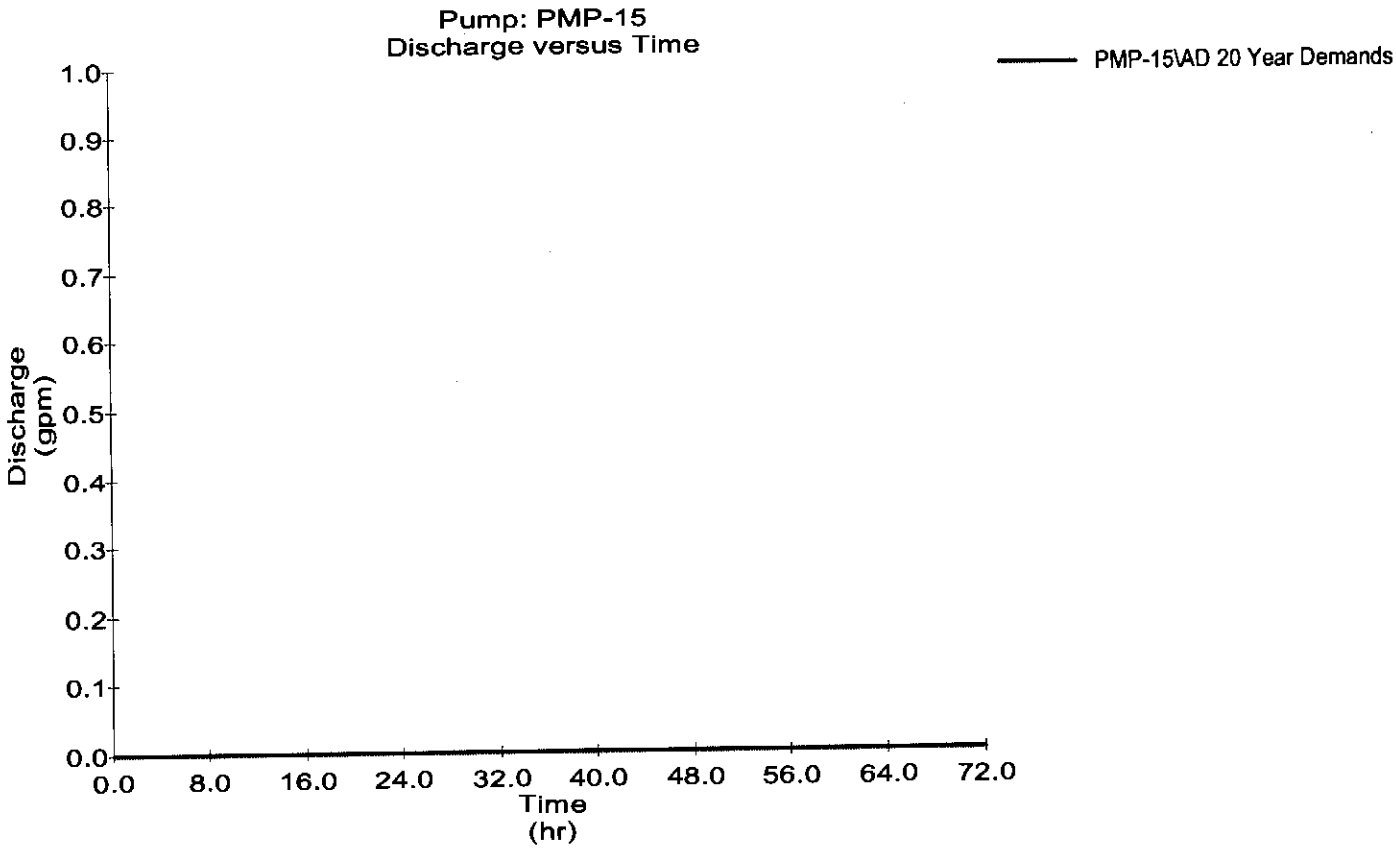
Clinton Ave. Pump
Running continuously



AD

Graph

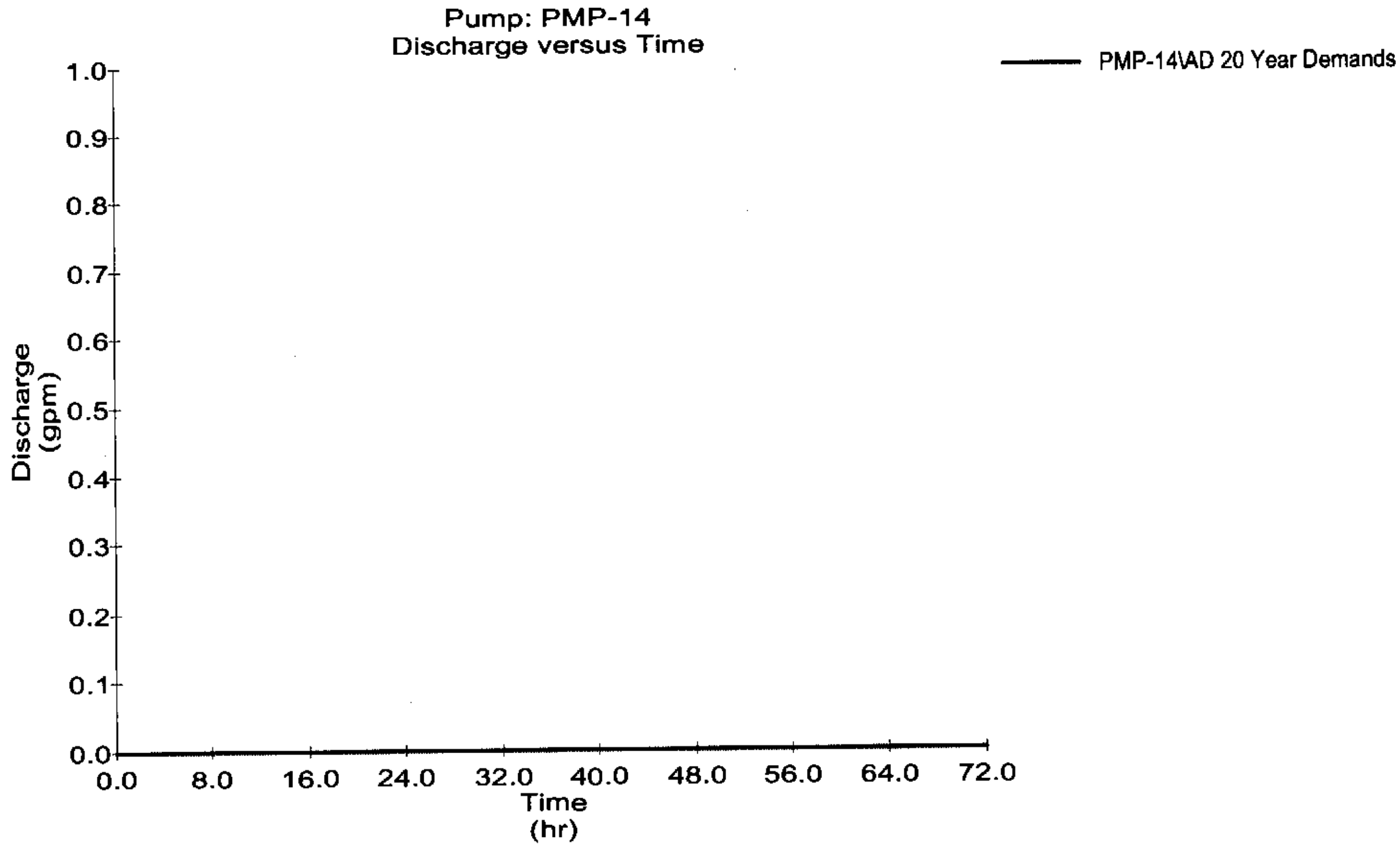
Clinton Ave. Pump
Level control w/ Frenchtown Rd.



AD

Graph

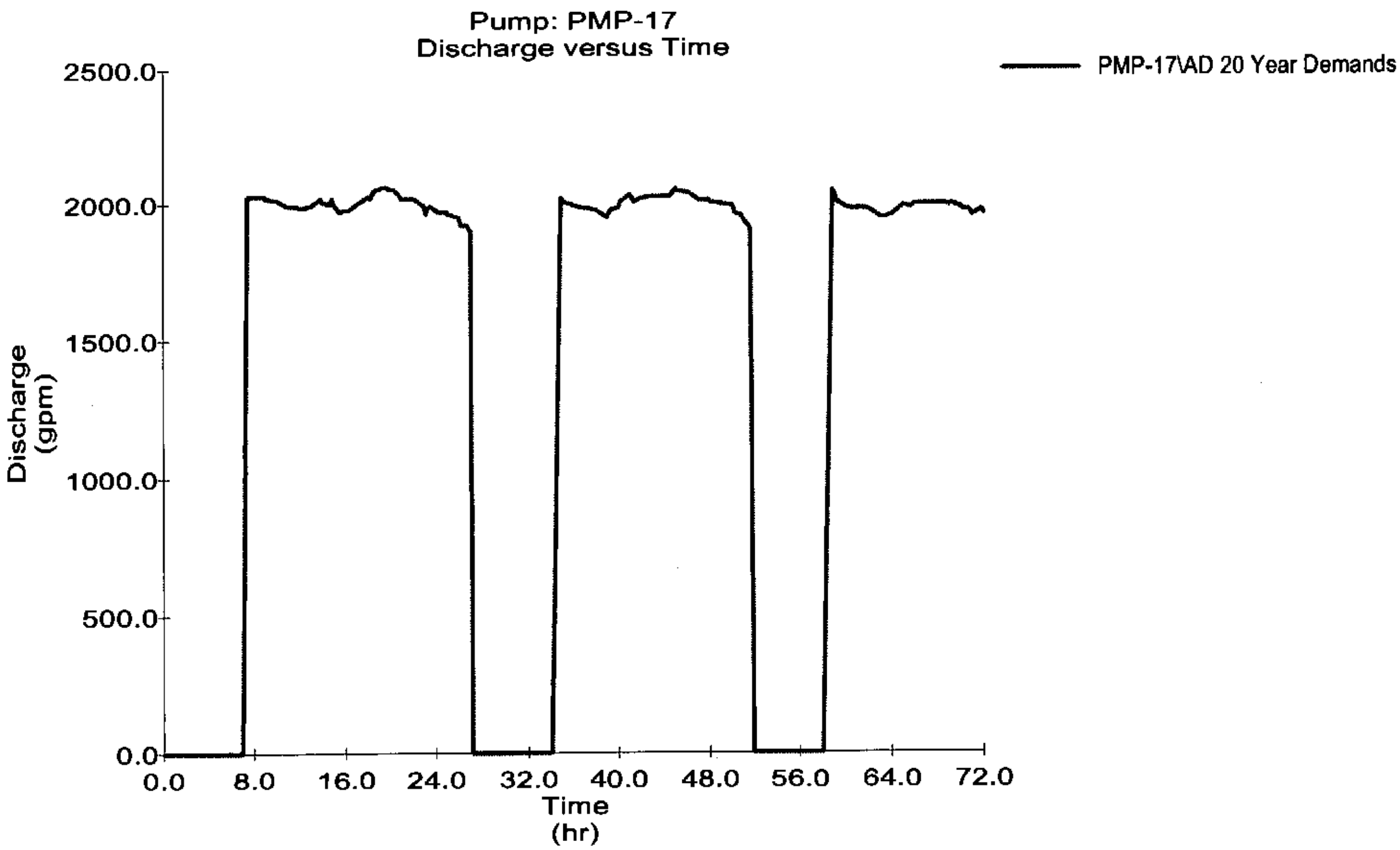
Clinton Ave. Pump
Level control w/ Frenchtown Rd.



