Final Plan Attachment 8.2

Distribution Mains & Services Integrity Plan

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Prepared By:

Position	Name
Manager, Network Asset Strategy and Planning, APA	Jan Krzys

Approved By:

Position	Name
General Manager Victoria Networks, APA	Ken Hedley
Manager Operations & Engineering, AGN	Ralph Mignone

Distribution List:

Position	Name
Group Executive Networks, APA	Andrew Foley
General Manager, Victoria Networks, APA	Ken Hedley
Manager, Planning & Engineering, APA	Alex Nicol
Manager, Systems, APA	Jarrod Dunn
Manager, Field Operations and Support, APA	Robert Davis
Manager, Capital Delivery , APA	Vijay Vetrivel
Manager, Network Asset Strategy & Planning, APA	Jan Krzys
Manager Operations & Engineering, AGN	Ralph Mignone

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Executive Summary

This Victorian Distribution Mains and Services Integrity Plan (the Plan) outlines Australian Gas Networks Limited's (AGN's) approach to managing the integrity of its mains and services. This Plan describes the current risk associated with mains in AGN's Victorian natural gas distribution network (the Network), and discusses the recommended risk treatment to lower the risk rating to 'low'[1] or manage it to as low as reasonably practical (or ALARP). This document also includes relevant costing and options analysis to help inform the most prudent and efficient course of action over AGN's next (2018-2022) Access Arrangement (AA) period.

There are 10,433 kilometres of distribution mains in the Victorian Network as of 30 June 2016. It is currently forecast that at 31 December 2017, 884 kilometres of mains which can plausibly crack or break will still have a 'high' or 'intermediate' risk rating under AS/NZS 4645. Therefore, the primary focus of this Plan is how to prudently lower or manage the risk associated with these mains, while having appropriate strategies in place to manage the risk of all other mains over the long term.

The risk associated with gas distribution mains is predominantly to people. While environmental and supply risk are a consideration, the greatest hazard associated with a gas network is the potential for mains to leak or fracture, and release gas that may collect in sufficient quantities (for example in or beneath a building) and cause explosion, leading to death or serious injury.

Those mains identified to pose the greatest risk is:

- 25 kilometres of cast iron (CI)/unprotected steel (UPS) located in the Melbourne Central Business District (CBD);
- 12 kilometres of polyvinyl chloride (PVC) located in the Melbourne CBD;
- 32 kilometres of CI/UPS medium pressure trunk mains;
- 96 kilometres of CI/UPS located in high density inner-city suburbs (HDICS)[2];
- 85 kilometres of PVC located in HDICS[3];
- 11 kilometres of CI/UPS located in lower density suburbs (LDS);
- 25 kilometres of PVC located in LDS; and
- 597 kilometres of high-density polyethylene class 575 (HDPE 575) aged more than 35 years (all areas).

The most effective way of addressing the risk associated with any gas main is replacement. However, though all mains will have to be replaced at some point, it may not always be prudent to replace large volumes of gas mains in a short space of time, or during a single AA period. If AGN did so, the cost to the customer would be too great.

Therefore, we have used a combination of qualitative and quantitative assessment, including a cost impact analysis, to determine which mains should be replaced within the next AA period; which mains can be managed with risk mitigation actions; and which mains can be prudently deferred for replacement to a later AA period. Consequently it is planned that 285 kilometres of the highest risk mains be replaced or abandoned in the next AA period. This amount is comprised

[1] Using the risk rating system under AS/NZS 4646.

[2] This includes 2km which are identified as 'piecemeal' for the purpose of financial modelling

[3] Included in HDICS and LDS PVC is 12 km of 'other' short length mains (PE and Steel) which are interspersed throughout the PVC networks and which will be replaced at the same time as it is inefficient not to do so.

of 132 kilometres of CI/UPS mains, 110 kilometres of PVC mains, 10 kilometres of HDPE mains (refer to Table 1) the decommissioning/abandonment of 32 kilometres of CI/UPS Trunk.

A further 12 kilometres of trunk main construction is also proposed for the next AA period to support the existing HP network as it is extended to replace the CI, UPS and PVC networks. This brings the total proposed program to 297 kilometres.

AGN is committed to operating our Networks in a manner that is consistent with the long-term interests of consumers. To facilitate this, we have implemented a stakeholder engagement program to understand and respond to the priorities of our customers and stakeholders. This Plan, and the proposed mains replacement and monitoring elements, are consistent with stakeholder feedback that maintenance and improvement of network safety is of highest importance. Importantly, when tested, customers indicated they were prepared to pay more on their gas bill for AGN to complete this mains replacement work. Further information on our stakeholder engagement program is available in Chapter 5 of our Final Plan.

Table 1: Risk Assessment of Gas Mains Inventory at 31 December 2017

#	Material Type	Location	Pressure	Km in Network*	Risk Rating**	Treatment During Next AA Period
1	CI/UPS	CBD	Low Pressure	25	High	Proactive replacement program
2	PVC (impact modified)	CBD	Low Pressure	12	Intermediate	Continue risk mitigation activities. Reactive replacement only as required.
3	Steel	CBD	Low Pressure	7	Low	Monitor
4	CI/UPS	Trunk (primary feed to the LP network)	Medium Pressure	32	High	Proactive decommission and/or abandon program
5	CI/UPS	HDICS	Low Pressure	96	High	Proactive replacement program
6	PVC	HDICS	Low Pressure	85	High	Proactive replacement program
7	CI/UPS	LDS	Low Pressure	11	High	Proactive replacement program
8	PVC	LDS	Low Pressure	25	Intermediate	Proactive replacement program
9	HDPE 575 >35yrs[4]	All	High Pressure	597	Intermediate	Replace 7 km of oldest pipe. Assess and monitor condition. Continue risk mitigation activities.
10	HDPE 575 <35yrs[5]	All	High Pressure	2,480	Low	Replace 3 km through sample program. Monitor
11	New generation Polyethylene (PE)	All	High Pressure	4,330	Low	Monitor

Note: The kilometres of the various asset categories have been estimated based on the network mains Geographic Information System (GIS) inventory as at 30 June 2016 and forecast replacement during 2016 and 2017.
** Risk rating under AS/NZS 4645.

We consider the categories of gas mains shown as having a 'high' risk rating in Table 1 pose the greatest risk to public safety. Their high risk rating is due to a combination of factors; material type, location, pressure and age. Historical data shows that gas mains constructed from CI/UPS, PVC, and HDPE that have aged and become brittle, have a propensity to crack, and that the frequency of cracking increases as the pipes age.

For example, Jacobs comments:

> *"Based on a number of studies... the [United Kingdom] UK Health Safety Executives (HSE) determined that the risk posed by cast and ductile iron, including the unpredictable nature of that risk and inability of well-intentioned risk management*

[4] Includes 67 kilometres in AGN's Albury network.
[5] Includes 157 kilometres in AGN's Albury network.

> *programs to effectively reduce that risk, could no longer be accepted. The UK Iron Main Replacement Program (IMRP) was introduced in 2002 to address societal concerns by dealing directly with the inherent risk posed by iron mains (both cast and ductile iron).”*[6]

CI / UPS Mains

CI/UPS mains in particular have a history of fracture and failure in gas distribution networks in Australia and overseas.

> *“In the UK, policy makers determined that cast iron mains posed a ‘societal risk’ meaning a hazard that impacts society at large, such as a risk of multiple fatalities from a gas explosion. In both the [United States] US and the UK, the qualitative case was built from a detailed review of a series of incidents that have occurred on iron mains and from a review of frequency and nature of breaks, leaks, and corrosion (failure modes) found on iron networks that can, under the certain conditions, result in an incident.”*[7]

CI/UPS were the first materials used to construct the network, meaning much of it is located in the Melbourne CBD and older suburbs that were developed as the city grew. This means much of the CI/UPS network is in densely populated areas that contain buildings with below-ground spaces, in which escaped gas has the potential to collect. As a result, the consequence of a risk event (such as an explosion) in these areas has a greater potential to cause serious harm and/or loss of life.

Due to this combination of age, propensity for cracking, and proximity to buildings and people, AGN has assessed all CI/UPS mains in the network at a ‘high’ risk rating. Though the likelihood of a gas explosion occurring and causing major harm is not high, (indeed, the frequency is ranked ‘occasional’ under the AS/NZS 4645 risk framework), the consequences of the event are so severe that AGN considers a prudent network operator would seek to remove all CI/UPS mains from the Network as quickly and efficiently as practicable.

PVC Mains

A similar risk to that of CI is posed by PVC mains in the network. Though typically not in as poor condition as CI/UPS mains, many PVC mains were installed over 35 years ago and have begun to fail by way of cracking and joint failure.[8] PVC in the Network is located in high density inner-city suburbs, and in low density suburbs.

A different grade of PVC, more resistant to impact (sometimes referred to as “impact modified PVC”), is installed in the Melbourne CBD. Though PVC mains in the CBD are in close proximity to people and buildings, this grade of PVC is of higher density, meaning it is more robust and less susceptible to impact failure than PVC used elsewhere. As a result, we consider the likelihood of a failure that leads to an explosion that causes major harm in the CBD to be ‘hypothetical’ rather than the ‘unlikely’ rating given for PVC in the high density inner city suburbs.

Current evidence supports our experience that standard PVC (installed in HDICS and LDICS) is more susceptible to cracking than impact modified PVC. Taking the same factors into consideration

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6 Jacobs, “*Mains Replacement Program Review*”, January 2016, pg. 9. Provided as Attachment 8.11 to AGN’s Revised SA AA Proposal.

7 Jacobs, “*Mains Replacement Program Review*”, January 2016, pg. 9. Provided as Attachment 8.11 to AGN’s Revised SA AA Proposal.

8 Leaks on PVC have been relatively constant over the last 10 years, with approximately 50 to 60 incidents per year being recorded, despite the inventory of PVC decreasing over time.

as were applied to CI/UPS, we have therefore rated PVC mains in high density inner-city suburbs as 'high' risk, with those located in the CBD and lower density suburbs as 'intermediate' risk.

We have rated the likelihood of an explosion on the PVC network in lower-density suburbs causing major harm as 'remote'. While the 25 kilometres of PVC used in lower density suburbs is of the same grade as that used in high density inner-city suburbs, the proximity to large populations and buildings with underground spaces is considerably less, meaning the likelihood of a 'gas in building' explosion is lower.

Notwithstanding the risk issues associated with PVC it is more efficient to replace these mains as part of the broader CI/UPS replacement program. Typically PVC mains are interspersed with CI/UPS within low pressure networks. Leaving 'pockets' of PVC in a suburb that is due to be replaced, would require the whole of the mains and services in that suburb to be replaced size for size by direct burial, rather than by the much cheaper and more efficient insertion method.

HDPE

Early generation high density PE (HDPE 575) has been shown to have a propensity for slow crack growth (SCG) at sites where it has been subjected to 'local' stress, particularly from past squeeze-offs. The high gas pressure within PE mains also contributes to the likelihood of failure. The sudden and unpredictable failure of HDPE 575 that has become brittle and susceptible to crack failure presents a similar risk as that associated with CI.

Crack failures associated with HDPE 575 laid during the 1970s and 1980s in AGN's South Australian Network have resulted in three major gas in building explosion incidents since 2007. This raises concerns that this material could pose a risk in other networks, particularly where it is older than 35 years. Therefore, AGN has rated mains older than 35 years as 'intermediate' risk.

Risk Treatment

For all mains rated as 'high' risk, replacement is the only treatment that can reduce the risk rating to 'low'. While continuing mitigation activities such as leak surveys, pressure monitoring, and odorisation can help manage the risk up until mains replacement can occur, they will not reduce the risk to 'low', as required by AS/NZS 4645 and the Safety Case.[9] Therefore, it is planned to replace all CI/UPS pipe, plus PVC mains located in high density inner-city suburbs (categories #1, 4, 5, 6, and 7 in Table 1 above) during the next AA period.

The treatment of mains ranked as an 'intermediate' risk rating will vary depending on the particular characteristics of the mains. The 25 kilometres of PVC mains in the lower density suburbs will be replaced as part of the CI/UPS replacement program in these areas as it is efficient to replace the interspersed PVC whilst crews are replacing the CI and UPS. The 'intermediate' risk mains in the CBD will be prudently managed during the next AA period using the suite of risk mitigation activities currently being deployed on the Network until such time that they become redundant as a result of gas supply to the CBD being transferred to the high pressure system. Asset condition will continue to be monitored over the coming years, and the risk rating may be adjusted accordingly as new data becomes available.

The HDPE 575 mains aged greater than 35 years (category 9 in Table 1) are also rated as 'intermediate'. There are 597 kilometres of HDPE mains more than 35 years old in the Network. While the most effective solution is to replace all of these mains as quickly as possible, it is considered prudent to improve our understanding of the HDPE material properties and condition before undertaking wholesale replacement. Data on the condition of these assets is limited, and though there have been no major incidents related to Victorian HDPE mains to date, experience with the same material in AGN's South Australian network suggests HDPE has a propensity for cracking and sudden failure.[10]

Therefore, AGN will undertake a sample program of HDPE mains (3 kilometres across the Network) and replace those mains that are considered to have reached the end of their technical life (estimated to be 50 years) during the next AA period (7 kilometres). The information gleaned from investigations on pipe material, condition and cracking characteristics will inform the most efficient replacement profile for the remaining inventory of these assets.

No risk treatment other than ongoing monitoring is required for mains ranked 'low' risk (categories #10 and 11 in Table 1).

Cost and Options Considered

The cost of the proposed program discussed above is estimated at $147 million, which equates to $3.85 per customer on average. The benefits to the customer of undertaking this program over the next AA period would be to reduce the associated risk rating from 'high' or 'intermediate' to 'low' by the end of 2022.

A total of 696 kilometres of mains are expected to be replaced over the current (2013 to 2017) AA period. This includes 508 kilometres replaced at the end of 2015, and a total of 188 kilometres of renewal is planned over the period 2016 and 2017.

The cost of undertaking replacement will be efficient and at least cost because of AGN's procurement processes and competitively tendering of replacement work.

[9] The Safety Case is a regulatory obligation of the distribution business, and specifies that one of the requirements of a compliant Safety Case is compliance with all applicable Australian Standards.

[10] Three major gas in building explosions have occurred in the South Australia network since 2007.

We have considered several other risk mitigation and mains replacement scenarios. The most conservative scenario is to only replace the high risk CI/UPS mains (177 kilometres) over the next AA period, while the most aggressive scenario considers replacing all 'high' and 'intermediate' rated mains (896 kilometres). The replacement scenarios are summarised in Table 2.

Table 2: Cost and Risk Outcomes of Scenarios ($2016)

Scenario	Description	Km to be Replaced in Next AA	Risk Rating at the end of the 2018 AA Period	Capital Expenditure ($million)	Cost per Customer Per Annum
Replace all 'high' risk CI and UPS mains	Replace all CI and UPS mains	177	High	[redacted]	[redacted]
Replace all 'high' risk mains	Replace all CI and UPS mains plus PVC in HDICS	262	Intermediate	[redacted]	[redacted]
Replace all 'high' risk mains and all 'intermediate' risk PVC mains	Replace all CI, UPS and PVC mains	299	Intermediate	[redacted]	[redacted]
Replace all 'high' risk mains and 'intermediate' risk PVC mains in LDS	Replace all CI, UPS and PVC mains except PVC mains in CBD	287	Intermediate	[redacted]	[redacted]
Replace all 'high' and 'intermediate' risk mains	Replace all CI, UPS, PVC and HDPE 575 >35 years old	896	Low	[redacted]	[redacted]
PREFERRED OPTION: Replace all 'high' risk mains and achieve ALARP or 'low' for all other mains	Replace all CI, UPS, and PVC except PVC in CBD plus 7km of HDPE 575> 50 years old and 3km HDPE sample program	297	Intermediate (ALARP)	[redacted]	[redacted]

On balance, we consider the amount of 297 kilometres would represent a prudent and efficient level of replacement. The estimated cost of the program reflects the lowest cost of achieving the risk reduction required by AS/NZS 4645. We believe we can mitigate the risk associated with the remaining 599 kilometres of mains by continuing regular leak surveys, monitoring odorant levels, and expediently responding to and repairing leaks when they occur.

We will also continue to monitor and sample the condition of HDPE 575 pipes (which material has had a history of catastrophic failure in South Australia) to identify the most prudent time to replace these particular mains and the action that can be taken to mitigate the risk.

We consider this represents a prudent and efficient replacement program. It will result in a small cost to customers, who, together with the community, will benefit from the highest risk mains being removed from the Network. We have the capacity to undertake this work over the next AA period, as shown by the fact we have replaced nearly 700 kilometres of mains over the current AA period.

This Plan is consistent with AGN's:

- current Safety Case submitted to (and approved by) Energy Safe Victoria (ESV) in 2010; and
- revised Safety Case (which includes this document) submitted at the end of 2016, for consideration by the ESV.

This mains replacement program best meets the National Gas Objective (NGO) as it addresses the inherent Network risk, using a combination of risk treatments that minimises asset replacement in the short term, and allows for prudent asset management over the long term. Customers will benefit from a safer network with minimal cost impact.

1. Purpose

The purpose of this Plan is to document the basis for managing the integrity of distribution mains and services in AGN's Victorian gas distribution network. It outlines the timing, scope and cost of proposed risk mitigation strategies, including mains and services replacement.

This Plan considers risk mitigation activities (such as leak surveys and piecemeal repair) and balances these against proactive block replacement programs. Recommended risk treatments are based on an assessment of the asset condition and risks associated with mains and services, utilising the qualitative risk assessment framework provided by AS/NZS 4645.

This plan will be reviewed annually as part of the annual asset management planning process. That review takes into account any new information/data, and will inform future strategy and planning.

This Plan is an input into the Asset Management Plan (AMP) which is also developed each five years and reviewed annually. The asset management cycle is illustrated in Figure 1.1.

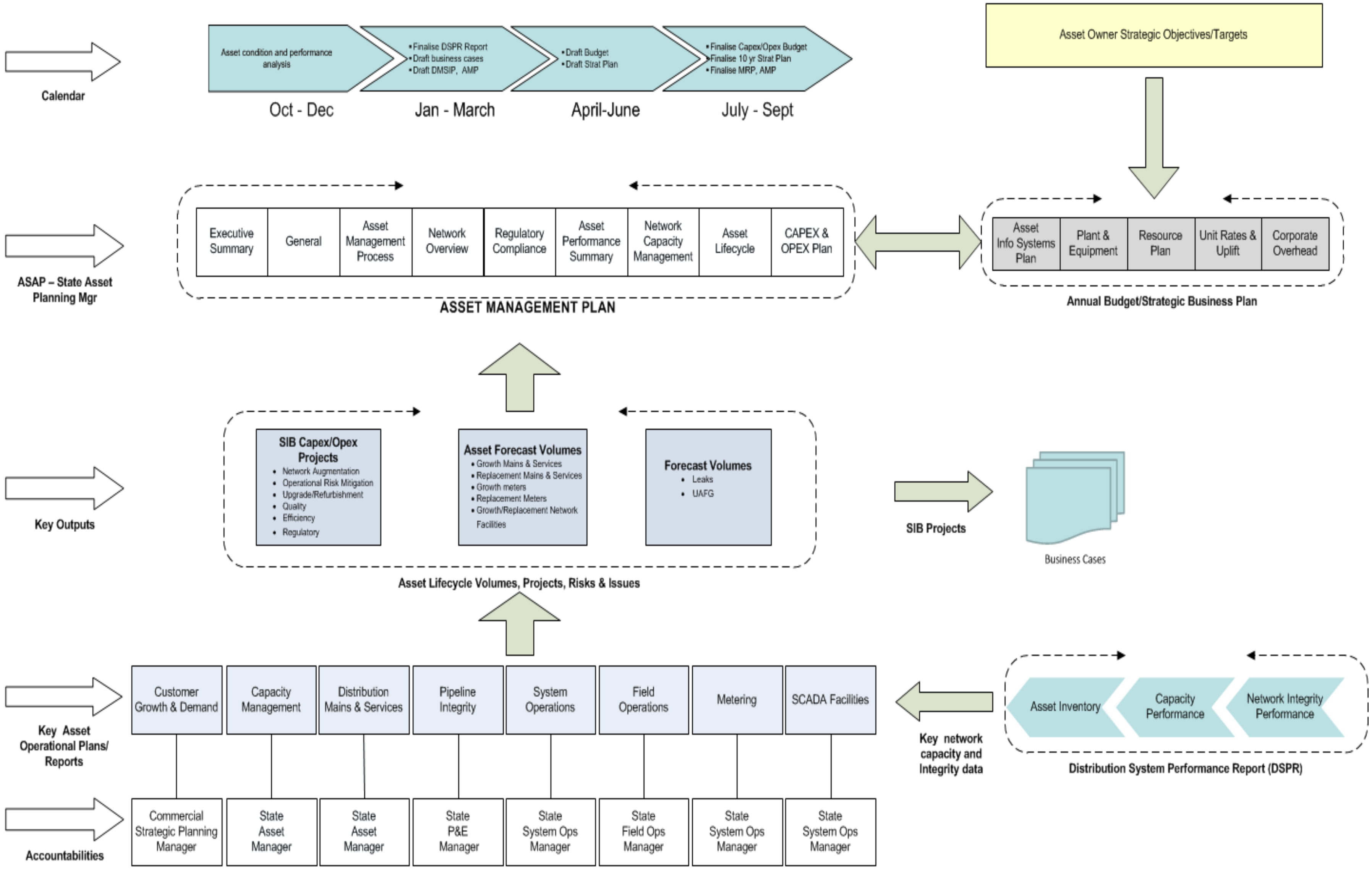
The modelling and resultant forecasts in this Plan are based on trends and assumptions concerning the rate of deterioration of pipework. The purpose of the modelling and quantitative outputs is not to accurately forecast annual increments or decrements in parameters, but to provide indications of likely outcomes, and relative outcomes, given available information and reasonable assumptions.

To develop this Plan, AGN has:

- considered the framework for managing the integrity of mains, including corporate objectives, regulatory obligations, good industry practice and Australian Standards;
- reviewed asset integrity performance indicators to identify any emerging issues and the effectiveness of existing activities;
- undertaken a risk assessment based on integrity performance, available information/data, engineering experience, and consideration of new and emerging issues;
- identified options to mitigate risks, including the cost and effectiveness of the options compared to the risk reduction; and
- identified the required activities to prudently and efficiently manage the risks going forward, which incorporates the next AA period.

This process is outlined in the remaining sections of this Plan.

