Commentary Report

Victorian Networks Urban Encroachment Business Case Review

APA Group

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APA Project No: Business Case Number 230

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EXECUTIVE SUMMARY

GPA Engineering has been engaged by APA Group (APA) to prepare this Commentary Report on its Business Case Number 230 document (BCN230). This Commentary Report is intended to provide an independent opinion regarding:

1. Whether the statements regarding the Australian Standard for high pressure gas pipelines (AS2885) requirements are correct; and,
2. Whether the approach adopted by APA to demonstrate that the proposed remedial actions meet ALARP is consistent with pipeline industry practice which has been adopted since the most recent revision of AS2885.1 was published in 2012, and which is proposed to be incorporated into the next revision of AS2885.

This Commentary Report does not address the process by which APA risk assessments have been conducted or their conclusions.

This Commentary Report is based on the BCN230 revision provided to GPA under cover of the APA email sent 16 December 2016.

AS2885.1 REQUIREMENTS

GPA Engineering has reviewed BCN230 to determine whether the statements therein regarding the requirements of AS2885.1-2012 are correct. There are three relevant topics addressed by BCN230:

1) AS2885.1-2012 Section 4.7 *Special Provisions for High Consequence Areas* makes requirements where there is a change of land use around high pressure pipelines from rural to urban land use. This includes the requirement to demonstrate that risks associated with pipeline rupture are ALARP. In GPA's opinion the explanation provided in BCN230 accurately reflects the content and intent of the AS2885.1-2012 provisions for High Consequence Areas and is sufficient for the purposes of supporting the case as presented.
2) AS2885.1-2012 Appendix F *Qualitative Risk Assessment* provides the risk matrix which is to be used for pipeline risk assessment, and also specifies the actions required for the risk rank determined by risk assessment, and in particular, "Intermediate" risks. In GPA's opinion the explanation provided in BCN230 accurately reflects the content and intent of AS2885.1-2012 provisions for "Intermediate risks" and is sufficient for the purposes of supporting the case as presented. While the scope of this Commentary Report does not include the process by which APA risk assessments have been conducted or their conclusions, it is noted that:
    - Where the consequence assessment concludes that a pipeline failure results in a "Catastrophic" outcome (i.e. *inter alia* multiple fatalities), the risk matrix in AS2885.1-2012 does not permit a risk ranking lower than Intermediate, and therefore ALARP must be demonstrated.
    - For the pipelines considered by BCN230, if an ignited pipeline rupture occurs, people within a few hundred metres of the gas release will be subject to heat radiation which is sufficient to cause fatal or life-threatening injuries. In urban areas it is reasonable to conclude that a "Catastrophic" outcome will occur.
3) Based on the tables which show the susceptibility of each pipeline to penetration and the predicted failure mode for the pipelines, and APA's assessment of the credible threats, in GPA's opinion it is reasonable to conclude that pipeline rupture is a credible failure mode for each pipeline.

ALARP ASSESSMENT

GPA Engineering has reviewed BCN230 to determine whether the approach adopted by APA to demonstrate that the proposed remedial actions meet ALARP is consistent with pipeline industry practice which has been adopted since the most recent revision of AS2885.1 was published in 2012.

The Australian pipeline industry has recently developed guidelines for conducting ALARP assessments for high pressure pipelines based on current national and international practice, including obligations under modern Australian Work Health and Safety legislation and other similar legislation. This is documented in the EPCRC *Final Report, Project RP4.21A: Understanding ALARP*, Rev 0, August 2015. It is proposed that these guidelines will be incorporated into the next revision of AS2885.

A key point is that an ALARP assessment cannot be made on the basis of a single metric (which is likely to be subject to considerable uncertainty) but is rather a judgement call based on a broad range of factors. BCN230 documents a number of factors which APA has taken into account in order to form the judgement that slabbing of the pipelines under consideration is reasonably practicable. In forming this judgement, APA has taken into account the alternatives listed in AS2885.1 Section 4.7.4. APA has also formed the judgment that the “Do nothing” option is unacceptable.

It is GPA’s opinion that APA has broadly followed this guidance material for ALARP assessment (i.e. APA’s approach is consistent with current best practice for ALARP assessment in the Australian pipeline industry).

CONTENTS

1 INTRODUCTION

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This Commentary Report does not address the process by which APA risk assessments have been conducted or their conclusions.

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2 REFERENCES

2.1 DOCUMENTS

DOC. No.	REV	DESCRIPTION
Business Case Number 230		APA Group "Business Case – Capital Expenditure, Encroachment High Consequence" (provided to GPA by e-mail dated 16-12-2016)
n/a		EPCRC *Final Report, Project RP4.21A: Understanding ALARP*, Rev 0, August 2015
n/a		HAYES, J. & MCDONOUGH, R. 2016. *Reasonably Practicable – A Help or a Distraction In Ensuring Public Safety?* APGA Conference, Perth, October 2016

2.2 STANDARDS

REFERENCE	DOCUMENT TITLE
AS 2885.1-2012	Pipelines – Gas and liquid petroleum – Part 1: Design and construction
AS 2885.3-2012	Pipelines – Gas and liquid petroleum – Part 3: Operations and Maintenance

2.3 ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ALARP	As Low As Reasonably Practicable
APGA	Australian Pipeline and Gas Association
BCN	Business Gas Number
CDL	Critical Defect Length

ABBREVIATION	DESCRIPTION
EPCRC	Energy Pipelines Cooperative Research Centre
MAOP	Maximum Allowable Operating Pressure
VTS	Victorian Transmission System

3 AS2885 REQUIREMENTS

The Australian Standard which applies to the Victorian Transmission System is AS2885 *Pipelines – Gas and liquid petroleum*. In particular, the provisions of AS2885.1-2012 - *Pipelines – Gas and liquid petroleum – Part 1: Design and construction* apply where changes of land use around existing pipelines occur.

APA Business Case Number 230 (BCN230) references the requirements of AS2885.1-2012. This section provides GPA's opinion and reasoning as to whether the statements regarding the Australian Standard for high pressure gas pipelines (AS2885) requirements are correct.

3.1 HIGH CONSEQUENCE AREAS AND CHANGE OF LAND USE

The APA BCN230 discussion is primarily based around the provisions of AS2885.1-2012, Section 4.7 *Special Provisions for High Consequence Areas*.

BCN230, Section 3.1 provides the context and implications of these requirements.

Firstly, the requirements for protection measures to be applied to external interference (mechanical damage) threats are briefly explained:

- Protection requirements are based on the location classification of a pipeline, which in turn is determined by the land use within the "measurement length".
- The "measurement length" is calculated on the basis of the maximum allowable operating pressure and diameter of the pipeline.

BCN230 then quotes the relevant location class definitions from AS2885.1.

Following this, BCN230 summarises the requirements for designing a new pipeline in High Consequence Areas. "High Consequence Area" is defined in AS2885.1 as "A location where pipeline failure can be expected to result in multiple fatalities or significant environmental damage".

Section 4.7.2 *No Rupture* explicitly nominates the location classes for which the "no rupture" requirement must be achieved. The "no rupture" requirement is specifically included in AS2885 as rupture (which is a failure of the pipe such that the hole in the pipe is equivalent to the diameter of the pipe) results in a maximum energy release, which if it ignites is likely to result in a high number of casualties where people are present. BCN230 quotes one of the two ways by which this can be achieved, which is that the critical defect length of the pipeline is specified so that it exceeds 150% of the maximum axial defect length. (The other way this can be achieved is to reduce the pressure in the pipeline so that the stress in the pipe wall is less than the nominated threshold, however in most cases the pressure reduction required to meet this threshold significantly compromises gas supply capacity.)

Section 4.7.3 *Maximum Discharge Rate* nominates the maximum energy release rate that is allowed by location class. This is explained in BCN230. The maximum energy release rate requirement is applied where the pipeline may be punctured but does not result in rupture, and is specifically included in AS2885 to limit the consequence of an ignited gas release where people are present.

By quoting directly from AS2885, BCN230 then explains the AS2885 requirements for pipelines not designed to the current version of AS2885.1, or where a change of land use occurs along the route of the pipeline (regardless of whether or not it was designed to the current version of AS2885.1). In either case, the requirement of Section 4.7.4 *Change of Location Class* applies. The requirement is to modify the pipeline so that the provisions of Sections 4.7.2 and 4.7.3 are met, or otherwise undertake a documented safety assessment that demonstrates that the risk from loss of containment involving rupture is ALARP.

BCN230, Section 5 lists the options to be considered when conducting an assessment for the purposes of AS 2885.1, Section 4.7.4.

BCN230, Section 6.2 provides a summary of the foregoing:

> *AS2885.1 section 4.7.2 requires that for new pipelines rupture is a non-credible risk in high consequence area (T1 or T2). Clause 1.4 states "…each existing pipeline shall be assessed against the requirements of Clauses 4.7.2 and 4.7.3. Where the existing pipeline does not comply with either Clause, mitigation shall be applied in accordance with Clause 4.7.4 regardless of whether or not there has been a land use change."*

In GPA's opinion the explanation provided in BCN230 accurately reflects the content and intent of AS2885.1-2012 provisions for High Consequence Areas and is sufficient for the purposes of supporting the case as presented.

3.2 RISK ASSESSMENT

BCN230 Section 4 lists the risk rankings for the VTS in 2016. The quoted risk levels are in accordance with the risk ranking provided in the risk matrix in AS2885.1-2012 (Table F4).

In support of the statement that "Intermediate risks are only acceptable if ALARP is demonstrated", BCN230 provides an extract from the table of risk treatment actions in AS2885.1-2012 (Table F5) which are required to be applied for the assessed risk level.

In GPA's opinion the explanation provided in BCN230 accurately reflects the content and intent of AS2885.1-2012 provisions for "Intermediate risks" and is sufficient for the purposes of supporting the case as presented.

The scope of this Commentary Report does not include the process by which APA risk assessments have been conducted or their conclusions, and the Risk Assessment intended to be included as Appendix A to BCN230 has not been provided to GPA. However, the following should be noted:

1) Where the consequence assessment concludes that a pipeline failure results in a "Catastrophic" outcome (i.e. *inter alia* multiple fatalities), the risk matrix in AS2885.1-2012 (Table F4) does not permit a risk ranking lower than Intermediate, and therefore ALARP must be demonstrated.
2) For the pipelines considered by BCN230, if an ignited pipeline rupture occurs, people within a few hundred metres of the gas release will be subject to heat radiation which is sufficient to cause fatal or life-threatening injuries. In High Consequences Areas (where large numbers of people are likely to be exposed to this radiation), it is reasonable to conclude that a "Catastrophic" outcome will occur.

