



INFRAPIPE DESIGN MANUAL FOR BENDS (HORIZONTAL, VERTICAL OR BOTH), DEFLECTION AND CURVED ALIGNMENT

INTRODUCTION

The direction of flow of the fluids in a thermoplastic (PE/PP) pipeline design may be altered in the following ways:

- By including sections which incorporate bends (Bends)
- By bending the pipe itself (Deflection)
- By connecting to fittings which include a bend (Fittings)

This includes half-pipes or channels in manholes or other chambers.

The designer needs to understand the impact of:

- Geometry on hydraulics
- Design on cost
- Manufacturing practicalities on tolerances
- Pipe characteristics on design

OTHER RELEVANT DESIGN MANUALS

The design of piped solutions using thermoplastic pipes is covered in the following documents which are also available from the INFRAPIPE website.

1. [Trench & Pipe Design Manual \(including Easypipe, Mickey & Buoyancy Guide\)](#)
2. [Strength, Tolerances, Alignment & Dimensions](#)
3. [Hydraulics, Gradients, Flow Rates & Velocities](#)
4. [Connections](#)
5. [Lids, Covers, Risers & LoadRings](#)

Note some aspects of Nos 1, 2 & 3 are repeated in this document for expediency.





To clarify, this manual only covers the change in direction aspect of risers, not their access functions, waterproofing, strength calculation or interface with the surface (see 5 above). AS/NZS and ISO standards are light on requirements for bends. Information in this manual is taken from AS2200, NZS4404 and Territorial Authority (TA) Codes of Practice and DIN16961.

Bends are essential for repairs to legacy steel pipe Philippine hydroelectric systems!

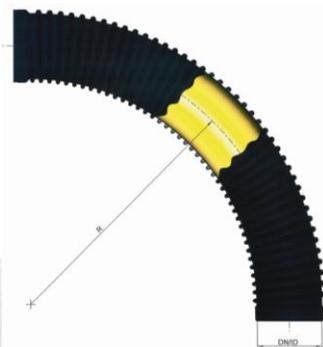


TERMINOLOGY

The standard INFRAPIPE glossary is at the back of this document, these are the terms most relevant to bends:

Fillet (gusset)	The straight part between one or two cuts/joins of a fabricated bend or fitting
Hydraulic radius	The radius the fluid must follow, taken from the centreline of the pipe or fitting typically expressed as a multiple of the ID of the pipe (see drawing below)
Segment	A section of a bend (or fitting) which has a different direction to that before or after it.
Territorial Authority (TA)	A government body responsible for engineering standards for a particular territory

Note that for INFRAPIPE, **changes in gradient are always converted to angles in degrees.** Manufacturers do not design or manufacture in % gradient or other measures only in degrees,





SOME COOL PROJECTS **INFRATANK**

AUCKLAND PORT
DN2500
CUSTOM BEND
AND RISER

AUCKLAND AIRPORT
DN2500
MANHOLE

MORRINSVILLE
26m DN2500
CULVERT

HAMILTON
100m³ DN2500
WASTE WATER TANK

HAMILTON
204m³ TANK DN3200
+ 908m DN525/600

TAMAHERE
86m³ DN2500
FIRE FIGHTING
TANK

NELSON
31m DN900
TO REPLACE
DESTROYED
WATER MAIN

NELSON
DN1800 SN8 2*130m
SLIPLINED THROUGH
60m OF BOX CULVERT

KINGSTON
400m SN8 & 16
DN1500 & 1800
STORMWATER
UPGRADE

INVERCARGILL
34m DN2500

WAIHEKE
13m DN1600
and DN1500
PILE LINERS

MANGERE
DN3200 SN4 42m
WASTEWATER
BRIDGE

PUKEKOHE
DN1500 SN2 40m
STREAM DIVERSION

PUKEKOHE
60m DN1000
SOLID WALL UNDER RAILWAY

WAIKATO
DN1800 SN8 4m

TAUPO
550m SN8
DN375-900
HE AHI

NEW PLYMOUTH
DN1350 SN11 91m
CULVERT DIVERSION
WITH 2 BENDS

NEW PLYMOUTH
118m³ DN3200

WELLINGTON
212m DN375-1000
SN16

WARRARAPA
30m DN1000

PUKETITIRI
HAWKE'S BAY
DN2500 SN8 23.2m
& DN900 SN8 11.6m
CYCLONE GABRIEL
REPAIRS IN FOREST

MANAWATU
250m SN6
DN225-450
CULVERT PIPES

CHRISTCHURCH
28m DN700
& DN2000
MANHOLE

MANAWATU
DN2000 SN35 4m
PUMP CHAMBER

WHANGAREI
PORT NIKAU
320m SN16
DN225-600
CIVILPIPE
CULVERTS

KAIPARA
CULVERTS UP TO
SN92 DN600-900
FOR THE
NORTHERN LINE
KIWI RAIL

TAURANGA
180m DN900
22DEG GRADIENT 4 MANHOLES

TAURANGA
DN2500
& DN2000
CLARIFIER

TAURANGA
40m DN3200
SN40+
WITH RISER
AND BEND

WHAKAHAHU
38m DN2500 SN15.3
STOPBANK REMEDIAL WORK

PATOKA
HAWKE'S BAY
30m of SN8
DN3200
CULVERT PIPE

HAWKE'S BAY
32m SN8 DN3200

HAWKE'S BAY
40m SN4 DN3200

PALMERSTON NORTH
DN800 SN8 156m
CIVILPIPE FOR SW
UPGRADES

MANAWATU
120m³
DN2500 SN8
FIRE SUPPLY
TANK

This is just a sample of the projects we have fulfilled showing how *versatile*, how *strong* and how *easy* to handle our KRAH™ HDPE product is.



