ADEQ
Arizona Department of Environmental Quality

ENGINEERING REVIEW
ALTERNATIVE REQUEST (A312G) FOR TYPE 4 GENERAL PERMIT APPLICATIONS

GENERAL INFORMATION

1 Project Name

Project Name Development Projects

2 Applicant (person responsible for overall compliance)

(Check One) [X] Owner [ ] Operator

Name Carol Johnson Phone 520 724-6334

Title Sanitary Engineering Manager Firm Name Pima County Wastewater Reclamation

Mailing Address 201 N. Stone Avenue City Tucson State AZ Zip 85701

Email carol.johnson@pima.gov

3 Contact Person/Agent (if different from applicant)

Name See Applicant. Phone

Title Firm Name

Mailing Address City State Zip

Email

4 Rule Information [ ] On-site ($250 fee), or [ ] Sewage Collection System ($750 fee)

Rule Citation of Requirement for Which Alternative is Requested R18-9-E301 4.01(D)(1)(c), PCRWRD EDS 5.1.10 (A)

Description of Requested Alternative PVC SDR35, PVC C900, and other classes of pipe as determined by design engineer as equivalent.

Continued on attachments [ ] No [X] Yes

5 Alternative Justification

The applicant shall provide sufficient information for the Department to determine that the change achieves equal or better performance compared with the general permit requirement, or addresses site or system conditions more satisfactorily than the general permit requirements (Please attach any necessary calculations, drawings, or other supporting documentation). .

See attachments.

Continued on attachments [ ] No [X] Yes

6 Applicant Certification

I, Carol Johnson, P.E., certify that this alternative request as described in this application and all attachments were prepared under my direction or authorization and all information is, to the best of my knowledge, true, accurate and complete. I also certify that this alternative request described in this form meets or exceeds the terms and conditions the General Aquifer Protection Permit(s) (A.A.C. R18-9-E301 through R18-9-E323) and applicable requirements of Arizona Revised Statutes Title 49, Chapter 2, and Arizona Administrative Code Title 18, Chapter 9 regarding aquifer protection permits.

Affix Seal (If appropriate)

Registered Professional Engineer (Sanitary) — Certificate No. 34048 — CAROL A. JOHNSON — Date Signed 10-19-2018 — Arizona U.S.A.

Carol A. Johnson

Expires Sept 30, 2020

Carol A. Johnson
Signature

10-18-2018
Date

DEPARTMENT USE ONLY			
File Number	Approved E301 PVC For DIP [signature] 11/6/18		
Fee for each request submitted	Yes / No	Check Number	

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TECHNICAL MEMORANDUM

August 21, 2018

TO: Eric Wieduwilt, P.E.

THRU: Carol Johnson, P.E., Francisco Galindo, P.E.

FROM: Kevin Josker, P.E.

SUBJECT: Engineering Design Standards, Section 5.1.10(A) – Separation from Other Utilities

Pima County Engineering Design Standard (EDS) 5.1.10(A) requires placement of the sewer line a minimum depth of 2-feet below stormwater drainage facilities If the vertical distance is less than 2-feet, the public sewer line shall be replaced with Ductile Iron Pipe (DIP) or "approved equal". An approved equal is a pipe with equivalent service life and performance to DIP.

The State of Arizona has granted Pima County Department of Environmental Quality (PDEQ) authority to review, approve, and permit sewer construction plans in Pima County. Recently, PDEQ indicated they may provide a blanket waiver of the DIP requirement for installations, if the available alternatives meet good engineering practice. RWRD recommends the practices described on the following pages as meeting the required criteria.

DESIGN CONSIDERATIONS

Engineering design of buried pipes require the pipe to perform while considering the static loads, live loads, and impact potential.

Static Loads - The deeper the pipe is buried, the larger the static loads, therefore, deep pipes have very heavy static loads. Flexible pipes do not react like rigid pipes, they deflect rather than crack. Surrounding soil becomes part of the support system. Soil stiffness is dependent on the level of compaction achieved, the higher the compaction, the less the pipe deflects.[1]

Dynamic Loads - Of less concern to sewer design engineers are live loads on deep pipes. Usually H20 loading is the design condition used to represent tractor-trailer traffic. Dynamic loading dissipates as depth increases. Proper backfill and compaction of the sewer bedding is important.

PVC Pipe Materials – Polyvinyl Chloride (PVC) sewer pipe normally used in RWRD's collection system is Standard Dimension Ratio (SDR) 35. This table indicates the physical characteristics of pipe available for installation.