3.3 PENETRATION CALCULATIONS

BCN230 Sections 5.2 (Project 1 – T24 Brooklyn – Corio), 5.3 (Project 2 – T74 Wollert – Wodonga), and 5.4 (Project 3 – T112 Brooklyn – Lara) provide penetration calculations for large excavators that operate in the vicinity of the nominated pipelines. It is not within GPA's scope to confirm the APA calculations, but it is understood that these calculation are done in accordance with the methodology in AS2885.1

Appendix M and APA's QA processes.

To understand the information as presented in these tables it is important to understand the difference between the "No rupture" criterion in AS2885.1, Section 4.7.2 and the determination of failure mode based on the comparison of the maximum tooth length with the critical defect length (CDL). The "CDL ratio" is the pipeline CDL divided by the maximum tooth length:

- Where the maximum defect length exceeds the CDL (i.e. "CDL ratio"<1) then the pipeline will rupture.
- Where the maximum defect length is less than the CDL (i.e. "CDL ratio">1) then the pipeline will leak rather than rupture.
- Where the maximum defect length is 2/3 of the CDL (i.e. "CDL ratio">1.5) then the "No rupture" criterion in AS2885, Section 4.7.2 is met.

The difference between the "No Rupture" criterion ("CDL ratio">1.5) and the failure mode assessment criterion ("CDL ratio">1) is that the calculations are normally based on <u>typical</u> excavator tooth geometries which are presented in AS2885.1 Appendix M. The "1.5 factor" is applied to provide a conservative margin to account for the fact that the <u>actual</u> excavator tooth that strikes the pipeline may be larger than the typical excavator tooth presented in Appendix M.

Therefore, the information presented in BCN230 should be interpreted as follows:

- Where the assessment concludes that the pipeline can be penetrated but that the CDL ratio <u>is less than 1.5</u> (which is a criterion for "no rupture" in accordance with AS2885.1 Section 4.7.2), then the failure mode is presented as Rupture. However:
  - Where the CDL ratio is <u>less than 1.5 but greater than 1</u>, then the actual failure mode may be Leak or Rupture, depending on the geometry of the actual excavator tooth that strikes the pipeline. If the actual tooth length is less than the CDL, then leak rather than rupture will occur. Rupture is more likely as the CDL ratio approaches 1.
  - Where the CDL ratio is <u>less than 1</u>, then the failure mode is Rupture.
- Where the assessment concludes that the pipeline can be penetrated but that the CDL ratio <u>exceeds 1.5</u> then the failure mode is presented as Leak (i.e. a hole rather than a rupture).
- Where the assessment concludes that the pipeline cannot be penetrated ("NP" = "no penetration") then the "CDL ratio" (the pipeline CDL divided by the maximum tooth length) is irrelevant to the assessment.

4 ALARP ASSESSMENT

4.1 AUSTRALIAN PIPELINE INDUSTRY APPROACH

As discussed in the previous section, where a risk level is determined to be "Intermediate" in accordance with AS2885.1, then ALARP must be demonstrated.

AS2885.1 defines ALARP to mean "…*the cost of further risk reduction is grossly disproportionate to the benefit gained from the reduced risk that would result*". This definition is based on two legal judgements in the UK in late 1940s and early 1950s. General guidance (non-mandatory) is provided in Appendix G of the Standard.

While the guidance in Appendix G of AS2885.1 does not provide any detail or a prescriptive approach, until recently, the interpretation of the Australian pipeline industry was that "cost benefit analysis alone" was the means by which ALARP should be demonstrated. However, by 2013 the pipeline industry had recognised that the "cost benefit analysis alone" approach had significant shortcomings and commissioned a study by the EPCRC to assess this approach in the light of legislative developments since the 1950s, including obligations under modern Australian Work Health and Safety legislation and other similar legislation. This resulted in the EPCRC *Final Report, Project RP4.21A: Understanding ALARP*, Rev 0, August 2015.

The outcome of this report is guidance on ALARP assessment for pipelines based on a wide range of national and international industry guidance:

1) The proposed ALARP assessment questions require that a broad range of issues are considered and documented.
2) In doing so, the intent is that a more complete picture of the issues is developed to support the ALARP judgement.
3) Cost benefit analysis is a consideration, but it is one among many.
4) The ALARP judgment is therefore not based on a single number or calculation, but rather on a number of competing and complementary factors (which may or may not have metrics attached), and which need to be weighed in balance.

A summary of this process and outcomes is provided in HAYES, J. & MCDONOUGH, R. 2016. *Reasonably Practicable – A Help or a Distraction In Ensuring Public Safety?* APGA Conference, Perth, October 2016 (Appendix 1). This paper documents that the ALARP guidance has been applied on a number of recent projects. The guidance is being promoted for wider use in the industry and it is proposed that it will be adopted by AS2885 via the current revision process. For cases where a “Formal ALARP Demonstration” is required (e.g. to address the requirements of AS2885.1, Section 4.7.4), the guidance is provided in the form of 35 questions under 6 general headings which need to be addressed and documented. The headings are:

- Current level of safety risk
- Risk drivers (other than safety)
- What more can we do?
- Risk benefits of proposed measures
- Cost of proposed measures
- Uncertainty

4.2 APA APPROACH IN BCN230

The following is a high level overview of the APA ALARP assessment presented in BCN230 in the context of the headings listed above and the guidance questions documented in Appendix 1.

4.2.1 Current level of safety risk

The current level of safety risk is documented in BCN230, Section 4, Table 3, and has been found to be “Intermediate”. As discussed above, the details of the risk assessment have not been provided to GPA, and it is not within the scope of this document to critique this process. However, where it is concluded that a “Catastrophic” consequence is a credible outcome, AS2885 does not permit a risk ranking lower than Intermediate.

APA’s conclusion that a “Catastrophic” consequence is credible is discussed for the pipelines under consideration in detail in BCN230 Sections 5.2 (Project 1 – T24 Brooklyn – Corio), 5.3 (Project 2 – T74 Wollert – Wodonga), and 5.4 (Project 3 – T112 Brooklyn – Lara). In each case (and taking into account the discussion in Section 3.3 above), the assessment demonstrates that the maximum credible threat for each pipeline can result in a pipeline rupture. As discussed in Section 3.2 above, in high consequence areas it is reasonable to conclude that a “Catastrophic” outcome will occur. This is consistent with the pipeline industry experience in Ghislenghien, Belgium in 2004 (24 fatalities and 132 injuries) and San Bruno, USA in 2010 (8 fatalities and many injuries).

On this basis, APA’s assessment that the risk level is “Intermediate” is consistent with the provisions of

AS2885.

The proposed ALARP guidance also poses the question *"If this is an existing facility, does it meet the standards that would be required for an equivalent new facility?"* APA discusses a direct example in BCN230 Section 6.2. In this case, the recently constructed T120 Victorian Northern Interconnect (VNIE) is installed parallel to the T74 Wollert – Wodonga pipeline. The T120 pipeline is designed as a "no rupture" pipeline so that it can resist the very same threats which can rupture the older T74 pipeline.

4.2.2 Risk drivers (other than safety)

Risk drivers other than safety range from the obvious to the less tangible, and in many cases are difficult to quantify. Factors that may be taken into account include: consequential impacts on the community immediately affected by the event (including impacts on families, health system, businesses); supply risk; property damage; regulatory imposts; legal costs; and, loss of company / industry reputation.

BCN230 provides the example of the San Bruno incident in California for reference:

> *To quantify the catastrophic event, the most recent pipeline failure that best represents a full bore rupture of a pipeline in an urban environment is that of the San Bruno incident in California. The rupture killed eight people and destroyed many assets and buildings in the vicinity. The cost of the explosion including fines and compensation claims is greater than US$2,000 million.*

4.2.3 What more can we do?

The proposed ALARP guidance poses the question "*How might risk be reduced further?"* and then suggests: *"List as many ideas as possible then assess each one, starting with the one with the likely biggest risk benefit."*

BCN230 Section 5 lists and discusses the options available to reduce risk which are provided in AS2885.1 Section 4.7.4. These are:

(a) MAOP reduction (to a level where rupture is non-credible)
(b) Pipe replacement (with no rupture pipe)
(c) Pipeline relocation (to a location where the consequence is eliminated)
(d) Modification of land use (to separate the people from the pipeline)
(e) Implementing physical and procedural protection measures that are effective in controlling threats capable of causing rupture of the pipeline.

While the actions required for Items (a), (b) and (c) are relatively self-evident, this is less so for Items (d) and (e). In general terms:

- MAOP reduction (to a level where rupture is non-credible) is possible, but needs to be assessed in the context of impacts to supply to the community. Further, while rupture is removed as a failure mode, MAOP reduction has little or no bearing on the likelihood of pipeline penetration without rupture (i.e. leak), so risks associated with this failure mode are largely unchanged.
- Pipeline replacement (with no rupture pipe) is possible but is normally a relatively expensive option. The replacement pipe can be selected so that it cannot be penetrated (i.e. "no leak" as well as "no rupture"), so can provide greater risk reduction that MAOP reduction without compromising supply capacity.
- Pipeline relocation is similar to pipe replacement. It is normally a relatively expensive option, as it involves increasing the length of the pipeline, and is likely to require sections of "no leak" or "no rupture" pipe where the route inevitably traverses high consequence areas to supply the community as intended.

- Modification of land use is not under the direct control of APA, and so APA has only limited influence within the general constraints of planning policy (which is to rezone areas previously used for agricultural purposes for urban development).
- Implementing further physical and procedural measures covers a number of options but primarily boils down to adding addition physical barriers to protect the pipeline (e.g. pipeline slabbing, or excluding activities from the pipeline corridor by fencing), and/or intensifying current procedural controls.
    - Slabbing protects the pipeline from vertical threats (excavators and vertical bores) by placing a physical barrier between the threat and the pipe. It does not provide protection from horizontal threats (i.e. HDD). It is relatively cost effective.
    - Similarly, exclusion provides protection from vertical threats by preventing these activities on the pipeline corridor. Exclusion is normally incompatible with other land uses (particularly in an urban context).
    - Intensification of procedural measures should always be considered, but ultimately do not provide the same level of protection as physical measures.

BCDN230 Section 5.1 discusses the “do nothing” option. There are two points to note. Firstly, there is clearly no risk benefit to this option. Secondly, this option can only be a consideration if all other risk reduction options have been considered and discounted by the ALARP assessment process.

