ELEMENT ENGINEERING LLC
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MEMORANDUM

TO: Paradise Hills HOA

FROM: Element Engineering

DATE: April 21, 2019

SUBJECT: Sunrise Drive Hydraulic Assessment

PURPOSE

The purpose of this memorandum is to summarize the hydraulic analysis performed on the Paradise Hills HOA (PHHOA) owned water lateral in Sunrise Drive and make recommendations to reduce or eliminate lateral breaks. This hydraulic analysis included compiling a water model and analyzing existing and proposed hydraulic conditions, reviewing construction plans and records of recent breaks, and walking the existing alignment.

BACKGROUND

The PHHOA owns and operates a water lateral system connected to the Lookout Mountain Water District (LMWD) main. The PHHOA system contains pipe sizes ranges from 6-inch diameter to 8-inch diameter and three pressure reducing valve (PRV) vaults and numerous fire hydrants and isolation valves. The general location of the PHHOA lateral system is shown in the attached PHHOA Lateral and Modeled Pressures map. This memorandum and analysis focus on the water lateral installed in Sunrise Drive. The location of the Sunrise Drive water main is also shown on the previously referenced map.

The PHHOA has historically experienced numerous costly main breaks on this lateral. Recent breaks have been documented on April 15, 2016, November 14, 2017, July 11, 2018, October 20, 2018, and November 13, 2018. An example of a break in the Sunrise Drive lateral, in this case a lateral fracture, is shown in Figure 1.

Oct 13, 2016, Nov 23, 2016,

July 18, 2018

2020 breaks - Aug 7, Aug 12, Aug 19, Oct 2

Figure 1 - November 10, 2018 Lateral Break

According to as-built documentation (attached to this memorandum) the Sunrise Drive lateral was installed in 1988. As-builts show a total of 1,849 linear feet of 6" Blue Brute PVC, 18 service connections, four (4) hydrant and hydrant assemblies (hydrant, valve, fire line), and three (3) gate valves. Excavations to fix water main breaks has shown the installed pipe to be white C900 DR18 PVC with a 150 PSI pressure rating stamp. Figure 2 shows pipe excavated to fix a break.

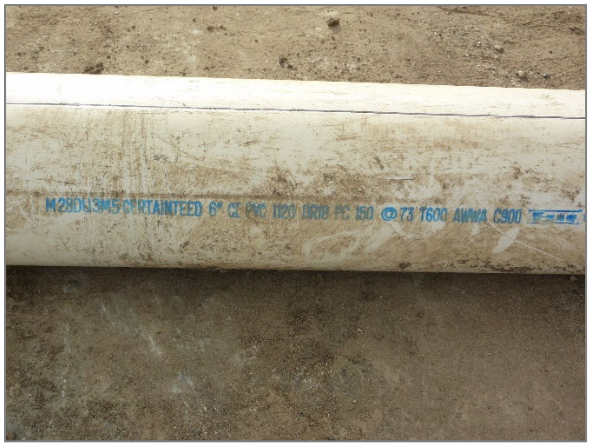


Figure 2 - Pipe Excavated from Sunrise Drive

Pressure data on the Sunrise Drive lateral was taken by installing a pressure logger on a fire hydrant on the lower end of the lateral. Pressure data was taken from August 18, 2018 through August 21, 2018. The maximum pressure during the testing period was 198.7 PSI and the pressure averaged 173.5 PSI. Pressure testing results are attached to this memorandum.

HYDRAULIC MODELING

Element Engineering completed a hydraulic model of the majority of the PHHOA lateral system in order to accurately model the Sunrise Drive lateral itself.

Data provided by PHHOA included the distribution piping layout, length, and size, existing PRV locations and settings, and pipe pressures at various points in the system. EPANET was utilized to develop the hydraulic water model, which is a commonly used program created by the U.S. Environmental Protection Agency (EPA). EPANET models a distribution system as a network of physical components such as reservoirs, pipes, junctions and valves. For calculations in the hydraulic model, EPANET utilizes the Todini and Pilati (1987) "Gradient Method" to iteratively solve the conservation of flow at each node/junction as well as the head loss relationship across each pipe linkage. Friction losses were determined using the Hazen-Williams formula.