CONTACT OUR TEAM: infrapipe.co.nz sales@infrapipe.co.nz 09 869 3030 3 Averton Place East Tamaki, Auckland 2013 INFRAPIPE NZ



CONTENTS

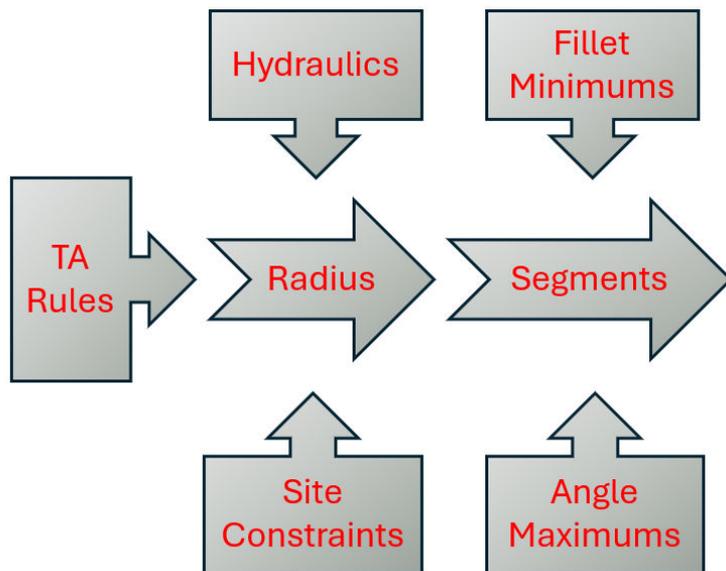
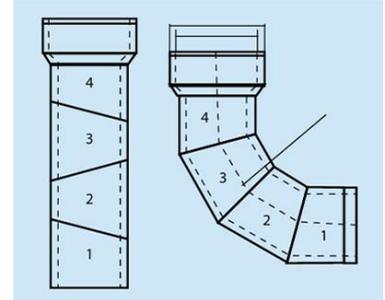
INTRODUCTION.....	1
OTHER RELEVANT DESIGN MANUALS.....	1
TERMINOLOGY.....	2
CONTENTS.....	4
BENDS.....	5
RADIUS SELECTION.....	5
FILLET MINIMUMS.....	6
SEGMENT MAXIMUM ANGLES.....	6
DEFLECTION.....	7
MINOR CHANGES OF DIRECTION/ANGLE.....	7
BENDING THE PIPE ITSELF FOR PROFILE PIPE (INFRAPIPE KRAH).....	8
BENDING THE PIPE ITSELF FOR SOLID WALL PIPE (CURVED ALIGNMENT).....	10
CIVILPIPE – BENDS FROM SOCKET ALIGNMENT.....	10
INSTALLING PIPES TO MAKE USE OF FLEXIBLE ALIGNMENT.....	11
BENDS FROM SOCKET ALIGNMENT – TA RULES.....	11
INFRAPIPE – BENDS FROM SOCKET ALIGNMENT.....	11
HYDRAULICS.....	12
MISCELLANEOUS.....	16
FITTINGS.....	16
DESIGNING COST DOWN.....	16
COMBINATIONS OF CHANGES OF DIRECTION OR ANGLE.....	16
PRE BENDS.....	17
ACCESS RISERS TO FABRICATED BENDS (OR DEFLECTED PIPES).....	17
VERTICAL BENDS (RISERS/DROPPERS).....	18
The use of multiple bends/connections.....	18
THE ADDITION OF LATERALS OR OTHER PENETRATIONS.....	18
COMPARISON TO OTHER MATERIALS.....	19
DIFFERENTIAL SETTLEMENT - SHEAR FORCE CALCULATION.....	20
TOLERANCES.....	21
FABRICATED (WELDED) BEND RADII.....	21



BENDS

This design manual covers fabricated bends DN225-3200, it does not provide information on moulded bends that are available in the smallest diameters.

Bends are manufactured by cutting a number of segments from a donor pipe and then welding those segments together (see right). A bend is then supplied with a socket, spigot or plain wall end to suit the remainder of the straight pipe, adjacent manhole or fitting etc.



THE ONLY MANUFACTURING CONSTRAINTS ARE FREIGHT AND FILLET MINIMUMS

Other than freight and the fillet minimums, INFRAPIPE can make any bend.

RADIUS SELECTION

Radius selection is driven by three factors:

1. Hydraulics and codes of practice (TA rules) which dictate hydraulic radius
2. Site requirements which dictate a physical radius
3. Minimum fillet size (in combination with segment angle rules) which can dictate a minimum radius

TA Hydraulic radius rules vary but **Auckland Council Sw CoP** requires a radius of $2.5 \times ID$ for deflections of $1-74^\circ$ and $3 \times ID$ for $75-90^\circ$. **Watercare** requires $3 \times ID$ with an absolute minimum of 2. **Watercare** also applies a 10% safety factor to proprietary fittings.



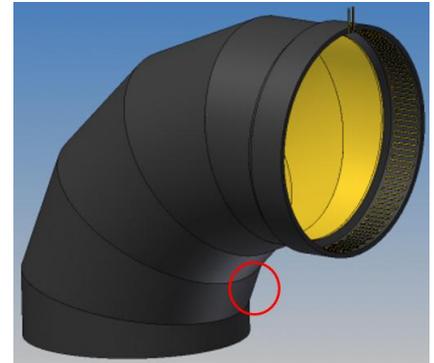
FILLET MINIMUMS

The fillet (or gusset) is the straight section that sits between welded joints as shown in the red circle to the right.

The minimum fillet typically used is 100mm. A smaller one is unstable when cutting/welding and to use no fillet (like a pizza or apple pie) removes the strength from that side of the pipe and makes good welding impossible.

For larger profile pipes or pressure pipes $SDR > 26$ it is common to use 10% of the ID as the minimum fillet size unless there is a substantial constraint as this permits the most economical fabrication.

There are no maximums on fillet size but the practicality of freight or site constraints typically minimize fillet size wherever possible.



SEGMENT MAXIMUM ANGLES

There is incomplete guidance on this issue, the best info on maximum segment size is as follows: Angles can be varied to achieve a lead-in ie 15,30,30,15 for 90.

FOR PRESSURE PIPE

- Pressure pipe must be cut to a maximum of 7.5° per cut in order to avoid derating by 0.2
- Watercare maximum 22.5°
- For manifolds and connections in wastewater treatment installations, 45° segments are permitted if the hydraulics permit

FOR PROFILE PIPE

- Profile pipe (or solidwall pipe used for gravity applications) is typically cut in angles of 11.25° , or equal divisible parts of the total angle which fall into the range $8-15^\circ$.
- DIN16961 requires 2 segments ($15^\circ-30^\circ$), 3 ($45^\circ-60^\circ$) or 4 ($75^\circ-90^\circ$).
- For low flow applications such as outfall diffusers (as shown below en route to their watery grave in Finland), 45° segments are used if the hydraulics permit





DEFLECTION

Note the information below relates to long-term [permanent] deflection. A greater deflection of 25 times ID as the radius can be used FOR SHORT-TERM ONLY during installation, as shown in this picture here.

