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Report: [redacted]-R0706-21

KINGS LYNN COMPRESSOR STATION – INTEGRITY ASSESSMENT OF BI-DIRECTIONAL PIPEWORK AFFECTED BY GROUND SUBSIDENCE

Confidential *Restricted to,* [redacted]

[redacted]

[redacted]

CUSTOMER	**CUSTOMER CONTACT**	**CUSTOMER ADDRESS**	**CUSTOMER REF: NO.**
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[redacted]	[redacted]	[redacted]	[redacted] STRESS ANALYSIS, IGE/TD/12

EXTERNAL DISTRIBUTION LIST	**COMPANY**
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

INTERNAL DISTRIBUTION LIST	**LOCATION**
Project File	[redacted]-F0488
Library File	Technical Section

03	16/12/21	[redacted]	[redacted]	[redacted]	Including Modifications
02	18/10/21	[redacted]	[redacted]	[redacted]	Incorporating Client Comments
01	13/09/21	[redacted]	[redacted]	[redacted]	Incorporating Client Comments
00	23/08/21	[redacted]	[redacted]	[redacted]	Draft for Client Comment
Revision	**Date**	**Author Signature**	**Verifier Signature**	**Approver Signature**	**Status**

REVISION STATUS INDEX							
SUMMARY OF CHANGES	**SECTION NUMBER**	**REVISIONS**					
		1	**2**	**3**	**4**	**5**	**6**
Incorporating client comments		**X**					
Discussion and Recommendations			**X**				
Updated code stress 900mm x 50mm weldolet (node 6160).				**X**			

[redacted]

Executive Summary

National Grid owns and operates Kings Lynn Compressor Station in Norfolk. At a part of the site, in the area of the bi-directional pipework, associated with the compressors, there is visible evidence of changes to the ground elevation, suggesting differential settlement. A site survey undertaken in 2017 observed significant movement of the above ground 50mm pipework, most likely due to differential settlement.

Excavations were undertaken in 2019 to expose all 50mm NB below ground pipework, during which large sections of concrete were found to be attached to the pipework which was likely responsible for at least some of the observed pipework movement. The concrete was removed where possible, allowing the pipework to return to normal vertical and horizontal positions. The pipework has since been re-bedded and backfilled.

A limited study was undertaken in 2018 using an iterative approach of applying various displacement profiles to the buried system in order to establish a profile that would give some agreement with the observed movement of the above ground pipework. This assessment was based on the assumption of settlement of both the 50mm and 900mm pipework and showed code stress exceptions in significant excess of the code allowable. It has since been confirmed that the ten 900NB valves in the bi-directional area were installed on piled supports and as such no settlement is anticipated at these locations.

Previous assessments were undertaken without direct investigation into the extent of the movement of the larger diameter buried pipework. A programme of work has therefore been agreed to determine the significance of the movement, of the 900mm pipework, on the pipeline integrity. This study is concerned with only Stage 1 of the works, which comprises the following activities:

- Establish the piping elevations at the current time.
- Predict the piping elevations at the time of construction.
- Predict the deformed profile due to the implied movement.
- Confirm that the stress levels are acceptable in accordance with the sustained and shakedown design stress requirements of IGE/TD/12.

The purpose of this report is to describe the analysis that was undertaken, to set out the conclusions and to make any recommendations as is necessary.

Conclusions

1. The current elevation levels of the piping in and around the bi-directional area has been established by performing an AOD survey at several trial hole locations around the site.
2. Very little data exists on the original as-built elevation profile. A trend line analysis using the measurements of the construction survey undertaken in 2003 for the pigging loop area and the recent AOD 2021 survey (current piping elevations) has been undertaken to estimate the as-built piping elevations in the bi-directional area.
3. Significant settlement (127mm) over a short span is estimated by the trend line analysis in the region of trial hole location TH-07. To determine the plausibility of the large displacements a sensitivity study has been undertaken based on a free span condition considering both sand and clay soil ground conditions. Indeed the sensitivity study showed that some of the estimated settlement values were suspect.
    i. The latest survey reading have been checked and found to be accurate, this suggests there is most likely an error in the as-built survey readings undertaken in 2003.
4. A limit on settlement has been set as the lesser of: that predicted by the free span assessment with clay soil properties and that predicted by the trend line analysis.
5. IGE/TD/12 code stress analyses have been undertaken of the as-built configuration and current configuration, including settlement, at Kings Lynn. Soft clay soil properties have been considered.
6. For the as-built configuration there is a single fitting exceeding the IGE/TD/12 sustained criterion.
7. For the model including settlement, there are twenty-eight fittings exceeding the IGE/TD/12 abnormal sustained criterion and twelve fittings exceeding the IGE/TD/12 shakedown criterion.
    i. It may be possible to show acceptability of the fittings by undertaking a more detailed design-by-analysis assessment involving the finite element method.

Recommendations

For the fittings which exceed the TD/12 code stress limit it is recommended a more detailed finite element analysis is undertaken to better understand the level and distribution of stress in the fittings.

It is possible to qualify the acceptability of multiple fittings of the same classification and size by performing a bounding assessment of the most highly stressed fitting, only. Table 17 and Table 18 summarise the highest stressed fitting type and size for the abnormal sustained and shakedown exceptions. This forms the scope of work for the Stage 2 programme of work.

[redacted]

Based on a recent visual indication that there may have been some movement of the pigging loop, and noting that the pigging loop is unsupported, it is recommended additional monitoring points are installed on the pigging loop piping to enable continued monitoring of the region.

[redacted]

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1 INTRODUCTION

National Grid owns and operates Kings Lynn Compressor Station in Norfolk. At a part of the site, in the area of the bi-directional pipework, associated with the compressors, there is visible evidence of changes to the ground elevation, suggesting differential settlement. A site survey undertaken in 2017 observed significant movement of the above ground 50mm pipework, most likely due to differential settlement.

Excavations were undertaken in 2019 to expose all 50mm NB below ground pipework, during which large sections of concrete were found to be attached to the pipework which was likely responsible for at least some of the observed pipework movement. The concrete was removed where possible, allowing the pipework to return to normal vertical and horizontal positions. The pipework has since been re-bedded and backfilled.

A limited study was undertaken in 2018 using an iterative approach of applying various displacement profiles to the buried system in order to establish a profile that would give some agreement with the observed movement of the above ground pipework. This assessment was based on the assumption of settlement of both the 50mm and 900mm pipework and showed code stress exceptions in significant excess of the code allowable.

There have previously been no direct investigations into the extent of the movement of the larger diameter buried pipework. A programme of work has therefore been agreed to determine the significance of the movement, of the 900mm pipework, on the pipeline integrity.

1.1 Purpose

The purpose of the analysis is:

- Establish the piping elevations at the time of construction.
- Establish the piping elevations at the current time.
- Determine the deformed profile due to the implied movement.
- Confirm that the stress levels are acceptable in accordance with the sustained and shakedown design requirements of IGE/TD/12[1].

The purpose of this report is to describe the analysis that was undertaken, to set out the conclusions and to make any recommendations as is necessary.

1.2 Scope

The location of the bi-directional pipework at Kings Lynn compressor station is shown in Figure 1.

Ground movement has been observed in the area of the bi-directional pipework, between Feeder 2 and the pigging loop of Feeder 4. Given the proximity of the scrubbers to the bi-directional area, the region between these locations has also been considered for potential settlement.

2 MODELLING

2.1 Drawings

In addition to the referenced national, international and National Grid standards, the following drawings and material take-offs have been provided and used where necessary.

Drawing Number	Issue	Title
[redacted]		
[redacted]585-GEN-7210-0010	E	Kings Lynn Compressor Station General Arrangement Trial Hole Locations
Navisworks Model		Kings Lynn – As-Built – 5-8-21.nwd
Navisworks Model		Kings Lynn – PC – 5-8-21.nwd
Fastflow		
CPEL-1238-DW01	1	General Arrangement
405000-MMD-LOT3-ZZ-DR-C-0001	E	NARC 3 Kings Lynn Compressor Station Lot 3 – Isolation Valves Civil General Arrangement
405000-MMD-LOT3-ZZ-DR-C-0002	D	NARC 3 Kings Lynn Compressor Station Lot 3 – Isolation Valves Isometric View
405000-MMD-LOT3-ZZ-DR-C-0003	D	NARC 3 Kings Lynn Compressor Station Lot 3 – Isolation Valves Foundation Details
405000-MMD-LOT3-ZZ-DR-C-0004	E	NARC 3 Kings Lynn Compressor Station Lot 3 – Isolation Valves Foundation Details Sections A & B
405000-MMD-LOT3-ZZ-DR-M-0001	F	NARC 3 Kings Lynn Compressor Station Lot 3 – Isolation Valves Mechanical General Arrangement
[redacted] **Utilities**		
	2	Kings Lynn Compressor Station Design Basis Report
M478/BE/39/01/4025/001	1	Kings Lynn Compressor Station Stress Analysis
AU/M/KIN/4001	C	Bi-Directional Pipework Line Diagram
AU/M/KIN/4003	A	Regulator Pipework Details Feeder No.4
AU/M/KIN/4004	C	Regulator Pipework Details Feeder No.2
AU/M/KIN/4005	B	Power Gas Supply Details
AU/M/KIN/4006	B	No.2 Feeder Valve Bridle Pipework Details
AU/M/KIN/4007	B	No.4 Feeder Valve Bridle Pipework Details

Drawing Number	**Issue**	**Title**
AU/M/KIN/4008	B	Instrumentation – No.2 Feeder
AU/M/KIN/4012	B	900NB Pipework Details
AU/M/KIN/4013	B	Instrumentation – No.4 Feeder
AU/M/KIN/4016	A	Outstation Gas Supply Details
Method Statement No.23		Preparatory Works to Allow Access for Piling Operation
[redacted] **Engineering**		
Factual Report	0	Ground Investigation Factual Report
[redacted]		
J17-577-003R-Rev0	0	Initial Site Assessment
[redacted] **Capital Projects Limited**		
C8594		Report on a Ground Investigation at King's Lynn Compressor Station Near East Winch King's Lynn Norfolk
[redacted] **Group**		
M830/BE/67/00/2020/914	B	Kings Lynn Compressor Stress Analysis Report
M830/BE/68/00/2020/020	F	Revised As-built Issue
The Gas Council		
BGHP/SC/1353		King's Lynn Compressor Link Twin 36" Pipelines
[redacted] **Ltd**		
Cert No. 25573		900mm x 300mm Sweepolet Test Certificate
[redacted]		
Sheet No. 3394		900mm 1.5D 90° Bends Dimensional Report
No. 9161		300MM 1.5D 90° Bends Material Test Certificate

[redacted]

Drawing Number	**Issue**	**Title**
Natural Gas Engineering Ltd		
2021-06-09 11-38		Piping General Arrangement Scrubber Area
2021-06-09 11-58		Details of Valve Supports
GC/L11/2/19		Piping General Arrangement Scrubber Area
GC/L11/2/20		Piping General Arrangement Of Station Valves
GC/L11/4/01		Civil Engineering Key Plan
GC/L11/4/9		Scrubber Supports Including Piles
BG/L20/1/3	B	Layout of Compressor Station
BG/L20/1/24	N	Arrangement of Pipework
0195/3/1001	M	Arrangement of Pipework

2.2 Navisworks Model & Software

Premtech have provided a Navisworks CAD model of the site in the as-built and current configuration. The files have been developed from an automated survey of the site, Above Ordnance Datum (AOD) survey and as-built drawings.

The files have been used to aid in developing models suitable for analysis using CAESAR II 2019[2]. This version of the software assesses pipework code compliance according to IGE/TD/12 (Edition 2, 2003), and is approved by National Grid for this purpose.

2.3 CAESAR II Models Created

The following models have been created of the as-built layout.

- KL_CLAY_FF_01.C2
- KL_CLAY_RF_01.C2
- KL_CLAY_FF_01B.C2
- KL_CLAY_RF_01B.C2

The following models have been created of the current piping profile, including settlement, to permit a stress comparison with the models directly above.

- KL_CLAY_SETTLEMENT_FF_01.C2
- KL_CLAY_SETTLEMENT_RF_01.C2
- KL_CLAY_SETTLEMENT_FF_01B.C2
- KL_CLAY_SETTLEMENT_RF_01B.C2

The models with a ‘B’ suffix are buried models and ‘Lower’ or ‘Upper’ refers to lower and upper bound soil properties respectively:

3 INPUT DATA

3.1 General

The site has been subject to several modifications over the past 50 years. Notably significant modifications were made circa 1998, to include the bi-directional functionality to the site. The pigging loop and associated tie-in pipework was installed circa 2003.

More recently minor alterations have been undertaken to include two new 900mm ball valves on Feeder 2. Figure 2 shows the general arrangement of the bi-directional area and the era in which the pipework was installed.

Details for pipework has been taken from the supplied drawings and applicable standards from the era of construction.

3.2 Materials

Materials are generally to the requirements of API 5L. For the analysis the API-5L equivalent materials, built into the CAESAR II material database, have been used.

The Specified Minimum Yield Stress (SMYS) and Specified Minimum Ultimate Tensile Strength (SMUTS) values, for the materials under the API-5L specifications, are shown for comparison in Table 1.

3.3 Pipework & Fittings

3.3.1 Pipe

Details of the pipework modelled for the assessment are shown in Table 2.

Details for pipework installed as part of the original construction, Circa 1970, is taken from historic drawings and BG/PS/DAT6 (1977) [3].

Details for pipework installed circa 1998 and 2003 is taken from historic drawings and BG/PS/DAT6 (1988) [4].

Details for pipework installed in 2019 is taken from TS/SP/DAT/6 [5].

3.3.2 Tees

Details of the tees modelled for the assessment are shown in Table 3.

For tees installed circa 1970, conservative diameter, wall thickness and material information was taken from 1972 edition of GC/PS/T1[6].

[redacted]

For tees installed circa 1998 and 2003, conservative diameter, wall thickness and material information was taken from 1993 edition of T1[7].

3.3.3 Bends

Details of the bends modelled for the assessment are shown in Table 4.

For bends installed circa 1970, conservative diameter, wall thickness and material information was taken from the 1973 edition of PS/B1 [8].

For bends installed circa 1998 and 2003, conservative diameter, wall thickness and material information was taken from the 1993 edition of B7 [9] and B4 [10].

3.3.4 Welding Fittings

For weldolets/weldoflanges Appendix 4.10 of TD/12 requires certain geometry validity limits to be met, which allows for more accurate calculation of stress concentration factors (SCFs). These dimensions have been chosen to meet the validity limits using data available from weldolet/weldoflange manufacturers.

Welding fittings installed circa 1970 are assumed to satisfy the requirements of T/SP/F1 [11] (1971)

Welding fittings installed circa 1998 and 2003 are assumed to satisfy the requirements of T/SP/F1 [12] (1993).

Details of the modelled fittings are provided in Table 5.

3.3.5 Reducers

Data for reducers installed circa 1998 has been taken from the 1990 edition of PS/F3 [13].

Details of the modelled fittings are provided in Table 6.

3.3.6 Rigid Weights

The weights of rigid elements such as valves and flanges are taken as those in the CAESAR II internal database and manufacturer catalogues.

3.4 Loading Conditions

Within CAESAR II a series of pressures, temperatures and other loads may be applied to each element. These individual loads are then combined into a series of loadcases describing the operation of the facility over its lifetime. These include loadcases to enable sustained, abnormal sustained, shakedown and fatigue assessments to be undertaken and assessed to the requirements of IGE/TD/12.

A loadcase table was created based upon the below pressure and temperature values, in accordance with the guidance of IGE/TD/12. The loadcase table as entered into CAESAR II is shown in Table 9.

3.4.1 Pressures

The following design pressures for the parts of the site were provided in Ref. [14]

- MIP 79.5 barg

3.4.2 Temperatures

3.4.2.1 Operating Temperatures

Taking guidance from T/SP/PW/13[15] and the supplied drawings, the following temperatures have been used;

- Above ground maximum and minimum temperatures of +50°C and -20°C, respectively.

Forward Flow (Kings Lynn to Bacton)

For forward flow the following temperatures have been used:

- An assumed minimum below ground temperature of 5°C.
- Maximum below ground, suction and discharge, flow temperature of 15°C and 47°C respectively [16].
- Minimum below ground suction temperature of 8°C [17].
- Assumed minimum below ground discharge temperature of 37°C, to produce a temperature swing of 10°C from the maximum.

Reverse Flow (Bacton to Kings Lynn)

For reverse flow the following temperatures have been used:

- An assumed minimum below ground temperature of 5°C.
- Maximum below ground, suction and discharge, flow temperature of 18°C and 47°C respectively [16].
- Minimum below ground suction temperature of 8°C [17].
- Assumed minimum below ground discharge temperature of 37°C, to produce a temperature swing of 10°C from the maximum.

The temperatures as applied to the models are shown in Figure 3 to Figure 5.

Temperatures and pressures used for the analyses are provided in Table 7 and Table 8.

3.5 Boundary Conditions

3.5.1 Buried Pipe Modelling

Soil restraint is modelled as a series of bi-linear springs. The CAESAR II soil modeller allows input of different values in the axial, lateral, upward and downward directions. The bi-linear springs consist of a spring, of constant stiffness, which gives a restive load that increases linearly with increasing displacement and an ultimate load cut-off point beyond which no further resistive load is transferred to the pipe regardless of displacement.

For this analysis the soil restraint has been calculated using the American Lifelines Alliance[18] methodology built into CAESAR II. This is in accordance with the recommendations in IGE/TD/12.

Historic boreholes have been provided for Kings Lynn Compressor Station, the locations of which are shown in 9Appendix A. At the depths considered, the boreholes indicate the ground varies between fine to medium sand and soft to stiff clay.

One of the main purposes of this study is to determine the maximum displaced profile due to ground movement (settlement). In view of this soil properties have been selected to favour soil characteristics which permit the most onerous levels of settlement for both sand and clay soil types.