AD

Graph

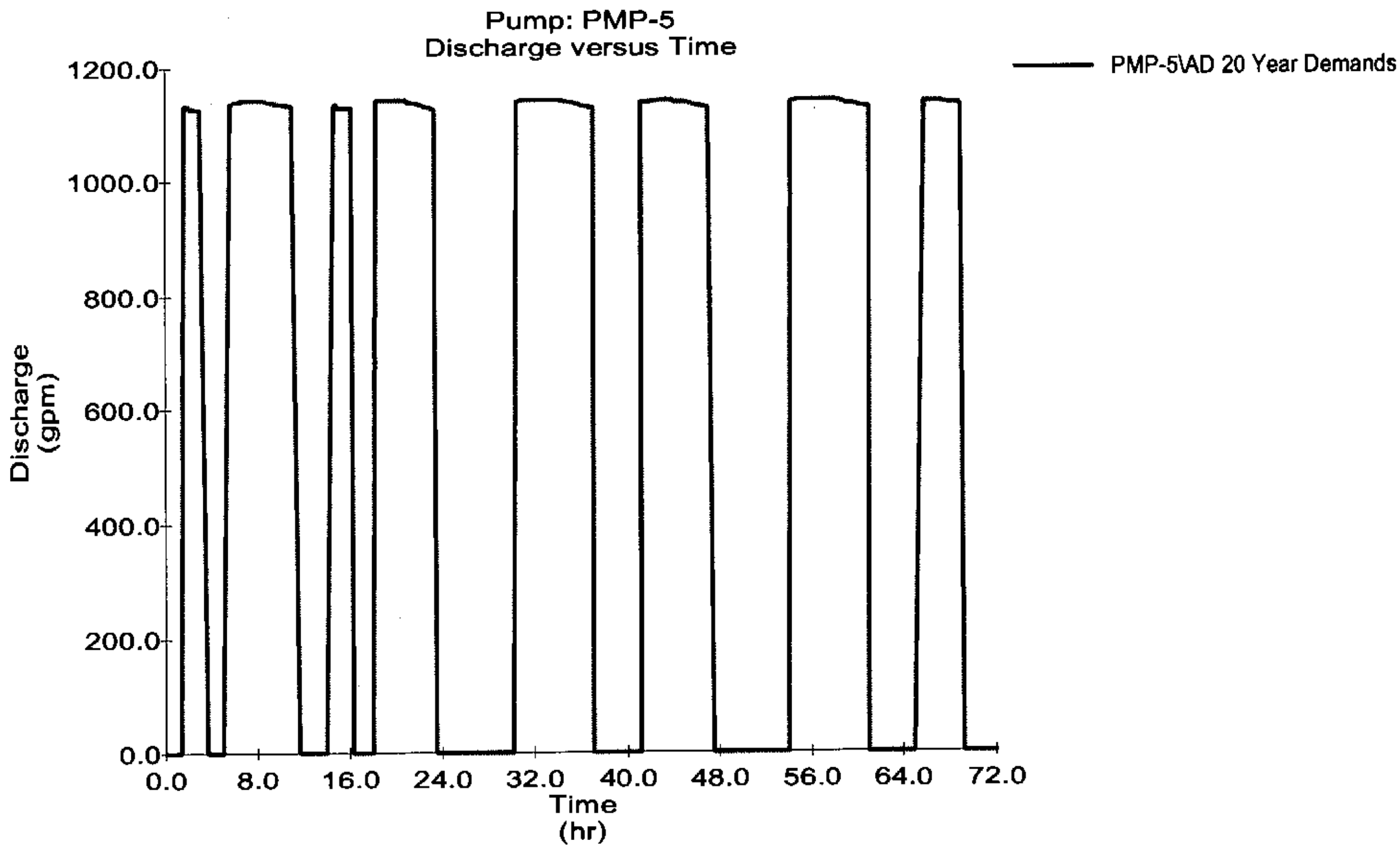
Quaker Ln. Pump
Level control w/ Setian Ln.



AD

Graph

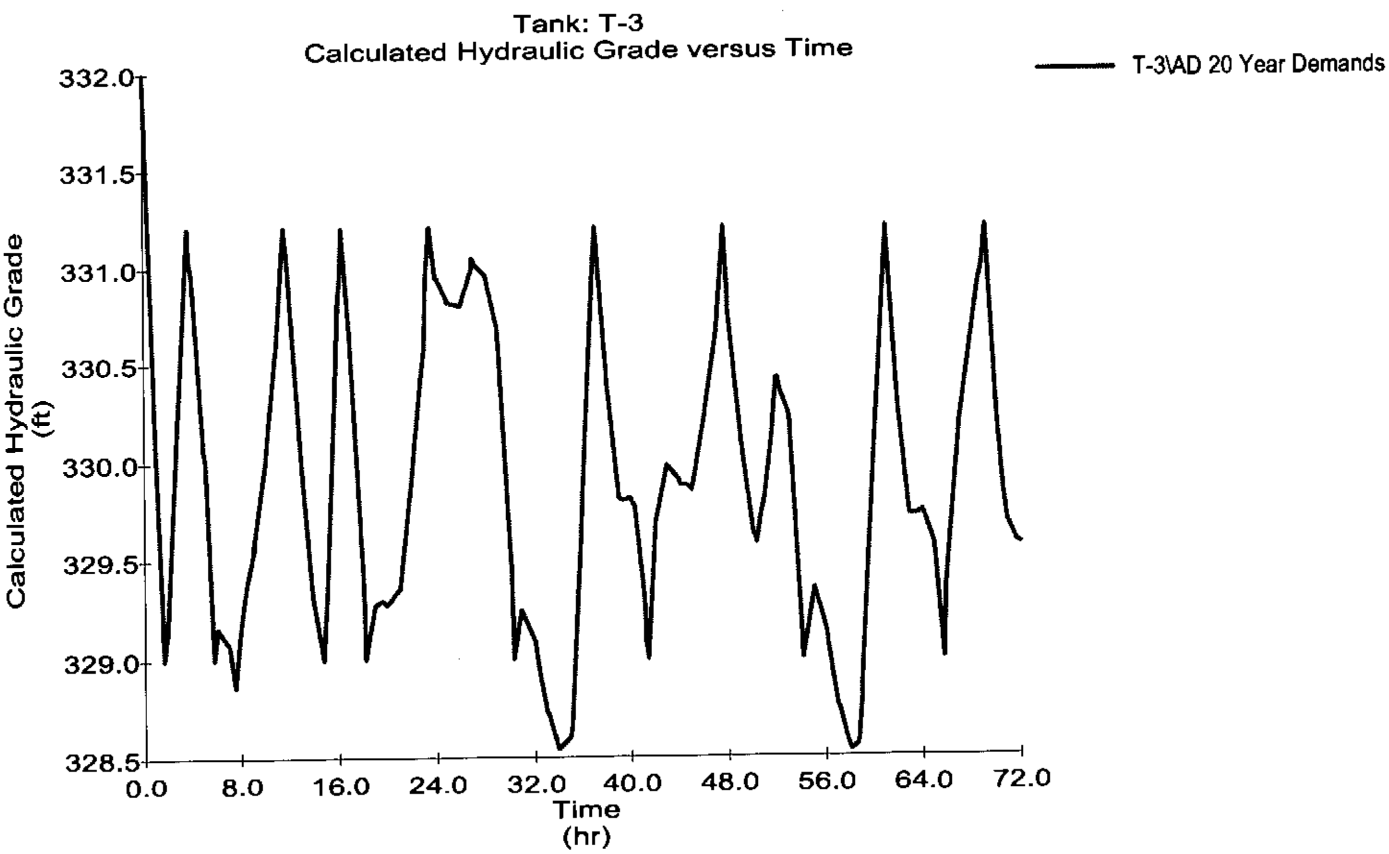
EG Well Pump
Level control w/ Frenchtown Rd.



