CITY OF JUNCTION CITY
Water System Master Plan
Junction City, Oregon

CHAPTER 8

DISTRIBUTION SYSTEM EVALUATION

Chapter Outline

DISTRIBUTION SYSTEM EVALUATION

8.1 INTRODUCTION

The collection of piping, storage, pump stations, and supporting infrastructure is conventionally defined as a water distribution system. The discussions of this chapter narrow this definition by excluding water supply, storage, and pumping. Evaluations and recommended improvements to the City's water supply and storage facilities are presented in Chapters 6 and 9 respectively. The proposed finished water pump station is discussed at the end of Chapter 7.

The evaluations of this chapter were derived from the creation and study of a computerized hydraulic model designed to replicate the City's pumps, reservoirs, and distribution network. This model was used to simulate various operational modes, fire flow scenarios, and failure states in order to develop improvement recommendations. These recommendations are presented at the end of this chapter. Capital costs and a prioritized ranking of the recommendations appear in Chapter 10.

8.2 EVALUATION CRITERIA

8.2.1 Sizing and Capacity

The primary purpose of a water distribution system is to deliver the full range of consumer demands and fire flows at pressures suited for the particular use. To accomplish this, the distribution system utilizes a combination of large transmission mains and networks of smaller distribution mains.

Transmission mains are typically classified as large diameter pipes—diameters of 16-inches and above—that transmit large flows for long distances between source, treatment, and storage facilities. They frequently have reduced connectivity to the overall distribution system grid and experience moderate changes in velocity over the daily operating cycle. For the purposes of this study transmission mains are categorized as diameters of 16-inches and greater. This recommendation is based on an observation of existing pipe function and connectivity in the City's distribution system.

Distribution mains are comprised of diameters smaller than 16-inches and provide connectivity throughout service areas. Distribution mains provide both fire flow and consumer demands and experience a much wider range of operating velocities. For this reason, distribution mains are evaluated on their ability to provide fire flow during MDD periods. The City's Public Works Development Standards (PWDS) define the minimum pipeline diameter for new and replacement distribution pipelines as 8-inches for single-family residential areas and 10-inches or larger for industrial, commercial, and multi-family areas.

The American Water Works Association (AWWA) recommends a limit of 5 feet per second (fps) for transmission mains and a maximum of 10 fps for distribution mains[23]. The City's PWDS, by

[23] AWWA, 2004

comparison, permit a line velocity of 6 fps for ADD conditions and allow a maximum of 10 fps for MDD plus fire flows. Maximum headloss recommendations for transmission and distribution mains are limited to 3 and 10 feet per 1,000 feet respectively. Exceeding these headloss criteria may result in loss of hydraulic conductivity and increased energy costs.

8.2.2 System Pressure

Pressure is the primary metric for evaluating the ability of a distribution system to deliver water. Pressure at any given point in the distribution system generally diminishes as demand for water increases. The target minimum operating pressure utilized for peak hour demand conditions was 30 psi.

Periods of heavy fire flow demand also depress system pressures. OAR 333-061-0025 stipulates water suppliers to provide a minimum pressure of 20 psi to all service connections at all times, including times of peak fire flow demand. Fire flows are conventionally simulated concurrent with the maximum day demand.

The Oregon Plumbing Specialty Code[24] (OPSC) defines 80 psi as the maximum unregulated pressure for domestic service. Service pressures above this range must be reduced with a pressure regulating valves. This plan recommends maintaining normal operating pressures between 40 and 75 psi.

8.2.3 Fire Protection

Table 5-7 in Section 5.6 details the fire flow standards adopted by the City. These standards will be utilized in the fire flow calculations of this chapter to ensure that the distribution system is suitably sized and configured to reliably deliver the required fire flows to all areas within the city limits.

8.2.4 Deficiency Categories

In general, distribution system deficiencies fall into several categories. Elements of the system may be experiencing one or more of these problems at the same time. These categories will be used to identify the deficiencies associated with particular elements of the system in the discussions of this chapter.

- *Lack of Capacity*

Undersized pipes cannot deliver peak water demands or fire flows. Although the water system may have capacity to deliver domestic flows, it is often unable to convey larger flows that may be required in an emergency. Pipes in this category have excessive headloss and create flow restrictions. This problem should be addressed either by increasing the size of the existing waterline or constructing new waterlines.

- *End of Useful Life*

This category of problem is the result of old, damaged, or worn out pipes. The most common examples of this problem are leaky pipes and broken valves or hydrants. The correction of these problems requires the replacement or reconstruction of the failing component.

[24] State of Oregon, 2008

- *Lack of Facility*

Problems in this category are caused by the absence of a waterline, valve or hydrant. In such cases new components should be constructed in order to increase system reliability or to simplify system operations.

8.3 Hydraulic Model Development

8.3.1 Model Methodology

Computerized modeling of water distribution systems is a proven and effective method for simulating and analyzing the performance of a distribution system under a wide range of operational and hydraulic conditions. A properly constructed and calibrated model permits a robust evaluation of the distribution system and often allows the designer to replicate and evaluate hydraulic scenarios that are too difficult or costly to perform in the real world. Such scenarios are useful to determine the overall strength of a distribution system and to identify weaknesses that require remediation. The evaluation of future pipeline sizes and routing can also be economically performed to assure that the expansion of the distribution system occurs in an optimized fashion.

The modeling software used for this project was WaterCAD[25], a commercial modeling software package developed by Bentley Systems Incorporated. This software was utilized to calculate the distribution of flow throughout the distribution network and to quantify flow rates, pressures, headlosses, reservoir levels, and well pump operating points under various consumer demand patterns and fire flow scenarios. The model was utilized to perform both steady state and extended period simulations.

The general methodology used in the modeling process was to examine the existing distribution grid during various demand and fire flow scenarios. Pressure, flow, or connectivity deficiencies were used to formulate improvement scenarios to remedy the problem. These scenarios were evaluated to determine their efficacy. Improvement scenarios that exhibited a favorable cost to benefit ratio were selected for final recommendation.

8.3.2 Model Development

At the most basic level the hydraulic model consists of nodes and links. Nodes represent the various elements of the system including water sources, pumps, storage tanks and pipe intersections. Links predominantly represent pipes and define the relationship between each node. The creation of the model utilized information from a variety of sources. The City's existing distribution system maps were used as a base in the early building stage and this information was supplemented with information from record drawings, previous engineering studies, field reconnaissance, and discussions with City staff.

