ENCLOSURE I
Water System Study

CHAPTER ONE

INTRODUCTION

Background

The Camp Grayling water system study is to assist the State of Michigan in analyzing the existing capacity of the water system in order to determine the potential for future expansion and also to determine the feasibility of making it a year-round training facility. The Camp's water supply and storage system currently consists of two (2) water production wells, one (1) 500,000-gallon in-ground storage reservoir and a water distribution system consisting of approximately 10 miles of 2" to 8" diameter water main (see Figure 2.1 – Existing Water System Map and Table 1.1: Water Distribution System Inventory).

Table 1.1
Water Distribution System Inventory

PIPE SIZE	PIPE LENGTH	PERCENT OF TOTAL
2"	19,319 ft	36.59%
3"	4,590 ft	8.69%
4"	9,443 ft	17.89%
6"	7,724 ft	14.63%
8"	11,717 ft	22.19%
TOTALS*	52,793 ft	100%

*Does not include < 2" diameter service lines

The existing water service area varies in elevation from +/-1,134' along the shore of Lake Margrethe to +/-1,336' (the topographic information provided for the project is limited primarily to the inhabited area of the Camp). Based upon the review of USGS maps, elevations reach upwards of 1,470' near the Southeasterly corner of Camp Grayling in the vicinity of the proposed SIRE complex. The in-ground storage reservoir has a top elevation of 1,328.62'. Under normal operating conditions the static water pressures in the system range between 55 pounds per square inch-gauge (psig) and 70 psig.

Purpose and Scope

The purpose and scope of the Water System Study was to build a hydraulic computer model of Camp Grayling's water system using the updated electronic water system map and the topographic survey provided by Camp Grayling staff. That information, along with hydrant flow testing, acoustic surveying and destructive testing of the in-ground pipe, helped to create the model necessary to analyze the adequacy of the existing water system. The model then enabled analysis of potential future changes to the

water system in order to see their impact and benefits. After analyzing a number of future scenarios, prioritized recommendations for improvements and additions to the Camp's water system were made.

The analysis includes available fire flow, system operating pressures, water storage capacity, present and future water demands, potential water main replacements, potential looping of the existing system, expansion of the transmission main network, future expansions to the distribution system, firm capacity of the Camp's wells, future storage tank options, general maintenance recommendations and overall reliability of the water system. The recommendations include cost opinions of the proposed work for budget planning.

CHAPTER TWO

EXISTING WATER SYSTEM ASSESSMENT

Existing Well Production

Currently, Camp Grayling does not maintain daily or monthly water production or demand records. Production numbers are taken periodically, sometimes monthly and otherwise quarterly. The two wells at Buildings 410 and 552, generally operate 1 week on and 1 week off and supply water to the 500,000-gallon in-ground storage reservoir and distribution system on an alternating basis. The wells operate on demand, based on the water level in the storage reservoir tank. The Building 410 well, constructed in 1952, had an original design yield of 760 gpm and currently produces in the vicinity of 600 gpm. This well is considered the primary well and for the purposes of this report it will be referred to as Well No. 1. The Building 552 well (Well No. 2), constructed in 1970, had an original design yield of 750 gpm. Well No. 2 is considered a secondary well but is used interchangeably with Well No. 1. According to Camp Grayling, in October of 2000, Well No. 2 pumped up to 1000 gpm during testing and maintenance procedures.

The firm capacity is a measure of the water system's well production capacity with the highest producing well (assumed to be Well No. 1) out of service. This is used to identify the capacity of the system under worst case conditions; when the demand is highest and the highest producing well is under maintenance. The Camp's firm well capacity is 864,000 gallons per day, with Well No. 1 out of service. Therefore, the Camp Grayling water system, with the normal operation of alternating the wells, operates under a firm capacity status. This information is shown below in Table 2.1: Existing Well Capacity.

Table 2.1
Existing Well Capacity

Well Name	Well No. 1 (Bldg 410)	Well No. 2 (Bldg 552)	Totals
Actual Flow (gpm)	600*	600*	1,200
Gallons Per Day (gpd)	864,000	864,000	1,728,000
Well Firm Capacity (gpd)	-	864,000	864,000

* Camp Grayling estimated well production (current use).

Both Well No. 1 and No. 2 have had recent work completed in the Fall of 2008 to improve performance, efficiency and safety. Both production wells had new backflow prevention devices and flow meters installed each with a 4-20mA remote read capability. A number of other cantonment area buildings also had backflow prevention devices installed.

Existing Water Storage and Fire Flow Capacity

Guidelines for available fire flows for public water systems are set by the ISO Commercial Risk Services. The range of needed fire flows is between 1,000 gallons per minute (gpm) for residential type areas and 5,000 gpm for large commercial facilities, industry and hotels. The majority of commercial businesses have needed fire flows in the range of 3,000 to 3,500 gpm. In order to have a full credit rating by the ISO, the needed fire flow rate must be supplied for a specific duration. The existing available fire flow within the Camp's water system ranges from a low of 137 gpm to a high of 1,398 gpm. There are many limiting factors for the low fire flow areas, including a low relative elevation difference between the storage reservoir and some of the existing hydrants, especially hydrants located on 2" and 3" water lines (existing hydrants 3, 4, 10, 11, 19 & 20).

Community water storage is sized to provide sufficient storage, when combined with the firm pumping capacity of the water supply wells, to meet maximum daily consumption requirements during a maximum fire flow demand. The Camp's in-ground storage tank provides a total storage capacity of 500,000 gallons to the water system. The Camp's water supply wells have a total pumping capacity of an estimated 1,200 gallons per minute, although typically only one well is operated at a time with approximately 600 gallons per minute. It is therefore assumed that the capacity of the active well meets the average daily demand, assumed to be 600 gallons per minute, and the storage reservoir provides the additional volume necessary to meet maximum daily demands when the Camp is at full seasonal capacity.

The maximum daily demand for the water system is unknown due to insufficient records and can only be estimated. Typically, the maximum daily demand ranges from between 1.7 and 2.2 times the average daily demand. Therefore, it is assumed that the maximum day would be 2 times the average daily demand over an 18-hour period of usage. Assuming that the in-ground storage reservoir is starting full, the amount of available fire flow during the maximum daily demand over a 3 hour duration can therefore be calculated as follows:

Available Fire Flow	= Storage + Well Capacity – Maximum Consumption
(Maximum Day)	= 500,000 + (600 x 3 x 60) – (1,200 x 3 x 60) = 392,000 gallons
	= 392,000 gallons / 180 min. (3 hour duration) = 2,178 gallons per minute

Normal recommended fire flows from the ISO Commercial Risk Services range from 3,000 to 6,000 gallons per minute for 3 to 5-hour durations for commercial and industrial areas. Normal recommended residential fire flow is a minimum of 1,000 gpm for up to two hours. The estimated available fire flow currently provided by the Camp water system during maximum day demands is under

the ISO recommended range of fire flow for commercial and industrial areas, but meets the recommended residential fire flow.

The limiting factor for the ability of the Camp's water system to provide adequate fire flow protection is the distribution system. Some existing hydrants are currently connected to 2" water lines, which cannot provide the required flow to the hydrants. The calculated available fire flow above indicates that the reservoir can provide more supply than the distribution systems capacity.

With the anticipated future growth of Camp Grayling and the desire to make it a year-round facility, this is an issue that will need to be addressed.

Existing Water Distribution System

The Camp Grayling water distribution system consists of 3" to 8" water mains. There are also a large number of 1" to 2" service lines, abandoned water lines and dead-end lines. The original installation dates of the majority of the water system lines is unknown but is estimated to be constructed in the 1950's based on the original construction date of Well No.1 (1952). The water system mains are mainly cast iron with some asbestos cement (transite) mains. The service lines are cast iron and copper. See Figure 2.1 Existing Water System Map.

There are 20 active existing hydrants throughout the Camp's water system. Seven of the hydrants were flow-tested in order to assist in the calibration of the hydraulic model (see Appendix A - Hydrant Flow Test Reports). All of the existing hydrants were inventoried and the results are in Appendix B - Hydrant Inventory & Photographs. The hydrant flow test locations and the existing hydrant numbers are indicated on Figure 2.1. The majority of the existing hydrants are very old and in poor working condition. Repair parts are no longer available for most; the exceptions are 5 newer hydrants in good condition (hydrant #'s 1, 3, 7, 13 and 20). Many of the hydrants have previously or are currently experiencing issues with leaking and are in imminent need of replacement. The hydrants are often located on small diameter water lines and often have too large of separation to provide adequate fire protection for all facilities.

There are a limited number of isolation valves throughout the system. The Camp Grayling maintenance staff has difficulties in isolating portions of the water system during repairs due to a limited number of valves with inadequate frequency and poor working condition. This requires a larger portion of the water system to be shut down during required repairs and makes the system unreliable and non-redundant. If repairs are required during times when the Camp is fully utilized, it plays a large impact on the Camp operations.

There are a large number of undersized water mains of less than 6" diameter throughout the water distribution system. 2 to 4" diameter water mains account for approximately 63% of the existing water system. These water lines are no longer permitted by the Michigan Department of Environmental Quality as new main sizes; the current minimum is 6" diameter for distribution mains and 8" diameter for transmission mains. Typically, older mains become hydraulically less efficient over time due to excessive build-up on the insides of the pipes.

The 2" through 4" water mains are restrictive hydraulically and typically with age have low "C-factors" due to build-up in the pipe. However, based upon past underground exploration at Camp Grayling and the results of the destructive testing completed for this project, the existing mains are surprisingly clean on the inside. There is very little, if any, buildup within the pipes and therefore the condition of the pipes are not limiting the flow hydraulically; only the small diameter. See Appendix C – Destructive Testing: Underground Pipe Photographs for example photographs of the exterior and interior of the inside of the existing water mains. Each undersized water main should be evaluated based on its location, relative demand and need for fire flow, and replaced as necessary with a larger diameter main in the future.

In addition to the existing water mains with diameters less than 6", other undersized transmission mains throughout the water system should be considered for replacement. Undersized water mains may cause isolated areas throughout the water distribution system to experience minimal flows and pressures during peak demand conditions. Wherever the transmission mains reduce down to a smaller diameter there is a resulting hydraulic impact.

There are a number of existing or proposed critical facilities within the system that currently either do not have water service or have very low pressures based on their location and elevation. The following is a list of those facilities:

- Building 413 — Distinguished Visitors Quarters (DVQ)
- Building 950 — Ammunition Supply Point (ASP)
- Building 955 — Surveillance Inspection Residue (SIRE), proposed
- Buildings 48 — Generals Mess Hall
- Buildings 49Q — Generals Officers BOQ
- Buildings 50 — Latrine

The DVQ, which currently is supplied by service pumps with backup pump and generator, has water supplied by gravity at approximately 12 psi. Buildings 48-50 are currently supplied by gravity with pressures at approximately 20 psi. The ASP and the future SIRE are located south of the main cantonment area and the existing water reservoir near the Taylor Hill area (per the USGS maps), nearly 100 feet in elevation higher than the next highest facility. The elevations at these two facilities make it impractical and financially restrictive to connect to the water system. If water service is desired for these facilities, they should have either a stand-alone water system or an alternative-type system to provide the required fire flow. Designing the cantonment area water system around these facilities is not recommended.

In portions of the cantonment area there is a high water table, despite the fact that the soils are primarily well-drained sand. Portions of Parade Route and the majority of Soldiers Drive along Lake Margrethe have a high water table. Existing water main along Soldiers Drive had to be abandoned due to issues with high water table, settling, freeze-thaw cycles and subsequent leaking joints. Therefore, these areas will be avoided for future water main consideration.

