APPENDIX SES2.3

PIPELINE ENGINEERING ASSESSMENT REPORT

PINS document reference: 14.6.2.3

Pipetechnics ltd.

REPORT ON ISSUES CONCERNING THE ANGLIAN WATER SERVICES WATER MAINS CROSSING THE AUGEAN SITE

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WS010005/14.6.2.3

May 2022

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APPENDICES

1 Introduction

1.1 Pipetechnics Ltd was engaged by Augean South Ltd to examine specific potential issues raised by Anglian Water Services (AWS) pertaining to their existing steel 800mm diameter twin water mains. These water mains cross diagonally through the site of the proposed future western expansion at the Augean site and adjacent to the existing East Northants Resource Management Facility (ENRMF).

1.2 The concerns raised by AWS relate to how the pipelines might be affected by being left insitu (rather than being diverted away from the active site). These issues include:

- Potential failure of the pipelines, including crater size and access for repair.
- External loading on the pipelines from equipment used to manage the Augean site.
- Effect of excavations at the Augean site on the pipelines.

2 Pipe Material

2.1 It is understood from AWS that the twin pipelines crossing the Augean site are made of steel. To date, no as-built information has been provided, so reasonably worst-case assumptions have been made regarding the original wall thickness of the pipes, the grade of steel from which they were manufactured, the coating and lining provided to the pipes, and their burial depth.

2.2 Steel is a ductile pipeline material, which can be susceptible to corrosion if it is not adequately protected. Steel is very strong in tension, and therefore the wall thicknesses used in water pipelines are generally governed by the handling, welding and installation requirements, rather than their ability to resist internal pressure. This is particularly true in the water industry, where operating pressures are generally low compared to, for example, oil pipelines.

2.3 If failures of the steel pipe body occur, they are most often associated with through wall corrosion, rather than a catastrophic burst that can be seen in more brittle materials, such as cast iron. More serious issues can occur at the welded joints, if these have not been correctly executed and supervised, or if, during construction, pipe alignments are not correct. As an example, I have investigated the failure of a large diameter welded steel special (a bespoke, factory-made bend). In this case, steel pipework laid under two different contracts was to be pieced together with a shop-made steel special. The alignment of the two legs of pipework was not accurate, and there was about a 5mm mismatch. The pipes were forced to fit the steel special, and were welded up, but less than a year later one of the welds had "let go" due to the stress it was under. I have heard of cases (but I don't have direct experience) of welds also "letting go" where unaccounted for differential settlement of the pipeline has put undue stress on welds.

2.4 Steel pipes can be typically supplied in lengths of 6m, 9m and 12m, so there could be in the region of 30 to 55 joints per pipeline in the length crossing the ENRMF site.

2.5 The precise age of the pipelines is not known at this time, but it is assumed that they were laid within the last 25 years based on the known diversion of the pipelines during the development of the existing landfill site. Given this information, it seems likely that the pipes were supplied by FT Pipelines (formerly known as Frazer & Tabberer).

2.6 Where bends and fittings are present in pressurised water mains, thrust forces are generated due to changes in pipeline diameter or direction. These forces are countered by the provision of thrust restraint. This can take the form of concrete thrust blocks, designed to resist the forces generated, or by joining pipes together by welded or anchored joints, and resisting the generated forces by the friction created between the embedment soil and the walls of the pipeline along the length of the continuous pipework.

2.7 The benefit of welding the joints means that thrust forces generated by the under-pressure water can be accommodated at changes of direction in the pipeline, without the need for large concrete thrust blocks.

2.8 Typically, the structural design of buried pipelines is concerned with the response of the pipe cross section when subjected to loads from both soil backfill and any vehicular loading. Steel pipes are generally classified as flexible in their behaviour, since their response to external load is to deflect into an out-of-circle shape.

2.9 The lining (internal protection) and coating (external protection) of the pipelines is also not known. Steel pipes are generally supplied with either a cement mortar lining, or an epoxy lining. Limits of pipe deflection are specified in order to ensure no damage occurs to the internal linings when the pipeline deflects into an out-of-circle shape. For this reason, a cement mortar lining has been assumed in the structural calculations, as this has a slightly more onerous deflection limit (3%, compared with an epoxy lining of 5%).

2.10 There have been no failures of the pipelines crossing the ENRMF site, although it is understood from AWS that there has been prior leakage on one of these pipelines in a different location.

3 Potential breach of mains

3.1 As indicated previously, the most likely failure scenario is a small, through-wall corrosion leak. Left undetected, small leaks can develop, and lead to loosening of the pipe embedment, and potential loss of support locally to the pipelines. Ultimately, this could lead to a more catastrophic failure.

3.2 It is not known whether these pipelines are already acoustically monitored, but if they're not, it would be possible to install equipment to specifically monitor the section of pipeline crossing the Augean site. Typically, this would consist of a pair of monitoring devices (ultrasonic / acoustic / correlators) which could be fixed to the outside of the pipelines at each end of the section to be monitored. These would detect any low-level leaks that may be developing in the pipelines, giving operators the location of the defect to enable a timely repair to be carried out.

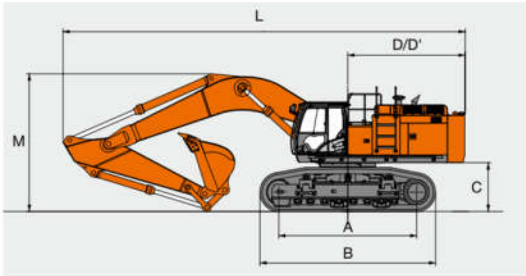
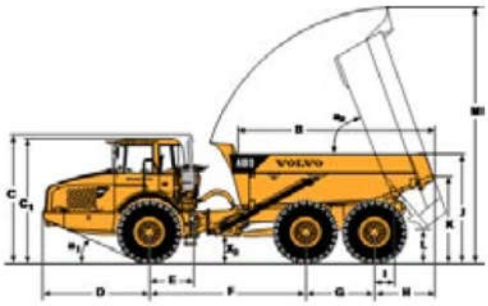
3.3 It was indicated by AWS at the hearing held on 8th June 2022 that the pipelines have an impressed current cathodic protection system in place, but they were unsure whether or not this was working. Cathodic protection is a process by which steel pipelines are electrically protected, either by provision of sacrificial anodes, or by application of an impressed current. It is typically used in more aggressive ground conditions as a back-up corrosion control measure in the event of damage to the external pipe coating.

4 External loading & potential for damage

4.1 Standard vehicular loading applied to pipeline structural design is laid out in BS EN 1295-1 (1997) National Annex A (likely to be the standard in place when the pipelines were laid), or in the more recent BS 9295 (2020). Both give vehicular loadings at various depths of cover for standard scenarios of main roads, light roads (omitted from BS 9295), and fields, as well as construction plant and rail loadings. The loadings incorporate an impact factor, to account for the dynamic effect of the vehicle movements. Vibration effects are not taken into account separately and are usually only considered where buried pipelines are likely to be subjected to the effects of piling or explosions arising from mining etc.

4.2 For more specific types of plant, a bespoke analysis can be carried out using Holl's integration of the Boussinesq equation. This is a standard way in pipeline engineering to evaluate the pressure at pipe crown of loads applied at the ground surface, and the procedure is laid out in the TRRL document "A guide to design loadings for buried rigid pipes" (1983), Appendix 2. The types of plant that would likely be used in the future development of the Augean ENRMF site have been analysed in this way, which has yielded the following results, for two likely burial depth scenarios. The burial depths used are 1.2m cover, a typical burial depth for water mains, and an indicated likely depth from AWS, and 3m cover, an estimated likely worst-case burial depth. The details of this analysis can be found in Appendix A.

Figure 1 – Vehicular loading

Vehicle	Load at pipe crown at 1.2m cover depth (kN/m²)	Load at pipe crown at 3m cover depth (kN/m²)	Image
Hitachi ZX670LCH-3 or similar	77.59	18.93	
A40 dump truck or similar	108.31	35.90	

4.3 These loadings have then been taken forward in calculations laid out in BS 9295 (2020) "Guide to the structural design of buried pipes". The pipelines are currently in a loading condition that would be defined in the current standard BS 9295 (2020) as "Fields & Gardens". In the earlier standard, BS EN 1295-1 National Annex A, this loading would have been classified as "Fields" (numerically, these two loading scenarios are the same). The date at which the pipelines were installed is not known, but is assumed to be approximately 25 years ago. Therefore, the standard that would have been used for the original structural pipeline design would have been BS EN 1295-1

(1997) "Structural design of buried pipelines under various conditions of loading".

4.4 The standard wall thickness for an 800mm diameter steel pipe supplied by Frazer and Tabberer is 7.1mm, which is a typical value for steel pipes of this diameter supplied to the water industry.

4.5 Steel pipes are generally classified as flexible in their behaviour, since their response to external load is to deflect into an out-of-circle shape. Calculations have been undertaken, following the procedure set out in BS 9295 (2020), Section 7 "Flexible Pipe Design". The details of this analysis can be found in Appendix B. Figure 2 below summarises the results using the original wall thickness of 7.1mm. Figure 3 shows the results using a reduced wall thickness scenario of 5.5mm (a corrosion allowance around the full circumference of 1.6mm).

Figure 2 – Structural analysis using a 7.1mm wall thickness

		Burial depth = 1.2m		
		Pipe wall thickness = 7.1mm		
		Field loading (current scenario)	A40 Dump Truck	Large Excavator
Earth Pressure	kN/m2	23.76	23.76	23.76
Vehicular loading	kN/m2	27.21	108.00	77.59
Total pressure	kN/m2	50.97	131.76	101.35
FOS against buckling	Must be >2	7.83	3.06	3.98
Ovalisation	Must be < 3%	1.05	2.39	1.88

		Burial depth = 3m		
		Pipe wall thickness = 7.1mm		
		Field loading (current scenario)	A40 Dump Truck	Large Excavator
Earth Pressure	kN/m2	59.40	59.40	59.40
Vehicular loading	kN/m2	5.47	35.90	18.93
Total pressure	kN/m2	64.87	95.30	78.33
FOS against buckling	Must be >2	6.18	4.23	5.13
Ovalisation	Must be < 3%	1.97	2.60	2.25

Figure 3 – Structural analysis using a 5.5mm wall thickness

		Burial depth = 1.2m Pipe wall thickness = 5.5mm		
		Field loading (current scenario)	A40 Dump Truck	Large Excavator
Earth Pressure	kN/m^2	23.76	23.76	23.76
Vehicular loading	kN/m^2	27.21	108.00	77.59
Total pressure	kN/m^2	50.97	131.76	101.35
FOS against buckling	Must be >2	6.09	2.39	3.09
Ovalisation	Must be < 3%	1.20	2.73	2.15

		Burial depth = 3m Pipe wall thickness = 5.5mm		
		Field loading (current scenario)	A40 Dump Truck	Large Excavator
Earth Pressure	kN/m^2	59.40	59.40	59.40
Vehicular loading	kN/m^2	5.47	35.90	18.93
Total pressure	kN/m^2	64.87	95.30	78.33
FOS against buckling	Must be >2	4.81	3.29	3.99
Ovalisation	Must be < 3%	2.25	2.97	2.57

4.6 These results show that, whilst the pipelines may not have been originally designed to accommodate significant vehicular loading, the pipelines comfortably pass the ovalisation check, and have a factor of safety against buckling significantly greater than the required value of 2 in all loading cases, using the original wall thickness. Even at a reduced pipe wall thickness of 5.5mm, the structural calculations pass all the required design checks. This demonstrates that there is a very low risk of an increased vehicular loading being detrimental to the integrity of the pipelines.

