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TECHNICAL MEMORANDUM

DATE: March 22, 2016

PROJECT: 14-1543.0404

TO: City of Bend, Oregon

FROM: Murray, Smith & Associates, Inc.

RE: On-Call Modeling, Development of Country Club Road Area and Proposed Elimination of the Former Juniper Utility, Tillicum Village and Nottingham from the City of Bend Water Distribution System

Background

Several areas that are located in the southeast part of the City and currently served by the City of Bend (City) Water Distribution System are under consideration for sale to private water systems. These include parts of the Former Juniper Utility as well as some surrounding properties. The areas under consideration for sale are listed below and shown in Figure 1:

- Stonegate
- The former Juniper Utility
 - Tillicum Village
 - Timber Ridge
 - Mountain High
 - Nottingham Village

This analysis was performed to determine the impact related to providing water service to the remaining and future City customers if these areas are sold. In some areas important piping and supply will be eliminated through the sale. With the sale of the former Juniper Utility area, the City will sell the Hole 10 Well facility and transfer those water rights to other City

wells. Existing Avion service area customers currently served by the City will also be eliminated. The City will however maintain ownership of the following facilities:

- Murphy Pump Station
- Shilo Well Facility
- 16-inch pipeline from Shilo Well Facility along Country Club Road to High Lead Drive
- Parallel 12-inch pipelines, one connecting Shilo Well to Pressure Zone 4B, and one connecting Murphy Pump Station to Zone 2B

This analysis also includes the evaluation of growth and development in several areas in the vicinity of Murphy Road. These areas include:

- JL Ward Co. near Country Club Road
- Deer Ridge (near Country Club Road and Brosterhous Road)
- Area adjacent to Shilo Well (Near Murphy Road and Country Club Drive)
- Future School Site and adjacent undeveloped area
- Existing School Site with adjacent undeveloped area
- The Pines
- Crown Villa
- Hidden Hills

This evaluation includes a change to the boundary of Zone 4B. Some areas currently served through zone 4B are changed to service through the Murphy Pump Station. In addition to new development in the JL Ward property, Deer Ridge, Shilo Well area and the future school site, several existing developments including The Pines, Hidden Hills, and Crown Villa will be served from Zone 3D. An overview of the study area, existing and future developments, and the City's distribution network is shown in Figure 2.

Distribution System Analysis Description

The elevation range for areas to be evaluated as part of this analysis and their existing pressure zones are presented in Table 1. Several existing areas currently served by Zone 4B are proposed for service through Zone 3D. The hydraulic grade line (HGL) for Zone 4B is 3,867 to 3,880 feet as established by the water surface in the Rock Bluff 1 Facility. The recommended HGL for the reconfigured Zone 3D is 3,933 feet.

Table 1| Summary of Development Elevations

Area	Min Elevation (feet)	Max Elevation (feet)	Existing Pressure Zone	Proposed Pressure Zone	Comment
JL Ward Co.	3,742	3,780	3D	3D	Proposed Service through Murphy PS
Deer Ridge	3,752	3,780	4B	3D	Proposed Service through Murphy PS
Adjacent to Shilo Well (SE corner of Country Club Dr and Murphy Rd)	3,756	3,776	3D	3D	Proposed Service through Murphy PS
The Pines	3,740	3,780	4B	3D	Rock Bluff WSE 3,859 ft at half full = 34 psi at max elevation, Proposed Service through Murphy PS
Hidden Hills	3,746	3,780	4B	3D	Rock Bluff WSE 3,859 ft at half full = 34 psi at max elevation. Proposed Service through Murphy PS
Crown Villa	3,744	3,780	4B	3D	Rock Bluff WSE 3,859 ft at half full = 34 psi at max elevation. Proposed Service through Murphy PS
Future School	3,752	3,780	3D	3D	Proposed Service through Murphy PS
Existing School	3,738	3,756	4B	4B	Proposed service in 4B

Note 1. psi = pounds per square inch

Demand Development

The distribution system was evaluated under existing and build-out demands with full development of areas potentially served by the Murphy Pump Station. During each of these stages of development, demand will vary over the course of a day (diurnal demand variation) as well as over the course of a year. Peaking factors are used to convert average day demand (ADD) to other design demands under which system performance is evaluated. Design demands are defined below:

1. Average Day Demand (ADD): This is the average annual water demand in the system. It represents the lowest rate of demand used to analyze system pressures. This demand rate is used to identify the highest potential pressures expected in the system.

2. Maximum Day Demand (MDD): This is the average daily demand on the day of highest demand during the year or years analyzed. Often the design maximum day demand is identified by looking at the ratio between the ADD and the MDD for more than one year. A design ratio is selected and that ratio is applied to the design ADD to determine the design MDD.
3. Peak Hour Demand (PHD): This represents the average demand on the hour of highest usage during the year. This value is also determined typically by looking at system wide diurnal usage patterns during periods of high use. The peaking factor of PHD to the daily average determines the ratio of PHD to MDD.
4. Low Flow (Low): Diurnal variation in demand over the course of a day was identified in the City as part of the 2010 Water Master Plan (WMP). The diurnal pattern of demand is characterized by 24 individual hourly factors. The lowest diurnal pattern factor multiplied by the daily demand provides the lowest design demand. This low demand is used to evaluate the operation and efficiency of pumps during low demand time periods and may vary throughout the year.

The peaking factors for MDD and PHD, as well as the ratio of low flow to ADD were developed as part of the WMP based on data from 2008 and 2009, and are shown in Table 2.

Table 2| Summary of Demand Peaking Factors

Demand Ratio	Value
Low : ADD	0.5
MDD:ADD	2.25
PHD:MDD	1.8

Table 3 provides ADD demand rates developed as part of the WMP and applied in this analysis to new development areas. These demand rates are applied in areas where more detailed information about the number of units to be served is not yet available.

Table 3| Unit Demand Rates for Average Day

Land Use Category	Units per Net Acre	Average Day Unit Demand (gpad)^{1,2}
Very Low Density Residential	2	836
Low Density Residential	4	1,672
Medium Density Residential	6	2,508
High Density Residential	10	4,180
Non-Residential	-	4,000
Schools	-	4,000

Note 1. Gallons-per-acre-per-day (gpad)

Note 2. Residential demand based on 418 gallons-per-unit-per-day x number of units.