Sewer Pipe Size Comparison[2]

Pipe	Size	SDR	Exterior Diameter	Interior Diameter	Minimum Wall Thickness
PVC	8	35	8.4"	7.92"	0.240"
		26	8.4"	7.75"	0.323"
PVC	10	35	10.5"	9.90"	0.300"
		26	10.5"	9.69"	0.404"
PVC	12	35	12.5"	11.78"	0.360"
		26	12.5"	11.54"	0.481"
PVC	15	35	15.3"	14.43"	0.437"
		26	15.3"	14.12"	0.588"

Calculating Allowable Burial Depth – Failure criterion of PVC pipe is not fracture strength, instead, it is measured by pipe diametric deflection. Industry recommendations for maximum deflection when used for gravity sewers is 7.5%. Safety factors of 4:1 or 6:1 are incorporated into this calculation.[3] Pipe deflection is estimated by use of an empirical equation known as the "Modified Iowa Equation".[4]

MODIFIED IOWA EQUATION
% Deflection = [0.1 (W' + P) 100] / [0.149 (PS) + 0.061 (E')]

Where:

% Deflection = predicted percentage of diametric deflection.
W' = Live Load (psi): pressure transmitted to the pipe from traffic on the ground surface. Live Load values are found in Table 2.
P = Prism Load (psi): pressure acting on the pipe from the weight of the soil column above the pipe (also called "Dead Load"). Prism Load values are found in Table 3.
PS = Pipe Stiffness (psi): a flexible pipe's resistance to deflection in an unburied state. Pipe Stiffness values for JM Eagle products are found in Table 4.
E' = Modulus of Soil Reaction (psi): stiffness of the embedment soil. Values for Modulus of Soil Reaction are found in Table 5.

PVC SDR 35 was used in the calculation with a minimum pipe stiffness of 46 psi (Table 4).[5] The Modulus of Soil Reaction of 2000 psi for a high degree of compaction for a Class III soil was used (Table 5).[6] The calculations demonstrate the Prism Load (box culvert) of soil, water, and concrete of 10.98 psi is lighter than the soil load of 12.10 psi (Table 3)[7](considering a Soil Unit Weight of 120 pcf and a height of 10.75-feet). The percent deflection of 0.8522% is far less than the 7.5% industry standard. The H20 loading is negligible at a depth of 10.75-feet (Table 2)[8].

The reinforced concrete pipe example is very similar to the box culvert. Two sizes were selected, a 3-foot and a 4-foot interior diameter crossing over the top of a PVC pipe at 2-feet. A Prism Load of 10.165 psi was calculated for the earth, culvert, water combination, and 10.879 psi for the soil only load (water weighs less than soil). Deflections for the 36- and 48-inch diameter pipes were well below the accepted 7.5%.

SDR 35 pipe is more than adequate for use in this application and is an approved equal.

DIP Disadvantages

DIP is centrifugally cast, has an ultimate tensile strength of 60,000 psi, a yield strength of 42,000 psi with 10% elongation, and high impact strength.[9] Pima County Regional Wastewater Reclamation Department (RWRD) intends to eliminate use of ductile iron pipe (DIP) for new sewers to the maximum extent possible. Due to internal pipe corrosion associated with exposure to sewer gases and routine maintenance, RWRD has experienced lining failures on DIP for many years and has tried various pipe coatings with little or no success. Often the coatings appear promising based on lab tests or manufacturing data; however, in actual practice the interior coatings tend to quickly fail, or fail quality assurance tests, at the construction site. Coating failures diminish flow capacity and require additional maintenance.

Disadvantages of DIP include:

1. DIP is subject to external corrosion (galvanic and electromagnetic currents due to soil chemical reactions).
    a. DIP is typically coated externally with an asphaltic compound by the manufacturer, then wrapped in polyethylene sheets when installed.
2. Internal corrosion (due to hydrogen sulfide gas production).
    a. This reduces the effective lifespan, and requires the application of coatings and wraps.[10]
    b. DIP has been coated internally with a cement-mortar lining, polyethylene, and petroleum asphaltic coal tar epoxy.[11]
3. DIP is heavy, requiring the use of heavy equipment and larger work crews for installation. Laying lengths are 18- and 20-feet, weighing 425/475 lbs for an 8-inch pipe and up to 4930/5460 lbs for a 36-inch pipe.[12] A work crew would typically consist of five people.

CIPP has been used to line the interior of pipes after corrosion has been cleaned, adding additional structural strength (4,500 psi for resin cured/felt composites).[13] CIPP manufacturing and installation costs are very high and require specialized contractors.

Conclusion

Polyvinyl Chloride (PVC) was discovered in the 1890's, developed in the 1920's, and saw increased usage in the 1950's. The American Society for Testing and Materials (ASTM) wrote the standards for PVC in 1955. It is resistant to chemical corrosion, abrasion, and wear without any coatings or liners. Smoother wall surfaces reduce fluid friction and resistance to flow resulting in higher capacity and lower maintenance costs. It is light weight and presents a lower cost for transportation and installation than DIP. It is more flexible than DIP, with a higher modulus of elasticity. Laying lengths are 14- and 20-feet, weighing 60/85 lbs for an 8-inch SDR 35 pipe up to 1302/1860 lbs for a 36-inch PS46 pipe.[14] A work crew of 3 people could handle installation of this pipe.

