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Memorandum

To:	Burt Knight – Broomfield		
From:	Rich Thornton, PE; Gary Fuller, PE – HDR	Project:	Water Distribution Level of Service Review
CC:	Dave Dalsoglio, David Allen – Broomfield		
Date:	January 16, 2009	Job No:	88390

RE: Customer Concern Response

Introduction

This memorandum addresses three concerns raised by a residential customer regarding water service in the vicinity of 136th Avenue and Main Street, southeast of the intersection. Specifically, this memorandum summarizes an evaluation of Broomfield's level of potable water service to existing and future water customers through:

1. Water system planning that addresses both growth and existing customer needs,
2. Distribution system design and operation to provide fire flows that meet industry criteria, and
3. System operations to provide adequate water pressure at the customer's meter and home.

The Broomfield Public Works Department has requested HDR to assist in responding to several concerns raised by a residential customer. HDR has reviewed the level of service that Broomfield provides to its water customers through a review of industry standards (City, state and national), Broomfield water distribution system data, and previous correspondence with the customer.

HDR is a recognized leader in the drinking water industry within Colorado and across the nation. Primary HDR staff reviewing Broomfield's level of potable water service includes Rich Thornton (Project Engineer) and Gary Fuller (Quality Control Reviewer). Rich Thornton is a Professional Engineer with 16-years experience in planning, hydraulic analysis, modeling and design of water distribution systems. Rich has been working with Broomfield in developing computer software to support Public Works in decision making for water supply and operational strategies. Rich has also been involved with Broomfield in refining their existing distribution system hydraulic computer model. Gary Fuller has 34-years professional experience in planning and design of water distribution systems, pumping stations, and treatment facilities. Gary is a nationally recognized expert in the drinking water industry and has been involved with water and wastewater infrastructure projects in Broomfield since the early 1980s.

The following is a discussion of the three issues noted above and their relevance to the customer's concerns regarding water service in the vicinity of 136th Avenue and Main Street.

Water System Planning that Addresses Growth and Existing Customers

Discussion

Basic considerations in the planning and design of a water distribution system include: 1) the topography (elevation) of the area to be served, 2) maximum water demands and location where the demands will occur, and 3) the size and layout of the distribution system pipelines. While water demands and their locations provide insight into the size of the distribution system, topography helps define the geographical boundaries of the distribution system and the resulting pressures with an individual service area. The following paragraphs illustrate how topography combined with distribution system facilities define the framework of the distribution system necessary to deliver safe drinking water to the consumers in sufficient quantities and operating pressures.

Distribution system planning and design criterion for pressure typically ranges from a minimum service pressure of 35 psi to a maximum of 120 psi. This criterion is based on the pressure in the pipeline supplying water to the customer. Broomfield's system uses 43 psi and 125 psi as the minimum and maximum pressures. The minimum pressure criteria consider items such as: 1) operating pressures for fire trucks (pumper trucks) and 2) the service pressure within the public water system that meets typical customer demands. The maximum pressure criteria considers the structural capabilities of the distribution system pipes within the public water system as well as acceptable operating pressure of plumbing fixtures within the customer's private water system. In most instances, water system pressures are a reflection of the elevation difference between the nearest water storage tank and the customer. For example, as elevation decreases down hill from a water storage tank, the water pressure increases. As a result, the first step in the planning of a water distribution system is to use the area topography to define the upper and lower elevation of a given service area that falls within the criteria of acceptable pressures. The geographic boundary of a service area is also called a pressure zone.

Establishing system water demands and location of the demands are the next step in the planning of a distribution system. Typically municipalities have a Land Use Plan that can be used to estimate the resulting water demand based on land use densities and population. Broomfield has the 2005 Broomfield Comprehensive Plan that performs is used to perform this function. Even though a property could be currently undeveloped, the Land Use Plan indicates the anticipated land use and can then be used to estimate the resulting water demand.

Once the individual pressure zone boundaries and water demands of a distribution system have been identified, the facilities required to supply these areas can be designed. A distribution system typically contains pipelines, water storage tanks, and pump stations. Water is normally pumped to the high elevation side of an area into a storage tank and allowed to flow back down hill to the lower elevation side of the pressure zone. As the level of water within a storage tank decreases from the water usage, it creates a minor reduction in the distribution system water pressure. These minor fluctuations constantly occur in a water distribution system, which are typically undetectable by the water customer.