Table 4 summarizes the specific build-out demands developed and applied during this analysis. The estimate of ADD from DOWL (Engineering Consultant) for development on the JL Ward Co. property was used in this analysis (74.4 gallons-per-minute, gpm). DOWL provided an estimated density of 5.2 residential dwelling units per acre for the 48 acre residential development. Based on the total acreage and development density, approximately 250 units are expected. The planning level ADD for this number of residential units is approximately 72.6 gpm, at the planning rate of 418 gallons per unit per day. The water demand estimate provided by DOWL (74.4 gpm) for this development includes a 4-acre irrigated park. This ADD is also slightly higher than the WMP developed demand for the area of 71 gpm.

Information available from the City for the Deer Ridge development indicates 86 units are to be developed. The total demand for this area was adjusted from the original WMP demand based on the number of lots platted and the design demand rate of 418 gallons per unit per day.

Table 4| Build-out Demand Summary

Area	ADD (gpm) ^{1, 2, 3}	MDD (gpm) ⁴	PHD (gpm) ⁴
Murphy Pump Station Service Area			
JL Ward Co.	74.4	167	301
Deer Ridge	25	56	101
The Pines	133	299	539
Hidden Hills	25	56	101
Crown Villa	46	104	186
Future School and Undeveloped	121	272	490
Adjacent to Shilo Well	30	68	122
Total	454	1,022	1,840
North of Murphy Pump Station Service Area			
Existing School and Undeveloped Area	50	113	203

Note 1. Gallons-per-minute (gpm)

Note 2. Incremental values, except for total.

Note 3. Based on specific land use, demand factors, and projected units x 418 gallons-per-unit- per-day where projected unit data is available. Based on 4 units/acre x 418 gallons-per-unit-per-day where projected unit data is unavailable.

Note 4. $MDD = ADD \times 2.25$; $PHD = MDD \times 1.8$

The system was evaluated for three demand scenarios as described below.

1. *Existing System Demands* – Estimated 2015 system demands
2. *Near-term Demands* – The full build-out demands were applied to the proposed Zone 3D Murphy Pump Station service area as shown in Figure 2. The properties served and their demands are consistent with those presented in Table 4. The demand associated with full development of the Undeveloped/Existing School area in pressure Zone 4B was also applied (Shown in Figure 2), as potential near-term growth. Estimated 2015 demands were applied throughout the rest of the system.

3. *Build-out Demands* – The full build-out demands were applied to the proposed Murphy Pump Station service area (Zone 3D) and other projected build-out development within the Urban Growth Boundary (UGB).

Design and Performance Criteria

Table 5 outlines the design criteria used to evaluate system performance under design demand conditions. The relevant design and performance criteria applied in this analysis are consistent with the criteria applied in the WMP including system pressure during ADD, MDD, and PHD demands, and available fire flow during MDD.

Table 5| Summary of Design Criteria - Pressure

Category	Water System Master Plan Criteria	Applicability or Exceptions
Minimum Allowable Service Pressure	40 psi	To be maintained under ADD, MDD and PHD demand conditions at service locations.
Maximum Allowable Service Pressure	80 psi	Existing service pressure maximum without individual PRVs
Maximum Allowable Service Pressure New Development	80 psi preferred, 120 psi with individual PRVs	Individual PRV's may be used to reduce pressure if needed in areas of existing and new development.
Minimum Service Pressure During Fire Flow Conditions	20 psi	Evaluated under MDD conditions. This criteria is considered applicable where service connections exist.

Existing minimum pressures may be lower than 40 psi at several locations throughout the system such as transmission lines that do not directly supply service. These may also include the areas near water storage tanks and near the suction side of booster pump stations. The WMP describes locations for which pressures in the range of 30 to 40 psi are expected. Minimum pressures associated with this analysis include the transmission pipeline from Rock Bluff 1 Facility.

Table 6 provides the required fire flow for residential, non-residential and school facilities. These requirements are consistent with fire flow requirements used in the WMP. The areas within the proposed Murphy Road Pump Station service area (Zone 3D) are primarily residential except for the school site(s).

Table 6 | Summary of Design Criteria – Fire Flow

Category	Fire Flow Requirement (gpm)
Residential	1,500
Non-Residential	2,500
School	2,500

The hydraulic model was evaluated under steady state conditions to determine resulting pressures and flows in the system under specific demand scenarios (eg. ADD, MDD, PHD).

System Boundary Conditions

Table 7 provides a summary of boundary conditions used in this analysis to evaluate PHD and MDD + fire flow. Boundary conditions define the operations and status of facilities, such as reservoirs and pump stations. Boundary conditions are used together with network and demand information to determine system performance.