A total of 22 nodes and junctions were used in the EPANET model placed at locations systematically around the PHHOA lateral to simulate elevations, also PRV valves were modeled using PRV settings provided by PHHOA. Upstream and downstream pressures modeled for each PRV station are shown in Table 1.

Table 1 - PHHOA PRV Settings

Location	Inlet Pressure (PSI)	Outlet Pressure (PSI)
Charros & Dekker	110	60
Lamb Lane	140	80
Cabrini & Paradise Rd.	140	84

Elevation inputs for the nodes and junctions were interpreted from Google Earth. One reservoir was used in the model to simulate and represent the known internal pipe pressures at specific upstream locations within the distribution system, as provided by PHHOA. To do this, the hydraulic head input for the reservoir was determined by summing the elevation and the head contribution from the internal pipe pressure, as seen in
Equation 1.

$$Hydraulic\ Head(ft) = \frac{Pipe\ Pressure(\frac{lbs}{in^2})}{Specific\ Wt\ Water(\frac{lbs}{in^3})} * \left(\frac{1\ ft}{12\ in}\right) + Elevation(ft)$$

Equation 1

MODEL RESULTS

The model simulated pressures in the Sunrise Drive lateral within four (4) PSI. For the purposes of this analysis this is a very accurate approximation. Water pressure at the top of Sunrise Drive was shown to be

approximately 123 PSI and the pressures at the end (bottom) of Sunrise Drive were modeled to be 168 PSI. therefore, it can be assumed that the pressure along Sunrise Drive ranges between these two values. An exhibit depicting the water model is shown in Figure 3. Note that this models only the portions of the PHHOA system necessary to determine pressures on Sunrise Drive. Modeled pressures throughout the system are shown in the attached PHHOA Lateral and Modeled Pressures map.