Broomfield System

In the Broomfield system, there are two primary pressure zones; East Zone and West Zone. The East Zone is at a lower elevation than the West Zone (refer to Figure 1 for an overview of the areas served by the East and West Zones).

Pressures within the East Zone are influenced by the finished water pumps at the Broomfield Water Treatment Plant (WTP) which deliver treated water to the distribution system and into the Carbon Road Tanks. These pumps increase the pressure of the water to deliver it to a higher elevation thus

filling the Carbon Road Tanks. Thus the water pressure is *higher* near the WTP and *lower* as the system increases in elevation toward the Carbon Road Tanks. The distribution pressures within the East Zone are controlled by the Carbon Road Tanks elevation and the topography of the region extending toward the Northwest Parkway and I-25.

Pressures within the West Zone are influenced by the Carbon Road Pump Station (CRPS) which receives water from the Broomfield WTP. The CRPS then increases the pressure of that water to deliver it to a higher elevation of the West Zone thus filling water storage tanks like the Airport Tank and Interlocken Tank. The pressure within the distribution system pipelines is *higher* near the CRPS and *lower* as the system increases in elevation toward the water storage tanks. The CRPS and receiving storage tanks then serve customer demands within the West Zone.

Due to the pumping and storage facility influences noted above, the higher elevation West Zone is hydraulically isolated from the lower elevation East Zone. As a result, demands and distribution facilities in the East Zone do not affect customer pressure in the West Zone since the West Zone is influence by the CRPS and associated West Zone storage tanks.

Most of the future growth in Broomfield will occur in the East Zone. As property develops, new pipelines and other facilities will be required to be constructed by the developments. These new facilities are required to be built so the new development will not affect existing water customers.

Criteria and Standards

Below is a summary of applicable criteria that are used in defining pressure zones and the resulting pressure necessary to meet typical customer demands.

1. 10 States Recommended Standards for Water Works. This document identifies that a system shall be designed to maintain a minimum pressure of 20 psi at ground level at all points in the distribution system under all conditions of flow. The normal working pressure in the distribution system should be approximately 60 to 80 psi and not less than 35 psi.

2. The City & County of Broomfield, Standards and Specifications. This document identifies distribution system pressures to be between 43 psi and 125 psi.

3. Design Criteria for Public Water Systems, Colorado Department of Public Health and Environment. This document identifies the "normal working pressure within a distribution system should be approximately 60 psi, and not less than 35 psi." The document also identifies that "when static pressures exceed 100 psi, pressure reducing devices should be provided on mains in the distribution system."

4. Standards and specifications for 14 communities along the Colorado Front Range were surveyed. Water pressure criteria ranged from 30 psi to 150 psi. The average over the communities surveyed resulted in a minimum of 39 psi with a maximum of 122 psi.

Findings

Distribution system static pressures within the West Zone are anticipated to range from 60 psi to 115 psi based on a review of Broomfield's water distribution system model. The citizen who had concerns about the system is located within the West Zone where the system pressure was measured continuously for 4-days (09/08/2007 – 09/12/2007) at a nearby fire hydrant. The average measured pressure during that four-day period was approximately 78 psi ranging from 74 psi to 80 psi over the period monitored. The water distribution system model predicts a distribution system pressure of 76 psi during a fire flow simulation of 3,500 gpm with maximum day demands. Based on our review we have found that:

- The measured pressures at the location in question are well within industry standards and design criteria and can be expected to meet residential customer demands. In addition the

pressures predicted by Broomfield's water system computer model for the same area are also within industry standards and design criteria.

Growth and increased water demands have primarily occurred within the East Zone, toward the Northwest Parkway and I-25. Broomfield's water system computer model has been used to develop pipeline and storage tank improvement recommendations within the East Zone that have influence on meeting demands and pressure criterion to serve the growth within that zone. Using the water system computer model as a distribution system planning tool, future growth can be served while maintaining or improving the level of service to existing customers. Based on our review we have found that:

- The West Zone is hydraulically isolated from the lower elevation East Zone. Therefore increased demands or distribution system improvements in the East Zone will not affect water distribution system pressure or service to existing customers in the West Zone. Further, Broomfield has installed, or required the installation, of new pipelines sized for new developments based on anticipated the development land use to maintain or improve the level of water services to customers in the east zone.