There are three forms of deflection for INFRAPIPE solutions:

- The bend which the pipe itself can be bent to (for INFRAPIPE KRAH)
- The bend of the pipe itself for solid wall solutions (for INFRAPIPE KRAH)
- The bend which can be created from the flexibility of the socket (for CIVILPIPE)



For profile pipes, often the observed behaviour of the pipe *in situ* is a combination of the natural flexibility of the pipe, and the flexibility of the socket.

MINOR CHANGES OF DIRECTION/ANGLE

It is practical, economical and permitted in the official guidance (such as AKL SW COP and Watercare) to accommodate minor changes of direction through the flexibility of the pipe itself, ie not to fabricate bends.

For changes of gradient the grading of the trench and bedding material will normally suffice to induce the curve but for horizontal changes then some form of pinning or temporary/permanent blocks may be required.

A minor change is one where:

- The total displacement is less than the ID of the pipe such that there remains an unbroken line of sight throughout the pipe to the next access **AND**
- The change of angle per joint is less than that of Table 4 or Table 6 – whichever applies





BENDING THE PIPE ITSELF FOR PROFILE PIPE (INFRAPIPE KRAH)



As can be seen from the pictures above, INFRAPIPE KRAH solutions, whether open profile (PR) or covered profile (CPR), can be PERMANENTLY bent to a radius of 50 times the ID.

TAs such as Watercare permit pipe bending but with a safety factor of 1.25 then applied.

Table 1 Maximum deflection angles for a 5.8m pipe from bending the pipe itself, and with 25% Safety Factor applied

Note that whilst the trench itself is normally sufficient to achieve and maintain vertical deflection, horizontal deflection can require the use of thrust blocks or other restraining mechanism to preserve the curvature of the pipe.



DN	Angle°	25% SF
450	7.8	6.3
525	6.7	5.4
600	5.9	4.7
700	5.1	4.0
800	4.4	3.5
900	3.9	3.2
1000	3.6	2.8
1100	3.2	2.6
1200	3.0	2.4
1350	2.6	2.1
1500	2.4	1.9
1600	2.2	1.8
1800	2.0	1.6
2000	1.8	1.4
2300	1.5	1.2
2500	1.4	1.1
3200	1.1	0.9



Table 2 Permissible long-term deflection in metres for a given lay length (in pipes and metres)

DN	Length m Radius	6 1	11.8 2	17.6 3	23.4 4	29.2 5	58.2 10
450	22.5	0.80	3.03	6.55	11.12	16.4	>90°
525	26.25	0.68	2.61	5.69	9.77	14.6	>90°
600	30	0.60	2.29	5.02	8.68	13.1	>90°
700	35	0.51	1.97	4.34	7.54	11.5	>90°
800	40	0.45	1.73	3.81	6.66	10.2	35.4
900	45	0.40	1.54	3.40	5.95	9.2	32.7
1000	50	0.36	1.39	3.07	5.38	8.3	30.2
1100	55	0.33	1.26	2.79	4.91	7.6	28.1
1200	60	0.30	1.16	2.57	4.51	7.0	26.1
1350	67.5	0.27	1.03	2.28	4.02	6.2	23.6
1500	75	0.24	0.93	2.06	3.62	5.6	21.5
1600	80	0.23	0.87	1.93	3.40	5.3	20.3
1800	90	0.20	0.77	1.72	3.03	4.7	18.2
2000	100	0.18	0.70	1.55	2.73	4.2	16.5
2300	115	0.16	0.61	1.35	2.37	3.7	14.4
2500	125	0.14	0.56	1.24	2.19	3.4	13.3
3200	160	0.11	0.44	0.97	1.71	2.7	10.5

Table 3 Permissible long-term deflection in degrees for a given lay length (in pipes and metres)

DN	Length m Radius	6 1	11.8 2	17.6 3	23.4 4	29.2 5	58.2 10
450	22.5	7.56	14.39	20.40	25.42	29.39	>90°
525	26.25	6.50	12.47	17.91	22.65	26.64	>90°
600	30	5.70	11.00	15.92	20.35	24.22	>90°
700	35	4.89	9.49	13.84	17.87	21.50	>90°
800	40	4.29	8.34	12.23	15.88	19.26	31.32
900	45	3.81	7.43	10.94	14.28	17.41	29.33
1000	50	3.43	6.71	9.89	12.95	15.86	27.46
1100	55	3.12	6.11	9.02	11.85	14.55	25.73
1200	60	2.86	5.60	8.29	10.91	13.43	24.16
1350	67.5	2.55	4.99	7.39	9.75	12.03	22.07
1500	75	2.29	4.49	6.67	8.80	10.89	20.27
1600	80	2.15	4.21	6.26	8.27	10.24	19.20
1800	90	1.91	3.75	5.57	7.37	9.14	17.36
2000	100	1.72	3.38	5.02	6.65	8.26	15.81
2300	115	1.50	2.94	4.37	5.80	7.20	13.92
2500	125	1.38	2.70	4.02	5.34	6.64	12.89
3200	160	1.08	2.11	3.15	4.18	5.20	10.21



BENDING THE PIPE ITSELF FOR SOLID WALL PIPE (CURVED ALIGNMENT)

For solid wall pipes the calculations are different and the governing document is AS/NZS2033:2024 and PIPA POP022 which define the minimum radius in DN(OD) for each SDR:

Table 4 Minimum Radius for solid wall pipes by SDR

PE PIPE SDR	MIN RADIUS	PE PIPE SDR	MIN RADIUS
9	12	21	35
11	15	26	45
13.6	21	33	65
17/17.6	25		

Note it is unclear if Watercare wish to impose a Safety Factor on the above, but the likelihood of a pipe being bent to these radii is very low.

CIVILPIPE – BENDS FROM SOCKET ALIGNMENT

This table shows the offset that can be achieved using the deflection available for CIVILPIPE from the flexibility of the socket, in metres for a given lay distance in metres. The angle in degrees that can be achieved is also shown.