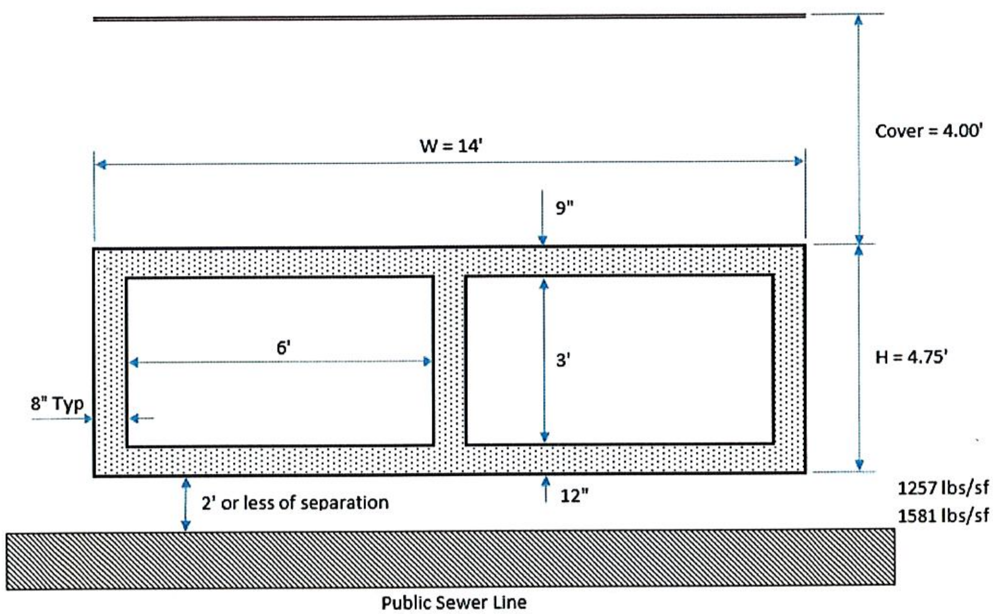
Advantages of using PVC include: [15]

1. PVC is lighter than DIP, costs less, is transported easily, installs for less.
2. PVC is compatible with any natural soil condition.
3. PVC does not require corrosion protection internally or externally.
4. PVC is not subject to galvanic and electromagnetic effects.
5. PVC reduces operation and maintenance costs.
6. PVC tensile strength and modulus of elasticity are more than adequate for its application.

PVC SDR 35 pipe meets the expectations of an "approved equal" to DIP for the applications and service life contained in the Pima County Engineering Design Guide for sanitary sewer. It is recommended DIP be replaced with PVC in the mentioned conditions of drainage facility crossing.

The following are examples of drainage facility crossings. Note the dead load of culvert combination weights (earth, concrete, and water) is less than a uniform soil layer. Water weight is less than soil weight displaced.

Culvert Example



Concrete
$W = 3(8 \text{ in}/12 \text{ in/ft}) + 2(6 \text{ ft}) = 14 \text{ lf}$
$H = 3 \text{ ft} + (9 \text{ in} + 12 \text{ in})/12 \text{ in/ft} = 4.75 \text{ lf}$
$Area_{TOTAL} = (14 \text{ lf})(4.75 \text{ lf}) = 66.5 \text{ sf}$
$Area_{OPENINGS} = 2(6 \text{ ft})(3 \text{ ft}) = 36.0 \text{ sf}$
$Area_{NET} = 66.5 \text{ sf} - 36.0 \text{ sf} = 30.5 \text{ sf}$
$Wt_{CONC} = 30.5 \text{ sf} \times 150.0 \text{ lbs/cf} = 4575 \text{ lbs/lf}$
$Wt_{CONC/sf} = 4575 \text{ lbs/lf} / 14 \text{ lf} = 327 \text{ lbs/sf}$

Earth
$Wt_E = 4.00 \text{ lf}(120 \text{ lbs/cf}) = 480 \text{ lbs/sf}$

Water
$Wt_{WATER} = 62.4 \text{ lbs/cf} \times (3 \text{ ft})(6 \text{ ft})(2) = 2246 \text{ lbs/lf}$
$Wt_{WATER/sf} = 2246 \text{ lbs/lf} / 14 \text{ lf} = 160 \text{ lbs/sf}$

$Sum_{CULVERT}$ (327 + 480 + 160) = 967 lbs/sf

Load Factors Dead Load = 1.25 (Concrete & Water) AASHTO LRFD T3.4.1-2
Vertical Earth Pressure = 1.35
= (327 + 160)1.25 + (480)1.35 = 1256.75 lbs/sf 8.73 lbs/si

Assume maximum load top of pipe at 2 feet below bottom of culvert
$Wt_E = 2.00 \text{ lf}(120 \text{ lbs/cf}) = 240 \text{ lbs/sf}$
240 lbs/sf(1.35) = 324 lbs/sf