Table 7 | Model Boundary Conditions

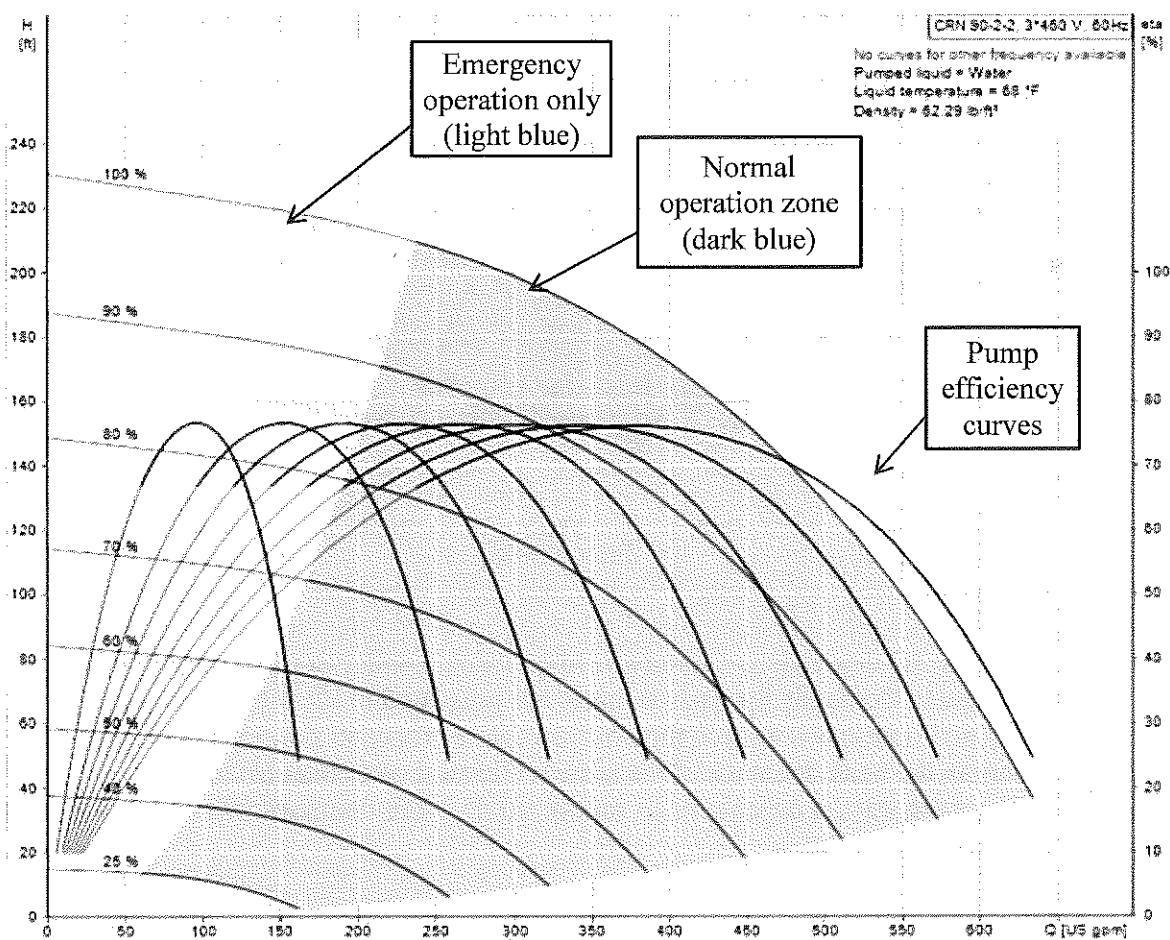
	Existing Conditions	Build-out Conditions
Wells/Pumps	Shilo Well 3 – OPEN (900 gpm) Rock Bluff Well 1 - OPEN Rock Bluff Well 2 - CLOSED Rock Bluff Well 3 - OPEN Bear Creek Well 1 - OPEN Bear Creek Well 2 – OPEN Scott Street Pump Station – OPEN (largest pump out of service) Murphy Pump Station – OPEN (116 psi, one pump out of service)	Shilo Well 3 – OPEN (1,900 gpm) Rock Bluff Well 1 - OPEN Rock Bluff Well 2 - CLOSED Rock Bluff Well 3 - OPEN Bear Creek Well 1 - OPEN Bear Creek Well 2 – OPEN Scott Street Pump Station – OPEN (largest pump out of service) Murphy Pump Station – OPEN (116 psi, one pump out of service)
Reservoirs	Rock Bluff 1 – 3859 feet (50-60% full) Pilot Butte 2 – 3859 feet (50% full)	Rock Bluff 1 – 3,859 feet (50-60% full) Pilot Butte 2 – 3,859 feet (50% full)

The pipeline network adjacent to the Shilo Well Facility has been improved since construction of the well including a 12-inch pipeline connection to Zone 4B which reduced headloss associated with conveying flow to the pressure zone. The original well pump was not replaced, and as a result has the potential to operate outside of the efficiency point on the pump curve while supplying flow to Zone 4B. To prevent damage to the pump, a pressure sustaining valve was used at the well to create back pressure at the pump discharge. Flows of 1,200 gpm may be produced from the well when the pressure sustaining valve is not in

use, however this analysis assumes the well is controlled to not exceed the best efficiency point of 900 gpm. For the build-out analysis, recommended capacity improvements from the WMP are implemented at the Shilo Well Facility including increased water supply up to 1,900 gpm firm capacity.

Murphy Pump Station currently includes five (5) 25-hp variable frequency drive (VFD) pumps set to maintain 116 psi [4016 feet hydraulic grade line (HGL)] at the discharge side of the pump station. Each pump produces approximately 400 to 600 gpm. The pumps are set to shut down for 30 seconds at speeds below 40 Hz. Based on the design drawings, the pump station also has three (3), 36-inch diameter bladder tanks (unknown height, volume and working pressures). Typically bladder tanks are sized to deliver flows at rates lower than the pump curves manufacturer recommend operating range. Figure 3 shows the manufacturer recommended operating range for the Grundfos CR 90-2-2 pumps.