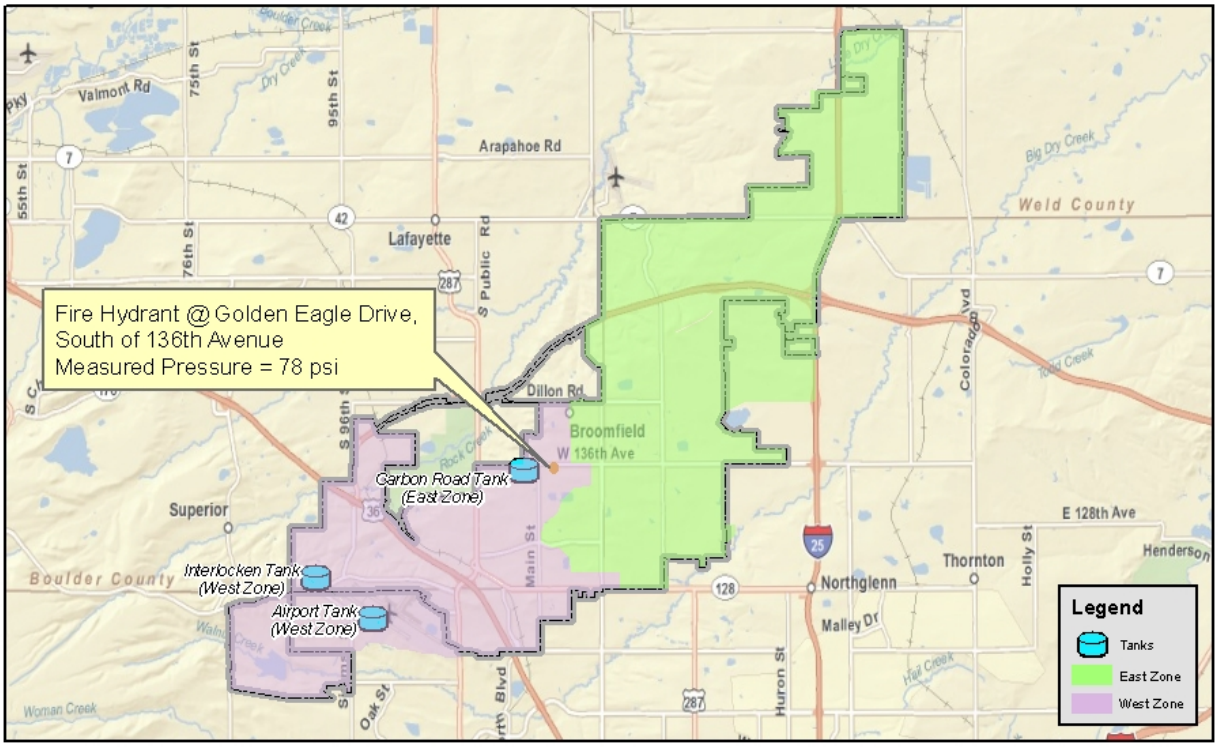

Figure 1 – Pressure Zone Overview

Distribution System Design, Operation and Resulting Fire Flows

Discussion

In planning and design of a water distribution system to meet fire flows, once the pressure zone boundaries are defined, distribution system sizing and configuration is the next key strategy in delivering water to meet customer needs. The distribution system pipe size and configuration of the pipe network are directly related to the quantity of water the system needs to deliver. Generally speaking, higher demands result in larger pipes. The amount of water a distribution system must deliver is made up of two components: customer water demand and fire flow demand. Typically, a distribution system is sized and configured to supply the combination of the peak day customer demand plus the fire flow demand. In most distribution systems, a majority of the line sizes are driven by the fire flow demand as it significantly exceeds the domestic demand at a given location.