AD

Graph

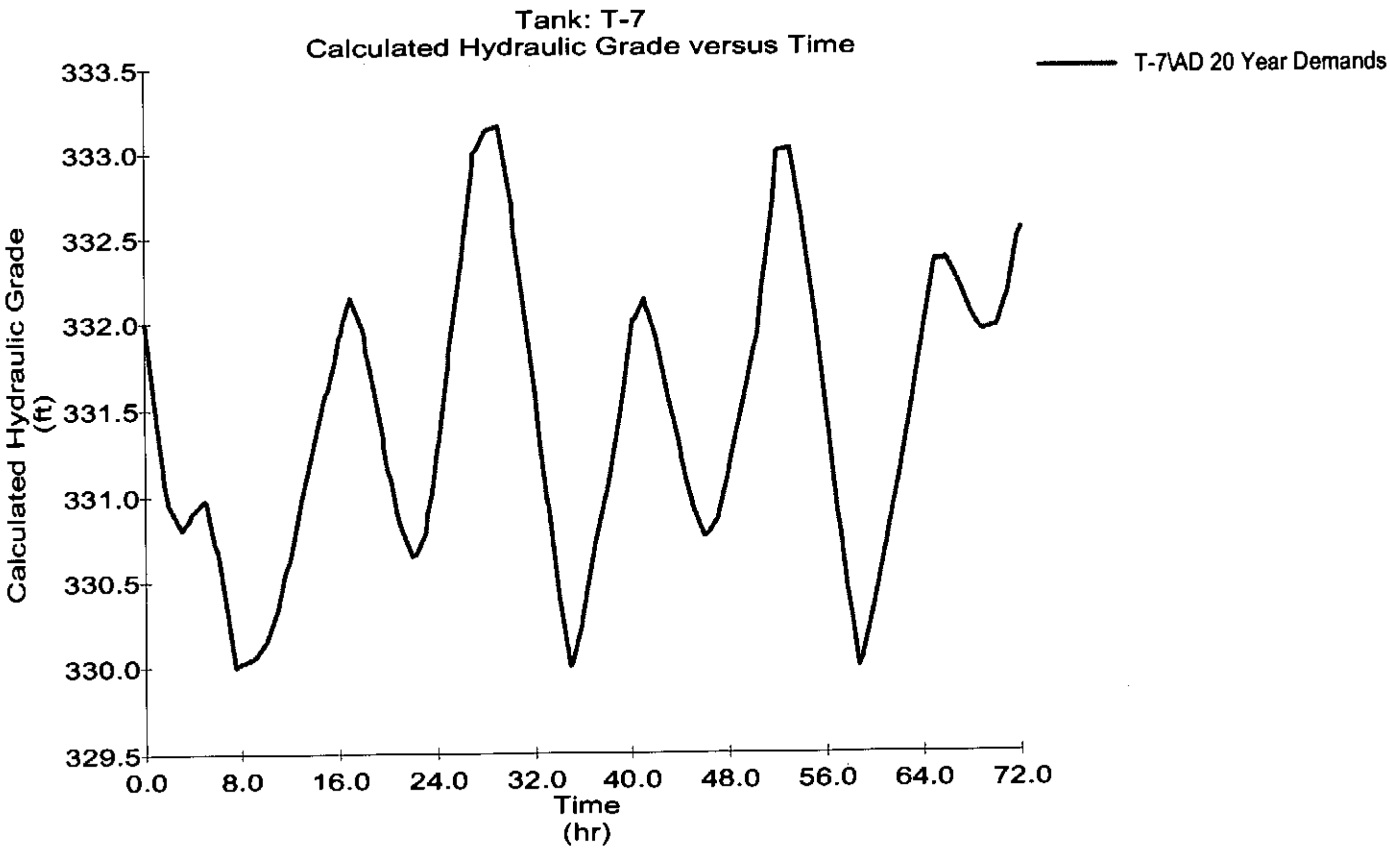
Frenchtown Rd Tank



AD

Graph

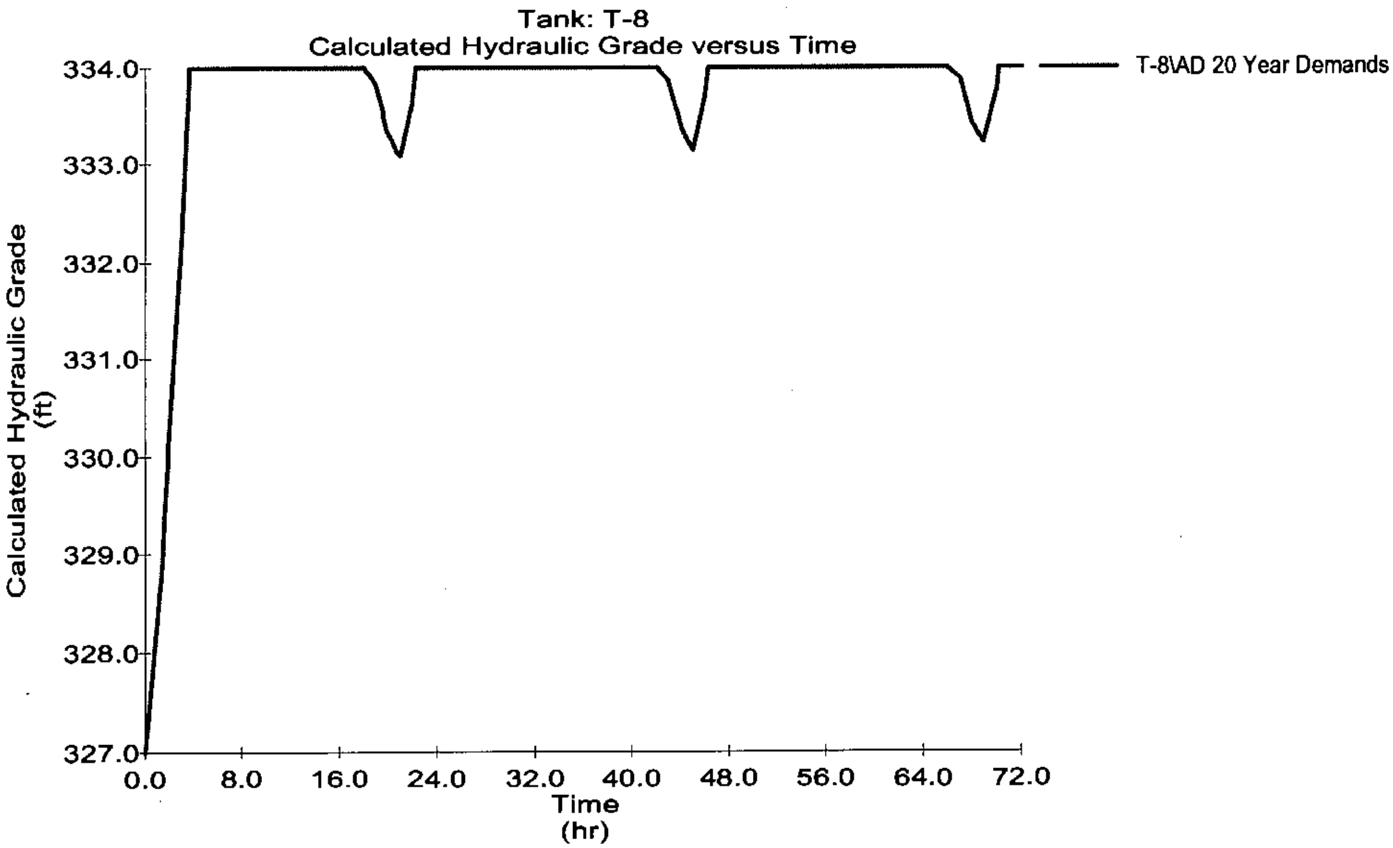
Setian Ln. Tank



AD

Graph

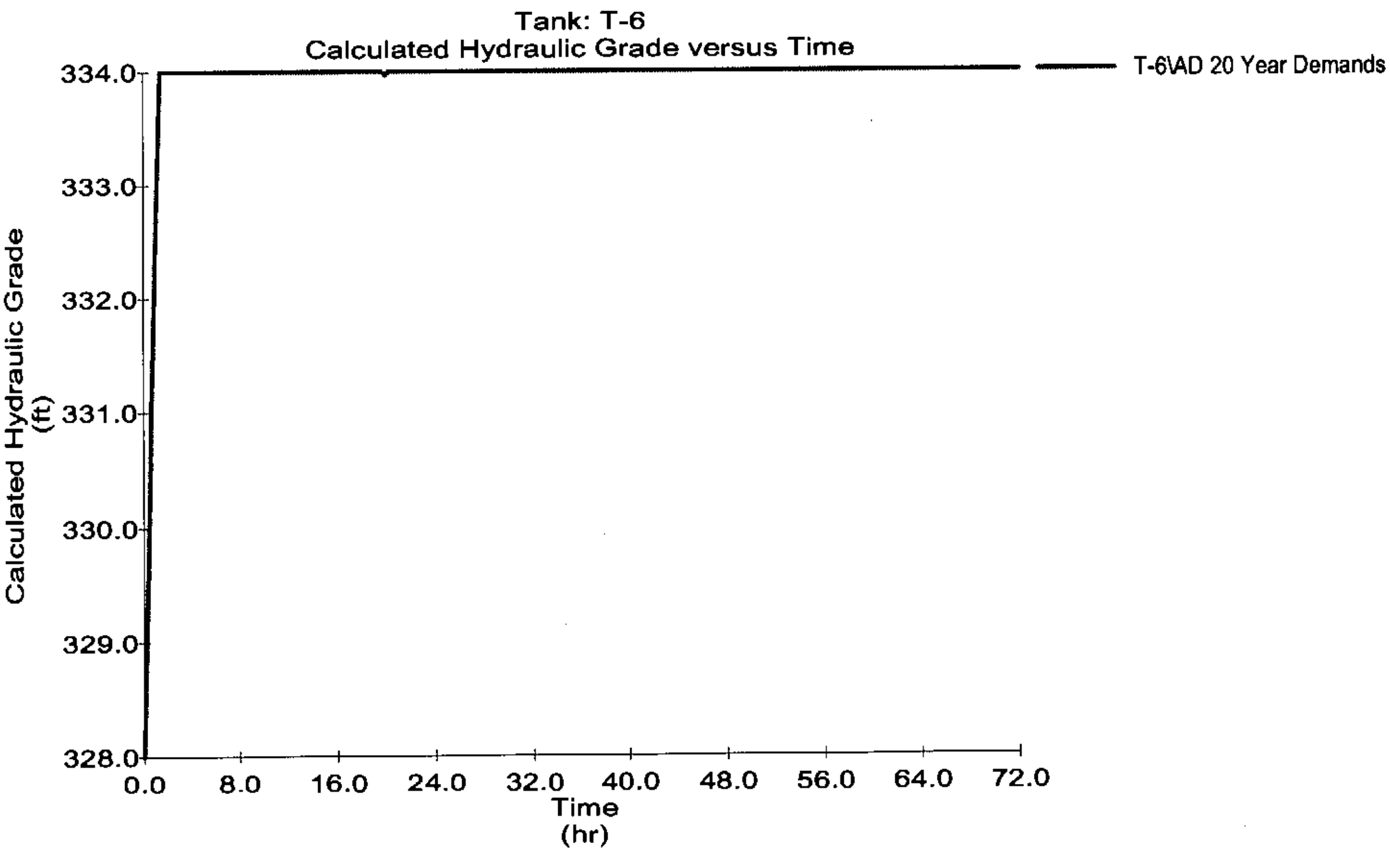
Wakefield St. Tank



AD

Graph

West St. Tank



ATTACHMENT NO. 7

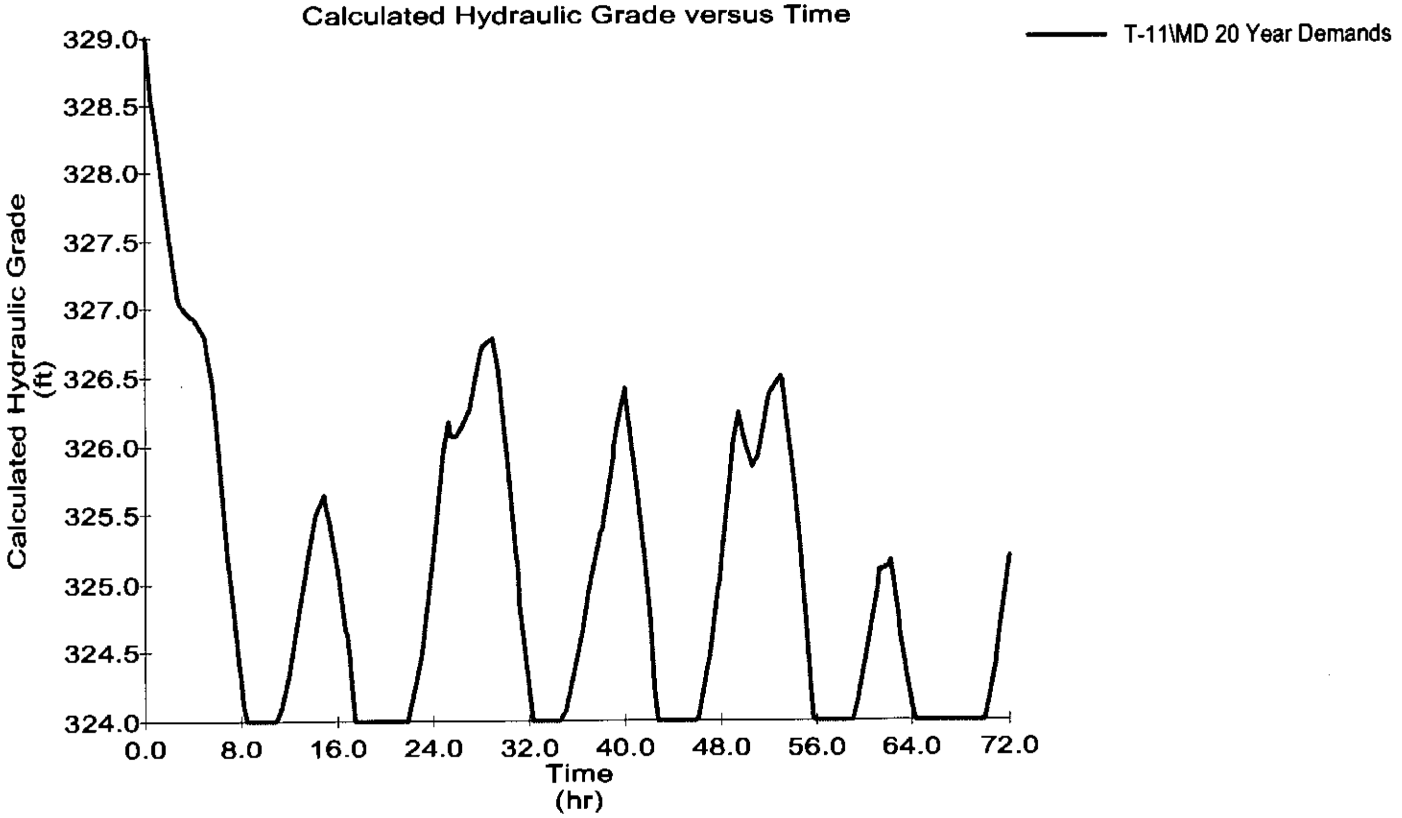
FUTURE MAXIMUM DAY DEMAND WITH PEAK HOUR EXTENDED PERIOD SIMULATION WITH MISHNOCK STORAGE RESERVOIR LOW SERVICE PUMP AND STORAGE TANK GRAPHS