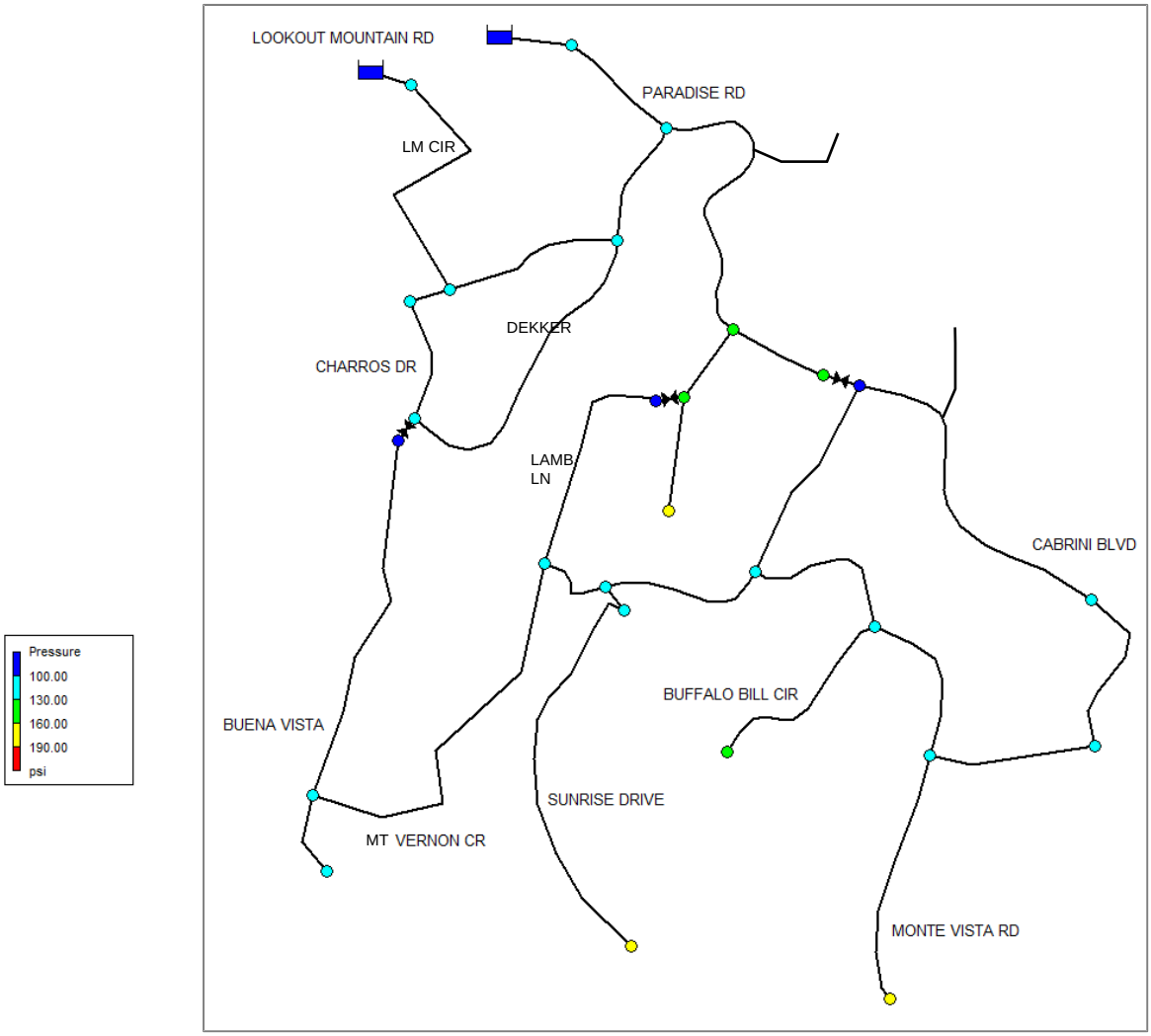


Figure 3 - PHHOA Modeling Results (Pressure)

ANALYSIS OF MODELING

Modeling clearly confirms the pressures in Sunrise Drive range between approximately 123 PSI and 168 PSI. As previously discussed, the installed pipe is white 6-inch diameter DR18 C900 with a 150 PSI pressure rating stamped on it. Therefore, most of the Sunrise Drive lateral is likely under higher pressure than the

installed pipe is specified for. It is possible that this is either contributing to or exacerbating the lateral breaks in this area.

Prior to assuming that static pressure in the existing lateral is the culprit for all of the historical breaks it is important to note that the American Water Works Association (AWWA), the governing standards body for PVC water piping, changed pressure classifications on C900 pipe in the mid 2000's. While pressure ratings were changed, no manufacturing, pipe thickness requirements or other physical property requirements were changed. Therefore, DR18 pipe that is now rated for 235 PSI exactly matches the physical properties of the DR18 PVC installed in Sunrise Drive stamped with a rating of 150 PSI. For reference the previous and newly implemented pressure ratings of C900 PVC are shown in Table 2.

Table 2 - New and Old AWWA C900 Pressure Ratings

Dimention Ration	Old Rating (PSI)	New Rating (PSI)
DR 25	100	165
DR 18	150	235
DR 14	165	305

Theoretically an engineer could specify a replacement pipe that matches the internal diameter, wall thickness of the existing lateral piping (specifically SDR18 C900) but this new piping would technically meet all pressure requirements of the system. Based on this information it is possible that the pressure and pipe rating in Sunrise Drive may contribute to the main breaks, or make the breaks worse, but may not be the sole contributing factor.

There are several primary drivers of pipe breaks. These are:

1. Improper Pressure Rating: Failure of the design engineer to properly specify the proper pipe material and/or pressure rating.

2. Improper Installation: Improper installation of pipe and bedding can cause point stresses by impinging rocks which can then increase the chances of failure (breaks). Improper installation is the most common cause of breakage in water mains.

3. Manufacturing Defects: Manufacturing defects such as air bubbles and foreign particles in the pipe wall, weak extrusion knit lines, etc. resulting from poor quality control by the manufacturer can lead to breaks.

4. Mishandling of Pipe: During or prior to installation pipe could be left out in the sun, dropped, or otherwise mishandled which could contribute to future failure.

It is impossible to determine the exact cause of the breaks without further analysis of the pipe itself. However, the similar pipe material (size and pressure rating) and similar pressures seen on Monte Vista Road (adjacent to Sunrise Drive) without chronic lateral breaks would point to a wider issue than just local pressures.