An efficiently configured distribution system network looks to create a grid of larger diameter pipes (diameters $\geq$ 16") to serve as the main delivery system. These larger diameter pipes are referred to as the transmission system which carries higher flows with less friction (pressure) loss. Smaller diameter pipes (8" and 12") connect to the transmission pipes in a grid pattern to serve customer demands and make up the local distribution system. A key consideration for the local distribution system is to have at least two connections to the transmission system. This is referred to as "looping" which provides redundancy in the local distribution system for maintenance considerations and increases the system ability to meet peak day demands plus fire flow demands by producing two water flow paths to each customer.

Broomfield System

A good example of a typically configured distribution system, within the Broomfield system, is located near 136th Avenue and Main Street (Figure 2). A 16" transmission main is located in Main Street and the local distribution system is looped with an 8" pipeline in Red Tail Drive and Golden Eagle Drive and a 12" pipeline in 136th Avenue. The 12" line provides additional strength to the system in this location. There are multiple connections to the transmission main that serves the area.

One of the primary engineering tools in sizing and configuring the distribution system is the use of computer based water system hydraulic models. These computer models allows for the engineer to simulate how the distribution system responds to water demands, including fire flow demands. This tool provides an efficient means in evaluating system pressures, pipeline flow rates, and available fire flow for the existing distribution system as well as future demands and recommended improvements to serve the demands. The water system hydraulic computer model also helps make operational decisions such as regulating system pressure, pumping operations, supply strategies, etc. Broomfield has been using a computer based hydraulic model for system planning and design for the past 23 years. This model has been used by Bromfield to size pipeline improvements to meet projected peak day demands and fire flow demands.

Broomfield Public Works and the North Metro Fire Rescue District also perform fire flow tests to obtain physical measurements of the system pressure and available flow rates at the fire hydrants. These fire flow tests are considered an excellent way to evaluate the performance of the distribution system in meeting system demands as the water system is operating under stress and would then magnify problems within the system.

Criteria and Standards

Below is a summary of applicable fire flow criteria that are used in distribution system design and in evaluating system performance.

1. The City & County of Broomfield, Standards and Specifications. This document identifies the minimum fire flow for the distribution system to provide as:
    a. Pressure at a fire hydrant during a fire flow test is required to be a minimum 20 psi residual pressure (pressure while the flow is occurring).
    b. The rate of fire flow for single-family residential detached dwelling and duplexes is 1,500 gpm
    c. The rate of fire flow available for all other buildings is 3,500 gpm
2. 2003 International Fire Code. This document identifies a minimum fire flow of 1000 gpm for residential subdivisions with single-family or duplex dwellings having dwelling area of 3600 square feet or less.

Findings

Broomfield's distribution system has been designed and analyzed using standard of practice engineering tools and criteria. The distribution system serving the citizen who had concerns about the system, is well looped and in close proximity to an existing water transmission main. Based on our review we have found that:

- The distribution system at the location in question meets the industry standard of practice as it provides redundancy to account for potential maintenance activities and is sized appropriately to meet domestic and fire flow demands.

Fire flow tests were performed at a fire hydrant on Golden Eagle Drive, shown on Figure 2, in March 2005 and resulted in a measured flow rate of 3200 gpm at 65 psi residual pressure. It should be noted the 65 psi pressure well exceeds the minimum 20 psi residual pressure indicating there is additional capacity within the system to meet increased demands while still meeting the fire flow criteria. Based on our review we found that:

- The distribution system at the location in question delivers fire flows that far exceed Broomfield criteria and other industry standards.