For the sand based soil the analysis is based on the assumption that soil behaves as a loose sand, whilst for the clay based soil the analysis is based on the assumption that soil behaves as a soft clay, where these two soil types are defined in NEN 3650[19]..

For both soil types the water table is conservatively assumed to be at the surface.

The original buried piping is assumed to be coal tar coated and an appropriate coating coefficient of friction has been used in the soil modelling.

The soil properties used are shown in Table 10, whilst the information as entered into CAESAR II is shown in Table 11 and Table 12.

3.5.2 Supports

Sliding supports on the 300mm NB above ground regulator pipework have a PTFE lining. These supports have been modelled as +Y restraint and coefficient of friction of 0.12[20].

Adjustable supports on the 50mm NB above ground pipework have been modelled as Y with Guide and a coefficient of friction of 0.12.

The ten 900mm NB valves in the bi-directional area are installed on concrete piled supports. The piled support bases, installed circa 1998, have a neoprene lining, and the same has been assumed for the support bases installed circa 1970. The supports have been modelled as +Y restraint and coefficient of friction of 0.2 [21].

Similarly, the remaining below ground supports have been modelled as +Y support and coefficient of friction of 0.2.

[redacted]

There are several pits, associated with Feeder 2, in the bi-directional area. It is assumed the pit wall will have been lined with Neoprene or similar, therefore the pit-wall transition has been modelled as Y with Guide restraint and coefficient of friction of 0.2.

To avoid conflicting boundary conditions for the models including settlement, non-piled restraints located in regions of applied settlement have been removed. See Figure 6 for locations at which restraints have been removed.

3.5.3 Trial Holes / Settlement

An AOD survey has been performed to determine the current elevation levels of the piping in and around the bi-directional area. Figure 1 shows the locations where trial holes (identified with a TH prefix) and subsequent elevations have been taken.

Very little data is available regarding the elevations at which the pipe was constructed. However, drawing M830/BE/03/01/2020/007 Rev. F, reproduced here in Figure 7, details some elevations of the piping. The construction survey was undertaken in 2003 during installation of the pigging loop area and was limited to the newly installed pipework, including tie-in location, only. This data has been used to match some of the points where measurements have been taken in the latest survey.

To estimate the as-built profile of the pipework, where no original construction datum is available, the current elevation profile moving down a length of piping has been tabulated and the as-built elevation determined using 'trend line' analysis. Details of the analysis are provided in 9Appendix B.

The AOD comparison and trend line analysis both predict significant, and questionable, levels of settlement at the tie–in location of the pigging loop to the bi-directional area. Specifically, a settlement of 127mm is predicted over a relatively short span at TH-07. A sensitivity study was therefore undertaken to determine the likelihood of the predicted settlement values from the trend line analysis and AOD comparison.

The sensitivity study considered the piping in the bi-directional area to have no soil restraint and be restrained only by known piled and below ground concrete supports; effectively allowing the piping to form a free span between supported regions. In addition to the loss of soil restraint a soil load was applied to the crown of the pipe equivalent to the soil burden load at one metre cover depth. Both loose sand and soft clay soil properties were considered for the adjacent buried piping.

Table 13 shows the result of the study alongside the predicted settlement from the AOD comparison and trend line analysis. For location TH-07 the predicted settlement, with clay based soil properties, is now 22mm. This is similar in magnitude to the predicted settlement at the adjacent trial hole, TH-23, from the trend line analysis. The source of the large discrepancy at this location is unclear, however a check of the latest survey readings has been performed and the error is most likely due to a calibration or reading error of the 2003 AOD survey.

For the free span model with sand based ground conditions the predicted settlement values are significantly less than observed in the AOD survey comparison, trend line analysis and from the sensitivity study with clay soil properties.

In view of the study a limit on settlement has been specified as the lesser of: that predicted by the trend line analysis and that predicted from the sensitivity study with soft clay soil properties. This takes into consideration that settlement cannot be greater than the free-span case but also that regions of the site remain supported by the surrounding soil.

Given that for some locations the settlement predicted by the free span case is less than that predicted by the trend line analysis it is possible that the four Streams in the bi-directional area were not installed at a constant gradient, as assumed in the trend line analysis. It is further possible that in this region there has been significantly less settlement than it is proposed to consider herein, and that the latest AOD readings are actually closer to the original construction datum. However, it is highly unlikely that settlement in this region is more onerous than what has been considered and thus the approach considered above is a worst case scenario.

The final column of Table 13 shows the settlement value to be considered for the TD/12 assessments considered herein.

4 IGE/TD/12 ASSESSMENTS

4.1 Normal Sustained

The normal sustained loadcase assessment addresses the effects of primary loadings such as the dead weight of the pipework, fittings, valves and soil loadings together with the full design pressure. It addresses those loadings that may cause failure due to global plastic collapse. Thermal loadings (other than long range thermal effects with elastic follow up) are treated as secondary in a TD/12 analysis and are not assessed for this failure mode.

The maximum predicted von Mises equivalent stress (S_S) for each component is evaluated for the primary loadings and checked against the normal sustained criterion specified in TD/12.

The facility is in a Type ‘R’ area, and hence the design factor is 0.67. The normal sustained acceptance criterion for such pipework is given by:

$$S_s = 0.80MYS \quad if\ \frac{SMYS}{SUTS} \leq 0.74 \qquad [1]$$

or

$$S_s = 0.34SMYS \quad if\ \frac{SMYS}{SUTS} > 0.74 \qquad [2]$$

where S_S is the calculated von Mises equivalent stress, SMYS is the Specified Minimum Yield Strength and SUTS is the Specified Ultimate Tensile Strength.

4.2 Abnormal Sustained

The abnormal sustained loadcase considers occasional loads such as hydrostatic test, wind, earthquake and settlement.

The maximum predicted von Mises equivalent stress (S_{sab1}, S_{sab2},….,S_{sabi}) for each component is evaluated for each of the possible abnormal loads and checked against the abnormal sustained criterion specified in TD/12.

For a design factor of 0.67, the abnormal sustained acceptance criteria are given by:

$$S_{sab} \leq\ 0.9SMYS \quad if \quad \frac{SMYS}{UTS} \leq 0.74 \qquad [3]$$

or

$$S_{sab} \leq\ 0.38(SMYS + UTS) \quad if \quad \frac{SMYS}{UTS} > 0.74 \qquad [4]$$

where S_{sab} is the calculated von Mises equivalent stress, SMYS is the Specified Minimum Yield Strength and UTS is the Ultimate Tensile Strength.

4.3 Shakedown

When part of a structure is initially loaded beyond its elastic limit, local plasticity can occur. Upon removal of the load a self-equilibrating residual stress can remain. Subsequent applications of loads of the same magnitude will eventually produce an elastic response if shakedown is achieved. If shakedown is not achieved, failure by incremental plastic collapse, otherwise known as “ratchetting”, will occur under repeated cyclic loading. The shakedown analysis calculates the maximum allowable range of stresses before ratchetting occurs. To obtain these, a series of loadcases are run for both zero and design pressures at the minimum and maximum thermal conditions.

The differences (the self-weight and any prescribed forces cancel out) between all of the aforementioned loadcases are considered in turn, and a von Mises equivalent stress range, S_{VM}, is calculated using these differences. The TD/12 shakedown acceptance criterion requires the calculated equivalent stress range should not exceed S_{PR}, which is given by

$$S_{PR} = \frac{K_{SD}(S_Y + S_{YT})}{2} \qquad [5]$$

where K_{SD} is the shakedown factor of the material, which is 1.8 for carbon steel.

In the above, S_Y is taken to be equal to SMYS at room temperature and S_{YT} is taken to be equal to SMYS at maximum temperature.

5 RESULTS

Occurrences of stress that exceed the TD/12 allowable values are termed ‘exceptions’. Where a component has an exception for both the lower and upper bound analyses then the greater exception is said to ‘bound’ the lesser.

5.1.1 Normal Sustained (As-built)

There is a single fitting exceeding the TD/12 normal sustained allowable stress criterion, with a code stress ratio of 164.88% located on a 900mm x 200mm sweepolet fitting (node 15990).

Details of the exception is provided in Table 14 and the location is shown in Figure 10.

5.1.2 Abnormal Sustained

There are twenty-eight fittings exceeding the TD/12 abnormal sustained allowable stress criterion when considering settlement. A brief summary of the fitting exceptions is provided below, there are;

- Three exceptions on 900mm x 200mm sweepolets.
  - The highest reported exception is 255.31% at node 1310.
- Four exceptions on 900mm x 300mm sweepolets.
  - The highest reported exception is 341.18% at node 6070.
- Four exceptions on 900mm bends.
  - The highest reported exception is 164.94% at node 1550.
- Eleven exceptions on 900mm x 900mm equal tees.
  - The highest reported exception is 367.09% at node 6180.
- Three exceptions on 900mm x 50mm weldolets.
  - The highest reported exception is 105.97% at node 6160.
- Three exceptions on 50mm x 50mm tees.
  - The highest reported exception is 141.84% at node 16980.

Details of the exceptions, in the current and as-built configuration, are provided in Table 14 and their locations are provided in Figure 8 to Figure 11.

For some fittings it is shown that the predicted stress is significantly greater than the allowable code stress. The analysis undertaken herein considers a conservative approach whereby the nominal stress is scaled by a Stress Concentration Factor (SCF) which is determined by the fitting classification and dimensions.

For code stress exceptions IGE/TD/12 permits the use of a more detailed assessment, based on finite element theory, to better understand the stress distribution and potentially qualify the fitting for continued operation without intervention. Furthermore it is possible to qualify the acceptability of multiple fittings of the same classification and size by performing a bounding assessment of the most highly stressed fitting, only.

5.1.3 Shakedown

There are twelve fittings exceeding the TD/12 shakedown allowable stress criterion when considering settlement. A brief summary of the of exceptions is shown below, there are;

- Five exceptions on 900mm x 200mm sweepolets.
  - The highest reported exception is 237.4% at node 15990.
- Five exceptions on 900mm x 300mm sweepolets.
  - The highest reported exception is 153.91% at node 15920.
- Two exceptions on 900mm x 900mm equal tees.
  - The highest reported exception is 127.13% at node 15220.

Details of the exceptions, are provided in Table 15 and their locations are provided in Figure 8 to Figure 11. Where exceptions are observed for multiple loadcases per fitting, only the most onerous loadcase has been reported.

For some fittings it is shown that the predicted stress is significantly greater than the allowable code stress. The analysis undertaken herein considers a conservative approach whereby the nominal stress is scaled by a Stress Concentration Factor (SCF) specific to the fitting type and dimensions.

For instances where the code stress is exceeded IGE/TD/12 permits the use of a more detailed assessment, based on finite element theory, to better understand the stress distribution and potentially qualify the fitting for continued operation without intervention. Furthermore, it is possible to qualify the acceptability of multiple fittings of the same classification and size by performing a bounding assessment of the most highly stressed fitting, only.

6 DISSCUSSION

Notwithstanding the above, it might be worth giving further consideration to the pigging loop.

The as-built AOD (2003) survey did not consider the pigging loop beyond the two 900mm equal tees, and therefore, any settlement of the pigging loop is unknown. Since the pigging loop is largely unsupported (other than ground support) any settlement of the Feeder 4 piping could impose significant bending stresses on the two supported 900mm equal tees. With this in mind, it is noted, from an above ground visual inspection survey of the valve arrangement, adjacent the pigging loop, that there are several off-vertical valve stems, suggesting that some settlement may have taken place. This may of course, be relatively benign, indeed the AOD comparison study predicted settlement of about

19mm. However, owing to the potential significance of settlement in this region and noting that there have been some discrepancies between prediction and observation it might make sense to install additional monitoring rods on the pigging loop to enable continued monitoring of the region.

7 CONCLUSIONS

1. The current elevation levels of the piping in and around the bi-directional area has been established by performing an AOD survey at several trial hole locations around the site.

2. Very little data exists on the original as-built elevation profile. A trend line analysis using the measurements of the construction survey undertaken in 2003 for the pigging loop area and the recent AOD 2021 survey (current piping elevations) has been undertaken to estimate the as-built piping elevations in the bi-directional area.

3. Significant settlement (127mm) over a short span is estimated by the trend line analysis in the region of trial hole location TH-07. To determine the plausibility of the large displacements a sensitivity study has been undertaken based on a free span condition considering both sand and clay soil ground conditions. Indeed the sensitivity study showed that some of the estimated settlement values were suspect.

    i. The latest survey reading have been checked and found to be accurate, this suggests there is most likely an error in the survey readings undertaken in 2003.

4. A limit on settlement has been set as the lesser of: that predicted by the free span assessment with clay soil properties and that predicted by the trend line analysis.

5. IGE/TD/12 code stress analyses have been undertaken of the as-built configuration and current configuration, including settlement, at Kings Lynn. Soft clay soil properties have been considered.

6. For the as-built configuration there is a single fitting exceeding the IGE/TD/12 sustained criterion.

7. For the model including settlement, there are twenty-eight fittings exceeding the IGE/TD/12 abnormal sustained criterion and twelve fittings exceeding the IGE/TD/12 shakedown criterion.

    i. It may be possible to show acceptability of the fittings by undertaking a more detailed design-by-analysis assessment involving the finite element method.

8 RECOMMENDATIONS

For the fittings which exceed the TD/12 code stress limit it is recommended a more detailed finite element analysis is undertaken to better understand the level and distribution of stress in the fittings.

It is possible to qualify the acceptability of multiple fittings of the same classification and size by performing a bounding assessment of the most highly stressed fitting, only. Table 17 and Table 18 summarise the highest stressed fitting type and size for the abnormal sustained and shakedown exceptions. This forms the scope of work for the Stage 2 programme of work.

Based on a recent visual indication that there may have been some movement of the pigging loop, and noting that the pigging loop is unsupported, it is recommended additional monitoring points are installed on the pigging loop piping to enable continued monitoring of the region.

9 REFERENCES

1. IGE/TD/12 Edition 2, Reprint with Amendments, Communication 1757, 2012, Pipework Stress Analysis for Gas Industry Plant, Institution of Gas Engineers & Managers.
2. CAESAR II 2019 v11.00.03.0100, (Build 200605).
3. BGC/PS/DAT6, Standard Sizes of Carbon and Carbon Maganese Steel Pipe for Operating Pressures Greater than 7 Bar, 1977.
4. BGC/PS/DAT6, Standard Sizes of Carbon and Carbon Maganese Steel Pipe for Operating Pressures Greater than 7 Bar, 1988.
5. TS/SP/DAT/6, Specification for Standard Sizes of Carbon and Carbon Manganese Steel Pipe for Operating Pressures Greater Than 7 bar, National Grid, February 2015.
6. BGC/PS/T1, Specification for Forged Tees 450mm Nominal Size and Above Operating at Pressures of 7 to 70 bar, March 1972.
7. BGC/PS/T1, Specification for Carbon and Carbon Manganese Steel Tees Equal to or Greater than 450mm Nominal Size Produced from Plate for Operating Pressures Greater than 7 bar, February 1993.
8. BGS/PS/B1, Specification for Forged Bends 457mm Diameter and Above Operating at Pressures of 7 to 70 bar, June 1973.
9. B7, Specification for Carbon and Carbon Manganese Steel Bends Equal to or Greater than 450mm Nominal Size for Operating Pressures Greater than 7 bar, February 1993.
10. B4, Specification for Carbon and Carbon Manganese Steel Bends 50mm to 400mm Inclusive Nominal Size Produced from Seamless Pipe for Operating Pressures Greater than 7 bar, February 1993.
11. BGPS/F1, Specification for Steel Forging for Flanges and Brancholets, January 1971.
12. F1, Specification for Carbon and Carbon Manganese Steel Forgings and Forged Components for Operating Pressures Greater than 7 bar, February 1993.
13. PS/F3, Specification for Carbon and Carbon Manganese Steel Reducers 50mm to 1050mm Nominal Size for Operating Pressures Above 7 bar, September 1990.
14. [redacted], ‘Kings Lynn Compressor Station Design Basis Rev 2’, December 1999.

15. T/SP/PW/13, Specification for Carrying Out Pipework Stress Analysis to the Requirements of IGE/TD/12, National Grid, September 2011.
16. [redacted] Utilities, ‘Kings Lynn Compressor Station Stress Analysis Rev 1’, September 1999.
17. Email from [redacted], ‘NARC - Stress Info’, 16/08/2018.
18. Guidelines for the Design of Buried Steel Pipe, American Lifelines Alliance.
19. NEN3650-1+C1:2017, Requirements for Pipeline Systems, Nederlands Normalisatie Institute.
20. Datasheet for PTFE Slide Bearing. Fluorocarbon Company Ltd, Caxton Hill, Hertford.
21. RR031, Development of design guidance for neoprene lined clamps for offshore application, MSL Engineering Ltd for HSE, 2002.