4.2.4 Risk benefits of proposed measures

The general risk benefits of the proposed measures are summarised above. A similar discussion which relates directly to the VTS is included in BCN230, Section 5. The most viable alternatives (on the basis of practicality, relative effectiveness and relative cost) in each case are either MAOP reduction or protective slabbing. More detailed, pipeline-specific assessments of the risk benefits of these alternatives are discussed in BCN230 Sections 5.2 (Project 1 – T24 Brooklyn – Corio), 5.3 (Project 2 – T74 Wollert – Wodonga), and 5.4 (Project 3 – T112 Brooklyn – Lara).

Ultimately, the risk benefit of the proposed measures is the avoidance of a catastrophic event, which based on overseas experience, could result in a monetary cost well in excess of hundreds of millions of dollars (notwithstanding societal costs which are difficult to quantify), (refer Section 4.2.2 above).

4.2.5 Cost of proposed measures

Following the general discussion of costs in BCN230 Section 5, more detailed, pipeline-specific assessments of the costs of the most viable alternatives are discussed in BCN230 Sections 5.2 (Project 1 – T24 Brooklyn – Corio), 5.3 (Project 2 – T74 Wollert – Wodonga), and 5.4 (Project 3 – T112 Brooklyn – Lara).

- *Project 1 – T24 Brooklyn – Corio*: Slabbing is nominated as the preferred option as it is substantially cheaper than the proposed pressure reduction options.
- *Project 2 – T74 Wollert – Wodonga:* While the cost of both options is similar, MAOP reduction reduces pipeline capacity. APA nominates slabbing is its preferred option on the basis that if there is increased demand in future, additional capital to re-establish capacity will be required.
- *Project 3 – T112 Brooklyn – Lara. S*labbing is nominated as the preferred option on the basis that any reduction in MAOP results in a capacity reduction for which there is no viable replacement option.

The proposed ALARP guidance includes a direct comparison of the costs and benefits of the proposed risk mitigations. The sum total of the proposed slabbing program is ~$25m. The context provided by APA for this expenditure are the examples of the Ghislenghien and San Bruno disasters, which resulted in multiple fatalities and injuries, and costs running into the billions of dollars.

4.2.6 Uncertainty

The proposed ALARP guidance includes a number of questions relating to the uncertainties in the assessment. While not necessarily explicitly addressed in BCN230, the following points are noted:

- Urban growth around the pipelines (i.e. change of land use) is matter of government policy, and therefore needs to be addressed (i.e. this is a current and future issue).
- The consequence of an ignited pipeline rupture in an urban area is most likely to be "Catastrophic" (as defined by AS2885).
- APA has a long history of designing, construction and operation gas transmission pipelines in Victoria and is therefore very familiar with the threats associated with different land uses (and change of land use) in different locations.
- Following this, APA is very familiar with the physical and procedural measures required to effectively control these threats.

4.2.7 ALARP Determination

The Australian pipeline industry has recently developed guidelines for conducting ALARP assessments for high pressure pipelines based on current national and international practice, including obligations under modern Australian Work Health and Safety legislation and other similar legislation. This is documented in the EPCRC *Final Report, Project RP4.21A: Understanding ALARP*, Rev 0, August 2015. It is proposed that these guidelines will be incorporated into the next revision of AS2885.

A key point is that an ALARP assessment cannot be made on the basis of a single metric (which is likely to be subject to considerable uncertainty) but is rather a judgement call based on a broad range of factors. BCN230 documents a number of factors which APA has taken into account in order to form the judgement that slabbing of the pipelines under consideration is reasonably practicable. In forming this judgement, APA has taken into account the alternatives listed in AS2885.1 Section 4.7.4. APA has also formed the judgment that the "Do nothing" option is unacceptable.

It is GPA's opinion that APA has broadly followed this guidance material for ALARP assessment (i.e. APA's approach is consistent with current best practice for ALARP assessment in the Australian pipeline industry).

5 CONCLUSIONS

5.1 AS2885.1 REQUIREMENTS

GPA Engineering has reviewed BCN230 to determine whether the statements therein regarding the requirements of AS2885.1-2012 are correct. There are three relevant topics addressed by BCN230:

1) AS2885.1-2012 Section 4.7 *Special Provisions for High Consequence Areas* makes requirements where there is a change of land use around high pressure pipelines from rural to urban land use. This includes the requirement to demonstrate that risks associated with pipeline rupture are ALARP. In GPA's opinion the explanation provided in BCN230 accurately reflects the content and intent of the AS2885.1-2012 provisions for High Consequence Areas and is sufficient for the purposes of supporting the case as presented.
2) AS2885.1-2012 Appendix F *Qualitative Risk Assessment* provides the risk matrix which is to be used for pipeline risk assessment, and also specifies the actions required for the risk rank determined by risk assessment, and in particular, "Intermediate" risks. In GPA's opinion the explanation provided in BCN230 accurately reflects the content and intent of AS2885.1-2012 provisions for "Intermediate risks" and is sufficient for the purposes of supporting the case as presented. While the scope of this Commentary Report does not include the process by which

APA risk assessments have been conducted or their conclusions, it is noted that:

- Where the consequence assessment concludes that a pipeline failure results in a “Catastrophic” outcome (i.e. *inter alia* multiple fatalities), the risk matrix in AS2885.1-2012 does not permit a risk ranking lower than Intermediate, and therefore ALARP must be demonstrated.
- For the pipelines considered by BCN230, if an ignited pipeline rupture occurs, people within a few hundred metres of the gas release will be subject to heat radiation which is sufficient to cause fatal or life-threatening injuries. In urban areas it is reasonable to conclude that a “Catastrophic” outcome will occur.

3) Based on the tables which show the susceptibility of each pipeline to penetration and the predicted failure mode for the pipelines, and APA’s assessment of the credible threats, in GPA’s opinion it is reasonable to conclude that pipeline rupture is a credible failure mode for each pipeline.

5.2 ALARP ASSESSMENT

GPA Engineering has reviewed BCN230 to determine whether the approach adopted by APA to demonstrate that the proposed remedial actions meet ALARP is consistent with pipeline industry practice which has been adopted since the most recent revision of AS2885.1 was published in 2012.

The Australian pipeline industry has recently developed guidelines for conducting ALARP assessments for high pressure pipelines based on current national and international practice, including obligations under modern Australian Work Health and Safety legislation and other similar legislation. This is documented in the EPCRC *Final Report, Project RP4.21A: Understanding ALARP*, Rev 0, August 2015. These guidelines are currently in the process of incorporated into AS2885.

A key point is that an ALARP assessment cannot be made on the basis of a single metric (which is likely to be subject to considerable uncertainty) but is rather a judgement call based on a broad range of factors. BCN230 documents a number of factors which APA has taken into account in order to form the judgement that slabbing of the pipelines under consideration is reasonably practicable. In forming this judgement, APA has taken into account the alternatives listed in AS2885.1 Section 4.7.4. APA has also formed the judgment that the “Do nothing” option is unacceptable.

It is GPA’s opinion that APA has broadly followed this guidance material for ALARP assessment (i.e. APA’s approach is consistent with current best practice for ALARP assessment in the Australian pipeline industry).

APPENDIX 1 APGA PAPER

REASONABLY PRACTICABLE – A HELP OR A DISTRACTION IN ENSURING PUBLIC SAFETY?

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REASONABLY PRACTICABLE – A HELP OR A DISTRACTION IN ENSURING PUBLIC SAFETY?

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Abstract

Pipelines must be designed, constructed, operated and maintained so that risk to workers and the public is as low as reasonably practicable (ALARP). This is fairly simple to say and sometimes the requirements are clear. One example is that new pipelines must be designed in accordance with AS2885.1. Any new pipeline in an urban area must be designed for 'no rupture'. Much trickier cases are those where pipelines that were installed decades ago in relatively unpopulated areas are now close to urban development. If the pipeline does not conform to current design standards for this service, how does a pipeline operator decide whether the suite of safety measures in place is sufficient?

The answer is a matter of judgement that will never be formally tested unless there is an accident and yet as an industry we have legal and moral responsibilities to get this right. In this paper we draw on the diverse fields of law, ethics, social science and engineering to talk about where the concept of 'reasonably practicable' came from, what it means and what obligations it imposes on management of pipeline companies.

Changes are being proposed to AS2885.1 to include more guidance on how to make ALARP judgements. In this paper, we use a real case study to show how the proposed changes to AS2885.1 in this area are designed to help pipeline companies come to reasoned and informed judgements about what they need to do in order to keep the public safe. In cases like this, risk can rarely be eliminated, but following a structured process makes for better outcomes that are more consistent and defensible if something goes wrong.

1. Introduction

In countries such as Australia with a legal system based on considerations of common law, it is normal for safety legislation to be grounded in the notion that risk should be reduced to a level that is as low as reasonably practicable or ALARP. The concept has been in use in law for several centuries but it remains much-discussed because there is uncertainty in its application in any specific case. Whilst ALARP provides a guiding principle, ultimately decisions about safety, especially for rare but potentially catastrophic events, often come down to a matter of judgement based on engineering expertise informed by societal expectations.

This paper aims to provide an overview of the history of the concept and its application to support current work on updating AS2885.1. The approach taken is based on document review including legislation, academic literature from various disciplines and also industry practices and guidelines from various sectors.

The paper starts by laying out the origins and history of the concept of ALARP (Section 2).

Current references to ALARP in AS2885 and in relevant legislation are then described (Section 3).

Safety decision making also involves an ethical dimension since peoples' lives may be significantly impacted by the choices made. Section 4 discusses ALARP from an ethical perspective.

Some parts of the Australian pipeline sector have adopted a cost benefit analysis approach to demonstration of ALARP. Section 5 discusses this approach in detail including its strengths, weaknesses and limitations.

Section 6 moves to a new pipeline industry framework for demonstration of ALARP based on both legal and ethical considerations.

Section 7 provides a case study which shows how the framework has been applied to a number of examples. Issues encountered, benefits noted and challenges for future industry implementation are discussed.

2. Origins of ALARP

The idea that employers have a duty to do all that is 'reasonably practicable' to ensure the safety of workers and the public has a long history. Whilst it has been influential in risk management practice and as such become a common phrase in both management and engineering, the origins of the concept are in law. To understand what ALARP means now, it is useful to understand the origins of the concept and how current thinking has developed from that.

There is no simple definition of the legal expression 'reasonably practicable'. The starting point for discussion is two mid twentieth century judgements that addressed this issue. Legal interpretations in Australia and the UK are often traced to the definition by Asquith LJ in Edwards v National Coal Board (1949) quoted in Bluff and Johnstone (2004):

> *'Reasonably practicable' is a narrower term than 'physically possible' and seems to me to imply that a computation must be made by the owner, in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other; and if it be shown that there*

is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them. Moreover, this compensation falls to be made by the owner at the point of time anterior to the accident.