MD

Graph

Mishnock Storage Tank

Tank: T-11
Calculated Hydraulic Grade versus Time

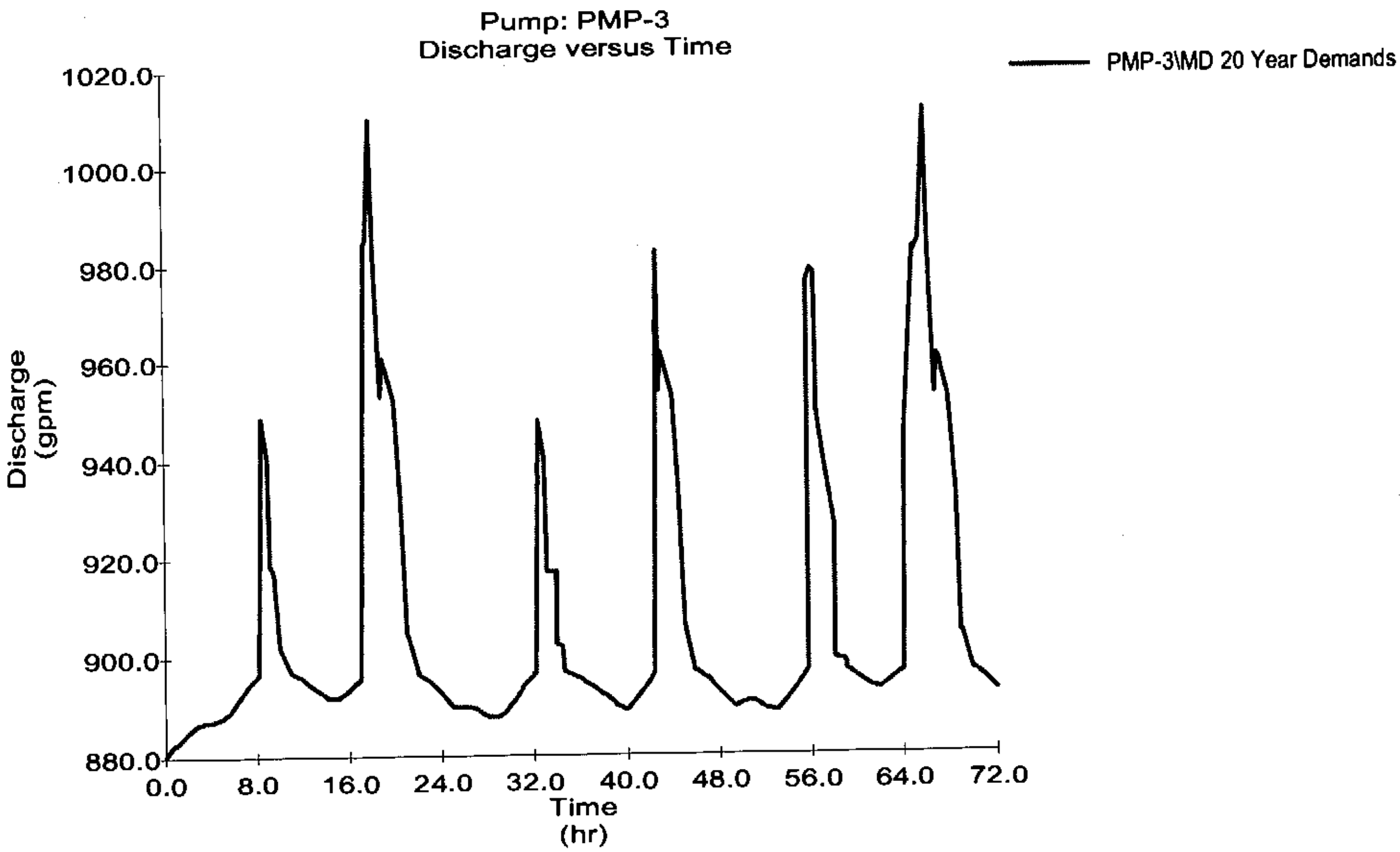


MD

Graph

Mishnock Well Pump

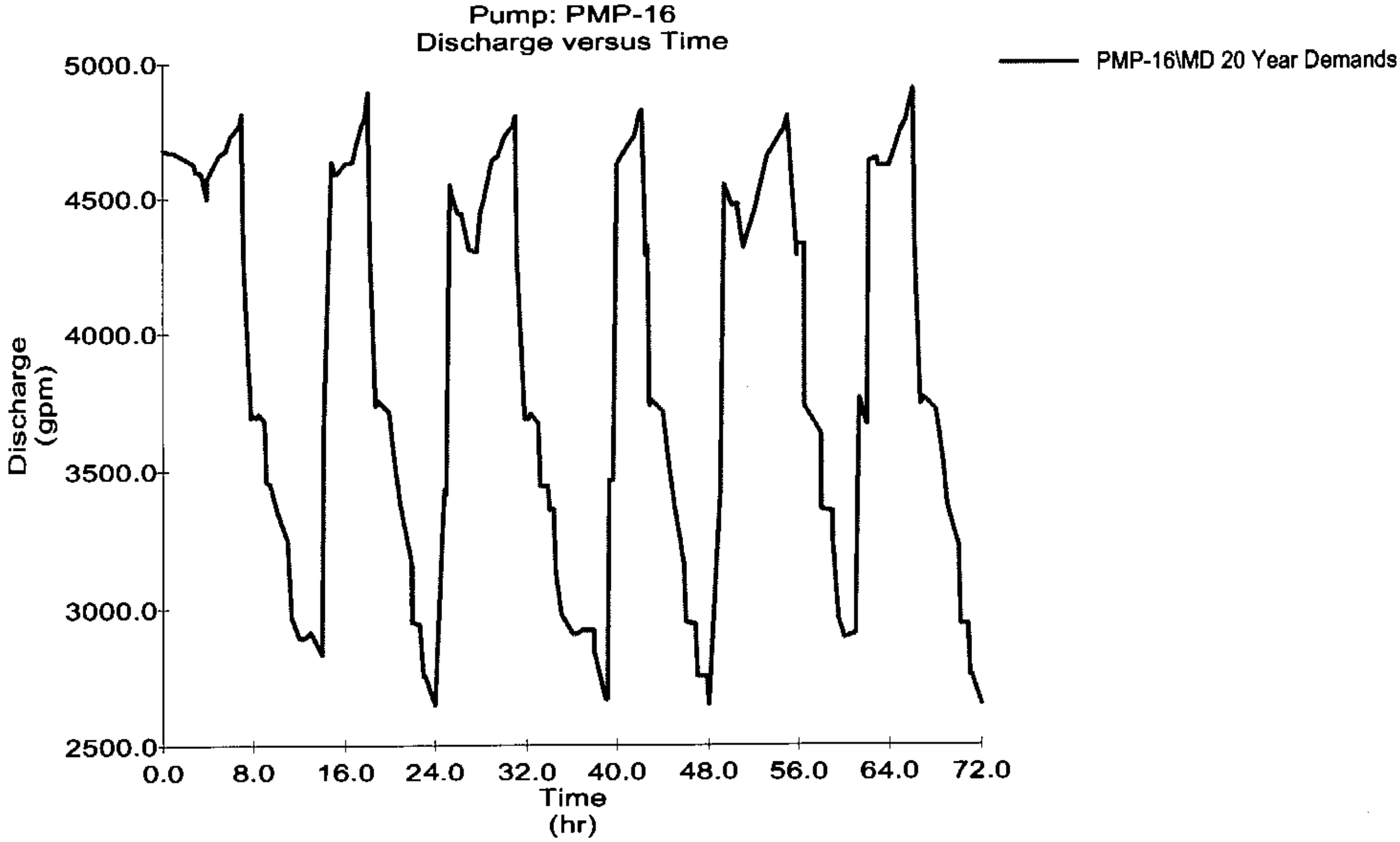
Level control w/ Mishnock



MD

Graph

Clinton Ave. Pump
Running continuously

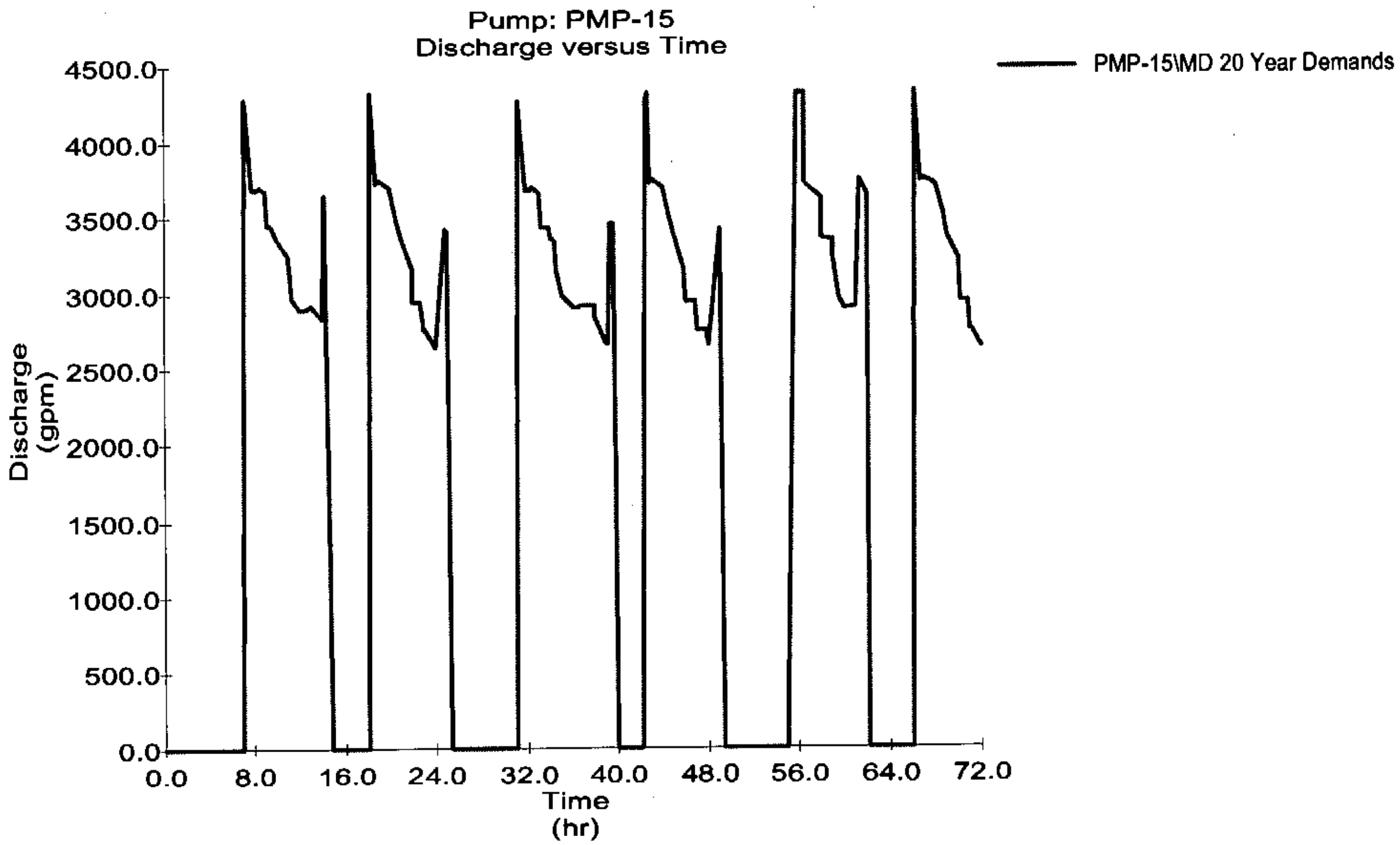


MD

Graph

Clinton Ave. Pump

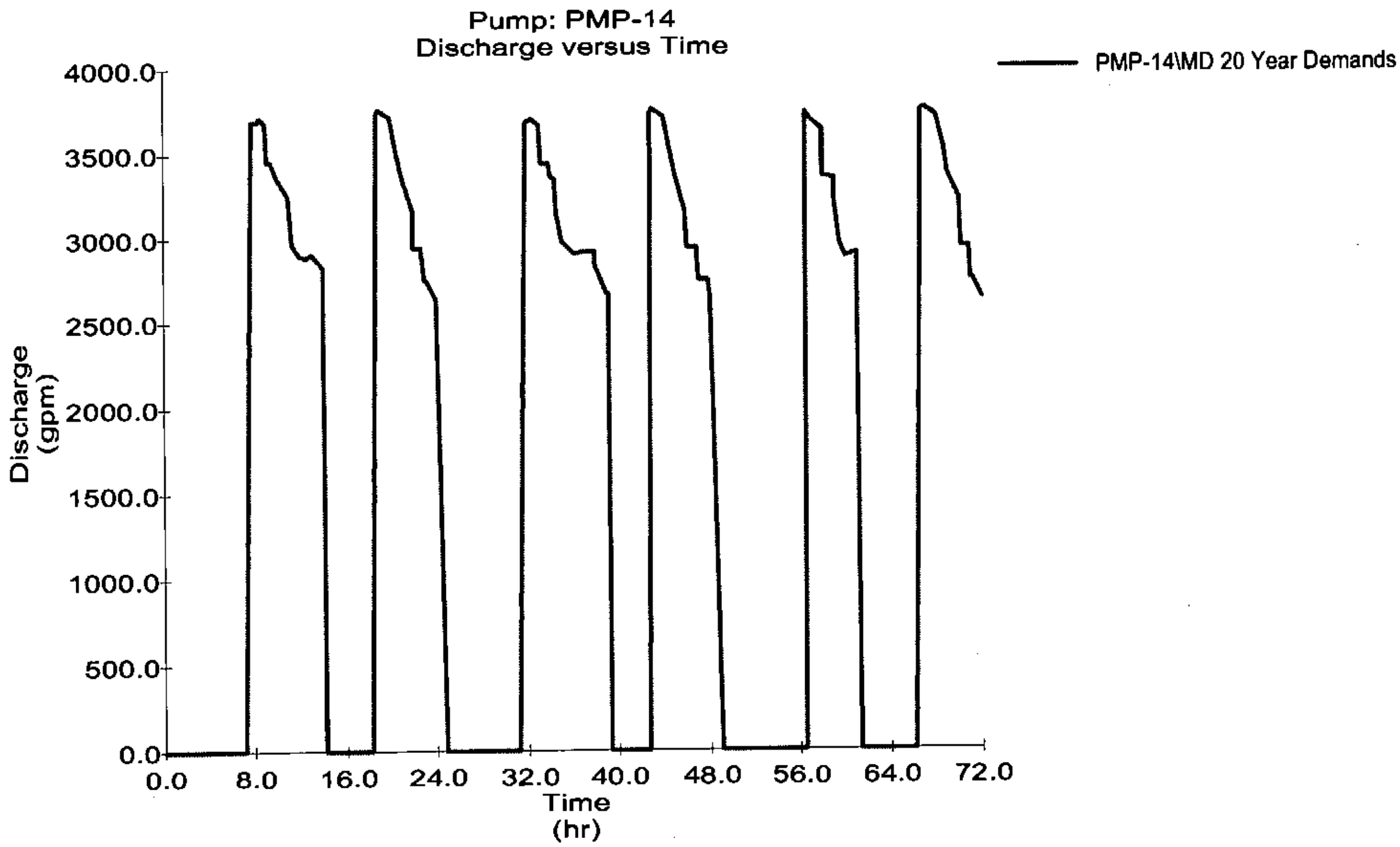
Level control w/ Frenchtown Rd.