1580.75 lbs/sf
Round up 1581.00 lbs/sf 10.98 lbs/si

Range of pressure within 2-feet will be between 1257.00 - 1581.00 lbs/sf

If all earth pressure = (10.75 lf x 120 lbs/cf)1.35 = 1741.50 lbs/sf
Round up 1742.00 lbs/sf 12.10 lbs/si

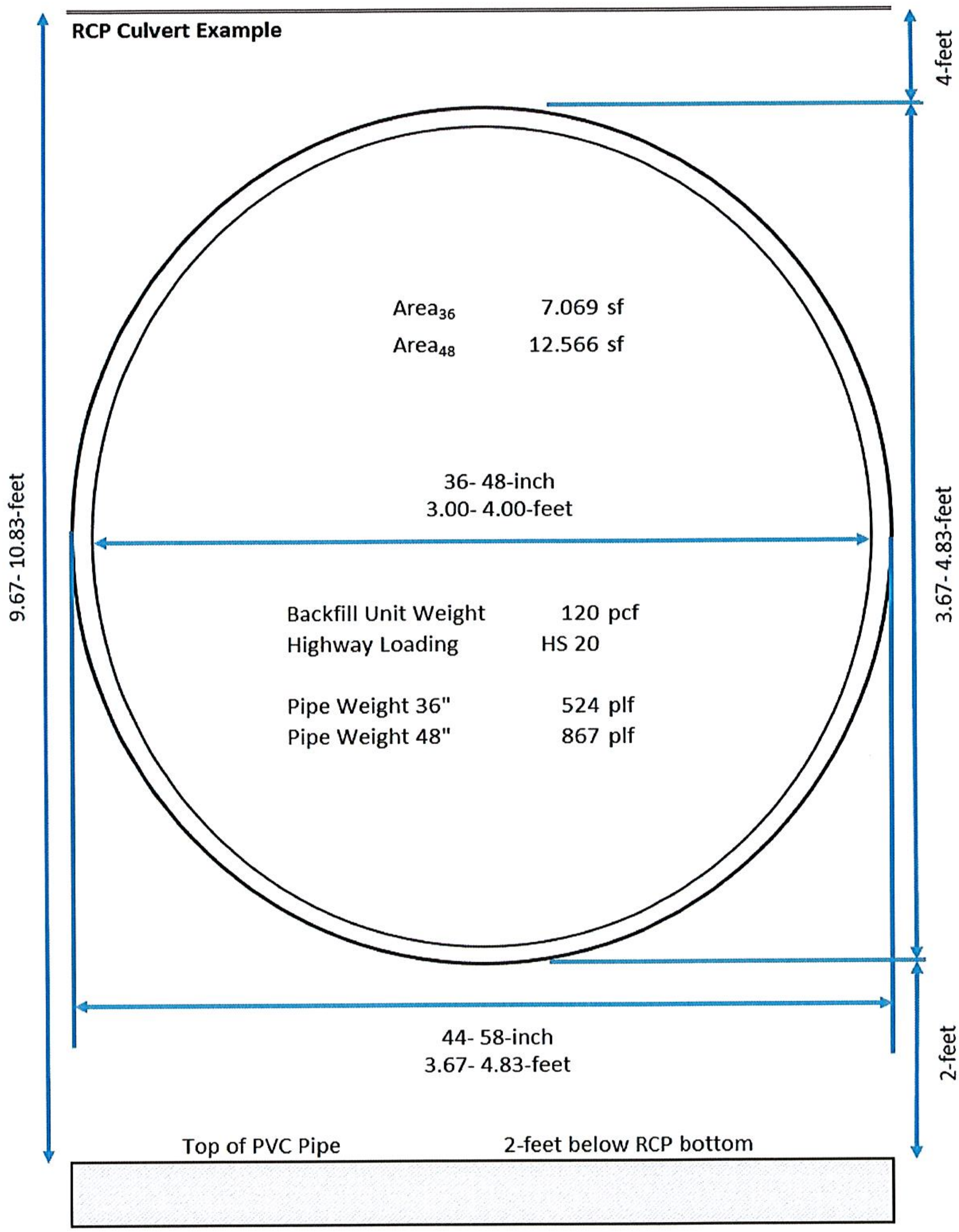
Note weight of culvert on top of pipe is less than continuous earth load