Model pipe elements were constructed based on the diameter, length and material type of each pipe. Hazen-Williams roughness factors were assigned to the pipes based on the pipe material type and age. These initial roughness factors were later modified in the calibration process as described in Section 8.3.3. Model nodes were placed at pipeline intersections, near fire hydrant

[25] Version 8 XM Edition

locations, and in locations to simulate clustered water service connections. The model nodes were populated with topographic information to ensure that elevation differences across the planning area were properly accounted for.

Existing wells and well pumps were replicated to perform at the currently utilized levels and set points. Ground storage and elevated reservoirs were constructed with tanks to match the physical geometry and assigned elevations to match the existing facilities.

Fire hydrants were modeled using a hydrant element that accounted for a typical 6-inch diameter hydrant lateral with an average length of 15 feet. Headloss charts were secured for the three hydrant styles that are most commonly utilized by the City and these hydrant-specific headloss factors were configured into the model hydrants.

The City currently utilizes four wells activated in a sequenced order to supply municipal demands. These wells deliver water directly into the distribution grid and are called on and off by the level of the elevated storage tank. This operational control sequence and the current well pumping rates were replicated in the model.

After a review of the raw data, the network was simplified or 'skeletonized'. This process eliminated or combined short pipe segments, consolidated pipe junctions and eliminated small diameter pipes with insignificant connectivity. These simplifications were carefully conducted to ensure integrity and hydraulic equivalency with the physical distribution system. Although there is no national standard for the skeletonization of a distribution system, the criterion in Table 8-1 are recommended by the EPA[26].

Table 8-1 | Distribution System Skeletonization Criteria

EPA Recommendation	Utilized in this Model
At least 50% of total pipe length in the distribution system	88%
At least 75% of the pipe volume in the distribution system	98%
All 12-inch diameter and larger pipes	All 4-inch and larger pipes
All 6-inch and larger pipe that connects remote areas of a distribution system to the main portion of the system	✓
All storage facilities with controls or settings applied to govern the open/closed status of the facility that reflect standard operations	✓
All active pump stations with realistic controls or settings applied to govern their on/off status that reflect standard operations	✓
All active control valves or other system features that significantly affect the flow of water through the system.	✓

Once the distribution network was created, the water demands established in Chapter 5 were allocated to specific nodes across the system. Billing records for 2008 were utilized to differentiate residential, commercial, and industrial demands. Total demand for a user group was distributed across the model nodes encompassed in the corresponding zoned areas within the

[26] USEPA, 2005

City. Demands from the top 35 large water users were selectively modeled as discrete demands at the locations designated on the billing records.

Lastly, demand patterns for the various use types as developed in Section 5.4.3.5 were assigned to each node to properly modulate nodal demands across a 24-hour period.

8.3.3 Model Calibration

Model calibration is the process of adjusting model input data and structure so that the simulated hydraulic output sufficiently mirrors observed field data. Model calibration is typically an iterative process whereby the model is executed to calculate flows and pressures for all or a series of nodes in the distribution system. These results are then compared to physical measurements taken at those same nodes. Pipe roughness factors are then adjusted to increase or decrease pressures and flows and the model is re-run. This process continues until the model results converge with the measured data. A calibrated model, as defined in this report, refers to an acceptable level of quality for data inputs, as well as the simulated results of a model that reasonably emulate field observations. It is a statement that encompasses data input and output.

The calibration process for this model utilized flow and pressure data extracted from an extensive set of hydrant flow tests provided by the City. In general, three or four separate flow tests were available for each of the roughly 250 hydrants in the City. Results for each hydrant were evaluated and a set of 67 hydrants were selected for the calibration process based in part on their location within the network, and on the fact that tests at these locations produced consistent results. Pipe materials in the downtown core of the City are predominantly comprised of cast iron and asbestos cement piping. PVC pipe is generally used in the newer portions and the periphery of town. Three hydrant sets were developed, and sequentially calibrated. A set of hydrants located within the most central portion of the distribution system and served predominantly by cast iron pipe was evaluated first. Roughness factors for the cast iron pipe were uniformly adjusted, until the modeled fire flow results at these hydrants replicated observed data. The second group of hydrants, located within distribution areas dominated by asbestos cement pipe, was evaluated next, followed by the tertiary group of hydrants around the perimeter and newer portions of town. Figure 8-3 presented at the end of this chapter depicts the locations of the calibration hydrants.

Results of the calibrated model were cross checked with the results of a pressure test conducted by the City across six days in June of 2007 in which the pressure at 13 nodes, equally distributed across town, were continuously monitored. System demands during this period were developed from the well pumping records of that period and were entered into the model.

The model replicated hydrant flow rates within 10% and the extended period pressure test results within 1%. Pressure fluctuations observed within each day of the City's pressure test were replicated by the model results. This level of calibration falls within the conventional standards for calibration.

It should be noted that the implementation of the instrumentation and control recommendations of this report will permit the future collection of a large amount of data that can be utilized for future refinements to the model. In particular, an hourly record of total system demand, corresponding tank levels, and system pressures will benefit future modeling efforts.

8.3.4 Model Scenarios

The calibrated model was used to investigate a number of hydraulic scenarios in the distribution system. These scenarios were evaluated using a combination of steady state and extended period simulations. Steady state simulations are most commonly utilized to evaluate fire flows in a distribution system. The simulation produces a snap-shot of hydraulic conditions at a fixed period in time. Although useful for a number of distribution system evaluations, this analysis method is limited in that it does not account for the dynamics of a water system operating over time. Extended period simulations fill this need and permit a more complex accounting of time-varying demand. This methodology is most often utilized to simulate the filling and draining of reservoirs as well as the cycling of well pumps during diurnal demand conditions.

The following hydraulic scenarios were performed for the existing and future distribution systems:

- *Average Day Demand*

Scenarios utilizing ADD were conducted and reviewed for consistency with historical operating frequencies of the wells and known production volumes from each. ADD scenarios were utilized in the evaluation of the future distribution to evaluate patterns of well operation, and fill-draw cycling (water turnover) in the proposed reservoirs.

- *Peak hour demands*

Extended period simulations were conducted to ensure that pipe velocities were less than 10 feet per second and that a minimum system pressure of 30 psi was maintained.

- *Maximum day demands*

Maximum day demands were evaluated with extended period simulations to ensure that flow velocities and headlosses within the network were not excessive. Reservoir recharge was also evaluated during periods of high seasonal demand.

