Response to UKOPA Concerning their Issue paper on "Applying a Fixed "Ground Movement/Other" Rupture Failure Rate to all Pipelines" (UKOPA/16/007)

Below is HSE's response to UKOPA/16/007. I have tried to lay out the response in the same format as the original document so that the 2 can be read side by side. Unfortunately, this results in a slightly disjointed response in places but I will try to link common areas together as I proceed.

Opening comments in UKOPA/16/007

HSE has used a fixed value of "ground movement/other failures" because the operational data available to HSE does not have sufficient information to derive a wall thickness based failure rate with any degree of statistical certainty. HSE are aware that UKOPA developed a model to determine the failure rates for natural ground movement but this is only one element of the overall failure category. No such model exists for man-made ground movement or for events which are unforeseen or uncategorised (i.e. "other").

The "significant LUP zones" applied to thick walled pipelines is misleading because the zones that HSE has generated for the ~260 thick walled pipelines (equal to or greater than 11.91 mm) show that the Inner and Middle Zones (IZ and MZ) are almost always 3 m either side of the pipeline (i.e. the BPD). It is only the Outer Zone (OZ) that extends beyond the BPD although, for some pipelines, this value can be significant.

HSE LUP arrangements do not "sterilise" land. There is always some form of development that can take place ranging from "light industrial" (which is rarely advised against) to large, sensitive developments (which are usually the only ones advised against in the Outer Zone). I would direct you to HSE's website for further details on HSE's land use planning methodology http://www.hse.gov.uk/landuseplanning/methodology.pdf .

HSE has well defined categories for holes in pipelines following failure. Any hole with an equivalent diameter greater than 110 mm is considered to progress to full bore failure. The Palaceknowe incident produced a hole with an equivalent diameter of 130 mm which clearly places it in the rupture category. It is accepted that this is the only event within this particular category but this is a reflection of the limited number of events in the database. Over time, as the operational experience increases, the influence of this event will reduce (unless there is another rupture event linked to ground movement/other). As such, the Palaceknowe event represents an unexpected/unforeseen event triggered by ground movement (probably man-made) and HSE considers it appropriate to include it in its calculations.

HSE considered its method for the calculation of failure rates when determining updated values in 2014 and concluded that it remains fit for purpose when considering land use planning around major accident hazard pipelines. The UKOPA suggestion of a methodology based on wall thickness appears to HSE to be unrealistic given the unexpected/unforeseen nature of the events that would be categorised as "Other". There would be no data to support this methodology and any other method would have a high level of uncertainty associated with it.

It is worth pointing out that HSE has cooperated with UKOPA in developing parts of its methodology which relate to the use of slabbing to reduce third party interference failure rates and the reduction in failure rates with increased depth of cover.

UKOPA's Argument

1. UKOPA appear to define proximity pipe here as pipeline with a wall thickness greater than 11.91 but later (Section 3) defines it as pipelines with wall thickness equal to or greater than 19.1mm. Whichever is the case, the assertion that these pipelines have negligible risks of rupture appears unsupported. HSE agrees that the use of proximity pipe minimises the risks to adjacent populations but does not agree that the use of a fixed failure rate either removes this option or imposes large LUP distances. As explained above, the IZ and MZ for these pipelines is 3m (i.e. BPD). It is only the OZ that is greater than 3m (though not always). It should also be pointed out that proximity pipe is used in only a minority of pipelines.
2. HSE does not dispute the fact that the LUP zones for some suburban pipelines increased when HSE moved from a BPD based LUP system to a risk based system (at British Gas's request). However, at the same time, a significant number of rural pipelines were assigned reduced LUP zones. The recalculation of the failure rates in 2014 reduced the LUP zones for a significant number of both suburban and rural pipelines.
3. It is our understanding that the distances in TD/1 are used for routing purposes and would not exclude the presence of occupied buildings within the BPD if the density was sufficiently low. The fact that the IZ and MZ of the pipelines in question are equal to the BPD means that only large, sensitive developments would be advised against within the LUP zones. This type of development is less likely than housing development (for example). Consequently, for the majority of cases, the HSE LUP distances do not conflict with the TD/1 proximity distances.
4. The failure at Palaceknowe represents an unexpected/unforeseen event triggered by ground movement (probably man-made) and HSE considers it appropriate to include it in its calculations.
5. Firstly, HSE has well defined and documented categories for holes in pipelines following failure. Any hole with an equivalent diameter greater than 110mm is considered to progress to full bore failure. The Palaceknowe incident produced a hole with an area of 13273mm^2 which is equivalent to a diameter of 130mm which clearly places it in the rupture category. Secondly, we have made it clear that HSE are not taking the last 20 years of data only, but are using a fixed start date and adding extra years in. This is due to the lack of data in more recent years. If HSE only used the last 20 years of data then there will be less statistical certainty over the results.
6. The UKOPA methodology determines failure rates for natural ground movement and HSE has previously raised no objections to this. However, pipelines can run across large stretches of land which may have varying degrees of ground movement associated with them. HSE initially consider the whole length of pipeline (until one or more of its parameters change e.g. wall thickness, depth of cover etc.). The use of the ground movement work would imply the need to make all the pipeline zones location specific from the outset.