Figure 1

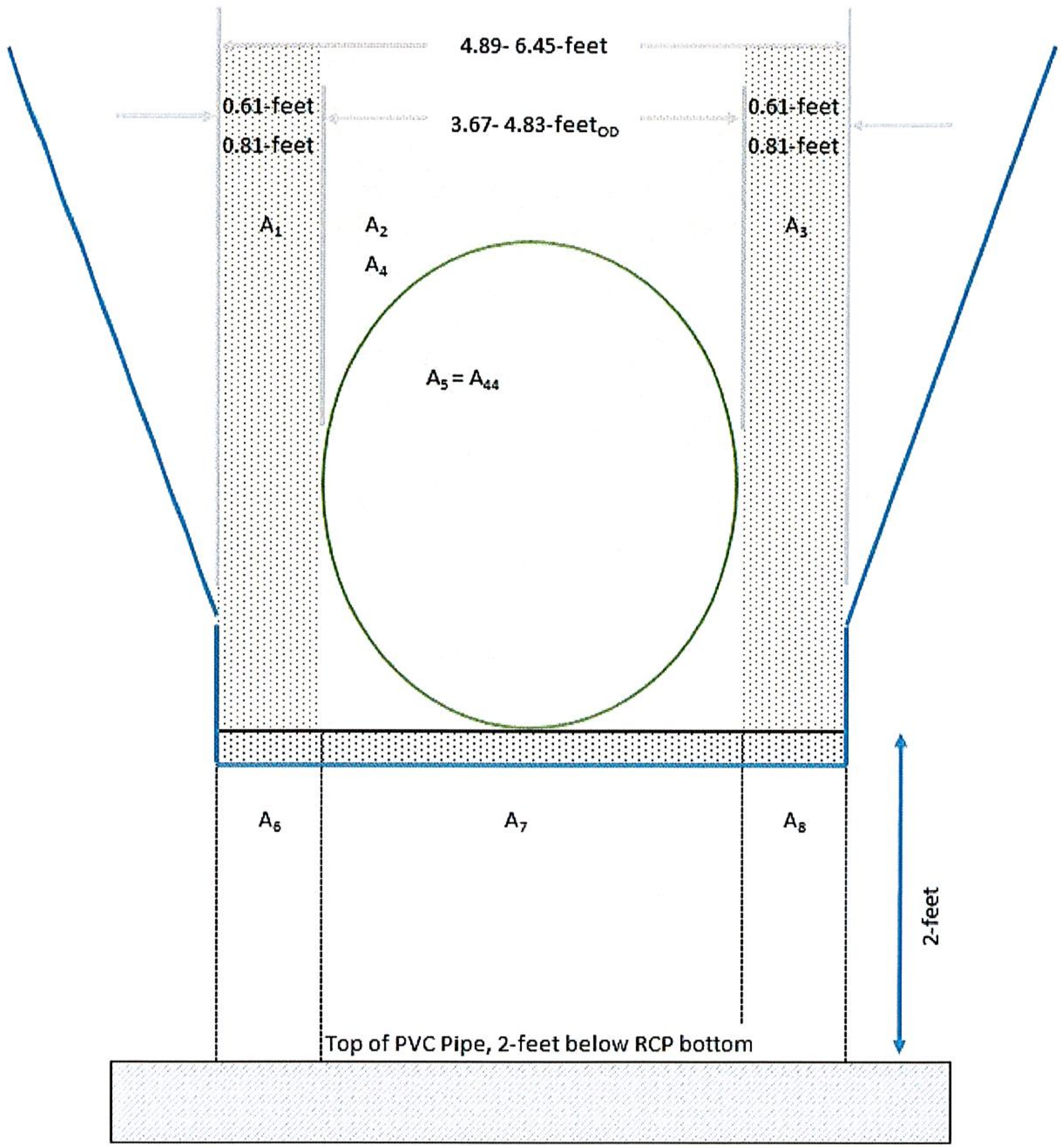
MODIFIED IOWA EQUATION
% Deflection = [0.1 (W' + P) 100] / [0.149 (PS) + 0.061 (E')]
Where: **% Deflection** = predicted percentage of diametric deflection. **W' = Live Load** (psi): pressure transmitted to the pipe from traffic on the ground surface. Live Load values are found in Table 2. **P = Prism Load** (psi): pressure acting on the pipe from the weight of the soil column above the pipe (also called "Dead Load"). Prism Load values are found in Table 3. **PS = Pipe Stiffness** (psi): a flexible pipe's resistance to deflection in an unburied state. Pipe Stiffness values for JM Eagle products are found in Table 4. **E' = Modulus of Soil Reaction** (psi): stiffness of the embedment soil. Values for Modulus of Soil Reaction are found in Table 5.

	Earth, Culvert, Water		% Deflection
Wt_{TOTAL}	W'	0 psi	0.8522%
	P	10.98 psi	<< 7.5%
	PS	46 psi	
	E'	2000 psi	

	Full Earth		% Deflection
Wt_{DRY}	W'	0 psi	0.9388%
	P	12.1 psi	<< 7.5%
	PS	46 psi	
	E'	2000 psi	


RCP Culvert Example
4-feet
Area36 7.069 sf
Area48 12.566 sf
36- 48-inch
3.00- 4.00-feet
9.67- 10.83-feet
3.67- 4.83-feet
Backfill Unit Weight 120 pcf
Highway Loading HS 20
Pipe Weight 36" 524 plf
Pipe Weight 48" 867 plf
44- 58-inch
3.67- 4.83-feet
2-feet
Top of PVC Pipe
2-feet below RCP bottom