- *Maximum day plus fire flows*

Steady state simulations were performed for each hydrant in the existing and proposed distribution system to develop a comprehensive account of available fire flows across the City. Fire flows were evaluated against the criterion previously presented in Table 5-7 to ensure that these demands could be supplied concurrent with MDD while maintaining a minimum 20 psi residual pressure in the distribution system.

Modeling results for each of these scenarios are discussed in Sections 8.4 and 8.5 to follow. Numerous other scenarios were conducted to prove out the strength of the distribution system and to evaluate potential improvement projects. Summaries of the notable findings follow.

8.4 EXISTING DISTRIBUTION SYSTEM ANALYSIS

The distribution system was analyzed at the year 2008 using the City's ADD MDD and PHD values as derived in Section 5.4. The evaluation of the existing system was performed to identify system deficiencies and possible remedies for the portion of town currently served by the existing distribution grid. It did not consider growth-related needs. This section presents improvements for the existing distribution system broken down into three categories comprised of transmission, distribution and fire flow improvements. Table 8-2 at the end of the chapter summarizes these improvements. Growth related improvements for future service areas are presented in Section 8.5 to follow.

8.4.1 Transmission Analysis

The City's transmission lines are comprised of 16-inch and 18-inch lines that each begin at the intersection of 12th & Front Street. The 16-inch line runs north to 18th Avenue and bounds the developed portion of town along the north and west in 18th Avenue and Oaklea Drive respectively. The line in Oaklea Drive stops at 10th Avenue and resumes after 1,300 feet for a 700 foot run between 6th and 4th Avenues. The 18-inch transmission main, by comparison, is much shorter. This line heads south from the aforementioned point of origin for approximately 700 feet on the east side of Front Street. These lines are shown in Figure 8-1 at the end of this chapter. There are no flow, velocity or pressure deficiencies with the existing transmission lines.

The expansion of these transmission lines will be required to serve the near term DOC and DHS developments to the south as well as future municipal development within the industrial corridor and to areas west of Oaklea Drive.

8.4.2 Distribution Analysis

Due to an essentially flat topography, the City's distribution system operates as a single pressure zone with minimum ADD pressures ranging from 55 to 64 psi. With limited localized exceptions, the City is able to supply PHD and meet the 30 psi minimum pressure criterion. The topography rises gradually to the south and this contributes in part to lower system pressures in the south-central part of town near the intersection of Bailey and Prairie Roads. Future distribution system pressures in the southern portion of the industrial corridor are likely to be somewhat less than those in the municipal core for the same reason.

The City's distribution grid generally provides an adequate level of looping with the exception of a portion of the commercial zone bounded to the north and south by 6th and 1st Avenues and to the east and west by Ivy and Deal Streets. Looped distribution systems are more desirable than branched systems because, coupled with sufficient valving, they provide service redundancy and facilitate repair work with limited outage areas. This configuration also reduces velocities in any given flow path and increases the system's ability to provide high volume fire flows.

As existing pipes and valves near the end of their useful life, they should be replaced before failure occurs. Depending on several factors, it can be reasonably assumed that waterlines will have a 75 year service life. Accordingly 1.3 percent of the system should be replaced every year to prevent long term degradation. This level of replacement translates to 2,600 feet of pipe for the Junction City system and a funding level of roughly $250,000 per year. It is recommended that the City budget for a perpetual pipe replacement program and develop replacement strategies to effectively manage and reduce system maintenance efforts that result from failed pipe.

The City has approximately 8,500 feet of small diameter galvanized, steel and wrought iron pipe. These pipes, with a diameter of 4-inches and smaller, were typically installed prior to 1965. They have exceeded their service life and must be replaced. These pipes are of particular concern due to their heavily corroded state and the proposed increase in system pressure as new storage facilities come on line. This plan recommends replacing all these pipes by the year 2015. The

City should continue the pipe replacement program for 2 inch waterlines in the wider system as well as the selective replacement of 6-inch cast iron pipe on an as needed basis.

City staff has identified the locations of several broken mainline valves. Water age peaks in pipes with broken valves since the lines effectively function as dead-end mains. Such cases are relatively few and have localized impacts; however, the replacement of these valves as time and resources permit will improve water quality.

Discussions with City staff indicate that maintenance efforts to repair broken distribution pipes average 10 to 12 breaks each year. This level of main break activity is roughly equivalent to the "reasonable goal" stated in a recent AWWARF study of 25 to 30 main breaks per 100 miles per year,[27] an equivalence of roughly 9 to 11 breaks per year for a system of this size.

Deficiencies in the existing distribution system generally occur in three categories; failure to meet the PHD pressure criteria of 30 psi in localized areas, the need to replace deteriorated pipes, and the inability to provide adequate fire flows. Discussions of the latter category appear in the following section of this chapter. The inability to deliver PHD flow stems from the large number of small diameter pipes (2 to 4-inches) in the City system. Several improvement projects were developed to concurrently remedy PHD flows, and replace the most deteriorated pipe in the City's grid. Several other projects were developed to improve looping in the distribution grid, an improvement that benefits PHD delivery as well as fire flows. A list of these specific distribution system improvements appears in the recommendations section at the end of this chapter under section 8.6.2. These recommendations are also summarized in Table 8-2 and depicted on Figure 8-2. Both appear at the end of the chapter.

8.4.3 Fire Flow Analysis

The provision of fire flows are conventionally modeled as demands occurring during periods of MDD. A minimum residual pressure of 20 psi must be maintained in the distribution system for the duration of the fire flow event.

An evaluation of fire flows at critical facilities (schools, commercial plazas, key industrial locations) was conducted to confirm that available fire flows met or exceeded those required by fire code and adopted by the City. Fire flow analysis was limited to the evaluation of a single fire occurrence within a 24-hour period. It was determined that fire flow deficiencies occur in several residential and commercial/industrial areas of town. A discussion of each follows.

While each deficiency requires local distribution system improvements, each of the proposed projects assumes that the proposed 16-inch transmission line will be completed around the west and south perimeter of town and that the new elevated storage tanks are constructed to raise the base pressure in town by 10 psi.