RECOMMENDATIONS

There are three alternatives to alleviate or eliminate main breaks in the study area. Each alternative is discussed in detail. These alternatives are:

I. Install a PRV on Sunrise Drive

II. Replace the Sunrise Drive Lateral

III. Replace the Sunrise Drive Lateral and Install a PRV

Alternative I – Install a PRV on Sunrise Drive

This alternative would include installing a PRV on the upper end of Sunrise Drive, reducing pressures to 60 PSI downstream of the PRV and allowing a high pressure of 110 PSI at the low (bottom) end of Sunrise Drive. As previously discussed, there is no guarantee that pressure itself is the only cause of breaks in the area, so this alternative may not eliminate the breaks. If not eliminating the breaks, this alternative could make them less catastrophic (less water lost).

This alternative would include a valve vault, 6-inch diameter PRV, 2-inch diameter low flow bypass PRV, and ancillary piping, valves, and fittings. The estimated construction and non-construction costs of this alternative is shown in Table 3. A detailed construction cost estimate is attached to this memorandum.

Table 3 - Alternative I Cost Summary

Item	Cost
Construction	$ 60,853
Non-Construction	$ 21,200
Contingency	$ 12,171
Total	**$ 94,223**

Alternative II – Replace the Sunrise Drive Lateral

This alternative would replace the existing Sunrise Drive lateral with new piping with a pressure rating that is acceptable to the LMWD. According to the LMWD engineer, and the district's draft engineering standards "PVC pipe shall not be used for any installations below 7,250 feet in elevation". In the case of the Sunrise Drive lateral, the LMWD would require ductile iron (DI) pipe be installed.

6-inch diameter ductile iron pipe is only available in Pressure Class 350 meaning it is designed to operate under a sustained pressure of 350 PSI with another 100 PSI surge allowance. This alternative would include a parallel installation of new DI pipe, service connections, fire connections, fire hydrants, and valves. The estimated construction and non-construction costs for this alternative is shown in Table 4. A detailed construction cost estimate is attached to this memorandum.

Table 4 - Alternative II Cost Summary

Item	Cost
Construction	$ 457,094
Non-Construction	$ 61,700
Contingency	$ 91,419
Total	**$ 610,213**

Note: The philosophy of LMWD requiring specific pressure ratings within specific elevation bands is the following: If a LMWD PRV station higher in the LMWD system were to fail or were to be brought out of service, lower elevation laterals could experience significantly higher sustained pressures than are normally seen. These pressures could be much higher than the pressure rating of the installed pipe. Therefore, LMWD requires that any newly installed pipe be capable of sustaining pressures assuming the LMWD (and any other) PRV stations are inactive or not functioning. This is a safety precaution to prevent catastrophic pipe failures.

Alternative III – Replace the Sunrise Drive Lateral and Install a PRV

This alternative is a combination of Alternatives I and II. The reason that this alternative is included is that the LMWD has indicated that their goal is to maintain system pressures of between 60 PSI as a minimum and 100 PSI at a maximum. LMWD will allow some discretion on the minimum and maximum pressures. If all LMWD design requirements including pipe pressure class, and maximum and minimum pressures were followed this alternative would be required. The estimated construction and non-construction costs for this alternative is shown in Table 5. A detailed construction cost estimate is attached to this memorandum.

Table 5 - Alternative III Cost Summary

Item	Cost
Construction	$ 508,161
Non-Construction	$ 67,700
Contingency	$ 101,632
Total	**$ 677,494**

LMWD Review and Approval

Element Engineering met with the LMWD engineer and a board representative to discuss engineering, design, review, and construction requirements. LMWD indicated that any new construction or modification of a lateral system would require their review and approval. LMWD also strongly indicated that the installation of a PRV (Alternative I) was a band-aid or temporary fix at best and would not be acceptable in the long term. LMWD did indicate that they may accept Alternative I as a temporary measure if future planning was in place to replace the Sunrise Drive lateral entirely, caveating this with the fact that Alternative I may not solve the issue of lateral breaks anyway.