TABLES

Steel Name	SMYS (MPa)	SUTS (MPa)
B	241	413
X42	289	413
X46	317	434
X52	358	455
X56	386	449
X60	413	516
X65	448	530

Table 1 – Materials

Installation Date (Year)	Nominal Diameter (mm)	Outside Diameter (mm)	Wall Thickness (mm)	Specification	Strength Grade
1970	900	914.4	15.9	Ref. [Gel 2003 Stress]	X60
2003	900 (Proxy Pipe)	914.4	19.1	Ref. [Gel 2003 Stress]	X60
2003	900 (AGI Pipe)	914.4	15.9	Ref. [Gel 2003 Stress]	X65
1998	300	323.9	9.5	Ref. [Gel 2003 Stress]	X46
2003	200	219.1	8.2	Ref. [Gel 2003 Stress]	X42
1998/2003	50	60.3	5.5	Historic Drawings	B

Table 2 – Details of Pipe

Installation Date (Year)	Pressure Rating (barg)	Nominal Diameter (mm)	Outside Diameter (Header/Branch) (mm)	Wall Thickness on the Tee (Header/Branch) (mm)	Spec.	Strength Grade
1998 / 2003	103	900 x 900	970.6 / 970.6	44 / 44	BGC/PS/T1 (1993)	X56
1998	80	900 x 900	956.6 / 956.6	37 / 37	BGC/PS/T1 (1993)	X56
1970	-	900 x 900	945.2 / 945.2	31.3 / 31.3	BGC/PS/T1 (1972)	X56
2003	-	200 x 200	229.5 / 229.5	13.4 / 13.4	BGC/PS/T2 (1993)	X42
1998 / 2003	-	50 x 50	60.3 / 60.3	5.5 / 5.5	BG/PS/T2 (1993)	B

Table 3 – Details of Tees

Installation Date (Year)	Nominal Diameter (mm)	Radius	Fitting Wall Thickness (mm)	Spec.	Strength Grade
1970	900	3D	17.5	BG/PS/B1 (1973)	X60
2003	900	3D	17.5	BG/PS/B7 (1993)	X65

2003	900	3D	21	BG/PS/B7 (1993)	X60
1998	900	1.5D	19.9	BG/PS/B7 (1993)	X65
2003	900	1.5D	19.9	BG/PS/B7 (1993)	X65
1998	300	1.5D	10.7	BG/PS/B4 (1993)	X52
2003	200	1.5D	10.5	BG/PS/B4 (1993)	X42
1998	50	1.5D	5.5	BG/PS/B4 (1993)	B
2003	50	1.5D	5.5	BG/PS/B4 (1993)	B

Table 4 – Details of Bends

Installation Date (Year)	Nominal Diameter (mm)	Type	Spec.	Strength Grade
1998	900 X 300	Sweepolet	BGC/PS/F1 (1993)	X65
2003	900 x 200	Sweepolet	BGC/PS/F1 (1993)	X65
1998	900 x 50	Weldolet	BGC/PS/F1 (1993)	X60
1998 / 2003	600 x 50	Weldolet	BGC/PS/F1 (1993)	X65

Table 5 – Details of Forged Branch Connections

Nominal Diameter, D_1 (mm)	Nominal Diameter, D_2 (mm)	Wall Thickness, T_1 (mm)	Wall Thickness, T_2 (mm)	Type	Grade	Length	α (°)	R_1	R_2
300	250	9.5	8.74	Concentric	X46	203	11.8	30	30

Table 6 – Details of Reducers

<table>
<tr><th rowspan="3">CAESARII Designation</th><th rowspan="3">Description</th><th colspan="4">Temperature (°C)</th></tr>
<tr><th colspan="2">Suction</th><th colspan="2">Discharge</th></tr>
<tr><th>Above Ground</th><th>Below Ground</th><th>Above Ground</th><th>Below Ground</th></tr>
<tr><td>T1</td><td>Max Temp, no flow</td><td>50</td><td>15</td><td>50</td><td>15</td></tr>
<tr><td>T2</td><td>Min Temp, no flow</td><td>-20</td><td>5</td><td>-20</td><td>5</td></tr>
<tr><td>T3</td><td>Max Temp, flow</td><td>50</td><td>15</td><td>50</td><td>47</td></tr>
<tr><td>T4</td><td>Min Temp, flow</td><td>-20</td><td>8</td><td>-20</td><td>37</td></tr>
<tr><td colspan="6"></td></tr>
<tr><th>CAESAR II Designation</th><th colspan="3">Description</th><th colspan="2">Pressures (barg)</th></tr>
<tr><td>P1</td><td colspan="3">MIP (SOL)</td><td colspan="2">79.5</td></tr>
</table>

Table 7 – Temperature and Pressure Table – Forward Flow (KL to Bacton)

CAESARII Designation	Description	Temperature (°C)			
		Suction		Discharge	
		Above Ground	Below Ground	Above Ground	Below Ground
T1	Max Temp, no flow	50	15	50	15
T2	Min Temp, no flow	-20	5	-20	5
T3	Max Temp, flow	50	18	50	47
T4	Min Temp, flow	-20	8	-20	37

CAESAR II Designation	Description	Pressures (barg)
P1	MIP (SOL)	79.5

Table 8 – Temperature and Pressure Table – Reverse Flow (Bacton to KL)

Case	Combination		Identifier
	As-built	Current Configuration	
L1	W+T1	W+D1+T1	OPE
L2	W+T2	W+D1+T2	OPE
L3	W+T1+P1	W+D1+T1+P1	OPE
L4	W+T5+P1	W+D1+T3+P1	OPE
L5	W+T6	W+D1+T4	OPE
L6	W+P1	W+D1+P1	SUS
L7	L1-L2	L1-L2	EXP
L8	L3-L2	L3-L2	EXP
L9	L4-L2	L4-L2	EXP
L10	L5-L2	L5-L2	EXP
L11	L6-L2	L6-L2	EXP
L12	L3-L1	L3-L1	EXP
L13	L3-L4	L3-L4	EXP
L14	L3-L5	L3-L5	EXP
L15	L3-L6	L3-L6	EXP
L16	L1-L4	L1-L4	EXP
L17	L4-L5	L4-L5	EXP
L18	L4-L6	L4-L6	EXP
L19	L5-L1	L5-L1	EXP
L20	L5-L6	L5-L6	EXP
L21	L1-L6	L1-L6	EXP

Table 9- Loadcase Combinations for CAESAR II

Soil Type	Effective Density (kg/m^3)	Effective Cohesion c' (kN/m^2)	Effective Angle of Internal Friction (°)
Cohesive	427	25	-
Granular	937	-	30

Table 10 – Soil Strength Parameters

LOWER	
GAMMA PRIME – EFFECTIVE SOIL DENSITY (kg/cu.m.)	427
H – BURIED DEPTH TO TOP OF PIPE (mm.)	Varies
C – SOIL COHESION OF BACKFILL (N./sq.mm.)	0.025
ALPHA – ADHESION FACTOR (CALCULATED IF OMITTED)	
dT – YIELD DISP FACTOR, AXIAL (mm.)	10
dP – YIELD DISP FACTOR, LAT, MAX MULTIPLE OF D	0.15
dQu – YIELD DISP FACTOR, UPWARD, MULTIPLE OF H	0.2
dQu – YIELD DISP FACTOR, UP, MAX MULTIPLE OF D	0.2
dQd – YIELD DISP FACTOR, DOWN, MULTIPLE OF D	0.2
THERMAL EXPANSION COEFFICIENT xE-6 (L/L/deg C)	11.2131
TEMPERATURE CHANGE, Install-Operating (deg C)	5

Table 11 – CAESAR II Soil Input, Clay Based Soil

LOWER	
F – COATING FACTOR	0.9
GAMMA – DRY SOIL DENSITY ....(kg/cu.m.)	1733
GAMMA PRIME – EFFECTIVE SOIL DENSITY (kg/cu.m.)	937
H – BURIED DEPTH TO TOP OF PIPE .... (mm.)	Varies
FRICT. ANGLE (Sand=27-45;Silt=26-35;Clay=0)(deg)	30
K0 – COEFFICIENT OF PRESSURE AT REST	
dT – YIELD DISP FACTOR, AXIAL .... (mm.)	5
dP – YIELD DISP FACTOR, LAT, MAX MULTIPLE OF D	0.15
dQu – YIELD DISP FACTOR, UPWARD, MULTIPLE OF H	0.02
dQu – YIELD DISP FACTOR, UP, MAX MULTIPLE OF D	0.1
dQd – YIELD DISP FACTOR, DOWN, MULTIPLE OF D	0.1
THERMAL EXPANSION COEFFICIENT xE-6 (L/L/deg C)	11.2131
TEMPERATURE CHANGE, Install-Operating (deg C)	5

Table 12 – CAESAR II Soil Input, Sand Based Soil

Trial Hole Number (TH)	Node Number	Predicted Settlement (mm)			
		Case 1: Trend Line Analysis/AOD Comparison	Case 2: Clay Soil – Inc. 1m Cover Soil Burden Load	Case 3: Sand Soil – Inc. 1m Cover Soil Burden Load	Applied to Model - Lesser of Case 1 and Case2
1	21530				
2	21280				
3**					
4**					
5	15945	48	84	13	48
6	6115	63/187	225	36	63
7	5815	126/127	22	4	22
8	1550	171	606	100	171
9	1380	134	272	45	134
10	15307	36	40	13	36
11	15795	25	81.4	11	25
12	6265	68	71.4	10	68
13	5615	66	46	15	46
14***	16305				
15***	16125				
16	15134	18	0		0
17	15220	0	0	0	0
18	15305	-1	9.8	3	-1
19	15935	45	14.3	2	14
20	15810	-4	21	3	-4
21	6124	86	44	7	44*
22	6250	39	18.5	3	19
23	5744	13	0.8+	0	13*
24	5670	0	0	0	0
25	5617	65	15.2	6	15
26***	6695				
27***	6775				
28	510	0	0	0	0
29	1220	32	46	5	32
30	380	19	26+	4	19
31	6267	58	110	13	58
32	5580	70	44	14	44
33	5570	0	0	0	0
34	15335	11	41	16	11
35	15792	4	134	16.8	4
36	1040	0	26	5	0

<u>**Table 13 – Applied Settlement**</u>

**Considered by the settlement values at adjacent trial holes.*

*** Trial Holes not undertaken*

****Adjacent piled supports, therefore no settlement applied and gradient presumed unchanged between as-built and current profile.*

Node	Fitting	Code Stress Ratio (%)	
		As-built (Sustained)	Current (Abnormal Sustained)
410	900 x 200 Sweepolet	81.0	109.62
1310		65.37	255.31*
15990		164.88	228.04
5810	900 x 300 Sweepolet	75.46	156.67
6070		78.05	341.18*
15760		79.83	197.31
15920		99.70	129.98
1380	900 Bend	59.54	123.95
1530		59.56	128.91
1550		59.54	164.94*
5565		65.85	102.65
1220	900 x 900 Tee	52.63	110.82
1650		47.68	141
5600		46.78	135.79
5670		41.97	224.35
5770		45.97	182.89
6180		44.19	367.09*
6250		35.99	166.71
15220		69.60	124.26
15350		63.69	120.46
15810		36.51	175.35
15880		51.14	239.1
6150	900 x 50 Weldolet	70.10	101.08
6160		70.06	105.97*
6220		69.09	103.92
8900	50 x 50 Tee	23.25	132.95
16980		22.96	141.84*
18070		23.54	101.06

Table 14 – Sustained Exceptions – (See Figures 7 to 9 for Fitting Location)

**Highest code stress per fitting type*

Loadcase	Node	Fitting	Code Stress Ratio (%)	
			Forward Flow	Reverse Flow
9 (EXP)	410	900 x 200 Sweepolet	104.72	122.62
9 (EXP)	480	900 x 200 Sweepolet	108.95	137.21
9 (EXP)	1480	900 x 200 Sweepolet	-	100.04
9 (EXP)	15040	900 x 200 Sweepolet	111.88	103.64
9 (EXP)	15990	900 x 200 Sweepolet	164.47	239.5*
9 (EXP)	5810	900 x 300 Sweepolet	108.48	108.26
9 (EXP)	6070	900 x 300 Sweepolet	120.3	125.8
9 (EXP)	15090	900 x 300 Sweepolet	125.65	113.90
9 (EXP)	15760	900 x 300 Sweepolet	127.09	134.94
9 (EXP)	15920	900 x 300 Sweepolet	152.82	153.91*
9 (EXP)	15220	900 x 900 Tee	127.13*	108.41
9 (EXP)	15880	900 x 900 Tee	104.05	-

Table 15 – Worst Case Shakedown Exceptions – (See Figures 9 and 10 for Fitting Location)

**Highest code stress per fitting type*

Wall Thickness	Node	Fitting	Code Stress Ratio (%)	
			As-built (Sustained)	Current (Abnormal Sustained)
15.9	1310	900 x 200 Sweepolet	65.37	255.31
15.9	6070	900 x 300 Sweepolet	78.05	341.18
19.9	1550	900 Bend	59.54	164.94
31.3 x 31.3	6180	900 x 900 Tee	44.19	367.09
15.9	6160	900 x 50 Weldolet	70.06	105.97
5.5	16980	50 x 50 Tee	22.96	141.84

Table 16 – Fittings Recommended for Finite Element Analysis – Sustained/Abnormal Sustained Exceptions

Wall Thickness	Loadcase	Node	Fitting	Code Stress Ratio (%)	
				Forward Flow	Reverse Flow
15.9	9 (EXP)	15990	900 x 200 Sweepolet	164.47	237.4*
15.9	9 (EXP)	15920	900 x 300 Sweepolet	152.82	153.91*
31.3 x 31.3	9 (EXP)	15220	900 x 900 Tee	127.13*	108.41

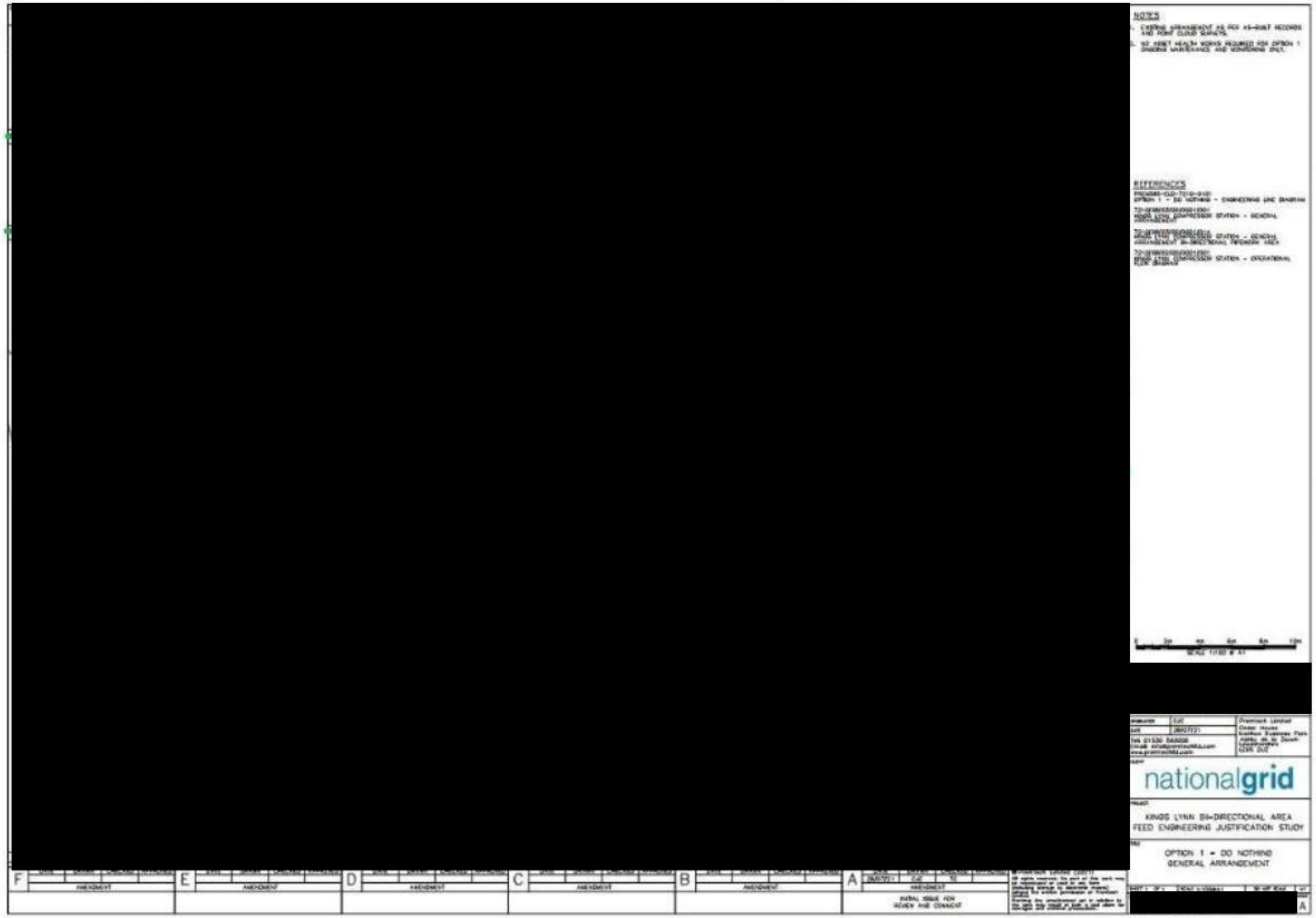
Table 17 – Fittings Recommended for Finite Element Analysis – Shakedown Exceptions

[redacted]

FIGURES

Figure 1 – Location of Bi-directional Area and Trial Hole Locations

[redacted]



[redacted]

[redacted]

[redacted]