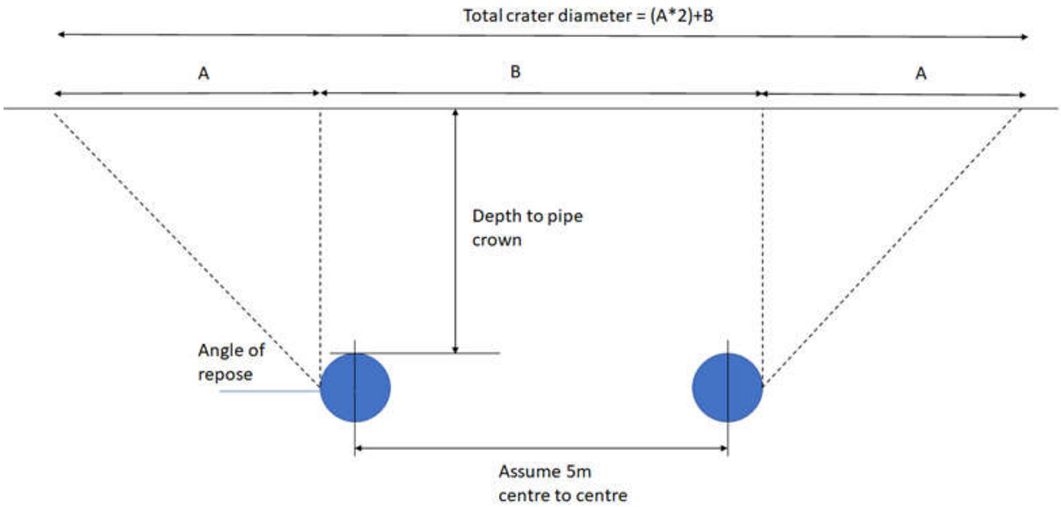
4.7 Despite the results of the analysis above, it is recommended that designated crossing points are constructed to allow vehicular movement across the pipelines, simply to ensure that the ground surface doesn’t deteriorate. Rutting of the ground surface could result in wheel loads becoming unacceptably close to the pipeline crowns, and this should be avoided. However, the analysis has shown that the predicted loads are unlikely to compromise the structural integrity of the pipelines. The options for the crossing detail could range from a simple slab or crane mat at ground level, in order to protect the ground surface and spread the loads, to a piled bridge construction which would take any loads to below the invert level of the pipelines. A piled bridge solution is seen as an extreme solution not justified by the preliminary analysis undertaken, and whose construction would introduce new risks of load and vibration in close proximity to the pipelines. For these reasons, the piled bridge option is not a preferred crossing solution.

5 Potential size of crater in the event of pipe rupture

5.1 The potential size of crater has been calculated using geometry, for a number of different burial depths, and assuming a worst-case scenario of both pipelines failing. An angle of repose of 45 degrees has been used, which is a very conservative estimate for the stiff clay found in the boreholes on site (this angle of repose is more commonly used with looser, granular soils). An average pipe spacing centre to centre of 5m has been assumed.

5.2 Although a burial depth to pipe crown of 1.2m has been indicated by AWS, a further conservative estimate of 3m burial to pipe crown is suggested as a reasonable worst-case assumption. As can be seen from Figure 3 below, this would lead to a crater size of diameter approximately 12.6m.

Figure 4 – Diameter of failure crater

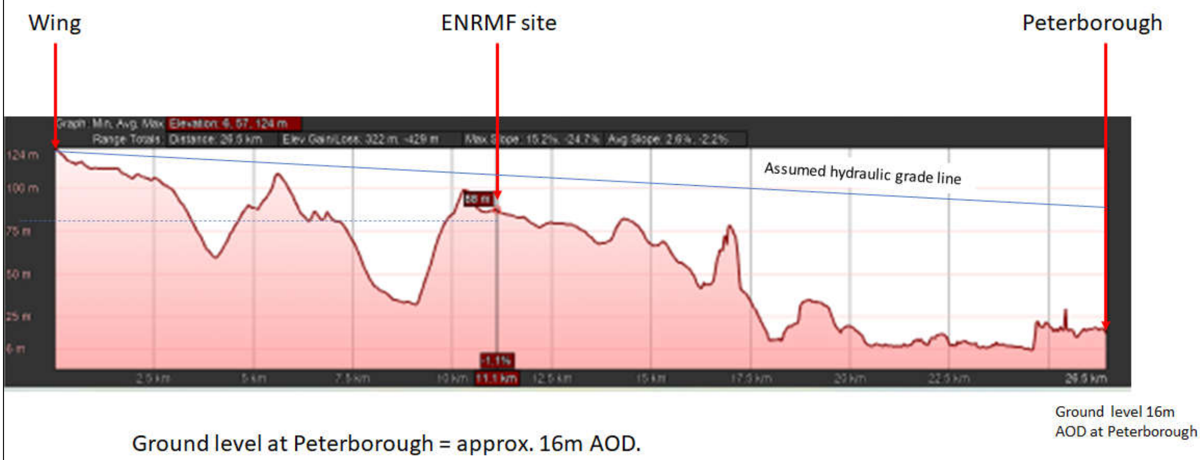


Depth to pipe crown	m	1.5	2	2.5	3
Pipe spacing (centre to centre)	m	5	5	5	5
Pipe inside diameter	m	0.8	0.8	0.8	0.8
Pipe outside diameter	m	0.813	0.813	0.813	0.813
Depth to springing	m	1.91	2.41	2.91	3.41
Worst case angle of repose	degrees	45	45	45	45

Dimension A	m	1.91	2.41	2.91	3.41
Dimension B	m	5.813	5.813	5.813	5.813
Crater diameter	m	9.63	10.63	11.63	12.63

5.3 It has been indicated by AWS that the pipelines run at a pressure of 8 bars. They are gravity fed from the Wing WTW, taking potable water to the city of Peterborough. Examination of the topography of the land between Wing and Peterborough, and accounting for the level at the Augean site would suggest that the likely pressure in the mains at the Augean site is approximately 2.6 bars. This is shown in Figure 5 below:

Figure 5 – Profile of the ground between Wing WTW and Peterborough



Ground level at Peterborough = approx. 16m AOD.
Say pipe invert level = approx. 13m AOD
To have 8 bar pressure at Peterborough, 8/0.098 = 81.6m head at pipe level at Peterborough
= 81.6 + 13 = 94.6m
Ground level at ENRMF site = approx. 88m AOD.
Level of assumed hydraulic grade line at ENRMF site = 111.69m
Worst case assume 3m cover to pipelines ∴ pipe crown at 85m AOD
111.69 – 85 = 26.69m * 0.098 = approx. 2.6 bar pressure at ENRMF site

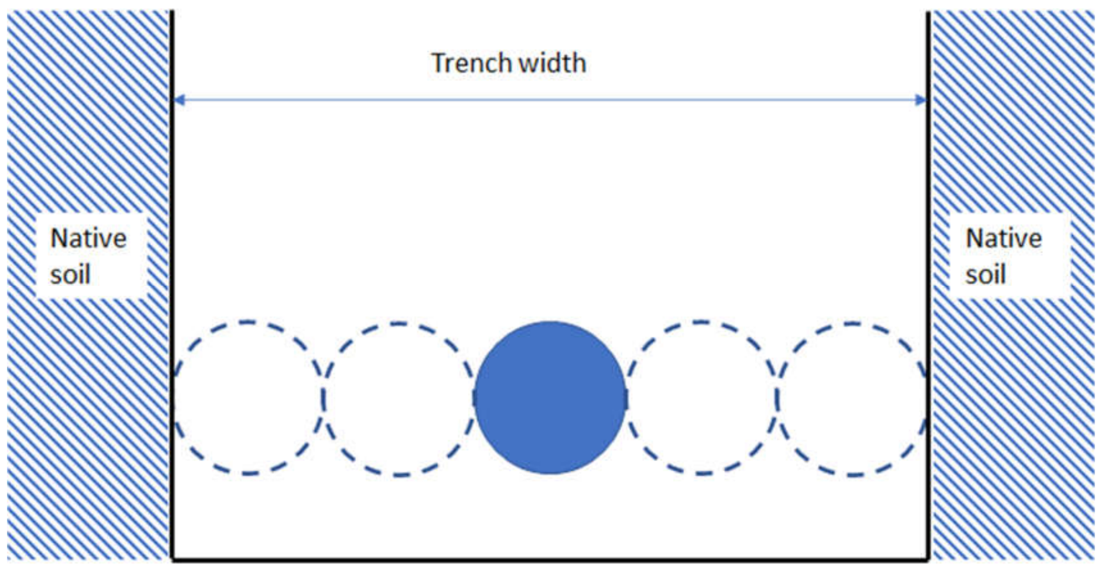
5.4 Despite the apparent pressure at the ENRMF site being approximately 2.6 bars, the structural design calculations have been undertaken using an internal pressure of 8 bars as stated by AWS.

6 Stability of pipelines due to excavations & effect of shrink/swell clays

6.1 It is understood from the soils investigations undertaken at the ENRMF site that the soils are stiff clays, which may be subject to shrink / swell upon loading and unloading.