Table 5 CIVILPIPE bend offsets from socket alignment

DN	Deg	12	18	24	30	36
225	1.5	0.31	0.47	0.63	0.78	0.94
300	1.4	0.29	0.44	0.58	0.73	0.87
375	1.4	0.29	0.44	0.58	0.73	0.87
450	1.6	0.33	0.5	0.67	0.83	1.00
525	1.3	0.27	0.41	0.55	0.68	0.82
600	1.1	0.24	0.35	0.47	0.59	0.71
800	1.2	0.25	0.38	0.51	0.63	0.76
1000	1.2	0.25	0.38	0.51	0.63	0.76

The picture below shows the natural flexibility of the CIVILPIPE system





INSTALLING PIPES TO MAKE USE OF FLEXIBLE ALIGNMENT

This is best achieved by lifting the socket of the pipe that has been laid and fully penetrating the socket with the new spigot, then relaying the socket and allowing the pipe to take its new shape.

BENDS FROM SOCKET ALIGNMENT – TA RULES

There is little guidance on the limits of acceptable deflection using the spigot joints. Watercare states that “The deflection shall be applied to the manufacturers recommendation” and supplies a formula for instances where there is no manufacturers recommendation.

Watercare then proposes a table of maximums which exceeds the amounts proposed below for INFRAPIPE and CIVILPIPE shown **below left**

Table 6 Watercare permitted deflection

Nominal pipe size (mm)	Deflection angle θ (degrees)
80	5
100	5
150	5
200	4
250	4
300	4
350	3
400	3
450	3
500	3
600	3
700	2
800	2
900	1
1000	1

Table 7 KRAH Socket Bends

DN	Angle°
450	2.54
525	2.18
600	1.91
700	1.64
800	1.43
900	1.27
1000	1.15
1100	1.04
1200	0.95
1350	0.85
1500	0.76
1600	0.72
1800	0.64
2000	0.57
2300	0.50
2500	0.46
3200	0.36

INFRAPIPE – BENDS FROM SOCKET ALIGNMENT

INFRAPIPE KRAH has a machined socket with very small tolerances. The socket can accept a maximum offset of 20mm in the socket and this dimension dictates the angular deflection that can be achieved by asymmetrical installation – where a smaller diameter gives a bigger angle of deflection. **See table 7 above right**

Some further deflection of the pipe itself can be achieved (though not as much as $r = 50 * ID$ above) but this varies with the profile design, contact INFRAPIPE for more details.



HYDRAULICS

The guidance on head loss from bends is varied. **AKL SW CoP** (Table 4.3) states 0.9 for 90°, 0.6 for 45° and 0.25 for 22.5° though without guidance on interpolation or using the higher figure, but then goes on to also offer the table on the next page (Head Loss Coefficients). The following pages then show guidance from **AS2200:2006** (Chart 14) and **DIN16961**.

Table 8 Watercare transmission networks from Dp-07:2020

4.3.2.1 Head loss in bends and junctions

- a) For manholes on bends or with junctions, a minimum loss of head shall be as shown in the following table. Velocity is that for the sewer flowing full, losses are shown in millimetres for angles and velocities given, for bend centreline radius ≥ 3 . For R/d of 2, increase losses by 50%.

Note: this table considers energy losses for smooth benching/bends.

Velocity (m/s)	Bend angle				Additional for MH & junction
	0°	30°	60°	90°	
	Head loss (mm)				
0.6	0	10	20	20	10
0.9	10	10	20	20	10
1.2	10	20	20	30	10
1.4	20	20	30	30	20
1.6	20	30	40	50	20
Velocities >1.6	$0.13(v^2/2g)$	$0.19(v^2/2g)$	$0.26(v^2/2g)$	$0.32(v^2/2g)$	$2.0(v^2/2g)$

- b) Where bends are formed of chords instead of curves, an increased loss may also need to be provided for. R/d should preferably be kept at 3 or over where possible. Values under 2 are undesirable.

For lobster-back bends use: **Head loss (mm) = $1.3(v^2/2g)$**

- c) To achieve good hydraulic conditions for lobster-back bends formed from CLS and PE pipe, and to minimise losses, the bends shall have a minimum nominal radius of 3 x pipe diameter. The deflection in any one joint shall not exceed 22.5 degrees.