As other improvements are made to the Camp's infrastructure, such as road reconstruction, site development, storm and/or sanitary sewer construction, etc., the looping and replacement of undersized water mains is highly recommended. The replacement of undersized existing water mains will provide improved transmission throughout the entire water distribution system. The Camp's transmission mains are adequate in size; the suggested replacements outlined in Table 2.2 include undersized distribution mains, primarily leads up to existing hydrants and extended length, small-diameter service lines.

Table 2.2
Undersized Water Mains

STREET NAME	EXISTING SIZE	PROPOSED SIZE	LENGTH	FROM	TO
Howe Road	2"	6"	300'	Building 12 (H19)	Building 3 (H20)
Howe Road	3"	6"	180'	Building 316Q	Bldg. 310Q (H10)
Kitchen Road	3"	6"	80'	8" Main	Hydrant 11
Brigade Road	2"	6"	450'	8" Main	Hydrants 3 & 4
	Total Length		1,010'		

The preferred layout of water main in a public water system incorporates as much looping of the water mains as possible. Looping of the water main will provide improved reliability, redundant supply (secondary source in case of a water main break), improving hydraulics for normal and fire flow demands, and water quality. Factors to be considered in the looping of dead-end mains include existing

right-of-way (if applicable), cost, location, need and size, type and use of the affected existing facilities and potential future development. The suggested areas for looping water mains are listed in Table 2.3: Potential Water Main Looping.

Table 2.3
Potential Water Main Looping

STREET NAME	PROPOSED SIZE	LENGTH	FROM	TO
Howe Road	8"	2,650'	8th Street	4th Street
8th, 10th, Soldiers, & Howe Road	8"	5,350'	Howe Road	Soldiers Drive
2nd Street	6"	1,750'	Soldiers Drive	Wilson Hill Road
Kitchen Road	6"	425'	Building 208M	Building 206B
Cross-Country	6"	1,060'	Building 191	Trailer Park
		11,235'		

System Controls

The existing water system has SCADA (Supervisory Control and Data Acquisition) system communication equipment connecting the two production wells. Camp Grayling has plans to expand the SCADA system in the near future. The following is a summary of the Camp Grayling Well House and Storage Reservoir Control Equipment:

- Water Storage Reservoir: The tank is equipped with a float and level transmitter connected to the wells for on-demand pumping.
- Well No. 1 (Bldg. 410): Communication with the Water Storage Reservoir and Well No. 2. The primary well alternating on a weekly basis with Well No. 2, with manual control.
- Well No. 2 (Bldg. 552): Communication with the Water Storage Reservoir and Well No. 1. The secondary well alternating on a weekly basis with Well No. 1, with manual control.

Lost Water

Lost water is the volume of water produced at the wells less the volume of water actually consumed by the Camp. Because the Camp only provides water for its own use and does not sell water to customers, the water consumption is not currently metered. Non-metered water systems are difficult to monitor for lost water. Typically, examples of causes of lost water in a metered municipal system can be non-metered consumption by the municipality, such as; non-metered water for landscaping; non-working or inaccurate water meters; water used from hydrants for construction or flushing; water fountains, park and cemetery faucets and/or locations where water is intentionally left running to prevent freezing of the

water lines. For Camp Grayling sources of lost water are leaking water mains, valves, hydrants, services and various fixtures throughout the water distribution system. Without adequate metering, the only way to determine lost water throughout the system is by either reservoir monitoring or leak detection surveys. While both provide valuable information, monitoring a reservoir will only provide information on the degree of water loss and not locate the source or sources. A leak detection survey, like the one that was completed for this study, will acoustically pinpoint water leaks throughout the system and estimate the rate of water loss through the leak. See Appendix D – Water Leak Detection Survey for details on the results of the survey completed for this project in the Fall of 2008. The majorities of the 5 leaks identified were at known locations of leaking valves, hydrants, etc. and were relatively minor in volume when compared to the total volume of water produced per day.

A 10 to 15 percent lost water component represents a relatively sound system. A lost water component of 20 percent and above indicates significant water losses are occurring in the water distribution system. For Camp Grayling's water system, the most efficient method of reducing the lost water is to schedule regular leak detection surveys every 2-3 years. Especially with an aged system, new leaks will happen regularly and scheduling regular leak detection surveys will help to minimize the loss of water. Pinpointing the locations and severity of the lost water will also help the Camp's staff to most efficiently use its monetary and staff resources. Leak detection surveys are an inexpensive, quick and non-destructive approach as a first-level of water system operation and maintenance.

Future replacement or abandonment of existing old water mains with sub-standard joints should lower the amount of lost water.

CHAPTER THREE

FUTURE WATER SYSTEM DEMANDS

Future Population Trends and Projections

According to the staff, the current population at Camp Grayling varies seasonally. Currently, Camp Grayling does not operate year-round as a training facility and has a limited year-round staff. Based upon population data supplied for the year 2008, winter time use averaged 644 bed uses per day. The bed spaces available year-round is currently 2,114 with a seasonal maximum of 6,383 bed spaces. With the Future 600-Block buildout, an additional 2,000 bed spaces is anticipated, including all winter time. Therefore, the total year-round capacity will be 4,114 and the seasonal capacity for Camp Grayling would then be 8,383 with the 600 Block build-out. See Appendix E - Camp Grayling Population Estimates.

Camp Grayling is interested in turning into a year-round training facility, and therefore it is anticipated that the total capacity of the Camp will continue to grow over time. The expansion of Camp Grayling, including the water system, will have an impact on the Camp's existing sanitary sewer collection, treatment, storage and discharge capacity. See Appendix F - Camp Grayling Sanitary Sewer Evaluation for information on the existing and future capacity of the sanitary treatment system.

Future Water Demand Projections

Without a definite plan and concrete numbers on how much expansion the Camp will experience in the future, it is difficult to make any projections on water demand. However, the existing system currently operates under a firm capacity status, with only alternating use of the two groundwater wells. Therefore, the water system has room for future expansion without further development of groundwater wells. Because the two wells have similar production yields, the water system could nearly double the water production if both were in service simultaneously. If the system gets to a point where utilizing both wells simultaneously is the normal standard, then the system's water demand, firm capacity and water storage should be monitored closely to determine the adequacy of the overall system over time. In order to better monitor the water system, regular production data including maximum daily use should be maintained. The future demands for the 600-block facilities have been included within the analysis.

Future Fire Flow Requirements

The base should look towards improving the distribution and fire-protection capabilities of the system. Currently, parts of the existing water system have very low available fire flow. For the majority of the facilities in the Camp, a typical 1,000 gpm available fire flow is acceptable and is the Camp's target fire flow availability. However, a few of the facilities, especially facilities with ammunition, fuel or other combustible storage (as previously noted) should have available fire flows ranging from 2,000 to 3,500 gpm. Typically, commercial facilities would require 3,000 gpm for a 3-hour duration fire. As the Camp continues to grow in the future and additional facilities are constructed, providing adequate fire flow and duration will be increasingly important.

CHAPTER FOUR

COMPUTER MODELING SUMMARY

WaterCAD®, by Haestad Methods, is computer simulation software that analyzes steady state and/or dynamic flows in pressure pipe networks. This software was used to model the steady state of the Camp's water distribution and storage system, including the pressure pipes, the wells and the water reservoir. Once developed, the water model can help provide valuable information for future infrastructure expenditures.

A physical description of the pipe network (i.e., diameter, length, elevations, material type, age, roughness coefficient "C-factor" and condition) is required for the analysis. The roughness coefficient or "C-factor" is a measure of the "roughness" of the interior of the pipe. It varies depending upon the diameter, the age and the type of pipe material. Scale build-up on the interior of the pipe causes the equivalent flow diameter of the pipe to decrease, which in turn affects the flow capacity. The C-factors were initially assumed and then adjusted as necessary in order to provide an accurate model when compared with the actual field results. This existing system information was input into the software in order to develop a base model from which to evaluate existing and proposed conditions.

The base model was developed from Camp Grayling water system schematic maps provided by staff. Camp Grayling staff assisted with additional system information in relationship to operation and maintenance of the water storage reservoir, the supply wells and the distribution system.

Calibration of Model

The calibration model run must reflect the same conditions that existed within the water distribution and storage system at the time of the fire flow tests. These conditions include the water storage reservoir settings, well pumping status, the status of all valves and residual and static pressures in the system. With limited water production records and control systems on the water system components, it was not possible to identify the existing status of the water storage reservoir during fire flow testing. Therefore, the calibration of the model is limited in accuracy and must rely on straight field results of the fire flow tests, accurate elevations of the model junctions and estimated water pumpage. Fire flow test locations were selected and reviewed with Camp Grayling staff. The fire flow test locations were selected based upon location within the system, pipe diameter and hydrant conditions. Out of 20 active hydrants, 7 were selected for fire flows with 7 other hydrants used to determine the respective residual pressures. Several hydrants are on very small diameter water lines and would not give valuable information for calibrating; therefore they were not utilized for flow testing.

During calibration of the water system model, the three variables to set and/or adjust are the node demands, the pipe "C" factors and the node elevations. The node elevations, once determined from field data or topographic mapping, are fixed and are not adjusted in the calibration. The hydraulic model was adjusted until the static flow conditions simulated by the computer significantly matched the field-tested results witnessed in the water distribution system during hydrant flow tests.

Results of Model

The calibration results reflect that the model can be used to reliably predict conditions throughout the water system. In addition to the physical descriptions of the pipe network, the output from the model may include the following information: flow rate, flow velocity, direction of flow, pressure head, hydraulic grade, pressure, demand, available fire flow, calculated residual pressure, reservoir status reports and valve status reports.

After completion of the calibrated model, the model was utilized to evaluate proposed improvements to the water distribution system. See Figure 4.2 Hydraulic Water System Model map. The following Table 4.1: Description of Model Scenarios is a list of all the scenarios of the proposed improvements to the water system with descriptions of the current system and reasons for evaluating each scenario. All scenarios assume that the existing water storage reservoir is full, well pumps are on and average annual daily demands are present.

Copies of the final hydraulic model for the Camp Grayling water system will be provided.

Description of Model Scenarios

Table 4.1
Description of Model Scenarios

Water Model Scenario List	Calibration Run: Update the water system and model with additions/changes. Setting up the model for evaluation by using known field test settings and results to recreate the same results in the model. Reason For Evaluation: To create a reliable model of the Camp's Water System.
Scenario 2 (Baseline)	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir. Reason For Evaluation: This scenario is the baseline for all Scenario comparisons to see the impact of running both wells with the anticipated new construction on the base.
Scenario 2A	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir. **Proposed Construction: Hydrant Lead Improvements (6" mains)** This scenario would improve the available fire flow to several hydrants across the Camp. Currently, hydrants 3, 4, 10, 11, 19 and 20 are at the ends of 2" or 3" water lines. These small diameter lines severely limit the available fire flow to each hydrant.
Scenario 2B	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir. **Proposed Construction: 600 Block Loop (8" mains) plus Scenario 2A** This scenario would provide a new water main loop to the area of future construction of several new buildings in the area defined by 8th and 10th Streets, Soldiers Drive and Howe Road. Currently there is no existing water service in the area. This loop should utilize the existing 8" diameter main along 8th Street between Howe Road and Parade Route and connect back to the existing 8" main near Building 552 (Well 2) for a complete 8" diameter loop. Without a loop for this new construction area, a single water main break could shut down the use of the facilities. A loop will improve reliability, water quality and redundancy.
Scenario 2C	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir. **Proposed Construction: Howe Route Loop (8" mains) plus Scenario 2B** This scenario would increase the overall reliability and redundancy of the system. The new 600 block construction would be on a very long, single-source connection to the existing water reservoir without this second connection. This construction would connect the existing 8" water mains on 8th Street and 4th Street and provide a second transmission source to the system in case of a water main break or shut-down.
Scenario 2D	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir. **Proposed Construction: Second Street Loop (6" mains) plus Scenario 2C** This scenario would improve the reliability and redundancy of the system. The Second Street Loop would shorten the length of the existing by connecting the existing 6", 8" and 4" mains crossing Second Street on Soldiers Drive, Howe Road and Wilson Hill Road. In conjunction with Scenario 2J, the water lines between Kitchen Road and the new Tank at Wilson Hill would become 8" diameter instead of the 6" (new) and 4" (existing) mains.
Scenario 2E	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir. **Proposed Construction: 200 Block Main (6" mains) plus Scenario 2D** This scenario would provide improved fire flow for this area, which is currently low and in an area of dense buildings with distant hydrants.
Scenario 2F	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir. **Proposed Construction: Trailer Park Loop (6" mains) plus Scenario 2E** This scenario would help improve the circulation, water quality, redundancy and reliability of this portion of the water system by connecting the existing dead-end 4" mains and 6" mains on the North end of the water system.