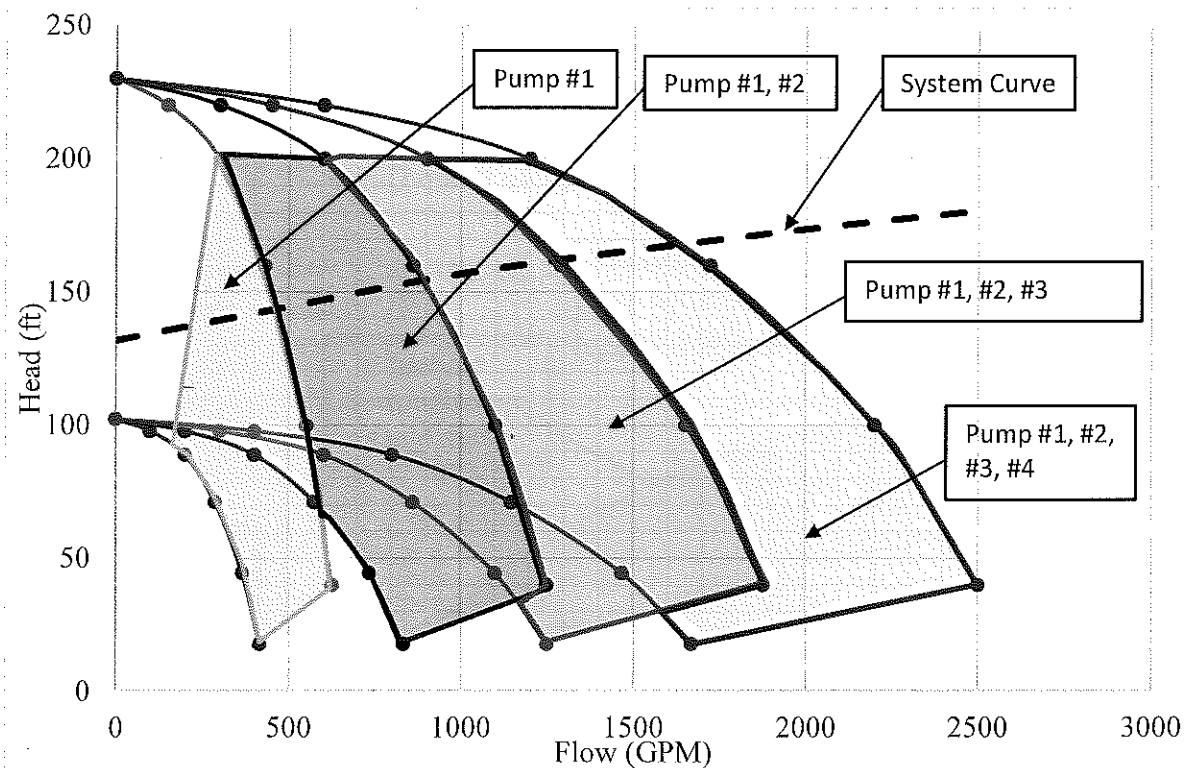
Figure 3. CR 90-2-2, 25-Hp Pump Curve



Murphy Pump Station Operation and Capacity

The Murphy Pump Station was evaluated for use in serving the modified pressure Zone 3D boundary and a range of system demands. Using the pump curve presented in Figure 3, the total composite pump curve for Murphy Pump Station is shown in Figure 4. An approximate system curve is also shown in Figure 4 and was developed using the assumed constant discharge pressure of 116 psi.

Figure 4. Murphy Pump Station System Curve and Composite Pump Curve



The proposed Zone 3D demands are summarized in Table 8 under existing, near-term, and build-out conditions. Demands for each scenario are presented to identify the required pump station capacity and operations at each time horizon. For proposed Zone 3D, storage is not available to supply the peak demands of the system (flows greater than MDD); however, the requirement for pump station capacity is to supply MDD + fire demands with the largest pump out of service.

Table 8| Murphy Pump Station Demands and Capacity

Demand Condition	Existing ¹	Near-term	Build-out	Capacity Notes
ADD (gpm)	100	454	454	At 100 gpm a single pump is operating below manufacture recommendations. Suction side pressure 55 psi, discharge 116 psi (141 feet).
MDD (gpm)	225	1,022	1022	1,600 - 2,400 gpm firm capacity ²
PHD (gpm)	405	1,839	1,839	1,600 - 2,400 gpm firm capacity ²
MDD + 1,500 Fire (gpm)	1,725	2,522	2,522	1,600 - 2,400 gpm firm capacity ²
MDD + 2,500 Fire (gpm)	2,725	3,522	3,522	1,600 - 2,400 gpm firm capacity ²
Diurnal Low Flow (gpm)	< 25	227	227	At <25 gpm a single pump is operating below manufacture recommendations. Suction side pressure 55 psi, discharge pressure 116 psi (141 ft)

Note 1. Existing service area associated with reconfigured Zone 3D.

Note 2. Firm capacity of 1,600 gpm at 116 psi discharge pressure. Firm capacity of 2,400 gpm at low discharge pressure.

With the sale of the former Juniper Utility and proposed changes to the Murphy Pump Station service area, existing low demands in the proposed Zone 3D are estimated at less than 25 gpm. Figure 4 shows that the Murphy Pump Station will have difficulty meeting flows less than 200 gpm at 1141 feet of total dynamic head (TDH, see Figures 3 and 4). The existing pump station is not sized to deliver the head and flow range required by the proposed service area particularly for fire flow requirements greater than 1,500 gpm (school fire flow requirement is 2,500 gpm).

The long-term recommendation for the Murphy Pump Station is to replace all pumps with models that will pump efficiently to the recommended HGL for the reconfigured Zone 3D (3,933 feet). The pump(s) selection should be considered in a preliminary design analysis including redundant VFD jockey pump(s) for low flows, mid-size VFD pumps for the range of flows from ADD to PHD, and larger pumps for fire flow. The preliminary design should also consider suction pressure from Zone 4D, and potential space and mechanical constraints in the existing pump facility.

An interim improvement recommendation utilizing existing pumps is also provided below with limitations on available fire flow to less than 1,500 gpm. The interim pump station improvement recommendations should also be reviewed through a preliminary design

analysis to ensure adequate space and mechanical constraints in the existing facility and to verify existing bladder tank capacity. The interim improvements include the following:

1. Install a jockey pump for low flow demands and verify existing bladder tank capacity.
2. Utilize the five (5) existing pumps with VFDs to maintain 116 psi discharge pressure.
3. Install a control valve (combination pressure sustaining and pressure reducing) downstream of the Murphy Road Pump Station. The pressure reducing function will burn excess head and reduce maximum pressures to approximately 80-85 psi within pressure zone 3D. The sustaining feature should only be activated when four (4) or more pumps are operating to supply fire flow to Zone 4B. The sustaining feature is intended to maintain a minimum back pressure on the pumps to minimize risk of cavitation.
4. Provide supplemental fire flow from Zone 4B through a check valve near the Shilo Well Facility.