Figure 2 – General Arrangement and Construction Year

	T1	T2
🟧	50	-20
🟪	15	5

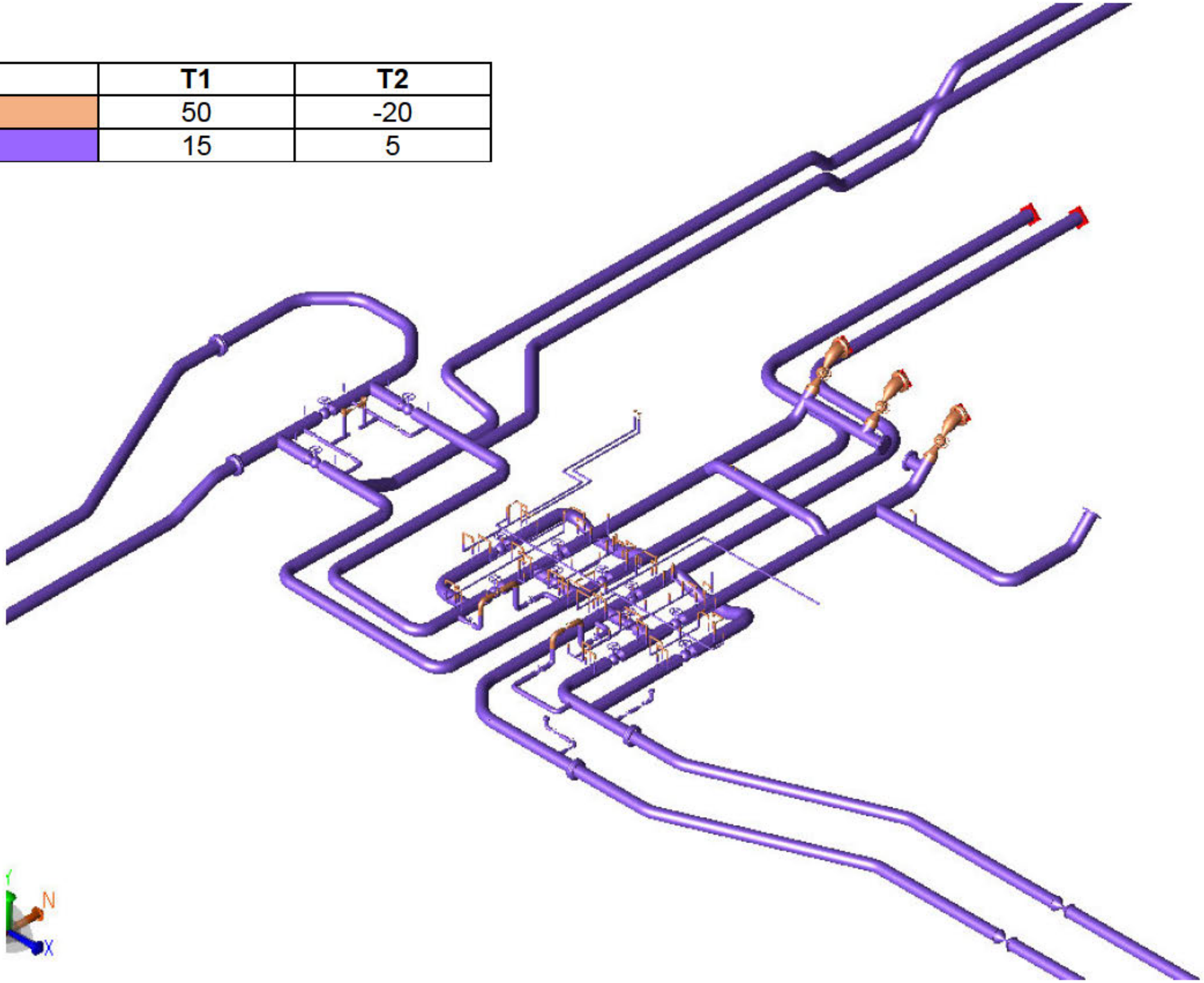


Figure 3 – Temperatures

	T3	**T4**
🟥	15	8
🟪	47	37
🟧	50	-20

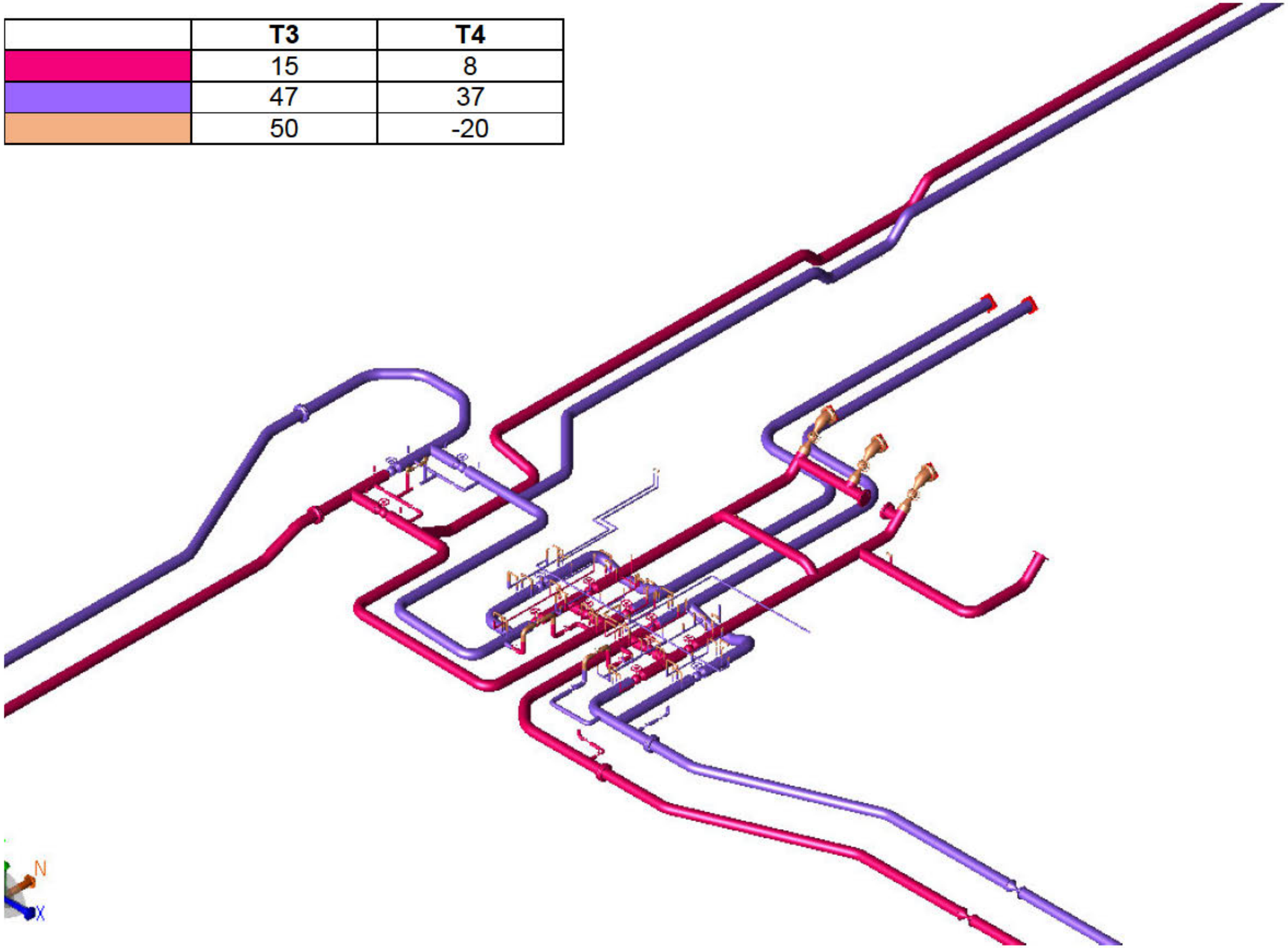


Figure 4 – Temperatures Cont'd (Forward Flow)

	T3	T4
🟥	50	-20
🟪	18	8
🟧	47	37

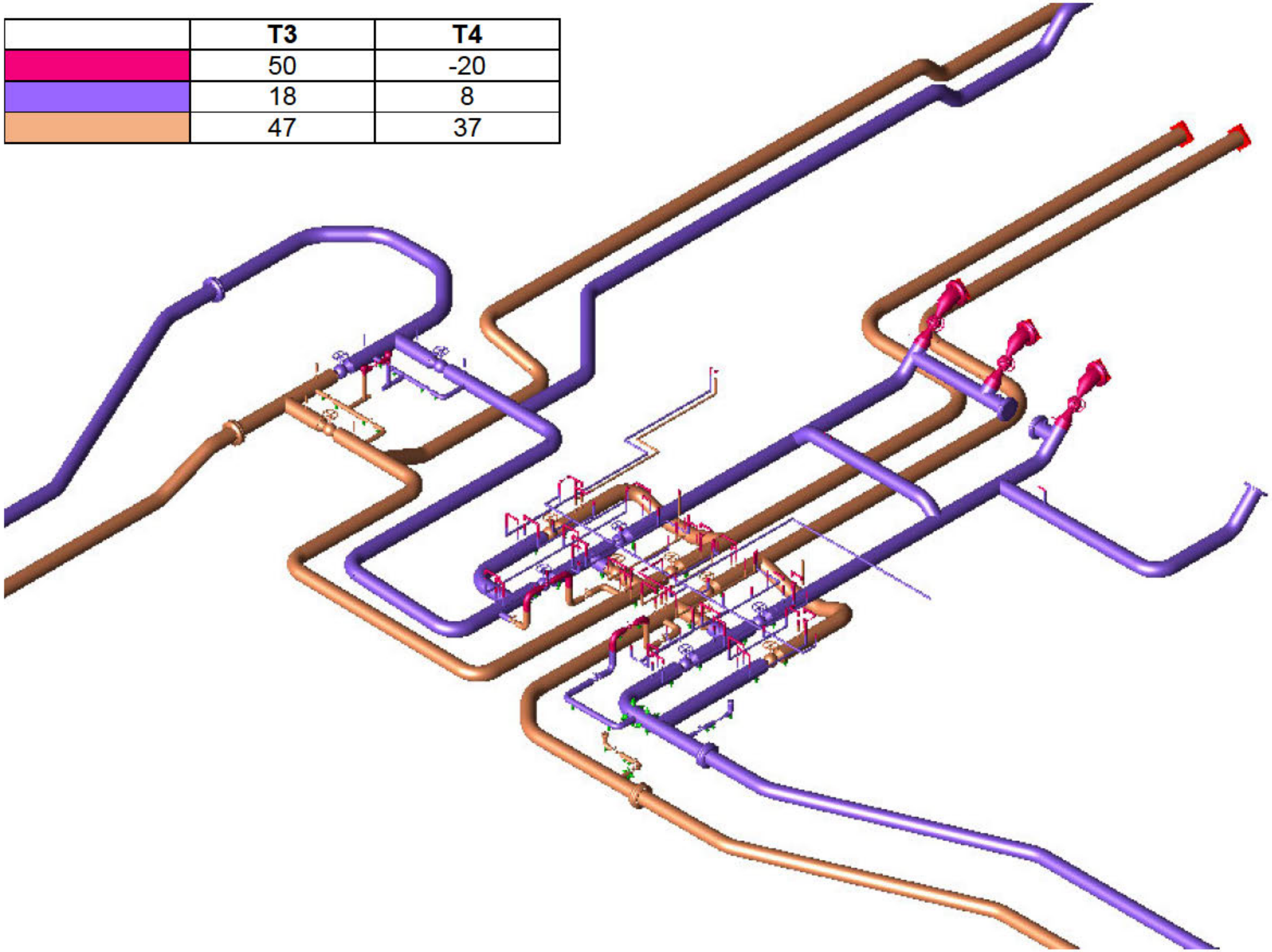


Figure 5 – Temperatures Cont'd (Reverse Flow)

[redacted]

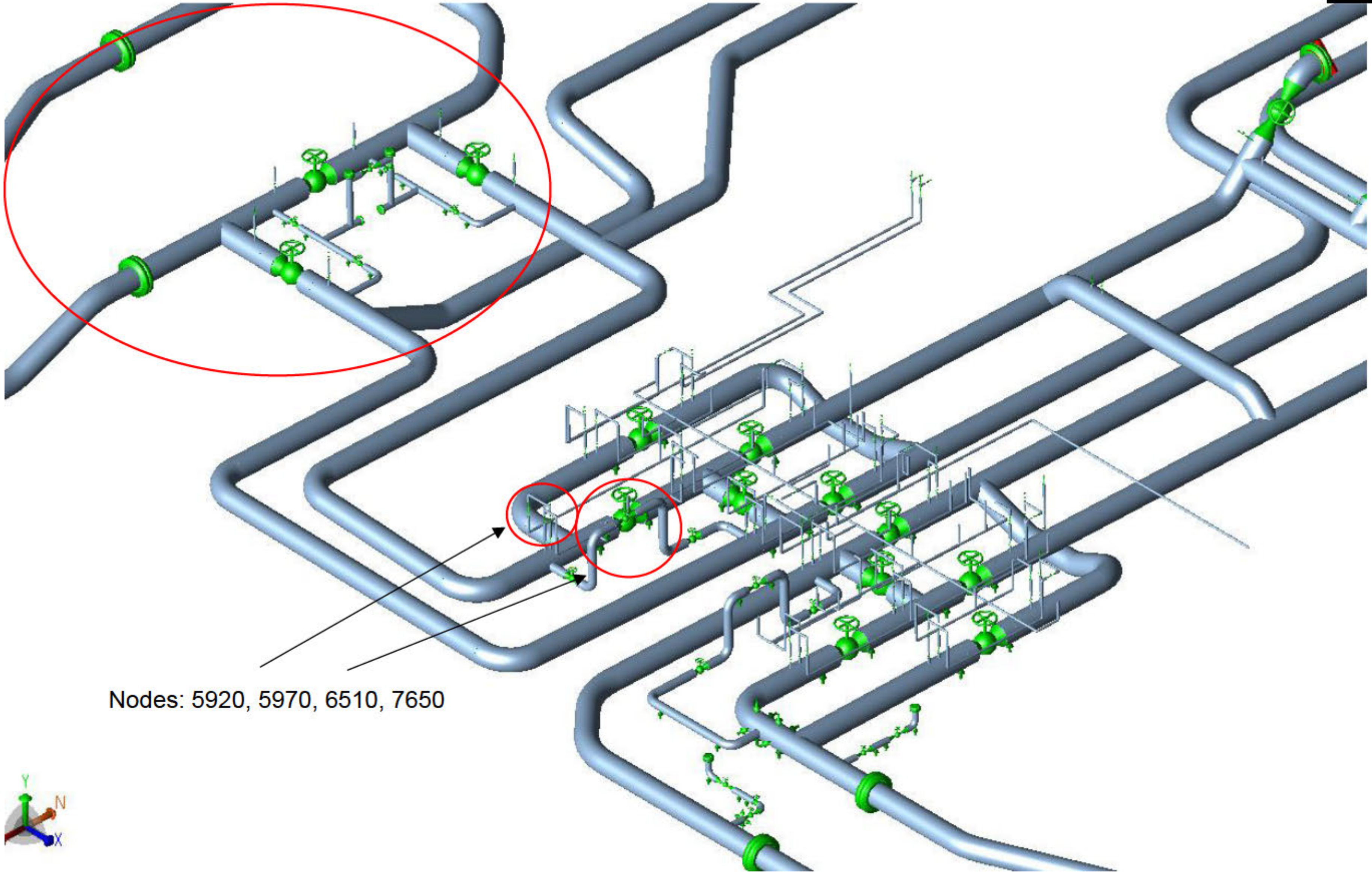
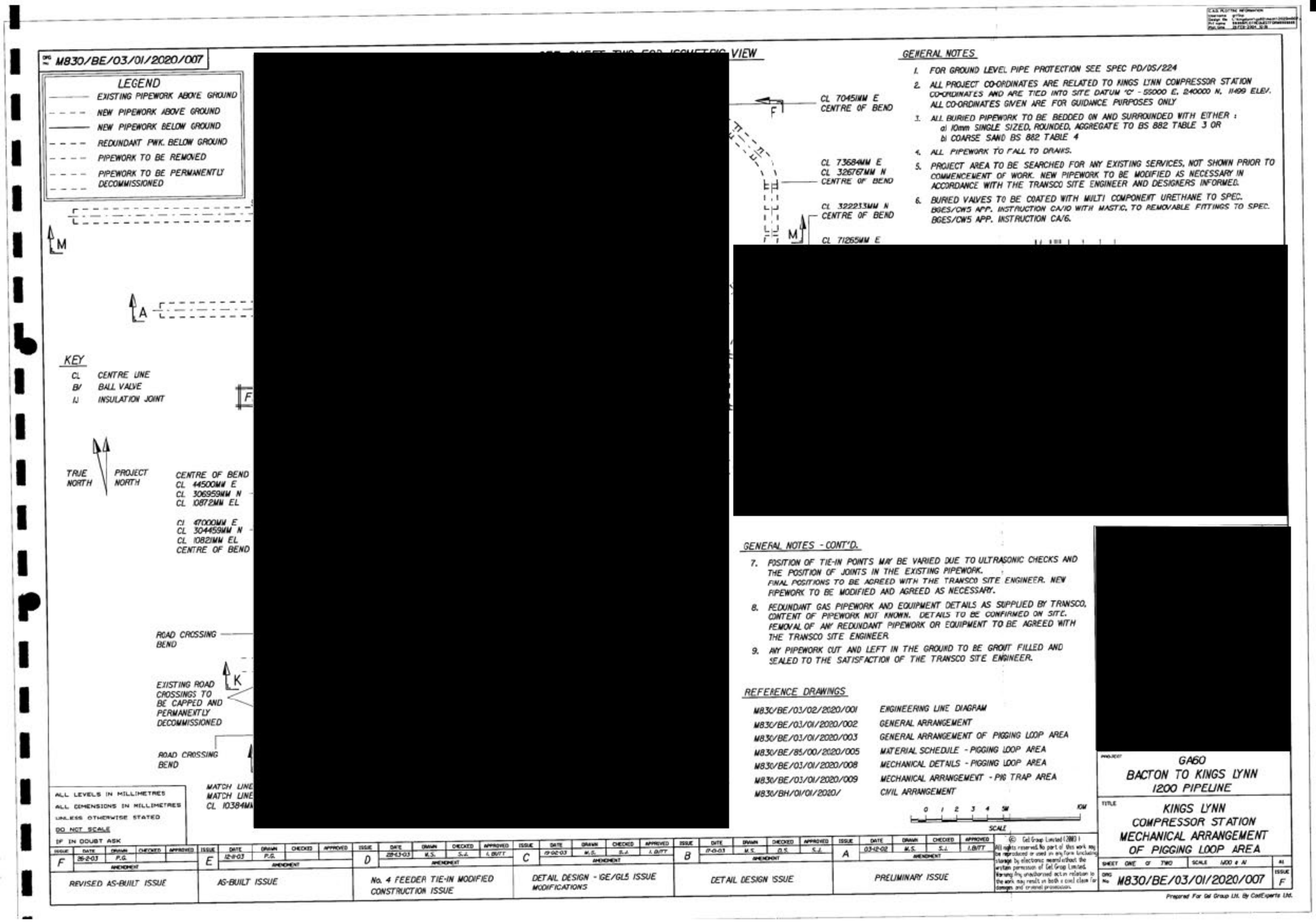


Figure 6 – Restraints Removed in Regions of Applied Settlement

[redacted]



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GENERAL NOTES

1. FOR GROUND LEVEL PIPE PROTECTION SEE SPEC PD/05/224
2. ALL PROJECT CO-ORDINATES ARE RELATED TO KINGS LYNN COMPRESSOR STATION CO-ORDINATES AND ARE TIED INTO SITE DATUM 'C' - 55000 E, 240000 N, 11499 ELEV. ALL CO-ORDINATES GIVEN ARE FOR GUIDANCE PURPOSES ONLY
3. ALL BURIED PIPEWORK TO BE BEDDED ON AND SURROUNDED WITH EITHER :
   a) 10mm SINGLE SIZED, ROUNDED, AGGREGATE TO BS 882 TABLE 3 OR
   b) COARSE SAND BS 882 TABLE 4
4. ALL PIPEWORK TO FALL TO DRAINS.
5. PROJECT AREA TO BE SEARCHED FOR ANY EXISTING SERVICES, NOT SHOWN PRIOR TO COMMENCEMENT OF WORK. NEW PIPEWORK TO BE MODIFIED AS NECESSARY IN ACCORDANCE WITH THE TRANSCO SITE ENGINEER AND DESIGNERS INFORMED.
6. BURIED VALVES TO BE COATED WITH MULTI COMPONENT URETHANE TO SPEC. BGES/CW5 APP. INSTRUCTION CA/10 WITH MASTIC, TO REMOVABLE FITTINGS TO SPEC. BGES/CW5 APP. INSTRUCTION CA/6.