Scenario 2G	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir. **Proposed Construction: New North Transmission plus Scenario 2F** This scenario will help improve the capacity and transmission capabilities of the water system, especially in the northeasterly area of the water system. This line will replace the failed and abandoned 6" water main south and along Soldiers Drive.
Scenario 2H	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoirs. **Proposed Construction: New 300,000-gallon Reservoir plus Scenario 2G** This scenario will help improve the capacity and transmission capabilities of the water system, especially in the area of new construction in the 600 block.
Scenario 2I	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir & tank 2. **Proposed Construction: New 300,000-gallon Elevated Tank 2 plus Scenario 2G** This scenario will help improve the capacity and transmission capabilities and system pressures of the water system, especially in the area of new construction in the 600 block and the westerly portions of the system.
Scenario 2J	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir & tank 2. **Proposed Construction: New 300,000-gallon Elevated Tank 2 plus Scenario 2G** This scenario will help improve the capacity and transmission capabilities and system pressures of the water system, especially in the easterly half of the water system & the Wilson Hill area.
Scenario 2K	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir & tank 2. **Proposed Construction: New 300,000-gallon Elevated Tank 2 plus Scenario 2G** This scenario will help improve the capacity and transmission capabilities and system pressures of the water system, especially in the middle section of the water system along 4th Street and the higher elevations (Building 413).
Scenario 2L	Estimated Annual Average Daily Demand – Well 1 on, Well 2 on, full reservoir & tank 2. **Proposed Construction: New Booster Stations (2) plus Scenario 2G** This scenario will help improve the pressures and capacity of select facilities if a second tank is not constructed. One booster would primarily service Building 413 and the other Buildings 48 through 50.

*See Figure 4.1 for Proposed Water System Map and Proposed Scenario Locations

Scenarios A through G are potential upgrades to the water system that were selected based on a comprehensive analysis of the existing water system. They will be evaluated on a cost-benefit basis when compared to the baseline scenario. The Scenarios are cumulative, to show the effect of completing all of the proposed construction. Each scenario can also be compared to the previous one (compare 2C to 2B, etc.) in order to see the benefit of each individual scenario improvement. Scenarios H through L are options for a second elevated tank or booster stations if a tank is not selected for construction.

Table 4.2: Model Scenario Comparison of Fire Flows (gpm), summarizes the results of the scenarios listed above for the available fire flow at the fire flow test locations only, for the Camp's water system. The available fire flow at all other junctions will be shown later in Table 4.3 through 4.6 in order to show the relative improvements.

All of the scenarios were modeled and the results were compared to its baseline scenario to show the individual effect on the overall water system.

Table 4.2
Model Scenario Comparison of Fire Flows (gpm)

TEST # JUNCTION #	1 J-700-H2	2 J-40-H8	3 J-770-H12	4 J-780-H15	5 J-320-H17	6 J-460-H14	7 J-760-H10
Fire Flow Test	838	1060	918	375	375	443	375
Scenario 2	1768	1326	567	NA*	452	441	271
Scenario 2A	1768	1326	567	NA*	452	441	401
Scenario 2B	830	688	389	NA*	324	332	339
Scenario 2C	786	676	381	NA*	317	325	336
Scenario 2D	794	683	389	NA*	384	355	336
Scenario 2E	794	683	389	NA*	384	355	336
Scenario 2F	794	683	389	NA*	384	386	336
Scenario 2G	830	718	563	NA*	558	566	351
Scenario 2H	2374	1489	911	208	897	679	399
Scenario 2I	3000	2083	1190	570	1172	744	488
Scenario 2J	2476	3000	3000	3000	2335	868	532
Scenario 2K	2826	2333	1487	856	1468	832	588
Test Locations	See Figure 2.1						

- Did not meet minimum zone residual pressure of 20 psi required for fire flow evaluation. This hydrant and junction is on Wilson Hill near Building 48M and has a high elevation when compared to the existing water storage reservoir.

Tables 4.3 through 4.6 on the following pages show all of the hydraulic model components and the results of each of the scenarios A through K for the Base Scenario 2. For Base Scenario 2, Table 4.3 indicates the available fire flow at each junction in the model for each of the scenarios 2 through 2K. It also lists a comparison of the fire flow between each consecutive scenario in order to show where and how much the available fire flow improved for each junction in the hydraulic model, as a result of the proposed construction. Table 4.4 lists the junction name, elevation, zone and pressure at each junction in the hydraulic model and also lists the junction demand for each scenario 2 through 2K. Table 4.5 lists the pipe name, start and stop junctions, diameter, material, C Factor, length, zone and open-close status for all pipes in the model. Table 4.6 lists the status of the existing and future reservoirs for each scenario 2 through 2K; including name, zone, base elevation, minimum elevation, initial elevation, maximum elevation, outflow and hydraulic grade.

The main item of interest in reviewing the results in Tables 4.3 through 4.6 is the available fire flow. The system already has been evaluated for potential areas of replacing hydrants, upsizing

Table 4.3
Scenario 2 through 2K
Fire Flow Report and Comparisons

Junction Label	2 Fire Flow Available	2A Fire Flow Available	2B Fire Flow Available	2C Fire Flow Available	2D Fire Flow Available	2E Fire Flow Available	2F Fire Flow Available	2G Fire Flow Available	2H Fire Flow Available	2I Fire Flow Available	2J Fire Flow Available	2K Fire Flow Available	Compare 2A 2	Compare 2B 2A	Compare 2C-2B	Compare 2D-2C	Compare 2E 2D	Compare 2F-2E
J-1-H6	1,773	1,773	835	823	831	831	831	869	2,181	3,000	3,000	3,000	0	-939	-12	8	0	0
J-10	1,734	1,734	824	812	820	820	820	857	2,141	3,000	3,000	3,000	0	-911	-12	8	0	0
J-20	1,612	1,612	787	777	785	785	785	821	2,024	2,887	3,000	3,000	0	-824	-11	8	0	0
J-30	1,572	1,572	774	766	774	774	774	810	1,985	2,830	3,000	3,000	0	-798	-8	8	0	0
J-40-H8	1,326	1,326	688	676	683	683	683	718	1,489	2,083	3,000	2,333	0	-638	-12	8	0	0
J-50	1,326	1,326	688	676	683	683	683	718	1,489	2,083	3,000	2,333	0	-638	-12	8	0	0
J-70	1,098	1,098	608	597	603	603	603	671	1,270	1,731	3,000	2,006	0	-490	-12	7	0	0
J-80	987	987	567	556	563	563	563	648	1,189	1,593	3,000	1,894	0	-419	-11	6	0	0
J-90	914	914	540	529	535	535	535	633	1,141	1,518	3,000	1,827	0	-374	-11	6	0	0
J-100-H9	891	891	531	521	527	527	527	629	1,126	1,496	3,000	1,806	0	-360	-11	6	0	0
J-110	884	884	529	518	524	524	524	627	1,122	1,489	3,000	1,800	0	-356	-11	6	0	0
J-120	856	856	518	508	513	513	513	622	1,105	1,463	3,000	1,775	0	-338	-10	6	0	0
J-130	769	769	484	474	480	480	480	606	1,051	1,384	3,000	1,697	0	-285	-10	6	0	0
J-140	719	719	463	454	459	459	459	596	1,019	1,340	3,000	1,651	0	-255	-10	5	0	0
J-150	701	701	455	446	451	451	451	593	1,007	1,323	3,000	1,634	0	-245	-9	5	0	0
J-160-H11	692	692	451	442	447	447	447	591	1,002	1,315	3,000	1,625	0	-241	-9	5	0	0
J-170	678	678	445	436	441	441	441	587	992	1,301	3,000	1,610	0	-233	-9	5	0	0
J-180	653	653	433	424	429	429	429	582	974	1,276	3,000	1,583	0	-220	-9	5	0	0
J-190	636	636	425	416	421	421	421	578	962	1,260	3,000	1,565	0	-212	-8	5	0	0
J-200	632	632	423	414	419	419	419	577	958	1,255	3,000	1,560	0	-209	-9	5	0	0
J-210	545	545	377	369	388	388	388	563	914	1,194	3,000	1,492	0	-168	-8	19	0	0
J-220	515	515	360	353	387	387	387	564	915	1,196	3,000	1,494	0	-155	-7	34	0	0
J-230	1,774	1,774	833	822	830	830	830	867	2,181	3,000	3,000	3,000	0	-941	-11	8	0	0
J-240	1,773	1,773	833	821	829	829	829	867	2,181	3,000	3,000	3,000	0	-940	-12	9	0	0
J-250	1,768	1,768	830	819	827	827	827	864	2,186	3,000	3,000	3,000	0	-937	-12	8	0	0
J-260	1,344	1,344	693	680	688	688	688	716	1,468	2,039	3,000	2,288	0	-652	-12	8	0	0
J-270	1,344	1,344	692	680	688	688	688	658	1,235	1,678	3,000	1,966	0	-652	-12	8	0	0
J-280	515	515	360	353	386	386	387	568	927	1,212	2,718	1,512	0	-155	-7	34	0	0
J-290	515	515	360	353	387	387	386	568	928	1,214	3,000	1,514	0	-155	-8	34	0	0
J-300	515	515	360	353	387	387	387	566	920	1,202	3,000	1,501	0	-155	-7	34	0	0
J-310	465	465	331	325	384	384	385	560	903	1,179	2,620	1,476	0	-134	-7	60	0	1
J-320-H17	452	452	324	317	384	384	384	558	897	1,172	2,335	1,468	0	-128	-7	67	0	0
J-330	443	443	319	312	383	383	384	557	894	1,167	2,189	1,463	0	-125	-6	71	0	0
J-340-H16	394	394	288	283	381	381	381	550	872	1,082	1,637	1,249	0	-106	-6	98	0	0
J-350	367	367	271	266	379	379	380	545	858	989	1,463	1,151	0	-96	-5	114	0	0
J-360	341	341	254	249	378	378	378	540	792	915	1,338	1,072	0	-87	-5	129	0	0
J-380	83	83	0	0	0	0	0	0	90	327	3,000	489	0	-83	0	0	0	0
J-390-H39	410	410	361	353	378	378	387	566	920	1,202	1,977	1,501	0	-49	-7	25	0	9
J-400-H13	515	515	360	353	386	386	387	565	920	1,201	2,258	1,501	0	-155	-8	34	0	0
J-410	515	515	360	353	387	387	387	566	920	1,035	1,316	1,161	0	-154	-7	34	0	0
J-420	515	515	360	352	386	386	386	566	814	901	1,110	1,017	0	-155	-8	34	0	0
J-430	515	515	360	353	387	387	387	566	726	801	956	902	0	-154	-8	34	0	0
J-440	446	446	360	353	387	387	387	455	493	549	625	618	0	-86	-8	34	0	0
J-450-H18	465	465	332	325	384	384	385	561	906	1,184	1,981	1,474	0	-134	-7	60	0	1
J-460-H14	441	441	332	325	385	385	386	564	917	1,178	1,562	1,310	0	-109	-6	60	0	1
J-470	382	382	332	325	355	355	386	566	679	744	868	832	0	-50	-7	30	0	31