Table 9 Auckland Council SW Code of Practice

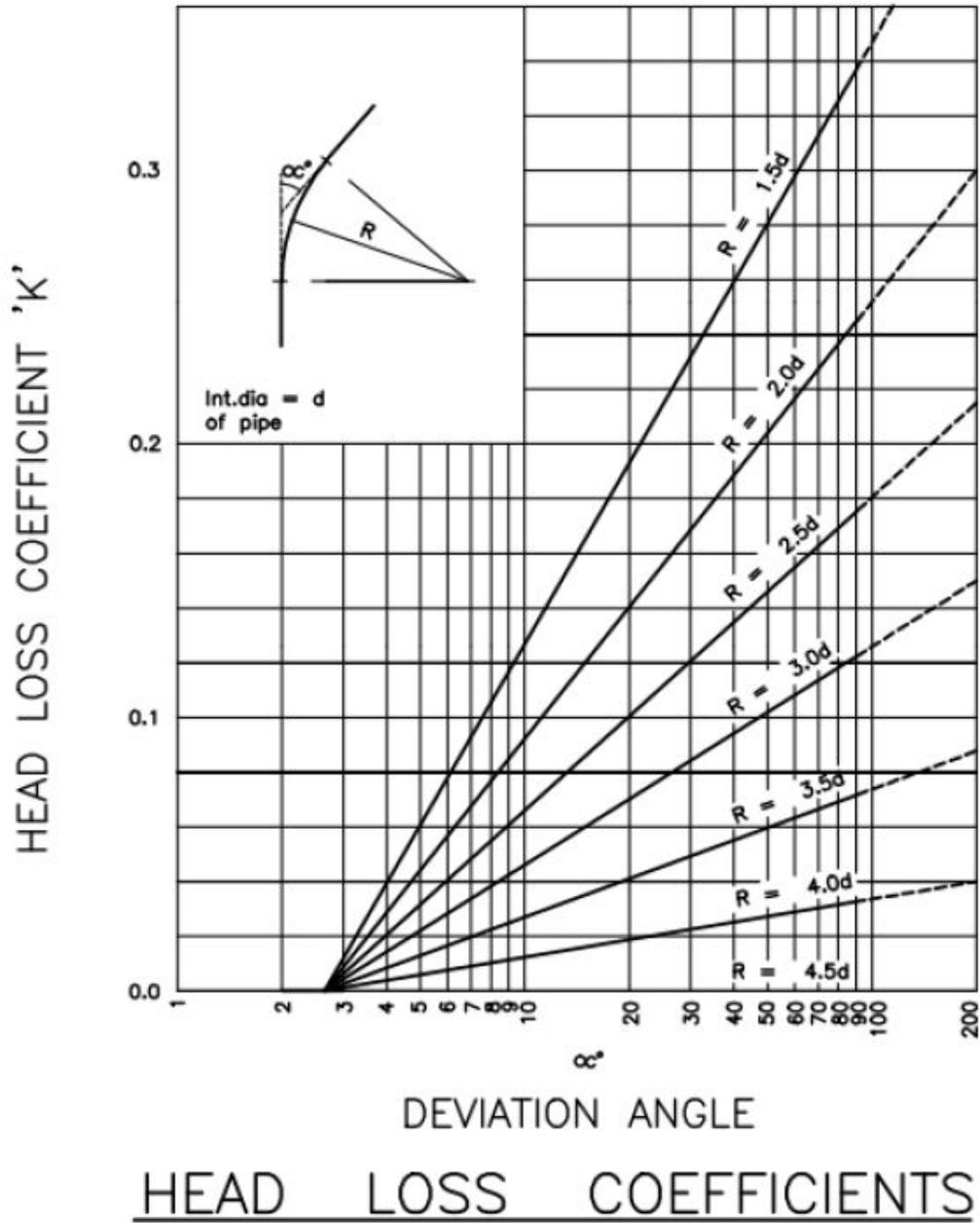
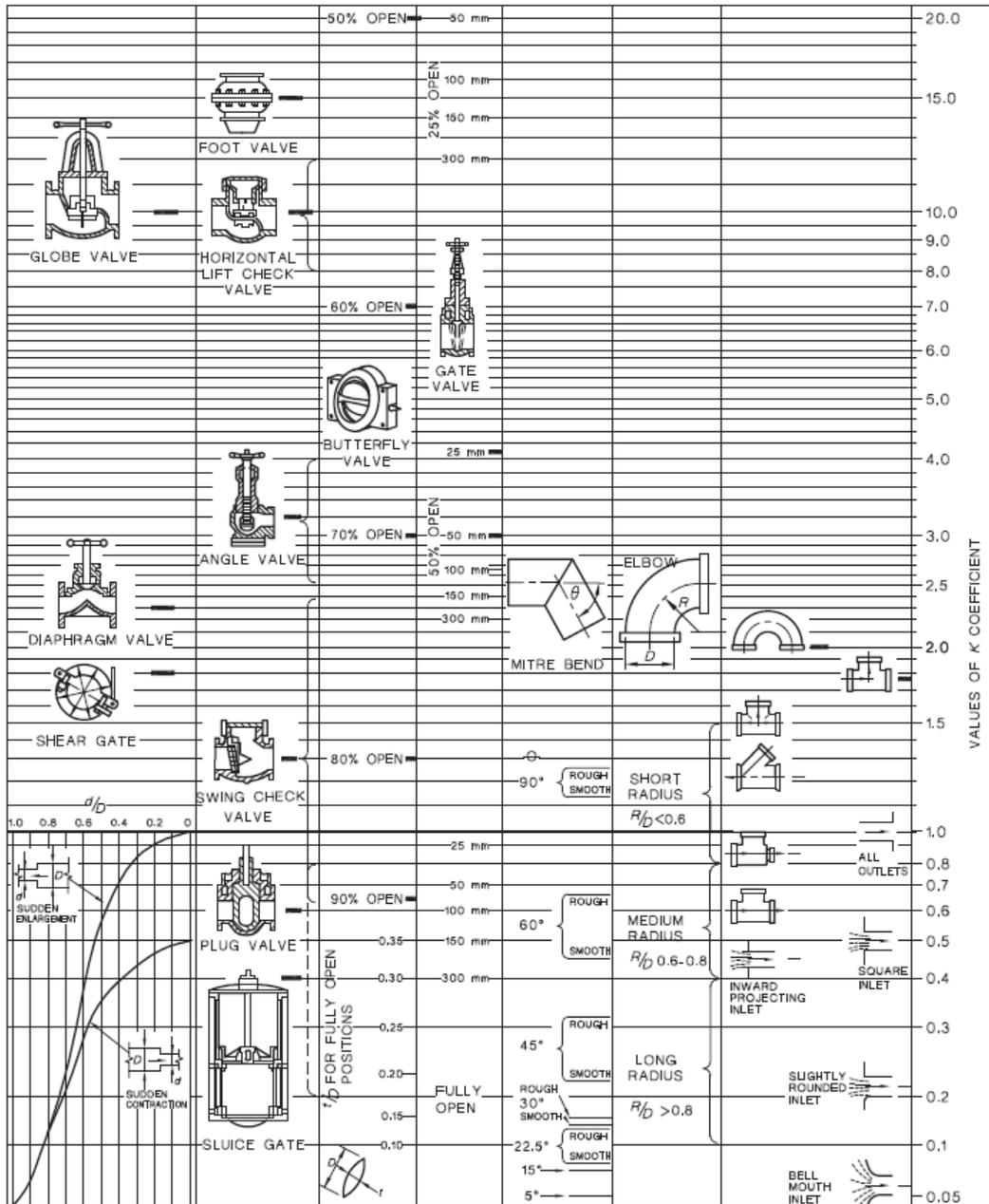




Table 10 AS2200:2006



NOTES:

- 1 To obtain approximate head loss in metres multiply k by $V^2/2g$ (V = velocity in m/s, g = acceleration due to gravity in m/s^2).
- 2 All valves fully open unless otherwise indicated.
- 3 See Appendix A, Example 3 for an example of calculations.
- 4 Brackets signify a range of values.