8.4.3.1 Residential Areas

Brentwood Homes and Oak View Apartments
The area south of Bryant Avenue and North of Hatton Lane and bounded to the west and east by Laurel Street and Highway 99 produces fire flows of 1,000 gpm or less. Fire flows to this area

[27] Deb et al, 1995

are improved by the following proposed projects detailed in the recommendations section of this chapter; Hatton Lane Phase I and II *(D-17* and *D-21*), Bryant Street *(D-20*), and First Avenue *(D-18*). The implementation of these projects combined with the increase in overall system pressure will increase the fire flow in this area to an average of 2,500 gpm. Flows average 3,000 gpm for hydrants served directly off the improved line in Hatton Lane.

Norman Park

The area of Norman Park east of Boden Street produces fire flows of 1,000 gpm or less. Flows to this area are improved by the following proposed projects; River Road *(D-19*) and 6th Avenue *(D-22*). The implementation of these projects will increase flow in this area to an average of 1,500 gpm.

8.4.3.2 School Areas

A four hour 3,500 gpm fire flow demand was simulated at the elementary school, the middle school and the high school during 2013 MDD. These simulations were performed with the assumption that the new transmission line around the southwest perimeter of town and the new elevated reservoirs were in service. Fire flows were demanded of a group of two to three hydrants at each site all located within 500 feet of each other. Fire flows at the elementary and high schools were satisfied despite the short duration reduction in operating pressure to 40 psi in localized areas around the fire. Adequate fire flow was not available at the middle school and the 3,500 gpm demand caused local pressures around the site to drop below 20 psi.

Oaklea Middle School

A review of the fire flow test records provided by the City show that the hydrants in Rose Street between 13th Avenue to a point just north of the Middle School show these hydrants to have yields below 1,000 gpm. One additional hydrant, located at 1420 West 13th Avenue, just west of this location is deficient as well. Outside of this localized area on Rose and 13th, hydrant flows exceed 1,700 gpm. Modeling results do not predict this localized depression and show that this area should be capable of producing uniform flows around 1,500 gpm. The cause for the localized depression in fire flows is unclear.

The minimum fire flow requirement for the Middle School facility is 3,500 gpm. Even without the localized depression in flows for this area, the base level of fire flows is insufficiently low. The limitation of high volume fire flow to the school is constrained by the undersized lines in Rose Street—the 8-inch line feeding the property from the north and the 6-inch from the south. The solution is to replace this 1,900 foot run with a new 12-inch pipe.

It is recommended that when the 18 acre property southwest of the intersection of 18th Avenue and Rose is developed, that the new distribution grid within the development be configured with a combination of lines that provide the hydraulic equivalent of a 12-inch line between 18th Avenue and Rose Street and that the connection to Rose Street is at a point as far south of 18th Avenue as possible. This will reduce the amount of line that will ultimately need to be replaced in Rose Street. This improvement combined with the increase in system pressure with the construction of the new elevated storage reservoir will increase fire flows to this area by approximately 1,000 gpm leaving estimated flows at roughly 2,700 gpm and still short of the target. This report accordingly recommends the installation of 1,900 feet of 12-inch pipe in Rose Street.

8.4.3.3 Commercial/Industrial Areas

The City's fire flow standards require the provision of 4,000 to 6,000 gpm for existing and new structures in commercial and industrial areas. Available fire flows from hydrants in these areas currently ranges from 1,000 gpm to 2,500 with an average of roughly 2,200. In some instances, hydrant spacing is adequate to reasonably deliver the stipulated flow from two or even three different hydrants; however, in many areas hydrant spacing is inadequate and the overall base fire flow stands to be improved. The installation of new in-fill hydrants is complicated by the lack of a looped network in many areas.

The central north/south distribution system in Ivy Street is comprised of a combination of aging 6-inch cast iron pipe and newer 10-inch pipe that lacks large diameter connectivity to the main transmission mains. A secondary north/south distribution corridor in Front Street contains 12-inch pipe but has inadequate hydrant spacing south of 6th Avenue.

Increasing fire flows in these areas will require a combination of near term and longer term projects. Near term projects include the installation of additional hydrants along the 12-inch line in Fronts Street at the intersection of 5th, 4th, and 2nd Avenues as well as constructing new segments of pipe to increase flow to key hydrants. The existing 10-inch line in 14th Street east of Greenwood should be extended to connect with the 10-inch line on the east side of Ivy Street. These specific projects are detailed in the recommendations of this chapter in Section 8.6.3.

The installation of the eastside transmission line (planned for the year 2020) presents another opportunity to increase available fire flows in the commercial and industrial corridor. The full discussion of this planned facility and associated fire hydrants appears in the discussion of the future distribution system in Sections 8.5.1.2 and 8.5.4 to follow.

8.4.4 Water Age Evaluation

Water quality is emerging as a major concern for many utilities. An important indicator of water quality is the age of the water in the pipes, also known as the hydraulic residence time. Based upon a survey of 800 utilities, an AWWA publication[28] reported an average distribution system retention time of 1.3 days, with a maximum retention time of 3.0 days. Examples of much longer retention times in portions of water supply systems have been reported. Water retention time is primarily a function of water demand, system operation, and system design. Water quality can change as it moves between sources of supply and treatment to the consumer. While there is no set requirement for minimum or maximum water age, utilities should be cognizant of their system's water age because elevated water age can lead to taste and odor complaints, increases in temperature, increases in disinfection byproducts, decreases in disinfection residual, and other water quality issues. The appropriate water age for any particular system is a function of the age and material of the pipes, the type of disinfection utilized (chloramines versus chlorine), and the amount of organic matter in the system.

The City's existing distribution system does not exhibit excessive water age. A maximum water age of 7 days occurs in the Raintree Meadows subdivision and is largely due to the fact that this part of town is at the far boundary of the distribution system. Water age in this part of town is significantly improved by the construction of the proposed 16-inch transmission main around the

[28] AWWA and EES, 2002

west and south boundary of town to serve the DOC and DHS complexes. Water age in this portion of town decreases to 24 hours after the construction of this transmission line and associated connections to select portions of the existing distribution grid as described in Section 8.5.1.1. Water age at the DOC/DHS site averages 3.5 days and will improve as additional development occurs within the industrial corridor south of town.

8.5 FUTURE DISTRIBUTION SYSTEM ANALYSIS

Growth within the study area will depend on regional socio-economic conditions and in part on the long term economic conditions on a larger national scale. Like many communities, Junction City has experienced a steady rate of development in the past decade. Several large housing developments have been completed and prospects for new residential developments appear strong in light of the near term development of the DOC prison and DHS hospital. Water service to these facilities will require a significant expansion to the City's distribution system.