Table 4.3
Scenario 2 through 2K
Fire Flow Report and Comparisons

Junction Label	2 Fire Flow Available	2A Fire Flow Available	2B Fire Flow Available	2C Fire Flow Available	2D Fire Flow Available	2E Fire Flow Available	2F Fire Flow Available	2G Fire Flow Available	2H Fire Flow Available	2I Fire Flow Available	2J Fire Flow Available	2K Fire Flow Available	Compare 2A 2	Compare 2B 2A	Compare 2C-2B	Compare 2D-2C	Compare 2E 2D	Compare 2F-2E
J-480-H19.20	465	465	332	325	385	385	385	561	906	1,179	1,665	1,329	0	-133	-7	60	0	1
J-490	210	210	169	167	175	175	176	196	218	290	359	359	0	-41	-2	8	0	0
J-500	700	700	456	446	451	451	451	593	869	965	1,132	1,092	0	-245	-10	5	0	0
J-510	440	440	379	376	375	376	375	391	441	525	570	623	0	-61	-3	-1	0	0
J-520	816	816	568	557	563	563	563	648	833	932	1,025	1,062	0	-248	-11	6	0	0
J-530	914	914	540	530	535	535	535	634	960	1,057	1,186	1,185	0	-374	-11	6	0	0
J-540	819	819	608	597	603	603	603	671	821	907	969	1,023	0	-211	-12	7	0	0
J-550-H7	672	672	570	568	568	568	568	568	659	750	742	876	0	-103	-1	0	0	0
J-560	1,768	1,768	830	808	817	818	817	854	2,273	3,000	3,000	3,000	0	-938	-22	9	1	-1
J-570	1,768	1,768	830	790	798	798	798	836	2,351	3,000	2,508	2,916	0	-938	-40	8	0	0
J-580	1,768	1,768	830	787	795	795	795	832	2,365	3,000	2,492	2,857	0	-938	-43	8	0	0
J-590	1,768	1,768	830	783	791	791	791	827	2,405	3,000	2,472	2,797	0	-938	-47	8	0	0
J-600	1,768	1,768	830	780	788	788	788	824	2,460	3,000	2,453	2,755	0	-938	-51	8	0	0
J-610	617	617	423	503	503	503	503	503	593	690	629	741	0	-194	81	0	0	0
J-620	700	700	492	776	784	784	784	820	2,492	3,000	2,578	2,880	0	-208	283	8	0	0
J-630-H1	1,723	1,723	785	777	785	785	785	821	2,563	3,000	2,473	2,759	0	-938	-8	8	0	0
J-640-H21	1,619	1,619	726	777	785	785	785	821	2,699	3,000	2,098	2,313	0	-893	51	8	0	0
J-650	1,461	1,461	765	777	785	785	785	822	2,481	2,942	1,820	1,993	0	-696	12	8	0	0
J-660	465	465	332	325	384	384	385	561	905	1,182	2,104	1,480	0	-134	-7	60	0	1
J-670	515	515	360	353	386	386	386	565	920	1,202	2,703	1,501	0	-155	-7	34	0	0
J-680	1,626	1,626	813	777	785	785	785	821	2,809	3,000	2,195	2,396	0	-812	-36	8	0	0
J-690	1,690	1,690	796	777	785	785	785	821	2,669	3,000	2,329	2,566	0	-894	-19	8	0	0
J-700-H2	1,768	1,768	830	786	794	794	794	830	2,374	3,000	2,476	2,826	0	-938	-44	8	0	0
J-710-H3	182	1,630	819	784	792	792	792	829	2,096	2,483	1,964	2,187	1,447	-811	-35	8	1	0
J-720	1,768	1,768	830	784	792	792	792	828	2,393	3,000	2,485	2,819	0	-938	-46	8	0	0
J-730-H4	108	1,388	723	784	792	792	792	829	1,551	1,806	1,508	1,728	1,280	-665	61	8	0	0
J-740	2,010	2,010	1,011	998	1,008	1,008	1,008	1,050	2,313	3,000	3,000	3,000	0	-998	-13	10	0	0
J-750-H5	1,768	1,768	830	796	805	805	805	841	2,340	3,000	2,731	3,000	0	-938	-34	8	0	0
J-760-H10	271	401	339	336	336	336	336	351	399	488	532	588	130	-62	-3	0	0	0
J-770-H12	567	567	389	381	389	389	389	563	911	1,190	3,000	1,487	0	-178	-8	8	0	0
J-780-H15	100	100	10	3	14	14	14	72	208	570	3,000	856	0	-90	-7	11	0	0
J-790	1,644	1,644	741	777	785	785	785	822	2,699	3,000	2,159	2,380	0	-902	36	8	0	0
J-800	1,656	1,656	739	777	785	785	785	821	2,699	3,000	2,203	2,433	0	-916	38	8	0	0
J-810	0	0	754	777	786	786	786	822	2,724	3,000	2,204	2,430	0	754	23	8	0	0
J-820-H22	0	0	676	777	785	785	785	821	2,870	3,000	1,904	2,117	0	676	101	8	0	0
J-830-H23	0	0	699	777	786	785	786	821	2,926	3,000	1,879	2,081	0	699	78	8	0	0
J-840-H24	0	0	696	777	785	785	785	821	3,000	3,000	1,836	2,036	0	696	81	8	0	0
J-850-H25	0	0	688	777	785	785	785	821	3,000	3,000	1,806	2,008	0	688	89	8	0	0
J-860-H26	0	0	654	777	786	786	786	822	3,000	3,000	1,599	1,804	0	654	124	8	0	0
J-870-H27	0	0	613	777	786	786	786	821	3,000	3,000	1,431	1,648	0	613	164	8	0	0
J-900-H30	0	0	760	777	785	785	785	822	2,972	3,000	1,952	2,140	0	760	17	8	0	0
J-910-H31	0	0	783	777	785	785	785	822	2,940	3,000	2,009	2,195	0	783	-6	8	0	0
J-920-H32	1,553	1,553	793	777	785	785	785	821	2,875	3,000	2,088	2,279	0	-760	-16	8	0	0
J-930-H33	1,661	1,661	810	777	785	785	785	821	2,751	3,000	2,255	2,469	0	-851	-33	8	0	0
J-980-H38	0	0	0	0	0	0	0	614	1,079	1,425	3,000	1,739	0	0	0	0	0	0
J-990	1,344	1,344	693	680	688	688	688	618	1,094	1,449	3,000	1,763	0	-652	-12	8	0	0

Table 4.3
Scenario 2 through 2K
Fire Flow Report and Comparisons

Junction Label	2 Fire Flow Available	2A Fire Flow Available	2B Fire Flow Available	2C Fire Flow Available	2D Fire Flow Available	2E Fire Flow Available	2F Fire Flow Available	2G Fire Flow Available	2H Fire Flow Available	2I Fire Flow Available	2J Fire Flow Available	2K Fire Flow Available	Compare 2A 2	Compare 2B 2A	Compare 2C-2B	Compare 2D-2C	Compare 2E 2D	Compare 2F-2E
J-1000	418	418	332	325	384	384	386	565	919	1,201	1,859	1,464	0	-87	-7	59	0	2
J-1010	0	0	0	0	0	0	387	565	920	1,201	2,228	1,501	0	0	0	0	0	387
J-1020-H40	293	293	267	266	266	388	388	563	914	1,193	2,126	1,492	0	-25	-1	0	122	0
J-1030	0	0	0	0	389	389	389	572	940	1,231	3,000	1,534	0	0	0	389	0	0
J-1040-H41	0	0	0	0	389	389	389	570	933	1,219	3,000	1,521	0	0	0	389	0	0
J-1050	574	574	393	385	389	389	389	562	909	1,189	3,000	1,485	0	-181	-8	5	0	0
J-1060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J-1070	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J-1080	143	465	332	325	384	384	385	561	906	1,075	1,460	1,219	322	-133	-7	59	0	1
J-1090	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J-1100	0	0	0	0	0	0	0	0	0	3,000	0	0	0	0	0	0	0	0
J-1110	0	0	0	0	0	0	0	614	1,079	1,426	3,000	1,739	0	0	0	0	0	0
J-1120	2,020	2,020	1,082	1,082	1,082	1,082	1,082	1,082	2,108	2,943	2,831	3,000	0	-938	0	0	0	0
J-1130	1,716	1,716	782	776	785	785	785	821	2,559	3,000	2,476	2,762	0	-934	-6	8	0	0
J-1140	128	128	0	0	0	0	0	0	0	312	286	520	0	-128	0	0	0	0
J-1150	1,509	1,509	740	744	752	753	753	788	1,906	2,704	3,000	3,000	0	-768	4	8	0	0
J-1160	1,491	1,491	746	744	752	752	752	787	1,899	2,695	3,000	3,000	0	-745	-2	8	0	0
J-1170	330	330	246	241	377	377	377	537	771	891	1,297	1,045	0	-84	-5	136	0	0
J-1180	968	968	684	684	684	684	684	684	879	1,045	1,025	1,269	0	-284	0	0	0	0

Table 4.3
Scenario 2 through 2K
Fire Flow Report and Comparisons

Junction Label	Compare 2G-2F	Compare 2G-2	Compare 2H-2G	Compare 2I-2G	Compare 2J-2G	Compare 2K-2G
J-1-H6	38	-905	1,312	2,131	2,131	2,131
J-10	37	-878	1,285	2,143	2,143	2,143
J-20	36	-790	1,203	2,066	2,179	2,179
J-30	36	-762	1,176	2,021	2,190	2,190
J-40-H8	35	-609	771	1,365	2,282	1,615
J-50	35	-609	771	1,365	2,282	1,615
J-70	67	-427	599	1,060	2,329	1,335
J-80	85	-339	541	946	2,352	1,247
J-90	98	-281	508	885	2,367	1,194
J-100-H9	102	-262	497	867	2,371	1,177
J-110	103	-257	495	862	2,373	1,173
J-120	109	-234	483	841	2,378	1,153
J-130	126	-163	445	779	2,394	1,092
J-140	137	-122	423	743	2,404	1,055
J-150	142	-108	415	730	2,407	1,041
J-160-H11	144	-101	411	724	2,409	1,034
J-170	147	-90	404	713	2,413	1,023
J-180	153	-71	392	694	2,418	1,001
J-190	157	-58	383	681	2,422	987
J-200	159	-54	381	678	2,423	982
J-210	176	18	350	631	2,437	928
J-220	177	49	352	633	2,436	931
J-230	37	-907	1,314	2,133	2,133	2,133
J-240	37	-906	1,314	2,133	2,133	2,133
J-250	37	-904	1,322	2,136	2,136	2,136
J-260	28	-629	752	1,324	2,284	1,572
J-270	-30	-687	577	1,020	2,342	1,308
J-280	181	53	359	644	2,150	944
J-290	181	53	360	646	2,432	947
J-300	179	51	354	636	2,434	935
J-310	175	95	343	619	2,060	917
J-320-H17	174	106	339	614	1,777	910
J-330	173	114	337	611	1,632	906
J-340-H16	169	156	322	532	1,087	699
J-350	166	179	313	444	918	606
J-360	163	199	251	374	797	531
J-380	0	-83	90	327	3,000	489
J-390-H39	179	156	355	636	1,412	936
J-400-H13	179	51	354	636	1,692	935
J-410	179	51	354	470	750	595
J-420	180	52	248	334	544	451
J-430	179	51	160	235	391	336
J-440	69	9	38	94	169	163
J-450-H18	176	96	345	623	1,421	913
J-460-H14	178	123	352	613	998	746
J-470	180	184	113	178	302	266