CHART 14 RESISTANCE COEFFICIENTS OF VALVES AND FITTINGS



Table 11 DIN16961:2017

Kind of fitting	Reference values	Resistance coefficient ξ [-]	Sketch
90° Bend	R = 1,0 x d R = 1,5 x d R = 2,0 x d R = 4,0 x d	0,51 0,41 0,34 0,23	
45° Bend	R = 1,0 x d R = 1,5 x d R = 2,0 x d R = 4,0 x d	0,34 0,27 0,20 0,15	
Elbow	$\alpha = 45^\circ$ $\alpha = 30^\circ$ $\alpha = 20^\circ$ $\alpha = 15^\circ$ $\alpha = 10^\circ$	0,30 0,14 0,05 0,05 0,04	
T-Branch	V2/ V3 = 0,0 V2/ V3 = 0,2 V2/ V3 = 0,4 V2/ V3 = 0,6 V2/ V3 = 0,8 V2/ V3 = 1,0	ξ V2 ξ V1 -1,20 0,06 -0,40 0,20 0,10 0,30 0,50 0,40 0,70 0,50 0,90 0,60	
	V2/ V1 = 0,0 V2/ V1 = 0,2 V2/ V1 = 0,4 V2/ V1 = 0,6 V2/ V1 = 0,8 V2/ V1 = 1,0	ξ V2 ξ V3 0,97 0,10 0,90 -0,10 0,90 -0,05 0,97 0,10 1,10 0,20 1,30 0,35	
Reducer ξ valid for $\lambda=0,025$	angle d2/d1 =1,2 d2/d1 =1,4 d2/d1 =1,6 d2/d1 =1,8 d2/d1 =2,0	ξ 8° ξ 8° ξ 20° 0,046 0,023 0,01 0,067 0,033 0,013 0,076 0,038 0,015 0,031 0,041 0,016 0,034 0,042 0,017	
Reducer ξ valid for $\lambda=0,025$	angle d2/d1 =1,2 d2/d1 =1,4 d2/d1 =1,6 d2/d1 =1,8 d2/d1 =2,0	ξ 4-8° ξ 16° ξ 24° 0,10 0,15 0,20 0,20 0,30 0,50 0,50 0,80 1,50 1,20 1,80 3,00 1,90 3,10 5,30	
<p>Note: R = Radius V1,2,3 = Volume flow</p>			



MISCELLANEOUS

FITTINGS

Other than requiring a 10% Safety factor on Head Loss coefficient, official guidance merely defers to the manufacturers recommendations for fittings. For the avoidance of doubt, COLLARFUSION and butt weld joints are not Fittings.

DESIGNING COST DOWN

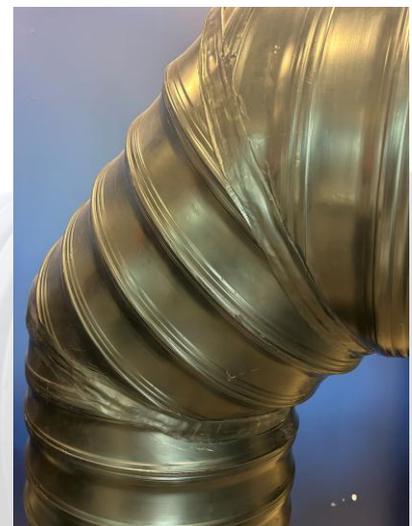
INFRAPIPE bends offer designers many ways of keeping cost down – reducing install cost by reducing total distance, minimizing manhole quantities and sizes and optimising head loss by:

- ✓ Changing direction without needing a structure
- ✓ [Using access risers](#)
- ✓ Achieving complex bends in one fitting
- ✓ Achieving minor gradient changes in the laying of the pipe
- ✓ Using pre-bends
- ✓ Bending the pipe
- ✓ Incorporating laterals and penetrations into bends



COMBINATIONS OF CHANGES OF DIRECTION OR ANGLE

Whilst deflection can be achieved in two axes simultaneously, a fabrication can incorporate a combination of horizontal or vertical changes of direction BUT NOT IN THE SAME SEGMENT. Biaxial welds and cuts require a level of complexity which has unjustifiable cost. As shown below, any complex system (this was a relocated culvert under an underground train station in Stuttgart) can be distilled down to horizontal or vertical change in direction components and then manufactured.



A segment of an example bend showing the fillet and cuts/joins

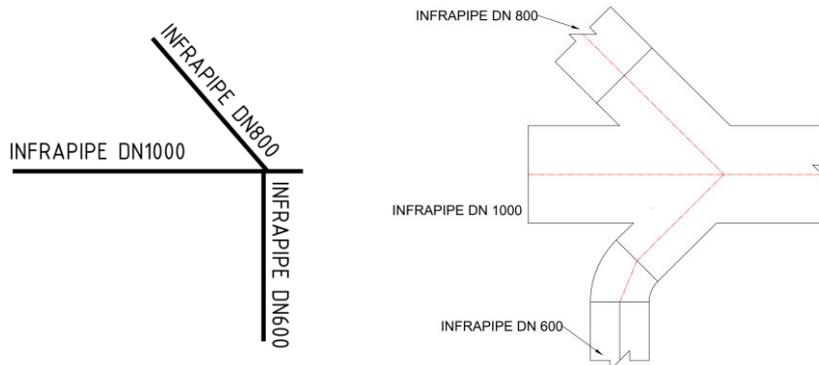


PRE BENDS

Hydraulic efficiency can be preserved by using pre-bends. From AS2200, a 90° bend has a headloss coefficient of 1.2 where two 45° bends are $2 * 0.3 = 0.6$.

INFRAPIPE can easily integrate prebends into manholes or other structures or fittings to minimize headloss.

The picture to the right shows a good use of a prebend:
The drawings below show how prebends are depicted.



ACCESS RISERS TO FABRICATED BENDS (OR DEFLECTED PIPES)

Most Codes of Practice require a manhole at a bend. The purpose of this is to ensure that the pipe can be inspected and maintained. This purpose can be achieved by the addition of a riser in the bend for a fraction of the installed cost

- Typically for pipes $DN \leq 900$, a 1000mm manhole installed in the line is used as shown here.
- For pipes $DN \geq 1000$, an access riser of 600, 800 or 1000mm is added to a segment.
- The segment in the bend therefore, must be equal to the OD of the riser (typically the $ID + 50mm$ so 650, 850, 1050) plus $2 * 100mm$ so 850, 1050, 1250 respectively.
- Pipes should not be deflected (laid with a curved alignment) if they have risers.