Figure 1.1: Asset Management Cycle



2. Background

2.1. Regulatory Environment

AGN's primary obligations in relation to asset management and safety are contained in the

- Gas Safety Act 2001 (Vic) and accompanying regulations; and
- Occupational Health and Safety Act 2004 (Vic).

The National Gas Law (NGL) and National Gas Rules (NGR) contain obligations in relation to pipeline safety duty as well as to ensure efficient investment, use, operation and management of assets and services.

In addition, AGN's approach to managing risks on the Network is consistent with AS/NZS 4645 (specifically the risk framework and assessment contained in Appendix C) and AS/NZS ISO 31000. These standards provide guidance on the principles and processes for managing risks and a framework for assessing and mitigating risk.

In summary, under the legislation, AGN has an obligation to provide services in a manner that minimises hazards and ensures the safety of its workers and the community.

These regulations are discussed in more detail in Section 3.

2.2. Network Composition

The following table summarises the inventory of distribution mains within AGN's Victorian distribution networks as at 30 June 2016.

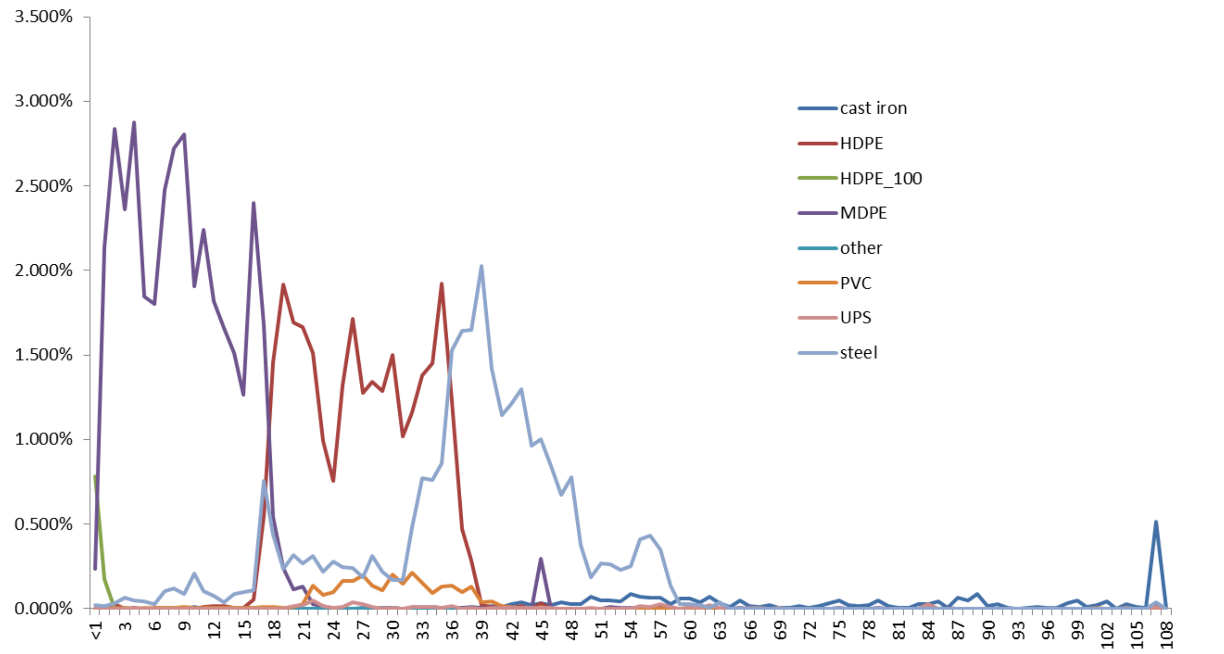
Table 2.1: Victoria Network Mains Inventory[11]

	Victoria Distribution Mains - kilometres							
Network	**MDPE**	**HDPE 575**	**HDPE 100**	**CI**	**PVC**	**UPS**	**SP**	**Total**
LP	1.6	0.3	0.1	168.8	187.3	18.4	18.8	**395**
MP	22.2	8.0	0	31.5	0	1.7	25	**88**
HP	3902	2853	373.9	0.0	0.4	0.0	2821	**9950**
Total	**3,925**	**2,861**	**374**	**200**	**188**	**20**	**2,864**	**10,433**

[11] This inventory excludes Mildura, which is managed out of South Australia, and the AGC network. For the sake of completeness, Mildura has 260km distribution network and AGC has 757 km of distribution network. Both operate at High Pressure.

The chart below shows the Victorian network's age profile by material, as a percentage of the total length of the Network.

Figure 2.1: Victorian Network Age Profile by Material



The weighted average age of CI and UPS mains is 68 and 42 years respectively, down from 72 and 54 five years ago and in line with the program targeting material in the worst condition which is usually the oldest mains. Typically CI and UPS mains are considered to be due for replacement once they reached approximately 60 years and 45 years respectively.

Approximately 26% of the CI mains are more than 80 years old, down from 30% five years ago.

There is about 3,000 kilometres of HDPE 575 the oldest material is now approaching 50 years of age. While the incidence of crack failures are relatively low, with no major incidents recorded to date, investigations are underway to determine the effects of age, environmental and degradation factors on the residual life of HDPE 575 in AGN's Victorian Networks.

Recent experience in AGN's South Australian network with sudden crack failures of HDPE 575 has highlighted that there may be an emerging integrity issue with HDPE 575 mains in Victoria, particularly as mains approach a life of 50 years. This is discussed in more detail in Section 4.2.6.

There is approximately 1,300 kilometres of HP cathodically protected steel pipe in the Network that is of the older coal tar enamel coated type. Indications are that the coating may be deteriorating, as evident in the increase in current required to maintain adequate voltage potentials, with potential for significant corrosion. Experience elsewhere has shown that corrosion underneath coal tar coatings can be extensive, particularly in coastal environments. The condition of these mains is currently under investigation with any changes to the integrity management to be incorporated into the next revision of this Plan.

2.3. Current Access Arrangement

The key mains integrity activity in the current (2013-2017) AA period is a mains replacement program approved by the AER, totaling 696 kilometres. Progress over the first three years has been ahead of schedule by a cumulative 97 kilometres (refer Table 2.2). Planned replacement for

2016 and 2017 will result in a replacement of 696 kilometres over the current period, consistent with the approved volumes.

The table below summarises progress to date and the forecast for the remaining two years.

Table 2.2: Allowance Replacement Performance

	Current AA Period Mains Replacement - kilometres					
	2013	2014	2015	2016	2017	Total
Allowance	195	172	148	91	90	696
Actual/Forecast	195	171	151	94	85	696
Annual Variance	0	(1)	3	3	(5)	0
Cumulative Variance	0	(1)	2	5	0	0

The program's objectives were (and remain) to reduce risk and improve supply reliability to gas consumers by replacing ageing CI and UPS mains and services. As discussed in Section 4 of this Plan, the objectives are being achieved.

2.4. Next Access Arrangement

There are 10,433 kilometres of mains in the Network as at 30 June 2016. It is forecast that at 31 December 2017, 884 kilometres of mains will remain with a 'high' or 'intermediate' risk rating (under Australian Standard AS/NZS 4645). Therefore, the primary focus of this plan is how to prudently lower or manage the risk associated with these mains, while having appropriate strategies in place to manage the risk of all other mains over the long term.

The key elements of the replacement program over the next AA period are:

1 Replacement of all LP CI and UPS mains within the Melbourne CBD;

2 Decommissioning or replacing all remaining MP CI and UPS mains;

3 Replacement of all remaining LP CI, UPS and PVC mains outside the Melbourne CBD;

4 Replacing HDPE 575 mains exceeding a 50 year life; and

5 Removing and replacing a small sample of HDPE 575 mains to establish the residual life and future integrity management strategies.

In total, about 285 kilometres of 'high' and 'intermediate' risk mains are planned to be replaced or abandoned and a further 12 kilometres of trunk mains constructed over the next regulatory period. Refer to Section 8.2 for a breakdown of asset category volumes, costs and schedule.

3. Relevant Obligations and Standards

In providing distribution services, AGN aims to achieve its corporate objectives, deliver on its business plan and comply with its obligations. AGN's corporate objectives include the safe distribution of gas, which entails maintaining the integrity of distribution mains and services to minimise safety and supply risks. This section describes the relevant legislative framework governing AGN's obligations, and how these requirements are incorporated into the approach and processes for managing mains integrity.

The primary obligations in relation to asset management and safety are contained in the Gas Safety Act 2001 (Vic) and accompanying regulations and the Occupational Health and Safety Act 2004 (Vic). Under the legislation, AGN has an obligation to minimise hazards and ensure the safety of its workers and the community. The NGL and NGR contain obligations in relation to pipeline safety duty as well as to ensure efficient investment, use, operation and management of assets.

AGN's approach to managing risks on the Network is consistent with AS/NZS 4645 and the risk framework and assessment contained in Appendix C of that standard, including AS/NZS ISO 31000. These standards provide guidance on the principles and processes for managing risks and a framework for assessing and mitigating risk.

3.1. Gas Safety Act 1997 (Vic)

The *Gas Safety Act 1997* is the primary regulatory instrument in respect of AGN's obligations regarding gas safety.

According to Section 1, the purpose of the *Gas Safety Act 1997*:

> *"…is to make provision for the safe conveyance, sale, supply, measurement, control and use of gas and to generally regulate gas safety."*

Under section 32, AGN has a general duty to

> *"… manage and operate each of its facilities to minimise as far as practicable –*
>
> *(a) the hazards and risks to the safety of the public and customers arising from gas; and*
>
> *(b) the hazards and risks of damage to property of the public and customers arising from gas; and*
>
> *(c) the hazards and risks to the safety of the public and customers arising from –*
>
> *(i) interruptions to the conveyance or supply of gas; and*
>
> *(ii) the reinstatement of an interrupted gas supply.*
>
> *Penalty: In the case of a natural person, 300 penalty units*
>
> *In the case of a body corporate, 1500 penalty units"*

What is 'practicable' is defined in section 3 as:

> *"practicable in sections 32, 33, 61, 62 and 63 means practicable having regard to–*
>
> *(a) in sections 32, 61, 62 and 63 the severity of the hazard or risk in question; and*

...

(c) the state of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and

(d) the availability and suitability of ways to remove or mitigate the hazard or risk; and

(e) the cost of removing or mitigating the hazard or risk."

Under section 37, AGN is required to provide a 'safety case' with respect to its facilities. The Safety Case must be submitted to ESV for approval. The Safety Case outlines how AGN proposes to comply and demonstrate compliance with its obligations.

Section 37(2) requires that the safety case for a facility must –

"(a) be in writing; and

(b) in accordance with the regulations, specify the safety management system being followed or to be followed by the gas company –

(i) to comply with the gas company's duties under division 1; and

(ii) in relation to any other matters relating to the safe conveyance, supply, sale, measurement or control of gas that are prescribed."

If AGN fails to comply with its approved Safety Case, then AGN will be in breach of section 44(2) of the *Gas Safety Act 1997*. Such a breach exposes AGN to a penalty of 1500 penalty units[12] ($227,505). However, AGN's driver for compliance with the safety case is to ensure the safety of the community and its employees.

The prescribed content of a gas safety case is set out in the *Gas Safety (Safety Case) Regulations 2008*. Regulations 25 and 26 require a gas safety case to include a formal safety assessment and a safety management plan:

"25 Formal safety assessment

(1) A safety case must contain a formal safety assessment.

(2) The formal safety assessment for a facility must be consistent with the facility description for the facility and must provide—

(a) a description of the methodology used and investigations undertaken for the formal safety assessment; and

(b) an identification of hazards having the potential to cause a gas incident; and

(c) a systematic assessment of risk, including the likelihood and consequences of a gas incident; and

(d) a description of technical and other measures undertaken, or to be undertaken, to reduce that risk as far as practicable.

26 Safety management system

(1) A safety case must specify the safety management system followed or to be followed in relation to the facility.

[12] Each unit is $151.67, so 1500 units represents $227,505.

> (2) *The safety management system must contain the information specified in Division 5."*

Under regulation 30 of the *Gas Safety (Safety Case) Regulations 2008*, the safety management system must specify the procedures and the asset management plan that are used or to be used by the gas company to ensure that the design, construction, commissioning and installation, operation, maintenance and decommissioning of the facility and any modification of the facility:

> *"(a) is adequate for the safety and safe operation of the facility; and*
>
> *(b) is adequate for the safe and reliable conveyance and supply of gas; and*
>
> *(c) is adequate for ensuring the quality of gas conveyed or supplied;*
>
> *(d) takes into account the results of the formal safety assessment for the facility."*

In summary, the Gas Safety Act 1997 and regulations under it create two principal duties relevant to managing the safety and supply risks of mains and services:

- First, to assess and manage the risks and the likelihood that a gas incident may result from the condition and utilisation of a main; and
- Second, to do what is practicable to minimise hazards and risks to the public, customers and their property. This duty includes having a system in place to identify the most efficient and effective risk mitigation option including replacing any mains that cause a risk or hazard.

Failure to comply with the *Gas Safety Act 1997* can lead to the imposition of financial penalties.

In addition, clause 9 of AGN's Gas Distribution Licence issued under the *Gas Industry Act 2001* requires AGN to comply with all applicable laws (which include the *Gas Safety Act 1997*). Ultimately failure to comply with AGN's licence, if not remedied, could lead to revocation of that licence (see clause 3 of the Distribution Licence and section 53 of the *Essential Services Commission Act 2001*).

AGN's current Safety Case was submitted to Energy Safe Victoria in 2010. A revised Safety Case is to be submitted by the end of 2016.

3.2. Occupational Health and Safety Act 2004

In addition to its safety obligations under the Gas Safety Act 1997, AGN has obligations under the Occupational Health and Safety Act 2004 to ensure the safety of its workers and the community.

Section 21(1) of the Occupational Health and Safety Act 2004 provides:

> *"(1) An employer must, so far as is reasonably practicable, provide and maintain for employees of the employer a working environment that is safe and without risks to health.*
>
> *Penalty: 1800 penalty units for a natural person;*
>
> *9000 penalty units for a body corporate."*

AGN's approach to ensuring the safety of its workers (and the community) is outlined in the Safety Case and incorporated in the procedures and practices adopted in operating and maintaining the network. These are captured in the Asset Management Plan and supporting plans and reports outlined in Figure 2.1.

While section 21(1) is limited in its scope to workers, section 23(1) imposes a general duty on an employer to ensure that persons other than an employer's employees are not exposed to risks to their health or safety arising from the conduct of the undertaking of the employer.

Section 23(1) provides:

"(1) An employer must ensure, so far as is reasonably practicable, that persons other than employees of the employer are not exposed to risks to their health or safety arising from the conduct of the undertaking of the employer.

Penalty: 1800 penalty units for a natural person;

9000 penalty units for a body corporate"

Section 20 defines 'ensuring' health and safety and provides:

"(1) To avoid doubt, a duty imposed on a person by this Part or the regulations to ensure, so far as is reasonably practicable, health and safety requires the person—

(a) to eliminate risks to health and safety so far as is reasonably practicable; and

(b) if it is not reasonably practicable to eliminate risks to health and safety, to reduce those risks so far as is reasonably practicable.

(2) To avoid doubt, for the purposes of this Part and the regulations, regard must be had to the following matters in determining what is (or was at a particular time) reasonably practicable in relation to ensuring health and safety—

(a) the likelihood of the hazard or risk concerned eventuating;

(b) the degree of harm that would result if the hazard or risk eventuated;

(c) what the person concerned knows, or ought reasonably to know, about the hazard or risk and any ways of eliminating or reducing the hazard or risk;

(d) the availability and suitability of ways to eliminate or reduce the hazard or risk;

(e) the cost of eliminating or reducing the hazard or risk."

AGN's approach to identifying and managing safety risk is consistent with AS/NZ ISO 31000 as outlined in section Risk Management Standards.

3.3. National Gas Law

The NGL plays an important role to ensure AGN's approach to manage integrity of mains and services is efficient as well as reinforcing the duties to provide services in a safe and effective manner. The NGO under the NGL provides:

> *"The objective of this Law is to promote efficient investment in, and efficient operation and use of, natural gas services for the long term interests of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas."*

The focus of the NGO is on the long term interests of consumers with respect to price, quality, safety, reliability and security of supply. This Plan facilitates this outcome by ensuring that the system and approach to managing supply and safety risks effectively identifies and mitigates these risks in the most efficient way.

The NGL also outlines the role of the AER in ensuring that the proposals and outcomes of gas distribution businesses will or are likely to contribute to the achievement of the NGO. The AER must also take into account the revenue and pricing principles under section 28(2) of the NGL when exercising a discretion in approving or making those parts of an AA relating to a reference tariff.

This ensures that the ability for a gas distribution business to recover the cost of efficient and effective risk management practices so as to not put at risk the implementation of effective risk management practices. In the context of this Plan the most relevant revenue and pricing principle is section 24(2) of the NGL, which provides:

> *"A service provider should be provided with a reasonable opportunity to recover at least the efficient costs the service provider incurs in—*
>
> *(a) providing reference services; and*
>
> *(b) complying with a regulatory obligation or requirement or making a regulatory payment."*

Section 6 of the NGL also includes a "pipeline safety duty" which is in turn defined in section 2 of the NGL as:

> *"pipeline safety duty means a duty or requirement under an Act of a participating jurisdiction, or any instrument made or issued under or for the purposes of that Act, relating to—*
>
> *(a) the safe haulage of natural gas in that jurisdiction; or*
>
> *(b) the safe operation of a pipeline in that jurisdiction;"*

There are several pipeline safety duties arising from the *Gas Safety Act 1997* and the *Occupational Health and Safety Act 2004* requiring AGN to implement risk mitigation activities such as mains replacement. They are:

- Section 32 of the *Gas Safety Act 1997* which requires AGN to operate and manage its facilities to minimise as far as is practicable hazards and risks to customers and the public and the property of customers and the public;
- Section 37 of the *Gas Safety Act 1997* and corresponding regulations 25, 26 and 30 of the *Gas Safety (Safety Case) Regulations* which requires AGN to have certain management plans in place (as part of its safety case) to ensure the safe operation of its facilities; and

- the *Occupational Health and Safety Act 2004* which requires AGN to ensure so far as is reasonably practicable that the health of workers, and any other person who may be affected by AGN's business undertaking, is not put at risk.

These duties support AGN's risk treatment activities.

3.4. National Gas Rules

The NGR impose requirements on a gas distribution business to ensure that its asset management strategies and plans are efficient. In order to recover the efficient cost of providing services, the NGR provides for the AER to assess whether the expenditure required complies with the capital and operating expenditure criteria. Those criteria require that expenditure must be such as would be incurred by a prudent service provider acting efficiently, in accordance with accepted good industry practice, to achieve the lowest sustainable cost of delivering pipeline services[13]. In addition, capital expenditure must also be justified under NGR 79(2) as follows:

(a) the overall economic value of the expenditure is positive; or

(b) the present value of the expected incremental revenue to be generated as a result of the expenditure exceeds the present value of the capital expenditure; or

(c) the capital expenditure is necessary:

(i) to maintain and improve the safety of services; or

(ii) to maintain the integrity of services; or

(iii) to comply with a regulatory obligation or requirement; or

(iv) to maintain the service provider's capacity to meet levels of demand for services existing at the time the capital expenditure is incurred (as distinct from projected demand that is dependent on an expansion of pipeline capacity); or

(d) the capital expenditure is an aggregate amount divisible into 2 parts, one referable to incremental services and the other referable to a purpose referred to in paragraph (c), and the former is justifiable under paragraph (b) and the latter under paragraph (c)."

AGN's approach to managing mains and services integrity includes an assessment of options available to manage risk and ensure that the most efficient option is chosen and delivered at least cost. AGN has adopted the framework of AS/NZ ISO 31000 to guide this process.

3.5. Risk Management Standards

AGN manages the integrity of its mains and services and the arising safety and supply risks consistent with the relevant standards for managing risks on gas distribution networks. AS/NZS 4645.1:2008 Gas distribution networks Part 1: Network management (AS/NZS 4645) is the standard that applies to the management of gas distribution networks in Australia. This standard prescribes a risk management approach in accordance with AS/NZS 4360 (Risk Management). Risk management standard AS/NZS 4360 was superseded by AS/NZS ISO 31000 in 2009 (AS/NZS ISO

[13] NGR 78(1)(a) and NGR 91.

31000). AS/NZS ISO 31000 outlines the process that should be adopted by a business that includes:

- communication and consultation with external and internal stakeholders during all stages of the risk management process;
- the internal and external environment in which the organisation seeks to achieve its objectives is to be assessed;
- risk assessment is the overall process of risk identification, risk analysis and risk evaluation;
- risk treatment involves selecting one or more options for modifying risks, and implementing those options;
- there should be planned monitoring and review as part of the risk management process; and
- risk management activities should be traceable.

The risk analysis process under AS 31000 may be undertaken with varying degrees of detail, depending on the risk, the purpose of the analysis and the information, data and resources available. This standard provides a framework for considering, assessing, rating and mitigating risks.

This standard is general in nature and so AGN has applied the guidance contained in Appendix C of AS/NZS 4645 to consider the consequence and frequency of a risk event to inform a rating system and risk treatment options.

AS/NZS 4645 requires that all actions and activities not unduly expose personnel, the public or the environment to unacceptable risks. Measures to mitigate those risks are to be identified, reviewed and documented. The areas to be considered include:

- safety of the public (including consumers);
- safety of personnel working on the gas distribution network;
- integrity of the network;
- minimisation of environmental impacts; and
- protection of property.

This framework provides for circumstances where the cost of mitigating risk is disproportionate to the impact on the risk when a risk is rated as ‘intermediate’. Where this occurs and the costly mitigation activities are not undertaken, a business is able to determine the risk to be ‘as low as reasonably practical’ (ALARP).

4. Network Condition and Integrity

This section provides an overview of AGN's network as well as the network condition and integrity and performance indicators used to assess these factors and identify appropriate actions and plans.

4.1. Network Overview

The Victorian networks contain about 10,433 kilometres of mains composed of various pipe materials and pipe sizes ranging from 15 mm to 900 mm.

There are over 650,000 inlet services connecting the main to customer meters. The service comprises the service pipe and fittings with transition from the buried service to the above-ground meter via a metallic service upstand, on which an isolation valve is installed so that supply can be shut off in an emergency.

The pressure classes within the network are classified into high-pressure (HP), medium-pressure (MP) and low-pressure (LP) tiers. The minimum allowable operating pressure for each tier set out in the Victorian Gas Distribution System Code. Table 4.2 below summarises the operating pressure ranges of the various pressure tiers.