GENERAL NOTES - CONT'D.

7. POSITION OF TIE-IN POINTS MAY BE VARIED DUE TO ULTRASONIC CHECKS AND THE POSITION OF JOINTS IN THE EXISTING PIPEWORK. FINAL POSITIONS TO BE AGREED WITH THE TRANSCO SITE ENGINEER. NEW PIPEWORK TO BE MODIFIED AND AGREED AS NECESSARY.
8. REDUNDANT GAS PIPEWORK AND EQUIPMENT DETAILS AS SUPPLIED BY TRANSCO. CONTENT OF PIPEWORK NOT KNOWN. DETAILS TO BE CONFIRMED ON SITE. REMOVAL OF ANY REDUNDANT PIPEWORK OR EQUIPMENT TO BE AGREED WITH THE TRANSCO SITE ENGINEER.
9. ANY PIPEWORK CUT AND LEFT IN THE GROUND TO BE GROUT FILLED AND SEALED TO THE SATISFACTION OF THE TRANSCO SITE ENGINEER.

REFERENCE DRAWINGS

M830/BE/03/02/2020/001	ENGINEERING LINE DIAGRAM
M830/BE/03/01/2020/002	GENERAL ARRANGEMENT
M830/BE/03/01/2020/003	GENERAL ARRANGEMENT OF PIGGING LOOP AREA
M830/BE/85/00/2020/005	MATERIAL SCHEDULE - PIGGING LOOP AREA
M830/BE/03/01/2020/008	MECHANICAL DETAILS - PIGGING LOOP AREA
M830/BE/03/01/2020/009	MECHANICAL ARRANGEMENT - PIG TRAP AREA
M830/BH/01/01/2020/	CIVIL ARRANGEMENT

ALL LEVELS IN MILLIMETRES
ALL DIMENSIONS IN MILLIMETRES
UNLESS OTHERWISE STATED
DO NOT SCALE
IF IN DOUBT ASK

ISSUE	DATE	DRAWN	CHECKED	APPROVED	AMENDMENT
F	26-2-03	P.G.			REVISED AS-BUILT ISSUE
E	12-11-03	P.G.			AS-BUILT ISSUE
D	28-03-03	M.S.	S.J.	I. BUTT	No. 4 FEEDER TIE-IN MODIFIED CONSTRUCTION ISSUE
C	19-02-03	M.S.	S.J.	I. BUTT	DETAIL DESIGN - IGE/GL5 ISSUE MODIFICATIONS
B	17-01-03	M.S.	D.S.	S.J.	DETAIL DESIGN ISSUE
A	03-12-02	M.S.	S.J.	I.BUTT	PRELIMINARY ISSUE

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PROJECT
GA60
BACTON TO KINGS LYNN
1200 PIPELINE

TITLE
KINGS LYNN
COMPRESSOR STATION
MECHANICAL ARRANGEMENT
OF PIGGING LOOP AREA

SHEET ONE OF TWO
SCALE 1:200 @ A1
DRG No M830/BE/03/01/2020/007
ISSUE F

Prepared For Gel Group Ltd. By CadExperts Ltd.

Figure 7 – 2003 As-built Above Ordnance Datum (AOD) Levels

[redacted]

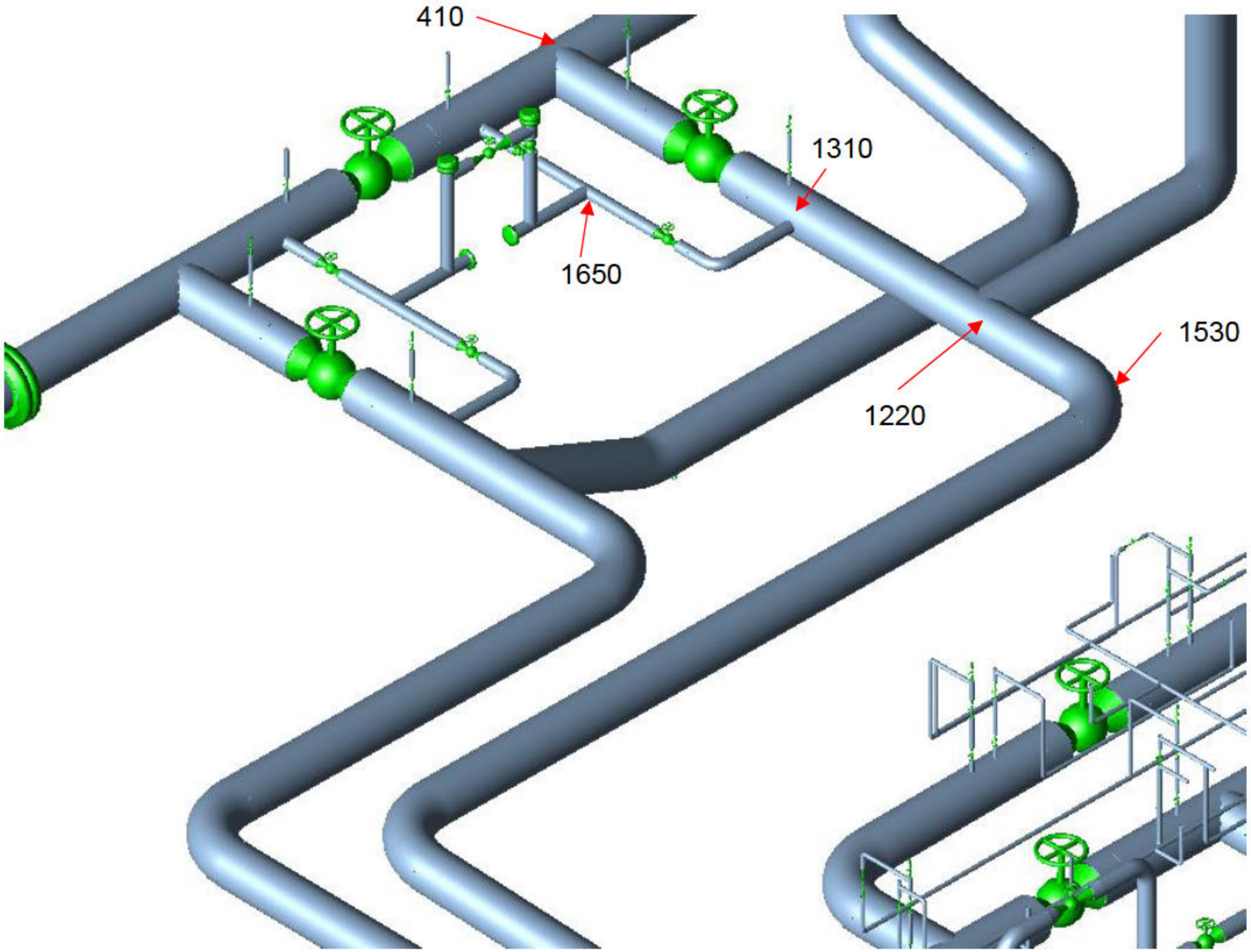


Figure 8 – Stress Exception Locations

[redacted]

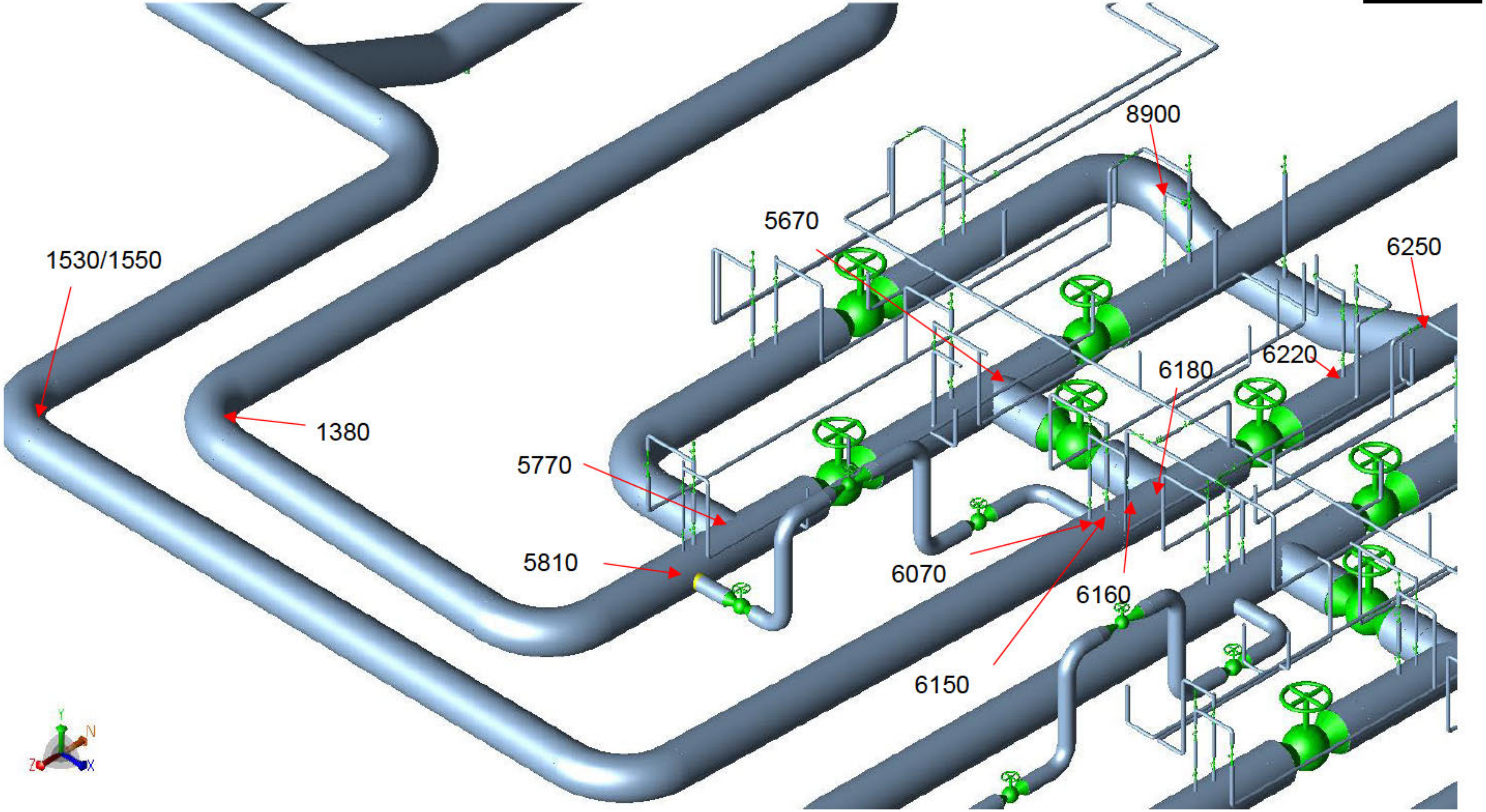


Figure 9 – Stress Exception Locations Cont'd

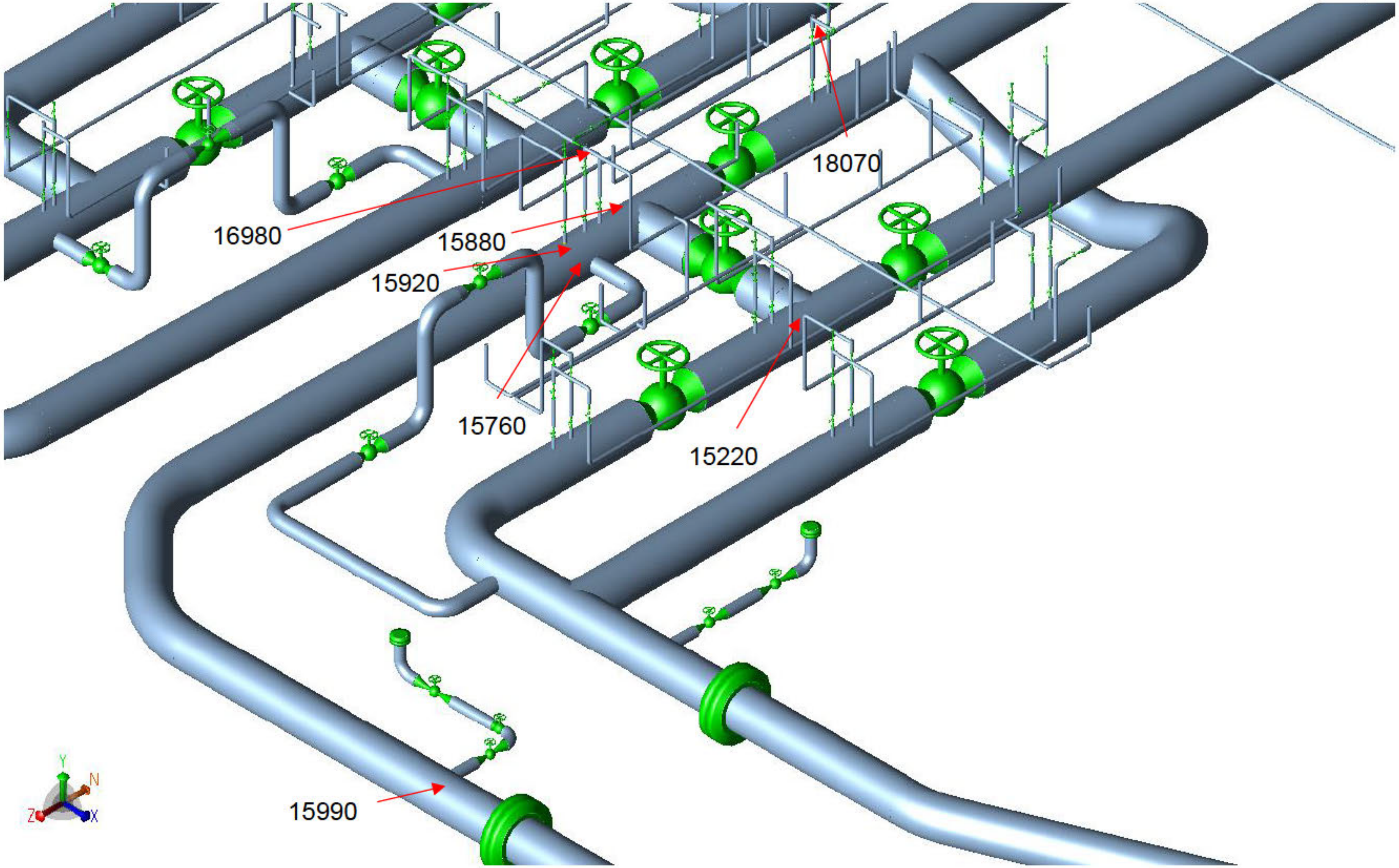


Figure 10 – Stress Exception Locations Cont'd

[redacted]