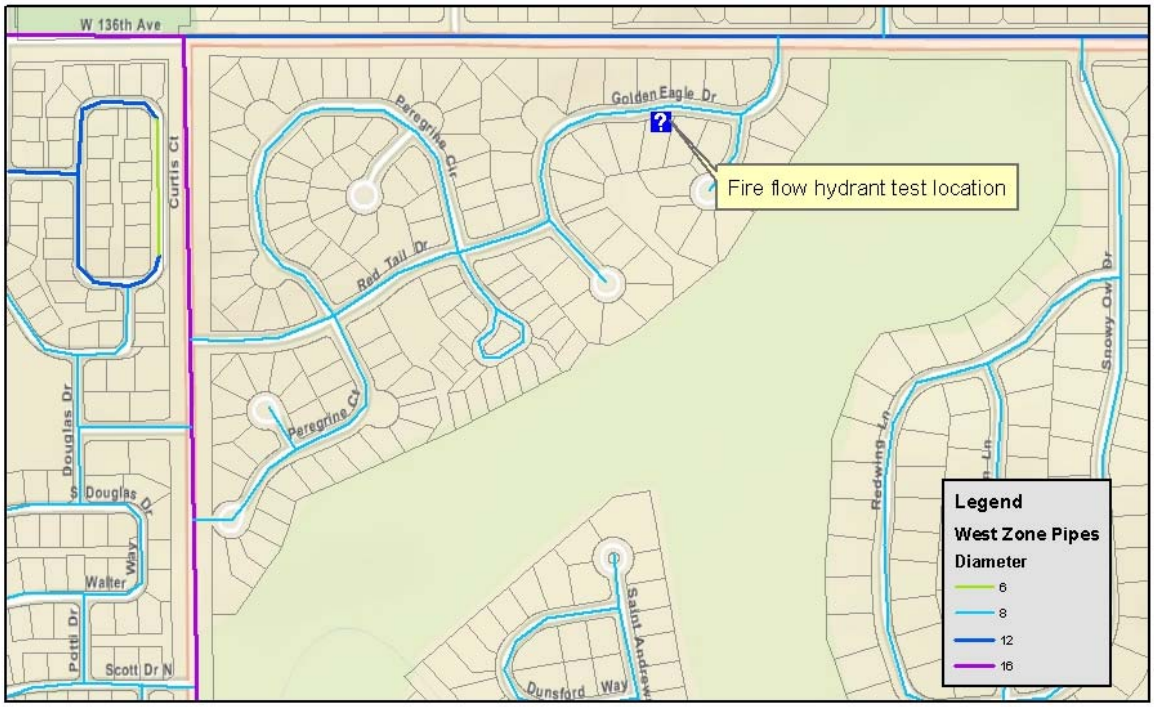

Figure 2 – Distribution System near 136th and Main

Water System Operations Providing Pressures at the Customer's Meter and Home

Discussion

Typically, the limits of municipal or agency responsibility for water distribution systems include water mains and customer water service lines up to the customer's property line. Beyond the property line and into the customer's structure is the property owner's responsibility. The limits of water system operations, maintenance and construction are shown graphically on Figure 3 as obtained from City & County of Broomfield, Standards and Specifications.

The size of the water service line and meter are determined by the customer's water demand. Typically, along the Front Range, single-family residential customers have a 3/4" service line and a 3/4" x 5/8" meter. Water demands flowing through the service line and meter depend on the account/customer type (e.g. residential, commercial, etc.) and the anticipated water use. In the City & County of Broomfield, Standards and Specifications, Broomfield defines typical water demands that are used in distribution system planning. For residential customer types, average day unit water demands are estimated at 145 gallons per person per day. Using Broomfield design flow requirements and assuming an average of 3 people per single-family residence, the resulting instantaneous peak demand can range between 1.75 gpm to 7.0 gpm. The 1.75 gpm value assumes the peak demand occurs across a 1-hour time frame. The 7.0 gpm value assumes the peak demand is compressed within a 15-minute time frame. For the 7.0 gpm demand scenario, the type of fixtures operating simultaneously would equate to toilet, shower, sink and dishwasher.

Water demands can also be estimated using information from the Uniform Plumbing Code (UPC). Many communities along the Front Range have plumbing fixture worksheets based on the UPC that can be used to estimate demands if all fixtures are on. For example, water demands for a 2,000 ~ 2,500 square foot home can be estimated assuming typical fixtures that may include two full bathrooms, a half-bath, dishwasher, clothing washer, etc. Using a UPC based plumbing fixture worksheet, with all fixtures turned on, the resulting peak demand estimate for a 2,000 ~ 2,500 square foot home could range between 16 and 20 gpm. A 20 gpm demand would include the fixtures noted above in addition to 3 outside hose bibs operating. This water demand estimate process is typically used for selecting the appropriately sized meter to account for peak flow through the meter. A review of the Badger 25 specifications (3/4" x 5/8" meter required by the Broomfield Standards) indicates the peak 16 – 20 gpm demand range noted above is within the operating characteristics of the meter. The pressure loss in the meter at a 20 gpm flow rate is approximately 6 psi based on the manufacturer's specifications.