Table 4.1: Operating Pressure of Mains

Pressure	Minimum Allowable Operating Pressure	Maximum Allowable Operating Pressure
High pressure	140	500
Medium pressure	15	210
Low pressure	1.4	7

4.2. Mains Condition

Mains performance and network integrity is reviewed annually and reported in the Distribution System Performance Review (DSPR).

Key integrity indicators include:

- *leaks* – leaks indicate a failure of pipe integrity. Leaks are detected by regular leak surveys or through public reporting. Leak numbers and leak rate (number of leaks per kilometre) provide an indicator of the integrity of mains;
- *cracks or breaks* – a sub-category of leaks. Cracks or breaks have been usually associated with CI mains, however PVC and HDPE 575 mains also have a propensity, albeit lower, to crack or break. Unlike small leaks from joints, these types of failures can result in a sudden unpredictable large gas release and as such present a public higher risk;
- *water in mains* – water in main incidents are indicative of the integrity of LP networks. Water ingress occurs when ground water head (pressure) is greater than that of the pressure inside the pipe entering through corrosion pinholes, cracks, or poor sealing joints.

- *Unaccounted for Gas (UAFG)* – UAFG is the difference between gas metered entering the network and the metered volume delivered to customers. UAFG has a number of contributing factors, including metering accuracy, fugitive emissions (leaks from the network), administrative errors and theft. UAFG is sometimes used as a proxy measure for the network condition (how 'leak tight' the network is), but this is only valid where the level of UAFG is relatively high compared to industry norms.

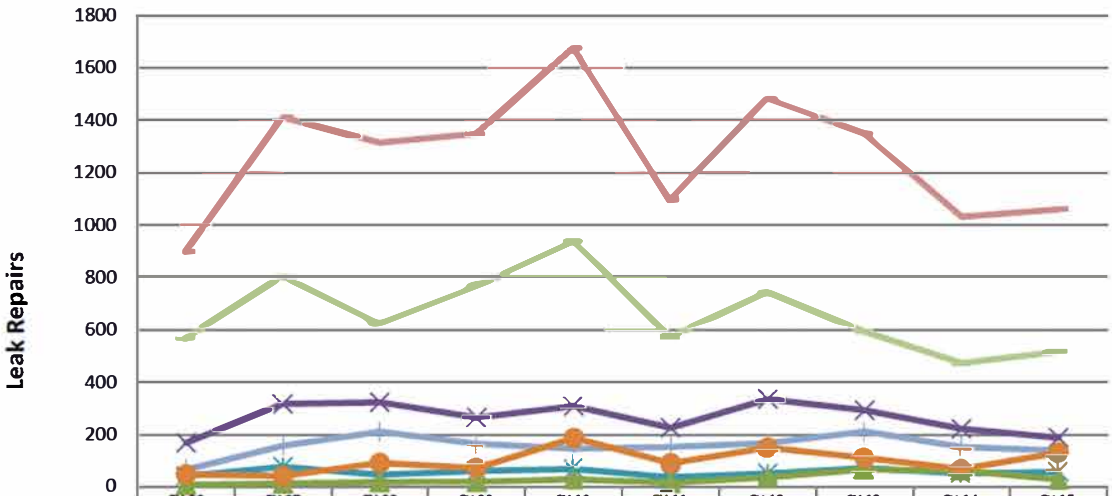
AGN compares the performance and integrity indicators for different types of mains in order to understand contributors to risk, and facilitate preventative action by identifying mains that may be prone to failure. All things being equal, increasing trends in these indicators are usually a sign of deterioration in the condition/integrity of the network.

The following sections provide details of key network integrity measures.

4.2.1. Network Leaks

The following section provides historic trends in network mains leaks.

Figure 4.1: Mains Leaks

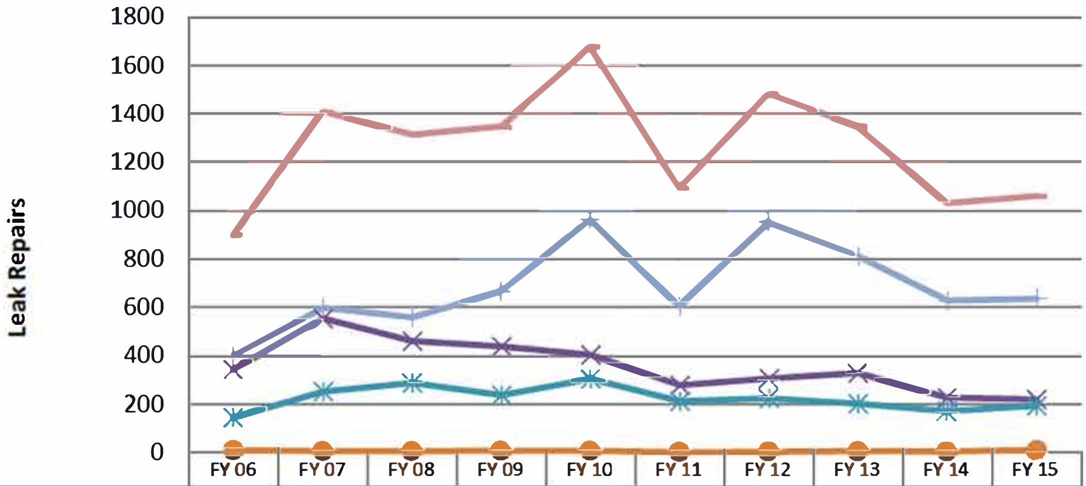


	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Cast Iron	566	803	623	765	937	573	742	593	473	516
UPS	66	157	211	165	146	152	167	212	153	139
PVC	42	77	47	61	68	37	52	72	51	58
PE	168	317	323	265	309	226	335	293	222	188
Other	8	14	18	20	29	16	37	67	63	28
Steel	48	42	92	72	187	91	150	111	69	131
Grand Total	898	1410	1314	1348	1676	1095	1483	1348	1031	1060

CI, UPS and PVC mains have accounted for over 68% of mains leaks over the last ten years despite representing only about 4% of the distribution network.

The reduction in CI leaks since financial year (FY) 2010 is related to the mains replacement program with over 330 kilometres of CI mains replaced over the last four years.

Figure 4.2: Mains Leak Cause



	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Joint Leak	401	599	559	666	961	604	950	812	629	636
Crack/Break	343	554	461	438	404	278	306	329	227	220
Corrosion	145	252	288	237	304	212	224	201	171	194
Failure of Prior Repair	9	5	6	7	7	1	3	6	4	10
Total	898	1410	1314	1348	1676	1095	1483	1348	1031	1060

The most prevalent cause is failure from joint leaks followed by cracks/breaks and corrosion.

The table below summarises the leak and break rates per kilometre by mains type.

Table 4.2: Leak Rate

Material	Km (31 Dec 2015)	Mains Leaks FY 15	Leaks per kilometre	Mains Cracks FY 15	Cracks per kilometre
CI	226	516	2.28	55	0.24
PVC	228	58	0.25	29	0.13
UPS	21	139	6.7	0	0
Steel	2,860	131	0.05	0	0
PE	6,995	188	0.03	86	0.013

The leak and crack rates of CI, UPS and PVC mains are significantly higher than that of steel or PE, and considered to pose the greatest public risk.

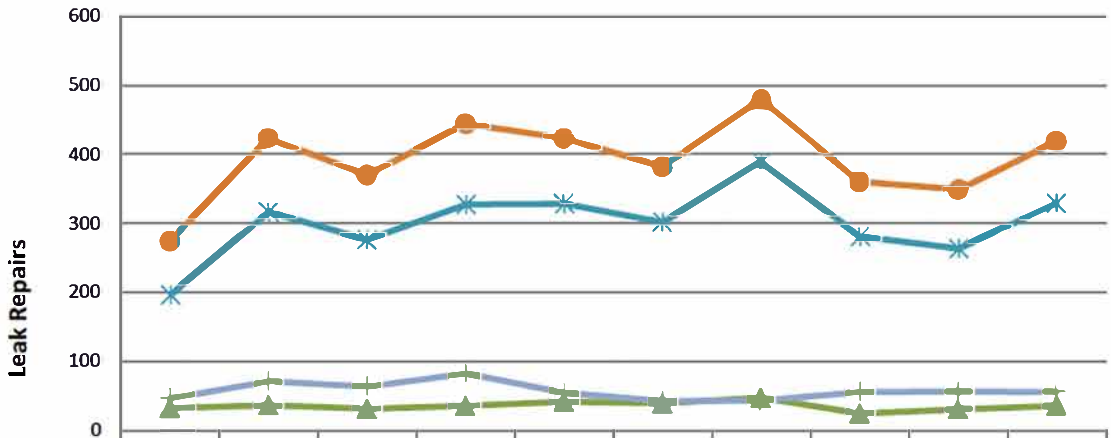
4.2.2. CI Mains

The leak and crack rates of CI mains in the Victorian network has given rise to the current replacement program aimed at replacing all this material with new generation PE mains.

It is well known that CI has a propensity for cracking or breaking due to its inherent brittle characteristics. Such failures cannot be predicted resulting in a sudden release of relatively large volumes of gas that in certain circumstances could migrate to nearby buildings creating a risk of fire or explosion. In addition CI mains have a propensity for leaking at pipe joints[14].

The following graph details the failure history of the residual (as at 31 December 2015) inventory of CI mains.

Figure 4.3: CI Mains Leak History



	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Joint Leak	196	316	276	327	328	301	389	281	263	329
Corrosion	32	36	31	35	41	39	47	24	30	35
Crack	46	71	63	82	54	42	43	55	56	55
Grand Total	274	423	370	444	423	382	479	360	349	419

The leak and crack rate per kilometre of residual CI main is about 2.3 and 0.24 respectively. This compares with 1.1 and 0.27 respectively in AGN's CI South Australian network.

The leak rate on CI mains is deteriorating at about 1.5% per year while the crack rate appears to be relatively constant year on year.

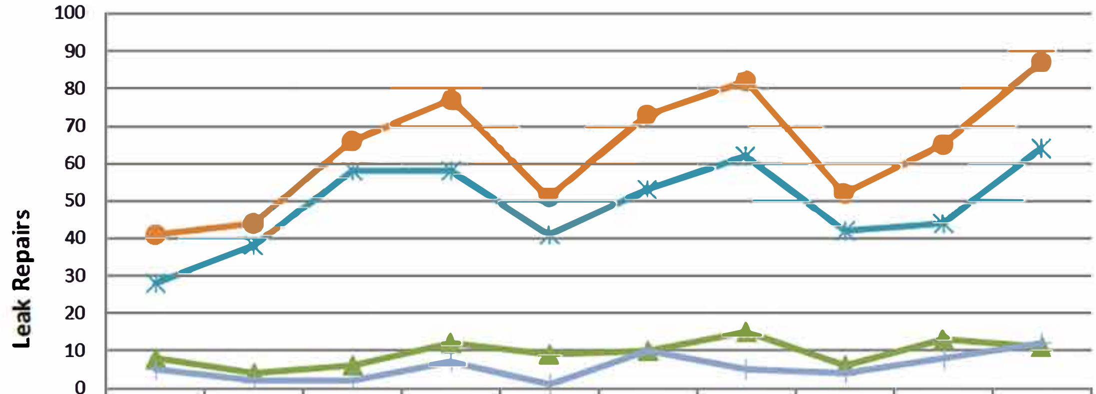
It is expected that the crack and leak rate will deteriorate further as these mains continue to age. This is because degradation of joints, and graphitic corrosion, increases over time. Soil movement (expansion and contraction from weather, traffic impact, root damage, etc.) also leads to cracking of mains over time.

4.2.2.1. CI in the Melbourne CBD

The Melbourne CBD has some of the oldest CI mains in the network with leaks presenting a relatively higher public risk due to the population density and proximity of buildings. The following graph details CI mains leak history within the Melbourne CBD (postcode 3000).

[14] CI joints were designed to be used with wet towns gas, not dry natural gas which is currently being transported.

Figure 4.4: Melbourne CBD CI Mains Leak History



	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Joint Leak	28	38	58	58	41	53	62	42	44	64
Corrosion	8	4	6	12	9	10	15	6	13	11
Crack	5	2	2	7	1	10	5	4	8	12
Grand Total	41	44	66	77	51	73	82	52	65	87

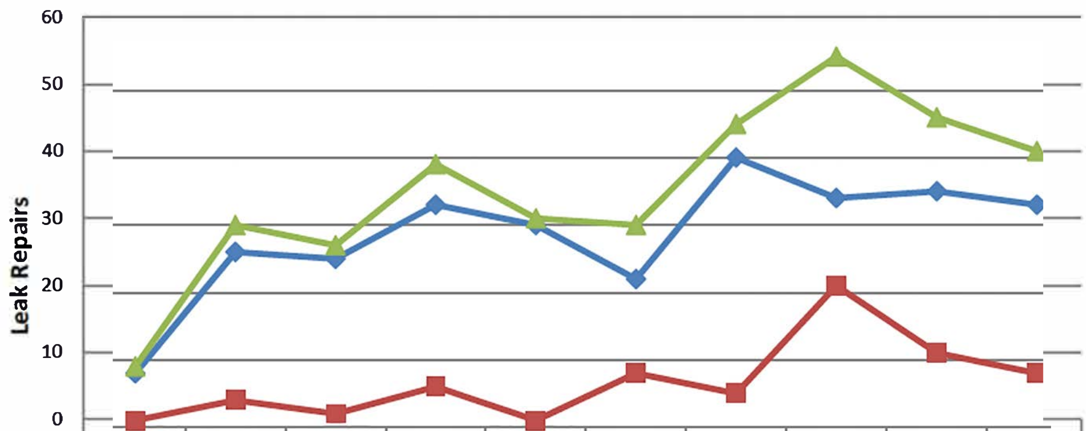
The average leak rate is about 2.5 per kilometre per year and a crack rate of about 0.2 per kilometre per year. Over the last two years there has been an increasing trend in both these rates.

4.2.3. UPS Mains

UPS mains have no cathodic protection and as such are very susceptible to corrosion. These mains are typically more than forty years old with the first response to a leak invariably revealing extensive corrosion that in many cases cannot be repaired and as such, 'piecemeal' replacement is the only option. These mains are typically interspersed throughout the LP CI network.

The following graph details the failure history of the residual (as at the end of December 2015) inventory of UPS mains.

Figure 4.5: UPS Mains Leak History



	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 1'
Corrosion	8	26	25	33	30	22	40	34	35	33
Joint Leak	1	4	2	6	1	8	5	21	11	8
Total	9	30	27	39	31	30	45	55	46	41

Leaks on UPS mains are deteriorating at about 10% per year with the average leak rate of 6.7 leaks per kilometre per year, the highest of all materials.

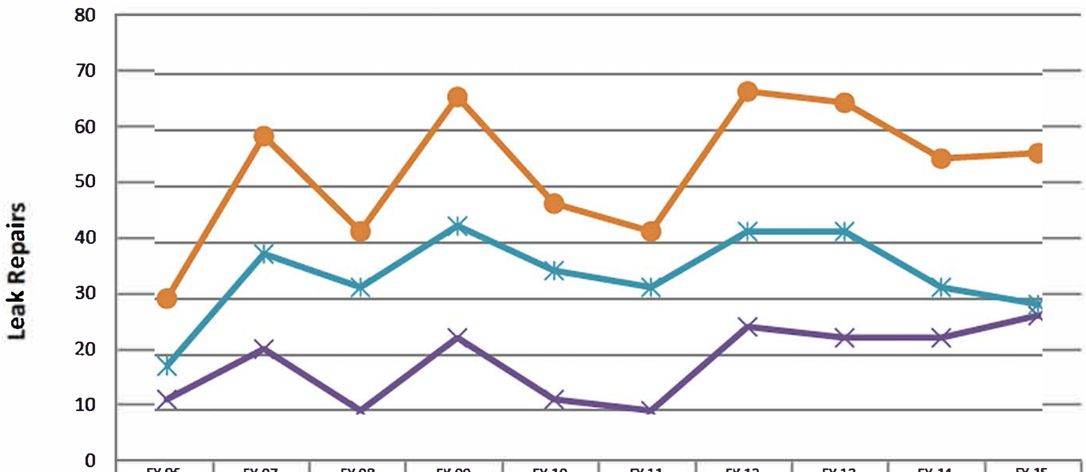
The increasing leaks from UPS mains create an ongoing public safety risk that is best managed as part of the broader network replacement.

4.2.4. PVC Mains

These mains are typically interspersed throughout the LP CI network, being used as part of piecemeal CI replacement programs in the 1970s and 1980s. PVC has a known propensity to become brittle with age making repairs and connections difficult.

The following graph details the failure history of the residual (as at 31 December 2015) inventory of PVC mains.

Figure 4.6: PVC Mains Leak History



	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Joint Leak	12	21	10	23	12	10	25	23	23	27
Crack	18	38	32	43	35	32	42	42	32	29
Grand Total	30	59	42	66	47	42	67	65	55	56

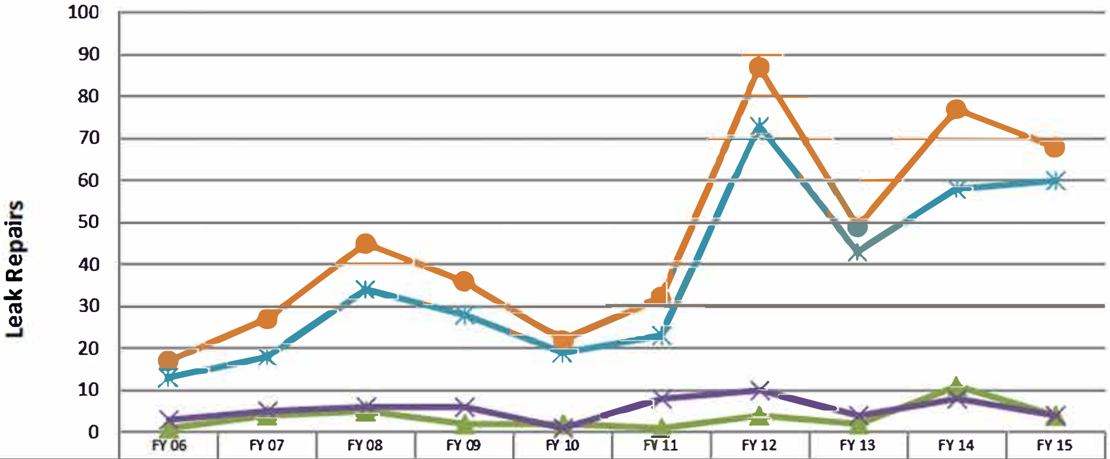
Leaks have been gradually increasing while the cracks have remained relatively constant. However, the crack rate for this material is about ten times higher than that of PE material.

4.2.5. MP Trunk Mains

There are about 32 kilometres of medium pressure CI and UPS trunk mains in the network that move gas across Melbourne, providing the primary supply to the LP network. As the LP network is replaced the majority of these mains will be made redundant and abandoned. Some of these mains will be replaced by HP trunk mains, in a different location, to support the extension of the HP network as it replaces the LP network.

The following graph details the failure history of the residual (as at the end of December 2015) MP CI and UPS trunk mains.

Figure 4.7: MP Trunk Mains Leak History



	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Crack	1	4	5	2	2	1	4	2	11	4
Corrosion	3	5	6	6	1	8	10	4	8	4
Joint Leak	13	18	34	28	19	23	73	43	58	60
Grand Total	17	27	45	36	22	32	87	49	77	68

The number of joint leaks on CI and UPS trunk mains is increasing and is expected to continue to increase as these mains age.

These mains are typically located in major roads and under or near other significant infrastructure, such as railway lines. Leaks on such mains can be very problematic to repair and can cause significant disruption to the community. For example, a leak on a MP trunk main in Thornbury required the train line to be closed for the afternoon, significantly disrupting commuter traffic.

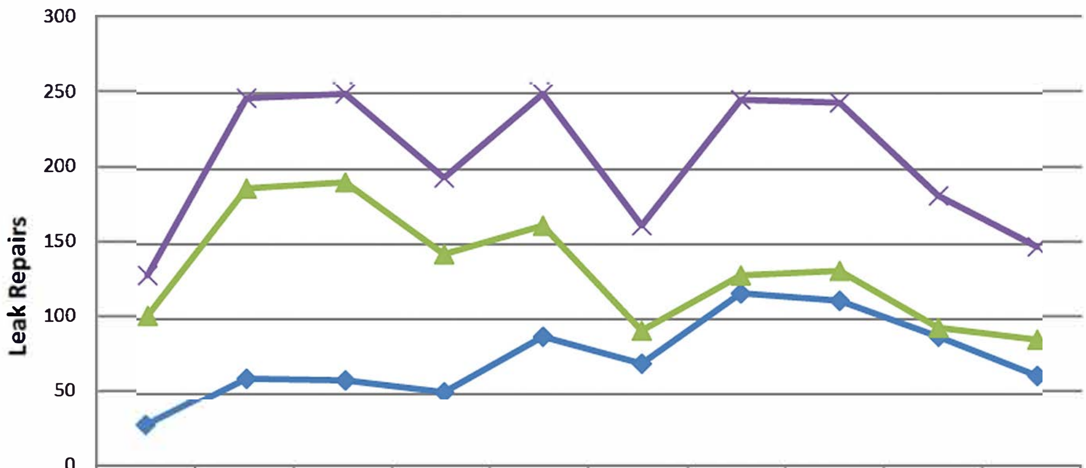
4.2.6. PE Mains

PE material is resistant to corrosion, very light to handle and easy to install and can be operated at significantly higher pressure than CI. It has been the material of choice by most gas utilities throughout the world over the last 40 years for iron gas main replacement and general network extensions.

There are over 7,000 kilometres of PE mains in the network of varying vintages and material types. HDPE 575 was used from the late 1970s to the late 1990s subsequently superseded by MDPE (PE80) from the late 1990's until a few years ago when it was superseded by HDPE 100. A breakdown of installed PE mains by material type can be found in Table 2.1

The following graph details the failure history of PE mains.