A preliminary analysis was performed to size the jockey pump and should be refined during preliminary design of improvements. Assuming the bladder tanks are 370 gallons and operated on an 8 psi pressure band as not to interfere with the VFD operation, the tanks are sized to provide up to 25 gpm flow while limiting the pump cycle to six starts per hour. Preliminary calculations indicate a 10 horsepower (Hp) jockey pump could be installed to provide flows to the proposed Zone 3D between 25 gpm and 200 gpm at 136 feet TDH. The size of the jockey pump was estimated using the hydraulic horsepower equation below:

$$W = \frac{h_A Q (SG)}{3965 (E)}$$

Where: W = Power (Hp) Q = Flow (gpm) E = Pump Efficiency
 h_A = Head (feet) SG = Specific Gravity Water

$$W = \frac{136 * 200 * (1.0)}{3965 (0.73)} = 9.39 \text{ Hp}$$

Consideration was given to using Shilo Well Facility as the primary supply for the proposed Zone 3D with the addition of pressure reducing valves (PRV) to limit the flow and pressure. However, this scenario creates a complex operational strategy when combined with control logic for filling and emptying the Rock Bluff 1 Facility. Additionally, the 900 gpm pump capacity at the Shilo Well is too large to serve the proposed Zone 3D under lower demand conditions. For this reason Murphy Pump station is recommended as the primary source of supply for the reconfigured Zone 3D.

Historically, some consideration has been given to placing a jockey pump at the Shilo Well Facility instead of the Murphy Road Pump Station. This option requires additional review and is only feasible if the jockey pump operates independently of Shilo Well 3.

Distribution System Analysis

Distribution system performance including evaluating pipe sizing and looping was conducted using the City's InfoWater hydraulic model under the following scenarios:

Existing Unimproved Conditions

This scenario includes the existing distribution system network and existing demands, without changes to service areas or anticipated growth. Under existing conditions the Shilo Well Facility is limited to 900 gpm capacity within Zone 4B, and the following WMP capital improvements have been completed according to City data provided in October of 2015:

- Existing 8-inch improvements through Tillicum Village on Mowitch Drive and Rae Road are active (to be sold).
- Existing 12 pipeline from Shilo Well Facility to Murphy Road and along Murphy Road to Brown Trout Place. The 12-inch pipeline conveys flow from the Shilo Well Facility to Zone 4B.
- Existing 16-inch pipeline between Murphy Pump Station and Brosterhous Road conveys water to the suction side of the pump station from Zone 4B.
- Existing 16-inch pipeline on Brosterhous Road, south of Murphy Road. This pipeline continues as an existing 12-inch pipeline south of Marble Mountain Lane. The line then becomes a 6-inch dead end pipeline when it enters Avion service area (6-inch pipeline to be sold).
- Existing 16-inch pipeline constructed from Shilo Well Facility along Country Club Drive to High Lead Drive.
- Existing 16-inch pipeline constructed along High Lead Drive (to be sold).
- Existing 12-inch pipeline improvement along Mountain High Loop (to be sold).

This analysis was conducted to provide context relative to what the existing pressure and flow availability is under the current system configuration. Under the existing system configuration (no new improvements) and existing demands, peak hour pressures may be lower than 40 psi in areas served by Zone 4B that are listed as part of the proposed Zone 3D. These include high elevation areas of The Pines and Hidden Hills. The existing areas of Crown Villa are at lower elevations and are not anticipated to experience pressures below 40 psi.

Existing peak hour service pressures may be lower than 40 psi in the Tillicum area (evaluated for removal in this analysis), and available fire flows are less than 1,500 gpm. Areas of inadequate fire flow also exist in the former Juniper Utility if served only from City facilities.

Existing (sold infrastructure) and Near-term Demands with Required Improvements

This scenario applies the proposed changes to service boundaries. These changes include the removal of areas considered for sale to Avion and Roats, and the use of improvements to serve higher elevation areas through Murphy Pump Station. The full build-out demand was applied to the area anticipating near-term growth in the proposed Zone 3D. Build-out demands were applied in this area so that improvements adequate to serve the system at build-out could be identified. Existing demands were applied throughout the rest of the system. The Shilo Well Facility is limited to 900 gpm capacity within Zone 4B. The following describes the status of capital improvements and new recommended improvements for the scenario:

- A 16-inch pipeline improvement to convey water from the discharge side of Murphy Pump Station to Brosterhous Road. This improvement connects to the existing 16-inch pipeline on Brosterhous Road, south of Murphy Road. Zone 4B is isolated north of this connection.
- 12-inch pipeline constructed as an extension from the existing 16-inch pipeline within Country Club Drive to the point of connection with 8-inch pipelines representing the JL Ward Co. development.
- 8-inch looped improvements are schematically included in this analysis to represent Deer Ridge and JL Ward Co. developments, connecting them and creating a loop between the existing 12-inch pipeline on Brosterhous Road south of Murphy Road and the 12-inch pipeline extension on Country Club Drive.
- A check valve is constructed between Zone 4B and the Murphy Pump Station service area (Zone 3D) near the Shilo Well Facility to supplement available fire flow.
- A New jockey pump and control valve at Murphy Pump Station (interim solution) or full pump replacements (long-term solution)

Results of this analysis indicate that pressure and fire flows in Zone 4B are adequate. With recommended improvements, pressures are higher for Hidden Hills and The Pines when served through Murphy Pump Station. The existing service area for Crown Villa does not reach the highest elevations present in the adjacent area, but full development of Crown Villa may benefit from service through Murphy Pump Station if higher elevation areas are developed. Results of both the Existing Unimproved scenario and Existing plus Near-term with the proposed service changes are summarized in Table 9. Fire flow for the unimproved system is less than 1,500 gpm. For the improved system with near-term demands and interim improvements at the Murphy Pump Station, approximately 1,500 gpm fire flow is available in Zone 3D while maintaining 20 psi residual except for the highest elevation areas (greater than 3,775 feet) as shown in Figure 2.

Table 9 | Existing and Near-term System Results

Scenario	Maximum ADD Pressure (psi)	Minimum PHD Pressure (psi)	Available Fire Flow (gpm, 20 psi Residual Pressure During MDD)¹
Existing Unimproved Pressure zone 4B South of Reed Market Rd.	70 psi	34 psi	<1,500 gpm (in areas to be removed)
Existing Unimproved Zone 3D	116 psi	55 psi	<1,500 gpm (in areas to be removed)
Near-Term Pressure Zone 4B South of Reed Market Rd. with proposed service changes	70 psi	40 psi	1,500 gpm
Near-Term Zone 3D with proposed service changes	116 psi	87 psi	<1,500 gpm

Note 1. Assumes Shilo Well Facility is not operating and largest Murphy Road Pump Station pump is out of service. See fire flow sensitivity analysis section of this document (Tables 11 thru 13 for alternate operational conditions).