VERTICAL BENDS (RISERS/DROPPERS)

In essence these are no different to manufacture to horizontal bends except the weight of components may need to be considered in design.

- For installation, an INFRAPIPE up to SN16 is capable of holding the weight of itself in tension or compression for 30m+. For larger profiles or permanent installs, contact INFRAPIPE.
- Typically support is employed for risers, usually embedment in a concrete haunching because of the hydraulic thrust.
- For droppers, the outlet of a culvert can be extended through a bend to divert outflows away from terrain or structures to minimise erosion

THE USE OF MULTIPLE BENDS/CONNECTIONS

As shown on the right, when a bend needs to become a connection, there are no restriction on what can be achieved due to the flexibility of HDPE. Where concrete structures lose their structural integrity with penetrations, HDPE chambers take on the strength of the pipe that is introduced to create the connection, making the structure stronger not weaker.



Anything is possible!

THE ADDITION OF LATERALS OR OTHER PENETRATIONS

As well as access risers as above, laterals, inlets or outlets can be accommodated in segments provide that the segment is large enough to accommodate the entire penetration.





COMPARISON TO OTHER MATERIALS

The maximum for PVC is 1 degree according to PIPA POP103 *Depth of Engagement of PVC Pipes*
 For concrete, manufacturers recommendations are as below.

Table 12 Comparison of concrete and INFRAPIPE socket bend angles

Concrete	INFRAPIPE	Concrete	INFRAPIPE
225	225	1.2	1.5
300	300	0.92	1.4
375	375	0.76	1.4
450	450	0.64	2.5
525	525	0.057	2.2
600	600	0.5	1.9
675	700	0.5	1.6
750		0.5	
825	800	0.5	1.4
900	900	0.5	1.3
1050	1000	0.5	1.1
	1100	0.5	1
1200	1200	0.5	1
1350	1350	0.5	0.8
	1500	0.5	0.8
1600	1600	0.5	0.7
1800	1800	0.5	0.6





UNWANTED BENDS

DIFFERENTIAL SETTLEMENT - SHEAR FORCE CALCULATION

A potential outcome of a seismic event is differential settlement where one section of the pipe which is supported on a structure or enjoys better sub-surface resilience than the next section, resulting in a vertical deflection.

INFRAPIPE can survive indefinitely with a deflection of $50 * ID$.

Therefore, if the pipe can be deflected to the revised ground levels, the risk to the pipe is the shear force on the point at which the pipe becomes unsupported which could therefore carry the weight of all of the soil across the unsupported section (plus the weight of the pipe and its contents).

For the DN1000 example pipe, using the 9MPa shear strength of HDPE and the CSA (Cross Sectional Area) of the pipe which is 9448mm^2 , the pipe can support a weight of 8,692kgs.

For 1m cover depth of soil above with a soil density of $1.68\text{m}^3/\text{m}$ the weight per metre is 1,680kgs/m.

The pipe weighs $(295/5.8=)$ 51kg/m

The contents of the pipe could weigh as much as $0.785 (\text{m}^3) * 1200 (\text{kg}/\text{m}^3 \text{ for sediment-entrained stormwater}) = 942\text{kg}/\text{m}$

Therefore the standard pipe will resist the shear force of an unsupported weight equal to $8692/(1680+51+942) = 3.25$ metres.

Longer unsupported lengths can be accommodated by strengthening the pipe at that section (and only that section); adding thickness to the waterway or outer layers increases the relevant volume of HDPE and hence the weight-bearing capacity of the pipe.

Note this is for welded pipe or other pipes with mechanical jointing (such as bolting or pinning), different results may apply for unrestrained pipe.





TOLERANCES

- Typical angular tolerances of fabricated bends are 3 degrees ie +/- 1.5 degrees
- Tolerances of +/- 1 degree are available on request (but come with a higher fabrication cost).
- Note that a minor change can typically accommodate the tolerance in the first pipe before/after the fabricated item, even for a DN3200 (1 degree flexibility)

FABRICATED (WELDED) BEND RADII

- ✓ These tables below show the dimensions of bends (if formed into a ring) for the 3 main segment sizes used, and with or without variable straight pieces.
- ✓ These tables show 7.5, 11.25 and 15 degrees for a 100mm fillet then a 10% fillet
- ✓ These figures are taken for the SN16PR/CPR profile for the relevant diameter. **Different profiles will alter the OD and hence the OD Bend** by +/- 7%

The serpent below was manufactured by INFRAPIPE to show what fabricated bends can do





Cut angle = 7.5 degrees

DN	OD	Straight	Outer	ID Bend	OD Bend
450	542	100	71	1529	2615
525	621	100	81	1529	2773
600	720	100	94	1529	2971
700	842	100	110	1529	3216
800	962	100	126	1529	3456
900	1096	100	144	1529	3724
1000	1178	100	154	1529	3889
1100	1332	100	175	1529	4197
1200	1464	100	192	1529	4462
1350	1596	100	209	1529	4726
1500	1776	100	233	1529	5087
1600	1878	100	246	1529	5291
1800	2068	100	271	1529	5672
2000	2308	100	302	1529	6153
2300	2634	100	345	1529	6806
2500	2842	100	372	1529	7223

10% fillet, cut angle = 7.5 degrees

DN	OD	Straight	Outer	ID Bend	OD Bend
1100	1332	110	175	1682	4350
1200	1464	120	192	1835	4768
1350	1596	135	209	2065	5261
1500	1776	150	233	2294	5851
1600	1878	160	246	2447	6208
1800	2068	180	271	2753	6895
2000	2308	200	302	3059	7681
2300	2634	230	345	3517	8793
2500	2842	250	372	3823	9516



Cut angle = 11.25 degrees

DN	OD	Straight	Outer	ID Bend	OD Bend
450	542	100	107	1020	2107
525	621	100	122	1020	2266
600	720	100	142	1020	2464
700	842	100	166	1020	2709
800	962	100	189	1020	2950
900	1096	100	216	1020	3219
1000	1178	100	232	1020	3383
1100	1332	100	262	1020	3693
1200	1464	100	288	1020	3957
1350	1596	100	314	1020	4222
1500	1776	100	350	1020	4584
1600	1878	100	370	1020	4788
1800	2068	100	407	1020	5170
2000	2308	100	455	1020	5651
2300	2634	100	519	1020	6306
2500	2842	100	560	1020	6723