6.2 When designing new pipelines, it is generally accepted that when the trench width is greater than 4.3 multiplied by the pipe outside diameter, the effect of the native soil to the sides of the pipe are ignored (see BS 9295 (2020) section 7.2.5). It is stated in Section 4.6 of that standard that "the zone of soil which has a structural influence on the buried pipe typically extends between one and two diameters from the pipe wall in all directions" (see Figure 6).

Figure 6 – Zone of influence around a buried pipeline

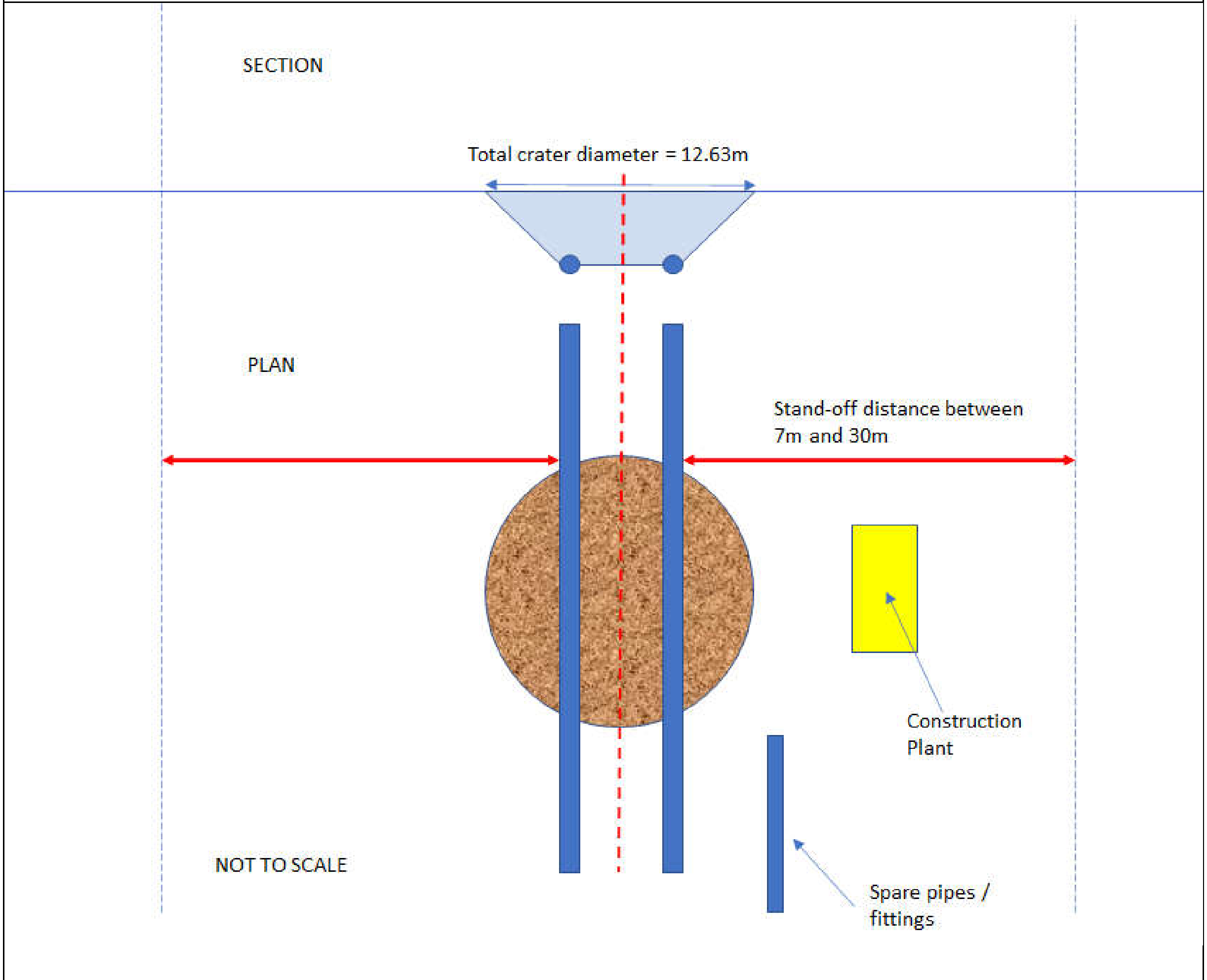


6.3 The stand-off dimension proposed by Augean of between 7m and 30m is more than adequate in all cases to ensure that the pipelines will be unaffected by any excavations taking place, and the presence of the excavation activity will not increase the likelihood of pipe failure from the shrink/swell effects associated with the excavation of the clay.

7 Access for pipe repair

7.1 A key consideration is the future access to the full length of the pipelines crossing the ENRMF site for maintenance purposes. The worst-case scenario is that of a catastrophic burst affecting both pipelines, as outlined in Section 5 above.

Figure 7 – Access requirements



7.2 If a burst were to occur, the following general steps are taken:

- Isolation of the affected pipeline.
- Removal of water at ground level and in crater.
- Secure the crater to allow safe access and establish safe working area.
- Repair can commence.

When a repair is undertaken, every effort is made to ensure the cleanliness of the pipeline is not compromised. Water and soil debris are kept away from the internal surfaces of the existing pipeline, the repair piece and couplings. AWS will have strict protocols regarding mains repair to ensure no contamination of the water occurs, and typically this will include spraying repair pieces and fittings with chlorous acid or similar, flushing of the main, and bacteriological sampling after completion of the repair to demonstrate water hygiene compliance.

7.3 All the activities for the repair of a pipeline burst outlined in 7.2 above can be safely carried out within the proposed stand-off distances of 7m to 30m, and well within the 20m stated as preferred by AWS.

8 Effect of water in pipeline embedment

8.1 Anecdotally, the pipelines do not have a full gravel embedment. It has been indicated by AWS that the pipelines are laid in gravel to their haunch level, with the remaining backfill being an as-dug material.

8.2 Generally, gravel pipe embedment can act like a land drain, and for this reason, it is good practice that impermeable layers are placed at regular intervals across the pipe trench in order to discourage the flow of water within the embedment. Whilst it is not known if this was done during the construction of the pipelines, since it is general good practice, it is assumed to have taken place.

8.3 If the ground water is static, it is unlikely to cause deterioration of the pipeline coatings, or to cause a loss of support to the pipelines. The groundwater body at the site is well below the level of the pipelines and, as addressed in the Pipeline Risk Assessment report, the Surface Water Management Plan is designed to maintain the surface water flow to follow the pre-development pattern.

9 Conclusions

9.1 The steel pipeline material is ductile, and any deterioration is likely to come about via local through wall corrosion, rather than catastrophic rupture.

9.2 The pipelines can be readily monitored to mitigate the risk of leakage / corrosion effects.

9.3 External loads placed on the pipelines due to future plant and equipment is unlikely to cause detriment to the pipelines as long as the surface is appropriately protected.

9.4 In the very unlikely event that a pipeline rupture were to occur, involving the failure of both pipelines together, the likely diameter of the resulting crater is around 12.5m (from a reasonable worst-case assumed pipeline burial depth of 3m).

9.5 The pressure in the pipelines at the Augean site is likely to be approximately 2.6 bars.

9.6 Water in the pipeline embedment should not significantly increase the risk of corrosion.

9.7 The suggested stand-off range of between 7m and 30m proposed by Augean includes the 20m distance preferred by AWS which is more than adequate to allow for the access, maintenance and repair of the pipelines, even in the unlikely event of a significant rupture.

References

BS 9295 (2020) – Guide to the structural design of buried pipes under various conditions of load.

BS EN 1295-1 (1997) – Structural design of buried pipelines under various conditions of loading

TRRL – A guide to design loadings for buried rigid pipes (1983).

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APPENDIX A

Vehicular loading analysis

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CALCULATION PACK

DOCUMENT No
PT/AU/Vehicular loads_1.2m

PROJECT NO.	PROJECT TITLE
N/A	**Augean / ENRMF site**

SUBJECT	SHEET No
Vehicular loading calcs @ 1.2m depth of cover	1 of 3

ISSUE	TOTAL SHEET (S)	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
1	3	SJRD	24/05/22	SJRD	27/05/22			First Draft
2								
3								
4								

SUPERSEDES DOC No		DATE	

DESIGN BASIS STATEMENT (Inc. sources of info/data, assumptions made, standards, etc.)

Source of Info

1. ENRMF DCO Application Anglian Water Pipelines. Table 1 Scoping Table for Scenarios of Risk Assessment
2.
3.

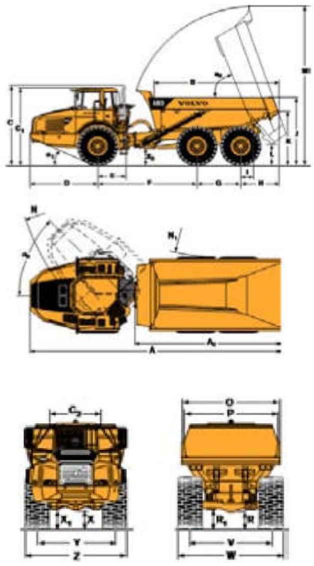
Standards and References

4. TRRL A guide to design loadings for buried rigid pipes, Appendix 2
5.
6.
7.

Remit

PROJECT	Augean ENRMF site	Date	24-May-22
Part of Work	Effect of A40 dump truck on buried steel pipelines	Job Number	
Calcs by	SJRD	Checked	
		Reviewed	

Data Sheets



	Metric (mm)		Imperial (Feet)	
Pos	A35D	A40D	A35D	A40D
A	11 178	11 287	36'8"	37'0"
A_2	6 224	6 428	20'5"	21'1"
B	5 527	5 730	18'2"	18'10"
C	3 681	3 746	12'1"	12'3"
C_1	3 560	3 626	11'8"	11'11"
C_2	1 768	1 768	5'10"	5'10"
C_3	3 987	4 093	13'1"	13'5"
D	3 103	3 103	10'2"	10'2"
E	1 275	1 275	4'2"	4'2"
F	4 501	4 448	14'9"	14'7"
G	1 820	1 940	6'0"	6'4"
H	1 754	1 796	5'9"	5'11"
I	725	638	2'5"	2'1"
J	2 912	3 075	9'7"	10'1"
K	2 302	2 492	7'7"	8'2"
L	915	906	3'0"	3'0"
M	7 242	7 384	23'9"	24'3"
N	8 720	8 863	28'7"	29'1"
N_1	4 397	4 238	14'5"	13'11"
O	3 103	3 268	10'2"	10'9"
P	2 870	3 078	9'5"	10'1"
R	584	654	1'11"	2'2"
R_1	670	751	2'2"	2'6"
U	3 528	3 590	11'7"	11'9"
V	2 515	2 636	8'3"	8'8"
V*	2 625	- - - - -	8'7"	- - - - -
W	3 208	3 432	10'6"	11'3"
W*)**	3 410	3 570	11'2"	11'9"
X	572	617	1'11"	2'2"
X_1	606	639	1'0"	2'1"
X_2	720	765	2'4"	2'6"
Y	2 515	2 636	8'3"	8'8"
Y*	2 625	- - - - -	8'7"	- - - - -
Z	3 208	3 432	10'6"	11'3"
Z*)**	3 410	3 570	11'2"	11'9"
a_1	23°	25°	23°	25°
a_2	70°	70°	70°	70°
a_3	45°	45°	45°	45°