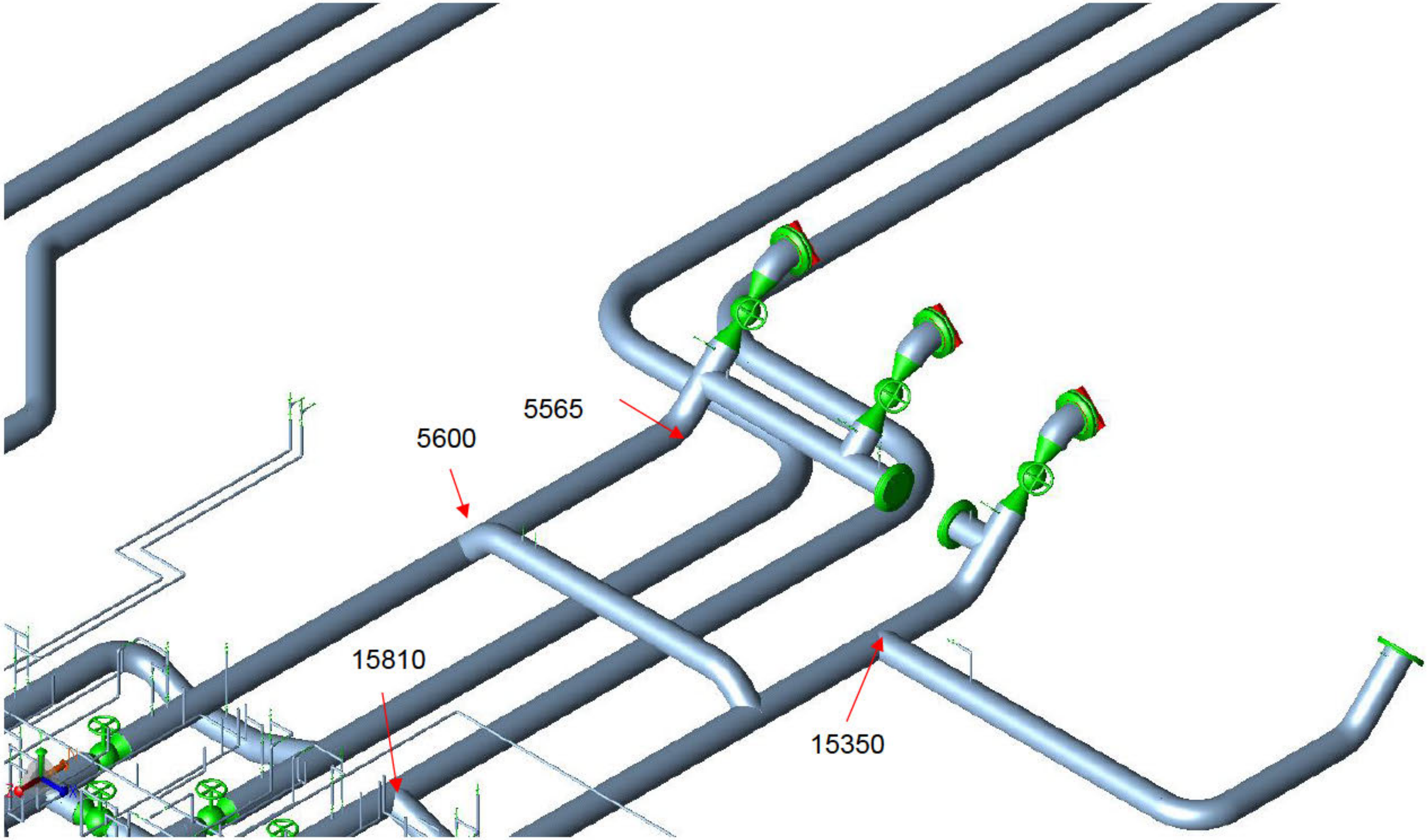
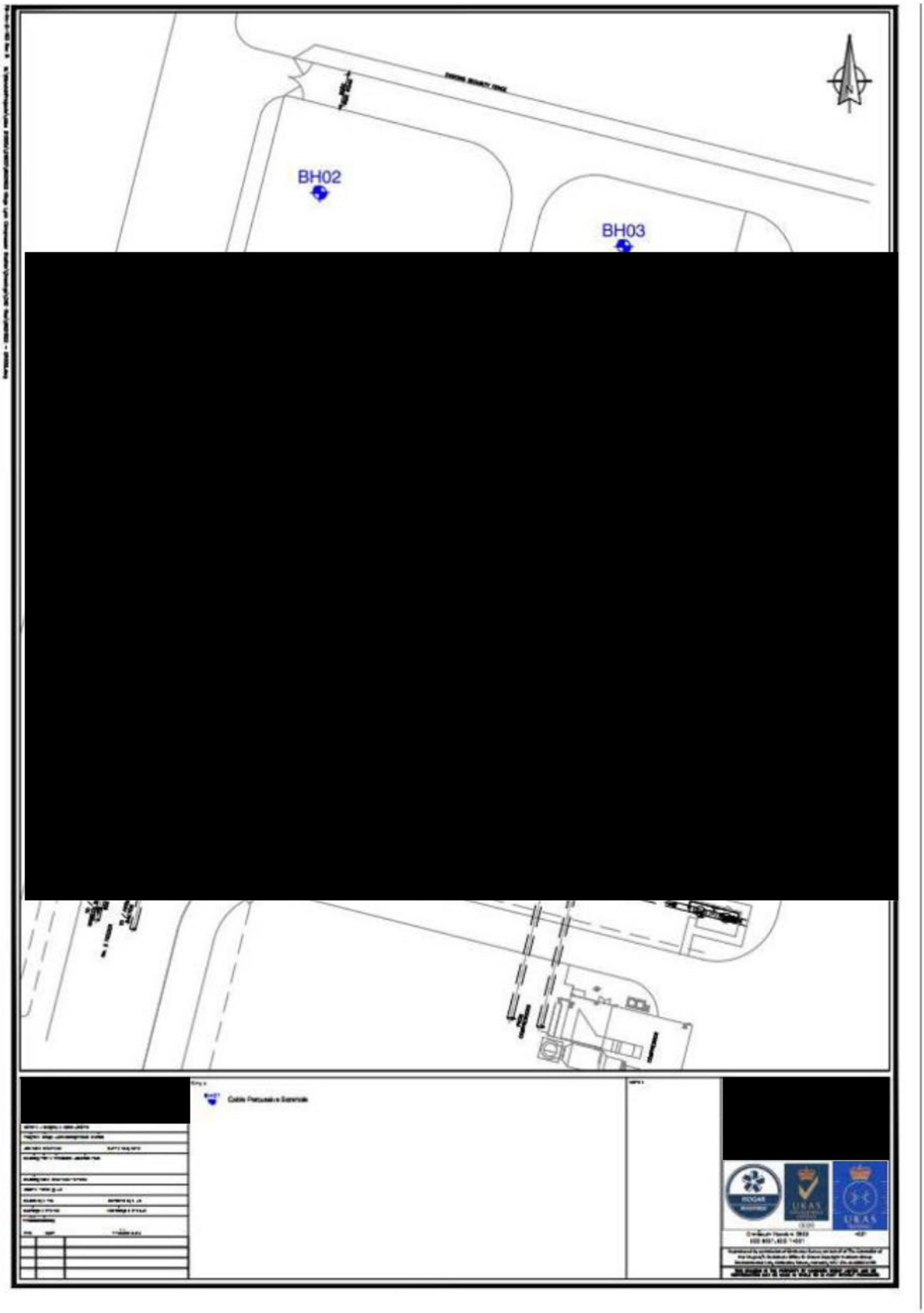


Figure 11 – Stress Exception Locations Cont'd

[redacted]

APPENDIX A HISTORIC BOREHOLES



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[redacted]

[redacted]

[redacted]

Rotary Borehole Record

BH01A

Sheet 1 of 6

Project ID:	GN21822	**E:** 572076.00	**N:** 316205.00
Location:	King's Lynn Compressor Station	**Date:**	24/05/2018 - 31/05/2018
[redacted]			
Plant used:	Comacchio MC405	SPT Hammer Serial No: ADP04 (ER: 62%)	

Geology Description	Legend	Depth (m)	Elevation (mAOD)	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	Type	Depth	Results / Remarks	Date - Depth (m) Casing (Water)
TOPSOIL (Dark brown slightly silty gravelly fine to coarse SAND. Gravel is angular to subrounded fine to coarse flint. Occasional rootlets present).		0.50					B1 ES1	0.10 0.10		
Dark grey clayey gravelly fine to coarse SAND. Gravel is angular to subrounded fine to coarse flint. Occasional pockets of black decaying organic matter with faint organic odour.		1.25					B2 ES2 B3 ES3	0.60 0.60 1.10 1.10		
Light yellowish brown clayey gravelly fine to coarse SAND. Gravel is angular to subangular fine and medium flint.		1.90					SPT(S) D1 D2	1.20 1.20 1.80	N=9 (2,2/2,2,2,3)	- (Dry)
Soft grey mottled brown sandy CLAY with rare gravel of subrounded fine and medium flint.		2.00					SPT(S) B4	2.00 2.00 - 2.50	N=9 (1,1/2,1,3,3)	2.00 (0.00)
Soft to firm black mottled dark grey silty CLAY with occasional gravel of subrounded fine flint. Slight organic odour present.							D3 D4	2.20 2.80 - 3.00		
From 2.80m: Occasional fine to coarse gravel-sized fossil shell fragments and whole shells.							SPT(S)	3.00	N=11 (2,1/2,3,3,3)	3.00 (0.00)
							D5	3.50		
At 3.70m: Rare coarse gravel-sized whole shell.							U1	4.00 - 4.60		
From 4.60m to 5.00m: Locally frequent coarse sand-sized and fine gravel-sized shell and shell fragments.							D6	5.00		
From 5.50m: Becoming firm.							SPT(S)	5.50	N=10 (1,2/2,2,3,3)	5.50 (0.00)
From 6.00m: Locally frequent fine and medium gravel-sized shell fragments.							B5 D7	6.00 - 6.50 6.00		
From 6.25m: Locally frequent fine to coarse gravel-sized fossil shell fragments.							SPT(S)	6.50	N=20 (3,3/4,5,5,6)	6.50 (0.00)
				13	0	0				
From 7.50m: Becoming firm to stiff. Fossil shell fragments becoming rare.										
From 8.00m: Locally frequent fine and medium sand-sized fossil shell fragments.				50	50	0	U2	8.40 - 8.70		
At 8.80m: 150mm open subhorizontal fracture. Drilling-induced.							SPT(S) D8	9.00 9.00	N=17 (3,3/4,4,5,4)	6.50 (0.00)
At 9.10m: 100mm open subhorizontal fissure.				86	86	0				
							D9	10.00		

Installation & Backfill

Hole Diameter by Depth		Drilling Flush Details		
Depth Base (m)	Diameter (mm)	Depth (m)	Type	Return (%)
6.50	146	6.50 - 7.50	WATER	100
51.00	116	7.50 - 9.00	WATER	100
		9.00 - 10.50	WATER	60

Casing Diameter by Depth	
Depth Base (m)	Diameter (mm)
6.50	150

[redacted]

Water Strike

Date	Strike Depth (m)	Depth Sealed (m)	Casing Depth (m)	Time Elapsed (mins)	Standing Level (m)	Remarks
						No groundwater encountered

Remarks:

1. Inspection pit GL to 1.20m.
2. Installations: Pipe1: 50mm standpipe GL to 8.00m plain, 8.00m to 50.00m slotted, fitted with gas tap and bung. Pipe2: 50mm standpipe GL to 1.00m plain, 1.00m to 6.00m slotted, fitted with gas tap and bung. Both installed in flush cover.
3. Backfill: GL to 0.50m concrete, 0.50m to 1.00m bentonite, 1.00m to 6.00m gravel, 6.000m to 9.00m bentonite, 9.00m to 51.00m gravel.
4. 0.33hrs standing time: Waiting for Murphy's to clear hole. 24/05/18. 5. 0.75hrs dayworks: Additional set up time 24/05/18.
6. 0.83hrs dayworks: Mixing mud into tank 29/05/18. 7. 0.5hrs dayworks: Mixing mud into tank 29/05/18.
8. 1hr standing time: Waiting for permit 30/05/18. 9. 1hr dayworks: Cleaning out tanks and mixing mud 30/05/18.
10. 1hr dayworks: Cleaning out tanks 30/05/18. 11. 2.5hrs standing time: Waiting for installation details 31/05/18.
12. 1hr dayworks: Clearing spoil 31/05/18.

Drilled by: [redacted]	Logged by: JE	Checked by: JA	Fm-Hn-R-3870-Rev D

[redacted]

[redacted]

Rotary Borehole Record

BH02

Sheet 1 of 6

Project ID: GN21822
Location: King's Lynn Compressor Station

[redacted]

E: 572081.83 **N:** 316300.54
Date: 17/05/2018 - 24/05/2018
Plant used: Comacchio MC405
SPT Hammer Serial No: ADP04 (ER: 62%)

Geology Description	Depth (m)
MADE GROUND (Multicoloured GRAVEL with high cobble content. Gravel is subangular to subrounded medium and coarse flint. Cobbles are flint).	0.05
MADE GROUND (Brown slightly silty slightly gravelly fine to coarse SAND. Gravel is subangular to subrounded fine to coarse flint and concrete).	0.90
MADE GROUND (Dark grey to dark brown slightly silty gravelly fine to coarse SAND with pockets of black fine to coarse sand. Gravel is angular to subrounded fine to coarse flint. Hydrocarbon odour present). *From 1.20m to 1.50m: Drilling flush cuttings.*	1.20
Light brown mottled brown slightly clayey fine to coarse SAND with rare gravel of subrounded fine and medium flint.	1.60
Medium dense becoming dense grey slightly silty fine to coarse SAND with occasional gravel of subrounded fine flint. *From 1.80m to 1.90m: Sand becoming locally medium and coarse with rare gravel of subangular medium flint.* *From 4.50m: Becoming slightly gravelly .Gravel is black subangular to subrounded fine and medium flint.*	4.90
Dark grey and brown slightly gravelly silty sandy CLAY. Gravel is subrounded fine and medium flint.	5.00
Soft dark grey slightly sandy silty CLAY with occasional gravel of fine and medium fossil shell fragments. Slight organic odour present. *From 5.00m to 5.10m: Becoming locally very gravelly.* *From 5.60m: Becoming locally silty fine and medium sand.* *From 5.90m: Becoming locally very sandy.*	6.00
Firm to stiff grey silty CLAY with occasional gravel of fine to coarse fossil shell and fossil shell fragments. *From 8.50m: Gravel becoming rare fossil shell fragments.* *From 9.00m: Becoming occasionally mottled black.*	

T.C.R. (%)	S.C.R (%)	R.Q.D. (%)
100	80	0
73	67	0
36	36	0

Sample / In-Situ Test Information			Date - Depth (m) Casing (Water)
Type	Depth	Results / Remarks	
B1	0.20		
ES1	0.20		
B2	0.60		
ES2	0.90		
B3	1.00		
SPT(S)	1.20	N=23 (2,3/5,6,6,6)	- (Dry)
ES3	1.30		
D1	1.40		
SPT(S)	2.00	N=32 (3,5/7,8,9,8)	2.00 (2.00)
B4	2.00 - 3.00		
D2	2.00		
SPT(S)	3.00	N=45 (4,7/11,11,11,12)	3.00 (3.00)
B5	3.50 - 4.00		
SPT(S)	4.00	N=50 (3,5/7,11,15,17)	4.00 (3.00)
D3	4.50		
D4	4.90 - 5.00		
SPT(S)	5.00	N=9 (2,2/2,2,3,2)	5.00 (3.00)
B6	5.50 - 5.90		
D5	5.90 - 6.00		
U1	6.00 - 6.60		
U2	7.00 - 7.30		
HV01	7.40		
SPT(S)	7.50	N=20 (3,2/5,4,5,6)	6.00 (3.00)
D6	7.50		
HV02	8.00		
D7	8.60		
U3	8.70 - 9.00		
D8	9.00 - 9.10		
HV03	10.00		

Hole Diameter by Depth	
Depth Base (m)	Diameter (mm)
6.00	146
51.00	116

Drilling Flush Details		
Depth (m)	Type	Return (%)
6.60 - 7.50	WATER	100
7.50 - 9.00	WATER	90
9.00 - 10.50	WATER	60

Casing Diameter by Depth	
Depth Base (m)	Diameter (mm)
6.00	150

Water Strike						
Date	Strike Depth (m)	Depth Sealed (m)	Casing Depth (m)	Time Elapsed (mins)	Standing Level (m)	Remarks
17-05-2018	1.30					Seepage

Remarks:

1. Inspection pit GL to 1.20m.
2. Backfill: GL to 51.30m bentonite.
3. 1hr dayworks: Additional set up time 17/05/18.
4. 1hr dayworks: Pulled geobore and flushed more casing in 18/05/18.
5. 0.33hrs dayworks: Flush casing to 12.00m 21/05/18.
6. 0.67hrs dayworks: Flush geobore back to 12.00m 21/05/18.
7. 0.83hrs dayworks: Mixing mud into tank 21/05/18.
8. 1hr dayworks: Cleaning out tanks and mixing mud 22/05/18.