Secondly, the failure at Palaceknowe could be categorised as having been caused by man-made ground movement (settling of previously disturbed ground) or as an unexpected/unforeseen event. Neither of these is covered by the UKOPA methodology but are part of the overall "Ground Movement/Other" failure mode. There may not have been any "Other" issues in the database but by continuing to include it HSE allows for the fact that there may be other types of incident that could occur that no one has anticipated.

1. UK Pipeline Standards

HSE has long accepted the use of TD/1 standards for the design and routing of pipelines and HSE does not wish to undermine its use. Indeed HSE relies on the TD/1 design framework for discussions with developers where improvements to the pipeline appear to be an option for managing major accident risks whilst allowing some development to proceed within HSE's consultation distance.

The design standard was written to try to ensure that the likelihood of ruptures of suburban pipelines is negligible but it can be argued that this means that the likelihood is not zero. The meaning of "negligible" is open to debate although one interpretation is that the risks have been reduced so that they are as low as reasonably practicable but have not been eliminated completely. The risks are "residual risks" and it is these residual risks that the land use planning process seeks to address.

The use of proximity distances in TD/1 is described in Section 6 which relates to pipeline design. It can be argued that the proximity distances are designed for routing purposes rather than land use planning (a fact that would have led, in part, to the development of TD/2). When considering population estimation based on occupied buildings, Section 6.7.2.1 of Edition 5 directs the designer to consider a strip of land which is 8 BPD wide, with the BPD in this case being based on a Type R pipeline as defined in Figure 5. For the pipeline described in Table 1 of UKOPA/16/007 (457mm diameter (Line F) and 70 bar), use of Figure 5 would generate a BPD of approximately 40m. The search area would be ~160m either side of the pipeline which is greater than any of the OZs reported in UKOPA/16/007 Table 1. This suggests that the pipeline designer needs to consider populations well beyond the final BPD. It would be inconsistent to not consider such populations to some degree once the pipeline is operational.

Bullet point ii appears to consider the full bore rupture of a pipeline as the basis for the proximity distances for Line A. It is difficult to see how the thermal consequences of the failure of a 168mm pipeline relate to the failure of suburban pipelines with diameters up to 457mm.

Bullet points iii and iv outline thermal hazard distances which form the basis of the proximity distances for Line B. The assumption is that the likelihood of a rupture is negligible. However, even if that were the case, the largest hole used by HSE is 110 mm which suggests that the proximity distances may be non-conservative from HSE's perspective.

Bullet point v assumes that either the pipeline does not fail at all or the consequences are always less than 3 m.

Figure 1 relates to pipeline design. HSE uses this figure to set a LUP IZ as a minimum where the risks from the pipeline are insufficient to set a risk based IZ (the norm for natural gas pipelines). In this way, HSE tries to maintain some link between the LUP zones and the standards used to design the pipeline by minimising the amount of development within the BPD (only the lowest sensitivity development is "not advised against" in the IZ). HSE could have taken the view that the risks were sufficiently low that an IZ (and in some cases an MZ and OZ) was not required. This may have led HSE to not advise against sensitive development right up to the pipeline. Clearly, HSE did not take this line and sees the benefit of appropriate separation between pipelines and development.

2. HSE Calculation of LUP Distances

HSE was asked by the pipeline industry (principally BG) to develop a risk based methodology for determining LUP zones around pipelines to replace its previous method which was based on multiples of the BPD.

UKOPA state that the industry were concerned that the "natural" failure mode contributed 50% to the failure rate for suburban pipelines. This is not in dispute. However, HSE has considered the issue a number of times and has consistently concluded that the method and data used to determine the failure rates is fit for purpose.

UKOPA have presented a table of LUP distances which appears (when read with the text above it) to contain a number of errors.

The previous BPD based methodology used multipliers of the BPD to set LUP distances. For pipelines with a BPD of 3 m, the IZ and MZ would be 3 m and the OZ would be 6 m (i.e. 2x BPD) suggesting the "Outer" column shaded blue does not reflect that original methodology.