Figure 4.8: PE Mains Leak History



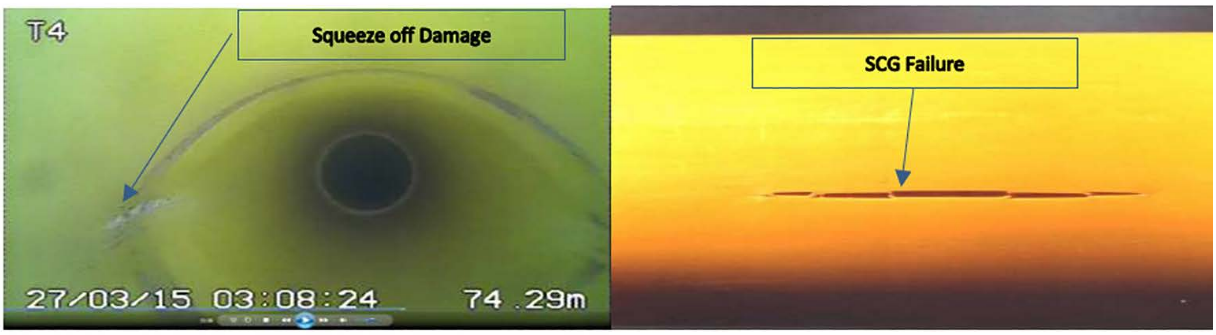
	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Joint Leak	27	60	59	51	88	70	117	112	88	62
Crack	102	187	191	143	162	92	129	132	94	86
Grand Total	129	247	250	194	250	162	246	244	182	148

The leak rate of PE mains is about 0.03 leaks per kilometre per year. This is around 50 times lower than for CI and UPS mains and 8 times lower than PVC mains. The crack rate of PE is about 0.02 leaks per kilometres per year which is about 14 times lower than CI.

While these rates are significantly lower than for other materials, analysis into 'catastrophic' failures[15] of HDPE 575 mains in AGN's South Australian network has shown that this material does have a propensity for 'slow crack growth' (SCG) at sites where it has been subjected to 'local' stress, particularly from past squeeze-offs.

The figure below highlights the initial damage caused by 'squeezed off' of the main and how this ultimately leads to SCG through wall failure.

Figure 4.9: Internal Squeeze-off Damage (Left) and SCG Failure (Right)



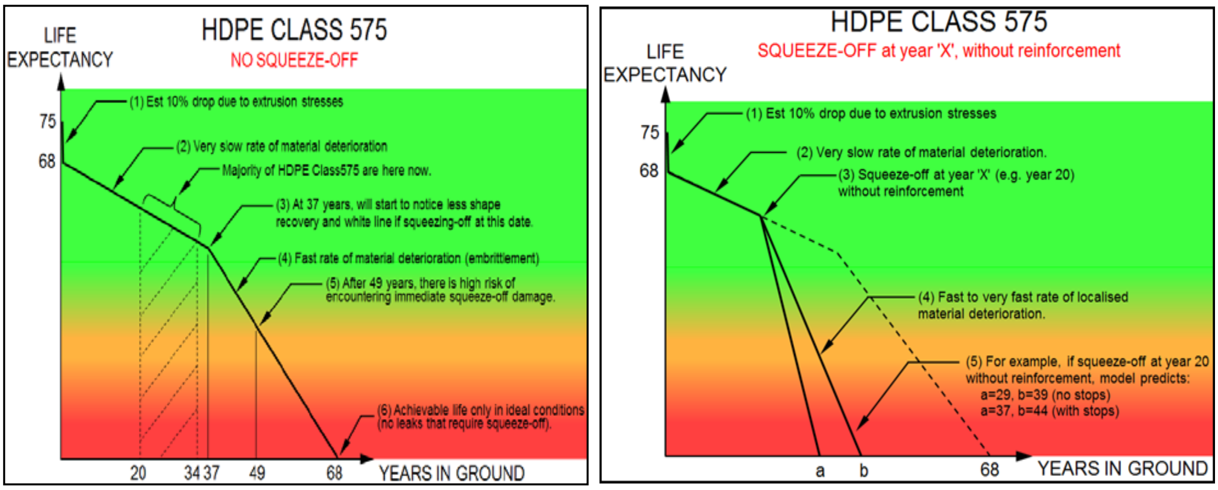
HDPE 575 has been shown to degrade over time becoming increasingly brittle. It is considered that once the material reaches about 50 years of age it can become highly susceptible to cracking. The time to 'brittle' failure can be significantly reduced as a result of squeeze-off damage. In the case of gas in building incidents in AGN's South Australian network, HDPE 575 failed

[15] Three gas in building explosions resulting in major injuries and building damage.

'catastrophically' after just over 20 years. Some PE SCG failures in the United States have been observed in this material less than two years old.

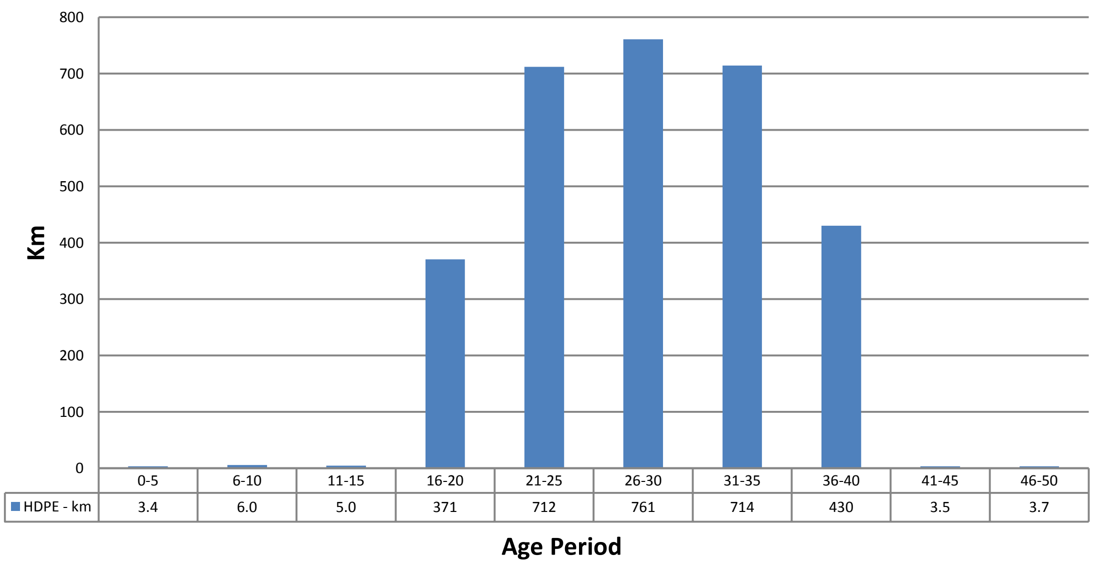
AGN has investigated the behaviour of HDPE 575 when squeeze off occurs. This has been detailed in the figures below. These illustrate how the time to failure reduces significantly where squeeze-off damage has occurred.

Figure 4.10: HDPE Behaviour Model 1 (Left) and HDPE Behaviour Model 2 (Right)



About 3,000 kilometres of HDPE 575 was laid in AGN's Victorian Networks during the 1970s and 1980s. The following graph details the age profile of these mains, as at 2016.

Figure 4.11: HDPE Mains Age Profile



Over the next 15 years, a significant quantity of HDPE 575 will reach 50 years of age, potentially increasing the risk associated with this material type. Hence this Plan includes work to understand the properties and expected remaining life of HDPE 575 used in the Victorian network.

Of concern is a small amount (7kilometres) of HDPE 575 that will reach a 50 year life over the next AA period.

Although no gas in building incidents have occurred to date as result of SCG in AGN's Victorian Networks, work is underway to investigate the condition of these mains to assess risk and future risk treatment options.

4.2.7. Steel Mains

There is just over 2,800 kilometres of protected steel mains (coated and cathodically protected from corrosion) in AGN's Victorian network. Though not yet reflected in the maintenance statistics there is some emerging evidence to suggest that the oldest mains in this category, coated with coal tar enamel, may be starting to lose coating cohesion. The evidence for this is higher current injection required to maintain the minimum voltage potential difference to maintain adequate cathodic protection. In other words, the imposed cathodic protection is able to 'leak' through to electrical ground via faults in the pipe's coating.

There are 1,389 kilometres of this mains type in service, operating at high pressure. 95% of these mains will be 40 years or older by the start of the next AA period.

Experience with this pipe coating type in AGN's South Australian steel transmission network, has shown that disbondment of the tar epoxy coating does occur with extensive corrosion and pitting of the pipe wall. Of greatest concern would be where the damage is not recognised until the corrosion is extensive, in which case piecemeal replacement may become the only practical means of rectification, at a higher cost than a localised leak fix.

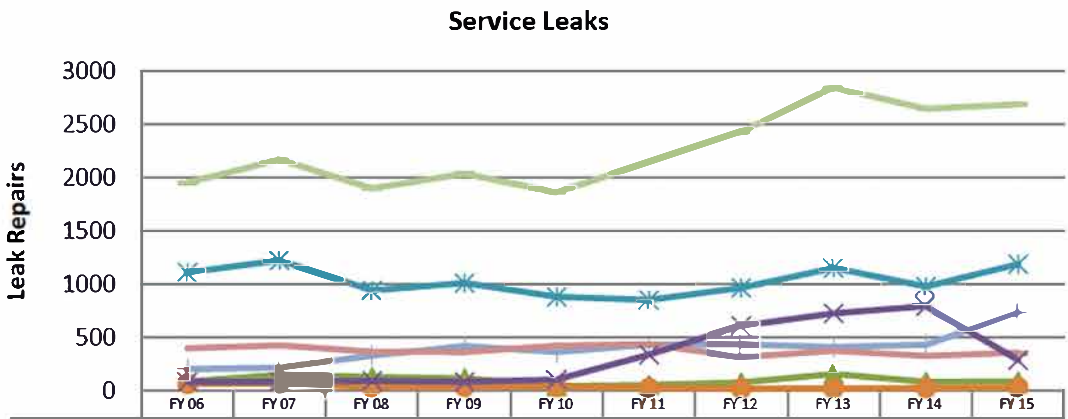
As the cathodic protection difficulties are a leading indicator of condition deterioration, this is now being investigated via a targeted leak survey and detailed reporting of leak fixes on affected assets.

4.2.8. Services

Services generally consist of material of the same vintage of the gas main to which they are connected, as they generally were laid together as one project. That is, when cast iron mains were laid, galvanised steel services would have been laid at the same time (and when such mains were replaced with PE, the associated services were renewed with PE). When a main is replaced, the associated services are deemed to have the same age of the main and share a similar risk profile (but with further risk associated with the closer proximity of service pipes to the house or building). Hence no distinction is made between mains and services when assessing useful life or risk.

The following graph details the leak history on services.

Figure 4.12: Service Leaks



	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
PE	1113	1226	945	1013	884	854	967	1153	979	1190
Steel	205	217	330	421	365	434	435	413	434	732
UPS	399	426	367	365	424	438	317	376	328	359
Cast Iron	87	151	129	118	45	54	80	158	84	89
PVC	67	68	37	40	41	29	22	22	28	35
Other	84	86	94	85	105	340	611	728	796	289
Total	1955	2174	1902	2042	1864	2149	2432	2850	2649	2694

Preliminary findings into the increase in steel service leaks over 2015 suggest there may be an emerging corrosion issue with protected steel pipes in the seaside suburbs of the Mornington Peninsula. Further investigation is required to establish the extent of the problem and any future risk mitigation requirements.

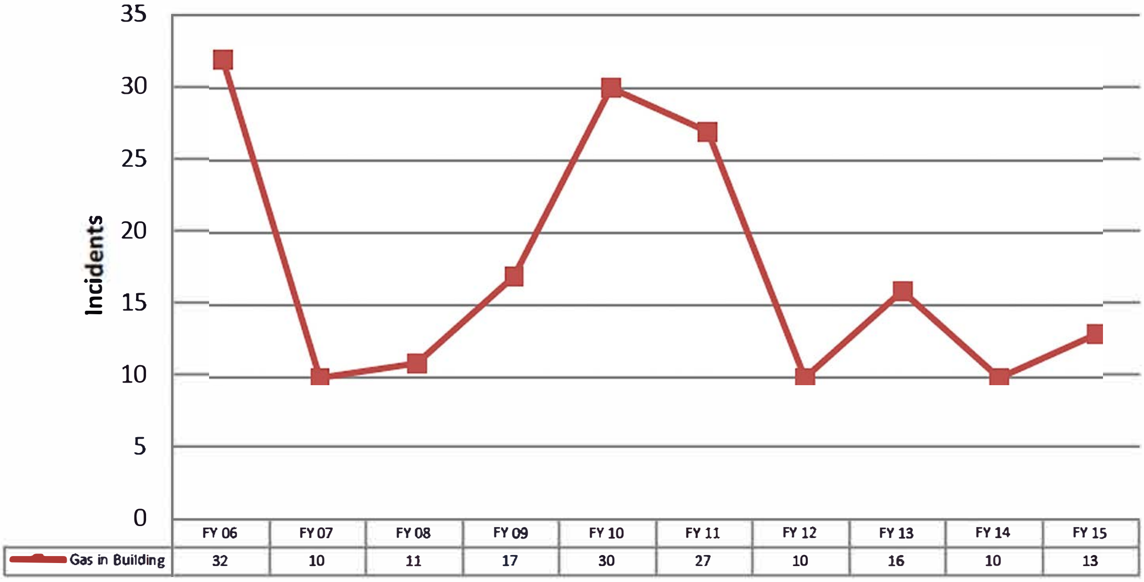
4.3. Gas In Building Incidents

AGN monitors gas in building (GIB) incidents as a check on the effectiveness of its other leak detection and repair activities. If a GIB incident is reported, it means that a leak has gone undetected long enough (which can be a short period of time) for gas to collect inside a building or structure. An explosion can occur if the quantity of gas is sufficient and comes into contact with a source of ignition.

Not all GIB incidents give rise to circumstances that can lead to an explosion. However, a small number of significant incidents do occur each year, where damage to a service line or a crack in a nearby main allows gas to enter a building in material amounts. Cracks in mains adjacent to buildings in particular, though low in overall number, present a risk profile that is judged to be 'high' and is a driver of the mains replacement program.

The following graph details the historic incidents of GIB incidents.

Figure 4.13: GIB Incidents



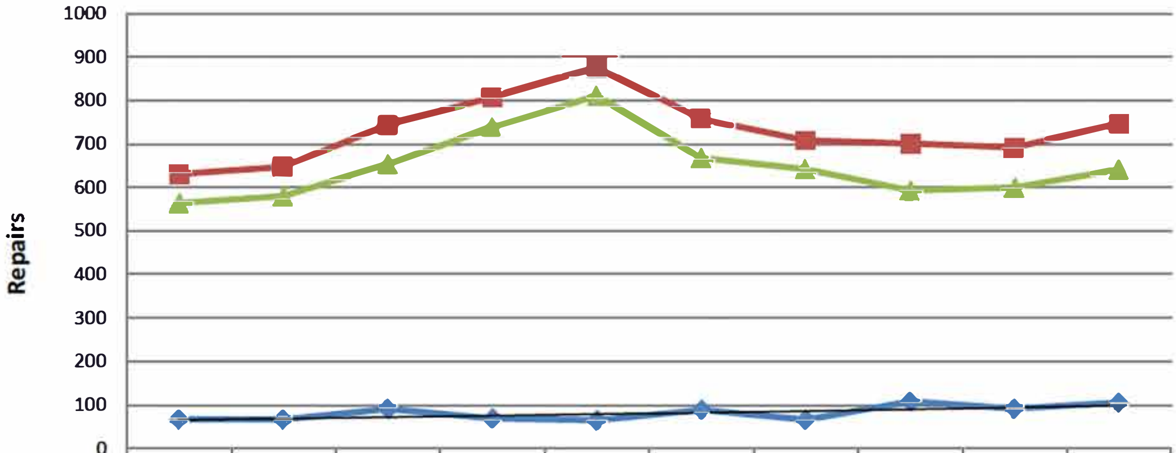
The number of GIB incidents has decreased since 2010, following a significant increase between 2007 and 2010. Historically, GIB incidents have occurred near CI and UPS mains. The significant reduction since 2010 has been attributed to the CI/UPS mains replacement program.

4.4. Third Party Incidents

Third party incidents are when damage occurs on the network as a result of the actions of a third party (for example damage caused by builders using mechanical diggers). We monitor third party incidents in order to monitor any changes in the contribution of events to leak repairs and water in mains, as well as to identify opportunities to prevent incidents.

The following graph details the history of third party damage incidents on mains and services.

Figure 4.14: Third Party Damage Incidents



	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15
Services	564	580	653	738	811	668	642	593	600	641
Mains	67	67	91	69	65	89	66	108	92	106
Total	631	647	744	807	876	757	708	701	692	747

The Dial Before You Dig service provides information to the public and construction industry about the dangers and location of the gas distribution network when digging or working on line of main. Use of the Dial Before You Dig service has increased year-on-year, and the low number of third party damage, despite high levels of construction activity in Melbourne, suggests the service has improved public awareness of these assets.

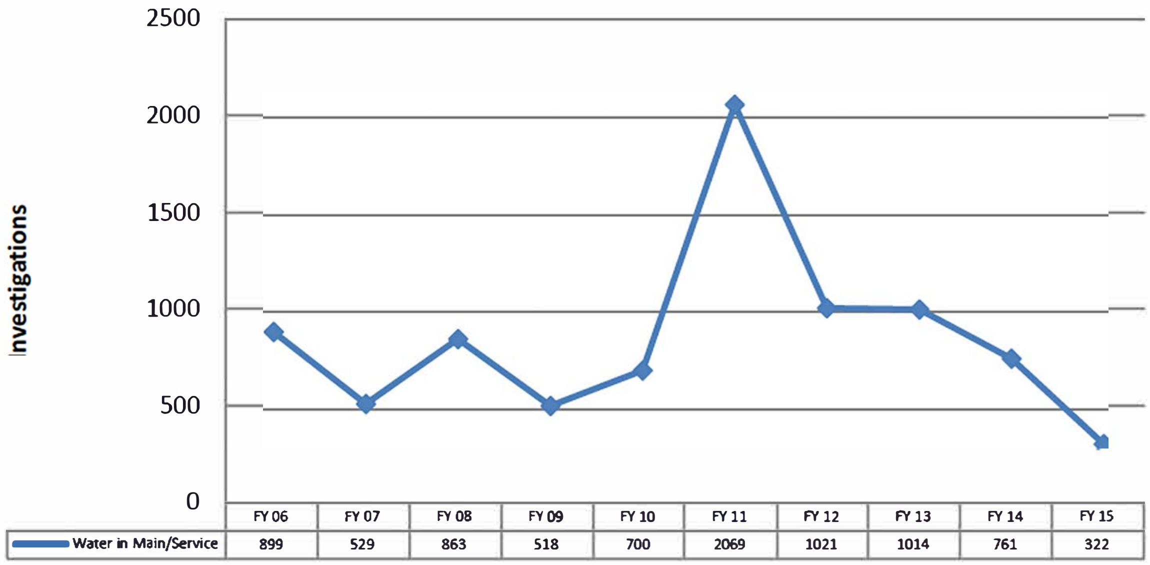
The highest number of incidents occurs on services, which are not captured in the GIS location data and hence such data is not available through the Dial Before You Dig service.

4.5. Condition Related Supply Interruptions

Groundwater ingress into pipes is largely due to; porosity; corrosion; joint failure and breakage of LP CI and UPS mains. The number of water in main (WIM) incidents are influenced by the amount of rain that falls and the level of ground movement associated with clay soils as they swell and contract during the 'wetting' and drying cycle. A high number of WIM incidents are indicative of mains reaching the end of their useful life.

The following graph details the historic trend in WIM incidents.

Figure 4.15: Water in Main Incidents



The sharp rise in incidents during 2011 was associated with the 'breaking' of the drought. While subsequent winters have been relatively wet there has been a declining trend over the last few years with a 68% reduction attributed to the CI/UPS mains replaced since 2011.

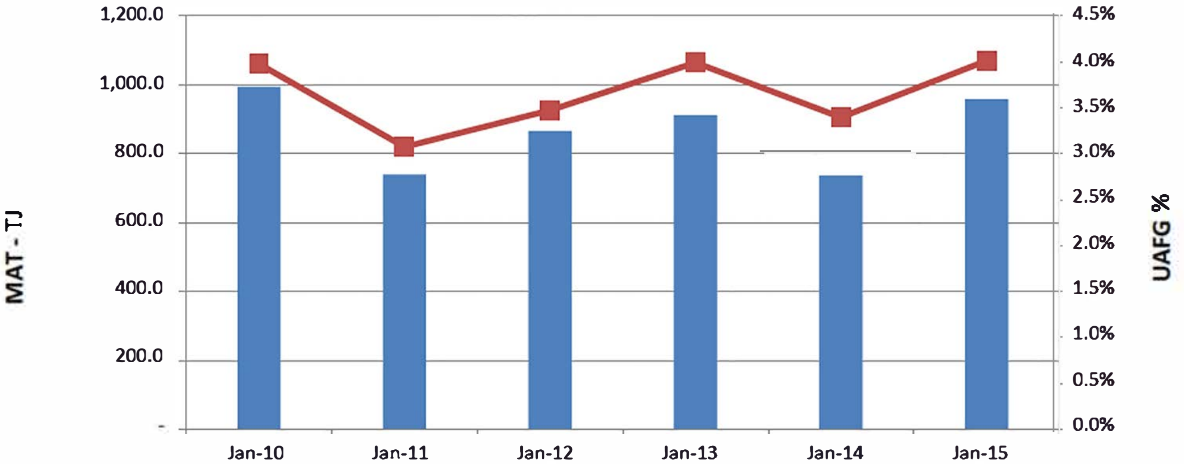
4.6. UAFG

UAFG is the volume of gas that is not accounted for when input metering data is compared to output metering data. UAFG can be a result of meter tolerances, heating value discrepancies, metering pressure tolerances, as well as leakage and other factors. Where the level of UAFG in a gas network is higher than industry norms, it can indicate issues with leakage in the network. The level of UAFG within the AGN network is considered to be within industry norms, and while there is an element of leakage in UAFG, the various factors that comprise UAFG are not constant and overshadow leakage factors from aged mains. Analysis of recent trends in UAFG give rise to the conclusion that it is not possible to make any direct correlation between UAFG trends and Network leakage associated with CI and UPS mains. Consequently, there is little value currently placed on UAFG as an indicator in relation to mains integrity[16] for AGN's Victorian network.

The following graph details the historic trend in UAFG for the Melbourne metropolitan network.

[16] UAFG analysis is considered in more detail in a report titled Assessment of Contributing Elements of UAFG in AGN's Victorian Networks, AIA, Sep 2016

Figure 4.16: Melbourne UAFG



	Dec-10	Dec-11	Dec-12	Dec-13	Dec-14	Dec-15
MAT UAFG - TJ	994.1	738.8	864.9	911.0	735.8	957.5
MAT UAFG - %	4.0%	3.1%	3.5%	4.0%	3.4%	4.0%

Melbourne's UAFG measurement would be expected to respond most strongly to mains replacement given that this network has the highest amount of residual CI and UPS material. However, as can be seen, the UAFG trend has been unresponsive to mains replacement over the 2010 to 2015 period, suggesting factors other than leakage are key influences in the level of UAFG.