In light of these known near term developments, it should be recognized that projections of demand and municipal growth are subject to many variables and inaccuracies. Accordingly, it is recommended that the City review its water system at five-year intervals and update this report as appropriate.

8.5.1 Future Transmission Improvements

Since transmission pipelines are not well suited for incremental expansion, it is cost effective to size the pipes for fully built-out conditions. In situations where property development is incipient, the sizing of transmission lines can be straight forward and the infrastructure can be readily tailored to suit the needs at hand; however, this task can become more challenging in cases where economic conditions predict development to occur on a more irregular basis. In these situations there is an economic burden resulting from the development of facilities with excess capacity that remains underutilized for long periods of time.

8.5.1.1 Southern Transmission

The development of the DOC and DHS facilities is a near term development that will require the construction of a new transmission line to serve the facility demands. The southward continuation of the existing 16-inch line in Oaklea Drive is a logical solution that benefits the City and the DOC. This improvement project is depicted on Figure 8-2. The segment of this transmission line between 10th and 6th Avenue provides important connectivity for the City along the west edge of town, and the continuation of the line around the southwest perimeter of town will strengthen flows to Raintree Meadows subdivision and the southern end of Prairie Road. It also provides the basis for future distribution improvements further to the east along Hatton Lane which will increase fire flows within the Oak View Apartment complex and the southern end of the Brentwood subdivision. From the intersection of Bailey Lane and Prairie Road, the line heads south until it intersects with Highway 99 where the diameter changes to 24-inch. From this point the line will continue south for approximately 12,000 feet before terminating at the DOC site.

8.5.1.2 Eastside Transmission

The development of the southern commercial and industrial corridor south of River Road and east of Highway 99 will ultimately require the development of a second large diameter transmission line. Figure 8-1 shows the proposed route for this line that can generally be viewed as the eastside complement to the existing transmission line in Oaklea Drive. Placement of a new 18-inch diameter transmission line along this route serves a number of existing and emerging needs. It primarily delivers uninterrupted flow from the proposed water treatment plant to the commercial industrial corridor. It also functions to offset the reduction in reserve capacity in the 16-inch transmission line as the UGB builds out to the west of Oaklea Drive. This is an important point with regard to the continued provision of suitable pressures to areas south of Bailey Lane, and in particular for the DOC facility at the far south of the UGB. The increase in elevation to the DOC site, although gradual, is enough to reduce the operating pressure margin for this portion of the distribution system. The new hydraulic grade line of the two elevated reservoirs (in-town and at DOC) has been matched, and is set to maximize municipal pressures without creating excessive pressures at the northwest corner of town. Due to its higher elevation, the DOC complex has a maximum system pressure of 63 psi compared to the 73 psi in town. As municipal demands increase, they exert a demand on the 16-inch perimeter transmission line that begins to erode service pressures along the south industrial corridor. The eastside transmission line mitigates this problem by directly linking a strong pressure source near the treatment plant to the intersection of Bailey Lane and Prairie Road and avoiding connections with the municipal grid along the way. This new line becomes the dominant supply line for the industrial corridor.

As further discussed in Section 8.5.4 to follow, the installation of new hydrants served from this line is viewed as a means of providing large volume fire flows in the central commercial zone and will not compete with the reserved purpose of the line.

It is anticipated that the construction of this facility will be necessary by the year 2020.

8.5.1.3 Westside UGB Buildout

The majority of residential growth over the next 20 years is projected to occur in undeveloped UGB areas west of Oaklea Drive. Zoning designations within this area are comprised of low and medium density residential, public, and professional/technical. The hydraulic model was utilized to prepare a conceptual plan for service to this area. Based on the current zoning designations, a new 16-inch diameter transmission main will be required to provide an adequate level of service through the full depth of this area. The proposed conceptual alignment of this line is shown in Figure 8-1. The planning period for this transmission line will be driven largely by future property development in this area; however, it is important that as development begins westward of Oaklea that the incremental construction of this transmission main or its hydraulic equivalent is conducted.

8.5.1.4 Eastside Industrial Area Buildout

Long-term buildout of the industrial area east of Highway 99 and south of River Road will require the construction of a large diameter transmission main to deliver fire flows into this area. It is currently envisioned that this line will connect to the 12-inch line at Front Street and River Road. Figures 8-1 and 8-2 show a conceptual plan for the routing of this new 16-inch transmission main. Other local improvements to the grid in the vicinity of Norman Park will be required to convey flows to the new line. A connection to the 18-inch eastside transmission line is currently not envisioned. The construction of this line will be demand driven and has a lower priority than the eastside transmission line. The City should confirm the proposed route as development plans for this area mature.

8.5.2 Future Distribution Improvements

Outside of large diameter transmission lines, the expansion of the distribution grid to serve new developments is anticipated to occur in areas selected by developers. In such cases the City's Public Works Development Standards provide a sound basis for ensuring that a properly sized and looped grid is constructed around the larger diameter transmission mains. Beyond this, localized distribution improvements will be evaluated on a case by case basis. For the above reasons, these projects are not included in the water systems project list.

Continued use of the City's hydraulic model is recommended as a tool to validate the performance of proposed distribution improvements.

8.5.3 Future Raw Water Lines

As discussed in Chapter 7, the construction of the new WTP will require the collection of flows from the 13th & Elm, the 8th & Deal, the 8th & Front, and the 11th & Elm Street wells. Raw water lines will be required to convey well production directly to the plant. It is anticipated that two separate lines will be constructed; one to handle the nitrified flows from 8th & Front and 11th & Elm and another to serve the remaining two wells. These lines will be a combination of 8 and 12-inch diameters, are identified as improvement alternatives D-31 and D-32, and will be constructed in Elm Street as shown on Figure 8-2.

8.5.4 Future Fire Flow Improvements

The provision of fire flows to the future DOC/DHS complex is currently planned as a series of transmission and distribution system improvements that provide an increasing progression of flow. The construction of the 16-inch transmission main south to the complex, combined with higher service pressures due to the construction of the proposed elevated storage tanks, will provide a baseline fire flow of 4,000 gpm. The completion of in-town distribution improvement projects D-17 through D-22 will increase flows to 4,500 gpm. The construction of the eastside transmission main is anticipated to occur 2020. As previously discussed, it is anticipated that this line will serve as the primary transmission line for ADD, MDD and PHD flows to the south industrial corridor and that the 16-inch west side transmission line will deliver complementary flows to the in-town municipal areas. The exception to this segregated operational mode occurs when the required fire flow in the south industrial corridor exceeds 5,500 gpm. Large fire flows, concurrent with MDD, will require the use of both west side and eastside transmission mains to satisfy demand. In such cases available fire flows to the industrial corridor exceed 6,000 gpm.

