Burns & McDonnell
SINCE 1898

MORRISON MAIERLE, INC.
An Employee-Owned Company

ENERGY CAPITAL OF THE NATION
CITY OF GILLETTE, WYOMING

Gillette Regional Water Supply Project
We Are All In This TOGETHER

GILLETTE MADISON PIPELINE PROJECT (GMPP)
TECHNICAL MEMORANDUM #7A
FINAL

TO:	Mike Cole, P.E., City of Gillette
FROM:	Casey Hanson, P.E., MMI
DATE:	December 16, 2010
JOB NO.:	BMcD # 54432, MMI #4776.001
RE:	In-Town PVC Pipe Class Calculations
CC:	Dan Korinek, P.E., BMcD
ATTACHMENTS:	

☐ **Urgent** ☐ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **For Your Use**

BACKGROUND

This memo covers the general design considerations and calculations associated with selecting a C905 DR or pipe class for the in-town piping between reservoirs Z1-R3 and Z1-R4. From TM #7, the recommended size of this pipeline is 30-inch. It should be noted that the northern edge of this reach of pipe along Westover Road will likely be Horizontal Directional Drilled (HDD) installation. This installation method can involve specialized thickness calculations that will be considered during final design, but are not presented herein. These calculations apply to the open-cut portion of the design.

PVC pipe thickness design is generally based on internal pressure (including surge), and pipe deflection due to external loading and backfill pressure. Each set of calculations is included below along with a final recommendation.

INTERNAL PRESSURE CALCULATIONS

From the 50% plan set and project files:

$$Maximum\ Water\ Surface\ Elevation\ (Z1\text{-}R4) = 4{,}764.50'$$

$$Minimum\ Pipe\ Invert = 4{,}547.00'$$

$$Maximum\ Working\ Pressure = \frac{4{,}764.5 - 4{,}547.0}{2.31} = 94.2\,psi$$

$$Maximum\ Velocity\ (Peak\ Day) = 2.37\ fps$$

$$Maximum\ Velocity\ (Peak\ Hour) = 1.6 * Maximum\ Velocity\ (Peak\ Day) = 1.6 * 2.37\ fps = 3.8\ fps$$

<u>From Unibell</u>

$$DR = \frac{2S}{P} + 1$$

Where:

S = design stress (psi)
P= pressure (psi)

For transmission mains, Uni-Bell recommends a factor of safety of 2.0, while they recommend a factory of safety of 2.5 for distribution mains. This pipeline is a hybrid of the two, so the more conservative factor of safety of 2.5 was selected.

$$S = \frac{HDB}{FS} = \frac{4000\,psi}{2.5} = 1600\,psi$$

$$\therefore DR = \frac{2 * 1600\,psi}{94.2\,psi} + 1 = 35$$

$$Try\ Next\ Available\ DR = 32.5$$

$$WPR = STR - V*(P_s^{'})$$

Where:

WPR = working pressure rating (psi)
STR = short-term rating (psi) (From Uni-Bell Table 5.6)
V = velocity (fps)
$P_s^{'}$ = surge for 1 fps velocity change (Varies by DR, from Uni-Bell Table 5.8)

For DR=32.5:

$$WPR = 165\,psi - 3.8\,fps * 12.8\,\frac{psi}{fps} = 116.4\,psi$$

$$WPR > P \therefore DR = 32.5$$

<u>Alternate Method (Include Surge with Working Pressure)</u>

P = 94.2 psi (From above)

Surge = V($P_s^{'}$)*

Assume DR = 25

$$Surge = 3.8\,fps * 14.7\,\frac{psi}{fps} = 55.9\,psi$$

94.2 psi + 55.9 psi = 150.1 psi

Next DR is 25 with PR = 165 psi

<u>Internal Pressure Conclusion</u>

Most conservative design method is Alternate Method that includes both surge and working pressure in long-term pressure rating calculation. Use DR =25.

DEFLECTION CALCULATIONS

Deflection is commonly limited to either 5.0% or 7.5%. Deflection is influenced by the depth of the pipe, the modulus of soil reaction ($E^{'}$), and the applied surface loading. Since this pipeline is near a highway, it is reasonable to assume it may be subjected to H20 surface loading. At its deepest location, the pipe has approximately 22 feet of cover. The only unknown is the modulus of soil reaction. Table 7.3 from the Uni-Bell handbook is a guide for $E^{'}$ values and is reproduced below for reference. Assuming the more conservative deflection limit of 5.0%, one can see from Table 7.4 from the Uni-Bell handbook shown below that for some lower $E^{'}$ values ($E^{'}$<400), DR 25 (and lower) pipes can exceed the 5.0% limit. DR 21 pipe meets the deflection limits for all $E^{'}$ conditions.

TABLE 7.3
AVERAGE VALUES OF MODULUS OF SOIL REACTION, E'
(For Initial Flexible Pipe Deflection)

Soil type-pipe bedding material (Unified Classification System[a]) (1)	E' for Degree of Compaction of Bedding, in pounds per square inch			
	Dumped (2)	Slight, <85% Proctor, <40% relative density (3)	Moderate, 85%-95% Proctor, 40%-70% relative density (4)	High, >95% Proctor, >70% relative density (5)
Fine-grained Soils (LL > 50)[b] Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E' = 0			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1,000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse-grained particles Coarse-grained Soils with Fines GM, GC, SM, SC[c] contains more than 12% Fines	100	400	1,000	2,000
Coarse-grained Soils with Little or no Fines GW, GP, SW, SP[c] contains less than 12% Fines	200	1,000	2,000	3,000
Crushed Rock	1,000	3,000	3,000	3,000
Accuracy in Terms of Percentage Deflection[d]	±2	±2	±1	±0.5

[a]ASTM Designation D 2487, USBR Designation E-3.