5. Mains Integrity Management

AGN manages mains integrity by undertaking activities to manage the supply and safety risks of operating the Network. Risk is managed by:

1. Taking action as soon as possible to mitigate the risk;
2. Undertaking activities that improve information on asset condition, causes of risk, and the effectiveness of risk mitigation activities; and
3. Monitoring asset condition and associated risk.

5.1. Risk Mitigation Activities

The risk mitigation activities we undertake include:

- replacing mains through block (proactive) programs;
- responding to leak reports and undertaking repairs in an expedient manner;
- leak surveys of mains, particularly in areas identified as higher risk (proximity of mains to buildings, type of premises and ground conditions);
- pressure reduction in areas with a history of crack failure;
- increasing the level of gas odorisation to improve leak detection;
- corrosion protection of steel mains; and
- replacing mains on a piecemeal (reactive) basis.

Ongoing research and investigation includes:

- research and development of inline camera technology to identify defects and effect repair in HDPE pipe;
- sampling programs to improve information on asset condition and deterioration rates;
- installation of ground vents over HDPE mains in locations where ground conditions could seal in gas leaks to improve leak detection; and
- developing a reliability forecast model for predicting the remaining life for HDPE pipe.

These activities are described further below.

5.1.1. Leak Surveys and Leak Repair

Leak surveys are an important tool to identify leaks. A comprehensive leak survey program facilitates early detection of leaks. Leak survey frequency (ranging from every five years to every six months) depends on the nature and location of the particular assets.

Where an increased risk is identified, the frequency of leak surveys can be increased to improve the timeliness of leaks being detected and repaired. For example, leak surveys are conducted every six months in the CBD. However, increasing leak survey frequency can only reduce the likelihood of a risk event, they cannot prevent the event or the consequence of the event.

A 24-hour call centre also allows for public reporting of leaks. AGN has a Leakage Management Procedure (LMP), which is a detailed process for managing gas leaks to ensure they are identified, responded to and classified in a consistent manner.

5.1.2. Pressure Reduction

AGN maintains sufficient distribution system pressure to ensure the minimum pressure is maintained at the distribution supply point. Newly installed mains are subjected to strength-pressure-testing, which establishes whether the supply main is leak-free in accordance with requirements of AS/NZS 4645.

Nominal safe working pressures throughout the network can vary considerably depending on gas demand and the number of leaks. When demand is expected to be high, safe working pressures may be adjusted to increase network capacity. However, higher pressures increase the risk of gas escape and explosion. Where mains are identified to be in locations or made of material prone to leaks, cracks or breaks, the operating pressure can be reduced. However, this can also impact supply and will only affect the likelihood of a risk event, not the consequence. As pressure is only one factor in consideration of risk, even a substantial pressure reduction may not result in a significant reduction in risk.

It should be noted that all CI/UPS and PVC mains are currently operated at the lowest possible pressure without putting supply at risk.

5.1.3. Gas Odorisation

The Gas Safety (Gas Quality) Regulations 2007 require that gas must:

- have an odour that is distinctive and unpleasant; and
- have an odour level that is discernible at one-fifth of the lower explosive limit of the gas.

Odorant is added to the normally odourless natural gas to facilitate the detection of leaks. Achieving the correct level of odorisation is vital, as under-odorisation may increase safety risk, and over-odorisation could result in members of the public reporting leaks that do not warrant repair.

It is possible to increase odorant in areas to increase the timeliness and likelihood of detection. However, this method is difficult to implement in the Network as injection of odorant is undertaken upstream of the network, and cannot be targeted to particular areas.

5.1.4. Corrosion Protection of Steel Mains

Corrosion mitigation and monitoring of steel pipelines is controlled in accordance with the Electricity Safety (Cathodic Protection) Regulations 2009, and AS 2832 Cathodic Protection of Metals and Formal Safety Assessment. AGN uses the following corrosion protection devices:

- *cathodic protection unit (CPU)* – supplies an externally powered direct current source to a pipeline to counteract corrosion;
- *sacrificial anode* – utilises the galvanic potential difference between metals to provide a protective current flow to the pipeline. Magnesium and zinc are commonly used as anodes and are consumed (sacrificed) while doing so;
- *electrolysis drainage bond* – drainage bonds return stray current from DC traction systems back to public transit operator's sub-stations. Drainage may be natural or forced by various

means. Although this is an asset belonging to public train and tram owners it is a vital part of stray current corrosion protection.

These corrosion protection methods are effective in addressing risk associated with steel pipelines. However, these methods must be applied prior to the steel mains being laid.

5.1.5. Replacement

Replacement of mains and services is the most effective mitigation of risk for all types of mains. Replacement can be undertaken through piecemeal replacement or block replacement. Piecemeal replacement (repair) is reactive, and usually occurs after a crack or water ingress has been detected. Additional sections of pipe may also be replaced where excavation identifies surrounding mains are in similar condition to the section that failed.

Block replacement is a proactive approach and undertaken where mains in a particular area or system are identified as likely to have characteristics that give rise to a higher risk. For example, mains that are at the end of their useful life, are of a particular material with a high propensity of cracking, located in areas with characteristics known to increase deterioration, or have been laid using techniques that are known to weaken the structure of the mains, are typically at risk and scheduled for block replacement.

Block replacement is the most efficient method of mitigating risk. The cost per metre of block replacement is significantly lower than piecemeal replacement, not only because the fixed costs associated with mains replacement are spread over a greater quantity of main, but because it usually involves the most efficient method of mains replacement whereby a smaller diameter main is inserted into the existing old larger diameter main. This avoids the costs associated with excavation for the whole length of new mains. The smaller diameter main can also be operated at a higher pressure, which can provide capacity benefits for no additional cost.

Practical considerations including the availability of resources, planning periods and ramp-up time are considered by management in preparing and reviewing plans for mains replacement. AGN also pursues opportunities to combine mains replacement with council and road authority road construction and resurfacing programs where practicable, in order to minimise costs and public disruption.

Although mains replacement is usually adopted to address a particular mains material type, in a block mains replacement other mains may also be replaced where they are interspersed as a result of prior repairs. This is more efficient and much less costly that attempting multiple small lengths of replacement by direct burial (size for size) and, in some cases, the condition of the other mains may also warrant replacement. For example, when replacing CI and UPS mains, some adjoining PVC or PE may also be replaced to maintain or improve the integrity of the section being replaced.

As with any long term program, areas prioritised for replacement may change over time to reflect latest information and evolving risk.

5.1.6. Inline Camera Technology for HDPE

A trial of this technology is underway in AGN's South Australian gas distribution network. A camera is inserted into HDPE mains to help identify cracks, weaknesses and squeeze-off points. The camera increases the effectiveness of monitoring as it provides visual information on the interior of the pipe, which cannot be achieved by any other means.

Inline camera use is an innovation-stage technology, with practical limitations, and the reliability of results and the scalability of the method is still being assessed. Continuation of the inline camera project is an important accompaniment to the mains replacement program, as it will help AGN address risk where replacement is not planned in the short term.

5.1.7. Material Sampling Programs

Samples of mains are extracted to help establish the condition and residual life of particular pipe material. Sampling programs are critical in developing integrity management plans and informing future replacement programs.

5.1.8. Ground Vents

This initiative has been undertaken in South Australia and provides for installation of vents on HDPE 575 mains where ground conditions could prevent escaped gas from dissipating into the atmosphere. Gas that collects underground poses a safety risk to the public, while also making leak detection difficult. The vents facilitate the dissipation of escaped gas, preventing it from travelling into buildings, while also improving the effectiveness of leak surveys by making detection easier. While not a substitute for replacement, installing gas vents is an effective method of mitigating the risk associated with HDPE 575 mains in the short term until such time that the pipes can be repaired or replaced.

5.1.9. Reliability Forecast Model

This is a longer term project that aims to predict the reliability/life of different mains materials under different conditions by researching various parameters and modelling their impact on the material that is in use in the Network. The information will be used to identify which mains should be prioritised for replacement.

5.2. Current Mains Replacement Program

During the last five years, AGN has undertaken a mains replacement program with the aim of replacing all remaining low and medium pressure CI, UPS and PVC mains within the network by the end of 2021. The plan was finalised in consultation with ESV.

The condition of these mains is considered poor with CI mains having a propensity to crack indiscriminately posing the greatest risks to safety and supply. Such failures can release relatively large volumes of gas that could migrate to nearby buildings, creating a risk of fire or explosion.

The strategy for replacement has focused on areas (identified by a Cast Iron Mains Fracture Model) known as ‘breakage zones’. These were areas where soils have a propensity to cause cracking of mains.

The replacement of mains was prioritised in areas where:

- cracks, leaks or water ingress were prevalent;
- pressure was falling due to the changeover of appliances by connected consumers; and
- mains were unable to be repaired through piecemeal replacement.

During the early 1980s the Gas and Fuel Corporation (network owners at the time) had a policy of replacing problematic CI and UPS mains on a piecemeal or reactive basis, using PVC material at low pressure. This practice ceased in the early 1990s.

The interspersed nature of PVC material throughout the LP network makes replacement of problematic CI and UPS mains (which have the highest failure rate), difficult without also replacing (by insertion) the PVC. Notwithstanding this the PVC has a history of cracking, albeit lower than CI, which is expected to increase over time, presenting a risk to the public.

The replacement of all LP in the network (regardless of material) allows the network to be designed and integrated with the existing high pressure infrastructure, using inserted smaller diameter mains. This significantly reduces the cost of replacement that otherwise would be necessary, as it allows for a complete insertion approach to replacement.

6. Risk Management

There is an inherent risk associated with gas mains. Whenever a gas main leaks, cracks, or breaks there is the potential for the community and our employees to be seriously injured, and/or for supply to be disrupted. The risk can vary according to the location, material type, pressure and age of each gas main. AGN reviews the performance indicators of mains to assess the potential risk associated with any deterioration in condition.

We manage network integrity by regularly updating our risk assessment to reflect new information on asset condition. A risk assessment and derived risk rating guides the actions and activities required ensuring that safety and compliance is maintained as efficiently and effectively as possible.

6.1. AGN's Risk Assessment Approach

AGN's risk management framework is based on:

- AS/NZS ISO 31000 Risk Management – Principles and Guidelines,
- AS 2885 Pipelines-Gas and Liquid Petroleum; and
- AS/NZS 4645 Gas Distribution Network Management.

AGN is required to comply with AS 2885 and AS/NZS 4645 as a 'regulatory requirement' by the Gas Distribution System Code (Code).

In accordance with Appendix C of AS/NZS 4645, for each risk event we consider the consequence and likelihood of that event occurring. Combining these produces the level of risk assessed (risk rating). Once the level of risk has been defined, we consider risk treatment options (guided by AS/NSZ 4645) and consider the effectiveness and cost of those options for remediating the risk.

The costs are considered against the inherent risk, the level of risk reduction and the residual risk, to determine a prudent and efficient course of action. Where we identify mains as 'extreme'[17] or 'high' risk under AS/NZ 4645, we assess the most effective way to reduce the risk to 'low' or 'negligible' and the efficient cost of doing so. Where mains are rated as 'intermediate', we assess whether the risk can be reduced to 'low' or 'negligible' and how that might be achieved. If the risk cannot be reduced to 'low' or negligible, or the cost of doing so is disproportionate to the risk reduction, we take action to reduce the threat to the extent practicable and demonstrate ALARP. For some mains, the only way to reduce the risk is to replace them.

6.2. Mains Risk Assessment – Crack or Break

AGN's risk assessment approach focuses on understanding the potential severity of failure events associated with each asset and the likelihood that the event will occur.

The focus of risk assessment is on pipe/materials with a propensity to crack or break, as these events are unpredictable, have the greatest scope to suddenly release large amounts of gas, and as a result are judged to pose the highest overall asset integrity benefits in the event that the risk is removed.

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17 Currently no mains in the network are rated as 'extreme'.

The level of risk varies between assets based on material, location, age and operating pressure. For example, an asset that:

- is made from a material that has a propensity to crack;
- is located in a built-up area;
- operates at high or medium pressure; and
- is more than 35 years old,

would carry the highest risk and should be prioritised for replacement. All mains carry an inherent risk of causing fatality or serious harm, simply due to the hazard associated with distributing natural gas. Taking into account the above factors allows us to understand the likelihood of asset failure resulting in a major (or potentially catastrophic) event.

To ensure proper consideration of the variables that affect risk, we categorise mains based on differentiating the key drivers of risk. We have identified 11 categories of mains in the Network. This allows for a more rigorous assessment of risk, particularly the likelihood of harm, compared to assessing mains as a single asset class.

For this exercise protected steel mains have been excluded as they are not found to have the propensity to crack or break.

The mains categories considered and the kilometres expected to remain in the Network at the end of the current AA period (31 December 2017) are presented in Table 6.1.

Table 6.1: Risk Assessment Mains Asset Categories

Item	Asset Category	Material type	Location	Pressure	Kilometres*
1	LP CI/UPS - CBD	CI/UPS	CBD	LP	25
2	LP PVC - CBD	PVC (impact modified)	CBD	LP	12
3	LP Steel - CBD	Steel	CBD	LP	7
4	MP CI/UPS - Trunk	CI/UPS	All	MP	32
5	LP CI/UPS - HDICS	CI/UPS	HDICS	LP	96
6	LP PVC - HDICS	PVC	HDICS	LP	85
7	LP CI/UPS - LDS	CI/UPS	LDS	LP	11
8	LP PVC - LDS	PVC	LDS	LP	25
9	HP HDPE575 > 35 years	HDPE	All	HP	597
10	HP HDPE575 < 35 Years	HDPE	All	HP	2,480
11	HP PE80/PE100	New generation PE	All	HP	4,330

*Note: The kilometres of mains in each category is estimated based on mains GIS inventory at 30 June 2016 and forecast replacement during 2016 and 2017.

6.2.1. Severity of the Consequence of the Event

The next step in the risk assessment is to identify the severity (or consequence) of a failure event for each category of main. The consequence of the potential event is then mapped against the AS/NZS 4645 severity classes.

The AS/NZS 4645 framework considers the consequences of a mains failure event on people, gas supply and the environment. The framework ranks the severity of the failure event from 'catastrophic' (multiple fatalities) to 'trivial' (minimal impact on health and safety).

The most significant threat posed by the network is that escaped gas gathers in a building and causes explosion. AGN has therefore used the AS/NZ 4645 consequence analysis to assess the following:

> *"The consequence of a crack that leads to the escape of sufficient gas that results in a 'gas in building' explosion".*

AGN has considered the consequence of this event on people, supply and the environment. The consequence on people will be at least 'major' (a few fatalities or several people with life-threatening injuries). In some instances, (high occupancy buildings) it could be 'catastrophic' (multiple fatalities).

Figure 6.1 illustrates AGN's assessment of the severity of consequences of mains failure on people, supply and environment as set out in AS/NZS 4645.

Figure 6.1: AS/NZ 4645 Consequence Assessment

Item	Catastrophic	Major	Severe	Minor	Trivial
People	Multiple fatalities result 1 2	Few fatalities or several people with life-threatening injuries 3 4 5 6 7 8 9 10 11	Injuries or illness requiring hospital treatment	Injuries requiring first aid treatment	Minimal impact on health and safety
Supply	Long Term interruptions of supply	Prolonged interruption or long-term restriction of supply	Short term interruption or prolonged restriction of supply 4	Short term interruption or restriction of supply but shortfall met from other sources 1 2 3 5 6 7 8 9 11	No impact, no gas restriction of gas distribution network supply
Environment	Effects wide spread viability of ecosystems or species affected, permanent major damage	Major off-site impact or long-term severe effects or rectification difficult	Localised (<1ha) and short-term (<2 years) effects easily rectified	Effect very localised (<0.1ha) and very short-term (weeks) , minimal rectification	No, effect, or minor on-site effects rectified rapidly with negligible residual effect 1 2 3 4 5 6 7 8 9 10 11

3	3	3	3	3	3	3	3	3	3	11
LP CI/UPS CBD	LP PVC CDS	LP Steel CBD	MP CI/UPS Trunk	LP CI/UPS HDICS	LP PVC HDICS	LP CI/UPS CBD	LP PVC CDS	HP HDPE 575 > 35 Years	HP HDPE575 < 35 Years	HP PE80/PE1 00

AGN considers it prudent to develop its integrity management plan based on the most severe consequences (as per the Standard) of a mains failure event, therefore the severity ratings in the 'People' category of AS/NZS 4645 take precedence for the purpose of assessing the risk associated with each category of mains.

The key drivers of consequence severity on people are the location of the main (proximity to population centres and buildings where escaped gas has the potential to collect and result in an explosion), and the pressure of the gas in the pipe. The inherent risk associated with pressurised natural gas means any substantial release of gas (regardless of the asset that fails) gives rise to the potential for explosion and fatalities or several people with life-threatening injuries.[18] Therefore, we consider the lowest plausible severity ranking for any gas main is 'major', with the severity rating of asset failure in densely populated areas such as the Melbourne CBD being 'catastrophic.'

[18] AS/NZS 4645 Risk Severity Matrix, 'Major' rating.

With regard to the impact on gas supply and environment, the consequences of a mains failure are far less severe. Only a failure in the trunk mains would have the potential for a restriction of supply (and then only to a limited number of customers in the Network for a limited time), with failure elsewhere only likely to result in a short term or very isolated interruption. Environmental impact of mains failure is minor and very isolated, not only because of the short duration of any escape but because natural gas will dissipate into the atmosphere and leave negligible residual effect.

6.2.2. Likelihood of Catastrophic / Major Event

The next stage of the risk assessment considers the likelihood (frequency) that the failure event will occur and cause harm to people. AS/NZS 4645 has five frequency classes, ranging from ‘Frequent’ (expected to occur once per year or more) down to ‘Hypothetical’ (theoretically possible but has never occurred on a similar gas distribution network).

Though the AS/NSZ 4645 risk matrix considers impact on people, supply and the environment, standard risk management practice is to assess the likelihood of the highest consequence risk occurring when rating the risk event. This approach is supported by Jacobs:

> *“We are specifically focused on the first ranking under the heading “People” as this is where the fundamental safety risk is. This should not in any way be taken as a diminution of the importance of reliability of supply or the environment, but is a direct acknowledgement that the risk of a gas escape leading to an explosion causing significant loss of life and/or property damage is, and should be, the principal concern.”*[19]

Therefore, we have used the AS/NZS 4645 frequency analysis to assess the following risk event:

> *The frequency that a crack or leak in the gas main results in gas collecting in a building and causes an explosion that results in fatalities or several people with life-threatening injuries.*

The table below shows AGN’s assessment of risk frequency associated with gas mains.

[19] Jacobs 2015, “*Mains Replacement Program Review*”, December 2015, pg. 29.

Figure 6: AS/NZ 4645 Likelihood Assessment

Frequency Class	Frequency Description	AGN Asset Classification
Frequent	Expected to occur once per year or more	
Occasional	May occur occasionally in the life of the gas distribution network	4 5
Unlikely	Unlikely to occur within the life of the gas distribution network, but possible	1 6 7
Remote	Not anticipated for this gas distribution network at this location	8 9
Hypothetical	Theoretically possible but has never occurred on a similar gas distribution network	2 3 10 11

3	3	3	3	3	3	3	3	3	3	11
LP CI/UPS CDC	LP PVC CBD	LP Steel CBD	MP CI/UPS Trunk	LP CI/UPS CDC	LP PVC HDICS	LP CI/UPS CDC	LP PVC LDC	HP HDPE575 > 35 Years	HP HDPE575 < 35 Years	HP PE80/PE100

The key drivers of risk frequency are the pipe material and condition (propensity to crack) and the mains pressure. When assessing frequency, it is also important to consider proximity of the mains to the general population and/or buildings, and the historical occurrence of incidents that either resulted in or had the potential to result in a catastrophic or major event.

CI/UPS mains pose a risk because many of these assets are situated in suburbs with older buildings that have underfloor cavities. Migration of gas even at relatively low pressure can result in an explosive gas/air mixture below or in a building, with catastrophic consequences. This has resulted in numerous fatalities overseas.[20]

Three recent CI/UPS mains failures (in 2004, 2015 and 2016) in AGN's South Australian network associated with CI/UPS mains (the most recent in the Adelaide CBD) demonstrate that gas has been known to escape and collect in buildings in sufficient quantities to cause explosion. These incidents and those experienced by distribution businesses overseas highlight that CI/UPS mains, left untreated, can eventually (during the residual life of those assets) lead to a GIB explosion with potential for fatalities.

When assessing the frequency of the risk event, the highest frequency rating considered appropriate for the Network was 'occasional' because, an event would not be expected to occur once per year for any main type. However, the differences between the remaining frequency ratings are more difficult to determine. Therefore, AGN has assessed frequency against the remaining ratings based on a relative assessment of each sub-category.

The following summarises the basis for the asset category frequency rating assessment:

- **Occasional – may occur occasionally in the life of the network**
  - The likelihood of an event on CI/UPS mains located in HDICS and MP CI/UPS trunk mains is rated as 'occasional' on the basis that CI and UPS mains have a high failure rate, trunk

[20] Jacobs, "*Mains Replacement Program Review*", December 2015.