Summary and Recommendation

A summary of the total cost for each alternative is shown in Table 6.

Table 6 - Alternative Cost Summary

Alternative	Total Project Cost
Alternative I - Install a PRV on Sunrise Drive	$ 94,223
Alternative II - Replace Sunrise Drive Lateral	$ 610,213
Alternative III - Replace Sunrise Drive Lateral and Install PRV	$ 677,494

Ultimately the HOA must determine, based on the availability of funds, if a short-term potential solution or long-term ultimate solution is desired. If funds are available Element Engineering recommends Alternative No. III – Replace Sunrise Drive Lateral and Install a PRV. While the costliest, this alternative offers several major advantages. These are:

- This alternative will without question remedy the main break issue.
- This alternative protects infrastructure from upstream PRV failures.
- This alternative is per LMWD standards and can be turned over to them in the future without other improvements to the Sunrise Drive area.

SCALE 1"=50'

PARADISE ROAD

SUNRISE DRIVE

153 154 155 156 157 158 159 160 42 147 148 146 145 144 143 149 150

6" FIRE HYDRANT
6" M.J. VALVE BOX
6" M.J. TEE W/KICK BLK.
20' OF 6" CL 52 D.I.P.
W/POLY WRAP (TIE ROD ALL)

6" FIRE HYDRANT
6" M.J. VALVE & BOX
6" M.J. TEE W/KICK BLOCK
22' OF 6" CL 52 DIP
W/POLY WRAP (TIE ROD ALL)

6" VALVE & BOX

6" BLUE BRUTE PVC

6" 22 1/2° BEND
W/KICK BLOCK

6" 22 1/2° BEND

6" FIRE HYDRANT
6" VALVE & BOX
6" M.J. TEE W/KICK BLK.
20' OF 6" CL 52 D.I.P.
W/ POLY WRAP (TIE ROD ALL)