This definition of 'reasonably practicable' was further considered in the House of Lords in Marshall v Gotham Co Ltd in 1954 (Jones-Lee and Aven, 2011) and they found:

The test of what is [reasonably practicable] is not simply what is practicable as a matter of engineering, but depends on the consideration, in the light of the whole circumstances at the time of the accident, whether the time, trouble and expense of the precautions suggested are or are not disproportionate to the risk involved, and also an assessment of the degree of security which the measures suggested may be expected to afford.

These two decisions are the origin of the well-known idea that reducing risk to a level that is as low as reasonably practicable requires implementation of all measures that are practicable in engineering terms, unless the cost of implementing a given measure is grossly disproportionate to the benefit gained.

Whilst these definitions / explanations are widely quoted, the term 'reasonably practicable' dates from well before this time. The concept has been in widespread use in countries where legal requirements originate from considerations of 'common law'[1] for several centuries (Ale, 2005, Hartford, 2009). In this view of how to structure legal matters, a primary function of the civil law is to address 'torts' or wrongful acts and the need for compensation. There are many cases in which the potential for damage cannot be eliminated and so the courts need a way to decide what level of protection must be provided in order to avoid the obligation to pay another party compensation in the event that something goes wrong. The idea that those in control must do what is 'reasonably practicable' arises from this need. Thus, the idea of ALARP can be traced to common law and civil penalties.

In the late 19th and early 20th centuries, the way workplace health and safety law was structured for coal mining and other industries was to set out a duty in absolute terms and then to include another section which exonerated duty holders from responsibility for a breach in cases where it was 'not reasonably practicable' to comply. UK mining and factory Acts dating from the nineteenth century were structured in this way.

Until the 1970s, it was common for civil action to be taken by victims of industrial accidents (or their families) to obtain compensation. In fact the oft-quoted Edwards and Marshall rulings cited earlier are both from civil cases addressing this need. In the Edwards decision, the Court of Appeal found in favour of the widow of a miner killed in an accident where the wall alongside an underground roadway collapsed, despite various protections in place. The Coal Mines Act 1911 required that such structures be made secure and yet protected mine owners from penalties based solely on breach of that duty provided it was not 'reasonably practicable' to prevent the breach. The court found for the appellant in this case because the company admitted that it would have been possible to do more to prevent the collapse and yet they failed to provide evidence 'as

[1] According to FOSTER, N. 2012. *Workplace Health and Safety Law in Australia,* Australia, LexisNexis Butterworths., law is defined as rules of behaviour to which our society attaches some sort of sanction through the courts. In Australia (and the UK) law comes from two sources – legislation and common law. Common law originates in court decisions and accumulates over centuries as lower courts are obliged to follow previous decisions of higher courts.

to the relative quantum of risk and sacrifice involved' and so failed to demonstrate that further measures were impracticable.

It is relevant to note that at this time civil action was based on the claim that an employer had breached a statutory duty. As Barrett and Howells (2000, pg 157) explain, 'breach of statutory duty is sometimes referred to as 'statutory negligence', but more naturally regarded as a separate species of fault distinct from negligence. There can be a breach of a statutory duty without any failure to take reasonable care.' Even in cases where duty holders failed to meet requirements, this provided a case for compensation, not for criminal prosecution.

In the early 1970s, UK health and safety law underwent major change following the review of the Robens Committee (Robens, 1972). The notion that duty holders must reduce risk to a level that is as low as reasonably practicable, or ensure the safety of workers so far as is reasonably practicable became central to meeting the requirements of the new legislation. As their report states, 'a positive declaration of over-riding duties, carrying the stamp of Parliamentary approval, would clearly establish in the minds of all concerned that safety and health at work is a continuous legal and social responsibility of all those how have control over the conditions and circumstances in which work is performed.'(Robens, 1972, pg 41-42) ALARP was no longer simply a means to determine compensation but an overarching general duty. Those who fail to meet it have become liable for prosecution.

Industrial safety law in Australia has continued to build on the UK foundations. In the 1970s, many of the criticisms made by Robens of UK safety law applied equally to Australian law of the time and most states adopted the spirit of some or all of the Robens changes, specifically the updated structure of safety law based on general duties supplemented by regulations and codes of practice. Further changes since that time have embedded the framework that risk must be reduced to a level that is ALARP even more strongly into the details of regulation. Goal setting, risk based legislation introduced in the oil and gas industry (following the Cullen Report produced by the inquiry into the Piper Alpha disaster (1990)) requires companies to produce a Safety Case. Now duty holders not only have an overall duty to reduce risk to ALARP, but the entire regulatory structure is driven by processes regarding hazards, risks and risk reduction.

3. Current Requirements for ALARP

For the pipeline sector, there are two key points of reference regarding ALARP. These are general workplace health and safety legislation and the requirements of pipeline-specific legislation as reflected in AS2885. These are addressed in turn below.

'Reasonably practicable' is a key principle of the model Workplace Health and Safety (WHS) Act applying directly to the general duty of the key duty holder, the Person Conducting a Business or Undertaking (PCBU). A PCBU has duties to all people who may be impacted by the activities that they control, irrespective of whether or not the PCBU employs them[2]. 'Person' in this context includes individuals and bodies corporate. (Johnstone and Tooma, 2012, pg 27)

Section 19 of the model Act specifies the general duty as follows:

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[2] A PCBU can be an employer, a principle contractor a franchisor or the Crown. See JOHNSTONE, R. & TOOMA, M. 2012. *Work Health & Safety Regulation in Australia: The Model Act,* Sydney, The Federation Press. Pg 28.

*A person conducting a business or undertaking must ensure, so far as is **reasonably practicable**, the health and safety of:*

(a) workers engaged, or caused to be engaged by the person, and
(b) workers whose activities in carrying out work are influenced or directed by the person,

while the workers are at work in the business or undertaking.(bold added)

In this way, the duty of care is qualified, rather than absolute, and a PCBU is required to do only what is reasonably practicable when it comes to their duty of care responsibility to others.

The Model WHS Act Section 18 defines reasonably practicable as that which is able to be done to ensure safety;

taking into account and weighing up all relevant matters including:

(a) the likelihood of the hazard or the risk concerned occurring; and
(b) the degree of harm that might result from the hazard or the risk; and
(c) what the person concerned knows, or ought reasonably to know, about:
  (i) the hazard or the risk; and
  (ii) ways of eliminating or minimising the risk; and
(d) the availability and suitability of ways to eliminate or minimise the risk; and
(e) after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.

It can be seen that the Model WHS Act definition incorporates the idea that more should be spent on risk control unless the cost is grossly disproportionate, but it also includes broader considerations about the hazard and risk under consideration and the ways it might be controlled. These have been developed based on other court decisions since Edwards and Gotham.

Another key point to note is that the model WHS Act lays out duties for company officers in addition to duties for a PCBU. This is one of the major changes introduced by the model WHS Act. In fact Johnstone and Tooma see this as 'the most significant of the reforms introduced by the Model Act'. (2012, pg 108) Senior company personnel now have specific proactive duties with regards to safety matters. Whilst this duty for officers does not impact directly on discussions regarding demonstration of ALARP, it is indicative of the likely future direction of safety requirements for specific industries too.

With the exception of WA and Victoria, all states have enacted legislation in the form of the model WHS Act. Legislation in WA and Victoria is similar at the level of general duties and so the definition of ALARP cited above applies broadly. There is a general intent by most state regulators to bring the health and safety aspects of sector specific legislation such as pipeline legislation, into line with the model WHS Act and regulations where appropriate. [3,4] For pipelines in all states,

[3] In some states (but not all), WHS legislation is disallowed where pipeline legislation applies and all relevant WHS requirements are included in the industry-specific Act.

[4] In WA, the Department of Mines and Petroleum is currently undertaking a process to enact a single safety legislative framework for the operations of pipelines, petroleum, mining and major hazardous facilities that is largely based on the Model OHS Law (it is proposed to be called the Work Health & Safety (Resources) Act). The timetable currently envisages enactment of the Bill by the end of 2016. As at August 2016, public consultation details can be found here - http://www.marsdenjacob.com.au/work-health-safety-resources-bill/

common requirements are set by the various parts of AS2885 which is called up by the relevant legislation in each state and so effectively has legislative force.

The term ALARP is used only very selectively in AS2885. The overarching principle according to AS2885.0 Section 1.3 is that risk is to managed to an 'acceptable level'. This is an important difference between AS2885 as it currently stands and the way in which ALARP is used in most other industries and in law. It is not an overarching principle but rather the Standard requires formal demonstration of ALARP in three situations:

- risks that fall into the Intermediate category on the risk matrix given in Appendix F.
- cases of land use intensification as defined in clause 4.7.4.
- and arguably, for all external interference threats (where clause 2.3.3.2 requires "all reasonably practicable controls" to be applied).

AS2885.1 includes a definition of ALARP:

> *ALARP means that the cost of further risk reduction measures is grossly disproportionate to the benefit gained from the reduced risk that would result.*

In contrast to the definition in the model WHS Act given above, this is very specific. Whilst it is clearly based on the Edwards decision, it lacks any further context or guidance drawn from further judgements made since that time. Reading these words in isolation seems to have led to the general conclusion by the pipeline sector that quantitative assessment in the form of cost benefit analysis is what is required and that this requirement only applies very specifically to three cases as described in the previous paragraph. In fact, cost benefit analysis has some major limitations (as will be described in Section 5). Adding to the confusion, Appendix G of AS2885.1 provides some basic background on ALARP which is heavily based on material published by the UK HSE (where ALARP is an overarching concept).

In summary, there are two issues with the way risk decisions and ALARP is treated in the current version of AS2885. Firstly, the overarching requirement is that risk should be acceptable, not ALARP. ALARP only applies in three specific cases. Secondly, when ALARP is used, the term is used in a very specific way. In contrast to WHS legislation and other sectors, it draws on the Edwards decision without context provided by later judgments. In this situation, it is no wonder that there have been industry calls for additional guidance in this area.

Updating the framing of the overall requirements of AS2885 to be consistent with legislative best practice makes good sense from the perspective of both pipeline safety and efficient regulatory compliance by industry. This paper aims to support that effort. Some have argued that to make the requirement to reduce risk to a level that is as low as reasonably practicable as the overarching principle of AS2885 would require the entire standard to be recast. This is overstating the impact of the change in practical terms. Firstly, much pipeline legislation already includes this requirement and so many pipelines and companies already have a requirement to meet this duty and presumably are doing so or we can expect that enforcement action would have been taken. Secondly as will be described further below, in many cases demonstration that risk is ALARP can be based on the technical requirements of a best practice industry standard such as AS2885 i.e. compliance with the specific technical aspects of AS2885 itself is a legitimate part of the overall argument that risk is ALARP. This is the primary means by which ALARP is demonstrated in the vast majority of cases – a formal "ALARP study" is only required in a specific subset of cases, for which guidance has been developed as detailed below.