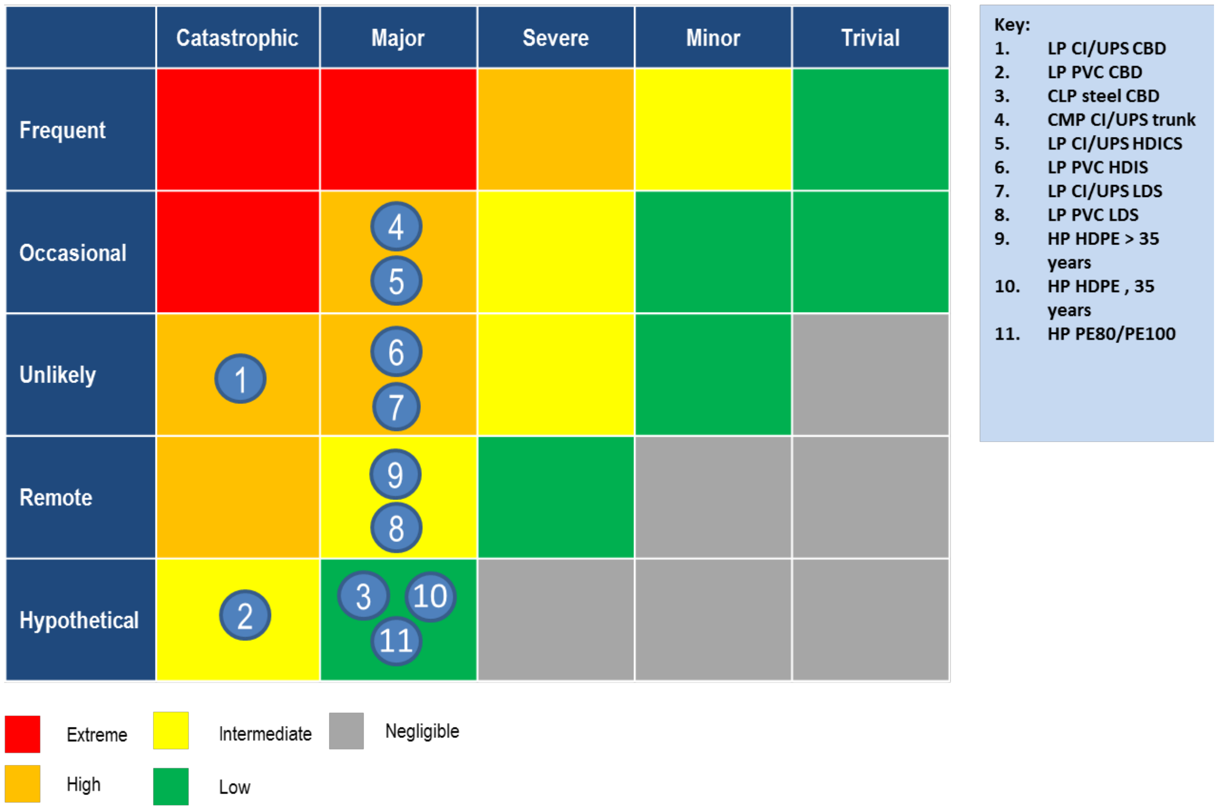
mains are operated at a higher pressure, and mains in HDICS have closer proximity of mains to buildings with underfloor cavities.

- **Unlikely – unlikely to occur within the life of the network, but possible**
  - The likelihood of an event on LP CI/UPS mains located in the Melbourne CBD is rated 'unlikely', which is lower than CI and UPS in the HDICS because of the higher pedestrian traffic leading to earlier detection and reporting of leaks.
  - The likelihood of an event on LP PVC mains located in HDICS is rated 'unlikely'. This is lower than CI and UPS mains in HDICS because of the relatively lower frequency of crack failures; and the type of crack failure (localised non circumferential crack) when compared to CI mains.
  - The likelihood of an event on LP CI and UPS mains located in lower density suburbs has been rated 'unlikely' because housing in these locations is located further from the gas main compared to CI and UPS in the CBD and HDICS. This means there is typically more open space for leaking gas to vent before accumulating in building underfloor spaces.
- **Remote – not anticipated for this network at this location**
  - The likelihood of an event on LP PVC mains located in lower density suburbs is rated 'remote' because of the relatively lower frequency of crack failures; the type of crack failure (localised non circumferential crack) and lower proximity to housing/buildings.
  - The likelihood of an event on HP HDPE 575 mains greater than 35 years old has been rated 'remote' because of the relatively lower frequency of crack failures compared to other materials in the network (and compared to HDPE 575 in AGN's South Australian network). These mains also tend to be located further from housing and buildings.
- **Hypothetical – theoretically possible but has never occurred on a similar gas distribution network**
  - The likelihood of an event on PVC and steel in the CBD, HDPE 575 mains less than 35 years old, and new generation PE is rated 'hypothetical'. This is because experience to date has shown that these materials do not have a propensity for sudden, indiscriminant crack failure.
  - The likelihood of an event on PVC mains in the CBD is lower than in HDICS because the PVC mains in the CBD are made of a higher density (impact modified) PVC.

6.2.3. Overall Risk Rating

The AS/NZS 4645 risk framework then provides for the consequence and frequency analysis to determine an overall risk rating. The ratings range from 'high' to 'negligible', and correspond to a recommended risk treatment action (presented in Section 6.2.4). Based on the above severity and frequency analysis, Figure 6.3 shows the overall risk rating for the different categories of mains in the network.

Figure 6.3: Overall Risk Rating



The risk assessment has resulted in a rating of ‘high’ for five categories of mains: all of the CI and UPS mains and PVC mains in the HDICS (250 kilometres). Three categories of mains have been rated as ‘intermediate’ (641 kilometres) and three rated as ‘low’ (6,738 kilometres). No mains are rated as ‘extreme’ or ‘negligible’ risk.

6.2.4. Risk Treatment Actions

AS/NZS 4645 provides direction on how the risks in a gas distribution network should be treated and places an obligation on network operators to take action. Figure 6.4 shows the relevant risk treatments required by AGN’s obligation under AS/NZS 4645 and the categories of main that require each treatment.

Figure 6.4: AS/NZ 4645 Risk Treatment Actions

Risk Rating	Required Action	Asset Classification
Extreme	Modify the threat, the frequency or the consequences to ensure that the risk rank is reduced to Intermediate or lower. For a gas distribution network in operation the risk must be reduced immediately.	
High	Modify the threat, the frequency or the consequences to ensure that the risk rank is reduced to Intermediate or lower. For a gas distribution network in operation the risk must be reduced as soon as possible, typically within a timescale of not more than a few weeks.	1 4 5 6 7
Intermediate	Repeat threat identification and risk evaluation process to verify and, where possible, quantify the risk estimation; determine the accuracy and uncertainty of the estimation. Where the risk rank is confirmed to be Intermediate, if possible modify the threat, the frequency or the consequence to reduce the risk rank to Low or Negligible. Where the risk rank cannot be reduced to Low or Negligible action shall be taken to: a remove threats, reduce frequencies and/or reduce severity of consequences to the extent practicable; and b demonstrate ALARP. For a gas distribution network that is in operation the reduction to low or negligible or demonstration of ALARP must be completed as soon as possible, typically within a timescale of not more than a few months.	2 8 9
Low	Determine the management plan for the threat to prevent occurrence and to monitor changes which could affect the classification.	3 10 11
Negligible	Review at the next review interval.	

1	2	3	4	5	6	7	8	9	10	11
LP CI/UPS CBD	LP PVC CBD	LP Steel CBD	MP CI/UPS Trunk	LP CI/UPS HDICS	LP PVC HDICS	LP CI/UPS LDS	LP PVC LDS	HP HDPE575 ¤ 35 Years	HP HDPE575 ¤ 35 Years	HP PE80/PE100

Appendix C of AS/NZS 4645 requires that AGN must reduce any risks rated as 'High' to 'intermediate' or lower as soon as possible, typically within a few weeks. ~~For risks rated as~~ 'intermediate' the reduction to 'low' or negligible or demonstration of ALARP must be completed as soon as possible, not more than a few months.

The next step in AGN's assessment is therefore to consider the risk mitigation options available to address the risk consistent with the risk rating.

6.2.5. Sensitivity Analysis

To challenge the rigour and reasonableness of the risk rating, we considered the sensitivity of the risk rating to the risk assessment of severity and frequency for each category of mains. The purpose of this exercise was to understand how a shift in risk assessment might impact AGN's obligation to replace the mains or change the recommended risk treatment. Figure 6.5 shows the revised AS/NZS 4645 risk assessment outcome if the risk severity or frequency assessment (or both) is lowered by one degree.

Figure 6.5: Risk Rating Sensitivity Analysis

#	Asset Category	AGN Risk Rating	Lower Consequence	Lower Likelihood	Lower Consequence and Likelihood	km
1	LP CI/UPS – CBD	High	High	High	Intermediate	25
2	LP PVC – CBD	Intermediate	Low	Intermediate	Low	12
3	LP Steel – CBD	Low	Negligible	Low	Negligible	7
4	MP CI/UPS – Trunk	High	Intermediate	High	Intermediate	32
5	LP CI/UPS – HDICS	High	Intermediate	High	Intermediate	96
6	LP PVC – HDICS	High	Intermediate	Intermediate	Low	85
7	LP CI/UPS – LDS	High	Intermediate	Intermediate	Low	11
8	LP PVC - LDS	Intermediate	Low	Low	Negligible	25
9	HP HDPE - > 35 years	Intermediate	Low	Low	Negligible	597
10	HP HDPE - < 35 Years	Low	Negligible	Low	Negligible	2,480
11	HP PE80/PE100	Low	Negligible	Low	Negligible	4,330

Lowering the severity assessment places mains sub-categories 3 to 11 in the 'severe' rating. Under AS/NZS 4645 a severe event results in injury or illness requiring hospital treatment, and excludes the possibility of a fatality. We do not consider excluding the possibility that a fatality could occur is a reasonable assumption. Therefore, the severity rating for categories 3 to 11 is appropriate at 'major'. It could be argued that the severity rating for categories 1 and 2 could be also lowered to 'major' rather than 'catastrophic'. However, we consider it is reasonable to assume a risk event occurring in the CBD has the potential to cause multiple fatalities. Nevertheless, if a lower severity rating is adopted, it does not change the rating for CI and UPS in the CBD.

If the likelihood rating is lowered the risk rating is altered for Categories 6 to 9. A rating of 'intermediate' for CI and UPS and 'low' for HDPE 575 greater than 35 years old is not consistent with the outcomes observed in other jurisdictions and would seem to be underestimating the risk associated with these mains. The sensitivity analysis is considered further in the cost assessment of risk mitigation options in Appendix B.

7. Cost and Options Analysis

Before deciding how best to address the risk associated with the mains, it is important that all options are considered. While replacement is unquestionably the most effective treatment to reduce the inherent risk associated with ageing gas mains, AGN understands that blanket replacement, particularly over a short time frame, is not always the most prudent course of action.

Therefore, we have analysed a range of options for mains replacement (and risk mitigation) over the next five years. The options analysis considers the activities available to reduce the risk consistent with the risk treatment guidance provided by AS/NZS 4645, and the cost of each option. When considering the options available AGN considers the cost impact to customers, deliverability, and whether the activities will be effective in reducing the consequence of the risk event or the likelihood of the risk event.

An important consideration when determining the most appropriate risk treatment is that the consequence of a risk event will always be ‘catastrophic’ or ‘major’. This is due to the co-location of buildings and people – no matter how likely or unlikely a risk event may be, if one was to occur, the **consequences** could be grave. As a result, in order to bring the overall risk ranking form ‘high’ to ‘low’ any risk treatment on mains must reduce the **likelihood** of the event occurring.

Another key point is that the inherent risk associated with natural gas and natural gas networks means that it is not possible to reduce the overall risk to ‘negligible’. All gas networks in all jurisdictions are prone to leaks, and the potential consequence that escaped gas can collect in sufficient quantities to result in an incident that could cause harm will always be there, no matter how remote the likelihood. Therefore, the lowest overall risk ranking achievable is ‘low’.

Further, in considering the risk treatment options for each sub-category of main, it is assumed the current level of operational risk mitigation activity will continue. Only the incremental impact of increasing operational activities and the cost of replacement programs have been considered when assessing the costs, benefits and impact on risk.

At the end of 2017 there will be approximately 10,433 kilometres of mains in the network, of which 7,628 kilometres currently require monitoring of risk and which are the subject of the current risk assessment. These mains and associated risk rating are allocated to the 11 categories described in section 6, as shown in Table 7.1.

Table 7.1: Asset Categories and Forecast Kilometres of Mains at 31 December 2017

#	Asset Category	Kilometres (2018)	Risk Rating	Proposed Action
1	LP CI/UPS CBD	25	High	Replace
2	LP PVC CBD	12	Intermediate	Monitor
3	LP Steel CBD	7	Low	Monitor
4	MP CI/UPS Trunk	32	High	Decommission/Abandon
5	LP CI/UPS HDICS	96	High	Replace
6	LP PVC HDICS	85	High	Replace
7	LP CI/UPS LDS	11	High	Replace
8	LP PVC LDS	25	Intermediate	Replace
9	HP HDPE 575 > 35 Years	597	Intermediate	Replace 7km
10	HP HDPE 575 <35 Years	2,480	Low	Monitor/sample 3km
11	HP PE80/PE100	4,330	Low	Monitor
Total		**7,768**		

Of these mains, around 250 kilometres are rated as 'high' risk and 633 kilometres as 'intermediate' risk. The remaining kilometres are rated as 'low' risk. The following sections outline the options considered, by risk rating and the proposed actions in the next AA period.

7.1. 'High' Risk Mains

There are 250 kilometres of mains ranked as 'high' risk. These include:

- *Categories 1, 4, 5 and 7* - all CI and UPS mains regardless of where they are located (164 kilometres); and
- *Category 6* - 85 kilometres of PVC mains located in the HDICS.

The risk treatment options and recommendations are outlined in the following sections.

7.1.1. CI and UPS Mains (Categories 1, 4, 5, & 7)

Table 7.2: CI and UPS 'High' Risk Mains Replacement Scenario

Risk Rating and Proposed Action	High/Replace
Replacement Length	164 kilometres
Cost of Planned Replacement	[redacted]
Cost of Unbundled Replacement	[redacted]

The options for reducing the likelihood of a risk event occurring for CI and UPS mains are limited. These mains are mostly operated at low pressure (the trunk mains at medium pressure) and their location is driven by the customers served from these mains. The inherent risk associated with these mains is directly related to the material, which has a high propensity for sudden crack failure which worsens as the material ages. Risk mitigation activities that increase the likelihood of detection therefore will not be effective as these activities will only detect a crack after the crack has occurred, and that detection may occur far too late to avoid an incident. Therefore, AGN considers that replacing CI and UPS is the only risk treatment that will reduce the risk rating from 'high' to 'low'.

This view is consistent with experience in the United Kingdom (UK) and the United States (US). Technical experts Jacobs were engaged by AGN to provide a review of the proposed mains replacement program in South Australia as well as advice on risk associated with CI/UPS and HDPE mains in other jurisdictions, drawing on its experience in the US and UK gas sectors. In both the US and the UK, the qualitative case was built from a detailed review of a series of incidents that have occurred on iron mains and from a review of frequency and nature of breaks, leaks, and corrosion (failure modes) found on iron networks that can, under certain conditions, result in an incident.[22]

Drawing on its experience in the US and UK gas sectors. In its expert report Jacobs states:

> *"Various risk-based cast iron replacement schemes have been adopted in the UK since the 1970s. However, over 30 years later the UK was still experiencing failures leading to about four serious fires and explosion incidents each year. Based on a number of studies into these incidents, the UK Health Safety Executives (HSE) determined that the risk posed by cast and ductile iron, including the unpredictable nature of that risk and inability of well-intentioned risk management programs to effectively reduce that risk, could no longer be accepted. The UK Iron Main Replacement Program (IMRP) was introduced in 2002 to address societal concerns by dealing directly with the inherent risk posed by iron mains (both cast and ductile iron)."*[23]

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[21] The cost estimate for Scenario A (unbundled pricing) reflects the much higher construction overhead associated with targeted renewal of CI and UPS in the HDICS and LDS areas. Size for size renewal involving direct lay of new LP mains would be required, along with a much larger amount of trunk infrastructure to replace the existing CI and UPS MP trunk mains. This work would be slower, more disruptive to the public and significantly more expensive on a unit length basis than block renewal and is therefore not only impractical, but inefficient.

[22] Jacobs, "*Mains Replacement Program Review*", January 2016, pg. 9. Provided as Attachment 8.11 to the AGN South Australian Revised AA Proposal.

[23] Jacobs, "*Mains Replacement Program Review*", January 2016, pg. 10. Provided as Attachment 8.11 to the AGN South Australian Revised AA Proposal.

And:

> *"US regulators have justified accelerated cast iron replacement based on a safety case. In the UK, policy makers determined that cast iron mains posed a 'societal risk' meaning a hazard that impacts society at large, such as a risk of multiple fatalities from a gas explosion. In both the US and the UK, the qualitative case was built from a detailed review of a series of incidents that have occurred on iron mains and from a review of frequency and nature of breaks, leaks, and corrosion (failure modes) found on iron networks that can, under the certain conditions, result in an incident. This was coupled in both cases with an unwillingness of policy makers and regulators to tolerate a known risk associated with obsolete materials.*
>
> *In both the US and the UK the risk to be avoided is not limited to the risk of multiple fatalities but also the risk of significant property damage such as, if an incident occurs when a building is empty, had the building been occupied it would have potentially resulted in loss of life.*
>
> *It is cast iron's failure mode that has caused regulators in the US and UK to support accelerated replacement. This failure mode has proven to be unpredictable and catastrophic. Ground movement is the primary trigger for failure."*[24]

Jacobs also referred to examples of incidents in US and UK gas distribution networks that resulted in death or serious injury, consistent with the catastrophic risk assessment. Data on gas distribution incidents in the US between 2005 and 2014 show that:

- 10.2% of the incidents on gas distribution mains involved CI mains. However, only 2.3% of distribution mains are CI;
- In proportion to overall CI main mileage, the frequency of incidents on mains made of CI is more than four times that of mains made of other materials;
- 40% of the cast/wrought iron main incidents caused a fatality or injury, compared to only 18% of the incidents on other types of mains; and
- 10% of all fatalities and 7% of all injuries on gas distribution facilities involved cast or wrought iron pipelines. [25]

The rate of cracking in the Victorian CI network is almost two and half times that of UK CI mains, where the UK HSE has mandated that all CI be replaced on an accelerated basis.

AGN has assessed that the only effective way of reducing the risk associated with CI and UPS mains is to replace them. The cost of replacing all the CI and UPS mains over the next AA period is $95 million if done as part of the proposed bundled program of work.[26]

By way of comparison, the projected expenditure over the period 2013 through to the end of 2017 on mains replacement is $232 million. The costs to customers of the proposed program of work is $3.85 per year (less than 20% of the cost incurred from the program in the 2013 - 2017 AA period) which will enable all of the 'high' risk CI and UPS mains to be eliminated from the network and the 'intermediate' risk PVC in HDICS and LDS.

AGN proposes to replace or abandon all CI and UPS mains located in the CBD and HDICS and all CI and UPS MP trunk mains within the next five years. Most of the 32 kilometres of MP trunk is

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[24] Jacobs, "*Mains Replacement Program Review*", December 2015, pg. 10. Provided as Attachment 8.11 to the AGN South Australian Revised AA Proposal.

[25] Jacobs, "*Mains Replacement Program Review*", December 2015, pg. 8. Provided as Attachment 8.11 to the AGN South Australian Revised AA Proposal.

[26] See Appendices A and B for cost and risk analysis.

expected to be able to be decommissioned but construction of about 12 kilometres of new trunk main is required to support the HP network as it is extended to replace the LP network.

As is usual practice, these mains will be replaced as part of a proactive block replacement program rather than a reactive piecemeal approach, to capture efficiencies in the replacement method. If these mains were to remain in the network, it is expected that there will be an increased number of repairs required. Repairs (or piecemeal replacement) can cost three to five times more than block replacement. The costs associated with the decommissioning or construction are included in the total cost of the CI/UPS shown above.

7.1.2. PVC Mains in High Density Inner City Suburbs (Category 5)

Table 7.3: PVC HDICS 'High' Risk Mains Replacement

Risk Rating and Proposed Action	High/Replace
Replacement Length	[redacted]
Cost of Planned Replacement	[redacted]

There will be 85 kilometres of 'high' risk PVC mains in HDICS as at the end of December 2017. These mains were laid during the 1980s to replace problematic CI and UPS on a piecemeal or reactive basis. As these mains age they become brittle and the glued joints are susceptible to failure. These integrity issues will worsen with age. While increasing survey frequency may reduce the time that leaks remain undetected, it will not prevent the risk event. Therefore, replacement of these mains is the only treatment that will reduce the risk from 'high' to 'intermediate' or 'low'.

Some of the PVC mains have been replaced in the more recent CI and UPS block replacement program. As PVC is interspersed with CI and UPS it is not feasible, from a practical or efficiency perspective, to undertake block replacement and leave sections of PVC embedded in an area. Retaining 'pockets' of low pressure PVC would result in increased renewal costs and ongoing maintenance costs, while resulting in a lower overall integrity of service and reliability due to :

- *Maintaining MP and LP CI trunk supply mains* - Block replacement and upgrade to high pressure allows the majority of these mains to be abandoned or inserted with smaller diameter pipe. This avoids significant cost of replacing these mains, size for size by direct burial, that otherwise would be necessary to maintain 'pockets' of LP PVC.
- *Lower economies of scale* - The existing unit replacement rates have been achieved due to economies of scale. Smaller replacement volumes (by retaining pockets of PVC) would require additional contractor 'mobilisation' and 'demobilisation' increasing replacement unit costs. In addition, leaving small sections of PVC pipe in a whole suburb that is due to be renewed, may require the whole of the mains and services in that suburb to be replaced by direct burial rather than by insertion.
- *Network fragmentation* - A 'contiguous' high pressure network allows replacement to be optimised by using more small diameter mains at significantly lower unit rates. Retaining low pressure pockets fragments the network and inhibits the movement of gas from one area to another. This results in either larger diameter mains or additional pressure regulating facilities, at a higher cost, to maintain supply within the high pressure network. Additionally, network fragmentation increases the degree and scale of disruption when mains get damaged, and make it easier for service interruptions to occur.

We consider that the cost of removing all the HDICS PVC mains is reasonable given the risk reduction from 'high' to 'low' and therefore plan to undertake the removal of all the 'high' risk mains in the network in the next AA period.

7.2. 'Intermediate' Risk Mains

There are 633 kilometres of mains ranked as 'intermediate' risk. These are:

- Category 2: Low pressure PVC mains located in the CBD (12 kilometres);
- Category 8: Low pressure PVC mains located in LDS (25 kilometres); and
- Category 9: High pressure HDPE 575 greater than 35 years old (597 kilometres).

The proposed risk treatment options for each of these categories of mains are discussed below.

7.2.1. PVC Mains in the CBD (Category 2)

Table 7.3: PVC 'Intermediate' Risk CBD Mains Replacement

Risk Rating and Proposed Action	Intermediate/Monitor
Replacement Length	[redacted]
Cost of Replacement	[redacted]

PVC mains in the CBD are rated lower risk than PVC mains in the HDICS because the PVC material used in the CBD is higher density and therefore, has a lower propensity to crack. However, the material is still more likely to crack than PE.

AGN considers that further operational activities including increasing the frequency of leak surveys in the CBD are unlikely to materially lower the risk as these surveys already occur every six months. The only effective risk treatment option would be to replace these mains. The ability to replace these mains in a desired timeframe is constrained by the difficulty of planning and scheduling works in the CBD. Therefore, it is expected that the program to replace these mains may take up to five years, meaning that the risk would not be reduced from 'intermediate' to 'low' quickly.