The third example on the Table 1 of UKOPA/16/007 (11.91 mm wall thickness and 70 bar pressure) would have a design factor greater than 0.3. Consequently, the correct BPD should be taken from Figure 5 (Line F) of TD/1 not Figure 6 (Line C). This gives a BPD of approximately 40m. Under the previous methodology this would have LUP distances of IZ = 80 m (2x BPD), MZ = 120 m (3x BPD) and OZ = 160 m (4xBPD). These are greater than the values given in Table 1.

The LUP distances shaded pink appear to be based on data not currently used by HSE. LUP distances determined using HSE current methodology and data are shown in the table below.

Table A: LUP zone sizes (m) from MISHAP12 V1.12

Diameter	*Wall thickness (mm)*	*Pressure (barg)*	*Inner zone*	*Middle zone*	*Outer zone*
457 mm X52	11.91	19	3	3	3
457 mm X52	11.91	38	3	3	39
457 mm X52	11.91	70	40	40	100
457 mm X52	15.88	19	3	3	3
457 mm X52	15.88	38	3	3	3
457 mm X52	15.88	70	3	3	40
457 mm X52	19.05	19	3	3	3
457 mm X52	19.05	38	3	3	3
457 mm X52	19.05	70	3	3	6

The results for the third case now reflect the rural design of this pipeline. The calculated LUP OZs are equal to, or significantly smaller than, the pink shaded results provided by UKOPA in Table 1 of UKOPA/16/007.

It can be seen that, for a given pressure, the LUP OZ reduces as the wall thickness increases. For example, for 70 bar, the OZ reduces from 100 m to 6 m as the wall thickness is increased from 11.91 mm to 19.05 mm. This result is also evident in the pink shaded results provided by UKOPA and negates UKOPA's claim that HSE's fixed failure rate discourages the use of thicker walled pipelines as a risk reduction option.

UKOPA reiterates their description of the work carried out on natural ground movement. HSE did not disagree with this work but point out that it is only one element of the "ground movement/other" failure category. The methodology does not address the man-made ground movement or unexpected/unforeseen elements. HSE has reviewed its own methodology and believes that it remains fit for purpose.

At a later date, UKOPA provided HSE with a spreadsheet containing pipeline details described as "625 km of thick wall pipe" (email from Steve Potts 28/07/2016). This information did not include the grade of steel used so it was not possible to carry out assessment on these pipelines to determine how many had OZs greater than 3 m. The information also did not include a PSR reference number so it was difficult to cross reference to the notification data that HSE already holds. A sampling of the information suggests that there may be a discrepancy between this data and HSE's.

3. TD/1 Use of Proximity Pipe

HSE accepts that the use of proximity pipe (here defined as greater or equal to a wall thickness of 19.1 mm) reduces the BPD to 3 m and results in significantly lower risks to the public than pipe with lesser wall thickness. For this reason, HSE has had occasion to suggest that pipelines are relayed with proximity pipe when it carries out site specific assessments following an "advise against" decision on a development.

Our records suggest that only 7 natural gas pipelines with a suburban design and wall thicknesses of 19.05 mm or greater have been notified to HSE. All these pipelines have IZ and MZs of 3 m which indicates that the issue is of a very limited nature. For these pipelines, only large, sensitive developments would be advised against between the LUP IZ/MZ and the OZ.

UKOPA appear to suggest that it would consider a hospital or large school to be acceptable 4 m from a 1219 mm pipeline operating at 85 bar (PSR number 2756, “Bathgate to Newarthill”) simply because it was beyond the BPD.

4. HSE Definition of “Ground Movement/Other”

HSE’s comments on this section are covered earlier.

5. Palaceknowe Consequences

HSE’s assumption is that any failure with an equivalent diameter greater than 110 mm is considered to be a rupture (or progress to full rupture). The Palaceknowe incident had a failure with an equivalent diameter of 130 mm. Additional ground movement may have caused the failure to be larger, up to full rupture.

The Palaceknowe failure involved a circumferential slot running for approximately 2/3 of the pipelines circumference. It is foreseeable that, had the ground movement been slightly greater, the failure may have extended to a full circumferential failure. It may be seen as fortuitous that the ground only moved to the extent it did. On a precautionary basis and for the purposes of land use planning, HSE is justified in categorising this failure as a rupture and retaining it in our data for the calculation of failure rates. This would reflect the fact that there may be other points on the network that may be subject to unexpected/unforeseen ground movement and subsequent failure.