Table 4.3
Scenario 2 through 2K
Fire Flow Report and Comparisons

Junction Label	Compare 2G-2F	Compare 2G-2	Compare 2H-2G	Compare 2I-2G	Compare 2J-2G	Compare 2K-2G
J-480-H19.20	175	96	345	619	1,105	768
J-490	20	-14	22	94	163	163
J-500	142	-107	276	372	539	499
J-510	16	-49	51	134	179	232
J-520	85	-168	185	284	377	414
J-530	98	-281	326	423	552	551
J-540	68	-148	150	236	298	352
J-550-H7	0	-104	91	181	173	307
J-560	37	-914	1,419	2,146	2,146	2,146
J-570	37	-932	1,516	2,164	1,672	2,080
J-580	37	-937	1,534	2,169	1,660	2,026
J-590	36	-941	1,578	2,173	1,645	1,970
J-600	36	-945	1,636	2,176	1,629	1,932
J-610	0	-113	90	187	126	238
J-620	36	120	1,672	2,180	1,757	2,059
J-630-H1	36	-902	1,742	2,179	1,652	1,937
J-640-H21	36	-798	1,878	2,179	1,277	1,492
J-650	37	-639	1,659	2,121	998	1,171
J-660	176	96	345	622	1,544	919
J-670	179	50	354	636	2,137	936
J-680	36	-805	1,988	2,179	1,374	1,575
J-690	36	-868	1,847	2,179	1,508	1,744
J-700-H2	36	-938	1,544	2,170	1,646	1,996
J-710-H3	37	646	1,267	1,654	1,135	1,359
J-720	36	-940	1,565	2,172	1,657	1,991
J-730-H4	37	720	722	977	680	899
J-740	42	-960	1,263	1,950	1,950	1,950
J-750-H5	36	-927	1,499	2,159	1,890	2,159
J-760-H10	15	79	48	137	181	237
J-770-H12	174	-5	348	628	2,437	925
J-780-H15	58	-28	136	498	2,928	784
J-790	37	-822	1,877	2,178	1,337	1,558
J-800	36	-834	1,878	2,179	1,382	1,612
J-810	36	822	1,902	2,178	1,383	1,608
J-820-H22	36	821	2,049	2,179	1,083	1,296
J-830-H23	36	821	2,105	2,179	1,057	1,260
J-840-H24	36	821	2,179	2,179	1,014	1,215
J-850-H25	36	821	2,179	2,179	985	1,187
J-860-H26	36	822	2,178	2,178	777	982
J-870-H27	36	821	2,179	2,179	610	826
J-900-H30	36	822	2,150	2,178	1,130	1,318
J-910-H31	36	822	2,119	2,178	1,187	1,373
J-920-H32	36	-732	2,054	2,179	1,267	1,458
J-930-H33	36	-840	1,929	2,179	1,434	1,648
J-980-H38	614	614	465	812	2,386	1,125
J-990	-69	-726	476	831	2,382	1,144

Table 4.3
Scenario 2 through 2K
Fire Flow Report and Comparisons

Junction Label	Compare 2G-2F	Compare 2G-2	Compare 2H-2G	Compare 2I-2G	Compare 2J-2G	Compare 2K-2G
J-1000	179	147	354	636	1,294	899
J-1010	179	565	354	636	1,663	935
J-1020-H40	175	271	350	630	1,563	929
J-1030	183	572	368	659	2,428	962
J-1040-H41	180	570	363	650	2,430	951
J-1050	173	-12	347	627	2,438	923
J-1060	0	0	0	0	0	0
J-1070	0	0	0	0	0	0
J-1080	176	418	344	514	899	658
J-1090	0	0	0	0	0	0
J-1100	0	0	0	3,000	0	0
J-1110	614	614	465	812	2,386	1,125
J-1120	0	-938	1,026	1,861	1,749	1,918
J-1130	36	-895	1,738	2,179	1,655	1,941
J-1140	0	-128	0	312	286	520
J-1150	35	-721	1,118	1,917	2,212	2,212
J-1160	35	-704	1,112	1,908	2,213	2,213
J-1170	161	208	234	354	760	508
J-1180	0	-284	195	361	341	585

Table 4.4
Scenario 2 through 2K
Junction Report

Junction Label	Elev.	Zone	Pressure 2-2H	Pressure 2I	Pressure 2J	Pressure 2K	2 Demand	2A Demand	2B Demand	2C Demand	2D Demand	2E Demand	2F Demand	2G Demand	2H Demand	2I Demand	2J Demand	2K Demand
J-1-H6	1,188	1-EX	55.5	73.1	71.4	90.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-10	1,187	1-EX	55.9	73.6	72.0	90.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-20	1,181	1-EX	58.3	76.2	74.9	92.9	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
J-30	1,178	1-EX	59.5	77.5	76.4	94.1	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-40-H8	1,164	1-EX	65.1	83.4	84.8	99.7	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
J-50	1,161	1-EX	66.4	84.7	86.1	101.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-70	1,168	1-EX	63.2	81.5	84.0	97.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-80	1,165	1-EX	64.5	82.7	86.0	99.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-90	1,165	1-EX	64.4	82.7	86.5	99.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-100-H9	1,167	1-EX	63.5	81.8	85.9	98.1	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-110	1,167	1-EX	63.5	81.8	85.9	98.1	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-120	1,167	1-EX	63.5	81.7	86.2	98.1	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
J-130	1,179	1-EX	58.2	76.5	82.1	92.8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
J-140	1,177	1-EX	59.1	77.3	83.7	93.6	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
J-150	1,177	1-EX	59.0	77.3	84.0	93.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-160-H11	1,178	1-EX	58.6	76.9	83.7	93.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-170	1,178	1-EX	58.6	76.9	84.0	93.2	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
J-180	1,178	1-EX	58.6	76.8	84.6	93.1	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
J-190	1,178	1-EX	58.6	76.8	85.1	93.1	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
J-200	1,178	1-EX	58.6	76.8	85.2	93.1	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2	27.2
J-210	1,174	1-EX	60.3	78.5	89.2	94.8	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
J-220	1,169	1-EX	62.4	80.7	91.3	97.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
J-230	1,195	1-EX	52.5	70.1	68.4	88.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-240	1,195	1-EX	52.5	70.1	68.4	88.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-250	1,188	1-EX	55.5	73.2	71.4	90.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-260	1,162	1-EX	66.0	84.3	85.7	100.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-270	1,155	1-EX	68.9	87.2	90.2	103.5	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
J-280	1,147	1-EX	72.0	90.2	100.0	106.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-290	1,163	1-EX	65.0	83.3	93.1	99.6	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
J-300	1,167	1-EX	63.3	81.6	91.9	97.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-310	1,175	1-EX	59.8	78.1	88.7	94.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-320-H17	1,177	1-EX	59.0	77.2	88.0	93.5	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
J-330	1,179	1-EX	58.1	76.4	87.1	92.7	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
J-340-H16	1,189	1-EX	53.8	72.0	83.2	88.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
J-350	1,192	1-EX	52.5	70.7	82.2	87.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-360	1,195	1-EX	51.2	69.4	81.3	85.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-380	1,267	1-EX	20.0	38.3	59.6	54.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-390-H39	1,138	1-EX	75.8	94.1	104.3	110.4	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
J-400-H13	1,150	1-EX	70.6	88.9	99.2	105.2	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
J-410	1,158	1-EX	67.2	85.5	95.7	101.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-420	1,161	1-EX	65.9	84.2	94.4	100.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-430	1,154	1-EX	68.9	87.2	97.5	103.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-440	1,150	1-EX	70.6	88.9	99.2	105.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-450-H18	1,166	1-EX	63.7	82.0	92.6	98.3	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-460-H14	1,154	1-EX	68.9	87.2	97.5	103.5	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
J-470	1,142	1-EX	74.1	92.4	102.7	108.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6

Table 4.4
Scenario 2 through 2K
Junction Report

Junction Label	Elev.	Zone	Pressure 2-2H	Pressure 2I	Pressure 2J	Pressure 2K	2 Demand	2A Demand	2B Demand	2C Demand	2D Demand	2E Demand	2F Demand	2G Demand	2H Demand	2I Demand	2J Demand	2K Demand
J-480-H19.20	1,170	1-EX	62.0	80.3	90.9	96.6	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
J-490	1,224	1-EX	38.6	56.9	68.4	73.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
J-500	1,166	1-EX	63.8	82.1	88.7	98.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
J-510	1,198	1-EX	50.0	68.3	72.7	84.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-520	1,174	1-EX	60.6	78.8	82.1	95.1	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
J-530	1,160	1-EX	66.6	84.8	88.7	101.1	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
J-540	1,161	1-EX	66.3	84.5	87.0	100.8	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
J-550-H7	1,190	1-EX	54.3	72.3	71.2	88.9	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
J-560	1,191	1-EX	54.0	72.4	70.0	88.6	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
J-570	1,181	1-EX	57.8	78.3	74.1	92.4	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2
J-580	1,175	1-EX	60.2	81.4	76.7	94.8	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
J-590	1,170	1-EX	62.3	84.4	78.8	96.8	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
J-600	1,169	1-EX	62.6	85.6	79.2	97.2	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-610	1,178	1-EX	58.7	81.7	75.3	93.3	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-620	1,159	1-EX	66.8	90.5	83.6	101.4	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-630-H1	1,165	1-EX	64.2	88.2	80.9	98.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-640-H21	1,171	1-EX	61.6	86.8	78.3	96.2	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-650	1,150	1-EX	69.6	95.8	86.3	104.2	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-660	1,167	1-EX	63.3	81.5	92.2	97.9	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
J-670	1,162	1-EX	65.5	83.7	94.0	100.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
J-680	1,149	1-EX	70.4	95.9	87.0	104.9	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
J-690	1,158	1-EX	67.0	91.5	83.6	101.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-700-H2	1,174	1-EX	60.6	82.1	77.1	95.2	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
J-710-H3	1,177	1-EX	59.3	81.2	75.8	93.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
J-720	1,170	1-EX	62.3	84.2	78.8	96.9	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
J-730-H4	1,183	1-EX	56.7	78.6	73.2	91.3	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-740	1,209	1-EX	47.8	63.2	61.7	78.3	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0
J-750-H5	1,178	1-EX	59.3	78.9	75.5	93.9	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
J-760-H10	1,208	1-EX	45.7	64.0	68.4	80.3	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
J-770-H12	1,177	1-EX	59.0	77.2	88.0	93.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
J-780-H15	1,264	1-EX	21.3	39.6	58.0	55.9	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
J-790	1,169	1-EX	62.5	87.7	79.2	97.1	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
J-800	1,170	1-EX	62.0	87.3	78.7	96.6	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0	-600.0
J-810	1,166	1-EX	63.6	89.0	80.3	98.2	0.0	0.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0
J-820-H22	1,173	1-EX	59.6	86.2	76.3	94.2	0.0	0.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0
J-830-H23	1,166	1-EX	62.3	89.7	79.0	96.9	0.0	0.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0
J-840-H24	1,165	1-EX	62.6	90.9	79.3	97.2	0.0	0.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0
J-850-H25	1,166	1-EX	62.1	91.7	78.8	96.7	0.0	0.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0
J-860-H26	1,169	1-EX	60.8	95.8	77.5	95.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-870-H27	1,174	1-EX	58.7	98.5	75.3	93.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-900-H30	1,153	1-EX	67.8	95.4	84.5	102.4	0.0	0.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0
J-910-H31	1,149	1-EX	69.6	96.7	86.3	104.2	0.0	0.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0	134.0
J-920-H32	1,150	1-EX	69.6	95.8	86.3	104.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-930-H33	1,152	1-EX	69.3	94.4	86.0	103.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-980-H38	1,155	1-EX	68.8	87.0	92.7	103.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-990	1,146	1-EX	72.7	90.9	96.2	107.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.4
Scenario 2 through 2K
Junction Report