4. Ethics and Emotions of ALARP

The focus so far has been on legal arguments about risk and ALARP. It is important to acknowledge that decisions about risk have an ethical dimension[5]. According to the Oxford English Dictionary, 'practicable' means 'to be done or put into practice successfully'. The question of what is practicable regarding pipeline safety therefore is largely one of engineering. On the other hand, 'reasonably' means 'by sensible standards of judgement; justifiably'. Importantly, this is not an engineering question. It is largely a matter for society at large as enacted by the courts and has a clear ethical dimension. The decisions made can have implications for people's lives in the near term and in future generations. Some ALARP decisions also have the potential to impact the environment. Decision makers have the ability to influence others in very significant ways which means questions of what is right and wrong in the broadest terms become relevant.

There are two main schools of ethical thought that are relevant to risk decision making. The first is utilitarianism. This school of ethical thought proposed by Jeremy Bentham in 18th century England and further developed by John Stuart Mill is based on the idea that ethical actions are those that produce the greatest good for the greatest number. Further, the benefit of an action, its 'goodness', is the pleasure or happiness it brings[6]. Cost benefit analysis is an attempt to identify all the costs and all the benefits for all stakeholders of a particular action and to evaluate them on a common basis i.e. a monetary value. It is therefore a form of utilitarianism. Having said that, many utilitarian philosophers would find the idea of placing a monetary value on all benefits to be problematic. We will cover the limitations of this aspect of cost benefit analysis further in Section 5.

The primary criticism of utilitarianism is that it can lead to great suffering by a few people if this were to bring even small benefits to wider society. The alternative view of ethics that addresses this is known as deontology. In this branch of ethical theory, ends do not justify means. Perhaps the best known philosopher in this area is Kant. In this theory, ethical considerations either permit or forbid actions based on the rightness of the action itself, not the outcome (as in utilitarianism). Kant's ideas essentially distil to the well-known adage 'do unto others as you would have them do unto you'. When it comes to risk assessments, a deontological approach suggests that utilitarianism should not be unbounded but rather there should be a maximum level of risk that it is not reasonable to expose others to, irrespective of the broader benefits that might result. Of course this has also been recognised in consideration of industrial risk to workers where most risk management systems include some definition of risk that is so high as to be unacceptable and therefore requiring reduction regardless of cost.

Later philosophers (such as Rawl and Habermas) have merged the two approaches to ethics described above with a focus on maximising utility whilst taking the rights of all stakeholders into account. In modern society, government has a key role here on behalf of broader societal stakeholders and so such ethical considerations should drive government regulatory policy. To look at government action in hindsight, with some caveats on accuracy, it is possible to calculate the value of a statistical life (VOSL) implicit in all risk-based policy decisions. Analyses have shown that values vary widely and that decisions are based on both ethical and emotional questions. One

[5] This section draws on ERSDAL, G. & AVEN, T. 2008. Risk informed decision-making and its ethical basis. *Reliability Engineering and System Safety,* 93**,** 197-205.

[6] The well-known contemporary Australian ethicist Peter Singer is a utilitarian. His application of this concept leads to some challenging conclusions about the rights of animals and the severely disabled.

example (Ale et al., 2015) is the fine of 40,000 Euros for having an unfenced swimming pool in France which is manifestly much higher than reasonable on a cost benefit basis taking into account likelihood and typical VOSL figures. The explanation is that a grandchild of the responsible minister drowned in a swimming pool accident prior to the introduction of this legislation.

It must be noted at this point that decades of research by Paul Slovic, Peter Sandman and others show that emotion plays an enormous role in decision making about risk issues. This applies equally to technocrats and engineers as to other stakeholders, for example risks associated with LPG are judged more favourably by those who drive an LPG-fuelled car and even more favourably by those who sell LPG (Ale et al., 2015). This is one reason why involving a wide range of stakeholders in decision making makes for a better outcome.

The idea that risk is subjective can be challenging to some. The foundation of the safety case approach is to identify and document the specific hazards, specific risks and the specific engineering, administrative and procedural measures that address them. To meet regulatory requirements, submissions to regulatory agencies must provide concrete details. Ultimately, compliance and enforcement activities focus on engineering hardware and activities in the field, prioritised on the basis of risk. In this case, risk is conceptualised by operating companies and regulators as the product of frequency and consequence and is often quantified. This in turn allows the results to be compared with numerical criteria and the justification for physical changes that reduce risk to be assessed on the basis of cost benefit analysis.

In some ways, this narrow conceptualisation of risk has served society well. There is no doubt that safer designs are produced when engineering failures that could occur during operation are explicitly considered as part of the design development process. Modelling techniques for physical effects such as the prediction of explosion overpressure and the impact of fires on structures have improved dramatically in the past two decades. On the other hand, attempts to incorporate human and organisational error into this narrow definition of risk have been largely unsuccessful.

Based on the collective imagination of technical professionals dealing with design decisions in particular, risks are discussed and managed as if they are real phenomena – a physical property of the engineered system that can be measured and manipulated. The role of human judgement and experience is often unacknowledged in technical decision making. Regulators and operating companies have lost sight of the view that risk is a mental model of how actual harm can be predicted and controlled (Aven et al., 2011, Douglas and Wildavsky, 1982). In making sense of the world, technical organisations and regulators have considered technical cues in constructing and enacting their reality because these are the issues that are apparently controllable. According to Scheytt et al (2006) "we call something a risk when we seek to bring the future into the present and act upon it, i.e. make it decidable".

The technical view of risk systematically emphasises those risks that can be calculated and quantified. Whilst this has led to improvements in engineering analysis, it has also resulted in issues such as leadership, professionalism, competence, experience and judgement being ignored despite compelling evidence that the potential for harm from any hazardous activity depends critically on these factors. A broader understanding of the concept of risk is needed to encompass identification and management of relevant organisational factors and views of other stakeholders. Of course these same arguments apply to government policy making as well as industrial decisions that have the potential to impact workers and the public. The UK HSE's stated position on policy making is described in their oft quoted document Reducing Risks, Protecting People (HSE, 2001) sometimes known as R2P2. The process detailed in this document includes firstly quantitative analysis of costs and benefits as far as possible. This information is then combined with relevant qualitative data before a decision is made.

In summary, risk assessment is a mental model that is useful to frame decision making. It is not something that is real or absolute. By definition it is fuzzy and imprecise. For this reason, decision making based on risk assessment needs to 1) acknowledge this fact; and 2) consider a broad range of factors.

5. ALARP and Cost Benefit Analysis

The discussion to date has focussed at a philosophical level on the nature of risk and ALARP. This section moves to consideration of what this concept means in practice.

In grappling with how to apply the concept of ALARP, some industries have adopted an approach based on quantification of risk and so demonstration of ALARP by cost benefit analysis. Quantitative Risk Analysis or QRA is a mathematical technique that originated in the nuclear industry in the 1970's. Since that time, its use has spread to other high hazard industries such as offshore oil and gas, onshore chemical and petrochemical facilities, transportation of hazardous goods and aviation. The technique attempts to determine a numerical estimate of the frequency of fatality (of either workers or the public or both) associated with the facility, operation or activity in question. This is typically done by development of all possible causal chains that could lead to fatality and estimation of both the potential consequences (size of fire, extent of structural damage etc.) and the likely frequency or probability of each step in the causal chain.

When faced with a choice between two or more courses of action, the results of a QRA can assist in decision making by providing a numerical ranking of the options based on the estimated frequency of fatality (i.e. risk). This analysis itself is subject to a range of uncertainties in representing complex issues by a single index. Even once these difficulties have been overcome, two significant questions remain unanswered:

- How is the cost of each option taken into account i.e. if the lowest risk option is more expensive to adopt than other options, which should be chosen?
- Is the absolute risk acceptable i.e. does the lowest risk option available still introduce an estimated frequency of fatality that is too high?

The process used to address these questions is comparison of the calculated risk with fixed criteria followed by cost benefit analysis. Specifically,

- There is a level of risk to an individual that is deemed to be intolerable. If the risk is found to be above this value, changes must be made in order to reduce risk, regardless of cost, except in the most exceptional of circumstances.
- There is a lower (but non-zero) level of risk that is deemed to be broadly acceptable. At this risk level (and below), risk should be monitored to ensure that no significant increase occurs, but further expenditure on risk reduction is not justified.
- Between these two risk levels is what is known as the ALARP region. If risk falls into this region, further analysis is required in order to demonstrate that the risk has been reduced to a level that is as low as reasonably practicable. Risk reduction measures must be identified and evaluated in terms of cost (money, time and effort) and possible risk benefit. Measures should be put in place provided that the cost is reasonable when compared to the benefit gained.

These concepts are shown in Figure 1.

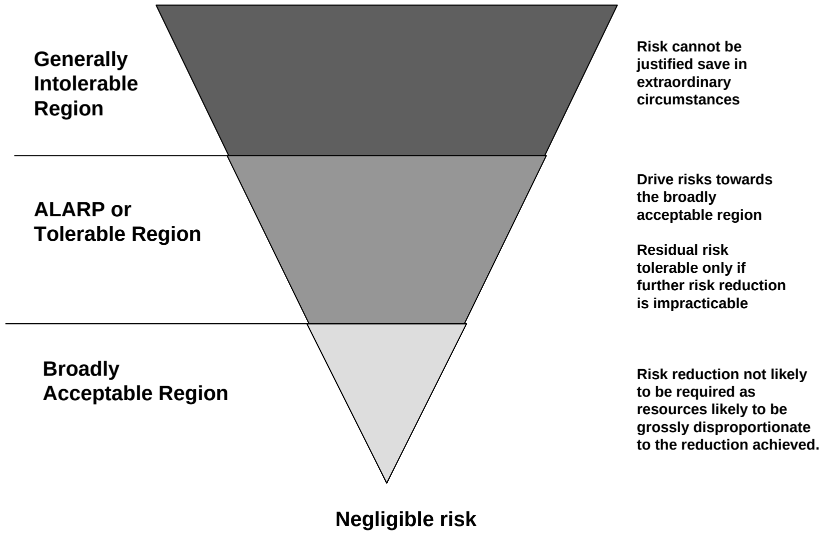

Figure 1: The ALARP Principle (Standards Australia, 2004)

Focussing in particular on the ALARP region, it is important to recognise that risks that are assessed to be in this region are not the only ones to which the ALARP principle applies. All reasonably practicable measures must be put in place for all risks. The distinction is that risks in this region are the ones that require most intensive study in order to work out what to do. They are neither unacceptably high (to the point where risk reduction MUST occur regardless of cost – even if that means not going ahead with the activity) nor negligibly low (in which case the incremental cost that can be justified is also effectively negligible) and so specific analysis is required to demonstrate that all reasonably practicable measures have been put in place. Neither are these risks already ALARP without further specific demonstration. The diagram shown in Figure 1 has been misinterpreted to mean each of these things.