The data presented by UKOPA at Table 2 is not relevant since HSE’s methodology assumes the failure progresses to full rupture.

HSE’s methodology for determining failure rates was reviewed in 2012 and, at that time, it was hoped that the data could be based on the most recent 20 years. However, when the data was re-examined in 2014 it was discovered that there would be insufficient information to enable a statistically valid calculation to take place. For this reason a fixed starting point was used and failure data from that time used to calculate the failure rates. The Palaceknowe incident occurred after that point so it is included in the data. Its influence will diminish with time as more operational experience is generated.

Had a “rolling 20 years” been used, as indicated above, the significantly reduced number of incidents in the database means the results would increasingly lose statistical validity and HSE would have had a low confidence in the failure rates generated. On that basis, using a precautionary approach, HSE may have needed to change its LUP methodology to one based on consequence rather than risk.

6. Ground Movement and Other

6.1 Natural Landsliding

HSE did not disagree with the work carried out by UKOPA. However, as stated earlier, this only addresses 1 element of the failure mode. In addition, use of this methodology may require HSE to generate LUP distances which vary along a pipeline as it moves between areas with varying risks of landslide. This would be impractical at the current time.

UKOPA have used data from EGIG to illustrate the influence of areas of Europe with higher risks of landslide. There are 3 comments to be made on this:

1. The EGIG data also includes areas which may have much lower risks of landslide (e.g. Netherlands?) so the influence of the high risk areas may not be as pronounced as claimed;
2. EGIG data does not appear to break down events by wall thickness which seems to be what UKOPA are asking for; and
3. HSE did not use EGIG data for "ground movement/other" failures; it uses UKOPA data which is UK specific. Had it used EGIG, the failure rate would have been approximately 5x larger (see comparison of Tables 70 and 69 of RR1035 http://www.hse.gov.uk/research/rrpdf/rr1035.pdf).

6.2 Man-made Ground Movement

UKOPA have used "Other/Unknown" failures from the EGIG data. It could be argued that mining and (to some extent) flooding (where this is caused by the actions of man) should also be included.

By their nature these types of event are (thankfully) rare in the UK. It is not surprising, therefore, that a rupture event has not been recorded in the database. However, to imply that, because it hasn't happened yet, it will never happen would seem to be overly optimistic.

The reference to the methodology in TD/2 and BS PD 8010-3 is unclear since those documents do not appear to contain a methodology for determining failure rates for man-made ground movement (see Section A4.5.2 of TD/2 and Section B.8.3 of PD 8010-3).

6.3 Other

HSE rejects the statement that "there is no logical justification for the application of fixed "Other" rupture failure frequency". The unexpected/unforeseen nature of the events (including that at Palaceknowe) that would be categorised as "Other" indicates that they should remain within the overall methodology.

HSE Conclusions

HSE has a well published methodology for determining the failure rates for major accident hazard pipelines. This methodology includes rupture failure rates for "ground movement/other" causes which are based on the Palaceknowe incident.

HSE reiterates that the unexpected/unforeseen nature of the events (including that at Palaceknowe) that would be categorised as "Other" indicates that they should remain within the overall methodology. This policy has been the subject of review and HSE concluded that it remains fit for purpose for land use planning.

The failure rates are used in HSE's LUP methodology to set LUP distances. For pipelines with a suburban design and wall thicknesses greater than or equal to 11.91 mm, the LUP distances include IZ and MZs which are almost always 3 m (i.e. the BPD) either side of the pipeline. Only large, sensitive development would be advised against beyond the BPD (up to the OZ) and this type of development is relatively uncommon.

HSE rejects the UKOPA position that the use of a fixed failure rate invalidates the use of proximity pipe as a risk reduction measure. UKOPA's own figures (pink shaded data in UKOPA/16/007 Table 1) shows that there is a significant reduction in LUP distances as pipe wall thickness is increased. This is confirmed (and strengthened) by HSE's own calculations provided in Table A earlier and in numerous other communications with pipeline operators and developers.

HSE's position was communicated to consultants in relation to a specific development in April 2016. I attach an edited version of HSE's response at that time at Appendix 1. Paragraphs 10 to 19 are probably most relevant and illustrate that HSE has held a consistent position on this issue.