Junction Label	Elev.	Zone	Pressure 2-2H	Pressure 2I	Pressure 2J	Pressure 2K	2 Demand	2A Demand	2B Demand	2C Demand	2D Demand	2E Demand	2F Demand	2G Demand	2H Demand	2I Demand	2J Demand	2K Demand
J-1000	1,153	1-EX	69.3	87.6	97.9	103.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1010	1,145	1-EX	72.8	91.1	101.3	107.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1020-H40	1,165	1-EX	64.2	82.4	93.1	98.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1030	1,143	1-EX	73.7	92.0	101.6	108.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1040-H41	1,165	1-EX	64.2	82.5	92.2	98.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1050	1,178	1-EX	58.6	76.8	87.6	93.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1060	1,167	1-EX	63.5	81.8	85.9	98.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1070	1,177	1-EX	59.0	77.3	84.2	93.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1080	1,172	1-EX	61.1	79.4	90.0	95.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1090	1,170	1-EX	62.0	80.3	90.9	96.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1100	1,176	1-EX	0.0	97.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1110	1,151	1-EX	70.5	88.8	94.4	105.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1120	1,235	1-EX	36.6	48.5	47.3	60.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1130	1,165	1-EX	64.2	88.2	80.9	98.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1140	1,280	1-EX	17.1	29.0	27.8	40.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1150	1,175	1-EX	60.6	78.9	78.0	95.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1160	1,175	1-EX	60.6	78.9	78.0	95.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1170	1,195	1-EX	51.2	69.4	81.5	85.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J-1180	1,235	1-EX	0.0	48.5	47.3	60.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.5
Scenario 2 through 2K
Pipe Report

Pipe Label	Start Node	Stop Node	Diameter	Material	Hazen-Williams C Factor	Scaled Length	Zone	Pipe Open?
P-10	J-1-H6	J-10	8 IN	Cast iron	130	50'	1-EX	TRUE
P-20	J-10	J-20	8 IN	Cast Iron	130	180'	1-EX	TRUE
P-30	J-20	J-30	8 IN	Cast Iron	130	73'	1-EX	TRUE
P-50	J-40-H8	J-50	8 IN	Cast Iron	130	74'	1-EX	TRUE
P-100	J-90	J-100-H9	8 IN	Cast Iron	130	71'	1-EX	TRUE
P-110	J-100-H9	J-110	8 IN	Cast iron	130	21'	1-EX	TRUE
P-120	J-110	J-120	8 IN	Cast Iron	130	94'	1-EX	TRUE
P-130	J-120	J-130	8 IN	Cast Iron	130	341'	1-EX	TRUE
P-140	J-130	J-140	8 IN	Cast Iron	130	240'	1-EX	TRUE
P-150	J-140	J-150	8 IN	Cast Iron	130	100'	1-EX	TRUE
P-160	J-150	J-160-H11	8 IN	Cast Iron	130	52'	1-EX	TRUE
P-170	J-160-H11	J-170	8 IN	Cast Iron	130	90'	1-EX	TRUE
P-180	J-170	J-180	8 IN	Cast Iron	130	173'	1-EX	TRUE
P-190	J-180	J-190	8 IN	Cast Iron	130	125'	1-EX	TRUE
P-200	J-190	J-200	8 IN	Cast Iron	130	38'	1-EX	TRUE
P-210	J-1060	J-100-H9	4 IN	Cast iron	130	60'	1-EX	TRUE
P-220	J-210	J-220	8 IN	Cast iron	130	481'	1-EX	TRUE
P-230	J-1-H6	J-250	8 IN	Cast iron	130	41'	1-EX	TRUE
P-240	J-250	J-560	8 IN	Cast iron	130	339'	1-EX	TRUE
P-250	H-9	J-1060	4 IN	Cast iron	130	36'	1-EX	TRUE
P-260	J-570	J-580	8 IN	Cast iron	130	313'	1-EX	TRUE
P-280	J-590	J-600	8 IN	Cast iron	130	378'	1-EX	TRUE
P-290	J-600	J-630-H1	8 IN	Cast iron	130	521'	1-EX	TRUE
P-310	J-240	J-250	6 IN	Cast iron	130	103'	1-EX	TRUE
P-330	J-260	J-270	6 IN	Cast iron	130	195'	1-EX	TRUE
P-350	J-280	J-290	6 IN	Cast iron	130	212'	1-EX	TRUE
P-360	J-290	J-300	6 IN	Cast iron	130	353'	1-EX	TRUE
P-370	J-300	J-220	6 IN	Cast iron	130	143'	1-EX	TRUE
P-380	J-220	J-310	6 IN	Cast iron	130	287'	1-EX	TRUE
P-390	J-310	J-320-H17	6 IN	Cast iron	130	103'	1-EX	TRUE
P-400	J-320-H17	J-330	6 IN	Cast iron	130	69'	1-EX	TRUE
P-410	J-330	J-340-H16	6 IN	Cast iron	130	507'	1-EX	TRUE
P-420	J-310	J-660	6 IN	Cast iron	130	289'	1-EX	TRUE
P-430	J-660	J-450-H18	6 IN	Cast iron	130	118'	1-EX	TRUE
P-440	J-450-H18	J-480-H19.20	6 IN	Cast iron	130	177'	1-EX	TRUE
P-450	J-610	J-600	4 IN	Cast iron	130	434'	1-EX	TRUE
P-460	J-600	J-620	4 IN	Cast iron	130	404'	1-EX	TRUE
P-470	J-30	J-550-H7	4 IN	Cast iron	130	307'	1-EX	TRUE
P-480	J-70	J-540	4 IN	Cast iron	130	236'	1-EX	TRUE
P-490	J-80	J-520	4 IN	Cast iron	130	190'	1-EX	TRUE
P-500	J-90	J-530	4 IN	Cast iron	130	159'	1-EX	TRUE
P-510	J-120	J-510	4 IN	Cast iron	130	501'	1-EX	TRUE
P-520	J-150	J-500	4 IN	Cast iron	130	171'	1-EX	TRUE
P-530	J-280	J-390-H39	4 IN	Cast iron	130	893'	1-EX	TRUE
P-540	J-300	J-670	6 IN	Cast iron	130	216'	1-EX	TRUE
P-550	J-670	J-400-H13	6 IN	Cast iron	130	477'	1-EX	TRUE

Table 4.5 Table
Scenario 2 through 2K
Pipe Report

Pipe Label	Start Node	Stop Node	Diameter	Material	Hazen-Williams C Factor	Scaled Length	Zone	Pipe Open?
P-560	J-670	J-410	4 IN	Cast iron	130	122'	1-EX	TRUE
P-570	J-410	J-430	4 IN	Cast iron	130	151'	1-EX	TRUE
P-580	J-410	J-420	4 IN	Cast iron	130	60'	1-EX	TRUE
P-590	J-450-H18	J-460-H14	4 IN	Cast iron	130	618'	1-EX	TRUE
P-610	J-340-H16	J-350	4 IN	Cast iron	130	53'	1-EX	TRUE
P-620	J-350	J-360	4 IN	Cast iron	130	62'	1-EX	TRUE
P-630	J-360	J-1170	4 IN	Cast iron	130	33'	1-EX	TRUE
P-650	J-350	J-490	4 IN	Cast iron	130	1164'	1-EX	TRUE
P-690	J-430	J-440	3 IN	Cast iron	130	105'	1-EX	TRUE
P-700	J-630-H1	H-1	6 IN	Cast iron	130	65'	1-EX	TRUE
P-710	J-580	J-700-H2	8 IN	Cast iron	130	129'	1-EX	TRUE
P-720	H-2	J-700-H2	6 IN	Cast iron	130	52'	1-EX	TRUE
P-730	J-700-H2	J-720	8 IN	Cast iron	130	216'	1-EX	TRUE
P-740	J-720	J-590	8 IN	Cast iron	130	104'	1-EX	TRUE
P-750	J-710-H3	J-720	6 IN	PVC	150	167'	1-EX	TRUE
P-760	H-3	J-710-H3	6 IN	PVC	150	61'	1-EX	TRUE
P-770	J-730-H4	J-710-H3	6 IN	PVC	150	265'	1-EX	TRUE
P-780	H-4	J-730-H4	6 IN	PVC	150	60'	1-EX	TRUE
P-790	J-560	J-750-H5	8 IN	Cast iron	130	577'	1-EX	TRUE
P-800	J-750-H5	J-570	8 IN	Cast iron	130	419'	1-EX	TRUE
P-810	H-5	J-750-H5	6 IN	Cast iron	130	54'	1-EX	TRUE
P-820	H-6	J-1-H6	6 IN	Cast iron	130	49'	1-EX	TRUE
P-830	H-7	J-550-H7	4 IN	Cast iron	130	41'	1-EX	TRUE
P-840	H-8	J-40-H8	6 IN	Cast iron	130	42'	1-EX	TRUE
P-860	J-510	J-760-H10	6 IN	PVC	150	168'	1-EX	TRUE
P-870	H-10	J-760-H10	6 IN	Ductile Iron	130	64'	1-EX	TRUE
P-900	J-770-H12	J-210	8 IN	Cast Iron	130	297'	1-EX	TRUE
P-910	H-12	J-770-H12	6 IN	Cast iron	130	72'	1-EX	TRUE
P-920	H-13	J-400-H13	6 IN	Cast iron	130	63'	1-EX	TRUE
P-930	H-14	J-460-H14	4 IN	Cast iron	130	69'	1-EX	TRUE
P-940	H-18	J-450-H18	6 IN	Cast iron	130	56'	1-EX	TRUE
P-970	H-17	J-320-H17	6 IN	Cast iron	130	58'	1-EX	TRUE
P-980	H-16	J-340-H16	6 IN	Cast iron	130	58'	1-EX	TRUE
P-990	J-1170	J-780-H15	4 IN	Cast iron	130	1018'	1-EX	TRUE
P-1000	J-780-H15	J-380	4 IN	Cast iron	130	296'	1-EX	TRUE
P-1010	H-15	J-780-H15	4 IN	Cast iron	130	60'	1-EX	TRUE
P-1020	J-240	J-230	8 IN	Cast iron	130	42'	1-EX	TRUE
P-1030	J-230	J-1-H6	8 IN	Cast iron	130	102'	1-EX	TRUE
P-1040	J-260	J-40-H8	6 IN	Cast iron	130	52'	1-EX	TRUE
P-1040	Reservoir 1	J-1120	8 IN	Cast Iron	130	1038'	1-EX	TRUE
P-1050	J-1120	J-740	8 IN	Cast Iron	130	313'	1-EX	TRUE
P-1060	J-740	J-1-H6	8 IN	Cast Iron	130	267'	1-EX	TRUE
P-1080	J-790	J-640-H21	8 IN	Cast iron	130	52'	1-EX	TRUE
P-1090	J-630-H1	J-800	8 IN	Cast iron	130	319'	1-EX	TRUE
P-1100	J-800	J-790	8 IN	Cast iron	130	66'	1-EX	TRUE
P-1110	J-680	J-920-H32	8 IN	Cast iron	130	318'	1-EX	TRUE