A35D: Unloaded machine with 26,5R25
A40D: Unloaded machine with 29,5R29
*) A35D with optional 775/65R29 tires
**) A40D with optional 875/65R29 tires

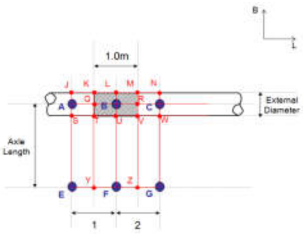
Weights		
	A35D	A40D
Tires	26,5R25*	29,5R25**
Operating weight unloaded		
Front	15 320 kg **33 775 lb**	16 300 kg **35 935 lb**
Rear	12 980 kg **28 616 lb**	14 970 kg **33 003 lb**
Total	28 300 kg **62 391 lb**	31 270 kg **68 938 lb**
Payload	32 500 kg **71 650 lb**	37 000 kg **81 571 lb**
Total weight		
Front	17 770 kg **39 176 lb**	19 170 kg **42 263 lb**
Rear	43 030 kg **94 865 lb**	49 100 kg **108 247 lb**
Total	60 800 kg **134 041 lb**	68 270 kg **150 509 lb**

Operating weight includes all fluids and operator
*) A35D with tires 775/65R29, add 200 kg **(441 lb)**/ axle
) A40D with tires 875/65R29, add 300 kg **(661 lb)/ axle

Load Capacity		
	A35D	A40D
Standard Body		
Load capacity	32 500 kg **36 sh tn**	37 000 kg **41 sh tn**
Body, struck	15,2 m^3 **19.9 yd^3**	16,9 m^3 **22.1 yd^3**
Body, heaped	20,0 m^3 **26.2 yd^3**	22,5 m^3 **29.4 yd^3**
With overhung tailgate		
Body, struck	15,5 m^3 **20.3 yd^3**	17,2 m^3 **22.5 yd^3**
Body, heaped	20,7 m^3 **27.1 yd^3**	23,2 m^3 **30.3 yd^3**

Body volume according to SAE 2:1

Wheel Arrangement



Calulations

Wheel	Virtual Rectangles	Dimensions (m)	
		B	L
A	AQTS	0.407	3.948
	ARVS	0.407	4.948
B	KLBQ	0.407	0.5
E	JMZE	3.043	4.948
	JKYE	3.043	3.948
	SVZE	2.230	4.948
	STYE	2.230	3.948
F	KLFY	3.043	0.5
	TUFY	2.230	0.5
C	QCWT	0.407	2.44
	RCWV	0.407	1.44
G	KNGY	3.043	2.44
	MNGZ	3.043	1.44
	TWGY	2.230	2.44
	VWGZ	2.230	1.44

Variable Inputs

Vehicle Axle Spacing 1 (m)	4.448	Dimension F
Vehicle Axle Spacing 2 (m)	1.94	Dimension G
Vehicle Axle Length (m)	2.636	Dimension V/Y
Load per axle (front) kg	19170	
Load per axle (rear) kg	90000	
Load per Wheel (front) (kN)	94.03	
Load per Wheel (rear) (kN)	220.73	
Wheel Impact Factor	1.7	Construction plant (ref TRRL)
External Pipe Diameter (m)	0.81	

Results Summary

Depth to Pipe Crown (m)	Pressure (kN/m2)
1.2	108.305

Load Calculations

Depth under consideration (m) 1.2

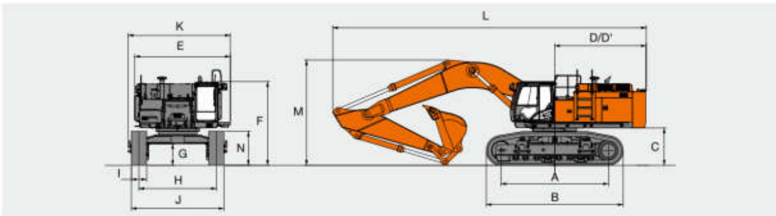
being considered	Value IQ
AQTS	0.100
ARVS	0.100
KLBQ	0.054
JMZE	0.244
JKYE	0.243
SVZE	0.237
STYE	0.236
KLFY	0.118
TUFY	0.117
QCWT	0.099
RCWV	0.093
KNGY	0.237
MNGZ	0.215
TWGY	0.231
VWGZ	0.211
Load Coeff for Each Wheel	
A	0.000339
B	0.217229
C	0.012371
E	0.000165
F	0.003469
G	0.001377
Sum of Load Coeff (front	0.000503
Load (front) (kN)	0.080478
Sum of Load Coeff (rear	0.234446
Load (rear) (kN)	87.971580
TOTAL LOAD (kN)	88.052
Total Pressure on Pipe Crown (kN/m^2)	**108.305**

PROJECT	Augean ENRMF site	Date	24-May-22
Part of Work	Effect of Hitachi large excavator on buried steel pipelines	Job Number	

Calcs by	SJRD	Checked		Reviewed	

Data Sheets

DIMENSIONS



Unit: mm

Retractable gauge		ZX670LC-5G	ZX670LCH-5G
A Distance between tumblers		4 590	4 590
B Undercarriage length		5 840	5 840
*1 C Counterweight clearance		1 530	1 530
D Rear-end swing radius		4 020	4 020
D' Rear-end length		3 910	3 910
E Overall width upperstructure		4 090	4 090
F Overall height of cab		3550	3 660
*1 G Min. ground clearance		860	860
H Track gauge : Extended / Retracted		3 300 / 2 830	3 300 / 2 830
I Track shoe width		650 / 750 / 900	650
J Undercarriage width	with 650 mm shoe	3 950 / 3 480	3 950 / 3 480
: Extended / Retracted	with 750 mm shoe	4 050 / 3 580	—
	with 900 mm shoe	4 200 / 3 730	—
K Overall width		4 360	4 360
L Overall length		13 400	13 400
M Overall height of boom		4 460	4 460
N Track height		1 440	1 440

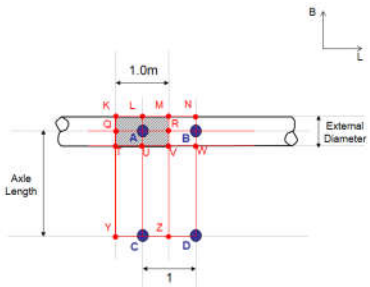
*1 Excluding track shoe lug

WEIGHTS AND GROUND PRESSURE

Operating Weight and Ground Pressure

				ZX670LC-5G	
Shoe type	Shoe width	Boom type	Arm type	kg	kPa (kgf/cm²)
Double	650 mm	6.8 m BE	2.9 m BE	67 300	101 (1.03)
		Bucket capacity		3.5 m³	
		7.8 m	3.6 m	66 800	100 (1.02)
		Bucket capacity		2.9 m³	
		7.8 m	4.2 m	67 000	101 (1.02)
		Bucket capacity		2.5 m³	
	750 mm	6.8 m BE	2.9 m BE	67 600	88 (0.90)
		Bucket capacity		3.5 m³	
		7.8 m	3.6 m	67 200	87 (0.89)
		Bucket capacity		2.9 m³	
		7.8 m	4.2 m	67 400	88 (0.89)
		Bucket capacity		2.5 m³	
	900 mm	6.8 m BE	2.9 m BE	68 700	74 (0.76)
		Bucket capacity		3.5 m³	
		7.8 m	3.6 m	68 200	74 (0.75)
		Bucket capacity		2.9 m³	
		7.8 m	4.2 m	68 400	74 (0.76)
		Bucket capacity		2.5 m³	

Wheel Arrangement



Calculations

Wheel	Virtual Rectangles	Dimensions (m)	
		B	L
A	AQTU	0.4065	0.5
B	BQTW	0.4065	5.09
	BRVW	0.4065	4.09
C	CLKY	3.2365	0.5
	CUTY	2.4235	0.5
D	DNKY	3.2365	5.09
	DWTY	2.4235	5.09
	DNMZ	3.2365	4.09
	DWVZ	2.4235	4.09

Variable Inputs

Vehicle Axle Spacing 1 (m)	4.59	Dimension A
Vehicle Axle Length (m)	2.83	Dimension H
Total operating weight (kg)	68700	Worst case
Assumed Load per Wheel (kN)	168.49	
Wheel Impact Factor	1.7	Construction plant (ref TRRL)
External Pipe Diameter (m)	0.81	

Results Summary

Depth to Pipe Crown (m)	Pressure (kN/m²)
1.2	77.586

Load Calculations

Depth under consideration (m) 1.2

Virtual Rectangle being considered	Influence Value IQ
AQTU	0.054
BQTW	0.100
BRVW	0.100
CLKY	0.119
CUTY	0.117
DNKY	0.245
DWTY	0.240
DNMZ	0.244
DWVZ	0.239
Load Coeff for Each Wheel	
A	0.217229
B	0.000292
C	0.002566
D	0.000134
Sum of Load Coeff	0.220
Total Load (kN)	63.077
Total Pressure on Pipe Crown (kN/m²)	**77.586**

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CALCULATION PACK

DOCUMENT No
PT/AU/Vehicular loads_3m

PROJECT NO.	PROJECT TITLE
N/A	**Augean / ENRMF site**

SUBJECT	SHEET No
Vehicular loading calcs @ 3m depth of cover	1 of 3

ISSUE	TOTAL SHEET (S)	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
1	3	SJRD	24/05/22	SJRD	27/05/22			First Draft
2								
3								
4								

SUPERSEDES DOC No		DATE	

DESIGN BASIS STATEMENT (Inc. sources of info/data, assumptions made, standards, etc.)