MD

Graph

Clinton Ave. Pump
Level control w/ Frenchtown Rd.

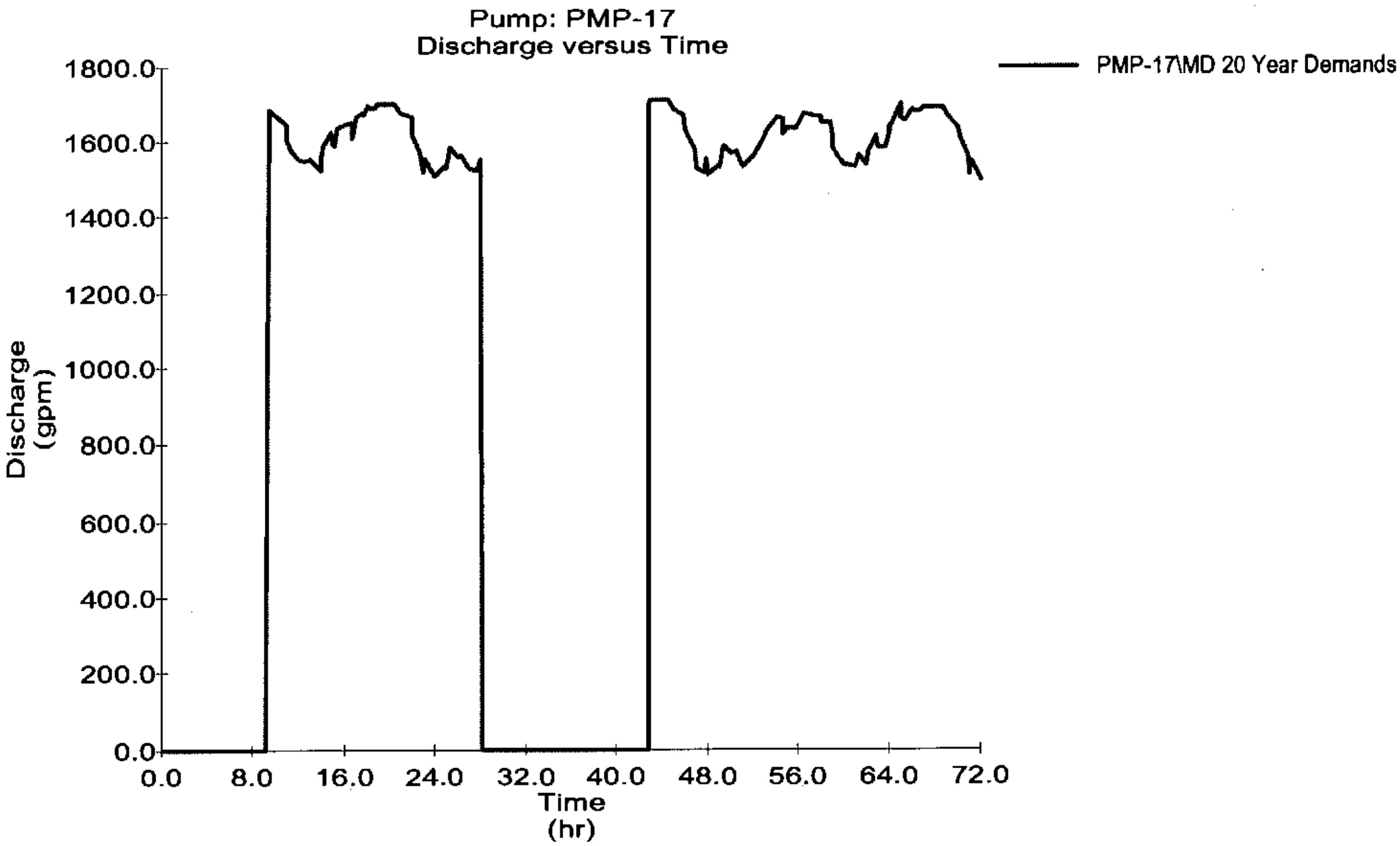


MD

Graph

Quaker Ln. Pump

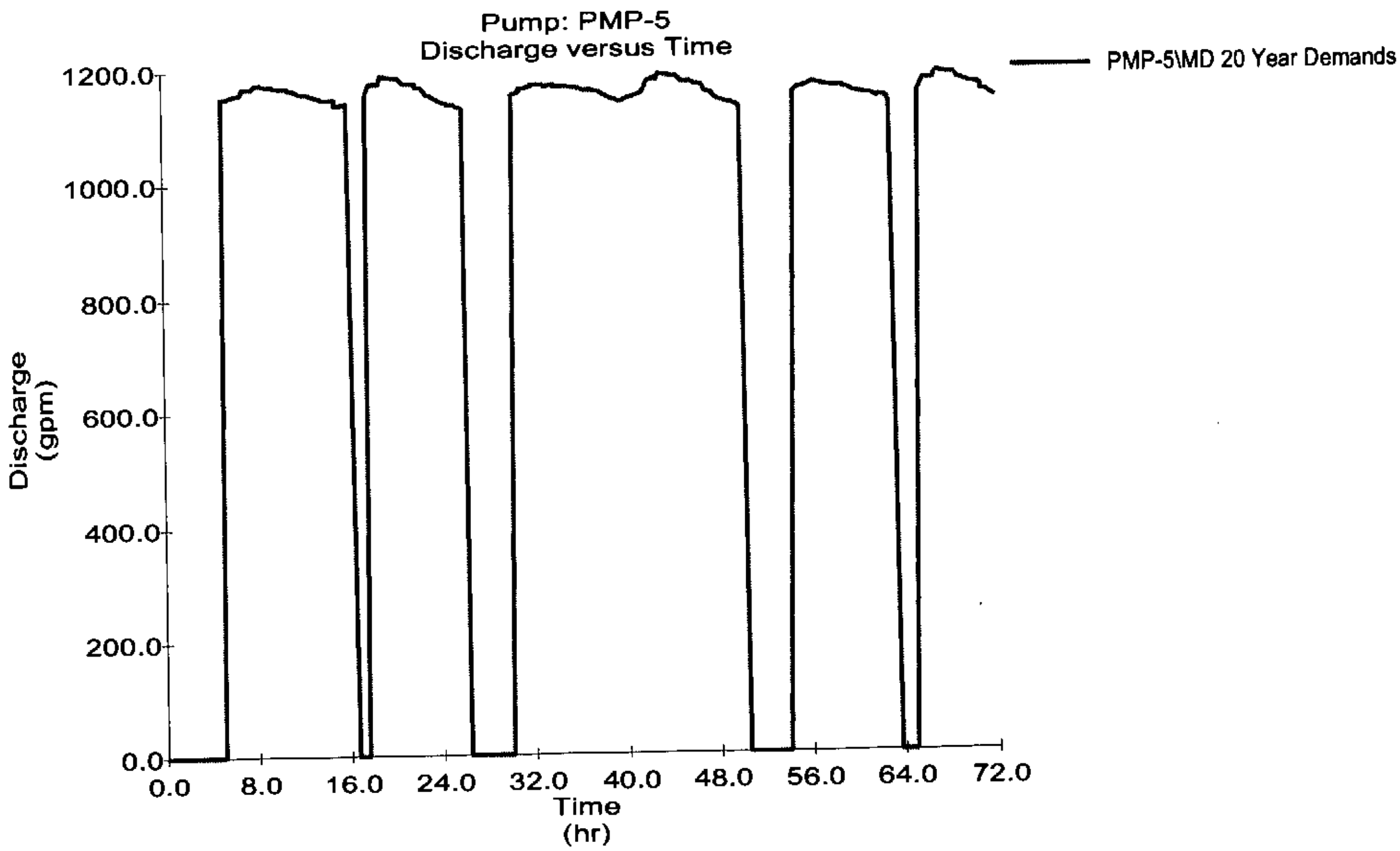
Level control w/ Setian Ln.