The comparison of cost and benefit often takes the form of a quantitative cost benefit analysis where a notional financial value is assigned to each cost and benefit contributor, including a numerical value for notional cost of lives saved, known as value of a statistical life or VOSL. This idea was widely adopted in safety legislation in the late twentieth century. Since that time however, most jurisdictions have recognised that cost benefit analysis has major limitations (not least of which being that it is open to manipulation), for example NOPSEMA's guidance material on this subject (2014) takes a much broader view of what is required for demonstration of ALARP although CBA is listed as one of ten possible methods that might contribute. In most jurisdictions, CBA is now seen as something that may provide an input to decision making but not something that dictates an outcome. As the UK HSE guidance on this matter says. 'A CBA cannot form the sole argument of an ALARP decision nor can it be used to undermine existing standards and good practice'.(HSE, 2015)

AS 2885.1 takes a view on CBA that is consistent with best practice several decades old. Currently, Appendix G of AS2885.1 specifically directs readers to cost benefit analysis as the mechanism by which judgments are to be made stating 'determining if the risk from a specific threat has been reduced to ALARP involves an assessment of the risk to be avoided, the cost (in money, time and trouble) involved in avoiding the risk and a comparison of the two. Determining ALARP is in effect a cost-benefit analysis.'

In practice some companies have adopted cost benefit analysis based on the calculation of maximum justifiable spend (MJS) to attempt to determine whether specific risk controls are justifiable. The basis of this method is to determine the maximum expenditure that would be justified if the risk in question were to be eliminated completely. Embedded in the calculation are an assessment of the estimated annual frequency of pipeline rupture (F_R), its impact on people (C), a value of statistical life (VOSL), the remaining life of the pipeline (T) and perhaps a factor to take into account 'gross disproportionality' (GD).

$$\text{Maximum justifiable spend, MJS} = F_R \times C \times VOSL \times T \times GD$$

In a typical application of this method, a very large number (VOSL) is multiplied by a very small number (F_R). Each of these figures includes significant uncertainty. For this reason and others, numerous criticisms have been levelled at this whole approach.

The first issue relates to the value used for VOSL. This is a figure that must be based on societal expectations. In most pipeline cases, the tradeoff being addressed is the cost of additional expenditure by the pipeline owner/operator with the benefit of a decreased probability of a major accident impacting members of the public. The cost is born by the company and yet the benefit is a societal one. Meeting this requirement is part of the pipeline industry's social licence to operate. This explains why the value of cost of a life that is used is taken from broader government policy debates. There is no expectation (at least from the mainstream application of this technique) that private industry should pay more to protect the public than would be expected by government in equivalent situations.

The challenge therefore is to develop a figure for society's willingness to pay. Clearly there are differences in willingness to pay to reduce risk that could be introduced by differing economic circumstances. In fact that the value assigned to life in CBA is culture specific – being orders of magnitude higher in the advanced countries than in the most impoverished ones (Heinzerling and Ackerman, 2002, Hopkins, 2005). In the developed world this is seen to be an average societal value. Values applied should not be adjusted in relation to the income levels of those directly affected by a safety improvement (Jones-Lee and Aven, 2011) although some CBA calculations regarding government policy in the developed world have done this.

Another challenge for safety decisions that have long term consequences is that assigning a figure to VOSL is effectively valuing future generations. This introduces another suite of ethical and practical problems with arriving at a single figure. As Aven and Kørte (2003, pg 290) point out, the answer to such questions as the appropriate value of current human life or future generations 'is neither trivial nor obvious and all methods of quantifying the value of a risk, such as willingness-to-pay/accept or revealed preferences can be questioned on a number of grounds'.

A second major difficulty is the value used for the frequency of the rare but catastrophic incident under discussion. The past is not a good predictor of the future in such cases and such figures always include significant uncertainty. To keep this in mind, risk can be thought of as a two dimensional array of consequences and frequencies, rather than single figure. Reducing risk to a single index is an example of what is called an 'expected value'. As Aven points out, 'expected value decision-making is misleading for rare and extreme events. The expected value (the mean or the central tendency) does not adequately capture events with low probabilities and high consequences.' (2009, pg 800). Given the large uncertainty in the frequency, and the very low estimated value, as Hopkins (2015) points out, it becomes effectively meaningless for any individual company or facility.

Further, using frequency-based arguments to avoid expenditure is likely to lead to liability issues in the event of an accident since frequency-based arguments are often contested in the event that something does go wrong. The work of Sappideen and Stillman (1995) in particular has highlighted the problems in aligning the engineering ex-ante approach to managing hazardous assets and activities with the ex-post judicial view of due diligence which largely centres around the foreseeability of the consequence, irrespective of its likelihood.

Another issue is that use of CBA implies incorporation of the 'gross disproportion' factor in the calculations. Whilst it could be argued that such a factor is illogical, Jones-Lee and Aven (2011) have concluded that there are at least four reasons why such a factor is appropriate. These are:

i. Safety improvements may have societal benefits over and above those captured in the value used for cost of a statistical life.
ii. Significant uncertainty in calculations of costs and benefits
iii. That society has a greater aversion to events that have a higher level of risk and so it makes sense in societal terms to spend more than simply a pro rata amount to reduce the most significant risks.
iv. It makes the calculations less vulnerable to manipulation by overestimating the cost of the proposed risk reduction in order to make its implementation unjustifiable.

This same study comes to no firm conclusion regarding a quantitative value that adequately represents gross disproportionality, with a range of values quoted in the range 3-10. Even this analysis by authors who clearly believe in the value of cost benefit analysis is acknowledging that the results may be wrong by at least one order of magnitude.

In summary, there are major questions raised regarding at least three of the five factors used to calculate a value for maximum justifiable spend. Other authors such as Aven and Kørte (2003) also criticise the use of cost benefit analysis on a broader basis, warning that it ignores qualitative arguments both for and against proposed measure whilst hiding uncertainty in the false clarity of a single number.

Finally even the famous process safety engineer Trevor Kletz expresses doubts about use of CBA (2005) highlighting that pursuing safety in a specific industrial setting can come at an overall increase in risk to society. His examples include cases where risk is shifted to other parties by reducing risk at one specific industrial setting, specifically the Flixborough site[7] where the hazardous process involving oxidation of cyclohexane was replaced with a safer one based on hydrogenation of phenol. His point is that phenol manufacture itself is very hazardous, but this was not carried out at the Flixborough site, the phenol was transported to the site. This probably greater risk was simply transferred to another site. His examples also include a pipeline case involving the trade off in risk of increased helicopter inspections versus the risk reduction obtained from additional oversight and so reduced chance of third party damage. Whilst no details of the calculation are given, he claims that in this case, the additional helicopter risk was justifiable when the boundaries of the system were expanded to include all elements.

[7] The explosion at the Nypro plant in Flixborough that killed 28 people in 1974 led to many changes in the chemical industry including the development of HAZOP as a method for assessing plant modifications. See KLETZ, T. 1988. *Learning from Accidents in Industry,* London, Butterworths.

6. Demonstrating ALARP

Cost benefit analysis clearly has some weaknesses if it is used to dictate action. The challenge then is to develop a process that guides decision makers in line with the broader principle. Now that ALARP is a general duty, it requires a holistic and proactive approach.

It is useful to start by thinking again about the purpose of risk assessment and the meaning of the results. Risk assessments by necessity include an estimate of the probability that an undesired event occurs in a given year. This same figure can be interpreted in two ways (Aven, 2009):

i. In the classical statistical sense, this figure represents the relative fraction of times the event would occur if the particular situation were repeated a hypothetically infinite number of times.
ii. Alternatively, it can be thought of as the uncertainty as to the possible outcome seen through the eyes of the expert assessor, often developed via a 'thought experiment'.

These alternative ways of conceptualising the meaning of a risk estimate are important because they drive different views of their role in decision making. The first definition leads us to the view that there is a single correct figure that represents the risk and so should drive decision making. CBA assumes that risk can be conceptualised in this way.

There is no reason why the same overall idea cannot be applied, but in a more general and qualitative way to ensure that a broad range of factors can be taken into account, rather than just those that lend themselves to quantification in financial terms. Criteria to be taken into account fall into several categories[8]:

<u>Current level of safety risk</u>

- Are the potential consequences of this event particularly severe?
- What is the level of safety risk to the public from the current arrangement from this threat?
- What is the level of safety risk to workers from the current arrangement from this threat?
- Does the risk change in the future?
- If this is an existing facility, does it meet the standards that would be required for an equivalent new facility?

<u>Other drivers for further risk reduction</u>

- Are there significant security of supply consequences for this event?
- Are there significant environmental consequences for this event?
- Are there significant reputational or other corporate reasons for wanting to reduce this risk further?
- Are external stakeholders aware of and objecting to this risk?

[8] This list of questions has been checked against the requirements contained in a range of industry and regulatory guidance material including SAFE WORK AUSTRALIA 2013. How to determine what is reasonably practicable to meet a health and safety duty, HSE. 2015. *HSE principles for Cost Benefit Analysis (CBA) in support of ALARP decisions.* [Online]. http://www.hse.gov.uk/risk/theory/alarpcba.htm. [Accessed 4 June 2015], NOPSEMA 2014. Guidance Note N-04300-GN0166 Revision 5 ALARP. National Offshore Petroleum Safety and Environmental Management Authority, UKOOA 1999. A Framework for Risk Related Decision Support. UK Offshore Operators Association, WORKSAFE VICTORIA 2011. Guidance Note, Requirements for demonstration, Advice to operators of major hazard facilities on demonstrating an ability to operate the facility safely.

What more could we do?

- How might risk be reduced further? List as many ideas as possible then assess each one, starting with the one with the likely biggest risk benefit.