RCP Culvert Example, Trench Detail



$A_1 + A_6 = A_L$

$A_2 + A_4 + A_7 = A_5$

$A_{44} = A_5$

$A_{36} = A_W$

$A_3 + A_8 = A_R$

Calculations			36-inch	48-inch	
RCP	OD	44 inch	3.667 ft	58 inch	4.833 ft
	ID	36 inch	3.000 ft	48 inch	4.000 ft
		Area A_{44}	10.554 sf	Area A_{58}	18.338 sf
		Area A_{36}	7.065 sf	Area A_{48}	12.560 sf
		A_{44}-A_{36} = $A_{CONCnet}$	3.489 sf	A_{58}-A_{48} = $A_{CONCnet}$	5.778 sf
Areas	A_1	(3.67 + 4.00)0.61 =	4.679 sf	(4.83 + 4.00)0.81 =	7.152 sf
	A_2	3.67(4.00) =	14.680 sf	4.83(4.00) =	19.320 sf
	A_3	(3.67 + 4.00)0.61 =	4.679 sf	(4.83 + 4.00)0.81 =	7.152 sf
	A_4	(3.67)3.67 - A_5 =	2.915 sf	(4.83)4.83 - A_5 =	4.990 sf
	A_5	A_{44} =	10.554 sf	A_{58} =	18.338 sf
		A_{36}=	7.065 sf	A_{48}=	12.560 sf
	A_6	(0.61)2.00 =	1.220 sf	(0.81)2.00 =	1.620 sf
	A_7	(3.67)2.00 =	7.340 sf	(4.83)2.00 =	9.660 sf
	A_8	(0.61)2.00 =	1.220 sf	(0.81)2.00 =	1.620 sf
$Area_L$	Earth	$A_1 + A_6 = A_L$	5.899 sf	$A_1 + A_6 = A_L$	8.772 sf
$Area_S$	Earth	$A_2 + A_4 + A_7 = A_S$	24.935 sf	$A_2 + A_4 + A_7 = A_S$	33.970 sf
$Area_C$	Concrete	$A_{CONCnet}$ = A_{44}-A_{36}	3.489 sf	$A_{CONCnet}$ = A_{58}-A_{48}	5.778 sf
$Area_W$	Water	$A_{36} = A_W$	7.065 sf	$A_{48} = A_W$	12.560 sf
$Area_R$	Earth	$A_3 + A_8 = A_R$	5.899 sf	$A_3 + A_8 = A_R$	8.772 sf
Weight		Earth	120.000 pcf		
		Concrete	150.000 pcf		
		Water	62.400 pcf		
Earth	W_L	A_L sf(120 pcf)	707.844 plf	A_L sf(120 pcf)	1052.676 plf
	q_L	W_L plf / lf	1160.400 psf	W_L plf / lf	1299.600 psf
Earth	W_S	A_S sf(120 pcf)	2992.188 psf	A_S sf(120 pcf)	4076.451 psf
	q_S	W_S plf / lf	816.051 psf	W_S plf / lf	843.404 psf
Concrete	W_C	$A_{CONCnet}$ sf (150 pcf)	523.333 plf	$A_{CONCnet}$ sf (150 pcf)	866.771 plf
	q_C	W_C plf / lf	142.727 psf	W_C plf / lf	179.332 psf
Water	W_W	A_{36} sf (62.4 pcf)	440.856 plf	A_{36} sf (62.4 pcf)	783.744 plf
	q_W	W_W / lf	146.952 psf	W_W / lf	195.936 psf
Earth	W_R	A_R sf(120 pcf)	707.844 plf	A_R sf(120 pcf)	1052.676 plf
	q_R	W_R plf / lf	1160.400 psf	W_R plf / lf	1299.600 psf

Load Factors

Vertical Earth Pressure		1.35	
Dead Load (Concrete & Water)		1.25	AASHTO LRFD T3.4.1-2

q_{ULT}

$q_L(1.35)$	1566.540 psf	$q_L(1.35)$	1754.460 psf
	10.879 psi		**12.184 psi**
$q_S(1.35) + (q_C + q_W)1.25$	1463.768 psf	$q_S(1.35) + (q_C + q_W)1.25$	1607.680 psf
	10.165 psi		**11.164 psi**
$q_R(1.35)$	1566.540 psf	$q_R(1.35)$	1754.460 psf
	10.879 psi		**12.184 psi**

MODIFIED IOWA EQUATION

% Deflection = [0.1 (W' + P) 100] / [0.149 (PS) + 0.061 (E')]

Where:

% Deflection = predicted percentage of diametric deflection.
W' = Live Load (psi): pressure transmitted to the pipe from traffic on the ground surface. Live Load values are found in Table 2.
P = Prism Load (psi): pressure acting on the pipe from the weight of the soil column above the pipe (also called "Dead Load"). Prism Load values are found in Table 3.
PS = Pipe Stiffness (psi): a flexible pipe's resistance to deflection in an unburied state. Pipe Stiffness values for JM Eagle products are found in Table 4.
E' = Modulus of Soil Reaction (psi): stiffness of the embedment soil. Values for Modulus of Soil Reaction are found in Table 5.