Dr. Peter J Harper
H.M. Principal Specialist Inspector
5th May 2017

Appendix 1: HSE Response Respect to a Development Adjacent to a Natural Gas Pipeline

Dear ,

1. I write in response to your enquiries about the failure rates for the XXXXXXX pipeline "XXXXXXXXXXXX". I understand that this comes about because of a proposed development of a care home in the vicinity of the pipeline.
2. HSE understands that you are questioning the validity of the failure rates used to determine the risks at the proposed. Specifically, you believe that the inclusion of the Palaceknowe incident in the failure event data means that the "Ground movement and other" element of the failure rate is greater than it should be. The resulting risk values generate a HSE response of "advise against" the development whereas you believe this should be a "don't advise against"
3. Our response to the issue falls into a number of areas.

Land Use Planning

4. Land use planning (LUP) around major hazards is a requirement of UK planning legislation. HSE adopts a "cautious best estimate" approach to LUP whereby some degree of caution is built in to our methods and policies without being overly conservative.
5. HSE's risk based methodologies are made up of a combination of consequence models, failure rates and criteria against which the risks can be compared. Often, perceived conservatisms in one part of the methodology are balanced by non-conservatisms in other parts. Care is needed when considering only one part of that methodology as is the case here.
6. HSE's policy is that suitable separation should be maintained between major hazards and proposed developments. This is particularly the case where the development is sensitive. In the case of a care home this sensitivity arises from the increased vulnerability either due to their susceptibility to harm or the problems in evacuation during an emergency. In these circumstances, it is right that the caution in HSE's approach is not eroded.
7. From the information provided by the developer, the care home appears to be of a scale which would categorise it as a Sensitivity Level 4 development under HSE's LUP methodology. This is the highest level of sensitivity and requires the greatest separation from the major hazard. HSE would advise against such a development anywhere within the consultation zone of a major hazard site or pipeline.
8. It is not clear why you are supporting a development for a vulnerable population so close to a major hazard. Failure rates are only one aspect of HSE's LUP methodology.
9. It should be noted that there is a similar development further along the same pipeline which also received an "advise against" response from HSE. In this case, the developer has committed to changing the layout of the development to improve public safety rather than challenging the basis of HSE's advice.

Palaceknowe Incident

10. The failure rates calculated by HSE are based on data supplied by the pipelines industry. The original intention was that these failure rates should be based on the most recent 20 years of data.
11. The set of failures included the incident at Palaceknowe which involved the failure of a forged end seal (FES) under differential load due to ground movement. UKOPA have made representations that this event could not be repeated and have provided some documentary evidence to suggest that HSE have agreed this position on the basis of these particular circumstances and this method of line construction.

12. HSE may accept that the work done to determine the suitability of FESs for operation at 85 bar and that those that remain (4 FESs on No. 11 and 12 Feeders) are unlikely to fail due to ground movement.
13. However, it is likely that there are other points on the network where pipelines are fixed/anchored in some way so that the line could be subject to differential forces caused by ground movement. The Palaceknowe incident could be seen as representative of other "designed" situations where differential settling could lead to line failures.

Failure rates

14. The most recent update to the failure rates is recorded in a Health and Safety Laboratory (HSL) report numbered MSU/2012/38/R. It was recognised that the move to a 20 year rolling dataset would involve a much reduced set of failures and would produce failure rates that may be statistically invalid. For this reason, the start point for the failure rate calculation was fixed at a given year.
15. This update to the failure rates was such that the Middle Zone for pipeline XXXXX reduced to such an extent that it was close to the BPD distance. Overall, the LUP zones for XXXXX changed from 8, 80, 125m to 8, 9, 120m.
16. The use of single failures to inform failure frequencies leads to a high level of statistical uncertainty around final calculated values i.e. the true value may be significantly higher or lower than the calculated value. The removal of the Palaceknowe incident from the data set would further reduce the statistical validity of the failure rates and thereby reduce the confidence in the calculated risks.
17. This reduced confidence in the calculated risks might require HSE to fall back on the "precautionary principle" whereby more weight is given to the consequences of an event than the frequency. The outcome of this would be a move back to a consequence based LUP methodology.
18. Over time, assuming no further failures occur, the significance of the Palaceknowe event will diminish as the pipeline experience increases (i.e. increase in the pipeline length x years of operation value). It does not mean that the failure mechanism has disappeared.
19. The issue has been discussed within our peer review panel. There was unilateral agreement that the failure rates that we currently use are appropriate for land use planning purposes in that they contain an element of conservatism that satisfies the "cautious best estimate" principle.

Conclusion

20. Overall, whilst HSE may accept that the failure of forged end seals may not be repeated in the future, this may not be the only cause of failure due to differential settling. HSE is strongly of the opinion that the data set of failures should not be invalidated by the removal of the Palaceknowe incident. HSE believes that the current pipeline failure rates satisfy the "cautious best estimate" principle and are fit for purpose for land use planning.