Risk benefit of proposed measure

- What is the benefit in terms of safety risk to the public from the proposed measure?
- Is the risk benefit 'real' or does this measure simply shift risk to another part of the system?
- Is the proposed risk measure effective in all cases against this threat or it is designed to address only some cases?
- Is the proposed risk measure reliable in all cases against this threat?
- Is the proposed risk measure available to be used in all cases when it might be called upon?
- Is the proposed risk measure likely to be impacted by the same threat that it is designed to mitigate?
- Is the proposed risk measure a standard industry practice, or something novel?
- Is there a plan in place to monitor effectiveness etc?
- Has this proposal been benchmarked against practices of others? If so, what do others think of this proposal?
- Are there other tangible or intangible benefits of this measure?
- Are there risks associated with the proposed measure itself?

Cost of proposed measure

- What is the cost of the proposed measure (capital and operating)?
- Is this proposed measure an industry standard approach to managing this threat?
- Is the proposed measure more expensive than it would be for a similar new pipeline?
- Is the proposed measure justified on a pure cost/benefit analysis basis?

Uncertainty

- Do we understand the nature of the threat well?
- Is our risk assessment based on a comprehensive review of the history of this threat across the pipeline sector?
- Is the current and future land use / population well understood?
- Is the environment around the pipeline at this location well controlled?
- Is this scenario novel or a standard industry situation?
- Are all industry standard methods of controlling this threat already in place?
- If we are subcontracting aspects of this situation, how certain are we that those involved have the necessary expertise and have in place the systems, processes and procedures to ensure the work is carried out as we intended?
- Is there evidence that existing risk controls for this threat are effective, available when needed, reliable, will survive in an accident?
- Is there evidence that there are gaps in our knowledge about other risk controls for this threat?
- Is there significant uncertainty associated with the effectiveness of the proposed measure?

The answer as to whether or not a given measure is justified is a judgement call based on the answers to the above questions.

It is worth noting some things that are not included in the above list. Firstly, capacity to pay is not relevant. As NOPSEMA's guidance on this topic says 'The criterion is reasonably practicable not reasonably affordable: justifiable cost and effort is not determined by the budget constraints/viability of a project.' (NOPSEMA, 2014, pg 5)

Also companies sometimes try to use a 'reverse ALARP' argument to justify removing controls on the basis that the increase in risk is more than balanced by gains from reduced operational costs or increased operating profit. The legal requirement to reduce risks as low as reasonably practicable would rule out any regulator accepting a change to a less effective but significantly cheaper approach to the control of risks.

The recommended approach to ensuring and demonstrating that risks in the pipeline sector are indeed ALARP is to develop the above list of questions.

7. Case Study

The pipeline industry is increasingly encountering situations where urban development or major infrastructure developments are proposed in locations where an existing pipeline was originally designed for rural activities. The ALARP assessment questions above have been applied to some recent examples where these situations have occurred. These projects are still in process, so the case study is more focused on the process itself rather than the specifics of the individual cases.

Where a change of land use occurs around a pipeline, AS 2885 requires that a safety management study be conducted to:

i. Identify and define any new threats and consequences arising from the new development.
ii. Review the external interference protection to determine whether the minimum requirements for the revised location classification still apply where the threat profile and consequence profile has changed.
iii. Review controls for other threats that may be introduced by the development.
iv. Undertake risk assessment where required. In many cases the external interference protection for the risk assessment will not meet the minimum requirements specified in AS 2885.1 Clause 5.5.4, and so risk assessment is required. As detailed above, where risk assessment determines that risk is Intermediate a formal demonstration of ALARP is required.
v. Determine whether the provisions of AS 2885.1 Clause 4.7 regarding "no rupture" and energy release rate are met. Where rupture is rupture is credible, risk that loss of containment involving rupture must be demonstrated to be ALARP.

The examples from which the following is drawn included all of these activities.

7.1 Approach

At the highest level, the approach taken is as follows:

i. Confirm land planning and development details
ii. Confirm threats
iii. Document the answers to all of the ALARP Assessment Questions
iv. Collate and summarise information for ALARP judgement.

These steps are more likely to be iterative rather than sequential but need to be covered to provide sufficient information to support the ALARP judgement.

7.2 Confirmation of land use and threats

Confirmation of land planning and development details is necessary to both determine the threat profile which will apply in future and also the consequence of a loss of containment from the pipeline.

Threat confirmation follows from this, and to some extent is dependent on the level of detail available from confirmation of land planning and development details. Threat confirmation is important for a number of reasons.

Where the requirement for ALARP demonstration is driven by an Intermediate risk, the assumptions that underpin the risk assessment need to be confirmed. If threats are not adequately defined by current SMS, then there is potential that:

i. Threats which are not credible are carried through to risk assessment and ALARP studies.
ii. Threats which are credible but have not been identified are overlooked.
iii. Threats which are credible but are not sufficiently characterised are assessed with an inappropriate risk ranking.

This highlights the requirement that preparation for a SMS must be diligent and robust, so that there is confidence in the information and assumptions that support the risk assessment which in turn drives the requirement for the ALARP study in the first place. There can be a tendency for 5-year SMS reviews to be based on the threat profile from the previous SMS workshop (5 years ago). This can compound over time, so that the threat profile considered may be that developed for the original design (up to 20 years since the original SMS requirements in AS2885-1997). While the general threat profile may not change substantially, where this is the case it is dependent on the quality of the original design threat assessment, or the previous operational SMS review. Issues are:

- It should not be assumed that the threat profile has remained static over time.
- The engineering team responsible for the current review needs to understand and own the threat assessment.
- Threat details such as types of equipment, teeth, depth of excavation, frequency of operations, circumstances in which specific equipment is used, and third party procedures are important factors which determine the risk assessment outcome.
- Conservatism for the sake of conservatism may result in an Intermediate risk and ALARP assessment where this is not actually warranted (e.g. is a 35 tonne excavator fitted with tiger teeth truly a credible threat, or is it a convenient assumption because no one has bothered to find out?)

Recent examples of threat confirmation undertaken as part of SMS workshop review and ALARP assessment involved questionnaires, interviews and site visits with pipeline patrollers, civil contractors managing site developments, and service providers such as HDD[9] contractors and power pole installers. The questionnaires provided to pipeline patrollers ahead of a recent SMS workshop included over sixty questions which covered topics such as "when, what, where, why and how" for a number of different threat types (e.g. excavation, vertical boring, HDD), percentage breakdown of the size of equipment and tooth type, the process by which patrollers are advised of third party works on the pipeline (e.g. DBYD[10], direct contact), and the percentage of activities that are detected by patrol (i.e. DBYD has not been followed).

[9] Horizontal Directional Drilling

[10] Dial Before You Dig

For the project where a number of third parties were interviewed, the questions included:

- Are they aware of pipelines?
- What equipment do they use?
- How often do they use equipment that could penetrate the pipeline and in what circumstances?
- What do they do to identify pipelines prior to breaking ground?
- What are their general work procedures to monitor for underground assets during operations?
- How would they know if they contacted the pipeline?
- What is there general impression of how other people in their industry operates?
- What could the pipeline industry do to better alert third parties to the pipeline?

In each case, the outcomes of the detailed investigations resulted in different conclusions about the threat profile than had been recorded in the previous SMS. In one case it was concluded that tiger teeth were not used for the activities that posed an excavation threat to the pipeline. In another case, it was confirmed that the threat which drove the ALARP assessment (HDD capable of penetrating the pipeline) was only credible at one specific location where the land use had changed, while for the remaining sections the HDD bits used in the predominantly clay soil were not capable of penetrating the pipeline. This investigation also identified that use of tiger teeth on excavators was unusual but credible over the section under investigation, where this had previously been assessed as non-credible.

Given that an ALARP assessment is a potentially costly and time consuming exercise, and also that decisions made on the basis of the assessment may cost many millions of dollars, there needs to be confidence that it undertaken with good reason and its conclusions are based on the best available information. If the necessary pre-work has not been done prior to SMS and risk assessment, then the ALARP assessment will need to do this.

It is only after this information has been established that the ALARP questions can be addressed.

7.3 ALARP assessment questions

One method of documenting the assessment is to tabulate the questions and then record the answers. This may be done in a workshop setting, but experience to date indicates that it more efficient to undertake a preliminary assessment as a desktop exercise, followed by a workshop review if required.

Questions answered under the general headings of “Current level of safety risk”, “Other drivers for risk reduction” and “What more could we do?” set the context for the assessment and articulate the issues relating to the broader questions that need to be considered.

A framework for considering “What more could we do?” is provided by AS 2885.1 Clause 4.7.4:

(a) MAOP reduction (to a level where rupture is non-credible).
(b) Pipe replacement (with no rupture pipe).
(c) Pipeline relocation (to a location where the consequence is eliminated).
(d) Modification of land use (to separate the people from the pipeline).
(e) Implementing physical and procedural protection measures that are effective in controlling threats capable of causing rupture of the pipeline.

It should be noted that items (d) and (e) are particularly broad, and that many measures are likely to be available under these headings. Further, the measures may be confined to very specific locations or features, or may be applicable for the full length of the pipeline. With the proliferation of new development on the outskirts of most of our capital cities in the last few years, the industry has developed a portfolio of approaches which can be considered. These include (in no particular order):

- Wholesale or targeted slabbing
- Pre-installation of crossing points to avoid the requirement for future trenched or bored crossings
- Liaison with the planning authorities or developers at an early stage to create open space over the pipeline with bike paths, robust marker boards buried below the surface, and controlled access to the space (e.g. locked bollards)
- Increased signage
- Increased patrolling (perhaps including citizen patrols?) and surveillance (e.g. security cameras at high risk sites)

The point to note here is that a single broad brush solution is unlikely to be enough, and a suite of these measures may be need to be considered for a specific development, but identified under the general heading of “targeted protection”.

Once the risk reduction measures have been identified, the remaining questions under the headings “Risk benefit of proposed measure”, “Cost of proposed measure” and “Uncertainty” need to be answered for each measure (or suite of measures). While on the surface this is a relatively straightforward process, the requirement to develop cost estimates for the measures, and also clearly define the implications of any proposed measure may involve significant cost and time. For example, an assessment of the technical and commercial implications of MAOP reduction may require modelling and commercial assessment to determine whether there are limiting factors. Another example is that the original route of the pipeline is likely to be chosen for reasons of constructability or environmental constraints, relocation of the pipeline may not be straightforward. Major works such as pipeline relocation or replacement need to account for approvals costs and timeframes.

The process generates a lot of information. The pros and cons for each measure are very well documented, allowing assessment of the relative advantages or disadvantages of each measure. This provides the basis for an informed judgement which takes into account a broad range of factors.

7.4 Presenting results

The fact that a lot of information is generated creates the challenge of distilling and presenting the information to those required to form the judgement as to the course of action required to achieve ALARP. One approach that has been adopted[11] is to summarise the data into a matrix, using a traffic light approach to indicate the relative merit of each option under a number of key headings:

[11] This approach is based on that adopted for a recent project in which the author was a contributor. However, the approach was developed by the project team and not the author.