Table 4.5
Scenario 2 through 2K
Pipe Report

Pipe Label	Start Node	Stop Node	Diameter	Material	Hazen-Williams C Factor	Scaled Length	Zone	Pipe Open?
P-1120	J-920-H32	J-650	8 IN	Cast iron	130	487'	1-EX	TRUE
P-1130	J-690	J-930-H33	8 IN	Cast iron	130	238'	1-EX	TRUE
P-1140	J-930-H33	J-680	8 IN	Cast iron	130	214'	1-EX	TRUE
P-1150	J-270	J-990	6 IN	Cast iron	130	271'	1-EX	TRUE
P-1160	J-800	J-810	8 IN	PVC	150	71'	1-EX	TRUE
P-1170	J-810	J-820-H22	8 IN	PVC	150	628'	1-EX	TRUE
P-1180	J-820-H22	J-830-H23	8 IN	PVC	150	500'	1-EX	TRUE
P-1190	J-830-H23	J-840-H24	8 IN	PVC	150	500'	1-EX	TRUE
P-1200	J-840-H24	J-850-H25	8 IN	PVC	150	500'	1-EX	TRUE
P-1210	J-850-H25	J-860-H26	8 IN	PVC	150	500'	1-EX	TRUE
P-1220	J-860-H26	J-870-H27	8 IN	PVC	150	443'	1-EX	TRUE
P-1230	J-870-H27	J-1100	8 IN	PVC	150	190'	1-EX	(N/A)
P-1240	J-1100	T2-Option 2	12 IN	PVC	150	890'	1-EX	(N/A)
P-1250	J-850-H25	J-900-H30	8 IN	PVC	150	768'	1-EX	TRUE
P-1260	J-900-H30	J-910-H31	8 IN	PVC	150	216'	1-EX	TRUE
P-1270	J-910-H31	J-920-H32	8 IN	PVC	150	524'	1-EX	TRUE
P-1330	J-980-H38	J-990	8 IN	PVC	150	214'	1-EX	TRUE
P-1350	J-460-H14	J-1000	4 IN	Cast iron	130	107'	1-EX	TRUE
P-1360	J-1000	J-470	4 IN	Cast iron	130	321'	1-EX	TRUE
P-1370	J-390-H39	J-1010	6 IN	PVC	150	390'	1-EX	TRUE
P-1380	J-1010	J-1000	6 IN	PVC	150	459'	1-EX	TRUE
P-1390	J-1010	J-400-H13	6 IN	PVC	150	193'	1-EX	TRUE
P-1400	J-210	J-1020-H40	6 IN	PVC	150	423'	1-EX	TRUE
P-1430	J-200	J-1050	8 IN	Cast Iron	130	592'	1-EX	TRUE
P-1440	J-1050	J-770-H12	8 IN	Cast Iron	130	78'	1-EX	TRUE
P-1450	J-1030	J-1040-H41	6 IN	PVC	150	94'	1-EX	TRUE
P-1460	J-1040-H41	J-1050	6 IN	PVC	150	422'	1-EX	TRUE
P-1470	J-1050	J-780-H15	6 IN	PVC	150	962'	1-EX	TRUE
P-1480	T2-Option 1	J-870-H27	12 IN	PVC	150	484'	1-EX	(N/A)
P-1490	H-11	J-1070	6 IN	PVC	150	41'	1-EX	TRUE
P-1500	J-1070	J-160-H11	6 IN	PVC	150	66'	1-EX	TRUE
P-1510	J-480-H19.20	J-1080	6 IN	PVC	150	245'	1-EX	TRUE
P-1520	J-1080	H-20	6 IN	PVC	150	62'	1-EX	TRUE
P-1530	H-19	J-1090	6 IN	PVC	150	49'	1-EX	TRUE
P-1540	J-1090	J-480-H19.20	6 IN	PVC	150	66'	1-EX	TRUE
P-1550	J-380	T2-Option 3	12 IN	PVC	150	231'	1-EX	(N/A)
P-1560	J-1110	J-50	8 IN	PVC	150	136'	1-EX	FALSE
P-1570	J-630-H1	J-1130	8 IN	Cast iron	130	23'	1-EX	TRUE
P-1580	J-1130	J-690	8 IN	Cast iron	130	240'	1-EX	TRUE
P-1590	J-1130	J-620	8 IN	PVC	150	138'	1-EX	TRUE
P-1600	J-250	J-1150	6 IN	Cast iron	130	482'	1-EX	TRUE
P-1610	J-1150	J-260	6 IN	Cast iron	130	521'	1-EX	TRUE
P-1620	J-620	J-1150	8 IN	PVC	150	2467'	1-EX	TRUE
P-1630	J-30	J-1160	8 IN	Cast Iron	130	179'	1-EX	TRUE
P-1640	J-1160	J-40-H8	8 IN	Cast Iron	130	521'	1-EX	TRUE
P-1650	J-1150	J-1160	8 IN	PVC	150	46'	1-EX	TRUE

Table 4.5
Scenario 2 through 2K
Pipe Report

Pipe Label	Start Node	Stop Node	Diameter	Material	Hazen-Williams C Factor	Scaled Length	Zone	Pipe Open?
P-1660	J-1110	J-980-H38	8 IN	PVC	150	109'	1-EX	TRUE
P-1670	J-980-H38	J-1030	8 IN	PVC	150	2459'	1-EX	TRUE
P-1680	J-1030	J-290	8 IN	PVC	150	654'	1-EX	TRUE
P-1690	J-40-H8	J-70	8 IN	PVC	150	524'	1-EX	TRUE
P-1700	J-70	J-80	8 IN	PVC	150	341'	1-EX	TRUE
P-1710	J-80	J-90	8 IN	PVC	150	265'	1-EX	TRUE
P-1720	J-1140	J-1180	4 IN	PVC	150	186'	1-EX	TRUE
P-1730	J-1180	J-1120	4 IN	PVC	150	72'	1-EX	TRUE

Table 4.6
Scenario 2 through 2K
Tank Report

Label	Zone	Base Elevation	Minimum Elevation	Initial Elevation	Maximum Elevation	Outflow gpm	Hydraulic Grade
TANK SUMMARY 2							
Reservoir 1	1-EX	1,314.33	1,314.33	1,320.33	1,326.33	-767.73	1320.33
T2-Option 1	1-EX	1,314.33	1,314.33	1,320.33	1,326.33	(N/A)	(N/A)
T2-Option 2	1-EX	1,270.00	1,373.00	1,405.50	1,405.50	(N/A)	(N/A)
T2-Option 3	1-EX	1,270.00	1,373.00	1,405.50	1,405.50	(N/A)	(N/A)
T2-Option 4	1-EX	0.00	0.00	1,440.50	0.00	(N/A)	(N/A)
TANK SUMMARY 2A							
Reservoir 1	1-EX	1,314	1,314	1320.33	1326.33	-767.73	1320.33
T2-Option 1	1-EX	1,314	1,314	1320.33	1326.33	(N/A)	(N/A)
T2-Option 2	1-EX	1,270	1,373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1,270	1,373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2B							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	170.28	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	(N/A)	(N/A)
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2C							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	170.28	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	(N/A)	(N/A)
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2D							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	170.25	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	(N/A)	(N/A)
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2E							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	170.25	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	(N/A)	(N/A)
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2F							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	170.25	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	(N/A)	(N/A)
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)

Table 4.6 Table 4
Scenario 2 through 2K
Tank Report

Label	Zone	Base Elevation	Minimum Elevation	Initial Elevation	Maximum Elevation	Outflow gpm	Hydraulic Grade
TANK SUMMARY 2G							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	170.25	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	0	1320.33
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2H							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	-158.63	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	328.88	1320.33
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2I							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	-1203.91	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	0	1320.33
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	1374.18	1405.5
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2J							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	-1135.69	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	(N/A)	(N/A)
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	1305.96	1405.5
T2-Option 4	1-EX	0	0	1440.5	0	(N/A)	(N/A)
TANK SUMMARY 2K							
Reservoir 1	1-EX	1314.33	1314.33	1320.33	1326.33	-1750.48	1320.33
T2-Option 1	1-EX	1314.33	1314.33	1320.33	1326.33	0	1320.33
T2-Option 2	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 3	1-EX	1270	1373	1405.5	1405.5	(N/A)	(N/A)
T2-Option 4	1-EX	1300	1408	1440.5	1440.5	1920.75	1440.5

undersized mains, creating new system loops and increasing storage capacity. Pressures in the water system vary at all of the junctions based on elevation, hydraulics and system component location.

The new reservoir was set at the same elevation as the existing reservoir in order to avoid separate pressure zones in a relatively small water system. This option will supply increased capacity and reliability; however will not increase system pressures for a select few facilities that are higher in elevation. The new tank options were set at higher elevations to address the low pressure areas within the main cantonment areas. The SIRE and ASP facilities are at a large distance away and have approximately 100 feet of elevation difference to the existing facilities in the main cantonment area. They are not practical to be connected to the water system.

The recommended water system improvements will be prioritized based upon the level of benefit provided to the overall water system reliability and the associated construction costs.

CHAPTER FIVE

RECOMMENDED WATER SYSTEM IMPROVEMENTS

Water Supply & Firm Capacity

Camp Grayling does not currently maintain daily records on the well production or water consumption within its water system. It is assumed that based on the fact that only one production well is in service at any given time (Well 1 and 2 are alternately used, not simultaneously), that the combination of ground water production from one well and the reservoir storage are able to meet the maximum daily use. Even during full capacity of the Camp during summer training, the Camp's firm capacity of 600 gpm (estimated) (864,000 gpd) has provided adequate supply to the storage reservoir and distribution system. Metering and recording maximum daily demands in the future would help to monitor the status of the system, its ability to provide water during peak times and the percent of firm capacity utilized.

When the demand regularly exceeds 90 percent of the system's firm capacity and occasionally exceeds it, it is time to incorporate tandem use of the groundwater supply wells. In general, the Camp's water production should be closely monitored and as the Camp continues to grow in the future, the monitoring will become increasingly important. Due to known high future demands, the modeling has been completed with both wells on-line and in service.

Water Storage & Fire Flow Capacity

As previously discussed, the 500,000-gallon storage reservoir currently provides enough storage capacity in combination with the water production wells to supply the Camp's needs. Under a maximum daily demand of two times the assumed average daily demand, the Camp's water system currently can provide 2,178 gallons per minute for three-hour duration (as shown in Chapter 2). This is a decent fire flow for a water system, but below standard for commercial and industrial facilities. The additional production of Well #2 added to the system will help increase this fire flow capacity. However, due to constraints within the distribution system, the largest available fire flow across the entire water system currently is 1,398 gpm, with many areas below 1,000 gpm and some areas having almost negligible available fire flow. With the current water system, the Camp cannot adequately provide the fire flow capacity and duration necessary for all of the facilities. The Camp currently meets the required fire flow capacity and duration necessary for some of the residential-type facilities. Camp Grayling personnel have indicated that 1,000 gpm of available fire flow is sufficient for the vast majority of the facilities. While the majority of facilities are considered non-combustible and non-hazardous, there are a few facilities that would be considered something other than residential in nature. The following is a list of these facilities:

- P.O.L. Building 570
- A.S.P. Building 950
- Officer's Club Building 311
- LSF Building 560
- Camp Commander's Building 117

- Headquarters Building 103

These facilities are atypical and should be reviewed independently during future infrastructure design.

With the completion of the Camp's new water model, the proposed improvement scenarios indicate that the Camp will be able to obtain much higher available fire flows in most locations. The computer model assumes that the system can draw a fire flow until the minimum system residual pressure reaches 20 psi. In some cases, due to a high elevation relative to the water reservoir, some junctions (J-780-H15 & J-380) cannot meet the minimum requirements and are omitted from the fire flow computations (except for scenarios H through K).