Completed Capital Improvement Program (WMP, sold infrastructure) and Build-out Demands with Additional Capital Improvements

This scenario utilizes all capital improvements recommended in the WMP throughout the entire system, as well as the demand associated with full build-out of the Urban Growth Boundary. It also incorporates the proposed changes to service areas with removal of areas considered for sale to private water providers, and service of higher elevation areas south of Murphy Road through Murphy Pump Station. The Shilo Well Facility has improved capacity (existing 900 gpm well plus additional 1,900 gpm supply). The following describes additional improvements required to serve build-out demands. These improvements are in addition to the near-term improvements previously described.

- 18-inch pipeline improvement along Brosterhous Road between News Lane and American Lane
- 42-inch parallel pipeline improvement from the Rock Bluff 1 Facility to Brosterhous Road near News Lane
- 12-inch pipeline improvement from Brosterhous Road to 15th, east of Murphy Road, as well as 8-inch pipe loop to existing pipelines from 15th to Sotra Loop

Table 10 summarizes system performance results in Zone 4B south of Reed Market Road and in the proposed Zone 3D with all recommended WMP improvements, both before and after implementation of the recommended 18-inch line improvement along Brosterhous Road between News Lane and American Lane.

Table 10 | Build-out System Results

Build-out condition	Maximum ADD Pressure (psi)	Minimum PHD Pressure (psi)	Minimum Available Fire Flow (gpm, 20 psi Residual Pressure During MDD)
4B south of Reed Market Rd with WMP improvements and proposed service changes	68 psi	37 psi	1,500 gpm
Proposed Zone 3D with WMP improvements and proposed service changes	116 psi	87 psi	1,500 gpm
4B south of Reed Market Rd with WMP improvements, proposed service changes and 18-inch improvement	68 psi	40 psi	1,500 gpm
Proposed Zone 3D with WMP improvements, proposed service changes and 18-inch improvement	116 psi	87 psi	1,500 gpm

Note 1. Assumes Shilo Well Facility is not operating and largest Murphy Road Pump Station pump is out of service. See fire flow sensitivity analysis section of this document (Tables 11 thru 13 for alternate operational conditions).

The new 18-inch pipeline improvement along Brosterhous Road between News Lane and American Lane increases transmission from the Rock Bluff 1 Facility. Without this improvement peak hour pressures may be in the range from 35 to 40 psi in between Sydney Harbor Drive and Manhae Lane, as well as areas served by Zone 4B close to Murphy Road, and along Jacklight Lane.

For the improved system with build-out demands and interim improvements at the Murphy Pump Station, approximately 1,500 gpm fire flow is available in Zone 3D while maintaining 20 psi residual.

Fire Flow Sensitivity Analysis

The operational status of Shilo Well 3 impacts available fire flow and residual pressure. A sensitivity analysis was performed to show the minimum fire flow pressures in the proposed Zone 3D with Shilo Well off and the largest Murphy pump off; Shilo Well on and the largest Murphy pump off; and Shilo Well off with the largest Murphy pump on. These scenarios provide information on risk associated with providing fire flow up to 2,500 gpm without adding additional fire flow capacity at the Murphy Road Pump Station. The results of the sensitivity analysis are shown in Tables 11 thru 13. These results were developed with Rock Bluff 1 Facility at 60% full depth, under MDD conditions. Fewer than 20 acres in the proposed Zone 3D are estimated to experience pressures less than 20 psi during fire flow conditions greater than 1,500 gpm as shown in Figure 2.

Table 11| Fire Flow Results - Shilo Well Off, Murphy Pump Station at Firm Capacity

Shilo Well off, Murphy Pump Station at Firm Capacity	MDD+Fire Flow 1,500 gpm, Residual Pressure (psi)	MDD+Fire Flow 2,500 gpm, Residual Pressure (psi)
Near Term Highest Elevation (3,784 ft)	17	7
Near Term Typical High Elevation (3,775 ft)	28	17
Build-out Highest Elevation (3,784 ft)	21	18
Build-out Typical High Elevation (3,775 ft)	34	26

Table 12| Fire Flow Results - Shilo Well On, Murphy Pump Station at Firm Capacity

Shilo Well on, Murphy Pump Station at Firm Capacity	MDD+Fire Flow 1,500 gpm, Residual Pressure (psi)	MDD+Fire Flow 2,500 gpm, Residual Pressure (psi)
Near Term Highest Elevation (3,784 ft)	24	19
Near Term Typical High Elevation (3,775 ft)	37	28
Build-out Highest Elevation (3,784 ft)	29	27
Build-out Typical High Elevation (3,775 ft)	42	35

Table 13| Fire Flow Results - Shilo Well off, Murphy Pump Station at Full Capacity

Shilo Well off, Murphy Pump Station at Full Capacity	MDD+Fire Flow 1,500 gpm, Residual Pressure (psi)	MDD+Fire Flow 2,500 gpm, Residual Pressure (psi)
Near Term Highest Elevation (3,784 ft)	70	12
Near Term Typical High Elevation (3,775 ft)	82	19
Build-out Highest Elevation (3,784 ft)	74	22
Build-out Typical High Elevation (3,775 ft)	87	32

Summary

Under existing unimproved conditions, some areas currently served by the City's water distribution system in the southern portion of Zone 4B and Zone 3D experience pressures lower than 40 psi under PHD conditions, and achieve less than the 1,500 gpm fire flow with 20 psi residual pressure.

The sale of these areas to private water providers in combination with the implementation of the proposed Zone 3D, improves minimum pressures under PHD conditions and increases available fire flow.

The existing Murphy Pump Station is not sized to provide the ideal head and flow conditions to serve the proposed service area. The ideal operating head for the pump station is too high to meet the 80 psi service area criteria with efficient pump performance. In addition the low demands of the system cannot be met by the existing pumps.