[b]LL = Liquid limit.

[c]Or any borderline soil beginning with one of these symbols (i.e. GM-GC, GC-SC).

[d]For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only, appropriate Deflection Lag Factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select lower E' value or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using about 12,500 ft-lbs/cu ft (598,000 J/m^3) (ASTM D 698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 kPa.

SOURCE: "Soil Reaction for Buried Flexible Pipe" by Amster K. Howard, U.S. Bureau of Reclamation, Denver, Colorado. Reprinted with permission from American Society of Civil Engineers.

Table 7.4 (cont.)
CALCULATED DEFLECTIONS OF BURIED PVC PRESSURE PIPE
DEFLECTION (PERCENT) FOR PRISM, HIGHWAY H20, OR RAILWAY E80 LOADS

Height of Cover	12'			14'			16'			18'			20'		
Live Load	Prism	H20	E80	Prism	H20	E80	Prism	H20	E80	Prism	H20	E80	Prism	H20	E80
E' Value								DR 14							
50	0.80	0.80	1.25	0.94	0.94	1.27	1.07	1.07	1.35	1.21	1.21	1.43	1.34	1.34	1.51
200	0.75	0.75	1.16	0.87	0.87	1.19	1.00	1.00	1.26	1.12	1.12	1.33	1.25	1.25	1.40
400	0.69	0.69	1.07	0.80	0.80	1.09	0.91	0.91	1.15	1.03	1.03	1.22	1.14	1.14	1.29
1000	0.55	0.55	0.85	0.64	0.64	0.87	0.73	0.73	0.92	0.82	0.82	0.97	0.91	0.91	1.03
2000	0.41	0.41	0.64	0.48	0.48	0.65	0.55	0.55	0.69	0.62	0.62	0.73	0.68	0.68	0.77
E' Value								DR 18							
50	1.74	1.74	2.71	2.04	2.04	2.76	2.33	2.33	2.93	2.62	2.62	3.10	2.91	2.91	3.27
200	1.50	1.50	2.34	1.75	1.75	2.38	2.01	2.01	2.53	2.26	2.26	2.67	2.51	2.51	2.82
400	1.27	1.27	1.98	1.48	1.48	2.01	1.69	1.69	2.14	1.91	1.91	2.26	2.12	2.12	2.38
1000	0.87	0.87	1.35	1.01	1.01	1.37	1.16	1.16	1.46	1.30	1.30	1.54	1.45	1.45	1.63
2000	0.57	0.57	0.88	0.66	0.66	0.90	0.76	0.76	0.95	0.85	0.85	1.01	0.95	0.95	1.06
E' Value								DR 21							
50	2.75	2.75	4.28	3.21	3.21	4.35	3.66	3.66	4.62	4.12	4.12	4.89	4.58	4.58	5.15
200	2.20	2.20	3.42	2.56	2.56	3.48	2.93	2.93	3.69	3.29	3.29	3.90	3.66	3.66	4.12
400	1.73	1.73	2.70	2.02	2.02	2.74	2.31	2.31	2.91	2.60	2.60	3.08	2.89	2.89	3.25
1000	1.06	1.06	1.65	1.24	1.24	1.68	1.41	1.41	1.78	1.59	1.59	1.88	1.77	1.77	1.99
2000	0.64	0.64	1.00	0.75	0.75	1.02	0.86	0.86	1.08	0.97	0.97	1.14	1.07	1.07	1.21
E' Value								DR 25							
50	4.48	4.48	6.97	5.22	5.22	7.09	5.97	5.97	7.52	6.71	6.71	7.96	7.46	7.46	8.39
200	3.18	3.18	4.94	3.70	3.70	5.03	4.23	4.23	5.34	4.76	4.76	5.65	5.29	5.29	5.95
400	2.29	2.29	3.56	2.67	2.67	3.62	3.05	3.05	3.85	3.43	3.43	4.07	3.81	3.81	4.29
1000	1.25	1.25	1.94	1.45	1.45	1.97	1.66	1.66	2.09	1.87	1.87	2.21	2.08	2.08	2.33
2000	0.71	0.71	1.10	0.83	0.83	1.12	0.94	0.94	1.19	1.06	1.06	1.26	1.18	1.18	1.33

Prism & H20 <5.0%
All E' Conditions

Prism & H20 <5.0% for E'<400

CONCLUSIONS

The two different internal pressure calculations and the deflection calculation all yield different results from DR 32.5 to DR 21. The most conservative approach to this would be to use the lowest DR of 21 which would cover most soil conditions.

Another approach would be to break the pipeline into sections and calculate a DR for each section. This is commonly done over longer pipelines where detailed geotechnical information is available. At this point in the design, such information is not available, and the conservative action would be to specify DR 21 pipe.

It is also worth noting that in cold weather conditions PVC pipe becomes brittle, and handling concerns become even more important than in warmer weather. Additional wall thickness may help mitigate breakage and potential future damage if any part of the pipeline is to be constructed during the cold weather season.

SOURCES

Handbook of PVC Pipe. Uni-Bell PVC Pipe Association. Fourth Edition, 2001.