The construction of the eastside transmission main also provides an opportunity to improve flows in the central commercial corridor. Improvement alternative D-28 described in Section 8.6.3.2 details the construction of 12 new high volume hydrants served from this line.

An additional improvement facilitated by the construction of the eastside transmission main is the recommendation to install a 12-inch pipe from the bend in the proposed 18-inch eastside transmission line at the intersection of 10th and Holly westward to connect with the 10-inch line in Ivy Street. This line improves fire flows to the hydrants along Ivy Street and serves as the start of a future 12-inch line that may eventually extend the full length of 10th Avenue.

8.6 Recommended Improvements

Several improvement projects have been identified based on the hydraulic analyses presented in this chapter. Near term transmission line improvements to serve the DOC and DHS facilities make up a significant portion of the work. Distribution projects have been identified to improve a combination of pressure, flow and velocity deficiencies. Other improvement projects have been identified to strengthen fire flows, system redundancy and provide new connectivity between the wells and the proposed water treatment plant. These improvement recommendations are summarized in Table 8-2 and graphically depicted on Figure 8-2. Each appears at the end of the chapter. A ranked prioritization of these projects into a comprehensive implementation plan is presented in Chapter 12.

8.6.1 Transmission Improvements

- *Southern Transmission (D-1) & Transmission line in Oaklea Drive and Bailey Lane (D-2)*

These projects are required to provide service to the DOC and DHS facilities and to strengthen flows around the west and south perimeter of the City. The projects include 16,000 and 7,700 feet of 24 and 16-inch pipe respectively.

The projects should also include the following small projects to complete key connections to the existing distribution grid in the following locations; construct a short segment of 8-inch pipe to connect the Pitney Village grid to the transmission line as it passes Pitney Lane, construct a short segment of 8-inch pipe to extend the line in Quince Street with the transmission main in Bailey Lane, connect the 8-inch line from the southeast corner of Raintree Meadows and the 8-inch line in Prairie Road to the transmission line at the intersection of Bailey Lane and Prairie Road. A stub-out and 12-inch valve at this location should be installed for the future extension of a 12-inch line eastward on Hatton Lane.

City staff has observed fluctuating pressures within the Raintree Meadows development. Reports indicate that service pressures can vary by as much as 20 psi among houses within a one-block range. This phenomenon was not observed in the hydraulic model; however, the connections of this improvement alternative will improve fire flow and pressure to this area.

- *Eastside Transmission (D-3)*

This project will be required as the municipal base grows and is anticipated to be required in 2020. The 18-inch line will begin at the intersection of 10th and Front and will connect to the existing 18-inch line at this location. The new line will replace the existing 6-inch line in 10th Avenue between Front and Greenwood, then turn south at the intersection of 10th and Holly. From this point, the line continues south to the intersection at River Road, jogs westward, and follows the east side of Highway 99 to the intersection at Hatton Lane. The pipe crosses under Highway 99 and runs the length of Hatton Lane to its intersection with Prairie Road. A pressure reducing station in the vicinity of Hatton Lane will regulate the supply of roughly 1,000 gpm to this southern part of town and augment system pressures in the area. The installation of 11 new hydrants on this line is recommended and is detailed in the fire flow recommendations of Section 8.6.3.

From the perspective of function and long term service, this line provides the maximum value if it is installed in Holly Street rather than in Greenwood Street. It is recognized that there are short-term planning and permitting challenges due to the presence of the Burlington Northern railway in this same street; however, the waterline's function as a large diameter transmission main, the fact that it is designed to provide limited connectivity to the existing municipal grid, and the deficit of fire protection in this commercial corridor, makes a good case for locating the line as currently shown. The expiration of the 20 year Burlington Northern contract in 2012[29] may provide an opportunity for this line to be constructed in this location. The proposed alignment should be reevaluated in future planning and pre-design studies.

- *Future UGB Buildout Transmission Line (D-4)*

This project is demand driven and will be required as properties west of Oaklea Drive are developed as discussed in Section 8.5.1.3. The possible exception to this is the near term development of 2,200 feet of 16-inch line to serve the proposed wastewater treatment plant.

- *Eastside Industrial Area Transmission (D-5)*

This project will be required as the industrial area east of Highway 99 and south of River Road develops. The project is demand driven and the new 16-inch line is designed to provide large fire flows to this area. It is currently envisioned that this line will connect to the 12-inch line at Front Street and River Road and will require local improvements to the existing distribution grid in the vicinity of Norman Park to convey flows to the new line. These projects are identified as D-30a, b and c. A connection to the 18-inch eastside transmission line is currently not envisioned. The construction of this line will be demand driven, and the City should confirm the proposed route as development plans for this area are clarified.

8.6.2 Distribution Improvements

Although not specifically itemized, the following improvement projects include the installation of new isolation valves and hydrants, and in cases where existing lines are replaced, the re-connection of all water services and branch lines.

- *Galvanized Pipe Replacement Program (Program 1; Projects D-6 through D-14)*

The City should make preparations to begin replacing all of the galvanized pipes in the distribution system. This program is a sub-set of the system wide perpetual pipeline and valve replacement project, but due to its relatively small scope and the importance of these replacements, it has been identified as a near-term priority program of its own. Projects D-1 through D-9 are identified in Table 8-2 and on Figure 8-2 at the end of this chapter.

- *Perpetual Pipeline and Valve Replacement Program (Program 2)*

This program should be annually funded and executed by the City to replace pipe and valves that has reached the end of their useful life. The execution of this program should begin after the galvanized pipe replacements of the previous replacement program are completed in 2015.

- *Elm Street waterline replacement, 9th Avenue to 14th Avenue (D-15)*

Construct 1,550 lineal feet of 8-inch line to replace the deteriorated 4-inch steel line from 9th to 10th Street and the undersized 2-inch PVC line from 10th to 14th Street. The hydrant at the intersection of 10th & Elm should be replaced at this time as well as the installation of new hydrants at a 400 foot interval. This project should be completed at the same time as the

[29] LCOG, 2000a

construction of the new well collector lines linking the City wells to the WTP as both projects will require extensive work in Elm Street.