Earth, Culvert, Water		% Deflection		% Deflection
W'	0 psi	0.788877 %	0 psi	0.866407 %
P	10.165 psi	<< 7.5%	11.164 psi	<< 7.5%
PS	46 psi		46 psi	
E'	2000 psi		2000 psi	

Full Earth		% Deflection		% Deflection
W'	0 psi	0.844289 %	0 psi	0.945566 %
P	10.879 psi	<< 7.5%	12.184 psi	<< 7.5%
PS	46 psi		46 psi	
E'	2000 psi		2000 psi	

Table 2

LIVE LOADS ON PVC PIPE			
HEIGHT OF COVER (FT)	LIVE LOAD TRANSFERRED TO PIPE, (LBS/IN²)		
	HIGHWAY H20[1]	RAILWAY E80[2]	AIRPORT[3]
1	12.50		
2	5.56	26.39	13.14
3	4.17	23.61	12.28
4	2.78	18.40	11.27
5	1.74	16.67	10.09
6	1.39	15.63	8.79
7	1.22	12.15	7.85
8	0.69	11.11	6.93
10	*	7.64	6.09
12	*	5.56	4.76
14	*	4.17	3.06
16	*	3.47	2.29
18	*	2.78	1.91
20	*	2.08	1.53
22	*	1.91	1.14
24	*	1.74	1.05
26	*	1.39	*
28	*	1.04	*
30	*	0.69	*
35	*	*	*
40	*	*	*

[1] Simulates 20 ton truck traffic + impact.
[2] Simulates 80,000 lb/ft railway load + impact.
[3] 180,000 lbs. dual tandem gear assembly; 26-inch spacing between tires and 66-inch center-to-center spacing between fore and aft tires under a rigid pavement 12 inches thick + impact.
* Negligible live load influence.

Table 3

PRISM LOAD SOIL PRESSURE (LBS/IN2)					
HEIGHT OF COVER (FT)	SOIL UNIT WEIGHT (LBS/FT3)				
	100	110	120	125	130
1	0.69	0.76	0.83	0.87	0.90
2	1.39	1.53	1.67	1.74	1.81
3	2.08	2.29	2.50	2.60	2.71
4	2.78	3.06	3.33	3.47	3.61
5	3.47	3.82	4.17	4.34	4.51
6	4.17	4.58	5.00	5.21	5.42
7	4.86	5.35	5.83	6.08	6.32
8	5.56	6.11	6.67	6.94	7.22
9	6.25	6.88	7.50	7.81	8.13
10	6.94	7.64	8.33	8.68	9.03
11	7.64	8.40	9.17	9.55	9.93
12	8.33	9.17	10.00	10.42	10.83
13	9.03	9.93	10.83	11.28	11.74
14	9.72	10.69	11.67	12.15	12.64
15	10.42	11.46	12.50	13.02	13.54
16	11.11	12.22	13.33	13.89	14.44
17	11.81	12.99	14.17	14.76	15.35
18	12.50	13.75	15.00	15.63	16.25
19	13.19	14.51	15.83	16.49	17.15
20	13.89	15.28	16.67	17.36	18.06
21	14.58	16.04	17.50	18.23	18.96
22	15.28	16.81	18.33	19.10	19.86
23	15.97	17.57	19.17	19.97	20.76
24	16.67	18.33	20.00	20.83	21.67
25	17.36	19.10	20.83	21.70	22.57
26	18.06	19.86	21.67	22.57	23.47
27	18.75	20.63	22.50	23.44	24.38
28	19.44	21.39	23.33	24.31	25.28
29	20.14	22.15	24.17	25.17	26.18
30	20.83	22.92	25.00	26.04	27.08
31	21.53	23.68	25.83	26.91	27.99
32	22.22	24.44	26.67	27.78	28.89
33	22.92	25.21	27.50	28.65	29.79
34	23.61	25.97	28.33	29.51	30.69
35	24.31	26.74	29.17	30.38	31.60
36	25.00	27.50	30.00	31.25	32.50
37	25.69	28.26	31.67	32.12	33.40
38	26.39	29.03	32.50	32.99	34.31
39	27.08	29.79	33.33	33.85	35.21
40	27.78	30.56	34.17	34.72	36.11
41	28.47	31.32	35.00	35.59	37.01
42	29.17	32.08	35.83	36.46	37.92
43	29.86	32.85	36.67	37.33	38.82
44	30.56	33.61	37.50	38.19	39.72
45	31.25	34.38	38.33	39.06	40.63
46	31.94	35.14	39.17	39.93	41.53
47	32.64	35.90	40.00	40.80	42.43
48	33.33	36.67	41.67	41.67	43.33
49	34.03	37.43	42.53	42.53	44.24
50	34.72	38.19	43.40	43.40	45.14

Table 4

PVC Sewer / Drain Pipes
SDR 35, PWRIB
All have a minimum pipe stiffness of 46 psi
SDR 26 has a minimum pipe stiffness of 115 psi.