Increasing the Camp's current capacity of water storage should be monitored over time, however currently it should not be the highest priority for the water system.

Water Distribution & System Maintenance

The Camp's distribution system currently is the biggest obstacle for the efficiency, reliability and capacity of the water system. There are many maintenance and recommended new construction work items identified within this Water System Study and Master Plan that will help make substantial improvements to the distribution system. The Camp should implement a program to replace smaller and older mains during other Camp construction projects and/or for future developments to help improve the water system and minimize the cost impact to the general funds.

The distribution system currently is limiting the capacity of the water system. There is more storage available than the system can flow to the hydrants. Numerous hydrants are located on very small diameter water lines and are ineffective for fire flow. According to the recently updated Camp Grayling water system maps, there are four existing hydrants (3, 4, 19 & 20) on 2" water lines, two existing hydrants (10 & 11) on 3" water lines and five existing hydrants (7, 9, 14, 15 & 16) on 4" water lines. Of the 20 existing hydrants, only five are of recent construction. The improvements shown in the modeling indicate that a significant improvement in available fire flow is possible with relatively small changes to the water system distribution system. Generally, the 8" transmission mains are adequate for the current size of the system; the limitations are within the 2" to 6" water lines that make up the water distribution system.

There are many key items to consider that will upgrade the distribution system's strength and reliability. All of these items will help the Camp's staff maintain the highest level of capacity, pressure, quality, redundancy and reliability for the water system:

1. Maintain annual inspections of key components with water system including the water reservoir, wells, hydrants, valves and service connections.

2. Maintain annual (minimum) or semi-annual hydrant flushing.

3. Maintain annual (minimum) or semi-annual valve turning program.

4. Maintain regular well production records: Maximum Daily, Monthly, Annual Yield

5. Install new high-capacity (fire flow) water meter on the 8" transmission main downhill of Well No. 1 (Bldg. 410) to help determine system demands.

6. Install new hydrants to improve hydrant spacing for fire-fighting capabilities. Maximum spacing should be 500' or less based upon available hose length from the fire department. The spacing, the offset from roadways, the proximity to facilities and the hydrant specifications should be determined by the Camp Grayling Facility Engineering in conjunction with the Post Fire Department.

7. Install a metered hydrant to track major water usage for construction and training use.

8. Install replacement lines for shallow water services and mains.

9. Install new projects to improve system looping, whenever possible.

10. Reduce the numbers and lengths of dead-end mains. Provide hydrants or blow-off valves at each dead-end for the flushing program and water quality.

11. Replace old hydrants.

12. Replace small diameter hydrant leads (smaller than 6" diameter) back to the transmission main.

13. Replace smaller diameter and older water mains whenever possible. These have the most potential of leaking, breaking and reducing the available flow and pressure. Concentrated areas of smaller diameter mains should be eliminated, or surrounded by a larger diameter loop. Smaller distribution mains that are between large diameter transmission mains should be replaced to eliminate bottlenecks. Consider using 6" diameter pipe as a minimum for all new water main installation.

14. Install new isolation valves. Typically, maximum spacing of 800 feet and install one less valve than the number of water mains intersecting at any junction (depends on the spacing of junctions).

15. Install individual services and not clustered services that rely on a single connection to the main.

16. Complete a comprehensive review of system controls communicating between wells, reservoir, pump stations and the DPW facility. Expand the water system SCADA equipment to assist in monitoring the system. Include SCADA equipment within future infrastructure expenditures.

17. Complete Acoustic Leak Detection Survey every 2-3 years.

Many of the items listed above are general recommendations in nature, and are not hydraulically modeled.

Flushing Program

A flushing program is intended to be a systematic method to isolate and flush portions of the water system in order to improve the quality of the water distributed throughout the entire system. Regular flushing of the water distribution system will help to improve aesthetic water quality, will help monitor water treatment residuals throughout the system, will improve the operation and maintenance of fire hydrants and valves, and can improve the systems hydraulic performance.

Unidirectional flushing of the water system is a systematic method of isolating and flushing predetermined sections of the system starting from the water source and continuing to the outer limits of the distribution system. Hydrants and valves are opened and closed in a planned pattern in order to pull clean water from the source during the directional flushing of that section. The flushing operations should start with the large diameter transmission mains and finish with the small distribution mains. Flushing operations should also start with a cleaned section and work into the next section, continuously flushing away from the water source.

The flushing operations should obtain a minimum flow velocity of 5 to 6 feet per second; however the relative difference between the normal flow velocity and the flushing velocity is the critical factor. Matching the normal flow velocity during flushing will not clean out the settled particulates and will not produce the desired results. High flushing velocities are harder to obtain in large diameter water mains. Flushing velocity is the best indication of the effectiveness of the flushing operations. The hydrants that are used to flush the system should have free discharge during the flushing operations. The flushing must have duration long enough to produce clean water at the flowed hydrant. The flushing frequency should be determined based on experience once the flushing program has been implemented. Sensitive water users within the system should be considered when flushing operations are done. Medical facilities, laundry facilities, living quarters and food preparing facilities are examples of sensitive users. All efforts should be made to minimize the impact on these types of users.

Flushing operations should be aware of the following items:

- Dead-end mains: These valves/hydrants should be flushed regularly regardless of whether they are utilized in the sectional flushing of the overall system, for operational and water quality reasons.

- Large pipes w/small demands: These water mains should be flushed if normal demands are low (seasonal) in order to have water turnover.

- Status of water system valves: Intentionally closed valves and/or buried valves should be noted.

- Aged water mains, hydrants and valves: The flushing operations should be done without putting aged materials at risk of failure due to higher pressures during flushing. Notes should be taken of these locations in order to put them higher on the priority list for repair or replacement.

- Best flushing times: If possible, the flushing operations should be done during low demand times with a full water reservoir. This will allow the flushing operations to have higher than average pressures and the increased flow velocities required to properly flush the water system.

- Residual pressures: The water crew should note residual pressures during the flushing operations and avoid flushing where low residuals exist or are created by the flushing.

In addition to a regular flushing program, there are numerous items that can be reviewed and improved for locating and using the system hydrants. The hydrants can be color-coded by available fire flow. The specifications for hydrants and valves should be standardized for the whole water system to facilitate Fire Department use. Hydrant flags could be added to the hydrants to make them more visible and easier to locate during the winter. In the interim until hydrants can be replaced, Storz pumping connectors could be added to all existing hydrants to provide a universal connection for fire hoses. The hydrant locations and spacing should be reviewed. Hydrants should be easily accessible by the Fire Department; typically located adjacent to roadways or in open space with typical 500-foot spacing.

Prioritized Recommendations

Based on an analysis of the updated Camp's water model, the following Table 5.1: Master Plan Priorities presents a prioritized list of the recommended improvements to the Camp Grayling water system with the associated construction cost opinions. The ranking of the priorities is based on several factors, including types of benefits to the system, location and number of user benefits, system reliability, redundancy, available fire flow and cost. The associated cost includes the design and construction engineering as well as the construction cost with a 10% construction contingency.

There are twelve main scenarios that were evaluated for the water system, and numerous minor recommendations for improvements. The twelve scenarios previously listed are A through L, which are prioritized in the following:

Table 5.1
Master Plan Priorities

Priority No.	Scenario No.	Priority Descriptions – See Figure 5.1 Master Plan Priorities	Cost Opinion
1	2B	**Construct the 8" 600 Block Loop** for the proposed new construction between 8th and 10th Streets and Howe Road & Soldiers Drive. Utilize the existing 8" main on 8th Street. Do not use the 6" existing main as a connection point on Howe Road near Building 552, but add a new 8" connection to the existing 8" main.	$415,000
2	2C	**Construct the 8" Howe Road Loop**, a new 8" diameter transmission water main from 8th Street to 4th Street. This will add a second source from the existing reservoir to the new 600 Block facilities for system redundancy and reliability. This will not make any significant improvements to fire flow, only to insure continuous service. This will be especially important until such time as a second reservoir is constructed.	$227,000
3	2A	**Construct New Hydrant Lead Improvements** for existing hydrants #3, 4, 10, 11, 19 & 20. The existing hydrant leads, which vary in length, are connected to either 2", 3" or 4" mains, which hydraulically limit their fire flow capacities.	$105,000
4	NA	**Fire Hydrants: Replace Old & Install Additional.** 15 of the 20 existing hydrants are very old, do not have spare parts, and are in need of replacement. The hydrant separation across the Camp should be standardized. Typically, maximum separation distance should be limited to 500 feet, based upon available hose length of the fire department. Currently, the spacing is irregular and too far between hydrants. Approximately 26 additional hydrants should be considered just for the existing water system; a total of 44 additional hydrants with all of the proposed scenarios constructed.	$143,000
5	NA	**Isolation Valves: Replace Old & Install Additional.** Improve separation distance to 800-1000 feet maximum and add at critical junctions. There should be one less valve than the number of intersecting pipes at any given junction. Across the existing water system, approximately 29 additional valves should be considered; a total of 37 additional valves with all of the proposed scenarios constructed.	$72,000
6	2D	**Construct the Second Street Loop.** A new 6" main should be installed along 2nd Street from Soldiers Drive to Building 48M near Wilson Hill road to connect the three existing water mains (6", 8" and 4") that it would cross. This loop would provide system redundancy, would make minor improvements to fire flow and improve water circulation in this area of the system. If Scenario 2J (Wilson Hill Tank) is selected, then the 6" (new) and 4" (existing) mains from Kitchen Road up to Junction 380 should be replaced with 8" diameter transmission main.	$133,000

7	2J	**Construct a 300,000-gallon elevated tank (Wilson Hill)** When the existing reservoir cannot maintain the desired level of service, including the desired fire flow and pressures, a second source should be constructed in the Camp to supplement the fire flow and to improve system pressures for high elevation facilities (excluding ASP and SIRE). This would make dramatic increases in the available fire flow across the entire system, but especially east of 4th Street. A second storage facility would facilitate maintenance such that one storage facility would always be on-line during maintenance of the other. The tank should be constructed at an elevation higher than the existing reservoir and that provides the additional pressure desired at higher elevated facilities.	$1,282,000
8	2G	**Construct the North Transmission main.** A new 8" main should be installed to replace the failed and abandoned 6" main south of Soldiers Drive near the lake between 4th Street and 1st Street. This will improve the whole system east of 4th Street, especially in conjunction with the addition of Scenarios 2J and 2D.	$296,000
9	2F	**Construct the Trailer Park Loop.** A new 6" main should be installed cross country to connect three existing dead-end mains; 4" main near Building 191, 6" main near Building 100A and 4" main at the trailer park. This loop would provide system redundancy, would make minor localized improvements to fire flow and improve water circulation in this area of the system.	$91,000
10	2E	**Construct the 6" 200 Block Main.** This would be a minor project to improve fire flow in the vicinity of the cluster of buildings surrounding Building 206B. Install a 6" main from Kitchen Road to the sidewalk North of Building 206B. The improvements from this scenario would be local to this area.	$53,000
11	NA	**Complete an Acoustic Leak Detection Survey** every 2-3 years in order to maintain the system. The distribution pipes are in good condition but are old and susceptible to leaking. The survey can pinpoint leaks and estimate the water loss.	$4,000
12	NA	**Install a New High Capacity Meter (fire flow capable)** on the 8" transmission line downstream from Well No. 1 (Bldg. 410) to monitor the water demand for the Camp	$32,000
		Total Cost Opinion For Top 12 Water System Priorities See Figure 5.2: Priority Cost Opinions	2,853,00

A long list of general recommendations for the water system that are important to the operation and maintenance of the system were previously listed in the section entitled Water Distribution & System Maintenance. Some of that list made the primary priority list. The remaining recommendations are also vital to the water system operation and should also be considered and addressed.