It is also noted that the CBD network is experiencing supply capacity issues that have given rise to the need to upgrade the CBD network to high pressure in the next AA period. Once this occurs, the low pressure PVC in the CBD will eventually be redundant and abandoned.

The cost of replacing these mains with PE would be $14.5 million. There is a high cost associated with undertaking work in the CBD, due to the nature of undertaking works in such an environment. The incremental cost to customers is $0.44 per customer per year and is with the current information available to AGN, is not considered to be reasonable for the next AA period.

We will continue current operational measures to manage the risks associated with PVC mains in the CBD in order to manage the risk to ALARP.

7.2.2. PVC Mains in Lower Density Suburbs (Category 8)

Table 7.4: PVC 'Intermediate' Risk LDS Mains Replacement

Risk Rating and Proposed Action	Intermediate/Replace
Replacement Length	[redacted]
Cost of Planned Replacement	[redacted]

There are 25 kilometres of PVC mains located in LDS. The PVC mains in the LDS are rated as lower risk than the PVC mains in the HDICS due to further proximity to people and buildings. Nevertheless, the PVC material is prone to become brittle and crack. Again, although operational activities can facilitate the detection of leaks or cracks at some point in time after they occur, they will not reduce the severity of the risk event or the likelihood. Replacing these mains is the only effective risk treatment option.

The PVC mains were laid during the 1980s as part of the piecemeal replacement of CI and UPS mains. As discussed in section 7.1.2, these mains will continue to be replaced as part of the CI and UPS replacement program, as it is not possible to upgrade areas to high pressure and leave such mains in situ.

7.2.3. HDPE Mains Greater than 35 Years Old (Category 9)

Table 7.5: HDPE 'Intermediate' Risk Mains Replacement

Risk Rating and Proposed Action	Intermediate/Replace
Length	[redacted]
Cost of Replacement	[redacted]

HDPE 575 mains become increasingly susceptible to sudden crack failures as they age, particularly once the material approaches 50 years old. There are 3,005 kilometres of HDPE 575 mains in the Network with an average age of 28 years. There are 597 kilometres of HDPE 575 mains that are more than 35 years old rated as 'intermediate' in the Network.

Experience with HDPE 575 in the South Australian network has led to a higher risk rating for these mains. The mains in the Victorian network are of similar vintage to the mains that have shown a deteriorating crack rate in South Australia. There is considerable uncertainty surrounding the risk posed by these mains in Victoria, and so we intend to investigate the condition and material properties of these mains in order to better understand the likelihood of failure. This is to be assisted through a sampling program by replacing a nominal 3 kilometres of pipe.

Analysis and review of the samples provided will be undertaken by a Deakin University research team under the auspices of the Energy Pipelines Cooperative Research Centre (EPCRC) project. The project, "Cracking in Polyethylene Pipelines", has been initiated with Deakin University by AGN's Victorian Asset Manager.

A key aim of the project is to ascertain the remaining life of first generation HDPE pipes. This will be achieved by investigating PE pipe degradation (with an initial focus on HDPE 575), and how environment and stress concentrators (such as squeeze off practices) influence material failure.

The project aims to:

- identify suitable methods for measuring, distinguishing and quantifying the degree of degradation in various grades of "first generation" HDPE pipe materials; and
- provide information on how the interaction between pipe chemistry/structure, environmental degradation and introduction of defects through typical usage affect the cracking behaviour.

In addition, AGN will:

- continue to undertake research and development of inline camera technology to identify defects in pipe; and
- utilize project outcomes to develop a reliability forecast model to predict the remaining life of HDPE 575 that is specific to the Network, so that risk mitigation strategies, including replacement, can be optimised.

AGN will continue to monitor the activities and experience in its South Australian network as well as the condition of the mains in Victoria and revise the risk treatment options as new information becomes available.

The 'intermediate' rating of HDPE 575 mains older than 35 years means further risk treatment options should be considered. We remain of the view that where there is a propensity for sudden cracking, the likelihood of which will increase as the mains age, and the only effective risk treatment option is replacement. Therefore, we have assessed the incremental cost and risk impact of the options of piecemeal replacement of HDPE 575 older than 50 years, replacement over 15 years and replacement over five years.

The following table presents the cost and risks associated with these options.

Table 7.6: Options to Address 'Intermediate' Risk of HDPE 575 Mains > than 35 Years Old

Option	Km to be replaced in the Next AA Period	Risk at the End of the Next AA Period	Residual km at the End of the Next AA Period	Cost (Million)	Incremental Cost per Customer
Piecemeal replacement of mains > 50 years old plus sampling program - PROPOSED	10	'intermediate'	587	[redacted]	
Replace over 15 years	200	'intermediate'	397	[redacted]	$2.52
Replace over 5 years (the 2018 AA period)	597	'low'	0	[redacted]	$8.04

We consider the cost of achieving a 'low' risk rating after five and 15 years is disproportionate to the risk reduction given the uncertainty in the information informing the risk assessment at this time.

Research conducted following gas explosions in South Australia suggests that SCG failure in HDPE 575 is a matter of when, rather than if. To date there have not been any HDPE 575 SCG related GIB incidents in AGN's Victorian network, although there have been a number of reported crack failures. There may be a number of operational and environmental factors delaying the onset of SCG failures in the Victorian network (compared to the South Australian network). These include:

1. better controlled squeeze-off procedures historically;

2 the reduced number of squeeze-offs applied during construction – the majority of HDPE 575 in Victoria has been direct laid, which did not require squeeze off;

3 different soil types;

4 relatively lower ground temperatures; and

5 differing proximity to buildings with underfloor cavities.

However, the absence of any major incidents to date is not an indicator that incidents will not occur in the future. Therefore, it is considered prudent, pending further research and analysis, to replace the small quantity of the oldest HDPE 575 (laid up to 1975) that has the highest potential of exhibiting crack failure. Consequently 7 kilometres of these HDPE mains will be replaced.

7.3. ‘Low’ Risk Mains

There are 6,745 kilometres of mains ranked as ‘low’ risk. These are:

- Category 3: Low pressure steel mains located in the CBD (7 kilometres);
- Category 10: High pressure HDPE 575 mains that are aged less than 35 years (2,480 kilometres); and
- Category 11: High pressure PE80 or 100 mains (4,330 kilometres).

We consider the current operational measures such as maintaining rapid leak report response, leak surveys, odorant level monitoring, and maintaining operating pressures to as low as possible without putting supply at risk, are considered to be sufficient to maintain this rating. These measures will continue during the next AA period.

7.4. Summary of Proposed Risk Treatment

The following table summarises the proposed risk treatment options for each sub-category of main.

Table 7.7: Mains Risk Treatment Options

Item	Asset Category	Kilometres (2018)	Risk Rating	Risk Treatment Approach	Km of risk to be removed in Next AA Period*
1	LP CI/UPS CBD	25	High	Replace as soon as possible	25
2	LP PVC CBD	12	Intermediate	No additional risk treatment proposed (6 month leak surveys in place)	0
3	LP Steel CBD	7	Low	No additional risk treatment proposed (6 month leak surveys in place)	0
4	MP CI/UPS Trunk	32	High	Replace or decommission as soon as possible– scope and timing related to replacement and upgrade of underlying LP networks	32
5	LP CI/UPS HDICS	96	High	Replace as soon as possible	96
6	LP PVC HDICS	85	High	Replace as soon as possible as part of CI/UPS replacement program	85
7	LP CI/UPS LDS	11	High	Replace as soon as possible	11
8	LP PVC LDS	25	Intermediate	Replace as soon as possible as part of CI/UPS replacement program	25
9	HP HDPE 575 > 35 Years	597	Intermediate	7 km end of life program	7
10	HP HDPE 575 <35 Years	2,480	Low	No additional risk treatment proposed; 3 km sampling program	3
11	HP PE80/PE100	4,330	Low	No additional risk treatment proposed	0
Total as per Risk Assessment					**285**
n/a	MP Trunk [New]	n/a	n/a	Construction of new trunk mains to support new mains	12
Total as per Mains Replacement Program					**297**

The length of risk removed covers those mains to be replaced or abandoned effectively eliminating the risk from this category of main and trunk mains required to support the capacity of the HP network allowing the network to be extended to replace the LP and MP networks.

8. Proposed Integrity Activities

This section outlines the proposed activities for mains and services over the next AA period.

8.1. Ongoing Mains and Services Integrity Activities

AGN will continue to manage the risks associated with mains through various operational measures such as maintaining rapid leak report response; appropriate leak survey frequency; monitoring of odorant levels; and maintaining operating pressures as low as possible.

In addition, AGN will undertake a sampling program of HDPE mains and monitor and incorporate the experience and outcomes of the risk mitigation activities and treatments being trialed in South Australia.

8.2. Mains Replacement

In addition to the ongoing mains and services operational risk mitigation activities, AGN will undertake replacement or decommissioning of the following mains over the next AA period:

- 177 kilometres of CI and UPS mains:
  - 25 kilometres in the CBD;
  - 44 kilometres of trunk mains (32 kilometres will be decommissioned and replaced with 12 kilometres of new or inserted trunk main);
  - 96 kilometres in high density inner city suburbs;
  - 11 kilometres in lower density suburbs;
- 110 kilometres of PVC mains:
  - 85 kilometres in high density inner city suburbs;
  - 25 kilometres in lower density suburbs;
- 10 kilometres of HDPE 575:
  - 3 kilometres as part of a sampling program; and
  - 7 kilometres where the mains are older than 50 years.

Table 8.1 below summarises the overall replacement volumes and costs for various asset categories.

Table 8.1: Mains Replacement Lengths and Costs

Category	Program	Length kilometres	Cost $M
1	CBD – Block	25.3	[redacted]
2	CBD – Trunk	1.6	[redacted]
3	HDICS/LDS - Trunk	10.2	[redacted]
4	Trunk - Decommission	32.4	[redacted]
5	CI/UPS HDICS	94.2	[redacted]
6	CI/UPS LDS	10.9	[redacted]
7	PVC HDICS	85	[redacted]
8	PVC LDS	25	[redacted]
9	HDPE 575 sampling program	3	[redacted]
10	HDPE 575 50 year old replacement	7	[redacted]
11	Piecemeal (included in CI/UPS HDICS)	2	[redacted]
	Total Length & Cost	**296.9**	**147.2**

8.2.1. CI and UPS Mains

The replacement of CI and UPS mains to date has occurred by the insertion method (inserting smaller diameter PE mains into the existing main) on a 'block' basis (by location or section) as this is the most cost efficient technique.

Block replacement allows mains to be inserted with smaller diameter pipe that operates at higher pressure. This typically results in higher network capacity and avoids expensive trenching and reinstatement that otherwise would be required if size for size 'piecemeal' replacement were undertaken. In addition, equipment and planning approvals can be focused in an area, reducing the number of times a particular crew needs to move, store materials or be held up by planning approvals or site preparation.

To optimise the risk reduction, the areas are prioritised based on the highest crack rate. It is noted that the sequence of replacement may require 'lower' risk areas to be replaced to ensure the HP network can be extended effectively or in circumstances to take advantage of third party works where it is cost effective to do so.

8.2.1.1. CI and UPS Trunk Mains

CI and UPS trunk mains provide the primary supply to downstream LP networks. It is expected that the majority of the CI and UPS trunk mains will be decommissioned as the LP network is replaced by insertion and upgraded to high pressure.

In 2015 a MP cast iron trunk main leak was found in the metro rail corridor in Thornbury. Repair required shutting down the South Morang train line during the peak afternoon commute, causing serious disruption to public transport. The renewal or abandonment of the MP CI and UPS trunk network is a key target of the 2018 to 2022 program, and will also remove potential for similar incidents.

The majority (32 kilometres) of the residual MP (predominately CI/UPS) trunk main will be decommissioned after the LP networks they supply are replaced. About 12 kilometres of new trunk main is required to 'augment' the supply to areas that have been inserted and upgraded to high pressure. These mains are generally in different locations to the existing MP CI and UPS trunk mains to 'optimise' the movement of gas across the HP network as it extends and replaces the current LP network. So while about 32 kilometres of existing CI and UPS MP trunk main can be abandoned about 12 kilometres of new HP trunk main is required to support the broader replacement program.

8.2.1.2. CBD Replacement Plan

A replacement strategy for the Melbourne CBD has been developed to replace 'at risk' mains. This strategy is based on insertion, where possible, existing CI and UPS mains and operating the new mains at low pressure. This will minimise disruption to the community while providing an effective and efficient replacement solution. Planning for a staged replacement program, detailing the scope and sequence of work, has been underway for some time.

The CBD strategy focuses on replacement of CI and UPS mains, leaving about 12 kilometres of PVC and 7 kilometres of cathodically protected steel mains operating at low pressure. The steel mains have been rated as 'low' risk so no further intervention is considered warranted. The CBD PVC mains, while rated an 'intermediate' risk, have been assessed as ALARP (refer to Section 7) with replacement to be deferred as in the longer term these mains are expected to be redundant.

The replacement of the Melbourne CBD is expected to span the 5 years of the next AA period because of construction constraints (proximity of other underground utilities, Melbourne City Council road closure restricted conditions, minimising disruption of gas supply to commercial consumers, etc.) that apply to working in a high density, business critical location.

8.2.2. Non-CBD Mains Replacement

The schedule for replacing CI/UPS and PVC in non-CBD suburbs is based on addressing first the suburbs where the highest crack and leak rates have been identified. Each suburb has been ranked by considering the crack and leak rate as presented in Table 8.2 below.

Table 8.2: Mains Replacement Suburb Ranking

Suburb Category	Suburb	Crack Rate	Leak Rate	Crack Rank	Leak Rank	Total Rank Score	Overall Rank
HDICS	NORTHCOTE	0.4	2	1	3	4	1
HDICS	NORTH MELBOURNE	0.3	1.3	2	5	7	2
HDICS	FITZROY NORTH	0.3	1.4	4	4	8	3
HDICS	CARLTON	0.3	1.1	3	7	10	4
HDICS	PRESTON	0.2	2.5	9	1	10	4
HDICS	RICHMOND	0.2	2.1	8	2	10	4
HDICS	FITZROY	0.3	1.1	6	6	12	7
HDICS	WEST MELBOURNE	0.2	1.1	7	8	15	8
LDS	IVANHOE	0.3	0.6	5	12	17	9
HDICS	PARKVILLE	0.2	1	10	9	19	10
HDICS	EAST MELBOURNE	0.1	0.9	12	10	22	11
HDICS	CLIFTON HILL	0.1	0.9	14	11	25	12
LDS	IVANHOE EAST	0.1	0.3	11	14	25	12
HDICS	CARLTON NORTH	0.1	0.5	13	13	26	14
LDS	EAGLEMONT	0	0.1	15	15	30	15
HDICS	WEST MELBOURNE	0.2	1.1	7	8	15	8

The lower the total rank score, the higher the replacement priority. The actual sequence and timing of replacement will depend on the detailed design and follow logical areas based on network configuration and proximity to existing HP network infrastructure.

8.2.3. Piecemeal Replacement

Some 'reactive' piecemeal replacement will be required as a means of overcoming urgent leakage problems or localised cases of water ingress. Short lengths (less than 100 metres) are typically replaced on a size for size direct basis using direct burial, rather than insertion. Piecemeal replacements are typically related to LP CI/UPS/PVC materials where the first response to a leak identifies a main in poor condition with replacement considered a more effective and efficient solution than repair. An accurate forecast of piecemeal volumes and locations is difficult to determine. A 'nominal' 500 metres per year been assumed for planning purposes.

8.3. Service Replacement

Services (connection between the main and meter) are replaced when mains are replaced. There are however cases where services need to be renewed on a stand-alone piecemeal basis. The need for such service renewals arise when leaks or damage occur on the service and inspection reveals that the service is heavily corroded or in such poor condition that repairs are not viable. Such ad hoc replacement will continue up until the end of the replacement program.

8.4. Replacement Schedule

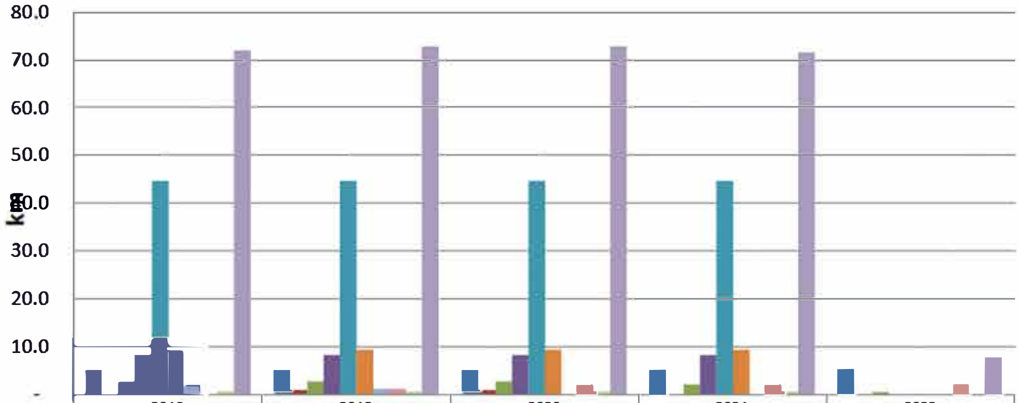
The following tables detail the mains replacement volumes and costs over the next regulatory period.

Table 8.3: Mains Replacement Summary

Category	2018	2019	2020	2021	2022	Total
CBD Block Replacement	5	5	5	5.1	5.2	25.3
CBD Trunk Replacement	-	0.8	0.8	-	-	1.6
General Trunk Replacement	2.6	2.6	2.6	2	0.4	10.2
Decommissioned Trunk Replacement	8.1	8.1	8.1	8.1	-	32.4
HDICS Block Replacement	44.6	44.6	44.6	44.6	-	178.5*
LDS Block Replacement	9.2	9.2	9.2	9.2	-	36.9*
HDPE Replacement (HDPE 575 Sampling)	2	1	-	-	-	3
HDPE Replacement (HDPE 575 > 50 year Replacement)	-	1	2	2	2	7
Piecemeal Replacement	0.5	0.5	0.5	0.5	-	2.0
Total Mains Replacement - km	**72.0**	**72.8**	**72.8**	**71.5**	**7.6**	**296.8**

*Note: HDICS and LDS block replacement includes CI, UPS, PVC and 'other' short lengths interspersed (SLI) material.

Figure 8.1: 2018 – 2022 Mains Replacement Kilometres Profile

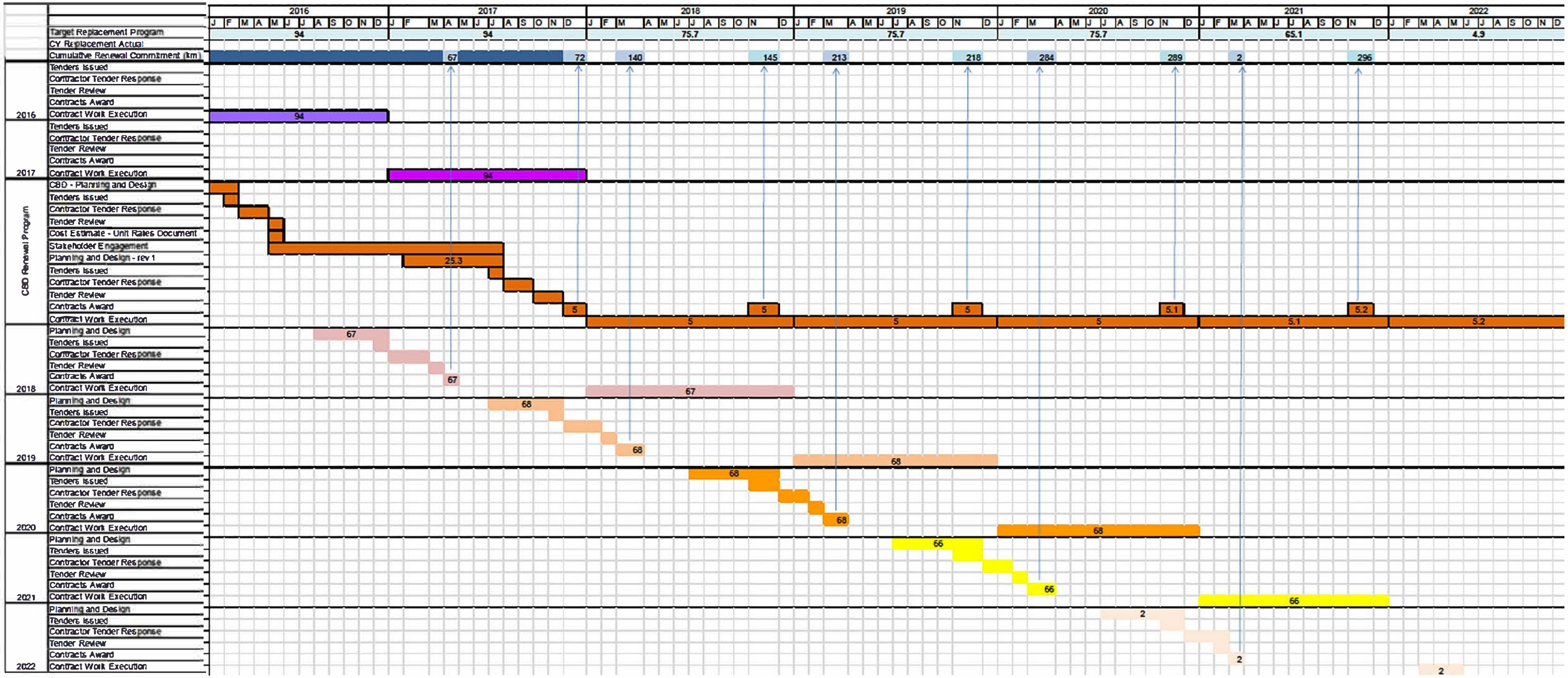


	2018	2019	2020	2021	2022
CBD - Block	5.0	5.0	5.0	5.1	5.2
CBD - Trunk	0	0.8	0.8	0	0
HDICS/LDS Trunk	2.60	2.60	2.60	2.00	0.40
Trunk - Decommission	8.10	8.10	8.10	8.10	0
HDICS - Block	44.61	44.61	44.61	44.61	-
LDS - Block	9.22	9.22	9.22	9.22	-
HDPE Sampling	2	1	0	0	0
HDPE > 50 Year	0	1	2	2	2
Piecemeal	0.5	0.5	0.5	0.5	0
Total Replacement	72.0	72.8	72.8	71.5	7.6

8.5. Mains Replacement Delivery Schedule

The following diagram presents the scheduling for each part of the program.