Broomfield System

Pressure loss between the distribution system pipeline and the customer depends on the flow rate, service line diameter and meter size. Generally, higher demands (e.g. flow rate) result in higher pressure loss within the service line system. Within Broomfield's system, when pressures exceed 80 psi at the residence a pressure reducing valve (PRV) is recommended. Many builders install a PRV since Broomfield's water distribution system operates at pressures that meet this requirement when they test the system during construction. The PRV reduces the higher distribution system pressure to a user defined setting of around 50 to 70 psi which is typically more compatible with residential plumbing fixtures. Figure 4 provides a graphical representation of pressure losses between the distribution system pipe line and a residential customer. Note this figure is more specific to the residential customer with pressure concerns as it shows the 3/4"x3/4" meter that was installed by Broomfield and the PRV.

Referring to Figure 4, the starting pressure within the system at the pipe line in the street is 78 psi as measured during the previously noted fire flow tests. The fire flow tests also showed that system pressure does not fluctuate much as it is controlled by the West Zone storage tanks and strength of the distribution system. There are two pressure profiles shown on the figure based on: 1) an all-fixture-on demand of 20 gpm and 2) an estimate of typical instantaneous peak demand using Broomfield design flow requirements of 7 gpm. Key findings from the pressure profile comparison are noted below:

- As shown on Figure 4, the 20 gpm pressure profile results in significantly more pressure loss through the service line system than the 7 gpm profile. The following pressures were calculated at the outlet side of the meter, before the PRV:
  - Pressure at residence (20 gpm) = 56 psi
  - Pressure at residence (7 gpm) = 74 psi
- Even under the very conservative 20 gpm demand scenario, the pressure exceeds the high-end 50 psi private PRV setting thus indicating the distribution system and service line are functioning well within industry standards.
- Pressure loss through the meter accounts for approximately 15% of the total pressure loss.
- A 5/8" x 3/4" meter has approximately 1.5 psi additional pressure loss that a 3/4"x 3/4" meter within the flow ranges evaluated. As a result, the Broomfield standard 5/8" x 3/4" meter can be considered to function essentially the same as the 3/4"x 3/4" meter in this instance.
- Under the more typical 7 gpm flow profile, there is very little pressure loss through the system indicating the level of service for system pressure is well within industry standards.

At the residence in question, there also exists a lawn irrigation system supplied by the from the residence's potable water system. Irrigation systems are installed after the meter and can cause a large draw on a water system in addition to the domestic demand. Lawn irrigation demands are not included in the above pressure and demand estimates and it is not reasonable to consider irrigation demands to be met in addition to the 20 gpm, an all-fixture-on demand scenario without experiencing noticeable drop in system pressure.

There are other factors within the private plumbing system that may impact service pressures at the fixtures. Factors within the private interior plumbing system that impact pressure include bends, valves, corrosion, length of pipe, and pipe diameter to name a few. Within a typical modern plumbed home, 1/2" copper is a standard size and material for interior plumbing. If a home owner is concerned about minimizing pressure loss under a high flow, all-fixture-on demand scenario, the interior plumbing system size can be increased to 3/4" or even 1" diameter pipe. However, this practice can be expensive for a home owner and may provide limited benefit considering the infrequency of an all-fixture-on scenario.

Criteria and Standards

1. The City & County of Broomfield, Standards and Specifications. This document identifies the limits of Owner and Broomfield responsibility with respect to water service line ownership (see attached detail drawing). In addition, this document also identifies design flow requirements, service line size and meter specifications.
   a. Residential Unit Water Demands: 145 gallons/capita/day, 3.05 max.day/avg.day peaking factor, 1.9 peak hour/max.day factor.
   b. Service Line: 3/4" Type K Copper
   c. Meter: 5/8"x3/4" (Bader Model 25)
2. Residential meter standards and specifications for 12 communities along the Colorado Front Range were surveyed and resulted in a 5/8"x3/4" being the standard meter size.

Findings

Broomfield has outlined the limits of responsibility between the customer's water system and the Broomfield system in the design standards and specifications document. The limits of system responsibility are consistent with those defined for similar sized Front Range communities. In addition, the 5/8"x3/4" meter specification is consistent with similar sized Front Range communities. Based on our review we found that:

- The City & County of Broomfield, Standards and Specifications provide a clear definition of water system responsibility and specifies facility components (meters, service lines, etc.) that are consistent with industry standards and other Front Range communities.