Table 5

AVERAGE VALUES OF MODULUS OF SOIL REACTION, E' (FOR INITIAL FLEXIBLE PIPE DEFLECTION)					
	PIPE BEDDING MATERIALS	E' FOR DEGREE OF COMPACTION OF PIPE ZONE BACKFILL (PSI)			
SOIL CLASS	SOIL TYPE (Unified Classification System[a])	Loose	Slight < 85% Proctor, < 40% relative density	Moderate 85% - 95% Proctor, 40% - 70% relative density	High > 95% Proctor, > 70% relative density
Class V	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			
Class IV	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
Class III	Fine-grained Soils (LL < 50)Soils with medium to no plasticity CL, ML,ML-CL, with more than 25% coarse-grained particles 1004001,0002,000 Coarse-grained Soils with Fines GM, GC, SM, SCC contains more than 12% fines	100	400	1,000	2,000
Class II	Coarse-grained Soils with Little or No Fines GW, GP, SW, SPC contains less than 12% fines	200	1,000	2,000	3,000
Class I	Crushed Rock	1,000	3,000	3,000	3,000
	Accuracy in Terms of Percentage Deflection	±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 50ft (15m). 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-lb/cu ft (598,000 J/m^3) (ASTM D 698, AASHTO T-99, USBR Designation E-11). 1psi = 6.9kN/m^2.

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 Journal of Geo-technical Engineering Division, January 1977, pp. 33-43.

Works Cited

1. "Depth of Burial for PVC Pipe". *JM Eagle*. 2009. Technical Bulletin*:* p.1.

2. "Gravity Sewer". *JM Eagle*. 2012. Technical Bulletin: p.2.

3. "Depth of Burial for PVC Pipe". *JM Eagle*. 2009. Technical Bulletin*:* p.1.

4. "Depth of Burial for PVC Pipe". *JM Eagle*. 2009. Technical Bulletin*:* pgs.1-2.

5. "Depth of Burial for PVC Pipe". *JM Eagle*. 2009. Technical Bulletin*:* p.4.

6. "Depth of Burial for PVC Pipe". *JM Eagle*. 2009. Technical Bulletin*:* p.3.

7. "Depth of Burial for PVC Pipe". *JM Eagle*. 2009. Technical Bulletin*:* p.2.

8. "Depth of Burial for PVC Pipe". *JM Eagle*. 2009. Technical Bulletin*:* p.2.

9. "Handbook of Ductile Iron Pipe (6^{th} ed.)".*Ductile Iron Pipe Research Association*. (1984).pgs. 10-11.

10. "Handbook of Ductile Iron Pipe (6^{th} ed.)".*Ductile Iron Pipe Research Association*. (1984).p. 94

11. "Handbook of Ductile Iron Pipe (6^{th} ed.)".*Ductile Iron Pipe Research Association*. (1984).p. 94.

12. "Handbook of Ductile Iron Pipe (6^{th} ed.)".*Ductile Iron Pipe Research Association*. (1984).pgs. 84-85.

13. "Technical Research: A Comparison of Cured-In-Place Pipe (CIPP) Mechanical Properties: Laboratory vs. Field-Manufactured". *Interplastic Corporation, Thermoset Resins Division*. (2008).p.5.

14. "Gravity Sewer". *JM Eagle*. 2012. Technical Bulletin: p.2.

15. "Gravity Sewer". *JM Eagle*. 2012. Technical Bulletin: p.1.

References

Ductile Iron Pipe Research Association. (1984). *Handbook of Ductile Iron Pipe* (6^{th} ed.). Birmingham, AL: Jon C. Schladweiler.

Interplastic Corporation, Thermoset Resins Division. (2008). *Technical Research: A Comparison of Cured-In-Place Pipe (CIPP) Mechanical Properties: Laboratory vs. Field-Manufactured.* St.Paul, MN: Author.

JM Eagle. (2009). *Technical Bulletin: PVC Sewer Pipe Burial Depth Chart.* Livingston, NJ: Author.

JM Eagle. (2009). *Technical Bulletin: Depth of Burial for PVC Pipe.* Livingston, NJ: Author.

JM Eagle. (2012). Technical Bulletin: *Gravity Sewer.* Livingston, NJ: Author

John Wiley & Sons. (1969).*Basic Soils Engineering.* Canada: B.K. Hough.

PWPipe. (2002). *Gasketed PVC Sewer Pipe.* Eugene, OR: Author.

Uni-Bell PVC Pipe Association. (2001). *Handbook of PVC Pipe: Design & Construction.* Dallas, TX: Author.