EXAMPLE ALARP MEASURES SUMMARY SHEET							
Details	**Safety Risk**	**Effective / Reliable**	**Industry Practice**	**Other Benefits**	**Uncertainty**	**Relative Cost**	**Summary / Comments**
Measure 1							Summary 1
Measure 2							Summary 2
Measure 3							Summary 3
Measure 4							Summary 4
Measure 5							Summary 5
Measure6							Summary 6
Measure 7							Summary 7
Measure 8							Summary 8

EXAMPLE RANKING LEGEND							
	Eliminate Risk	Totally Reliable	Standard	Significant	Not Significant	Low	
	Large Reduction	Highly Reliable	Common	Minor	Minor	Moderate	
	Small Reduction	Mostly Reliable	Uncommon	Insignificant	Moderate	High	
	No Reduction	Unreliable	Novel	Negative	major	Very High	

It is emphasised that the example above does not purport to present a standard that should be adopted by the industry. It simply provides an example of how a large amount of complex data might be presented. Issues that would need to be addressed on a project basis include whether the key headings are appropriate or sufficient, whether the key headings are equally weighted or not, and whether the ranking criteria are appropriate and consistent across the headings for any given level.

Further, this paper is deliberately not suggesting how the information should be interpreted and what measures should or should not be adopted from the example above. The point is that there is not necessarily are right or wrong answer, but rather that a number of factors need to be weighed in balance to support the decision making. This will dependent on the specific circumstances under consideration.

7.5 Observations, benefits and challenges

It should be reiterated at this point that, in the context of AS 2885, a formal demonstration of ALARP is only required under specific circumstances, and that in the vast majority of cases demonstration of compliance with AS 2885 (via documentation required to be developed in accordance with AS 2885) constitutes demonstration of ALARP (as discussed in Section 3).

Based on the experience of adopting the process suggested by this paper to conduct a formal demonstration of ALARP, the following observations are offered:

- The determination of risk benefits and costs are largely treated as separate exercises and presented separately. A formal CBA can be considered, but it is one consideration among many.
- The question "If we built this today, what would we build?" helps to provide a strong context for the proposed ALARP measures and the objectives they are designed to achieve.

- Supply, environment, reputation, regulatory, legal and corporate impacts need to be considered and documented. A number of these do not fall under the normal remit of AS 2885, but given that they influence management decision making, they provide important context. It follows that the final ALARP assessment is likely to require multi-disciplinary input.
- The questions around risk benefit and uncertainty are similarly important to help articulate a number of complex issues that need to be considered when ALARP judgements are made.
- When required by AS 2885, a formal demonstration of ALARP is most likely to require significant time and effort outside of an SMS workshop, to provide management with sufficient information to make an informed judgement regarding ALARP measures that should be adopted.
- It follows from this that the information upon which the original requirement for a formal demonstration of ALARP is initiated need to complete, current and robust. Where this is not the case, the formal ALARP assessment will need to expect time and effort to develop this information.

For the examples where this approach has been used, the chief benefits are:

- The assessment is comprehensive. The questions cover a broad range of issues necessary for ALARP demonstration.
- The assessment is systematic. The questions are designed so that important details are addressed individually and not glossed over or lost.
- The assessment is structured and provides for clear, transparent documentation of decision making.
- The process of completing the assessment tends to force a more considered assessment of all measures, and thus has the potential to identify measures (or combinations of measures) which effectively reduce risk but may not have been obvious at the outset. Used well, it can help to guard against quick dismissal or inadequate assessment of options which may turn out to be preferred.
- For these reasons, the approach suggested here serves to address the concerns of those in the industry who have used the “CBA alone” approach and found that the outcomes are intuitively unsatisfactory.

The major challenge of the approach experienced to date is that of collating and presenting a large amount of information into a succinct format which can be readily communicated to stakeholders and decision-makers, but provides sufficient detail so that informed judgements are made. It is expected that the industry will develop different ways of presenting the information as it gains experience and responds to specific project, operator and regulatory needs.

8. Conclusions and Recommendations

We have seen that ALARP has moved from a device used in civil cases to assess the need for compensation, to an overarching duty placed on those in control of hazardous facilities and activities. In this way, it provides the context for all safety-related decisions. In applying this principle, the primary aim must be to improve safety by spending necessary funds in the best way. For industries such as the pipeline sector that need permission to operate, another driver for getting ALARP decision making right is proactive regulatory compliance to ensure business risks are well managed.

We might hope that this also provides some assurance of avoidance of prosecution in the event of an accident although as Ale et al warn, ‘after an accident, and even if regulatory support for the approach to safety has been obtained a-priori, the courts can be expected to judge each case on its merits with each case turning on the facts that are unique to that particular case.‘ (2015, pg 99)

The pipeline sector has used ALARP in a narrow way as a test that applies in three specific cases. AS2885 also strongly encourages users towards cost benefit analysis as a key approach. This paper has aimed to demonstrate that the requirement to reduce risk to a level that is as low as reasonably practicable is much broader and as such requires broader thinking. Firstly, in the vast majority of cases demonstration of compliance with AS 2885 (via documentation required to be developed in accordance with AS 2885) constitutes demonstration of ALARP. Secondly, for the relatively few circumstances where a formal ALARP assessment is required, this paper has proposed a methodology which provides for consideration and documentation of the broad range of issues which need to be addressed. The case study examples show how the process can be implemented, and highlights a number of key issues that need to be considered when undertaking such a study. The resulting documentation is intended to provide sufficient information to support an ALARP judgement.

The requirement to demonstrate ALARP is a fundamental obligation under the law of the land, and so cannot be considered a distraction to the business of the Australian pipeline industry. This paper seeks to provide tangible help to the Australian pipeline industry to meet this obligation and ultimately support decisions which provide for safe and secure energy supply.

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APPENDIX 2 RICHARD MCDONOUGH CURRICULUM VITAE

Richard McDonough – Resume

Senior Risk Engineer

Overview

Qualifications

Bachelor of Engineering, Chemical, Hons IIA, University of Adelaide, 1985

CPENG, RPEQ, FS Eng (TÜV Rheinland)

Key Skills

AS 2885 SMS and requirements; Environment assessment and management; Risk assessment; Economic modeling; Regulatory approvals processes; Policy analysis and legislation development; Long-term gas supply studies and market analysis; Major Hazard Facilities Legislation and safety case principles; Reservoir engineering and simulation, reserves analysis

Experience

31 years of experience and 8 years at GPA.

Richard has skills and experience in: AS 2885 Pipeline Safety Management Studies, AS 2885 requirements for high pressure pipeline design, construction, operations and maintenance, environment assessment and management for petroleum and pipeline projects, risk assessment principles and practice, economic modeling and analysis of petroleum industry projects, environmental and technical regulatory approvals processes, policy analysis and legislation development, gas supply studies and market analysis, Major Hazard Facilities Legislation and safety case principles, reservoir engineering and simulation, reserves analysis.

Richard has worked on high level national committees addressing technical, legislative and policy issues for both government and industry. He is vice chairman of the Australian Pipelines & Gas Association's Research and Standards Committee (APGA RSC). He is a member of the Energy Pipelines Cooperative Research Centre's Research Program Committee. He was the South Australian Government's representative on the ME38 Committee responsible for Australian Standards AS 2885 Pipelines – Gas and liquid petroleum, and actively participated in the development of AS 2885.1-2007 Design and Construction and AS 2885.3-2002 Operations and Maintenance. He is currently on the APGA RSC working group / ME38-01 committee which is reviewing AS 2885.1-2012.

Richard was awarded the 2015 APGA Award for Outstanding Contribution to the Australian Pipeline Industry.

He has authored / co-authored technical papers for the Energy Pipelines Cooperative Research Centre (EPCRC), the Australian Pipelines & Gas Association (APGA), the Australian Petroleum Production and Exploration Association (APPEA), and the Society of Petroleum Engineers (SPE).

Projects

- APA Group, AGN Victoria and Southern NSW Transmission Pipelines 5 Yearly SMS, Senior Risk Engineer
- SEA Gas, SEA Gas Pipeline ALARP Review, Senior Risk Engineer
- Origin Energy / Wood Group Kenny, Halladale Black Watch and Speculant Pipeline Project, Senior Risk Engineer.
- APA Group, Parmelia Pipeline Relocation Forrestfield, Senior Risk Engineer.
- Santos, Tirrawarra to Merrimelia GRE Trunkline, Senior Risk Engineer.
- APA Group, Victorian Northern Interconnect Pipeline, Senior Risk Engineer.
- Renewal SA, Bowden Development Safety Management Study, Senior Risk Engineer.
- Santos, South West Queensland Oil Spill Risk Assessment, Senior Risk Engineer.
- SEA Gas / Origin Energy, Mortlake Pipeline 5-year Safety Management Study Review, Senior Risk Engineer.
- APA Group, Eastern Goldfields Pipeline, Senior Risk Engineer.
- APA Group, Webb Dock Safety Management Study, Senior Risk Engineer.
- Beach Petroleum, Western Oil Flowline Project, Senior Risk Engineer.
- APA Group, Roma to Brisbane Pipeline (Metro Section) 5-year Safety Management Study Review, Senior Risk Engineer.

- SEA Gas, SEA Gas Pipeline 5-year Safety Management Study Review, Senior Risk Engineer.
- Dacland Pty Ltd, Manzeene Village Development Safety Management Study, Senior Risk Engineer.
- Spie Capag / Mott McDonald / Exxon Mobil, PNG LNG Pipeline Project, Senior Risk Engineer.
- Epic Energy, Epic Energy SA Pipelines System 5-year Safety Management Study Review.
- APLNG, Gladstone Pipeline FEED Safety Management Study, Senior Risk Engineer.

Training

- Functional Safety for Safety Instrumented System Professionals - HIMA Australia Pty Ltd
- HAZOP Leader Training Course - Myrna Hepburn Pty Ltd
- Pumping Fundamentals / Advance Pumping - Strategic Achievement

Memberships

- Chartered Member - Institution of Chemical Engineers
- Registered Professional Engineer - Board of Professional Engineers of Queensland
- Member - Australian Pipelines and Gas Association (APGA)
- Deputy Chair - APGA Research and Standard Committee Executive
- Member - Energy Pipeline Cooperative Research Centre (EPCRC) Research Program Committee
- Member - EPCRC Research Program 4 Public Safety and Security of Supply Steering Committee
- Member - Standards Australia ME38-01 Committee for AS 2885 Pipelines - gas and liquid petroleum, Part 1 Design and Construction