As noted previously in this document, Broomfield provides distribution system pressures that are well within industry standards.

- These distribution system pressures combined with the residential meter and service line sizing provide operating pressures that are expected to meet customer demands. At the residence in question, the Broomfield water system provides a high level of service that can be expected to meet above average residential customer demands.

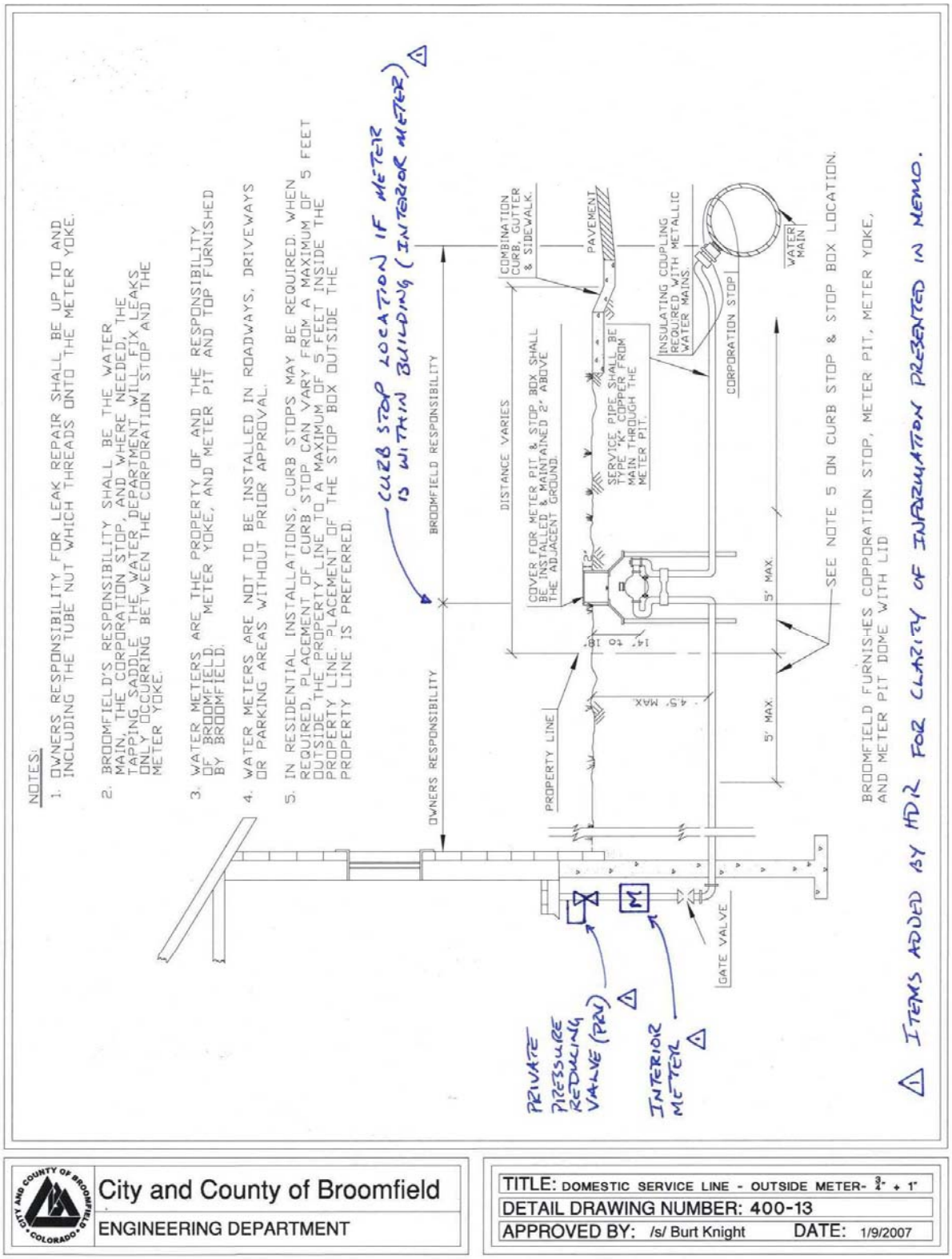

Figure 3 – Limits of Broomfield and Customer Service Line Responsibility

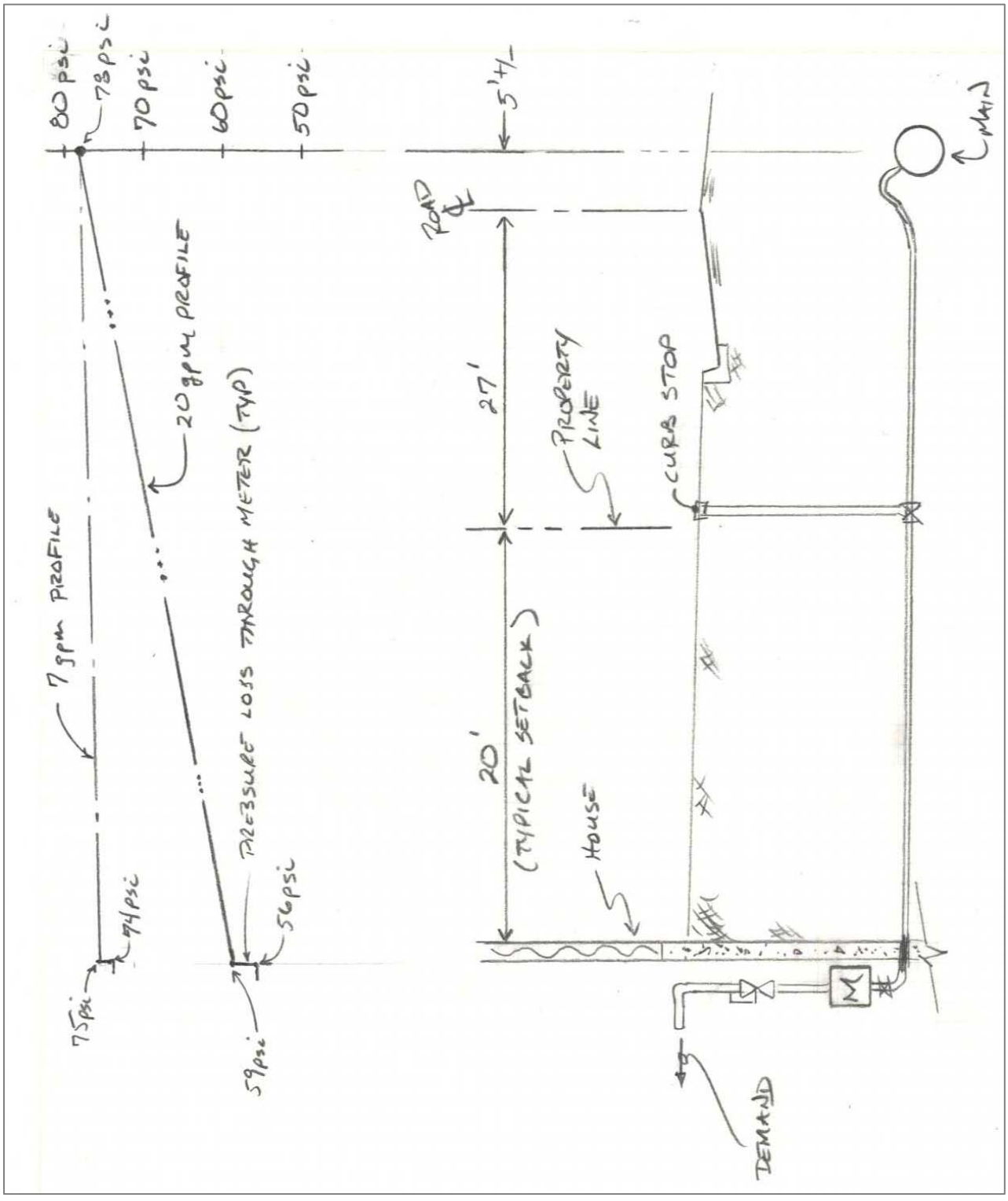

Figure 4 – Pressure Profile for Residential Water Service