Source of Info

1. ENRMF DCO Application Anglian Water Pipelines. Table 1 Scoping Table for Scenarios of Risk Assessment
2.
3.

Standards and References

4. TRRL A guide to design loadings for buried rigid pipes, Appendix 2
5.
6.
7.

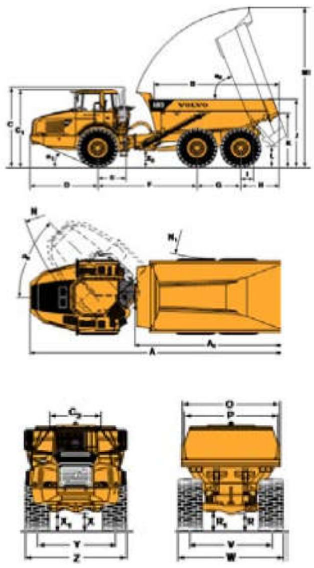
Remit

Pipetechnics ltd.

	Sheet No		
	2	of	3

PROJECT	Augean ENRMF site	Date	24-May-22
Part of Work	Effect of A40 dump truck on buried steel pipelines @ 3m burial depth	Job Number	
Calcs by	SJRD	Checked	
		Reviewed	

Data Sheets



	Metric (mm)		Imperial (Feet)	
Pos	A35D	A40D	A35D	A40D
A	11 178	11 287	36'8"	37'0"
A_2	6 224	6 428	20'5"	21'1"
B	5 527	5 730	18'2"	18'10"
C	3 681	3 746	12'1"	12'3"
C_1	3 560	3 626	11'8"	11'11"
C_2	1 768	1 768	5'10"	5'10"
C_3	3 987	4 093	13'1"	13'5"
D	3 103	3 103	10'2"	10'2"
E	1 275	1 275	4'2"	4'2"
F	4 501	4 448	14'9"	14'7"
G	1 820	1 940	6'0"	6'4"
H	1 754	1 796	5'9"	5'11"
I	725	638	2'5"	2'1"
J	2 912	3 075	9'7"	10'1"
K	2 302	2 492	7'7"	8'2"
L	915	906	3'0"	3'0"
M	7 242	7 384	23'9"	24'3"
N	8 720	8 863	28'7"	29'1"
N_1	4 397	4 238	14'5"	13'11"
O	3 103	3 268	10'2"	10'9"
P	2 870	3 078	9'5"	10'1"
R	584	654	1'11"	2'2"
R_1	670	751	2'2"	2'6"
U	3 528	3 590	11'7"	11'9"
V	2 515	2 636	8'3"	8'8"
V*	2 625	-----	8'7"	-----
W	3 208	3 432	10'6"	11'3"
W*)**	3 410	3 570	11'2"	11'9"
X	572	617	1'11"	2'2"
X_1	606	639	1'0"	2'1"
X_2	720	765	2'4"	2'6"
Y	2 515	2 636	8'3"	8'8"
Y*	2 625	-----	8'7"	-----
Z	3 208	3 432	10'6"	11'3"
Z*)**	3 410	3 570	11'2"	11'9"
a_1	23°	25°	23°	25°
a_2	70°	70°	70°	70°
a_3	45°	45°	45°	45°

A35D: Unloaded machine with 26,5R25
A40D: Unloaded machine with 29,5R29
*) A35D with optional 775/65R29 tires
**) A40D with optional 875/65R29 tires

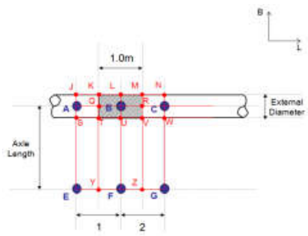
Weights		
	A35D	A40D
Tires	26,5R25*	29,5R25**
Operating weight unloaded		
Front	15 320 kg **33 775 lb**	16 300 kg **35 935 lb**
Rear	12 980 kg **28 616 lb**	14 970 kg **33 003 lb**
Total	28 300 kg **62 391 lb**	31 270 kg **68 938 lb**
Payload	32 500 kg **71 650 lb**	37 000 kg **81 571 lb**
Total weight		
Front	17 770 kg **39 176 lb**	19 170 kg **42 263 lb**
Rear	43 030 kg **94 865 lb**	49 100 kg **108 247 lb**
Total	60 800 kg **134 041 lb**	68 270 kg **150 509 lb**

Operating weight includes all fluids and operator
*) A35D with tires 775/65R29, add 200 kg **(441 lb)**/ axle
) A40D with tires 875/65R29, add 300 kg **(661 lb)/ axle

Load Capacity		
	A35D	A40D
Standard Body		
Load capacity	32 500 kg **36 sh tn**	37 000 kg **41 sh tn**
Body, struck	15,2 m^3 **19.9 yd^3**	16,9 m^3 **22.1 yd^3**
Body, heaped	20,0 m^3 **26.2 yd^3**	22,5 m^3 **29.4 yd^3**
With overhung tailgate		
Body, struck	15,5 m^3 **20.3 yd^3**	17,2 m^3 **22.5 yd^3**
Body, heaped	20,7 m^3 **27.1 yd^3**	23,2 m^3 **30.3 yd^3**

Body volume according to SAE 2:1

Wheel Arrangement



Calulations

Wheel	Virtual Rectangles	Dimensions (m)	
		B	L
A	AQTS	0.407	3.948
	ARVS	0.407	4.948
B	KLBQ	0.407	0.5
E	JMZE	3.043	4.948
	JKYE	3.043	3.948
	SVZE	2.230	4.948
	STYE	2.230	3.948
F	KLFY	3.043	0.5
	TUFY	2.230	0.5
C	QCWT	0.407	2.44
	RCWV	0.407	1.44
G	KNGY	3.043	2.44
	MNGZ	3.043	1.44
	TWGY	2.230	2.44
	VWGZ	2.230	1.44

Variable Inputs

Vehicle Axle Spacing 1 (m)	4.448	Dimension F
Vehicle Axle Spacing 2 (m)	1.94	Dimension G
Vehicle Axle Length (m)	2.636	Dimension V/Y
Load per axle (front) kg	19170	
Load per axle (rear) kg	90000	
Load per Wheel (front) (kN)	94.03	
Load per Wheel (rear) (kN)	220.73	
Wheel Impact Factor	1.7	Construction plant (ref TRRL)
External Pipe Diameter (m)	0.81	

Results Summary

Depth to Pipe Crown (m)	Pressure (kN/m2)
3.0	35.904

Load Calculations

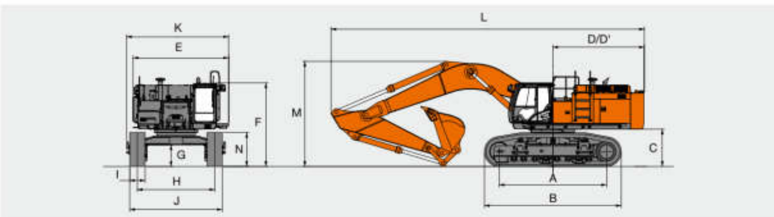
Depth under consideration (m) 3.0

being considered	Value IQ
AQTS	0.040
ARVS	0.041
KLBQ	0.010
JMZE	0.197
JKYE	0.190
SVZE	0.171
STYE	0.166
KLFY	0.046
TUFY	0.041
QCWT	0.035
RCWV	0.026
KNGY	0.162
MNGZ	0.117
TWGY	0.142
VWGZ	0.104
Load Coeff for Each Wheel	
A	0.002412
B	0.041534
C	0.018113
E	0.001398
F	0.010363
G	0.006159
Sum of Load Coeff (front	0.003810
Load (front) (kN)	0.609013
Sum of Load Coeff (rear	0.076169
Load (rear) (kN)	28.581061
TOTAL LOAD (kN)	29.190
Total Pressure on Pipe Crown (kN/m^2)	**35.904**

PROJECT	Augean ENRMF site	Date	24-May-22
Part of Work	Effect of Hitachi large excavator on buried steel pipelines @ 3m burial depth	Job Number	
Calcs by	SJRD	Checked	Reviewed

Data Sheets

DIMENSIONS



Unit: mm

Retractable gauge		ZX670LC-5G	ZX670LCH-5G
A Distance between tumblers		4 590	4 590
B Undercarriage length		5 840	5 840
*1 C Counterweight clearance		1 530	1 530
D Rear-end swing radius		4 020	4 020
D' Rear-end length		3 910	3 910
E Overall width upperstructure		4 090	4 090
F Overall height of cab		3550	3 660
*1 G Min. ground clearance		860	860
H Track gauge : Extended / Retracted		3 300 / 2 830	3 300 / 2 830
I Track shoe width		650 / 750 / 900	650
J Undercarriage width	with 650 mm shoe	3 950 / 3 480	3 950 / 3 480
: Extended / Retracted	with 750 mm shoe	4 050 / 3 580	—
	with 900 mm shoe	4 200 / 3 730	—
K Overall width		4 360	4 360
L Overall length		13 400	13 400
M Overall height of boom		4 460	4 460
N Track height		1 440	1 440

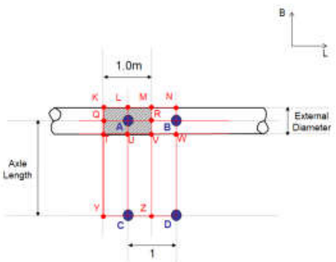
*1 Excluding track shoe lug

WEIGHTS AND GROUND PRESSURE

Operating Weight and Ground Pressure

				ZX670LC-5G	
Shoe type	Shoe width	Boom type	Arm type	kg	kPa (kgf/cm²)
Double	650 mm	6.8 m BE	2.9 m BE	67 300	101 (1.03)
		Bucket capacity		3.5 m³	
		7.8 m	3.6 m	66 800	100 (1.02)
		Bucket capacity		2.9 m³	
		7.8 m	4.2 m	67 000	101 (1.02)
		Bucket capacity		2.5 m³	
	750 mm	6.8 m BE	2.9 m BE	67 600	88 (0.90)
		Bucket capacity		3.5 m³	
		7.8 m	3.6 m	67 200	87 (0.89)
		Bucket capacity		2.9 m³	
		7.8 m	4.2 m	67 400	88 (0.89)
		Bucket capacity		2.5 m³	
	900 mm	6.8 m BE	2.9 m BE	68 700	74 (0.76)
		Bucket capacity		3.5 m³	
		7.8 m	3.6 m	68 200	74 (0.75)
		Bucket capacity		2.9 m³	
		7.8 m	4.2 m	68 400	74 (0.76)
		Bucket capacity		2.5 m³	

Wheel Arrangement



Calculations

Wheel	Virtual Rectangles	Dimensions (m)	
		B	L
A	AQTU	0.4065	0.5
B	BQTW	0.4065	5.09
	BRVW	0.4065	4.09
C	CLKY	3.2365	0.5
	CUTY	2.4235	0.5
D	DNKY	3.2365	5.09
	DWTY	2.4235	5.09
	DNMZ	3.2365	4.09
	DWVZ	2.4235	4.09

Variable Inputs

Vehicle Axle Spacing 1 (m)	4.59	Dimension A
Vehicle Axle Length (m)	2.83	Dimension H
Total operating weight (kg)	68700	Worst case
Assumed Load per Wheel (kN)	168.49	
Wheel Impact Factor	1.7	Construction plant (ref TRRL)
External Pipe Diameter (m)	0.81	

Results Summary

Depth to Pipe Crown (m)	Pressure (kN/m²)
3.0	18.928

Load Calculations

Depth under consideration (m) 3.0

Virtual Rectangle being considered	Influence Value IQ
AQTU	0.010
BQTW	0.041
BRVW	0.040
CLKY	0.047
CUTY	0.043
DNKY	0.202
DWTY	0.179
DNMZ	0.195
DWVZ	0.174
Load Coeff for Each Wheel	
A	0.041534
B	0.002162
C	0.008838
D	0.001192
Sum of Load Coeff	0.054
Total Load (kN)	15.388
Total Pressure on Pipe Crown (kN/m²)	**18.928**

Pipetechnics ltd.