MD

Graph

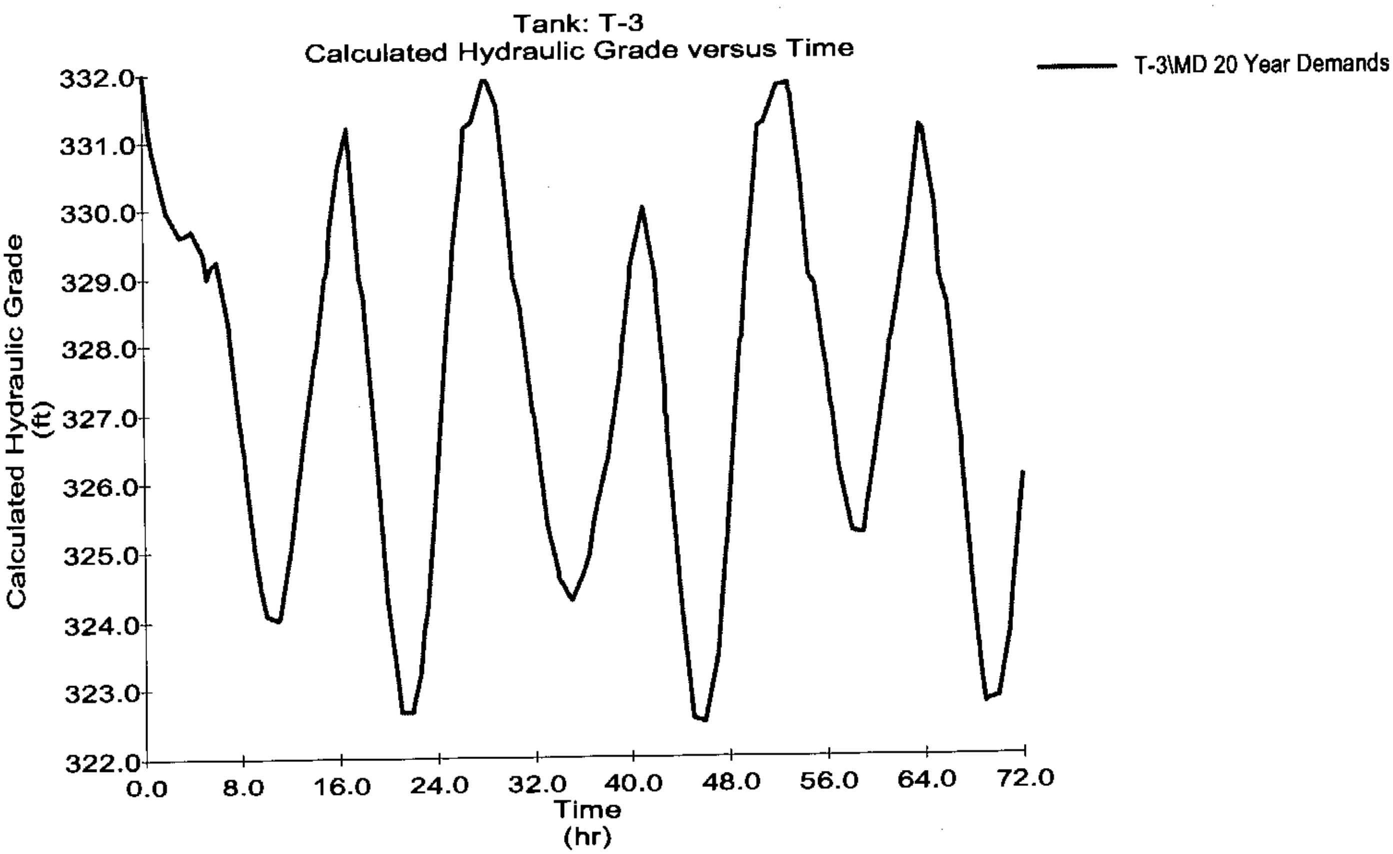
EG Well Pump
Level control w/ Frenchtown Rd.