- *Prairie Meadows (D-16)*

Construct approximately 220 feet of 8-inch pipe from the west end of Prairie Meadows Avenue and connect to the 8-inch line in Pitney Village east of this location. This improvement strengthens flow into Prairie and Raintree Meadows by providing additional connectivity to the future 16-inch transmission line in Pitney Lane.

- *Hatton Lane, Phase I (D-17)*

Construct approximately 350 feet of 12-inch line from the intersection of Prairie Road and Hatton Lane to the intersection of the existing 8-inch line that fronts the Oak View Apartments. This project is designed to improve fire flows and service to areas south and west of Bryant Court and Prairie Road. This project also provides future connectivity for the second phase of improvements in Hatton Lane.

- *First Avenue (D-18)*

Construct approximately 700 feet of 10-inch pipe from Kalmia to Highway 99 and connect with the existing 10-inch line in First Avenue on the east side of Ivy Street. This completes missing distribution system looping and strengthens fire flows to the southern portion of town and the southern industrial corridor.

- *River Road (D-19)*

Construct a new 8-inch line from Cedar to Boden Street. This project completes missing distribution system looping and strengthens fire flows to the Norman Park area south of 5th Avenue and east of Cedar Street. This line also has a role in the provision of fire flows for the transmission line into the industrial corridor, identified as project D-4. This transmission line currently bounds the eastern edge of the industrial area south of River Road. Should future development interests push the UGB eastward, the transmission line should also move east. This will require a 16-inch diameter for the new line of this option in lieu of the 8-inch line currently proposed.

- *Bryant Street (D-20)*

Construct a new 10-inch line from Prairie Road to Kalmia Street. The portion of this project from Laurel to Kalmia is a replacement of the existing 6-inch line. This project completes missing distribution system looping and strengthens fire flows to the southern portion of town and the southern industrial corridor.

- *Hatton Lane Phase II and Highway 99 (D-21)*

Replace the existing 8-inch line in Hatton Lane from the terminus of the Phase I project eastward to Highway 99. This project will include reconnecting the three existing hydrants served by this line as well as the 6-inch branch into the Oak View Apartment Complex. The second component of the project is to extend an 8-inch line north approximately 1,090 feet along the west side of Highway 99 to complete the connection with the existing 6-inch line in this location.

- *6th Avenue (D-22)*

Construct a new 12-inch line from the 6-inch cast iron pipe in Greenwood Street to the end of the existing 10-inch line at the intersection of 6th and Front Streets. This segment should include a connection to the 12-inch line on the west side of Front Street. A connection to the existing

4-inch wrought iron line at this same intersection is not recommended. Construct a second segment of 12-inch pipe from Elm to Cedar Streets replacing the existing 2-inch line between Deal and Cedar Streets. The portion of this project west of Front Street primarily improves fire flows to the hydrant at the intersection of 6th & Front Street. The portion east of Front is targeted to improve local service during peak hour demands. A 12-inch diameter has been selected for these lines for future compatibility with the long term goal of a larger diameter line running the full length of 6th Avenue.

8.6.3 Fire Flow Improvements

This section describes one general improvement program, and several specific improvement projects each designed to correct the previously identified fire flow deficiencies.

- *Hydrant Replacement and Infill Program (Program 3)*

The City's PWDS currently require a maximum hydrant spacing of 500 feet in residential areas, 300 feet in high-value districts including industrial subdivisions, and no further than 250 feet from the furthest point of any dwelling, business, garage or building. This coverage is enforced for new development; however, there remain portions of town where hydrant coverage is substandard. It is recommended that the City develop a hydrant in-fill program to inventory and prioritize areas that do not have adequate hydrant coverage. The planning level of this program should be undertaken as a joint effort with the Fire Department. The establishment of the program should be supported by annual funding to ensure incremental progress in resolving these deficiencies. At this time a minimal annual investment of $15,000 has been proposed for this project. This funding level is sufficient for three new hydrants per year and should be increased as funds become available and the need presents.

8.6.3.1 Residential Fire Flow Improvement Projects

The improvement of fire flows in residential areas will be accomplished by constructing the distribution system projects previously identified in Section 8.6.2 and summarized in Table 8-2.

8.6.3.2 Commercial/Industrial Fire Flow Improvement Projects

Improvements to the fire flows in the commercial and industrial areas rely on a combination of short term and longer term distribution system improvements as well as a hydrant infill program. These projects are described as follows.

- *Rose Street (D-23)*

Construct approximately 1,900 feet of 12-inch pipe from the intersection of Rose and Quince Streets to 18th Avenue. This improvement is designed to provide adequate fire flows to the middle school.

- *Hydrant Infill along Front Street (D-24 Conducted under the Hydrant Infill Program)*

Install three additional hydrants on the 12-inch line in Front at 5th, 4th, and 2nd Avenues. Hydrants in these locations are intended to utilize available flow in the 12-inch line and provide sufficient hydrant coverage to facilitate the use of multiple hydrants for a single large fire.

- *5th Avenue (D-25)*

Construct 415 feet of 10-inch pipe to replace the existing 4-inch line between Front Street and the alley between Greenwood and Holly Streets. This improvement is directed at increasing flows to the underperforming hydrant at 5th & Greenwood. The new pipe should connect to the 12-inch line in Front Street, to the 6-inch cast iron pipe in Greenwood, and to the south end of project D-8 as identified in the distribution improvements section above.

- *2nd Avenue (D-26)*

Install 300 feet of 10-inch pipe to replace the existing 2 and 1-inch galvanized pipe between Front Street and Greenwood. This improvement is directed at increasing flows to the hydrant at 2nd and Greenwood. The improvement will need to connect to the 6-inch cast iron pipe in Greenwood.

- *14th Avenue (D-27)*

Construct 550 feet of 10-inch pipe to extend the existing 10-inch line in 14th Street east of Greenwood to a connection point with the 10-inch line on the east side of Ivy Street. This line serves to relieve the bottleneck created by the 6-inch line in Ivy Street from 16th to the transmission line in 18th Avenue.