APPENDIX B

Structural design of steel pipelines at 1.2m and 3m burial depths

Pipetechnics ltd.	CALCULATION PACK	DOCUMENT No
		PT/AU/Calcs_1.2m

PROJECT NO.	PROJECT TITLE
N/A	Augean / ENRMF site

SUBJECT	SHEET No
Steel Pipeline Calculations @ 1.2m cover, wall thickness 7.1mm	1 of 6

ISSUE	TOTAL SHEET (S)	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
1	6	SJRD	24/05/22	SJRD	27/05/22			First Draft
2								
3								
4								

SUPERSEDES DOC No		DATE	

DESIGN BA 0.01

Source of Info

1. ENRMF DCO Application Anglian Water Pipelines. Table 1 Scoping Table for Scenarios of Risk Assessment
2.
3.

Standards and References

4. BS 9295:2020.
5.
6.
7.

Remit

Design Scenario:
Burial depth = 1.2m

STEEL PRESSURE PIPELINE

VARIABLE INPUTS	**Units**	**Symbol**	**Value**	**Notes (assumed values etc)**	
Pipe Properties					
Is this calculation for twin steel pipes laid in a single trench?			**Yes**	*Select*	
Steel Grade			L235	*Select pipe grade*	*Assumed - worst case*
Internal diameter (Nominal)	m	DN	0.8	*Select pipe diameter*	
External diameter	m	Bc	0.8142		
Wall thickness (standard for the diameter selected)	m	t	0.0071	*From look up table*	
Wall thickness (choose)	m	t	0.0071	*Type in value*	
Poisson's ratio (steel)		v_{steel}	0.3		
Type of pipe lining			Cement mortar	*Select*	*Assumed - worst case*
Cement mortar lining thickness	m	t_L	0.01		
Poisson's ratio (mortar)		v_{mortar}	0.3		
Weight of pipe + cement mortar		kg/m	219		
Poisson's ratio (epoxy)		v_{epoxy}	N/A		
Weight of pipe + epoxy		kg/m	N/A		
Modulus of Elasticity (steel)	MN/m^2	E	207000	*Standard value*	
Second moment of area of pipe wall	m^4/m	I	2.98259E-08		
Pipe stiffness (no CM lining)	N/m^2	S	11743		
Density of mild steel	Kg/m^3		7850	*Assumed*	
Yield Strength	MN/m2	F_y	235		

Installation variables				
Depth of cover	m	H	1.2	*ENRMF DCO application Table 1*
Height of water above pipeline	m	H_w	0	*No groundwater found in any borehole*
Trench width	m	B_d	7	*Assumed original trench width*
Soil density	kN/m^3	γ	19.8	*Typical value (BS EN 1295-1)*
Native soil modulus	MN/m^2	E`3	5	*Input soil modulus from BS 9295 Table 13 (stiff clay)*
Modulus of surround	MN/m^2	E`2	5	*BS 9295 Table 14 (Class B1 85% compacted gravel to pipe haunches)*
Thickness of bedding	m		0.15	*Assumed - standard value*
Deflection lag factor		D_L	1.5	*BS 9295 Table 14 (85% compacted graded gravel)*
Max pressure	bar	P_i	8	*ENRMF DCO application Table 1*
Min pressure - vacuum ONLY. If vacuum = 0, enter 0.01	bar	Pu	0.01	*No vacuum*
If twin pipes, spacing between pipes (OD to OD)	m	s	4.816	*Leave blank if single pipe*

Pipe Data

Source: FT Pipelines
https://ftpipelinesystems.co.uk/wp-content/uploads/2012/11/data-sheel-large-bore-welded-joints-nov2012.pdf

Internal diameter	Outside diameter	steel wall thickness*	Cement mortar lining thickness	Weight of pipe + CM lining	Weight of pipe + CM lining	Weight of pipe + epoxy lining	Weight of pipe + epoxy lining	Pressure rating**
m	m	m	m	kg/m	kN/m	kg/m	kN/m	Bar
0.08	0.0889	0.0036	0.003	11.4	0.11	8	0.08	123
0.1	0.1145	0.0036	0.003	14.6	0.14	10.2	0.10	95
0.15	0.1683	0.004	0.003	23.3	0.23	16.3	0.16	73
0.2	0.2191	0.0045	0.004	34.9	0.34	24.4	0.24	64
0.25	0.273	0.005	0.004	46.9	0.46	32.8	0.32	57
0.3	0.3239	0.0056	0.004	60.9	0.60	42.6	0.42	54
0.35	0.3556	0.0056	0.0071	69.4	0.68	48.6	0.48	50
0.4	0.4064	0.0063	0.005	86.4	0.85	60.5	0.59	49
0.45	0.457	0.0063	0.006	77	0.76	55	0.54	33
0.5	0.508	0.0056	0.006	92	0.90	67	0.66	27
0.6	0.61	0.0063	0.008	130	1.28	82	0.80	26
0.7	0.711	0.0071	0.008	164	1.61	106	1.04	26
0.8	0.813	0.0071	0.01	219	2.15	136	1.33	25
0.9	0.914	0.008	0.01	266	2.61	171	1.68	25
1	1.016	0.0088	0.012	333	3.27	213	2.09	24
1.1	1.118	0.01	0.014	417	4.09	256	2.51	25
1.2	1.219	0.01	0.014	485	4.76	315	3.09	24

* Where more than one wall thickness is given for a size, the lower value has been taken here
** Where more than one pressure rating is given for a size, the lower value has been taken here

Pipe lining

Lining	Poisson
Cement mortar	0.3
Epoxy	0.36

Vehicular loading data

	@1.2m deep	@3m deep
Main Roads		
Fields & Gardens		
A40 Dump Truck	108.31	35.9
Hitachi Large Excavator	77.59	18.93

General soil properties **BS 9295 Section 6.6**

Kµ	0.19	
Kµ'	0.13	
γ	19.6	kN/m3

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

Fields & Gardens

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**23.76**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	27.21	**Fields & Gardens**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	50.97	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	406.90	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	0.01	
Stiffness of pipe	kN/m^2		11.74	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**7.83**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**0.00**	***Fail (FOS<1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.01046	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**1.05**	***OK (deflection<3%)***
		m	**0.008**	
Hoop stress (Barlow)	kN/m^2		45070	
Factor of safety (against bursting)		**FOS**	**5.21**	***OK (FOS>2)***

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

A40 Dump Truck

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**23.76**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	108.00	**A40 Dump Truck**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	131.76	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	406.90	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	0.01	
Stiffness of pipe	kN/m^2		11.74	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**3.06**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**0.00**	***Fail (FOS<1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.02391	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**2.39**	***OK (deflection<3%)***
		m	**0.019**	
Hoop stress (Barlow)	kN/m^2		45070	
Factor of safety (against bursting)		**FOS**	**5.21**	***OK (FOS>2)***

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

Large Excavator

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**23.76**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	77.59	**Large Excavator**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	101.35	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	406.90	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	0.01	
Stiffness of pipe	kN/m^2		11.74	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**3.98**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**0.00**	***Fail (FOS<1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.01885	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**1.88**	***OK (deflection<3%)***
		m	**0.015**	
Hoop stress (Barlow)	kN/m^2		45070	
Factor of safety (against bursting)		**FOS**	**5.21**	***OK (FOS>2)***

Pipetechnics ltd.	CALCULATION PACK	DOCUMENT No
		PT/AU/Calcs_1.2m

PROJECT NO.	PROJECT TITLE
N/A	Augean / ENRMF site

SUBJECT	SHEET No
Steel Pipeline Calculations @ 1.2m cover, wall thickness 5.5mm	1 of 6

ISSUE	TOTAL SHEET (S)	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
1	6	SJRD	24/05/22	SJRD	27/05/22			First Draft
2								
3								
4								

SUPERSEDES DOC No		DATE	

DESIGN BA 0.01

Source of Info

1. ENRMF DCO Application Anglian Water Pipelines. Table 1 Scoping Table for Scenarios of Risk Assessment
2.
3.

Standards and References

4. BS 9295:2020.
5.
6.
7.

Remit

Design Scenario:
Burial depth = 1.2m

STEEL PRESSURE PIPELINE

VARIABLE INPUTS	Units	Symbol	Value	Notes (assumed values etc)	
Pipe Properties					
Is this calculation for twin steel pipes laid in a single trench?			**Yes**	*Select*	
Steel Grade			L235	*Select pipe grade*	*Assumed - worst case*
Internal diameter (Nominal)	m	DN	0.8	*Select pipe diameter*	
External diameter	m	Bc	0.811		
Wall thickness (standard for the diameter selected)	m	t	0.0071	*From look up table*	
Wall thickness (choose)	m	t	0.0055	*Type in value*	
Poisson's ratio (steel)		v_{steel}	0.3		
Type of pipe lining			Cement mortar	*Select*	*Assumed - worst case*
Cement mortar lining thickness	m	t_L	0.01		
Poisson's ratio (mortar)		v_{mortar}	0.3		
Weight of pipe + cement mortar		kg/m	219		
Poisson's ratio (epoxy)		v_{epoxy}	N/A		
Weight of pipe + epoxy		kg/m	N/A		
Modulus of Elasticity (steel)	MN/m^2	E	207000	*Standard value*	
Second moment of area of pipe wall	m^4/m	I	1.38646E-08		
Pipe stiffness (no CM lining)	N/m^2	S	5491		
Density of mild steel	Kg/m^3		7850	*Assumed*	
Yield Strength	MN/m2	F_y	235		