[redacted]

Drilled by: [redacted]
Logged by: JE
Checked by: JA
Fm-Hn-R-3070-Rev D

[redacted]

[redacted]

Rotary Borehole Record

BH03

Sheet 1 of 6

Project ID: GN21822	[redacted]	E: 572130.02	N: 316292.03
Location: King's Lynn Compressor Station		Date: 08/05/2018 - 16/05/2018	
	Plant used: Comacchio MC405	SPT Hammer Serial No: ADP04 (ER: 62%)	

Geology Description	Depth (m)
TOPSOIL (Dark brown slightly gravelly CLAY. Gravel is angular to subrounded fine to coarse flint).	0.20
MADE GROUND (Dark brown mottled brown slightly sandy gravelly CLAY. Gravel is angular to rounded fine to coarse flint. Occasional cobbles of rounded flint).	0.40
MADE GROUND (Dark brown mottled brown and black slightly clayey gravelly fine to coarse SAND. Gravel is angular to subrounded fine to medium flint. Slight hydrocarbon odour present).	0.60
Light brown mottled brown slightly clayey gravelly fine to coarse SAND. Gravel is angular to subrounded fine to medium flint.	1.20
Medium dense brown slightly gravelly fine to coarse SAND. Gravel is subrounded fine flint. *From 1.60m: Becoming silty.*	1.80
Grey very clayey fine to medium SAND.	2.50
Firm black mottled grey silty CLAY with occasional medium sand-sized fossil shell fragments. *From 2.70m to 3.20m: Drilling flush cuttings.* *From 3.40m: Becoming firm to stiff.* *From 3.50m: Fossil shell fragments becoming frequent and fine to medium gravel-sized.* *From 3.80m to 3.90m: Band of locally grey silty fine to medium sand.* *From 4.10m: Rare coarse gravel-sized fossilised wood fragments.* *From 4.20m: Rare grey silty fine to medium sand.* *From 6.00m: Becoming stiff and dark grey with occasional fine to medium gravel-sized fossil shell fragments.* *From 7.75m to 7.80m: Open fissuring approx. 3mm and medium spaced.* *From 8.00m: Becoming locally firm.* *From 8.50m: Fossil shell fragments becoming occasional.* *From 9.00m: Rare coarse gravel-sized whole fossil shells.*	

T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
40	40	40
89	89	81
100	100	100

Type	Depth	Results / Remarks	Date - Depth (m) Casing (Water)
B1	0.20 - 0.40		
ES1	0.30		
B2	0.50 - 0.60		
ES2	0.55		
B3	0.70 - 1.00		
ES3	0.80		
D1	1.00		
SPT(S)	1.20	N=18 (3,4/4,6,5,4)	- (1.00) 08/05/2018 - 1.20 - (1.20) 09/05/2018 - 1.20 - (1.00)
B4	2.00 - 2.50		
D2	2.00		
SPT(S)	2.70	N=11 (1,1/2,3,3,3)	2.70 (1.00)
D3	3.00		
D4	3.50		
D5	4.20		
U1	4.20 - 4.80		
D6	5.00		
B5	5.50 - 6.00		
SPT(S)	6.00	N=16 (2,2/3,4,4,5)	6.00 (0.00)
D7	6.00		09/05/2018 - 6.00 6.00 (1.00) 10/05/2018 - 6.00 6.00 (1.00)
U2	7.30 - 7.50		
SPT(S)	7.50	N=20 (2,2/4,5,5,6)	6.00 (1.00)
D8	7.80		
HV01	8.00		
HV02	8.80		
D9	9.00		
U3	9.00 - 9.30		
HV03	9.50		
D10	10.00		

Hole Diameter by Depth		Drilling Flush Details		
Depth Base (m)	Diameter (mm)	Depth (m)	Type	Return (%)
6.00	146	6.00 - 7.50	WATER	100
51.00	116	7.50 - 9.00	WATER	100
		9.00 - 10.50	WATER	100

Casing Diameter by Depth	
Depth Base (m)	Diameter (mm)
6.00	150

Water Strike						
Date	Strike Depth (m)	Depth Sealed (m)	Casing Depth (m)	Time Elapsed (mins)	Standing Level (m)	Remarks
08-05-2018	1.00					Seepage

Remarks:

1. Inspection pit GL to 1.20m. 2. Backfill: GL to 51.38m bentonite.
3. 2.33hrs standing time: Inductions 08/05/18. 4. 2hrs dayworks: Additional set up time 08/05/18.
5. 1hrs standing time: Waiting to start drilling 09/05/18. 6. 0.5hrs dayworks: Collecting water 09/05/18.
7. 0.75hrs dayworks: Collecting water 09/05/18. 8. 2hrs standing time: Waiting for kit 09/05/18.
9. 1hr standing time: Waiting to start drilling 10/05/18.
10. 2.5hrs dayworks: Change flush in tanks and borehole and clean out tanks 10/05/18.
11. 1hr dayworks: Pumping water out of skip and IBC 11/05/18. 12. 1.5hrs dayworks: Mixing mud into tank 14/05/18.
13. 1hr dayworks: Mixing mud into tank 14/05/18. 14. 0.5hrs standing time: Waiting for permit 15/05/18.
15. 1hr standing time: Waiting to replacing hydraulic hose 15/05/18. 16. 1hr dayworks: Travel to Pirtek to fix hose 16/05/18.
17. 1.5hrs dayworks: Travel back to site to fit new hose 16/05/18. 18. 1hr standing time: Waiting for installation details 16/05/18.
19. 1hr dayworks: Moving kit to next position 16/05/18.

[redacted]

Drilled by: [redacted] | Logged by: JE | Checked by: JA | Fm-Hs-R-3870-Rev D

APPENDIX B AS-BUILT ELEVATION TREND LINE ANALYSIS

B.1 2003 PIPING CONSTRUCTION AOD ELEVATION DATA

Figure B1 details some elevations of the piping the AOD survey undertaken in 2003. The construction survey was undertaken during installation of the pigging loop area and was limited to the newly installed pipework, including tie-in location, only. This data has been used to match some of the points where measurements have been taken in 2021.

No original construction elevation data from the scrubber area to the bi-directional area is available and assumptions have been made to determine the original elevation level.

B.2 2021 AOD SURVEY

An AOD survey has been performed to determine the current elevation levels of the piping. Figure B2 shows the locations where trial holes (identified with a TH prefix) and subsequent elevations have been taken.

B.3 ELEVATION COMPARISON

Only 8 trial hole point measurements (TH6, TH7, TH8, TH9, TH28, TH29, TH30 and TH36) can be compared to the 2003 construction AOD elevation data. The results of which are shown in Table B1.

It can be seen that several of the latest survey points show an increase in elevation, suggesting a potential calibration error of one or both of the surveys. As-built elevation data of the piping (Feeder 2) beyond TH-28 was not recorded and therefore it is assumed this location remains unchanged since the time of construction. Based on this assumption the 2003 survey points have been adjusted to account for the observed elevation discrepancy at TH-28. The adjusted elevation levels are provided in Table B1.

An additional point has also been considered in the latest survey, at TH-29, for which as-built elevation information is not available. The as-built elevation at this location has been estimated based on the assumption that the two lines: TH-28 to TH-36 and TH-30 to TH-29 were installed at the same gradient.

Within the bi-directional area a further twenty-six trial holes were undertaken at locations which would best help predict the as-built profile within this area, and produce the most conservative present profile; giving consideration to any potential ground movement.

B.4 PILED SUPPORTS

There is supporting evidence to suggest the scrubbers and all valves in the bi-directional area were installed on piled supports at the time of construction. Therefore, given the close proximity of: TH-17, TH-24 and TH-33 to piled areas, it is reasonable to assume the elevations at these locations have not changed since installation.

[redacted]

B.5 ESTIMATION OF AS-BUILT ELEVATIONS

To predict the as-built profile of the pipework where no data has been provided the elevation profile moving down a length of piping has been tabulated and the elevation determined using trend line analysis and comparing predicted and measured elevations. For the analysis, the length of piping has been identified as a ‘stream’ and the elevations are plotted from the scrubber area to the bi-directional area separately. Four streams have been identified and the stream identifiers are shown in Figure B2.

B.5.1 **Elevation Analysis of Stream_1**

Stream 1 considers elevations from TH07 – TH23 – TH24 – TH25 – TH13 –TH32 – TH33. The profile of Stream_1, based on the AOD measurements of the latest survey, is shown in Figure B3.

Also shown is the predicted as-built elevation based on the assumptions that no settlement has occurred at TH-24 and TH-33 since installation, and that the section of pipe between these two locations was installed at a constant gradient. The predicted settlement for each TH location on Stream_1 is shown in Table B2 and graphically in Figure B3.

Based on the above assumptions, it is shown that the predicted settlement at TH-07 is 126mm, which is in close agreement with the measured settlement of 137mm predicted by comparison of the two surveys.

B.5.2 **Elevation Analysis of Stream_2**

Stream 2 considers elevations from TH06 – TH21 – TH22 – TH12 – TH31 – TH33_2. The profile of Stream_2, based on the AOD measurements of the latest survey, is shown in Figure B4.

A trial hole was not undertaken in the piled region of the bi-directional area, however, since Stream_1 and Stream_2 were installed on the same piled foundation it is reasonable to assume that the location shown as TH-24* in Figure B2 is at the same elevation as TH24. By the same rationale an additional point, shown as TH-33_2 in Figure B2, is assumed to be at the same elevation as TH-33.

Based on the above reasonable assumptions the predicted as-built elevation of Stream_2 is shown in Figure B4. If a constant gradient is assumed between TH-06 and TH-33_2 the predicted settlement at TH-06 is approximately 63mm, as shown. This is significantly less than the settlement value of 187mm suggest by comparing the two AOD surveys.

The predicted settlement for each trial hole location on Stream_2 is shown in Table B2 and graphically in Figure B4.

[redacted]

B.5.3 **Elevation Analysis of Stream_3**

Stream 3 considers elevations from TH05 – TH19 – TH20 – TH11 – TH35 – TH33_3. The profile of Stream_3, based on the AOD measurements of the latest survey, is shown in Figure B5.

Similar to Stream_2, a trial hole was not undertaken in the piled region of the bi-directional area, however, since Stream_4 and Stream_3 were installed on the same piled foundation it is reasonable to assume that the location shown as TH-17* in Figure B2 is at the same elevation as TH17. By the same rationale an additional point, shown as TH-33_3 in Figure B2, is assumed to be at the same elevation as TH-33_4.

Based on the above reasonable assumptions the predicted as-built elevation of Stream_3 is shown in Figure B5. It is shown that all points follow the predicted trend very well.

The predicted settlement for each TH location on Stream_3 is shown in Table B1 and graphically in Figure B5.

B.5.4 **Elevation Analysis of Stream_4**

Stream 4 considers elevations from TH16 – TH17 – TH18 – TH10 – TH34 – TH33_4. The profile of Stream_4, based on the AOD measurements of the latest survey, is shown in Figure B6.

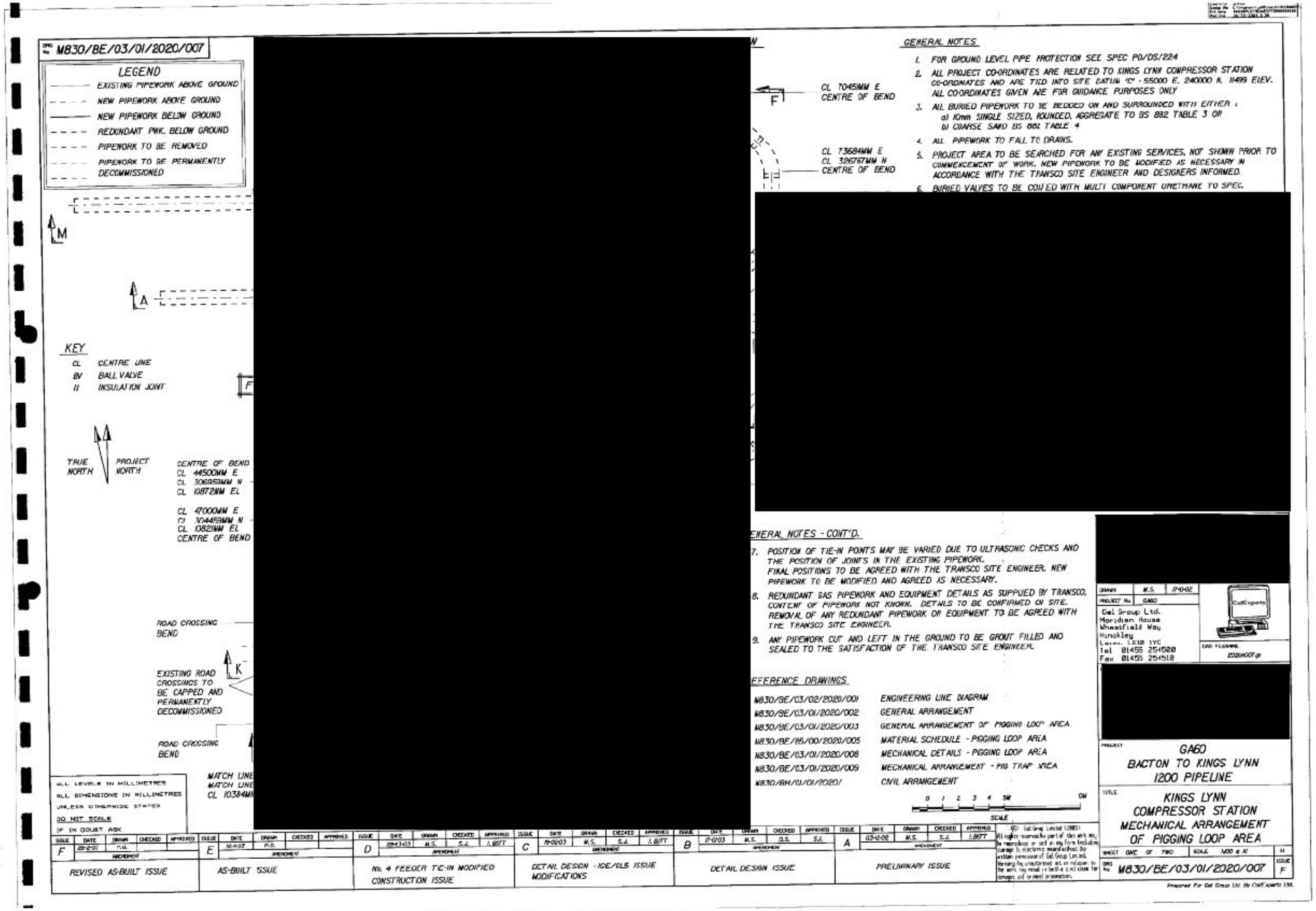
Also shown is the predicted as-built elevation based on the assumptions that no settlement has occurred at TH-17. A trial hole was not performed near the scrubbers for Stream_4, at the location identified as TH-33_4. Assuming Stream_4 was installed at a constant gradient, and assuming TH17 and TH24 are located in regions of zero settlement, the AOD at TH33_4 can be approximated by:

$$TH33\_4 = TH33-(TH24-TH17)$$

The predicted settlement for each trial hole location on Stream_4 is provided in Table B1 and shown graphically in Figure B6.

It is shown in Figure B6 that all points follow the predicted as-built trend very well.

[redacted]



[redacted]

[redacted]

[redacted]

[redacted]

ALL LEVELS IN MILLIMETRES
ALL DIMENSIONS IN MILLIMETRES
UNLESS OTHERWISE STATED
DO NOT SCALE
IF IN DOUBT ASK

GENERAL NOTES

1. FOR GROUND LEVEL PIPE PROTECTION SEE SPEC PD/DS/224
2. ALL PROJECT CO-ORDINATES ARE RELATED TO KINGS LYNN COMPRESSOR STATION CO-ORDINATES AND ARE TIED INTO SITE DATUM 'C' - 55000 E. 240000 N. 11499 ELEV. ALL CO-ORDINATES GIVEN ARE FOR GUIDANCE PURPOSES ONLY
3. ALL BURIED PIPEWORK TO BE BEDDED ON AND SURROUNDED WITH EITHER :
   a) 10mm SINGLE SIZED, ROUNDED, AGGREGATE TO BS 882 TABLE 3 OR
   b) COARSE SAND BS 882 TABLE 4
4. ALL PIPEWORK TO FALL TO DRAINS.
5. PROJECT AREA TO BE SEARCHED FOR ANY EXISTING SERVICES, NOT SHOWN PRIOR TO COMMENCEMENT OF WORK. NEW PIPEWORK TO BE MODIFIED AS NECESSARY IN ACCORDANCE WITH THE TRANSCO SITE ENGINEER AND DESIGNERS INFORMED.
6. BURIED VALVES TO BE COATED WITH MULTI COMPONENT URETHANE TO SPEC.

ENERAL NOTES - CONT'D.

7. POSITION OF TIE-IN POINTS MAY BE VARIED DUE TO ULTRASONIC CHECKS AND THE POSITION OF JOINTS IN THE EXISTING PIPEWORK. FINAL POSITIONS TO BE AGREED WITH THE TRANSCO SITE ENGINEER. NEW PIPEWORK TO BE MODIFIED AND AGREED AS NECESSARY.
8. REDUNDANT GAS PIPEWORK AND EQUIPMENT DETAILS AS SUPPLIED BY TRANSCO. CONTENT OF PIPEWORK NOT KNOWN. DETAILS TO BE CONFIRMED ON SITE. REMOVAL OF ANY REDUNDANT PIPEWORK OR EQUIPMENT TO BE AGREED WITH THE TRANSCO SITE ENGINEER.
9. ANY PIPEWORK CUT AND LEFT IN THE GROUND TO BE GROUT FILLED AND SEALED TO THE SATISFACTION OF THE TRANSCO SITE ENGINEER.