MD

Graph

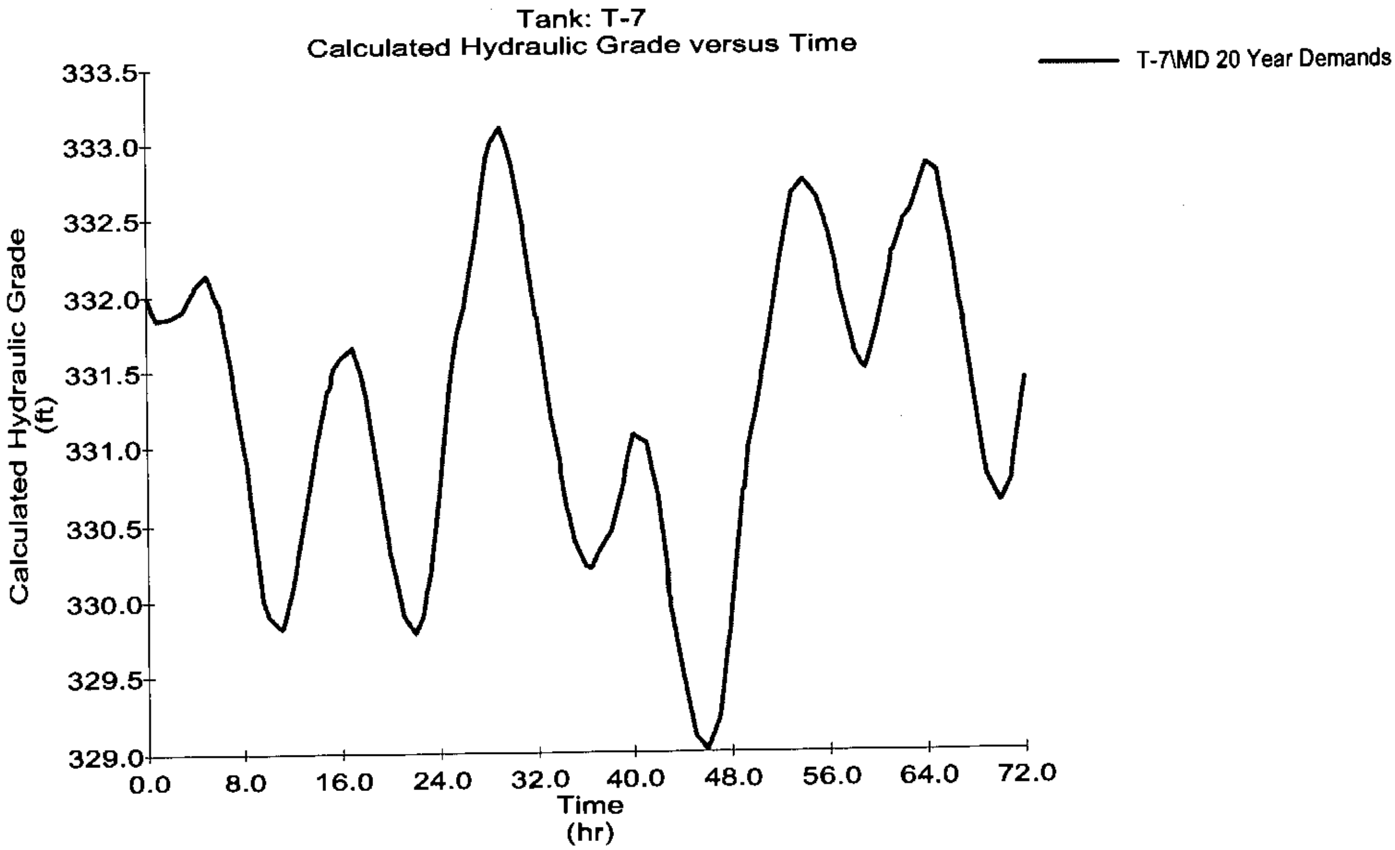
Frenchtown Rd. Tank



MD

Graph

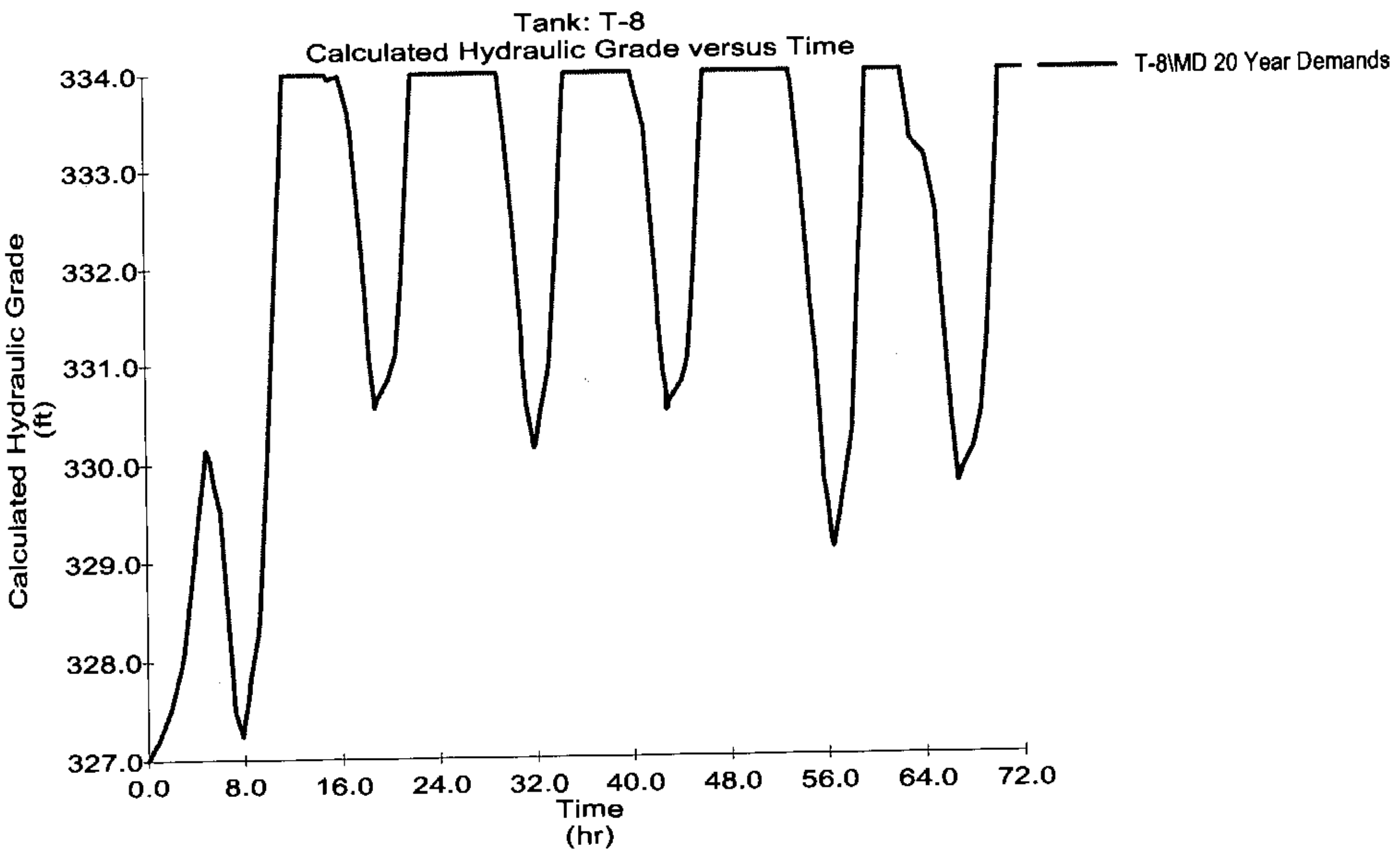
Setian Ln. Tank



MD

Graph

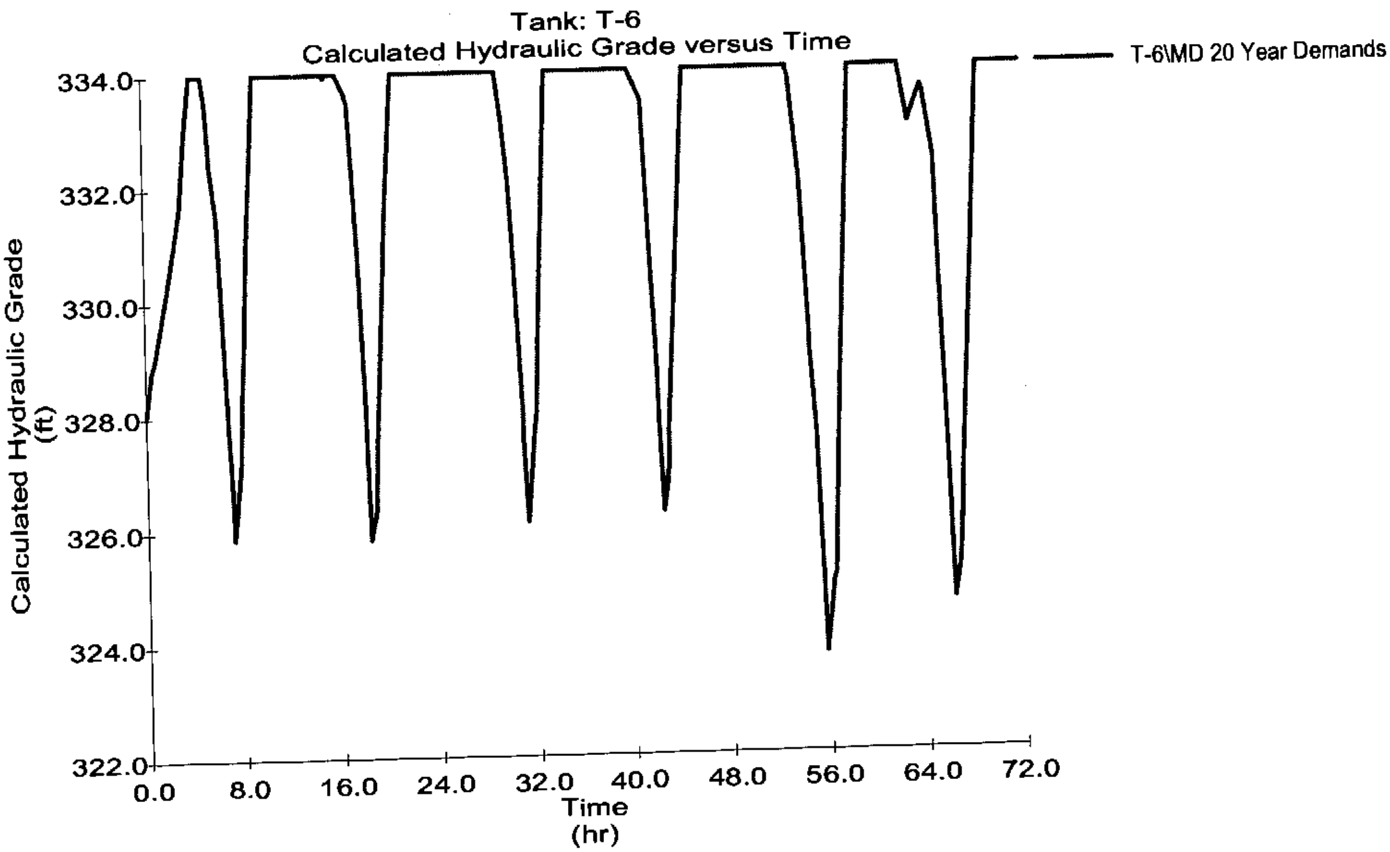
Wakefield St. Tank



MD

Graph

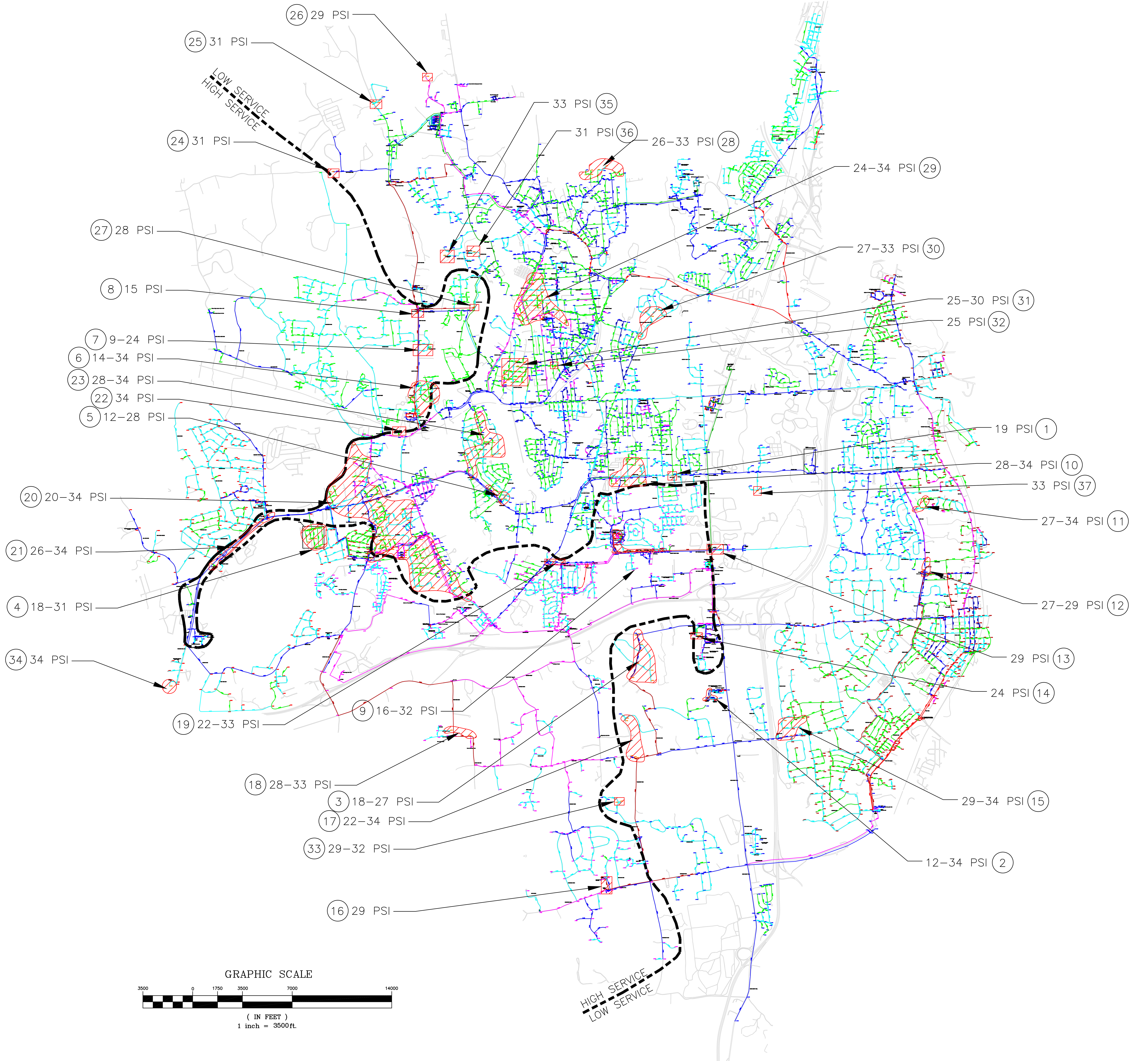
West St. Tank



ENCLOSURE NO. 1
KCWA SERVICE AREA LOW PRESSURE LOCATIONS

KCWA SERVICE AREA
LOW PRESSURE LOCATIONS

FUTURE AVERAGE DAY DEMAND – STEADY STATE SIMULATION



LEGEND

Color Coding Legend
Link: Diameter (in)

- <= 2.0
- <= 4.0
- <= 6.0
- <= 8.0
- <= 10.0
- <= 12.0
- <= 16.0
- <= 20.0
- <= 24.0
- <= 30.0

AREAS BELOW 35 PSI WITH 1 PUMP RUNNING AT CLINTON AVE. PS

KCWA WATER DISTRICT SYSTEM MAP

JULY 2007 *J0612*

SHEET 1 OF 1