Installation variables				
Depth of cover	m	H	1.2	*ENRMF DCO application Table 1*
Height of water above pipeline	m	H_w	0	*No groundwater found in any borehole*
Trench width	m	B_d	7	*Assumed original trench width*
Soil density	kN/m^3	γ	19.8	*Typical value (BS EN 1295-1)*
Native soil modulus	MN/m^2	E`3	5	*Input soil modulus from BS 9295 Table 13 (stiff clay)*
Modulus of surround	MN/m^2	E`2	5	*BS 9295 Table 14 (Class B1 85% compacted gravel to pipe haunches)*
Thickness of bedding	m		0.15	*Assumed - standard value*
Deflection lag factor		D_L	1.5	*BS 9295 Table 14 (85% compacted graded gravel)*
Max pressure	bar	P_i	8	*ENRMF DCO application Table 1*
Min pressure - vacuum ONLY. If vacuum = 0, enter 0.01	bar	Pu	0.01	*No vacuum*
If twin pipes, spacing between pipes (OD to OD)	m	s	4.816	*Leave blank if single pipe*

Pipe Data

Source: FT Pipelines
https://ftpipelinesystems.co.uk/wp-content/uploads/2012/11/data-sheel-large-bore-welded-joints-nov2012.pdf

Internal diameter	Outside diameter	steel wall thickness*	Cement mortar lining thickness	Weight of pipe + CM lining	Weight of pipe + CM lining	Weight of pipe + epoxy lining	Weight of pipe + epoxy lining	Pressure rating**
m	m	m	m	kg/m	kN/m	kg/m	kN/m	Bar
0.08	0.0889	0.0036	0.003	11.4	0.11	8	0.08	123
0.1	0.1145	0.0036	0.003	14.6	0.14	10.2	0.10	95
0.15	0.1683	0.004	0.003	23.3	0.23	16.3	0.16	73
0.2	0.2191	0.0045	0.004	34.9	0.34	24.4	0.24	64
0.25	0.273	0.005	0.004	46.9	0.46	32.8	0.32	57
0.3	0.3239	0.0056	0.004	60.9	0.60	42.6	0.42	54
0.35	0.3556	0.0056	0.005	69.4	0.68	48.6	0.48	50
0.4	0.4064	0.0063	0.005	86.4	0.85	60.5	0.59	49
0.45	0.457	0.0063	0.006	77	0.76	55	0.54	33
0.5	0.508	0.0056	0.006	92	0.90	67	0.66	27
0.6	0.61	0.0063	0.008	130	1.28	82	0.80	26
0.7	0.711	0.0071	0.008	164	1.61	106	1.04	26
0.8	0.813	0.0071	0.01	219	2.15	136	1.33	25
0.9	0.914	0.008	0.01	266	2.61	171	1.68	25
1	1.016	0.0088	0.012	333	3.27	213	2.09	24
1.1	1.118	0.01	0.014	417	4.09	256	2.51	25
1.2	1.219	0.01	0.014	485	4.76	315	3.09	24

* Where more than one wall thickness is given for a size, the lower value has been taken here
** Where more than one pressure rating is given for a size, the lower value has been taken here

Pipe lining

Lining	Poisson
Cement mortar	0.3
Epoxy	0.36

Vehicular loading data

	@1.2m deep	@3m deep
Main Roads		
Fields & Gardens		
A40 Dump Truck	108.31	35.9
Hitachi Large Excavator	77.59	18.93

General soil properties **BS 9295 Section 6.6**

Kμ	0.19	
Kμ'	0.13	
γ	19.6	kN/m3

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

Fields & Gardens

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**23.76**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	27.21	**Fields & Gardens**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	50.97	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	316.63	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	131.79	
Stiffness of pipe	kN/m^2		5.49	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**6.09**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**5.32**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.01196	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**1.20**	***OK (deflection<3%)***
		m	**0.010**	
Hoop stress (Barlow)	kN/m^2		58182	
Factor of safety (against bursting)		**FOS**	**4.04**	***OK (FOS>2)***

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

A40 Dump Truck

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**23.76**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	108.00	**A40 Dump Truck**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	131.76	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	316.63	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	131.79	
Stiffness of pipe	kN/m^2		5.49	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**2.39**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**5.32**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.02733	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**2.73**	***OK (deflection<3%)***
		m	**0.022**	
Hoop stress (Barlow)	kN/m^2		58182	
Factor of safety (against bursting)		**FOS**	**4.04**	***OK (FOS>2)***

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

Large Excavator

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**23.76**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	77.59	**Large Excavator**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	101.35	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	316.63	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	131.79	
Stiffness of pipe	kN/m^2		5.49	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**3.09**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**5.32**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.02155	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**2.15**	***OK (deflection<3%)***
		m	**0.017**	
Hoop stress (Barlow)	kN/m^2		58182	
Factor of safety (against bursting)		**FOS**	**4.04**	***OK (FOS>2)***

Pipetechnics ltd.	**CALCULATION PACK**	DOCUMENT No **PT/AU/Calcs_3m**

PROJECT NO.	PROJECT TITLE
N/A	**Augean / ENRMF site**

SUBJECT	SHEET No
Steel Pipeline Calculations @ 3m cover, wall thickness 7.1mm	1 of 6

ISSUE	TOTAL SHEET (S)	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
1	6	SJRD	24/05/22	SJRD	27/05/22			First Draft
2								
3								
4								

SUPERSEDES DOC No		DATE	

DESIGN BA 0.01

Source of Info

1. ENRMF DCO Application Anglian Water Pipelines. Table 1 Scoping Table for Scearios of Risk Assessment
2.
3.

Standards and References

4. BS 9295:2020.
5.
6.
7.

Remit

Design Scenario:

Burial depth = 3m

STEEL PRESSURE PIPELINE

VARIABLE INPUTS	Units	Symbol	Value	Notes (assumed values etc)	
Pipe Properties					
Is this calculation for twin steel pipes laid in a single trench?			Yes	*Select*	
Steel Grade			L235	*Select pipe grade*	*Assumed - worst case*
Internal diameter (Nominal)	m	DN	0.8	*Select pipe diameter*	
External diameter	m	Bc	0.8142		
Wall thickness (standard for the diameter selected)	m	t	0.0071	*From look up table*	
Wall thickness (choose)	m	t	0.0071	*Type in value*	
Poisson's ratio (steel)		ν_{steel}	0.3		
Type of pipe lining			Cement mortar	*Select*	*Assumed - worst case*
Cement mortar lining thickness	m	t_L	0.01		
Poisson's ratio (mortar)		ν_{mortar}	0.3		
Weight of pipe + cement mortar		kg/m	219		
Poisson's ratio (epoxy)		ν_{epoxy}	N/A		
Weight of pipe + epoxy		kg/m	N/A		
Modulus of Elasticity (steel)	MN/m^2	E	207000	*Standard value*	
Second moment of area of pipe wall	m^4/m	I	2.98259E-08		
Pipe stiffness (no CM lining)	N/m^2	S	11743		
Density of mild steel	Kg/m^3		7850	*Assumed*	
Yield Strength	MN/m2	F_y	235		
Installation variables					
Depth of cover	m	H	3	*ENRMF DCO application Table 1*	
Height of water above pipeline	m	H_w	0	*No groundwater found in any borehole*	
Trench width	m	B_d	7	*Assumed original trench width*	
Soil density	kN/m^3	γ	19.8	*Typical value (BS EN 1295-1)*	
Native soil modulus	MN/m^2	E`3	5	*Input soil modulus from BS 9295 Table 13 (stiff clay)*	
Modulus of surround	MN/m^2	E`2	5	*BS 9295 Table 14 (Class B1 85% compacted gravel to pipe haunches)*	
Thickness of bedding	m		0.15	*Assumed - standard value*	
Deflection lag factor		D_L	1.5	*BS 9295 Table 14 (85% compacted graded gravel)*	
Max pressure	bar	P_i	8	*ENRMF DCO application Table 1*	
Min pressure - vacuum ONLY. If vacuum = 0, enter 0.01	bar	Pu	0.01	*No vacuum*	
If twin pipes, spacing between pipes (OD to OD)	m	s	4.816	*Leave blank if single pipe*	

Pipe Data

Source: FT Pipelines
https://ftpipelinesystems.co.uk/wp-content/uploads/2012/11/data-sheel-large-bore-welded-joints-nov2012.pdf

Internal diameter	Outside diameter	steel wall thickness*	Cement mortar lining thickness	Weight of pipe + CM lining	Weight of pipe + CM lining	Weight of pipe + epoxy lining	Weight of pipe + epoxy lining	Pressure rating**
m	m	m	m	kg/m	kN/m	kg/m	kN/m	Bar
0.08	0.0889	0.0036	0.003	11.4	0.11	8	0.08	123
0.1	0.1145	0.0036	0.003	14.6	0.14	10.2	0.10	95
0.15	0.1683	0.004	0.003	23.3	0.23	16.3	0.16	73
0.2	0.2191	0.0045	0.004	34.9	0.34	24.4	0.24	64
0.25	0.273	0.005	0.004	46.9	0.46	32.8	0.32	57
0.3	0.3239	0.0056	0.004	60.9	0.60	42.6	0.42	54
0.35	0.3556	0.0056	0.0071	69.4	0.68	48.6	0.48	50
0.4	0.4064	0.0063	0.005	86.4	0.85	60.5	0.59	49
0.45	0.457	0.0063	0.006	77	0.76	55	0.54	33
0.5	0.508	0.0056	0.006	92	0.90	67	0.66	27
0.6	0.61	0.0063	0.008	130	1.28	82	0.80	26
0.7	0.711	0.0071	0.008	164	1.61	106	1.04	26
0.8	0.813	0.0071	0.01	219	2.15	136	1.33	25
0.9	0.914	0.008	0.01	266	2.61	171	1.68	25
1	1.016	0.0088	0.012	333	3.27	213	2.09	24
1.1	1.118	0.01	0.014	417	4.09	256	2.51	25
1.2	1.219	0.01	0.014	485	4.76	315	3.09	24