The long-term recommendation for the Murphy Pump Station is to replace all pumps with models that will pump efficiently to the recommended HGL for the reconfigured Zone 3D (3,933 feet). The pump(s) selection should be considered in a preliminary design analysis including redundant VFD jockey pump(s) for low flows, mid-size VFD pumps for the range of flows from ADD to PHD, and larger pumps for fire flow. The preliminary design should also consider suction pressure from Zone 4D, and potential space and mechanical constraints in the existing pump facility.

An interim improvement recommendation utilizing existing pumps is also provided below with limitations on available fire flow to less than 1,500 gpm. The interim pump station improvement recommendations should also be reviewed through a preliminary design analysis to ensure adequate space and mechanical constraints in the existing facility and to verify existing bladder tank capacity. The interim improvements include the following:

- VS 1. Install a jockey pump for low flow demands and verify existing bladder tank capacity.
- VS 2. Utilize the five (5) existing pumps with VFDs to maintain 116 psi discharge pressure.
- THEM
OUR \$ 3. Install a control valve (combination pressure sustaining and pressure reducing) downstream of the Murphy Road Pump Station. The pressure reducing function will burn excess head and reduce maximum pressures to approximately 80-85 psi within pressure zone 3D. The sustaining feature should only be activated when four (4) or more pumps are operating to supply fire flow. The sustaining feature is intended to maintain a minimum back pressure on the pumps to minimize risk of cavitation.
- VS 4. Provide supplemental fire flow from Zone 4B through a check valve near the Shilo Well Facility.

With the implementation of the recommended interim improvements at Murphy Pump Station, fire flow availability is limited to 1,500 gpm or less at a 20 psi residual pressure within the proposed Zone 3D.

Recommended pipeline improvements to serve existing and near-term development include the following:

THGM
OUR \$

- 16-inch pipeline constructed from Murphy Pump Station, along Murphy Road to Brosterhous Road. The pipeline improvement isolates the proposed Zone 3D from Zone 4B.

THGM

- 12-inch pipeline constructed as an extension from the existing 16-inch pipeline on Country Club Drive to the point of connection with 8-inch pipelines representing the JL Ward Co. development.

THGM

- 8-inch looped improvements within the Deer Ridge and JL Ward Co. developments, connecting them to and creating a loop between the existing 12-inch pipeline on Brosterhous Road south of Murphy Road and the 12-inch pipeline extension on Country Club Drive.

As demands increase to build-out through the system, additional pipeline improvements are required including the following:

- 18-inch pipeline improvement along Brosterhous Road between News Lane and American Lane
- 42-inch parallel pipeline improvement from the Rock Bluff 1 Facility to Brosterhous Road near News Lane
- 12-inch pipeline improvement from Brosterhous Road to 15th, east of Murphy Road, as well as 8-inch pipe loop to existing pipelines from 15th to Sotra Loop



UTILITY DEPARTMENT

62875 Boyd Acres Rd | Bend, Oregon 97701

- | | |
|---------------------------|----------------|
| - Sold | - Agata |
| - City Owned | - Aylon |
| - Proposed City to Retain | - City of Bend |
| - Tillicum Non-HOA | - Roads |



Scale: 1" = 100'