- *Commercial Corridor Hydrants (D-28) (Completed with the eastside transmission project)*

The construction of the eastside transmission project in 2020 will provide a strong source for the provision of new hydrants in the commercial corridor. It is recommended that six new hydrants be installed at the intersections of Holly Street with 9th, 7th, 5th, 4th, 3rd, and 2nd Avenues. Additionally it is recommended that the existing hydrant installed at the intersection of 1st and Holly be re-connected to the new eastside transmission line. An additional four hydrants have included in the project for unspecified locations between 1st Avenue and Hatton Lane. Due the large diameter of this transmission main and unrestricted flow, the limiting factor in available fire flow will certainly occur in the hydrant device. It is recommended that specialized high volume hydrants each capable of supplying two independent pumping operations be considered for this application.

- *10th Avenue (D-29)*

Construct approximately 270 feet of 12-inch pipe from the bend in the proposed 18-inch eastside transmission line at the intersection of 10th and Holly westward to connect with the 10-inch line in Ivy Street. This line improves fire flows to the hydrants along Ivy Street and serves as the start of a future 12-inch line that may eventually extend the full length of 10th Avenue.

- *Norman Park Area (D-30a, 30b, 30c)*

Construct a total of 2,200 feet of 12-inch pipe and 800 feet of 16-inch pipe in locations as shown on Figure 8-2. As previously discussed, these improvement projects are support projects for the proposed industrial area transmission line (*D-5*). The lines provide distribution system connectivity for the new line, and strengthen the aging network in this part of town. At the City's election, these lines can be constructed in advance of the transmission line to strengthen flows along the eastern edge of the UGB.

Table 8-2 | Recommended Distribution System Improvements

Project Code	Project Description	Basis	Recommended Diameter[1]	Length	Project Cost
Transmission Line Improvements					
D-1	Southern Transmission Line to DOC / DHS	MDD + FF	16	7,700	$ 4,608,000
D-2	Transmission Line in Oaklea Drive and Bailey Lane	MDD + FF	24	16,000	$ 1,479,000
D-3	Eastside Transmission Line	MDD + FF	18	8,000	$ 1,728,000
D-4	Future UGB Buildout Transmission Line	Service Area	16	11,000	$ 2,211,000
D-5	Future Industrial Corridor Transmission Line	MDD + FF	16	8,000	$ 1,536,000
Galvanized Pipe Replacement Program (Program 1)					
D-4	Laurel Street (9th Street to 12th Street)	PHD + Age	(2) 6	930	$ 67,000
D-5	Laurel Street (6th Street to 9th Street)	PHD + Age	(2) 6	940	$ 68,000
D-6	Addison Avenue & SW Laurel Street	PHD + Age	(2) 6	1,040	$ 75,000
D-7	Laurel Street (3rd Avenue to 5th Avenue)	PHD + Age	(2) 6	980	$ 71,000
D-8	Kalmia Street (3rd Avenue to 5th Avenue)	PHD + Age	(2) 6	980	$ 71,000
D-9	Juniper Street (3rd Avenue to 5th Avenue)	PHD + Age	(2) 6	980	$ 71,000
D-10	3rd Avenue (Laurel Street to Juniper Street)	PHD + Age	(2) 6	560	$ 41,000
D-11	Alley between Ivy and Holly Street (4th Avenue to 7th Avenue)	Age	(2) 6	950	$ 69,000
D-12	Alley between Holly and Greenwood Streets (5th Avenue to 7th Avenue)	Age	(2) 6	670	$ 49,000
General Distribution					
P-2	Perpetual Pipeline and Valve Replacement Program (Program 2)	Age + FF	Varies	2,600	$ 250,000
P-3	Hydrant Replacement and Infill Program (Program 3)	Age + FF	Standard	3 per year	$ 15,000
D-15	Elm Street (9th Avenue to 14th Avenue)	Age + FF	(2 & 4) 8	1,550	$ 149,000
D-16	Prairie Meadows (Connect west end of Prairie Meadows to Pitney Village)	MDD + FF	8	220	$ 22,000

[1] *Replacement projects show the existing pipe diameter in parenthesis*

Table 8-2 | *Continued from previous page*

Project Code	Project Description	Basis	Recommended Diameter [1]	Length	Project Cost
General Distribution continued…					
D-17	Hatton Lane, Phase I (Prairie Road to Oak View Apartments)	MDD + FF	12	350	$ 51,000
D-18	First Avenue (Kalmia Street to Highway 99)	MDD + FF	10	700	$ 84,000
D-19	River Road (From the alley between Cedar and Deal Streets to Boden Street)	MDD + FF	8	1,020	$ 98,000
D-20	Bryant Street (Prairie Road to Kalmia Street)	MDD + FF	10	570	$ 69,000
D-21	Hatton Lane, Phase II (Oak View Apartments to Hwy 99 then North on Hwy 99)	MDD + FF	(8) 12 & 8	870 & 1,090	$ 230,000
D-22	6th Avenue (Greenwood to Front Street & Elm to Cedar Street)	PHD + FF	12	600	$ 87,000
D-23	Rose Street (Intersection of Rose and Quince Street to 18th Avenue)	FF	(6 & 8) 12	1,900	$ 274,000
D-24	Hydrant Infill along Front Street (Total of three new hydrants)	FF	Standard	N/A	$ 15,000
D-25	5th Avenue (Greenwood to Front Street)	FF	(4) 8	415	$ 40,000
D-26	2nd Avenue (Greenwood to Front Street)	FF	(2) 10	300	$ 36,000
D-27	14th Avenue (Greenwood to Ivy Street)	FF	10	550	$ 66,000
D-28	Commercial Corridor Hydrants (Total of 12 new hydrants constructed in conjunction with D-2)	FF	Standard	N/A	$ 60,000
D-29	10th Avenue (Holly Street to Front Street)	FF	12	270	$ 39,000
D-30a	6th Avenue (Front Street to Elm Street)	MDD + FF	12	300	$ 44,000
D-30b	6th Avenue and Birch Street (Intersection of 6th & Cedar and south along Birch Street)	MDD + FF	12	1,900	$ 274,000
D-30c	River Road (Front Street to the alley between Cedar and Deal Streets)	MDD + FF	(10) 16	800	$ 116,000
Raw Water Lines					
D-31	8th & Front Well + 11th & Elm Well to WTP	Treatment	8 & 12	550 &1,100	$ 212,000
D-32	8th & Deal Well + 13th & Elm Well to WTP	Treatment	8 & 12	450 & 1,600	$ 274,000

[1] Replacement projects show the existing diameter in parenthesis