Figure 8.3: Mains Replacement Delivery Schedule



9. Delivery Capability

The mains replacement program planned for the next AA period is well within AGN's current delivery capacity and capability. The 297 kilometres to be replaced/laid during the next AA period is substantially less than the 696 kilometres replaced during the current AA period.

Efficient delivery during the current AA period was achieved by ensuring tenders were issued up to 18 months in advance of the work that was to be executed. This ensured that the planning, budgeting, negotiation and execution cycles were aligned to ensure a cost effective program. It also ensured that contractors could be issued stages of work in such a way that interference between adjacent replacement areas was minimised.

AGN is committed to using best practice procurement processes to minimise the risk and costs of procuring services and materials. These processes underpin efficient and cost effective capital expenditure.

The majority of the work will be conducted by external contractors delivering to unit rates established by competitive tender. An internal labour crew will also be maintained to ensure that a level of hands-on experience with the complexity, health, safety and environmental requirements of block mains replacement is available.

Major block renewal programs outside of the CBD will be delivered in the 2013 - 2017 AA period. In the CBD, the complexity of operating in such an environment is already well understood as a result of previous experience by AGN in undertaking CBD works in Adelaide and Brisbane, as well as in Melbourne.

Furthermore, the trunk mains program will be primarily a program of decommissioning, with a minority of such mains requiring insertion.

Notwithstanding, the delivery of the Melbourne CBD renewal program has been recognised as a major project with particular challenges. To enable program to progress on schedule, the following items/actions have been undertaken or scheduled:

1. Network concept design confirming capacity requirements and future network configuration (completed 2016).
2. Issue of initial tender, based on the concept design, to solicit feedback on unit rates and cost effectiveness of various renewal options such as insertion versus service transfer to HP steel main (completed 2016).
3. An additional twelve month round of planning, design and stakeholder engagement and tendering during 2017 has been built into the schedule to ensure that feedback from various stakeholders (including from the initial tender) can be incorporated into the final detailed design and sequence of delivery. This will allow the delivery of the program to be optimised, accounting for constraints and/or other capital works being undertaken within the CBD.
4. The difficult working environment in the CBD has been taken into consideration by schedule replacement over a five-year period. This equates to a planned replacement rate of 125 metres per week (assuming a forty week working year). This planned rate is purposefully low, aimed at providing an adequate 'buffer' to resolve construction issues that may arise without compromising the completion of the program. The replacement rates in other relatively congested inner city areas such as Carlton and Richmond have been more than double this planned rate and of the order of four times in AGN's Adelaide CBD replacement program. Given this past performance and experience, the delivery risk is therefore considered low.

Notwithstanding this, APA's project management processes and access to a pool of skilled and experienced contract resources will be used to ensure the planned replacement rates are met.

5 Each section of the CBD replacement is planned to occur on consecutive nights, with preliminary site works being completed on one night, and the renewal itself occurring over the course of the following one to two nights. The site preparations are planned to be done during the day, with resources such as supervision shared between the CBD and nearby inner city block renewal.

6 APA will maintain monthly management reviews of progress to ensure the program of work remains on track. A formal annual review, as part of the annual production of this DMSIP, will be undertaken detailing any changes necessary to the overall CBD strategy and program delivery (including options to bring forward replacement if higher replacement rates eventuate). As the block renewal program outside the CBD tails off and additional skilled resources become available, this may provide some flexibility to 'accelerate' the CBD program if required and if practical to do so.

In summary, the following factors provide a high degree of certainty in relation to program deliverability:

- extensive planning and preparation timeframe;
- work already undertaken in respect of contract preparations;
- the long time frame allowed for actual works, compared with similar works undertaken by AGN;
- the availability of additional resources as other parts of the replacement program are completed; and
- management monitoring and control processes.

In terms of transparency of deliverability of the risk reduction program, and deliverability to appropriate standards, AGN will be providing monthly/regular progress reporting to ESV on progress of the replacement program, including at quarterly meetings with ESV, and a number of other measures/indicators are also available for external review, including:

- *Contractor competency audit results* – competency audits are completed before a contractor commences a project, as part of the pre-start process; and
- *Contractor monthly KPI reports* – these KPIs cover, among other items, work quality, with KPIs benchmarked and compared across contractors on a monthly basis. Contractors also undergo Fatal Risk Activity Reviews (a field audit tool that allows for specific checks on a range of items that impact site risk, from Safe Work Method Statements to special procedure requirements (hot tap, deep excavations, etc).

10. Cost Estimation

10.1. Methodology

The methodology adopted to estimate the costs of the program has been to identify the mains to be replaced each year by main type, the kilometres to be delivered and location based on a schedule of works and supporting plans and procedures to achieve approval requirements. This is then multiplied by respective unit rates to develop the cost of replacement.

The unit cost per kilometre has been drawn from a mix of:

- historical information (tenders and outcomes);
- assessment of the extent and reasons for variations to past contract costs; and
- and new tender information for particular scope of works.

The unit cost is then applied to the schedule of works each year. Further information about the unit rates is provided in Attachment 8.2 to our Final Plan. This approach is consistent with that used to develop cost estimates in respect of the South Australian mains replacement program.

The following sections summarise the unit rates adopted when estimating the cost of the program.

10.2. Unit Rates

The following table presents the unit rates used for each main type and location to estimate the costs of mains replacement.

Table 10.1: Mains Replacement Unit Rates - $/metre

Volume Category	Unit Rate Category	Unit Rate
CBD Block – (CI, UPS, PVC)	CBD Block Replacement	[redacted]
CBD Trunk – (MP CI)	CBD Trunk Replacement	[redacted]
HDICS/LDS - Trunk Replacement (CI,UPS)	General Trunk Replacement	[redacted]
HDICS/LDS Trunk Decommission (CI,UPS)	Decommissioned Trunk Replacement	[redacted]
HDICS – Block (CI, UPS, PVC, Other)	HDICS Block Replacement	[redacted]
LDS – Block (CI, UPS, PVC, Other)	LDS Block Replacement	[redacted]
HDPE 575 - Sampling	HDPE Replacement	[redacted]
HDPE 575 - Replacement	HDPE Replacement	[redacted]
Piecemeal Mains Replacement (CI,UPS)	Piecemeal Replacement	[redacted]

10.3. Financial Assumptions

The following table summarises key financial assumptions used in the customer impact assessment detailed in Appendix B.

Table 10.2: Cost Impact Financial Assumptions

Financial Assumptions	
Post Tax Real Return on Equity	4.09%
Debt to Equity Ratio	60%
Interest Rate	4.42%
Debt Repayment	60 years
Project Assessment Period	60 years

These financial assumptions were adopted for illustrative purposes only. The outcome from the model in terms of ranking and risk profile do not materially change when modelled with alternative financial assumptions.

The assessment period used for this analysis is 60 years to reflect the useful economic life of the underlying asset.

Abbreviations

Abbreviation	Definition
AA	Access Arrangement
AER	Australian Energy Regulator
AGN	Australian Gas Networks Limited
ALARP	As Low As Reasonably Practical
APA	APA Operations and Maintenance Group
CAPEX	Capital Expenditure
CBD	Central Business District
CI	Cast Iron
Current AA Period	The current 1 January 2013 to 31 December 2017 Access Arrangement Period
CY	Calendar Year
DSPR	Distribution System Performance Review
FY	Financial Year
GIB	Gas In Building
GIS	Geospatial Information System
HDICS	High Density Inner City Suburbs
HDPE	High Density Polyethylene
HP	High Pressure
Km	Kilometre
LDS	Lower Density Suburbs
LP	Low Pressure
MAT	Moving Annual Total
MDPE	Medium Density Polyethylene
MP	Medium Pressure
Next AA Period	The next 1 January 2018 to 31 December 2022 Access Arrangement Period
NGL	National Gas Legislation

NGO	National Gas Objectives
NGR	National Gas Rules
OPEX	Operating Expenditure
PE	Polyethylene
PVC	Poly Vinyl Chloride
SA	South Australia
SLI	Short Lengths Interspersed Pipes
SP	Polyethylene Coated Steel Pipe
TP	Transmission Pressure
UAFG	Unaccounted for Gas
UPS	Unprotected Steel

Appendix A Summary of Cost and Risk Analysis

In assessing the cost and risk for each element of the mains replacement program, AGN looked at a number of replacement scenarios, their comparative cost and customer impact. This analysis helps inform the most prudent and efficient course of action to address the risk associated with AGN's Victorian gas mains.

AGN has developed several scenarios to compare the various costs of replacing its 'high' and 'intermediate' risk mains. These scenarios are:

- **Scenario A** – Replace all high risk CI/UPS mains (177 kilometres) over five years – This scenario demonstrates the cost impact of just replacing CI and UPS only without addressing the identified 'High' risk associated with PVC.
- **Scenario B** – Replace all high risk CI/UPS/PVC mains (262 kilometres over five years) – This is the base case scenario because AGN cannot accept an outcome that results in retaining a high risk.
- **Scenario C** – Scenario B + Replace all intermediate risk PVC mains (299 kilometres over five years) – This scenario demonstrates the incremental cost of addressing all intermediate risk of PVC by bundling with the program to replace all high risk CI/UPS.
- **Scenario D** – Scenario B + replace all intermediate risk PVC except the PVC in the CBD (287 kilometres over five years) – This scenario is designed to isolate the additional cost associated with replacing the PVC in the CBD to reduce the risk to 'low' over the next five years rather than sustaining this risk until these mains become redundant.
- **Scenario E** – Scenario D + replace 10 kilometres of intermediate risk HDPE 575 (297 kilometres over five years) – This scenario demonstrates the cost of achieving low or ALARP for all mains. **This is the planned replacement scenario.**
- **Scenario F** – Scenario D + replace all (597 kilometres) of intermediate risk HDPE 575 (884 kilometres over five years) – This scenario demonstrates the cost of achieving a low risk rating for all HDPE 575 mains rather accepting 'intermediate' risk on the CBD PVC and HDPE 575 mains.
- **Scenario G** - Scenario D + replace all intermediate risk HDPE 575 over 15 years (486 km over five years) – This scenario demonstrates the cost of achieving a low rating for HDPE 575.
- **Scenario H** – Replace all high and intermediate risks (896 km over five years) – This scenario demonstrates the cost of achieving a low rating for all mains.

The cost impact analysis for each scenario has been undertaken over a 60-year period consistent with the economic life of mains.

To understand the cost associated with addressing the network risk, price impact on customers, and the outcome under a range of delivery scenarios have been analysed. The analysis identifies the net present cost (NPC) to customers of each mains replacement scenario. The NPC over the economic life of the assets provides an indication of the impact on customers over the longer term, rather than just considering the impact in the next AA period.

The purpose of the cost impact analysis is to help AGN assess whether the mains replacement program is proportionate to the level of risk involved, and to evaluate the potential impact of changes to the composition and rate of replacement.

A similar analysis was adopted by Ofgem in assessing the iron mains replacement program (IMRP) in the UK. Ofgem used the cost benefit analysis to:

> "...*determine that if duty holder (responsible for managing the risk) has achieved ALARP the potential impact of the risk and the costs involved in trying to mitigate the risks needs to be considered. Unless there is a gross disproportion between them the duty holder has to undertake the risk reduction measure. Thus, the process is not one of simply balancing the costs and benefits of measures but, rather, of adopting measures except where they are ruled out because they involve grossly disproportionate sacrifices*." [27]

AGN agrees with the above statement specifically, that safety considerations are the primary driver and financial considerations are a secondary driver in developing a mains replacement program.

[27] HSE, "*HSE/Ofgem: 10 year* review *of the Iron Mains Replacement Programme*, prepared by Cambridge Economic Policy Associates Ltd for the Health and Safety Executive and Office of Gas and Electricity Markets 2011", pg.27.

Appendix B Cost Impact Methodology

A cost impact analysis of various scenarios for mains replacement has been undertaken for the planned replacement of mains rated as 'High' and 'Intermediate' risk. Each scenario considers the cost of the program, the residual risk achieved at the conclusion of each AA period and the average cost to each customer.

AGN has considered the risk and risk mitigation options in developing the mains replacement program in the following stages:

Stage 1 – Assess the cost of removing all 'High' risk mains:

- all CI/UPS/PVC high risk reduced to low over five years (Scenario B); and
- some PVC and all HDPE 575 risk would remain as intermediate.
- The cost per customer per year of this option is $3.52

Stage 2 – Assess the cost of achieving at least a 'Low' risk outcome consistent with AS/NZ 4645:

- the cost of achieving a low rating for all CI/UPS mains over the next AA period is $4.40 per customer per year (Scenario A);
- the cost of additionally achieving a low rating for all PVC over the next AA period is $4.06 per year, and less in cost per customer (Scenario C vs Scenario A), owing to higher productivity and practicality of block versus piecemeal renewal; and
- the cost of achieving a low rating for HDPE 575 over the next AA period is an additional $8.71 or 247% increase in cost per customer (Scenario H).

Stage 3 – Assess the cost of achieving the risk outcome to consider ALARP:

- AGN considers that there are no mitigation options for CI/UPS. These are the highest rated 'high' risk mains. Therefore, there is no option to reduce the risk to intermediate. Replacement will reduce the risk to 'low' and can be achieved within five years for $4.40 per year per customer (approximately 0.4% increase on annual bundled bill (assume $1,000)). (Scenario A);
- the marginal cost per customer to reduce the risk of PVC to low is $0.34 less, and is under 0.02% of annual bundled bill. (Scenario C):
  - the cost of reducing the risk of PVC mains in the CBD from 'intermediate' to 'low' is just 30 cents per customer per year (difference between Scenario C and Scenario D). Although this cost is low, these mains are higher density than other PVC (and therefore less likely to crack) and will be redundant in 10 years as supply of the CBD shifts to the high pressure steel system. It is not considered prudent to replace these mains before they become redundant. Once the system is redundant, the risk is removed. AGN will continue current risk treatment activities including 6 month leak surveys until these mains become redundant. Therefore, AGN considers the risk of PVC mains in the CBD is ALARP. (Scenario D - $3.72 per customer)
  - the additional cost per customer to reduce the risk associated with PVC mains in the LDS from 'intermediate' to 'low' is 20 cents per customer per year or less than 0.1% of the annual bundled bill (difference between Scenario C and Scenario E). This is not considered disproportionate. Further, the cost of replacing these mains at the end of their useful life is similar in NPV terms compared to bundling the program with the CI/UPS LDS replacement program. Therefore, it would be inefficient to not replace these mains as part of the

CI/UPS program and so the ‘intermediate’ risk associated with these mains cannot be demonstrated to be ALARP, and must be reduced to ‘low’.

- The cost of reducing the risk associated with HDPE 575 > 35 years from ‘intermediate’ to ‘low’ risk within 5 years is $8.18 or 0.8% of the annual bundled bill (difference between Scenario F and Scenario D). This is considered disproportionate to the risk reduction because of the uncertainty associated with the impact of age alone on risk.
- AGN also considered the cost of achieving ‘low’ , for HDPE 575, over 15 years which would reflect an age based replacement program – replacing all the mains expected to reach 35 years over the next 15 years (Scenario G). However, the cost is an additional $2.66 per customer (difference between Scenario G and Scenario D). Given the uncertainty of the risk, this is also considered disproportionate. Therefore, AGN considers that a program that replaces only those mains that will be more than 50 years old and undertaking a sample program to improve the information available on the contributors to failure will result in HDPE 575 mains > 35 years being ALARP for at least the next AA period. This is expected to be revisited in the subsequent AA period.

We have identified the categories and volume of mains requiring risk reduction treatment (896 kilometres rated as either ’High’ or ‘Intermediate’).

We have considered several risk mitigation and mains replacement scenarios.

The following table summarises the cost and risk impact of the various scenarios considered.

On balance, taking into account the estimated cost impact to consumers, we consider the amount of 297 kilometres in scenario E is the prudent and efficient level of replacement. The estimated cost of the program reflects the lowest cost of achieving the risk reduction required by AS/NZS 4645 to as low as reasonably practical. We believe we can mitigate the risk associated with the remaining mains by continuing regular leak surveys, monitoring odorant levels, and expediently responding to and repairing leaks when they occur.

We will also continue to monitor and sample the condition of HDPE 575 pipes (which material has had a history of catastrophic failure in South Australia) to identify the most prudent time to replace these particular mains and the action that can be taken to mitigate the risk.

Table B1: Cost Impact Analysis Scenario Summary

	Scenario	Capex Impact ($000, 2016)	CI/ UPS	PVC	HDPE	Net Present Value ($000, 2016)	Cost to Customer ($000, 2016)	Cost per Customer per Year ($)	Additional Price Reduction Per Customer per Year ($)
A	All CI/UPS (High Risk)	163,672	Low	High	Inter	[redacted]	[redacted]	[redacted]	-0.88
B	All high risk mains (Base Case)	132,741	Low	Inter	Inter	[redacted]	[redacted]	[redacted]	0.00
C	All high risk + intermediate risk PVC	156,057	Low	Low	Inter	[redacted]	[redacted]	[redacted]	-0.54
D	All high risk + intermediate risk PVC excluding CBD	141,730	Low	ALARP	Inter	[redacted]	[redacted]	[redacted]	-0.19
E	**Achieve ALARP for all mains (Proposal)**	147,220	**Low**	**ALARP**	**ALARP**	[redacted]	[redacted]	[redacted]	**-0.33**
F	Achieve low for HDPE 575 after five years	465,625	Low	ALARP	Low	[redacted]	[redacted]	[redacted]	-8.37
G	Achieve low for HDPE 575 after 15 years	247,123	Low	ALARP	ALARP	[redacted]	[redacted]	[redacted]	-2.85
H	Achieve low risk	479,953	Low	Low	Low	[redacted]	[redacted]	[redacted]	-8.71
I	Proposal + HDPE 575 average	279,209	Low	ALARP	ALARP	[redacted]	[redacted]	[redacted]	-3.66

Appendix C AS/NZS 4645 Risk Framework

Table C1: AS/NZS 4645 Consequence Matrix

Item	Catastrophic	Major	Severe	Minor	Trivial
People	Multiple fatalities result	Few fatalities or several people with life-threatening injuries	Injuries or illness requiring hospital treatment	Injuries requiring first aid treatment	Minimal impact on health and safety
Supply	Long Term interruptions of the supply	Prolonged interruption or long - term restriction of supply	Short term interruption or prolonged restriction of supply	Short term interruption or restriction of supply but shortfall met from other sources	No impact, no gas restriction of gas distribution network supply
Environment	Effects wide spread viability of ecosystems or species affected, permanent major damage	Major off-site impact or long-term severe effects or rectification difficult	Localised (<1ha) and short-term (<2 years) effects easily rectified	Effect very localised (<0.1ha) and very short-term (weeks) , minimal rectification	No, effect, or minor on-site effects rectified rapidly with negligible residual effect

Table C2: AS/NZS 4645 Frequency Matrix

Frequency Class	Frequency Description
Frequent	Expected to occur once per year or more
Occasional	May occur occasionally in the life of the gas distribution network
Unlikely	Unlikely to occur within the life of the gas distribution network, but possible
Remote	Not anticipated for this gas distribution network at this location
Hypothetical	Theoretically possible but has never occurred on a similar gas distribution network

Table C3: AS/NZS 4645 Treatment Matrix

Risk Rating	Required Action
Extreme	Modify the threat, the frequency or the consequences to ensure that the risk rank is reduced to Intermediate or lower. For a gas distribution network in operation the risk must be reduced immediately.
High	Modify the threat, the frequency or the consequences to ensure that the risk rank is reduced to Intermediate or lower. For a gas distribution network in operation the risk must be reduced as soon as possible, typically within a timescale of not more than a few weeks.
Intermediate	Repeat threat identification and risk evaluation process to verify and, where possible, quantify the risk estimation; determine the accuracy and uncertainty of the estimation. Where the risk rank is confirmed to be Intermediate, if possible modify the threat, the frequency or the consequence to reduce the risk rank to Low or Negligible. Where the risk rank cannot be reduced to Low or Negligible action shall be taken to: a remove threats, reduce frequencies and/or reduce severity of consequences to the extent practicable; and b demonstrate ALARP. For a gas distribution network that is in operation the reduction to low or negligible or demonstration of ALARP must be completed as soon as possible, typically within a timescale of not more than a few months.
Low	Determine the management plan for the threat to prevent occurrence and to monitor changes which could affect the classification.
Negligible	Review at the next review interval.

Table C4: AS/NZS 4645 Risk Matrix

	Catastrophic	Major	Severe	Minor	Trivial
Frequent	Extreme	Extreme	High	Intermediate	Low
Occasional	Extreme	High	Intermediate	Low	Low
Unlikely	High	High	Intermediate	Low	Negligible
Remote	High	Intermediate	Low	Negligible	Negligible
Hypothetical	Intermediate	Low	Negligible	Negligible	Negligible

Appendix D Conforming Capital Expenditure

Consistent with the requirements of rule 79(1)(a) of the National Gas Rules, AGN considers that the capital expenditure described in this Plan is:

- *Prudent:* The proposed expenditure is necessary to comply with the regulatory obligations identified in this Integrity Plan, and reduce the risk to human health and safety posed by gas leakages from mains with a propensity to crack and break to as low as reasonably practicable. As the options and sensitivity analysis undertaken shows, the proposed expenditure is also of a nature that a prudent service provider would incur.
- *Efficient*: The proposed renewal program is the most cost effective way of addressing the public and operator personnel safety risks identified in this Plan. The proposed expenditure is therefore consistent with that which a prudent service provider acting efficiently would incur. The manner in which AGN intends to carry out the work (i.e. field work to be carried out by an external contractor that has demonstrated specific expertise in completing the installation of the assets in a safe and cost effective manner and that will be selected through a competitive tender) can also be considered efficient.
- *Consistent with good industry practice*: Complying with the obligations set out in the Code by carrying out the proposed replacement program is consistent with accepted and good industry practice, both in Australia and internationally (both in the US and the UK). So too is reducing the risk to human health and safety posed by gas leakage from breaks to as low as reasonably practicable as required by Australian Standard AS4645 (Gas Distribution Network Management).
- *Achieves the lowest sustainable cost of providing the service*: The proposed renewal program is designed to maximise the reasonably available economies of scale for the capital expenditure, while maintaining network integrity and continuity. As has been shown using an NPV economic analysis, the proposed program achieves the outcome of the minimum required cost to consumer while achieving a risk rating of Intermediate (ALARP).

The capex can therefore be viewed as being consistent with rule 79(1)(a) of the NGR. The proposed capex is also consistent with rule 79(1)(b) because it is necessary to:

- maintain and improve the safety of services (rule 79(2)(c)(i));
- maintain the integrity of services (rule 79(2)(c)(ii))); and
- comply with a regulatory obligation (rule 79(2)(c)(iii)).