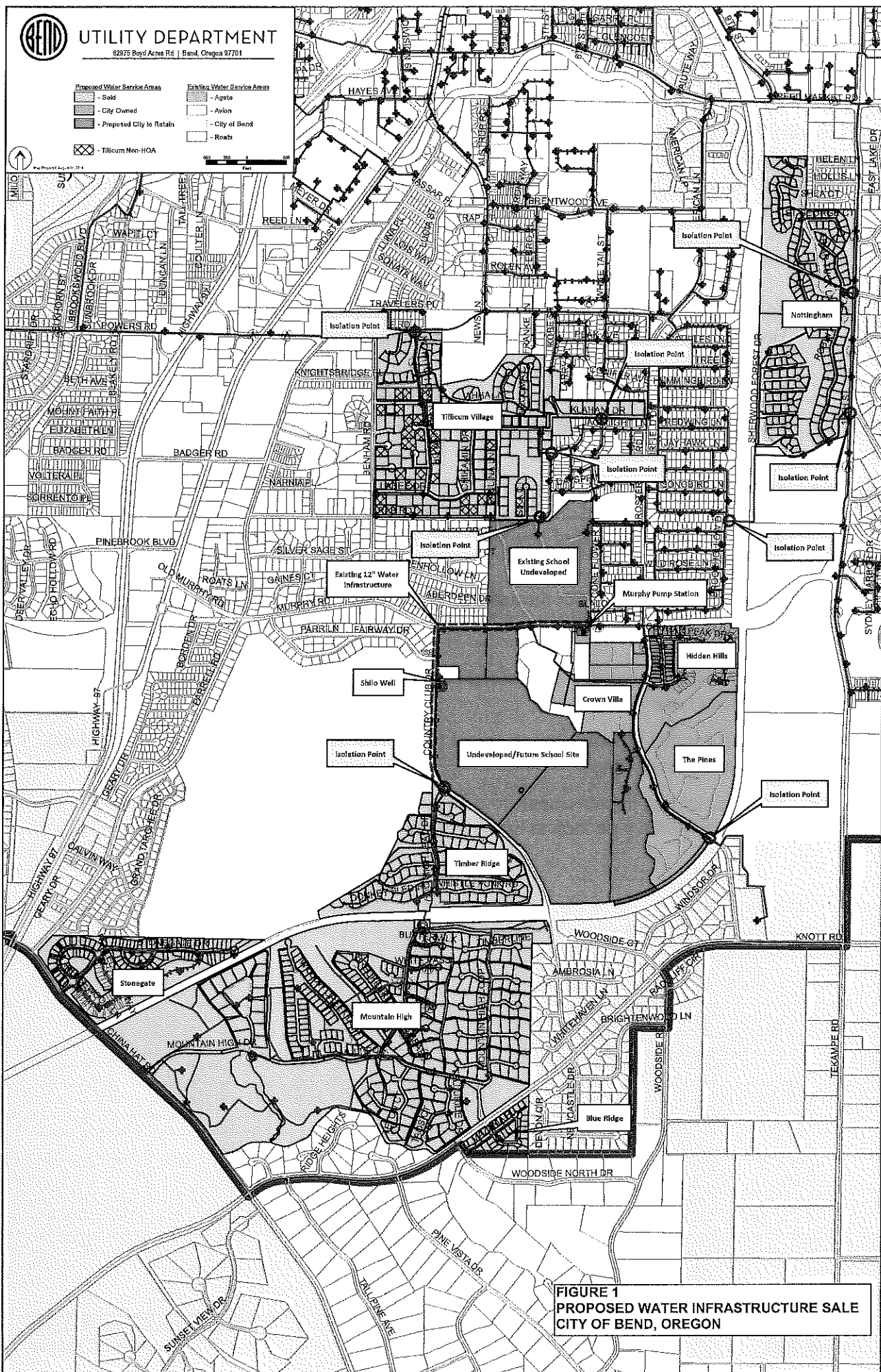
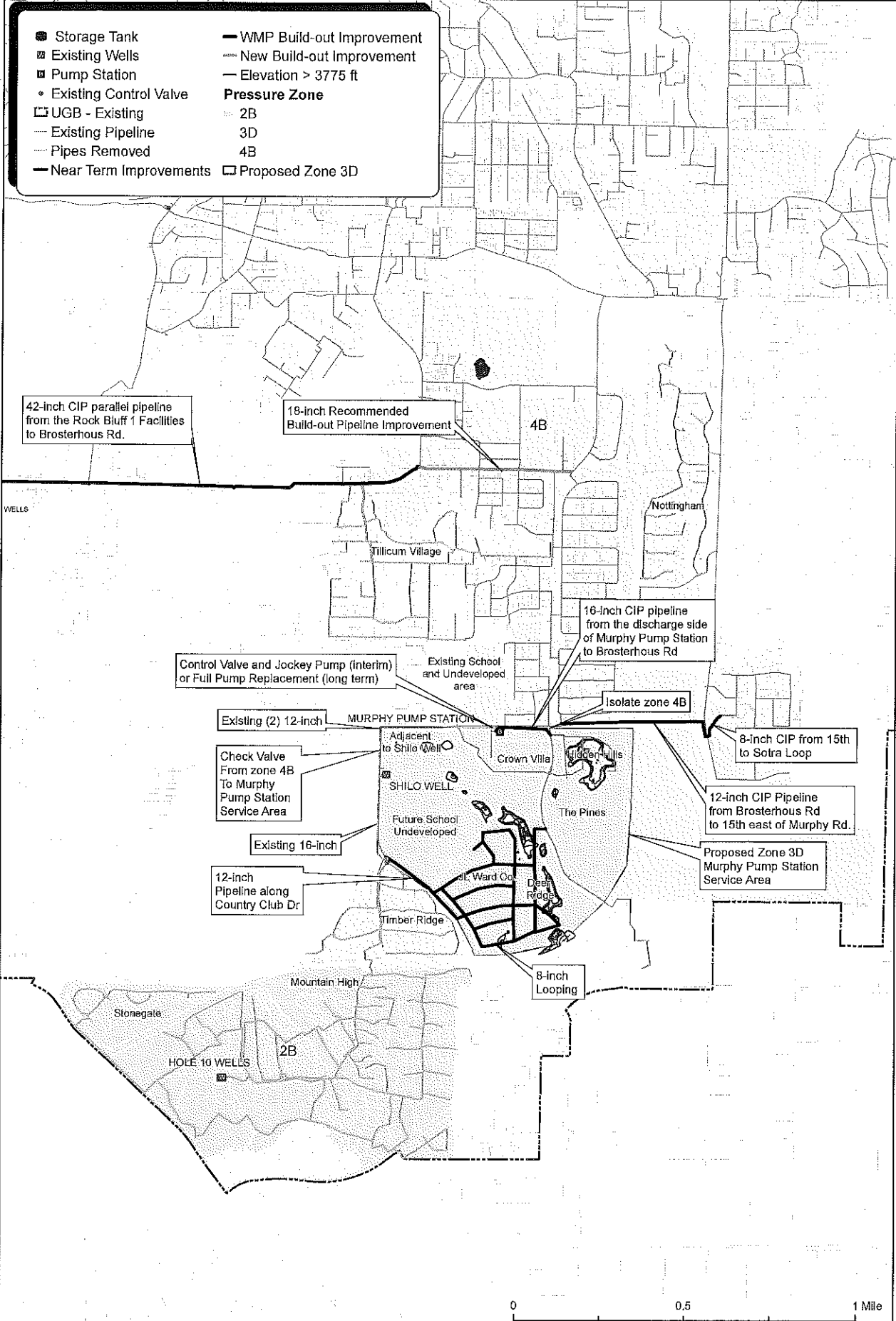


FIGURE 1
PROPOSED WATER INFRASTRUCTURE SALE
CITY OF BEND, OREGON



- Storage Tank
 - Existing Wells
 - Pump Station
 - Existing Control Valve
 - UGB - Existing
 - Existing Pipeline
 - Pipes Removed
 - Near Term Improvements
 - WMP Build-out Improvement
 - New Build-out Improvement
 - Elevation > 3775 ft
- Pressure Zone**
- 2B
 - 3D
 - 4B
 - Proposed Zone 3D

42-inch CIP parallel pipeline from the Rock Bluff 1 Facilities to Brosterhaus Rd.

18-inch Recommended Build-out Pipeline Improvement

Control Valve and Jockey Pump (interim) or Full Pump Replacement (long term)

Existing (2) 12-inch

Check Valve From zone 4B To Murphy Pump Station Service Area

Existing 16-inch

12-inch Pipeline along Country Club Dr

16-inch CIP pipeline from the discharge side of Murphy Pump Station to Brosterhaus Rd

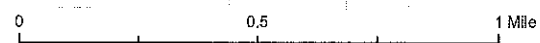
Isolate zone 4B

8-inch CIP from 15th to Sotra Loop

12-inch CIP Pipeline from Brosterhaus Rd to 15th east of Murphy Rd.

Proposed Zone 3D Murphy Pump Station Service Area

8-inch Looping



DRAFT
 City of Bend
 Water Distribution System
 WORK IN PROGRESS - SUBJECT TO CHANGE

Figure 2
 Study Area Map