EFERENCE DRAWINGS

M830/BE/03/02/2020/001	ENGINEERING LINE DIAGRAM
M830/BE/03/01/2020/002	GENERAL ARRANGEMENT
M830/BE/03/01/2020/003	GENERAL ARRANGEMENT OF PIGGING LOOP AREA
M830/BE/85/00/2020/005	MATERIAL SCHEDULE - PIGGING LOOP AREA
M830/BE/03/01/2020/008	MECHANICAL DETAILS - PIGGING LOOP AREA
M830/BE/03/01/2020/009	MECHANICAL ARRANGEMENT - PIG TRAP AREA
M830/BH/01/01/2020/	CIVIL ARRANGEMENT

ISSUE	DATE	DRAWN	CHECKED	APPROVED	AMENDMENT
F	28-2-01	P.G.			REVISED AS-BUILT ISSUE
E	12-4-03	P.G.			AS-BUILT ISSUE
D	28-3-03	M.S.	S.J.	I.BOTT	No. 4 FEEDER TIE-IN MODIFIED CONSTRUCTION ISSUE
C	19-02-03	M.S.	S.J.	I.BOTT	DETAIL DESIGN - ICE/CLS ISSUE MODIFICATIONS
B	17-01-03	M.S.	D.S.	S.J.	DETAIL DESIGN ISSUE
A	03-12-02	M.S.	S.J.	I.BOTT	PRELIMINARY ISSUE

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DRAWN	M.S.	17-10-02
PROJECT No	GA60	

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CAD FILENAME 2020n007.gi

PROJECT
GA60
BACTON TO KINGS LYNN
1200 PIPELINE

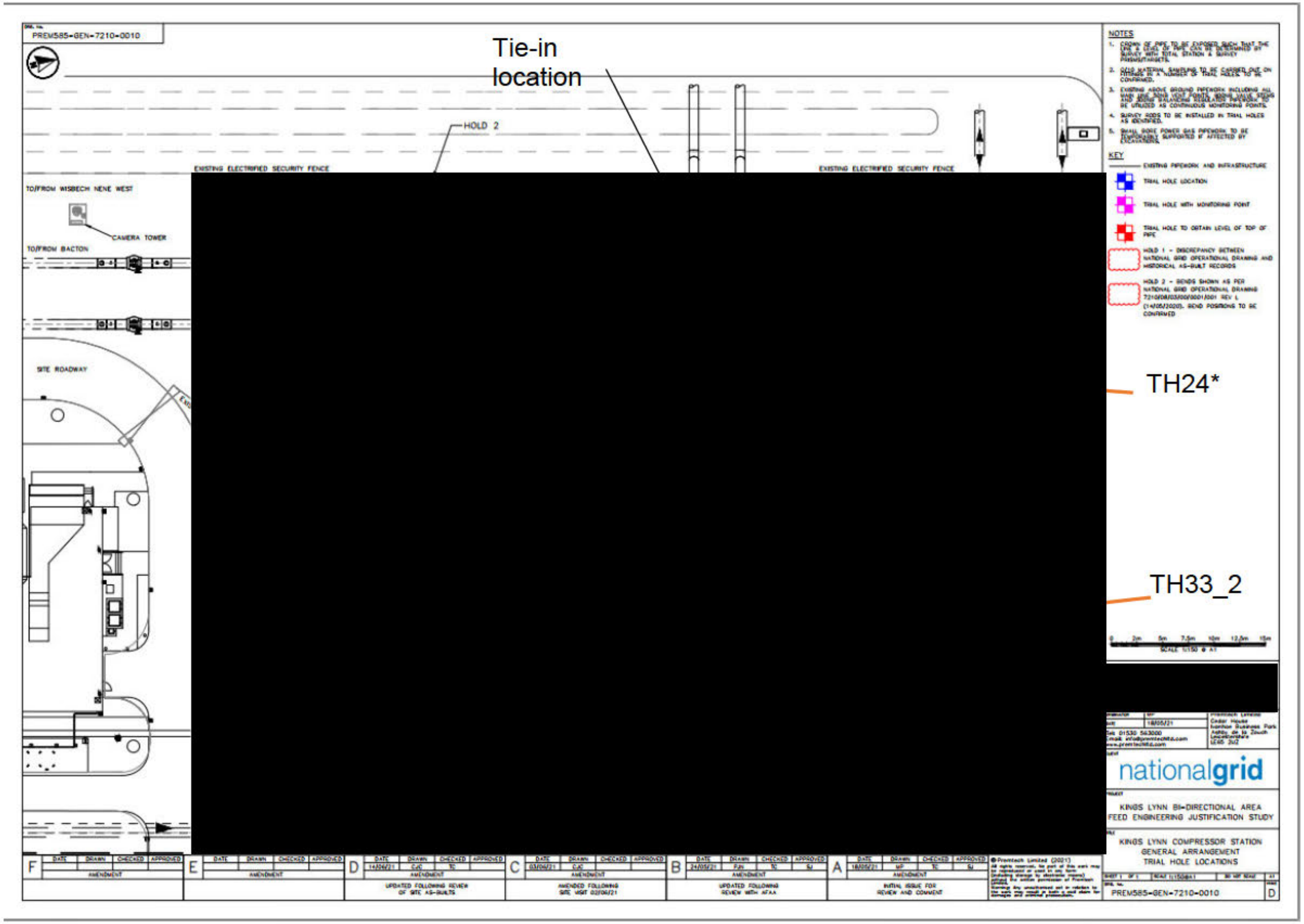
TITLE
KINGS LYNN
COMPRESSOR STATION
MECHANICAL ARRANGEMENT
OF PIGGING LOOP AREA

SHEET ONE OF TWO | SCALE 1:100 @ A1
DRG No M830/BE/03/01/2020/007 | ISSUE F

Prepared For Gel Group Ltd. By CadExperts Ltd.

Figure B1 – 2003 Piping Construction Elevation Data

[redacted]



[redacted]

[redacted]

Figure B2 – Trial Hole Locations

[redacted]

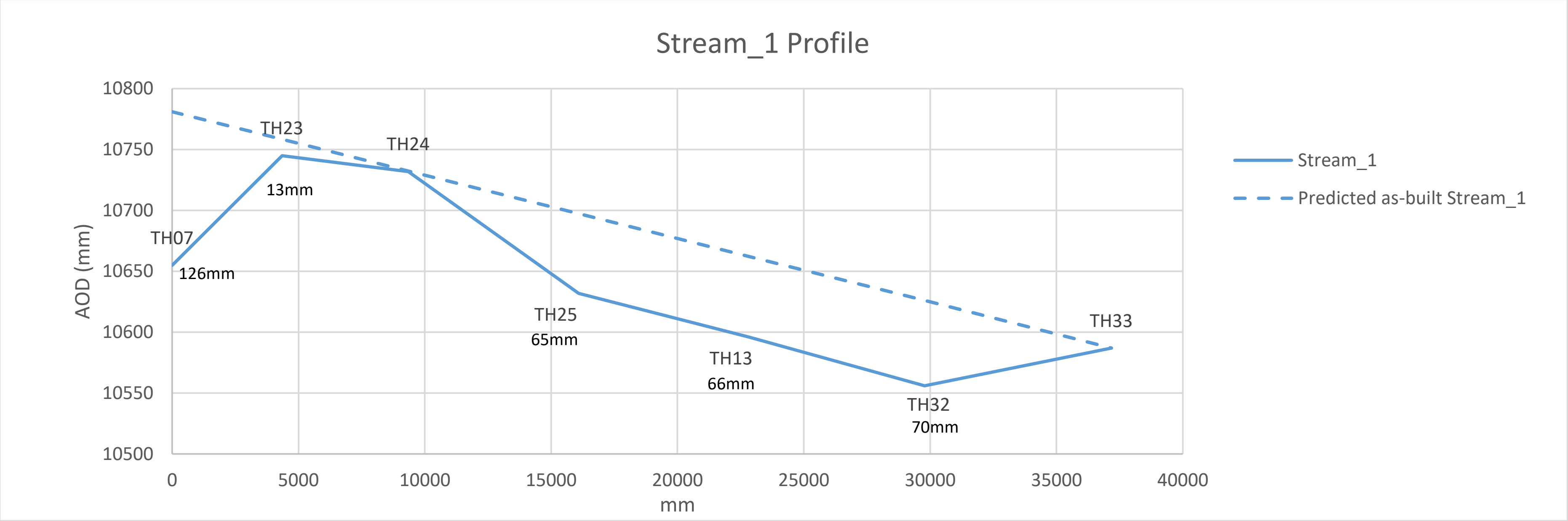


Figure B3 – Stream_1 Profile

[redacted]

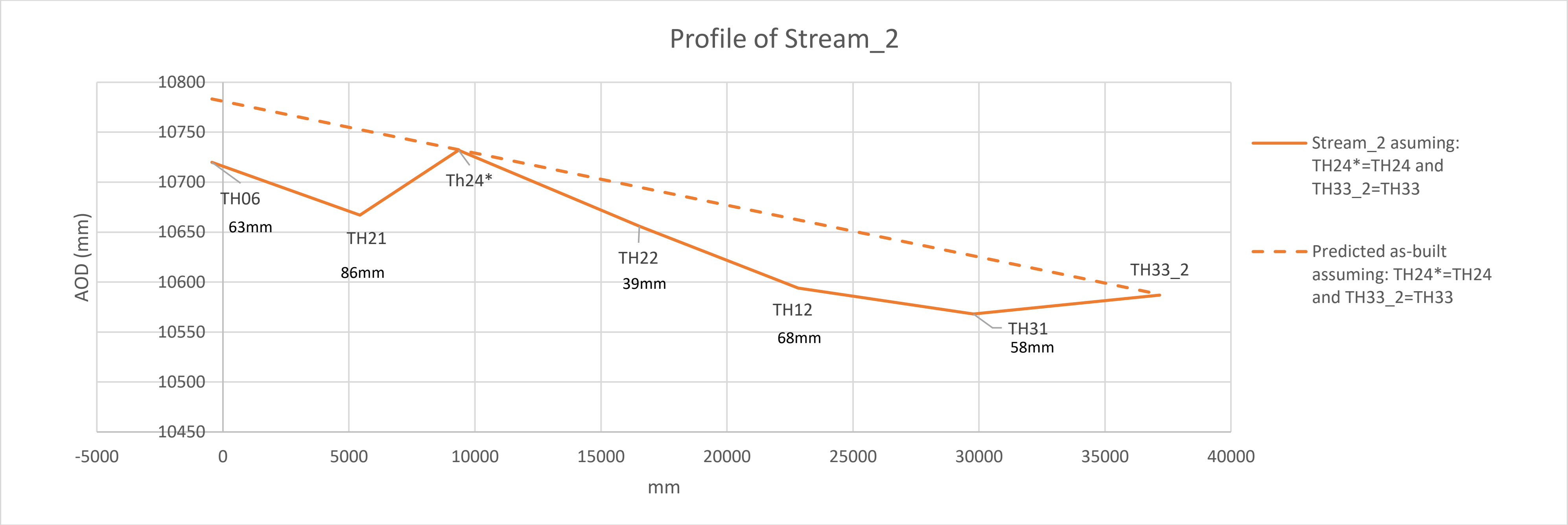


Figure B4 – Stream 2 Profile

[redacted]

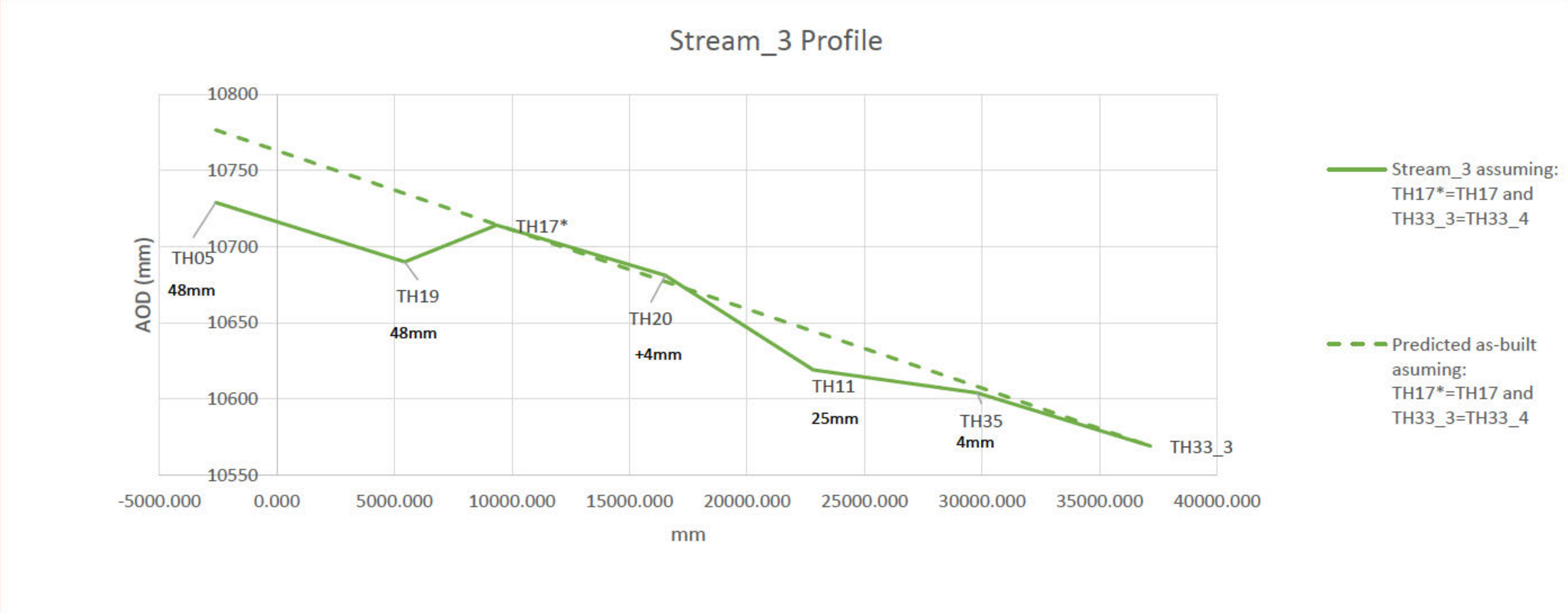
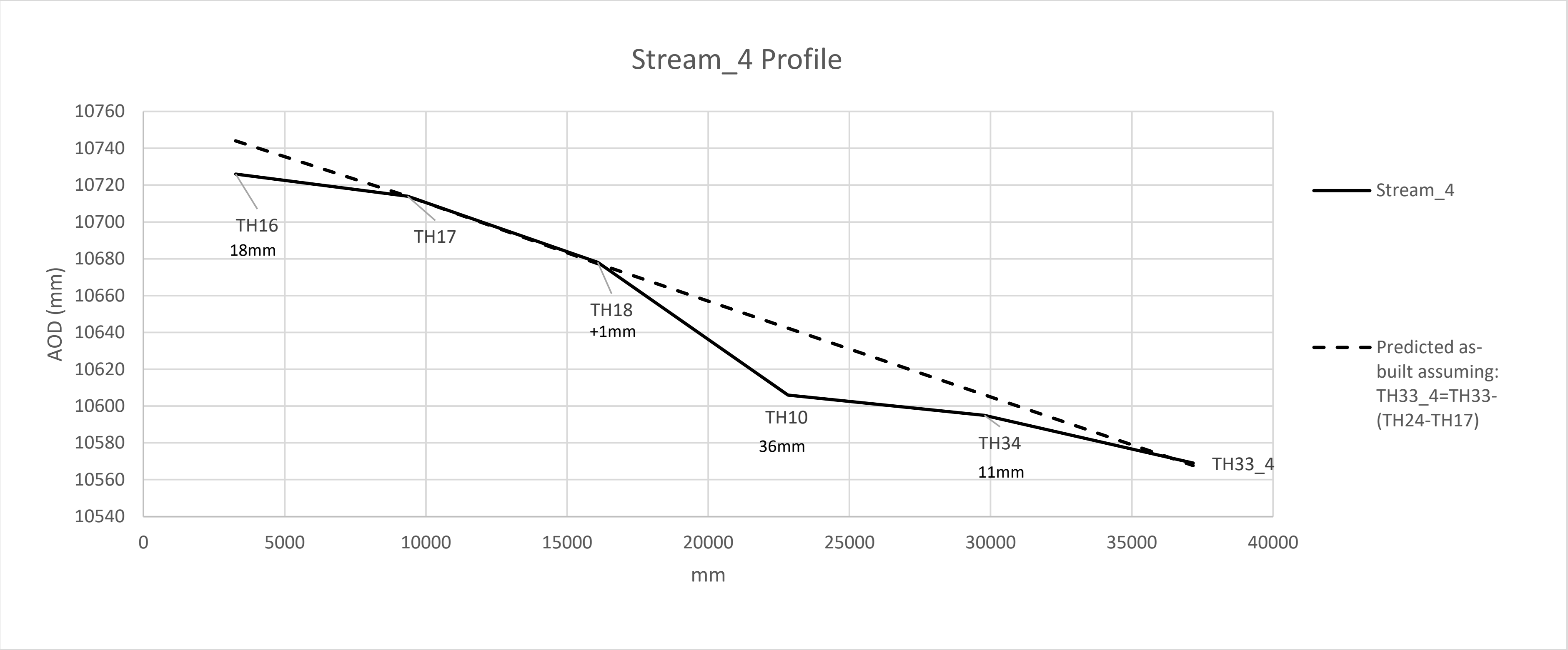


Figure B5 – Stream_3 Profile

[redacted]



<u>Figure B6 – Stream_4 Profile</u>

Trial Hole Number	Node Number	AOD (mm)			Settlement (mm)				
					AOD Comparison	Predicted			
		2003	2003 (Readings adjusted assuming no Settlement at TH-28)	2021		Stream_1	Stream_2	Stream_3	Stream_4
1	21530	-	-	10036	-	-	-	-	-
2	21280	-	-	9777	-	-	-	-	-
		-	-		-	-	-	-	-
		-	-		-	-	-	-	-
5	15945	-	-	10729	-	-	-	48	-
6	6115	10841.2	10907	10720	187	-	63	-	-
7	5815	10726.2	10792	10655	137	126	-	-	-
8	1550	11329.2	11395	11224	171	-	-	-	-
9	1380	11278.2	11344	11210	134	-	-	-	-
10	15307	-	-	10606	-	-	-	-	38
11	15795	-	-	10619	-	-	-	25	-
12	6265	-	-	10594	-	-	68	-	-
13	5615	-	-	10596	-	66	-	-	13
14	16305	-	-	10587	-	-	-	-	-
15	16125	-	-	10656	-	-	-	-	-
16	15134	-	-	10726	-	-	-	-	20 removed
17	15220	-	-	10714	-	-	-	0	0
18	15305	-	-	10678	-	-	-	-	1
19	15935	-	-	10690	-	-	-	48	-
20	15810	-	-	10681	-	-	-	+4	-
21	6124	-	-	10667	-	-	135	-	-
22	6250	-	-	10656	-	-	39	-	-
23	5744	-	-	10745	-	13	-	-	-
24	5670	-	-	10732	-	0	0	-	-
25	5617	-	-	10632	-	65	-	-	-
26	6695	-	-	10689	-	-	-	-	-
27	6775	-	-	10746	-	-	-	-	-
28	510	11393.2	11459	11459*	0	-	-	-	-
29	1220	11220.2	11286	11254*	32	-	-	-	-
30	380	11367.2	11433	11414*	19	-	-	-	-
31	6267	-	-	10568	-	-	58	-	-
32	5580	-	-	10556	-	70	-	-	-
33	5570	-	-	10587	-	0	-	-	0
33_2	6270								
33_3	15790								
33_4	15380								
34	15335	-	-	10595	-	-	-	-	-
35	15792	-	-	10604	-	-	-	4	-
36	1040	11280.2	11346	11348*	+2	-	-	-	-

Table B1 – AOD Survey Comparison and Predicted Settlement