6" 11 1/4° BEND
W/KICK BLOCK

6" 11 1/4° BEND
W/KICK BLOCK

6" PLUG & KICK BLOCK
WITH 2" BLOWOFF
TIE ROD 20' BACK

4" D.I.P ENDS MARKED
w/4x4 SKIDS

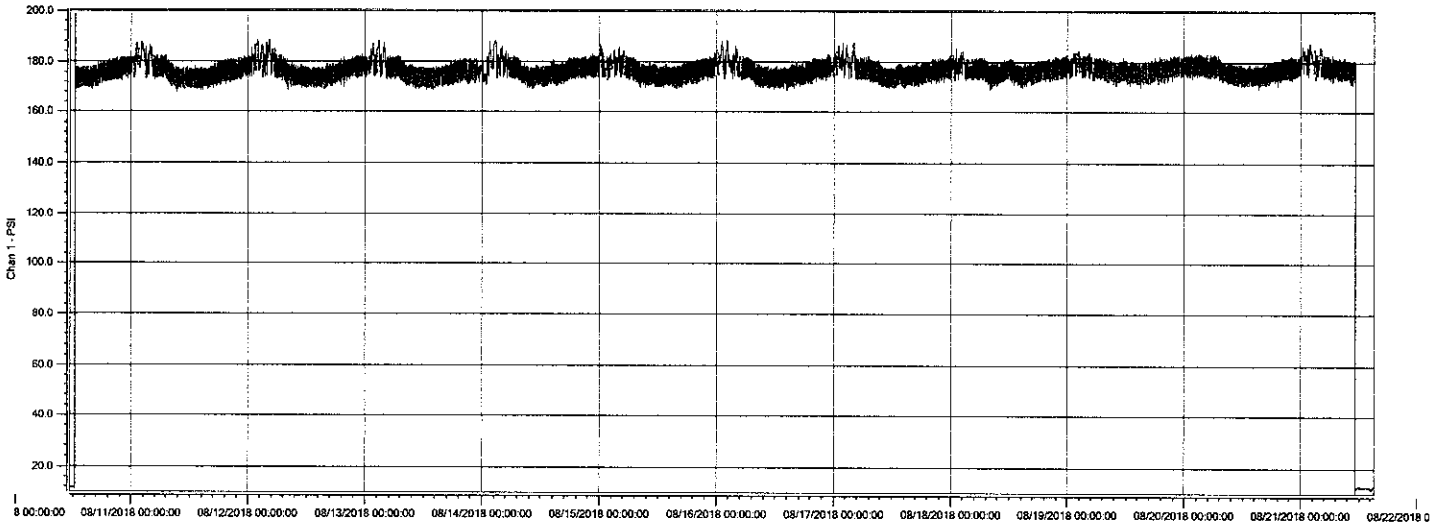
TEL. PED.
ELEC. SERV.
ELEC. TRANS.
GAS SERVICE
POWER POLE
MAIL BOX POST

AS CONSTRUCTED 10/20/88

VIEWPOINT ASSOCIATES
WATER MAIN EXTENSION TO SERVE
PARADISE HILLS
SUNRISE DRIVE WATER MAIN

REA, CASSENS AND ASSOCIATES, INC.
CONSULTING ENGINEERS

DRAWN: SPT	SUBMITTED:	
CHECKED:	APPROVED:	
SCALE:	Evergreen, Colorado May 1988	A8-1151-2



Data Date: 08/10/2018 11:23:02

Unit Tag: Pressure Logger

File:

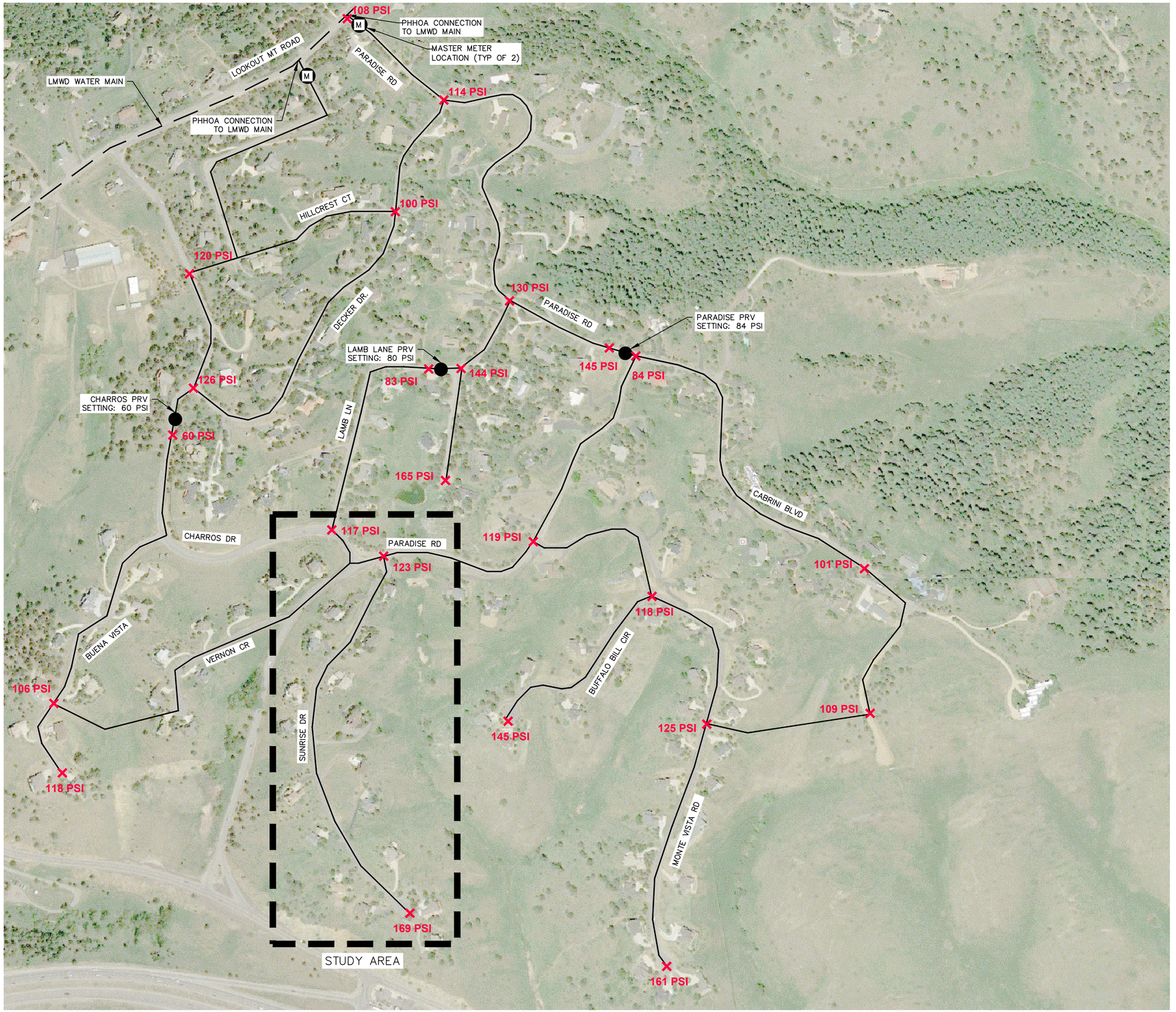
Serial Number: 3400011

Summary

File:

Channel Summary

Chan	Chan Tag	Chan Type	Eng Units	Max	Min	Total Samples	Average	MKT	Start Time	Stop Time
Chan 1	Chan 1	Pressure	PSI	198.7	9.8	32136	173.5		08/10/2018 11:23:02	08/21/2018 15:10:32



N

GRAPHIC SCALE
250 0 250 500
(IN FEET)
1 INCH = 250 FT

APPROXIMATE PHHOA LATERAL STATIC PRESSURE

NOTE: LATERAL LOCATION AND PRESSURES ARE APPROXIMATE.

ELEMENT ENGINEERING LLC
12687 W. CEDAR DRIVE, SUITE 300
LAKEWOOD, CO 80228
720.749.4165
WWW.ELEMENTENGINEERING.NET

REVISIONS			
NO.	DESCRIPTION	DATE	BY

SUNRISE DRIVE HYDRAULIC ANALYSIS

PHHOA LATERAL AND MODELED PRESSURES

PARADISE HILLS HOME OWNERS ASSOCIATION
25754 BRISTLECONE CT
GOLDEN, CO 80401-8682

PREPARED UNDER THE DIRECT SUPERVISION OF

FOR AND ON BEHALF OF ELEMENT ENGINEERING, LLC

DATE: APRIL 2019
JOB NUMBER: 0084.0002
SCALE: 1" = 250'
DRAWING NAME: MODEL
SHEET: 1 OF 1

Alternative I - Install a PRV on Sunrise Drive
Estimate Date: March, 2019

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CONSTRUCTION ITEMS					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT COST**	**SUBTOTAL**
1	10' x 6' PRV Vault	1	LS	$ 9,000	$ 9,000
2	6" DIA DI Pipe and Fittings (Exterior Tie-Ins)	20	LF	$ 160	$ 3,200
3	6" DIA PRV, 2" DIA Low Flow Bypass PRV, Vault Internal Piping and Fittings	1	LS	$ 16,800	$ 16,800
4	6" DIA FLG Gate Valve w/ Operator Wheel	2	EA	$ 2,500	$ 5,000
5	6" DIA MJ Gate Valve, Box, and Cover	3	EA	$ 3,500	$ 10,500
6	Asphalt Removal and Replacement	21	SY	$ 200	$ 4,200
7	Remove and Dispose of Unsuitable Subgrade	40	CY	$ 45	$ 1,800
				Subtotal Construction Items	**$ 50,500**
Erosion Control and Site Restoration (2.5% of Construction Subtotal)					$ 1,263
Traffic Control (3% of Construction Subtotal)					$ 1,515
Mobilization (15% of Construction Subtotal)					$ 7,575
				Total Construction Cost	**$ 60,853**
NON-CONSTRUCTION ITEMS					
Contingency (20%)					$ 12,171
Engineering Design and Bidding					$ 8,000
Construction Observation (Assumes 15 Working Days of Construction)					$ 13,000
Other Costs (Pre and Post Advertisement, etc.)					$ 200
				Total Non-Construction Cost	**$ 33,371**
				Total Project Cost	**$ 94,223**

Note: Construction observation assumes full time onsite observation during construction and submittal and pay application review and approval.