* Where more than one wall thickness is given for a size, the lower value has been taken here
** Where more than one pressure rating is given for a size, the lower value has been taken here

Pipe lining

Lining	Poisson
Cement mortar	0.3
Epoxy	0.36

Vehicular loading data

	@1.2m deep	@3m deep
Main Roads		
Fields & Gardens		
A40 Dump Truck	108.31	35.9
Hitachi Large Excavator	77.59	18.93

General soil properties **BS 9295 Section 6.6**

Kμ	0.19	
Kμ'	0.13	
γ	19.6	kN/m3

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

Fields & Gardens

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	59.40	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	5.47	**Fields & Gardens**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	**64.87**	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	406.90	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	0.01	
Stiffness of pipe	kN/m^2		11.74	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**6.18**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**no calc reqd**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.01968	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**1.97**	***OK (deflection<3%)***
		m	**0.016**	
Hoop stress (Barlow)	kN/m^2		45070	
Factor of safety (against bursting)		**FOS**	**5.21**	***OK (FOS>2)***

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

A40 Dump Truck

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**59.40**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	35.90	**A40 Dump Truck**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	95.30	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	406.90	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	0.01	
Stiffness of pipe	kN/m^2		11.74	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**4.23**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**no calc reqd**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.02601	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**2.60**	***OK (deflection<3%)***
		m	**0.021**	
Hoop stress (Barlow)	kN/m^2		45070	
Factor of safety (against bursting)		**FOS**	**5.21**	***OK (FOS>2)***

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

Large Excavator

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**59.40**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	18.93	**Large Excavator**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	78.33	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	406.90	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	0.01	
Stiffness of pipe	kN/m^2		11.74	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**5.13**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**no calc reqd**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.02248	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**2.25**	***OK (deflection<3%)***
		m	**0.018**	
Hoop stress (Barlow)	kN/m^2		45070	
Factor of safety (against bursting)		**FOS**	**5.21**	***OK (FOS>2)***

Pipetechnics ltd.	CALCULATION PACK	DOCUMENT No
		PT/AU/Calcs_3m

PROJECT NO.	PROJECT TITLE
N/A	Augean / ENRMF site

SUBJECT	SHEET No
Steel Pipeline Calculations @ 3m cover, wall thickness 5.5mm	1 of 6

ISSUE	TOTAL SHEET (S)	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
1	6	SJRD	24/05/22	SJRD	27/05/22			First Draft
2								
3								
4								

SUPERSEDES DOC No		DATE	

DESIGN BA 0.01

Source of Info

1. ENRMF DCO Application Anglian Water Pipelines. Table 1 Scoping Table for Scearios of Risk Assessment
2.
3.

Standards and References

4. BS 9295:2020.
5.
6.
7.

Remit

Design Scenario:
Burial depth = 3m

STEEL PRESSURE PIPELINE

VARIABLE INPUTS	**Units**	**Symbol**	**Value**	**Notes (assumed values etc)**	
Pipe Properties					
Is this calculation for twin steel pipes laid in a single trench?			**Yes**	*Select*	
Steel Grade			L235	*Select pipe grade*	*Assumed - worst case*
Internal diameter (Nominal)	m	DN	0.8	*Select pipe diameter*	
External diameter	m	Bc	0.811		
Wall thickness (standard for the diameter selected)	m	t	0.0071	*From look up table*	
Wall thickness (choose)	m	t	0.0055	*Type in value*	
Poisson's ratio (steel)		v_{steel}	0.3		
Type of pipe lining			Cement mortar	*Select*	*Assumed - worst case*
Cement mortar lining thickness	m	t_L	0.01		
Poisson's ratio (mortar)		v_{mortar}	0.3		
Weight of pipe + cement mortar		kg/m	219		
Poisson's ratio (epoxy)		v_{epoxy}	N/A		
Weight of pipe + epoxy		kg/m	N/A		
Modulus of Elasticity (steel)	MN/m^2	E	207000	*Standard value*	
Second moment of area of pipe wall	m^4/m	I	1.38646E-08		
Pipe stiffness (no CM lining)	N/m^2	S	5491		
Density of mild steel	Kg/m^3		7850	*Assumed*	
Yield Strength	MN/m2	F_y	235		

Installation variables					
Depth of cover	m	H	3	*ENRMF DCO application Table 1*	
Height of water above pipeline	m	H_w	0	*No groundwater found in any borehole*	
Trench width	m	B_d	7	*Assumed original trench width*	
Soil density	kN/m^3	γ	19.8	*Typical value (BS EN 1295-1)*	
Native soil modulus	MN/m^2	E`3	5	*Input soil modulus from BS 9295 Table 13 (stiff clay)*	
Modulus of surround	MN/m^2	E`2	5	*BS 9295 Table 14 (Class B1 85% compacted gravel to pipe haunches)*	
Thickness of bedding	m		0.15	*Assumed - standard value*	
Deflection lag factor		D_L	1.5	*BS 9295 Table 14 (85% compacted graded gravel)*	
Max pressure	bar	P_i	8	*ENRMF DCO application Table 1*	
Min pressure - vacuum ONLY. If vacuum = 0, enter 0.01	bar	Pu	0.01	*No vacuum*	
If twin pipes, spacing between pipes (OD to OD)	m	s	4.816	*Leave blank if single pipe*	

Pipe Data

Source: FT Pipelines
https://ftpipelinesystems.co.uk/wp-content/uploads/2012/11/data-sheel-large-bore-welded-joints-nov2012.pdf

Internal diameter	Outside diameter	steel wall thickness*	Cement mortar lining thickness	Weight of pipe + CM lining	Weight of pipe + CM lining	Weight of pipe + epoxy lining	Weight of pipe + epoxy lining	Pressure rating**
m	m	m	m	kg/m	kN/m	kg/m	kN/m	Bar
0.08	0.0889	0.0036	0.003	11.4	0.11	8	0.08	123
0.1	0.1145	0.0036	0.003	14.6	0.14	10.2	0.10	95
0.15	0.1683	0.004	0.003	23.3	0.23	16.3	0.16	73
0.2	0.2191	0.0045	0.004	34.9	0.34	24.4	0.24	64
0.25	0.273	0.005	0.004	46.9	0.46	32.8	0.32	57
0.3	0.3239	0.0056	0.004	60.9	0.60	42.6	0.42	54
0.35	0.3556	0.0056	0.005	69.4	0.68	48.6	0.48	50
0.4	0.4064	0.0063	0.005	86.4	0.85	60.5	0.59	49
0.45	0.457	0.0063	0.006	77	0.76	55	0.54	33
0.5	0.508	0.0056	0.006	92	0.90	67	0.66	27
0.6	0.61	0.0063	0.008	130	1.28	82	0.80	26
0.7	0.711	0.0071	0.008	164	1.61	106	1.04	26
0.8	0.813	0.0071	0.01	219	2.15	136	1.33	25
0.9	0.914	0.008	0.01	266	2.61	171	1.68	25
1	1.016	0.0088	0.012	333	3.27	213	2.09	24
1.1	1.118	0.01	0.014	417	4.09	256	2.51	25
1.2	1.219	0.01	0.014	485	4.76	315	3.09	24

* Where more than one wall thickness is given for a size, the lower value has been taken here
** Where more than one pressure rating is given for a size, the lower value has been taken here

Pipe lining

Lining	Poisson
Cement mortar	0.3
Epoxy	0.36

Vehicular loading data

	@1.2m deep	@3m deep
Main Roads		
Fields & Gardens		
A40 Dump Truck	108.31	35.9
Hitachi Large Excavator	77.59	18.93

General soil properties **BS 9295 Section 6.6**

Kμ	0.19	
Kμ'	0.13	
γ	19.6	kN/m3

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

Fields & Gardens

	UNIT	SYMBOL	VALUE
Loading			
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	59.40
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	5.47
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	**64.87**
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00

Fields & Gardens

	UNIT	SYMBOL	VALUE	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	316.63	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	131.79	
Stiffness of pipe	kN/m^2		5.49	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**4.81**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**no calc reqd**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.02250	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**2.25**	***OK (deflection<3%)***
		m	**0.018**	
Hoop stress (Barlow)	kN/m^2		58182	
Factor of safety (against bursting)		**FOS**	**4.04**	***OK (FOS>2)***

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

A40 Dump Truck

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**59.40**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	35.90	**A40 Dump Truck**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	95.30	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	316.63	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	131.79	
Stiffness of pipe	kN/m^2		5.49	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**3.29**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**no calc reqd**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.02973	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**2.97**	***OK (deflection<3%)***
		m	**0.024**	
Hoop stress (Barlow)	kN/m^2		58182	
Factor of safety (against bursting)		**FOS**	**4.04**	***OK (FOS>2)***

CALCULATIONS IN ACCORDANCE WITH BS 9295 (2020)

Large Excavator

	UNIT	SYMBOL	VALUE	
Loading				
Backfill pressure, *BS 9295 Equation 27*	kN/m^2	P_e	**59.40**	
Road traffic loading, *BS 9295 Section 5.3*	kN/m^2	P_s	18.93	**Large Excavator**
Total vertical pressure, *BS 9295 Equation 28*	kN/m^2	P	78.33	
Leonhardt's coefficient, *BS 9295 Equation 29*		C_L	1.00	
Overall modulus of soil reaction, *BS 9295 Equation 30*	MN/m^2	E'	5.00	
Buckling				
Critical buckling pressure, *BS 9295 Equation 31*	kN/m^2	P_{cr}	316.63	
Unconstrained buckling pressure, *BS 9295 Equation 34*	kN/m^2	P_{cra}	131.79	
Stiffness of pipe	kN/m^2		5.49	
Deflection lag factor		D_L	1.50	
Factor of safety (buckling - with soil support), *BS 9295 Equation 32, pg 52*		**FOS**	**3.99**	***OK (FOS>2)***
Factor of safety (buckling - without soil support), *BS 9295 Equation 33*		**FOS**	**no calc reqd**	***OK (FOS>1)***
Ovalisation & Bending Stress				
Ovalisation, *BS 9295 Equation 35*		Δ/D	0.02570	
Ratio of wall thickness to diameter		t/D	0.01	
Ovalisation	**%**	**Y**	**2.57**	***OK (deflection<3%)***
		m	**0.021**	
Hoop stress (Barlow)	kN/m^2		58182	
Factor of safety (against bursting)		**FOS**	**4.04**	***OK (FOS>2)***