10% fillet, cut angle = 11.25 degrees

DN	OD	Straight	Outer	ID Bend	OD Bend
1100	1332	110	262	1122	3794
1200	1464	120	288	1225	4161
1350	1596	135	314	1378	4579
1500	1776	150	350	1531	5093
1600	1878	160	370	1633	5400
1800	2068	180	407	1837	5985
2000	2308	200	455	2041	6671
2300	2634	230	519	2347	7631
2500	2842	250	560	2551	8252



Cut angle = 15 degrees

DN	OD	Straight	Outer	ID Bend	OD Bend
450	542	100	143	766	1855
525	621	100	163	766	2014
600	720	100	190	766	2213
700	842	100	222	766	2459
800	962	100	253	766	2700
900	1096	100	289	766	2970
1000	1178	100	310	766	3135
1100	1332	100	351	766	3444
1200	1464	100	385	766	3710
1350	1596	100	420	766	3976
1500	1776	100	468	766	4338
1600	1878	100	494	766	4543
1800	2068	100	544	766	4925
2000	2308	100	608	766	5408
2300	2634	100	693	766	6064
2500	2842	100	748	766	6483

10% fillet, cut angle = 15 degrees

DN	OD	Straight	Outer	ID Bend	OD Bend
1100	1332	110	351	843	3521
1200	1464	120	385	920	3863
1350	1596	135	420	1034	4243
1500	1776	150	468	1149	4720
1600	1878	160	494	1226	5002
1800	2068	180	544	1379	5537
2000	2308	200	608	1533	6173
2300	2634	230	693	1762	7058
2500	2842	250	748	1916	7629



INFRAPIPE Glossary

Definition	Meaning
BW	Butt Weld
CD	Cover Depth
CF (W)	CollarFUSION (Weld)
COP	A KRAH profile design with two or more layers of core tube and one or more outer layers
CoP	Code of Practice
CPR	A KRAH profile design with one layer of core tube and one or more outer layers
CSA	Cross-Sectional Area of the pipe
CT	Core Tube
DM	Design manual
DN	Nominal Diameter – how the pipe is known. For INFRAPIPE this is also the ID
DS	Datasheet
EF	Electrofusion Weld/Joint
EL	Effective Length
ESDR	Equivalent SDR – shows the equivalent SDR performance for a profile pipe
FGL	Finished Ground Level
FP	Fish Passage
FPAG	Fish passage Action Group
FPG	Fish Passage Guidelines
FW	Fire Water – fire supplied for sprinkler systems or for use by FENZ
GA	General Arrangement
GWL	Ground water level
GR	Gravity – that is Gravity Pipe and PN of 1 or less
HAS	A system for joining laterals to KRAH pipes which cuts and then welds a fitting
HDPE	High Density Polyethylene (PE100) – the material used for INFRAPIPE KRAH profile pipe and solid wall pipe



HP	High Pressure – for INFRAPIPE, requirements of greater than PN3 (3 Bar). GR (Gravity) is 1 Bar or less and LP is 1-3 Bar
ID (& OD)	Internal Diameter. INFRAPIPE refers to the ID of its pipes; some competitors market their products under their Outer Diameter (OD) which can imply a capacity 15-20% greater.
IL	Invert level
IPT	In Pipe Transition where a KRAH pipe transitions in the pipe from profile to solid wall, or vice versa
ITP	Installation & Test Plan
LB	Loadbearing
LDPE	Low Density Polyethylene used for irrigation pipes and by non-certified manufacturers
KR	KRAH is a helically (spiral-wound) product manufactured using the INFRAPIPE KRAH machine
LO	Length Overall
LP	Low Pressure – that is between 1 and 3 Bar of internal pressure
MDPE	Medium Density Polyethylene used for its ductility in small bore pressure pipes such as domestic watermain in the house.
MH	Manhole
ML	Manufactured Length
MMR	Maintenance, Modification & Repair
NLB	Non Loadbearing – no vehicular loading
NZBC	New Zealand Building Code
OC	Odour Control
OFP	Overland Flow Path
P&G	Provisional & General costs – the costs of running the site
PE100	The standard grade of HDPE used for civil work
PN	Used in pressure applications and expressed in bar, this is the pressure rating of the pipe. Corresponds to SDR for solid wall pipe, ie for PE100 PN16 = 16 bar = SDR11
PP	Polypropylene. Used for the core tube of Krah pipes and SN16 CIVILPIPE. Similar in most characteristics to HDPE but stronger for its weight though less ductile.
PR	A KRAH profile design with no outer layer



RCI	Relative Cost Index expressed as a percentage to show the cost impact of changes where the first option = 100%
RL	Reduced level
SCR or HSCR	A crack resistant form of HDPE. This is not required for spiral wound pipes as the extrusion is radial not axial, preventing the polymers from propagating any cracks longitudinally (profile pipes cannot propagate cracks due to the profile shape)
SDR	Standard Dimension Ratio – the ratio between WT and OD for solid wall Pipe, ie SDR has a WT of 1/11 the OD
SiDR	Standard Internal Dimension Ratio. Used overseas but not so much in NZ, this is the ratio of the wall thickness (WT) to the Inner Diameter (ID) NZ prefers to use SDR which uses the OD
SF	Safety Factor (for SN, PN or buoyancy calculations)
SKT	Socket
SN	Ring Stiffness – the strength of the pipe
SPG	Spigot
SW	Solid Wall or Stormwater. Solid wall is pipe is used for pressure applications 2Bar+, fabrication and some manholes and chambers
SWE	Solid Wall End
TA	Trench Angle or Territorial Authority
TCO (WLC/WoLC)	Total Cost of Ownership – also known as Whole life Cost or Whole of Life cost
TMP	Traffic Management Plan – the term TMP is often used as an abbreviation to refer to the costs of traffic management
TW	Twinwall (pipe such as CIVILPIPE) or Trade Waste
VW	Solid wall pipe (in INFRAPIPE's pipe design software)
WM	??
WT	Wall Thickness - the difference between ID and OD
WW	Waste Water
WWPS	Wastewater pump station
WWTC	Wastewater terminal chamber
WWTP	Wastewater treatment plant
ZoI	Zone of Influence – that area in the soil affected by a force from a load not directly above or below it, typically calculated at a 45 degree angle