Alternative II - Replace Sunrise Drive Lateral
Estimate Date: March, 2019

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CONSTRUCTION ITEMS					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT COST**	**SUBTOTAL**
1	6" DIA 350 PSI DI and Ancillary Fittings	1,950	LF	$ 120	$ 234,000
2	3/4" Type K Copper (Service Reconnection) and Ancillary Fittings	16	EA	$ 2,500	$ 40,000
3	Fire Hydrant and Assembly (Hydrant, Riser, Gate Valve)	4	EA	$ 6,500	$ 26,000
4	6" DIA MJ Gate Valve, Box, and Cover	3	EA	$ 3,500	$ 10,500
5	4" Thick Asphalt Removal and Replacement	1,230	SY	$ 65	$ 79,950
6	Remove and Dispose of Unsuitable Subgrade (30% of Trench Volume)	433	CY	$ 45	$ 19,500
				Subtotal Construction Items	**$ 409,950**
Erosion Control and Site Restoration (1.5% of Construction Subtotal)					$ 6,149
Traffic Control (2% of Construction Subtotal)					$ 8,199
Mobilization (8% of Construction Subtotal)					$ 32,796
				Total Construction Cost	**$ 457,094**
NON-CONSTRUCTION ITEMS					
Contingency (20%)					$ 91,419
Topographical Survey					$ 5,000
Engineering Design and Bidding					$ 25,000
Construction Observation (Assumes 35 Working Days of Construction)					$ 31,500
Other Costs (Pre and Post Advertisement, etc.)					$ 200
				Total Non-Construction Cost	**$ 153,119**
				Total Project Cost	**$ 610,213**

Note: Construction observation assumes full time onsite observation during construction and submittal and pay application review and approval.

Alternative III - Replace Sunrise Drive Lateral and Install PRV
Estimate Date: March, 2019

ELEMENT ENGINEERING LLC
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CONSTRUCTION ITEMS					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT COST**	**SUBTOTAL**
1	6" DIA 350 PSI DI and Ancillary Fittings	1,950	LF	$ 120	$ 234,000
2	3/4" Type K Copper (Service Reconnection) and Ancillary Fittings	16	EA	$ 2,500	$ 40,000
3	Fire Hydrant and Assembly (Hydrant, Riser, Gate Valve)	4	EA	$ 6,500	$ 26,000
4	6" DIA MJ Gate Valve, Box, and Cover	3	EA	$ 3,500	$ 10,500
5	4" Thick Asphalt Removal and Replacement	1,250	SY	$ 65	$ 81,250
6	10' x 6' PRV Vault	1	LS	$ 9,000	$ 9,000
7	6" DIA DI Pipe and Fittings (Exterior Tie-Ins)	20	LF	$ 160	$ 3,200
8	6" DIA PRV, 2" DIA Low Flow Bypass PRV, Vault Internal Piping and Fittings	1	LS	$ 16,800	$ 16,800
9	6" DIA FLG Gate Valve w/ Operator Wheel	2	EA	$ 2,500	$ 5,000
10	6" DIA MJ Gate Valve, Box, and Cover	3	EA	$ 3,500	$ 10,500
11	Remove and Dispose of Unsuitable Subgrade (30% of Trench Volume)	433	CY	$ 45	$ 19,500
				Subtotal Construction Items	**$ 455,750**
Erosion Control and Site Restoration (1.5% of Construction Subtotal)					$ 6,836
Traffic Control (2% of Construction Subtotal)					$ 9,115
Mobilization (8% of Construction Subtotal)					$ 36,460
				Total Construction Cost	**$ 508,161**
NON-CONSTRUCTION ITEMS					
Contingency (20%)					$ 101,632
Topographical Survey					$ 5,000
Engineering Design and Bidding					$ 28,500
Construction Observation (Assumes 40 Working Days of Construction)					$ 34,000
Other Costs (Pre and Post Advertisement, etc.)					$ 200
				Total Non-Construction Cost	**$ 169,332**
				Total Project Cost	**$ 677,494**

Note: Construction observation assumes full time onsite observation during construction and submittal and pay application review and approval.